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Groundwater Surface Trends in the North Florence Dunal Aquifer, Oregon Coast, USA

by

Sarah Rebecca Doliber

A thesis submitted in partial fulfillment of the
requirements for the degree of

Master of Science
in
Geology

Thesis Committee:
Curt Peterson, Chair
Robert B. Perkins
Dennis Nelson

Portland State University
2012

Abstract

The Florence Dunal Aquifer is the only feasible source for drinking water for the coastal city of Florence, Oregon and Florence's Urban Growth Boundary. High infiltration rates and a shallow groundwater table leave the aquifer highly susceptible to contamination from septic tank effluent, storm runoff, chemical fertilizers and recreational ATV use throughout the dunes. Public interest in the quality and quantity of the aquifer water has been sparked since the City of Florence received a grant from the Environmental Protection Agency for a watershed protection and restoration project.

Delineation of the shallow groundwater surface and its relationship to the surface water bodies within the dunes is crucial in protecting this drinking water source from contamination. This thesis project created a GIS representation of the shallow groundwater elevation and associated prediction error map. Surface water bodies were confirmed as window lakes into the dunal aquifer and no signs of perched aquifer conditions were observed between Holocene and Pleistocene dunes. Ground Penetrating Radar, well data provided by the city of Florence and LiDAR were the primary sources for data collection.

Dedication

For Dad- because if it was easy, everyone would do it.

Acknowledgements

Special thanks to Dr. Curt Peterson for allowing me to partake in his coastal research. Curt helped me grow as a scientist as well as an individual and I am forever grateful for the hours of advice and multiple cups of Dutch Brothers Coffee. Thank you to Dr. Ben Perkins for teaching me hydrologic processes in Groundwater Geology, Winter 2011. Thank you to Dr. Dennis Nelson for being enthusiastic from the very beginning and for providing me with my first contracting experience. I would like to express gratitude to my committee members for being flexible with me while I try to balance sanity and schoolwork. Thank you to Hollie Heesacker for help on the first GPR excursion, the extra pair of hands were invaluable! Thank you to the City of Florence municipal workers, in particular Matt B. and Dan Graber for help navigating the dunes.

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Chapter One-Introduction

Background

The North Florence Dunal Aquifer (Hampton, 1963; Couch et al, 1980) underlies the coastal city of Florence, Oregon and supplies municipal water to the city of Florence, and adjacent communities (Figure 1). In 1987 the aquifer was named a Sole Source Aquifer by the EPA, alerting local and state officials and citizens to the critical importance of preventing contamination of groundwater. Designation of an aquifer as a sole source aquifer is a tool used by the EPA to protect fresh water sources from contamination. A Sole Source Aquifer must supply at least 50% of the drinking water and if contaminated would leave no other dependable source for clean drinking water (EPA, 1987). The rapid infiltration rates of the North Florence Dunal Aquifer combined with a shallow water table leave the it extremely vulnerable to contamination from the surface (EPA, 1987).

In addition to directly supplying the North Florence area's drinking water, the aquifer is believed to be partly responsible for recharging Clear Lake (Figure 1) (EPA, 1987). The relationships between the surface water bodies in and surrounding the aquifer and the groundwater surface (water table) in the aquifer have not been established. It is suspected but not known whether the small lakes, ponds, and wetland bogs in the Florence dune fields are window lakes to the underlying dunal aquifer. Window lakes are bodies of groundwater that are exposed at ground surface, or areas where the ground is at a lower elevation than the groundwater. Window lakes grant direct access to the aquifer making these lakes possible entryways for surface contaminants. As the city of

Florence continues to expand, developments made in or near the aquifer recharge zones might result in aquifer contamination. Additionally, local well water draw down of the groundwater surface could impact sensitive creeks, ponds, and wetlands by lowering water levels or drying up the wetland or riparian habitats. Surveys are needed in the North Florence Dunal Aquifer to establish any potential links between the surface water bodies and the underlying groundwater surface and investigate groundwater flow direction. The city well field (Figure 1) pumps directly from the dunes and any contamination in the aquifer would surely manifest in the drinking water supply. Recent studies have been successful in identifying groundwater surfaces and their relationships to surface water bodies in coastal dunes of Oregon and Washington using a combination of piezometer well data, surface water data, and ground penetrating radar (GPR) surveys (Figure 2) (Brown, 2008; Peterson et al., 2007a; Nielsen, 2005; Thomas, B.E., 1995).

This study of the North Florence Dunal Aquifer 1) delineates the elevation of the shallow groundwater surface using Ground Penetrating Radar as a subsurface imaging tool, 2) establishes the relationship between surface waterbodies, including lakes, wetlands and bogs, and the dunal aquifer, and 3) creates a groundwater database and surface elevation map that shows groundwater surface trends for the North Florence Dunal Aquifer.

Figure 1: Aerial photograph mosaic of the city of Florence and its major water bodies. The City of Florence is outlined in black, Urban Growth Boundaries in yellow and the approximate boundaries of the North Florence Dunal Aquifer are outlined in blue. The current well field of the City of Florence as well as the location of a proposed well field are outlined in red. The bounding coordinates for this area are (from SW corner clockwise): 414369 E 486971N, 409760E 4882791 N, 413935 E 4882791 N and 414369 E 4869713 N. Map coordinates are in longitude and latitude.

Figure 2: Map of coastal dunes in Oregon and Washington (from Peterson et al., 2007b). The Florence dune sheet is centrally identified at FLOR, while CLAT represents the Clatsop Plains and LONG represents Long Beach Peninsula where previous ground penetrating radar groundwater studies have been successfully conducted

Previous Work

The dimensional parameters of the Florence Dunal Aquifer were first studied in 1979 by the Florence Dunal Aquifer Geophysics group at Oregon State University (Couch et al., 1980). This involved using seismic refraction and reflection to measure the thickness of Quaternary sand layers above the bedrock formations, located north of the Siuslaw River and south of Sutton Creek as well as the thickness of the sand layers beneath the Siuslaw River (Couch et al., 1980). Although the 'water table' was very roughly delineated by seismic refraction, the seismic study concentrated on the depth of the sand aquifer down to the bedrock, locally identified as the Eocene consolidated marine sandstone/siltstone Flourney Formation (Newton, 1980). Late Pleistocene bay and marine terrace deposits are thought to locally overlie the bedrock and underlie the Pleistocene-Holocene dune sands (C. Peterson, Personal Communication, 2012). The groundwater surface depths, slope directions, and slope gradients in the overlying Pleistocene and Holocene dunal aquifer were not well resolved by the seismic refraction methods.

This thesis study area overlaps that of Couch et al (1980), which is located north of the Siuslaw River. Large dunes, barrage lakes, popular ATV riding areas, and deflation plain bogs are located south of the Siuslaw River in the South Florence Dune sheet (Cooper, 1958; Reckedorf, 1975). Barrage lakes differ from window lakes in that they are created when a dune migrates and dams natural spring water which collects and forms a lake.

Groundwater surface (GWS) trends in beach plain aquifers in Long Beach Peninsula, southwest Washington (LONG in Figure 2), were studied with GWS elevation data from 150 shallow wells and 20 surface water locations, including streams and lakes (Thomas, 1995). A groundwater elevation model and surface flow trend model of the Long Beach Peninsula aquifer were created showing maximum water table elevation and ranges, and depth from land surface to water table. For the remainder of this thesis the surface of the groundwater aquifer is referred to as the ground water surface rather than as the groundwater table. The groundwater surface is defined by different characteristics depending on season, hosting deposits, and survey methods, as discussed further below.

A study of groundwater geochemistry was conducted in the prograded Clatsop beach plains, in northernmost Oregon, to test whether the numerous ponds and bogs in valleys between the abandoned foredune ridges were window lakes in the shallow groundwater aquifer (Nielson, 2005). Ground penetrating radar was then used in the Clatsop beach plains to identify the groundwater surface trends between abandoned foredune ridges and the environmentally sensitive lakes in the intervening valleys (Peterson et al., 2007a; Brown, 2010). A semi-continuous groundwater surface was identified at depths of 1.0-15.0m in prograded Clatsop beach deposits using GPR with a 1000v transmitter and 100 MHz antennae (Figure 3) (Peterson et al., 2007a).

The studies identified above are examples of successful groundwater surface surveys in low elevation coastal dune aquifers, which utilized piezometers, surface water bodies, and/or ground penetrating radar to establish the depth and slope of groundwater surfaces. Those studies focused on the shallow groundwater surface in low elevation

barrier beach plains and not in upland dune sheets, such as the North Florence Dunal Aquifer.

Figure 3: Ground penetrating radar profile in the southern Clatsop Plains showing a groundwater surface reflection as the semi-continuous, thick black line at maximum depth of 15m (Peterson et al., 2007a).

There is a general public interest in investigating the relationship between the groundwater surface and the dunal surface water bodies, in terms of water quality issues (Dennis Nelson GSI Water Solutions, personal contact 3/23/2011). In the Fall of 2009 the City of Florence was awarded a grant from the Environmental Protection Agency in order to assist local governments in managing land uses to protect watersheds. As one result of this grant support the Siuslaw Estuary Partnership was established to further local efforts in watershed restoration. The Siuslaw Estuary Partnership project includes water quality and water quantity monitoring, wetland and riparian protection, and planning for ecologically-sustainable growth in the Florence area. The City of Florence

is working with consultants from GSI Water Solutions to monitor groundwater and surface water at several locations throughout the City of Florence and the city's Urban Growth Boundary, in support of the EPA study objectives (Dennis Nelson GSI Water Solutions, personal contact 3/23/2011).

Study Area

The North Florence Dunal Aquifer encompasses the “entire continuous body of sand located north of the Siuslaw River and east of the Pacific Ocean” (EPA, 1987). Initial geologic mapping in this area identified the sand dunes as Pleistocene-Recent with no differentiation made between ages of dune forming events (Hampton, 1963; Lund, 1971, Reckendorf, 1980). These studies identified some major bodies of water including Clear Lake, Sutton Lake, Mercer Lake and Munsel Lake, as sitting on the contact between the dunes and the underlying sandstones and siltstones of the Flourney formation (Hampton, 1963; Lund, 1971). However, it was not determined whether the lakes occur from perched aquifers above internal dune aquitards, or what relations the larger barrage lakes and smaller deflation trough ponds have with regional ground water surface trends.

Radiocarbon and thermoluminescence dates from the upland dune deposits in the Florence and Coos Bay areas confirm that there are two dominant periods of dune deposition. Holocene and Pleistocene dune sheets correspond to periods of marine high and low stand, respectively (Peterson et al., 2007b). The Florence Pleistocene dune sheet deposits yield average dates of 40Ka and 49Ka from radiocarbon and thermoluminescence, respectively. The Pleistocene dunes are associated with loess

interbeds, weak interstratal cementation, and variably developed paleosols (Peterson et al., 2006).

The Florence Holocene dune sheet deposits yield average dates of 3Ka and 5Ka, based on radiocarbon and thermoluminescence techniques, respectively (Peterson et al., 2007b). The Holocene dunes are uncemented, contain no loess interbeds, and are lacking any well developed paleosols. The oldest Holocene dunes dated in the North Florence Dune Aquifer were deposited at 7,822 RCYBP (Radio Carbon Years Before Present) (Peterson et al., 2007b). GIS coverages of the surficial extent of the Holocene and Pleistocene dune sheets are available for the Florence dune sheets (Peterson et al., 2006) although some additional mapping was required for this thesis to confirm the boundaries of the two dune sheet types (see Methods below).

Chapter Two-Methodology

Data Collection

A Sensors and Software Inc. PulseEKKO PRO GPR system was towed behind a vehicle at speeds of 5-8 km/hr, while the data acquisition unit was in the car. The set up is shown in Figure 4. Ground Penetrating Radar data was collected in 54 lines or tracts throughout the city of Florence (Figure 5). The data was collected in three survey trips over the summer of 2011, which followed an unusually late and wet spring season. Two different sized antennae, 50 and 100 MHz, were used with a 1000 V transmitter. In both cases, the antennae were secured 1.0 meter apart in broadside orientation on a carbon trailer. A ground penetrating radar (GPR) profile is created when the transmitter generates and sends a high frequency electromagnetic pulse into the subsurface (Jol and Bistrow, 2003). A change in electrical impedance across deposit strata, such as produced by changes in water content or lithology, will cause part of the energy to be reflected back to the surface (Jol and Bistrow, 2003). The system was programmed to transmit a pulse every meter, as measured by the odometer. A signal velocity of (0.1 m/ns) was established for the dry to moist sand deposits above the groundwater surface from known groundwater reflectors at measured depths (see Results Section below). The reflected pulses are recorded as two-way nanosecond delay time, and are converted to depth from the surface using the established signal velocity. The depth to groundwater is later converted to elevation, based on the NAVD88 datum using surface elevations from LiDAR (see further details below). Sediments such as sand, gravel, peat and limestone or

fresh water saturated sediments have produced high quality data and are highly suitable for ground penetrating radar studies (Doolittle, 2002; Jol and Bistrow, 2003). Both the 50 mHz and 100 mHz antennae penetrated the dry sand and recognized changes in electrical conductivity throughout the dunes. The spatial resolutions of the 2m long 50mHz antennae and the 1m long 100 mHz antennae are .5m and .25m using a velocity of 0.1 m/ns (Jol and Bristow, 2003). Spatial resolution can be approximated as $\frac{1}{4}$ to $\frac{1}{2}$ of the wavelength, where wavelength = velocity/frequency (Jol and Bristow, 2003). Higher antenna frequencies have smaller wavelengths and increase spatial resolution but decrease the depth of penetration. In this study the primary focus was on regional depth of the ground water surface reflection(s) so the intermediate frequency antennae, 50 and 100 MHz, were used.

Figure 4: The Sensors and Software Inc. PulseEKKO PRO GPR unit was towed behind a vehicle on a carbon trailer in order to avoid any interference from metal hardware on the trailer. The receiver was placed next to the tow vehicle to reduce interference with shallow ground water reflectors.

Figure 5: Ground penetrating radar coverage shown as points in 100 m intervals. A LiDAR hillshade basemap shows the topography of the study area. Map coordinates in longitude and latitude. Lidar data is from (<http://seamless.usgs.gov>) (2011). Representative profiles (numbers) are from 1: Sutton Lake (purple), 2: Clear Lake (yellow), 3: City Center Profile E-W (green), 4: City Center Profile N-S (orange). The GPR tracts for these lines can be found in Figure 9, Figure 10, Figure 12 and Figure 15 respectively.

Data Processing

The GPR data acquisition unit stored each GPR profile or line as a data file (.dt1) with an associated header file (.hd). The GPR profile data were processed using Sensors and Software's ProEKKO View and ProEKKO View Deluxe programs. Topographic correction was achieved in several steps, beginning with LiDAR elevation data preprocessing in ESRI's ArcMap 10.0. The first step in the elevation preprocessing was recording coordinates in 100m intervals along each profile. Global positioning system (GPS) coordinates taken in the field intermittently throughout data collection were used as a guide to for recording the tracts in ArcMap and from GIS geo-referenced maps were used for surface water body elevations. Each line of GPR data was converted to points in 100 meter intervals in ArcMap using the simple measuring tool to measure the interval. Using the 'Add XY coordinates' tool, coordinates were assigned to each point and the elevations were extracted. Elevations were extracted from the USGS NED 1/9 arc-second dataset (the main source of this database is LiDAR) using the 'Extract Multi-values to Point' tool (<http://ned.usgs.gov/Ned/index.asp>). This dataset has 3 meter resolution vertical accuracy, expressed as a Root Mean Square Error of 2.44 meters (<http://ned.usgs.gov/Ned/index.asp>). This raster file was projected in North American Vertical Datum of 1988 (NAVD88), which uses a value of about 1 m below local mean tide or sea level as zero meters (<http://ned.usgs.gov/Ned/index.asp>, Gesch et al., 2007). All elevations used in this thesis study are relative to the NAVD88 datum. An ASCII format topography file (.top) was created for each GPR line consisting of two columns: meters traveled (0, 100, 200) and elevation at that location. When applied to raw data,

the topography file translated the calibrated signal velocity (0.1 m ns^{-1}) to the elevation given at that distance allowing for interpretation of water surface elevation, relative to the NAVD88 datum (Figure 6).

In some tracts reflections at depth were not well resolved and gain was applied during processing to amplify weaker reflections. Sensors and Software offers several types of gain to help increase the visibility of reflections at depth, which are sometimes muted as the signal is weaker at depth. In this study SEC (spreading and exponential compensation) gain was used as a primary gain. SEC sets starting and ending gain values, generally between 0 and 20. Less gain is needed near the surface but as depth increases, the signal becomes weaker and more gain is needed to amplify features. This gain application is typical for geologic and sedimentological GPR investigations.

Figure 6: Raw (A) and topographically corrected (B) subsurface images for the same survey line (profile number 2 in Figure 5). At about 1500 m position distance Clear Lake was approached (red line), from west to east, and an interpreted groundwater surface reflection is seen near the surface in both the raw and topography processed profiles, within the lake bounding dune ridge (see Results section for further interpretations of the Clear Lake GPR profile). Raw data (A) has a horizontal surface because the GPR antennas are at a constant height from the ground. Once elevation data is added (B) the reflection is adjusted to display actual elevation. The location of the Clear Lake GPR profile is shown in Figure 5. Figure 6 (C) shows the location of this line, with each 100-m interval represented as a blue point. Distances labeled on this map correspond to the Position of the GPR from 6A and 6B.

The identification of the groundwater surface was obtained using a combination of locating a strong and somewhat continuous GPR reflection in the processed GPR profile and groundtruthing the origin of the target reflection to an observed groundwater surface in 1) standing water in a lake, pond, or wetland bog, and 2) groundwater monitoring wells (well data provided by the City of Florence). Water elevations in creek bottoms were also recorded relative to road or bridge surfaces where GPR lines crossed the creeks. Field notes taken during the GPR profiling provide GPS positions of 1) surface water bodies, 2) hydrophytic or wetland plants in bogs that are indicators of the local depth of a shallow groundwater surface, and 3) creek bottom water elevations, (Figure 7). Once a GPR groundwater surface reflection was traced to an observed surface water body the GPR reflection was followed along the profile until it discontinued, became intermittent or branched into multiple reflections. Multiple reflections were observed in some wetlands or bogs and are interpreted to represent multiple horizons of variably saturated soil, all zones becoming fully saturated in winter months when wetlands receive more water from precipitation. Only continuous, single, groundtruthed reflections were used to pick subsurface groundwater surface depths from the GPR profiles. Multiple groundtruthing sites along the individual GPR profiles and multiple crossings of groundwater surface reflections in crossing GPR profiles reinforced the interpretations of subsurface ground water surface depths.

Once the groundwater surface reflection was confirmed by groundtruthing, a groundwater surface depth and associated elevation relative to the NAVD88 datum was

recorded for each 100 m interval or point where the groundwater surface reflection was traced along the GPR line. The groundwater surface elevation information is stored in a database file (.dbf) containing position coordinates, ground elevation and groundwater elevation for each 100 m interval point. These data are used to compile a groundwater surface map or model for the North Florence Dune Aquifer, as detailed below.

Figure 7: Surface water is not present in this seasonally ephemeral pond, but the presence of *Carex* sp. and willow shrubs, as well as the darker, more saturated soil indicate a shallow groundwater surface depth (less than 2 m depth). Earlier in the spring, a small surface water pond was observed at this site, at the south end of the City of Florence well field. The location of the City of Florence well field is shown in Figure 1.

Creating a GIS Representation of the Groundwater Surface

The input database (.dbf) file, North Florence Dunal Database, stores 943 points containing groundwater elevations at about 100 m intervals along GPR profiles (Appendix A). In order to construct groundwater elevation map with continuous data, these points were interpolated using the simple kriging method. This method is a geostatistical method that relies on autocorrelation within a variable (groundwater elevation). Another way of saying this is the elevations of points close to each other are more similar than points farther away. One advantage to using a geostatistical method is the ability to predict and conduct error analysis, discussed in results below (Davis, 2002). The Kriging method used in ArcGIS has a two-step procedure: 1) uncover dependency rules by creating a semivariogram and 2) make predictions. A histogram and a Normal Quartile-Quartile plot were created to confirm that the groundwater elevation data was normally distributed, which is assumed with simple kriging (Figure 8). Semivariograms show the variance between all point pairs:

$$2 \quad (1)$$

* h = the value of the semivariance for lag (distance) h ; $N(h)$ is the number of $i+h$ (Isaaks, 1989). In the case of the groundwater surface elevations in the study area the data is normally distributed (see Results section below) so a simple kriging method was employed to build the groundwater surface elevation map or model.

Histogram Transformation: None

Data Source: Measured Points Attribute: gwater

Normal QQPlot Transformation: None

Data Source: Measured Points Attribute: gwater

Figure 8: Basic statistics for the groundwater elevation data show a bell-shaped histogram using 10 quartiles. The same quartiles are plotted against the standard normal values for the data and show most of the data lies on or near a Gaussian (normal) trend line. Both of these diagrams suggest that simple kriging is a viable technique for interpolation of the groundwater surface elevation point data in the Florence dunal aquifer

Chapter Three-Results

Ground Penetrating Radar Survey Results

Ground Penetrating Radar successfully recorded the groundwater surface in 43 survey lines covering a total of 95 kilometers. In the homogenous North Florence Dunal Aquifer both 50 Mhz and 100 Mhz antennae were successful with average penetration depths of 17 and 20 meters respectively. Factors that affected the quality of the radar imagery include proximity to high power transmission lines (and other electromagnetic devices) and surveying over shallow bedrock (see Discussion)(Figure 9).

Figure 9: Subsurface image of the Sutton Lake GPR line where the survey began in bedrock (profile 1 in Figure 5). From position 0m to about 1100m (blue arrow) there is very little signal and no identifiable groundwater reflection. The strong and somewhat continuous shallow reflection in the thicker dune sand is the identified and groundtruthed groundwater reflection (arrows). Deeper GPR reflections could be bedrock contacts or dunal paleosols in the deeper subsurface. See Figure 5 for location of Sutton Lake GPR profile.

The majority of the surveying done throughout the North Florence Dunal Aquifer was done either on residential roads with little through traffic or on open dunes thus reducing interference with city traffic on the major roads and highways. GPR lines or

profiles were selected on the basis of 1) approximate equal spacing between profiles, 2) crossing of creeks and surface water bodies to groundtruth the groundwater reflection interpretations, and 3) orthogonal crossing of multiple GPR lines to confirm groundwater surface reflection interpretations.

Confirming Surface Water Bodies as Window Lakes

Groundwater reflection elevations identified from GPR were compared with the elevation of surface water bodies, including ponds, lakes and wetlands, in order to confirm interpreted GPR reflections as a groundwater surface, as well as, to establish surface water bodies as window lakes into the aquifer. Some small creeks were also measured for water elevation to test whether the creeks were recharging from or discharging into the dunal aquifer. Confirmation of the groundwater reflection interpretations differed slightly between dunal wetlands and lakes or ponds. Wetland areas exhibited multiple shallow reflections in dune deposits that were located immediately adjacent or over the top of the wetlands or bogs (Figure 10). With greater distance and increasing elevation away from the wetlands the multiple groundwater surface reflections generally transitioned into a single reflection. The very-shallow multiple groundwater reflections in some bogs or seasonal wetlands could represent capillary fringes above shallow saturated groundwater surfaces during summer months. Confirmation of window lakes (eg. Clear Lake) was achieved by running GPR profiles in perpendicular traverses from bounding dune shorelines down to the edge of the lake (Figure 11).

Water levels in monitoring wells provided by the City of Florence also served as groundtruthed data to compare the groundwater elevations interpreted from GPR profiles to measured phreatic surfaces in constructed wells (Table 1, Figure 12). For the most part the groundwater surface elevations identified from GPR profiles are within 3 meters of the monitoring well levels, though the GPR and well data were not collected synchronously in 2011

In several GPR profiles a deeper reflection was recorded in the dunal aquifer. Based on isopach maps from Couch et al. (1980) the deeper reflections are thought to represent the Pleistocene dune surface or loess paleosols within the Pleistocene dune strata (Figure 13). The trends of the shallow groundwater surface reflections are not apparently correlated to the terminations or slope trends of the deeper Pleistocene dune or paleosol reflections (see Discussion section below).

Figure 10: Plot of Clear Lake GPR profile, with interpretations of ground water surface reflections (same profile previously shown uninterpreted in Figure 6). From line position 50 m to about 800 m carax and ponded bog water was observed on either side of the road. The GPR reflections over that area shows one stronger reflection near the surface and multiples of that top reflection to a depth of about 4 m below the surface (red arrows). With continued GPR surveying into higher elevations in dune ridges (1100 m-1450 m line positions) a single groundwater surface reflection is shown to be more distinct (blue arrows). The location of Clear Lake is marked with a purple line. A much deeper reflection (10–15 m depth subsurface) in this area may be a Pleistocene dune surface or paleosol. The shallower groundwater surface trends are not correlated to the deeper GPR reflection trends. There is no evidence of groundwater elevation being affected by the deeper reflection feature(s). See Figure 5 for location of Clear Lake GPR profile.

Figure 11: Subsurface image from the Clear Lake GPR profile showing the groundwater surface reflection staying relatively horizontal beneath a large sand dune ridge (100 m-550 m line position) adjacent to Clear Lake. GWS variation beneath dune ridge (distances 100m-1000m) are attributed to changing dune morphology since LiDAR data was collected. At 550 m line position Clear Lake (red line) was approached and the groundwater surface reflection is observed at the elevation of the lake surface (about 40 m NAVD88). A reversal of profile direction (550-900 m line position) helps to confirm the connection between lake surface and the equivalent elevation of the subsurface groundwater surface reflection in the dune field aquifer. It is clear from in this figure that in higher elevations (open dunes 100m-1000m) the GWS is imaged as one continuous reflection, but in lower elevation wetlands and bogs the continuous line splits into multiple reflections (1100-1600m)

Figure 12: Locations of the City of Florence Monitoring wells used to help groundtruth GPR groundwater reflections.

Figure 13: The deeper reflection (lower red arrows) is believed to be a Pleistocene/Holocene dune deposit contact or Pleistocene dune paleosol, based on the dune isopach map from Couch et al. (1980). This GPR line was taken in the center of the city (Profile 3 in Figure 4) where the groundwater surface is close to the surface (blue upper arrows). The morphology of the Pleistocene dune contact does not show any control over the nearly horizontal groundwater surface reflection.

Table 1: Monitoring well water elevations from September 2011 are compared to nearby points (on GPR tracks) whose groundwater elevation was identified from Ground Penetrating Radar in Spring and Summer 2011. These monitoring wells represent vertical head components of the aquifer.

Well #	Water elevation in well (m)	GPR Point ID	GWS from GPR (m)	GPR Point ID	GWS from GPR (m)	GPR Point ID	GWS from GPR (m)
B-1	8	483	10	484	10	485	9
B-2	15	671	19	128	21	129	21
B-3	16	137	21	138	21		
B-6	18	602	19	601	19		
B-8	10	570	11	72	12	73	12
B-9	8	11	8	12	8	13	8
B-10	4	750	5	749	8	750	8
B-11	3	0	5	1	5	20	5.5
B-16	17	126	21	127	21	669	22
B-15	12	666	15	664	20		
B-14	31	653	27	654	26	655	26
B-13	29	162	26	163	25	164	24
B-12	29	181	29	182	29	183	30

Well #- City of Florence monitoring well number.

Water elevation in well-Elevation of vertical head in monitoring well (m).

GPR point ID- Each 100-m interval point is assigned an individual ID

GWS from GPR- The groundwater surface elevation as identified from GPR for that point.

Creating Predicted Groundwater Surface Maps

The Geostatistical Analyst extension in ArcGIS 10.0 was used to perform ordinary kriging methods for the groundwater surface elevations. This extension toolpack is more advantageous than the Spatial Analyst kriging method, which does not provide error analysis or statistics. Summary statistics on measured groundwater elevations show a mean elevation of 19.2 m and a standard deviation of 9.8 m. A semivariogram was created using values calculated from Equation 1 and a Gaussian model to fit the normally distributed data (Figure 14). Table 2 shows mean Prediction Error values for the dataset.

A contoured surface map of the predicted values of groundwater elevation was created as well as a map of the prediction standard error (Figure 15, Figure 16). The predicted groundwater elevation contours range from 0-57 meters and the standard error contours has a range of 0.57-5.48 meters. Analyses of mapped groundwater surface trends in the North Florence Dunal Aquifer are provided in the thesis Discussion section below.

Table 2: Table of summary statistics for the prediction error for groundwater elevation data.

Prediction Errors	
Mean (m)	.020
Mean Standardized (m)	.008
Root Mean Square (m)	1.86
Root Mean Square Standardized (m)	.946
Average Standard Error (m)	1.94

Figure 14: The semivariogram created for groundwater elevations with a Gaussian model (blue line) shows greater variability in groundwater elevation points when there is a larger distance between the measured points. This suggests that the groundwater elevations are somewhat spatially correlated. The y axis is variance and the x axis is distance between points. This dataset has been divided into 12 lags each with a lag size of .00062618. Each blue cross on this graph shows the averaged lag values.

Figure 15: Maps of predicted groundwater based on window surface water bodies and on subsurface groundwater surface reflections in GPR profiles (Appendix A and 2).

Figure 16: Prediction error map created during kriging process. In areas where measured GPR or lake elevation data is abundant, the error associated with the predicted groundwater surface is low (white areas). In locations where there was few or no measurements taken, more error is associated with the prediction of groundwater elevation (bright red).

Testing Environmentally Significant Wetlands

Particular wetland areas have been identified by the city as environmentally significant, based mainly on plant species and population, and efforts are being made to protect and maintain these areas (verbal communication Dennis Nelson September 2011, Figure 17). Significant wetlands are important for the city to preserve because of their suspected connection with the groundwater table (verbal communication Dennis Nelson 9/6/2011). A lowering of the groundwater elevation of the North Florence Dunal Aquifer could be fatal to many wetland plant species. Figures 10 and 11 show two lines surveyed in or near significant wetland boundaries. Both lines show a distinct groundwater surface in higher elevation dunes and multiple reflections subsurface in areas recognized as wetlands.

Previous groundwater modeling in this area has relied mainly on water levels in creeks, lakes, and monitoring wells. A modeled head map produced by GSI Water Solutions Inc. (Figure 18) was not based on any ground penetrating radar or LiDAR data and shows higher groundwater levels in the center of the city following the hydraulic gradient and flowing south to the Siuslaw and west to the Pacific (City of Florence, unpublished data, 2011). The model created by GSI Water Solutions Inc. used hydraulic conductivity values ranging from 5-55 ft/day. This was calculated as a function of the thickness of the sand, which varied from 20-200 ft. Average hydraulic conductivity used in the modeling was 40 ft/day. This map is compared to kriging results of the same area using only well data provided by the city (Figure 19). Predicted groundwater flow paths based on shallow groundwater gradient are shown with black arrows.

Figure 17: Map of Significant Wetlands in the Florence area. The map shows significant wetland in yellow, non-significant wetlands in green and wetlands that are significant only for public use or recognition (from City of Florence, Planning Department, 2011). The locations of two profiles taken near these wetlands (A and B) represent the GPR lines 49 and 51 (Figures 10 and 11).

Figure 18: Hydraulic Head map (in feet) modeled using MODFLOW GWVistas created by GSI Water Solutions based on water levels in city monitoring wells (red squares) (GSI Water Solutions Inc, 2012, unpublished data). Residual mean error (difference between measured and modeled water levels) is ± 4.3 feet.

Figure 19: Kriging results for the same area (in feet), based on a three month average of water levels in city monitoring wells (blue triangles). Black arrows indicate predicted groundwater flow based on hydraulic gradient. Both methods show higher groundwater elevation directly west of Clear and Collard Lakes with a downward gradient to the south and east. Modeling done by GSI Water Solutions Inc. does not extend far enough north to the groundwater trough (Figure 15).

Chapter Four-Discussion

Ground Penetrating Radar as a Subsurface Surveying Technique

Ground penetrating radar was successfully used as a method to record and identify the shallow groundwater surface in the North Florence Dunal Aquifer. There was little GPR penetration in the arkosic sandstone and siltstone bedrock, relative to the dune deposits in the north Florence dune sheets (Cooper, 1958). The bedrock in this area has weathering products of vermiculite, kaolinite and gibbsite making this clay rich material poorly suited for Ground Penetrating Radar (Hampton, 1963; Beckstrand, 2001). The lack of GPR signal penetration was helpful in identifying the contact between Tertiary bedrock and Quaternary dune deposits.

Using the ground penetrating radar close to high power electrical lines or in areas of under ground utility pipes, cables, and drains caused signal interference and made the groundwater surface less distinguishable. These EM field anomalies, evident as profile parallel reflections or crossing profile parabolas (Jol and Bristow, 2003), were particularly evident along Highway 101. This north-south highway divides the city (west from east) (Figure 2) and is a major traffic corridor with overhead transmission lines and underground utilities running parallel to the roadway. The HW 101 GPR profiles tended to have weaker or less continuous groundwater surface reflections relative to GPR lines in residential roads or in the undeveloped dune settings (Figure 20).

Figure 20: Ground Penetrating Radar image part of Line 14 running south to north along Highway 101 (profile 4 in Figure 5). Most of this tract lacks a strong, continuous reflection, in part, due to the surrounding electromagnetic interference along the highway. However, discontinuous groundwater reflections are apparent at 500 m, 1,500 m, 3,500m, 4,500 m, 5,500 m and 7,000 m line positions, showing rising groundwater surface from south to north in the North Florence Dune Aquifer.

The 50 mHz and 100 mHz antennae proved to be appropriate wavelengths for penetration to the groundwater surface in the relatively homogenous dune sand aquifer. The 50 mHz antennae provided greater penetration and tended to resolve a single groundwater surface reflection in the study area. The 2 meter wide 50 MHz antennae and antennae guards occupied an entire traffic lane when towed in residential streets and access roads. The shorter 100 mHz antennae (1 m width) were better adapted to towing behind the ATV on narrow tracks through the undeveloped dune fields.

The ground penetrating radar detected changes in saturation of the subsurface, including the vadose zone and/or capillary fringe, within several meters of the ground surface. Multiple reflections are interpreted as detection of water content from a non or partially saturated top reflection to a fully saturated bottom reflection, below which is the fully saturated aquifer. It is expected that during periods of high precipitation this

saturation gradient would be smaller and fully saturated conditions would occur near/at the surface. This change in saturation could be caused by precipitation draining through the sand, or from groundwater surface drawdown, but in both cases the bottom reflection represents the fully saturated aquifer. Capillary fringe zone height for a sandy aquifer like the North Florence Dunal Aquifer is estimated to range from 4-25cm (Fetter, 1980; Kuo, 1999; Bear, 1979). Spatial resolution in sands using a signal velocity of 0.1 m/ns for the 50 and 100 mHz antenna are 50 and 25 cm. Therefore identification of capillary fringe zone is unlikely with the 50 and 100 mHz antennae. For this study both multiple groundwater reflections in the vadose zone (2-4 m depth subsurface in bogs) and single groundwater surface reflections in dune ridges define the groundwater surface elevation in the North Florence dunal aquifer.

Confirmation Of The Window Lakes

Groundwater surface reflections in the dunal aquifer were traced to surface water bodies and wetlands, confirming that the surface water bodies are windows into the shallow underlying aquifer. LiDAR GIS map data for the North Florence dune fields provided elevation control (resolution better than 3 m vertical) relative to the NAVD88 datum for both 1) surface water bodies and 2) the ground surface where GPR picks of depth of groundwater surface reflections were made. All of the surface water bodies crossed by GPR profiles in the North Florence Dune Aquifer were found to have similar elevations as those of subsurface groundwater surface reflections in the adjacent dune deposits (Table 3, Figure 15). Table 3 shows the groundwater elevations taken from GPR reflections compared to nearby surface water bodies including larger lakes, wetlands, and ponds. When groundwater elevations from GPR were plotted against surface water

elevations a correlation coefficient of .98 shows a strong correlation indicating that the two variables have a strong relationship (Figure 21). The regional differences in surface water body elevation (Appendix A) in the dune aquifer are controlled by the regional variability of the groundwater surface in the North Florence study area (Figure 15).

Table 3: Table of groundwater elevations taken from GPR reflections and elevation of surface waterbodies. Measurements taken near the Siuslaw River represent the lowest elevations in the study and measurements near Mussel lake c represent the highest elevations. Surface water elevations were taken from LiDAR.

UTM E	UTM N	Groundwater Elevation	UTM E	UTM N	Surface Water Elevation	Surface Waterbody
411460	4881409	18	411353	4871435	19	Lake Marr
413008	4874909	36	413485	4875857	37	Collard Lake
411064	4875593	34	411040	4875322	31	Pond
410859	4874329	35	411085	4874492	34	Wetland
412449	4870515	7.5	412424	4870488	10	Munsel creek
412090	4872177	20	412252	4872064	19	Wetland
412127	4874989	32	412104	4874817	33	Wetland
413239	4871034	0	413359	4870638	0	Siuslaw River
412737	4875850	35	412583	4875604	37	Wetland
411921	4880667	55	411720	4880578	49	Mussel lake c

Figure 21: Groundwater elevations from GPR plotted against surface water elevations from LiDAR show a strong linear relationship. The highest and lowest elevations are shown by the points at (0,0) and (49,55).

A rise or lowering of the local groundwater surface level would have a direct impact on water level in the surface water bodies. Contamination of the local dune aquifer could similarly have an impact on water quality in the connected surface water bodies. Wetlands contained within the North Florence Dunal Aquifer are entirely controlled by local groundwater elevation (Figures 10, 11). The barrage lakes to the east (Munsel, Clear and Collard Lake) would certainly experience a lowering in elevation if drawdown in the aquifer occurred, but these lakes most likely receive additional input from surface water to the east. Munsel Creek is an example of a gaining stream, or a

stream that is fed by groundwater, evidenced by an increase in flow and temperature downstream (City of Florence, unpublished data, 2011) therefore contamination of the groundwater will present itself in gaining creeks. Seasonal variation in stream discharge, as reported for Munsel Creek (City of Florence, unpublished data, 2011) is likely due to seasonal changes in groundwater surface elevation in the dune aquifer. Seasonal variability of groundwater surface reflections in the North Florence dune fields were not performed in this GPR study, but they could be undertaken in future work.

Figures 10 and 11 confirm that at higher elevations a strong single reflection represents that groundwater surface and in lower elevation wetlands multiple reflections from the surface to a depth of about 5 m subsurface. The multiple reflections in wetlands are interpreted to be detecting changes in saturation. The 50 and 100 mHz antenna did not have the spatial resolution needed to detect capillary fringe which is expected to be between 4 and 25 cm in medium to coarse grained sand. Both environments can show surface expressions of the aquifer: lakes and ponds in higher elevations and wetlands in lower elevations.

Groundwater Surface Reflection Trends

GPR profiles in the study area demonstrated relatively horizontal trends of groundwater surface elevation in most areas after topographic processing (see Methods) (Appendix C). Steeper groundwater surface trends occurred on the steeper slopes of the bounding edges of the dune field aquifer (Figure 15). For example, steep gradients of the mapped groundwater surface occur in the southeast margins of the North Florence dune

field at the North Fork of the Siulsaw River, and in the southwest margins of the dune field where narrow valleys penetrate eastward from the main Siuslaw River (Figure 15). Groundwater monitoring wells located around the margins of the dune field would help to resolve the steeper groundwater surface trends at the edges of the North Florence Dunal Aquifer.

In many GPR profiles a deeper reflection is apparent well below the groundwater surface reflection (Figure 13; Appendix C). The deeper GPR reflections could represent contacts between Holocene dunes and underlying Pleistocene dune deposits or loess paleosols in the Pleistocene dune deposits (Couch et al., 1980; Peterson et al., 2006; Peterson et al. 2007b). In such cases the GPR reflection in the fully saturated media could be caused by changes in the 1) diagenetic cementation of pore spaces, 2) clay mineral abundance, and/or 3) organic content in dunal paleosols (Hampton, 1963; Jol and Bistrow, 2003; Peterson et al., 2006). Nevertheless, the overlying groundwater reflections were continuous and unchanged in elevation or slope by the presence of the underlying features. It is not known whether the underlying Pleistocene deposits serve as deeper aquitards in the mixed Holocene and Pleistocene dune aquifer, but they do not apparently influence the groundwater surface in the overlying Holocene dune deposits.

Creation of Groundwater Surface Map and Trend Assessment

ArcMap 10.0 Geostatistical Toolpack Simple Kriging tool was used to create a groundwater surface elevation map for the North Florence Dunal Aquifer. The advantage to using a geostatistical method such as kriging is the ability to assess the error associated

with each prediction. Summary statistics for this process (Table 1) show average standard error (variability from the mean groundwater elevation at each point), root mean error square (variability of the mean groundwater elevation between points) and mean error. The prediction error map (Figure 16) shows less error in areas where more measured values were available, generally less than 2m of error elevation (NAVD88). In areas where no surveying was conducted there is possible error of up to almost 6 m elevation.

In order to assess the flow of groundwater in the North Florence Dunal Aquifer porosity, hydraulic conductivity and boundary conditions would need to be established and entered into a groundwater flow model, such as MODFLOW (Brown et al., 2008). MODFLOW model (GWVista) is in the process of being created from this data by GSI Water Solutions Inc. Although this model is not complete early stages of development are consistent with groundwater surface elevations predicted in this study. Though groundwater flow is not directly addressed in this thesis, it is assumed that shallow groundwater flow should follow general trends or slopes of the groundwater surface.

Groundwater surface trends are shown on the groundwater surface elevation map (Figure 21) indicate that the groundwater elevation generally follows the ground surface topographic elevations in the North Florence Dunal Aquifer. Table 4 shows 55 points throughout Florence whose groundwater elevations mimicked the topography (Table 4). The groundwater surface elevations and ground elevations from Table 4 have a correlation coefficient of .72 indicating a moderate amount of correlation (Figure 23). Combined elevations from both window lakes and ponds (Appendix B) and subsurface

groundwater surface reflections (Appendix A) demonstrate two elevated mounds of groundwater surface in the north and central dune field areas. The north mound, reaching 50 m elevation (NAVD88) forms a peninsula that slopes downward to the east, west, and south. The northern mound slopes steeply down to the east into barrage lake valleys (5-10 m elevation) and less steeply to the west (Pacific Ocean shoreline) and to a central trough (10-22 m elevation) to the south.

Figure 22: Map of the Predicted Groundwater surface and expected shallow groundwater flow. Since the groundwater gradient regionally follows the ground elevation, shallow groundwater flow is expected to flow radially from two groundwater mounds south to the Siuslaw River, East to Lakes, and west to the Pacific Ocean (predicted flow indicated by arrows). Location of the City wellfield is outlined in the red box, receiving water from up gradient groundwater mounds.

Figure 23: Plot of ground elevations (meters) and groundwater elevations (meters) for 55 points throughout the city of Florence. A correlation coefficient of .72 indicates a linear relationship between the two variables.

The central groundwater surface trough, aligned east to west, separates the north and south groundwater surface mounds in the North Florence Dune Aquifer (Figure 15). The central trough dips from the east end (15-22 m elevation) to the west end (5-10 m elevation). A small creek, ponds, and wetlands are aligned along the central trough, which drains the barraged Sutton Lake and Mercer Lakes (Figure 1).

The south groundwater surface mound in the North Florence Dune aquifer lies below the north end of the City of Florence, and west of the high elevation barrage lakes, Collard Lake, Clear Lake, and Munsel Lake (Figure 1). The south groundwater surface mound reaches elevations of 27-44 m (Figure 15). The south groundwater mound slopes

downward to the Siuslaw estuary to the south, the central trough to the north, and to the Siuslaw tidal inlet to the west. The city well field (Figure 22) is located down gradient from the southern groundwater mound. The field receives water from this mound and is therefore highly susceptible to any contamination entering the aquifer through larger lakes, creeks or open dune areas located on the groundwater mound. Contaminants could easily enter the North Florence Dunal Aquifer at any location and could affect the quality of drinking water available to the city. However, introducing contaminants to the southern groundwater mound would result in contaminated water flowing directly to the well field. No GPR crossing lines were permitted across the eastside of the dune ridge that separates the City of Florence well field from the North Fork of the Siuslaw River, so groundwater surface trends on the east side of the City's well field are not established in this study.

Salinity intrusion reached at least 100-200 m northward of the Siuslaw Bay front at southernmost end of the dunal aquifer, as indicated by abruptly decreased GPR signal penetrations. Such limited salinity intrusion at the south end of the dune aquifer is likely to be prohibited due west of the south groundwater surface mound, which slopes steeply downward to Siuslaw tidal inlet. Groundwater monitoring wells could be installed to confirm the northward extent of shallow salinity intrusion under Old Town at the southernmost end of North Florence Dunal Aquifer.

Table 4: 55 points from 6 different GPR tracts compared the groundwater elevation and ground elevation. In areas throughout the city the groundwater elevation was observed to mimic the local topography, especially in Holocene dune fields.

Latitude	Longitude	GE (m)	GWE (m)	Latitude	Longitude	GE (m)	GWE(m)
44.04981	-124.1064	22	18	43.97867	-124.10881	13	12
44.05016	-124.1076	20	16	43.97783	-124.1088	15	14
44.05053	-124.1086	21	17	43.97692	-124.1087	17	15
44.05134	-124.1093	21	17	43.97603	-124.1087	14	13
44.05214	-124.1091	20	16	43.97512	-124.1087	9	8
44.05278	-124.1085	18	11	43.97421	-124.1086	9	8
44.05347	-124.1077	17	10	43.9733	-124.1086	8	7
44.05435	-124.1077	13	6	43.97239	-124.1088	8	7
44.05368	-124.1076	16	10	43.97151	-124.1086	7	6
44.05292	-124.1084	18	12	43.97097	-124.1091	7	6
44.05298	-124.1110	20	10	43.97095	-124.1104	7	6
44.05361	-124.1118	20	10	43.97063	-124.1112	6	5
44.05441	-124.1123	20	10	43.96978	-124.1110	7	6
44.05525	-124.1128	20	10	43.96917	-124.1106	5	4
44.06227	-124.1193	11	5	43.96842	-124.1110	4	3
44.06305	-124.1199	9	3	43.96782	-124.1102	4	3
44.06379	-124.1204	9	3	43.96709	-124.1108	3	2
44.06466	-124.1207	10	4	43.96677	-124.1109	3	2
44.06553	-124.1212	11	5	43.98794	-124.0988	16	14
44.06636	-124.1216	10	4	43.9876	-124.0980	15	13
44.06712	-124.1220	8	2	43.98768	-124.0967	15	12
44.06761	-124.1230	7	0	43.98763	-124.0956	15	13
43.97991	-124.1028	13	10	43.98758	-124.0943	15	13
43.97977	-124.1040	13	10	43.98757	-124.0938	14	12
43.97931	-124.1051	13	10	43.98673	-124.0936	15	11
43.97886	-124.1063	14	11	43.98629	-124.0926	12	8
43.97861	-124.1073	13	11	43.98544	-124.0922	13	9
43.97872	-124.1086	13	11				

GE (m)- Ground elevation in meters at specific coordinates taken from Lidar.

GWE (m)- Groundwater elevation in meters at specific coordinates taken from GPR.

Chapter Five-Conclusions

- 1) GPR was both successful and efficient in imaging the shallow groundwater surface throughout the large North Florence Dunal Aquifer.
- 2) The groundwater surface reflections were traced directly to surface water bodies, including lakes, ponds, and bogs in the North Florence dune fields, demonstrating that all of the surface water bodies are windows into the North Florence Dunal Aquifer. Furthermore the wetlands that are contained by the aquifer are entirely controlled by the aquifer while the lakes on the eastern edge of the aquifer receive additional input via surface runoff or spring water
- 3) The groundwater surface regionally conforms to ground surface elevations produced by dune sand accretion in the North Florence dune fields.

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Appendix A- North Florence Dunal Aquifer Groundwater Elevation Database

Line	X	UTM_E	UTM_N	LATITUDE	LONGITUDE	FloLIDAR	Groundwater	DTW
3	0	411872	4869634	43.97456	-124.09874	6	5	1
3	100	411783	4869645	43.97465	-124.09985	6	5	1
3	200	411683	4869653	43.97471	-124.10109	8	7	1
3	300	411583	4869661	43.97477	-124.10234	9	8	1
3	400	411483	4869659	43.97474	-124.10359	10	9	1
3	500	411280	4869656	43.97469	-124.10612	9	8	1
3	600	411183	4869658	43.97469	-124.10733	9	8	1
3	700	411183	4869658	43.97469	-124.10733	9	8	1
3	800	411082	4869660	43.9747	-124.10859	9	8	1
3	900	410979	4869657	43.97466	-124.10987	8	8	0
3	1000	410879	4869655	43.97463	-124.11112	9	8	1
3	1100	410785	4869652	43.97459	-124.11229	12	8	4
3	1200	410679	4869654	43.97459	-124.11361	9	8	1
3	1300	410572	4869655	43.97459	-124.11494	9	8	1
3	1400	410478	4869657	43.9746	-124.11612	8	7	1
3	1500	410384	4869659	43.9746	-124.11729	9	8	1
3	1600	410282	4869688	43.97485	-124.11856	8	7	1
3	1700	410212	4869755	43.97545	-124.11945	9	8	1
3	1800	410117	4869764	43.97552	-124.12063	12	11	1
3	1855	410127	4869768	43.97555	-124.12051	12	11	1
4	0	411882	4869647	43.97468	-124.09861	6	5.5	0.5
4	100	411881	4869746	43.97557	-124.09864	7	6	1
4	200	411878	4869846	43.97647	-124.0987	8	7	1
4	300	411879	4869946	43.97737	-124.0987	9	8	1
4	400	411879	4870046	43.97827	-124.09872	10	9	1
4	500	411879	4870146	43.97917	-124.09873	11	10	1
4	600	411879	4870246	43.98007	-124.09875	11	10	1
4	700	411878	4870340	43.98091	-124.09878	12	10	2
4	800	411879	4870452	43.98192	-124.09878	12	10	2
4	900	411879	4870552	43.98282	-124.0988	13	11	2
4	1000	411880	4870659	43.98379	-124.09881	14	11	3
4	1100	411881	4870746	43.98457	-124.09881	14	11	3
4	1200	411882	4870852	43.98552	-124.09881	14	11	3
4	1300	411883	4870953	43.98643	-124.09882	15	11	4
4	1400	411884	4871053	43.98733	-124.09882	16	12	4
4	1500	411885	4871153	43.98823	-124.09883	16	12	4
4	1600	411885	4871253	43.98913	-124.09884	16	12	4
4	1700	411886	4871346	43.98997	-124.09885	18	14	4
4	1800	411888	4871446	43.99087	-124.09884	19	15	4

4	1900	411889	4871553	43.99184	-124.09884	19	15	4
4	2000	411890	4871647	43.99268	-124.09885	20	15	5
4	2100	411892	4871753	43.99364	-124.09884	21	16	5
4	2200	411869	4871832	43.99434	-124.09914	23	18	5
4	2300	411791	4871865	43.99463	-124.10012	20	16	4
4	2400	411789	4871959	43.99548	-124.10016	20	16	4
4	2500	411786	4872065	43.99643	-124.10021	21	16	5
4	2600	411822	4872128	43.997	-124.09977	22	17	5
4	2700	411884	4872168	43.99737	-124.09901	22	18	4
4	2800	411884	4872268	43.99827	-124.09902	22	18	4
4	2900	411902	4872362	43.99912	-124.09881	21	17	4
4	3000	411935	4872457	43.99998	-124.09842	21	17	4
4	3100	411937	4872545	44.00077	-124.09841	22	18	4
4	3200	411938	4872651	44.00172	-124.09841	22	18	4
4	3300	411939	4872745	44.00257	-124.09842	23	19	4
4	3400	412010	4872800	44.00307	-124.09754	24	20	4
4	3500	412090	4872796	44.00305	-124.09654	24	20	4
4	3600	412159	4872775	44.00287	-124.09568	25	22	3
4	3730	412168	4872776	44.00288	-124.09557	25	22	3
5	0	411009	4868803	43.96697	-124.10935	3	2	1
5	100	411062	4868878	43.96766	-124.10871	8	5	3
5	200	411074	4868980	43.96858	-124.10857	5	5	0
5	300	411072	4869073	43.96941	-124.10861	6	5	1
5	400	411071	4869172	43.9703	-124.10864	7	5	2
5	500	411070	4869272	43.9712	-124.10867	7	5	2
5	600	411070	4869371	43.97209	-124.10869	7	5	2
5	700	411071	4869471	43.97299	-124.10869	8	5	3
5	800	411071	4869576	43.97394	-124.10871	9	6	3
5	900	411072	4869676	43.97484	-124.10871	9	7	2
5	1000	411073	4869781	43.97579	-124.10872	11	9	2
5	1100	411073	4869881	43.97669	-124.10874	17	15	2
5	1200	411074	4869980	43.97758	-124.10874	16	14	2
5	1300	411075	4870080	43.97848	-124.10875	13	13	0
5	1400	411075	4870179	43.97937	-124.10876	12	12	0
5	1500	411075	4870278	43.98026	-124.10878	12	12	0
5	1600	411075	4870378	43.98116	-124.1088	13	12	1
5	1700	411060	4870476	43.98204	-124.109	13	13	0
5	1800	411051	4870575	43.98293	-124.10913	14	14	0
5	1900	411046	4870680	43.98387	-124.10921	14	14	0
5	2000	411042	4870780	43.98477	-124.10927	15	14	1
5	2100	411028	4870872	43.9856	-124.10946	15	14	1
5	2200	411013	4870976	43.98654	-124.10967	15	14	1
5	2300	411001	4871075	43.98743	-124.10983	16	14	2

5	2400	410995	4871174	43.98832	-124.10993	16	15	1
5	2500	411002	4871273	43.98921	-124.10986	17	16	1
5	2600	411015	4871371	43.99009	-124.10971	17	16	1
5	2700	410991	4871461	43.9909	-124.11002	18	16	2
5	2800	410956	4871554	43.99173	-124.11048	18	12	6
5	2900	410920	4871653	43.99262	-124.11094	19	17	2
5	3000	410897	4871750	43.99349	-124.11124	24	19	5
5	3100	410908	4871854	43.99443	-124.11112	29	26	3
5	3200	410933	4871944	43.99524	-124.11083	31	26	5
5	3300	411010	4872015	43.99589	-124.10988	32	26	6
5	3400	411077	4872078	43.99646	-124.10906	32	26	6
5	3500	411098	4872168	43.99728	-124.10881	30	25	5
5	3645	411011	4872177	43.99735	-124.10989	33	26	7
8	0	413286	4871229	43.98908	-124.08137	7	0	7
8	100	413258	4871133	43.98822	-124.0817	7	0	7
8	200	413239	4871034	43.98732	-124.08192	7	0	7
8	300	413221	4870935	43.98643	-124.08213	5	0	5
8	400	413206	4870836	43.98554	-124.0823	4	2	2
8	500	413188	4870738	43.98465	-124.08251	4	2	2
8	600	413174	4870641	43.98378	-124.08267	5	0	5
8	700	413178	4870538	43.98285	-124.0826	4	0	4
8	800	413180	4870440	43.98197	-124.08256	4	0	4
8	900	413182	4870340	43.98107	-124.08252	5	2	3
8	1000	413182	4870239	43.98016	-124.08251	8	6	2
8	1100	413176	4870137	43.97924	-124.08256	7	6	1
8	1200	413158	4870041	43.97838	-124.08277	5	5	0
8	1300	413114	4869954	43.97759	-124.08331	4	4	0
8	1410	413042	4869838	43.97653	-124.08418	6	5	1
11	0	410277	4872313	43.99848	-124.11907	18	17	1
11	100	410258	4872406	43.99932	-124.11932	17	17	0
11	200	410217	4872494	44.0001	-124.11985	17	17	0
11	300	410169	4872580	44.00087	-124.12046	18	18	0
11	400	410175	4872678	44.00175	-124.1204	22	20	2
11	500	410157	4872782	44.00269	-124.12065	23	20	3
11	600	410119	4872869	44.00347	-124.12114	22	20	2
11	700	410053	4872945	44.00414	-124.12197	21	20	1
11	800	410041	4873039	44.00499	-124.12214	22	20.5	1.5
11	900	410080	4873124	44.00576	-124.12166	24	22	2
11	1000	410062	4873224	44.00666	-124.12191	22	21	1
11	1100	410045	4873318	44.0075	-124.12213	20	20	0
11	1200	410018	4873415	44.00837	-124.12249	20	20	0
11	1300	409995	4873518	44.00929	-124.12279	20	20	0
11	1400	409995	4873614	44.01016	-124.12281	21	21	0

11	1500	410013	4873709	44.01102	-124.1226	21	21	0
11	1600	410045	4873806	44.01189	-124.12222	21	21	0
11	1700	410045	4873906	44.01279	-124.12223	21	21	0
11	1800	410032	4874010	44.01373	-124.12241	21	21	0
11	1900	410023	4874107	44.0146	-124.12254	21	21	0
11	2000	410011	4874206	44.01549	-124.12271	21	21	0
11	2100	410000	4874297	44.01631	-124.12286	21	21	0
11	2200	409988	4874402	44.01725	-124.12303	21	21	0
11	2300	409993	4874504	44.01817	-124.12298	21	20	1
11	2400	410006	4874604	44.01907	-124.12284	21	20	1
11	2500	410022	4874701	44.01995	-124.12266	21	20	1
11	2600	410007	4874800	44.02084	-124.12286	22	22	0
11	2700	409967	4874893	44.02167	-124.12337	21	21	0
11	2800	409940	4874986	44.0225	-124.12373	21	21	0
11	2900	409919	4875085	44.02339	-124.12401	21	21	0
11	3000	409876	4875171	44.02416	-124.12456	21	21	0
11	3100	409813	4875257	44.02493	-124.12536	20	20	0
11	3200	409757	4875338	44.02565	-124.12607	20	20	0
11	3300	409729	4875434	44.02651	-124.12644	22	22	0
11	3400	409707	4875536	44.02742	-124.12673	24	24	0
11	3500	409682	4875632	44.02829	-124.12706	23	20	3
11	3600	409655	4875723	44.0291	-124.12741	19	16	3
11	3700	409620	4875818	44.02995	-124.12786	17	16	1
11	3800	409560	4875897	44.03066	-124.12862	19	18	1
11	3900	409516	4875982	44.03142	-124.12919	21	20	1
11	4000	409520	4876085	44.03234	-124.12915	18	17	1
11	4100	409521	4876190	44.03329	-124.12916	14	13	1
11	4200	409608	4876166	44.03308	-124.12807	16	15	1
11	4300	409707	4876127	44.03274	-124.12683	18	17	1
11	4400	409783	4876078	44.03231	-124.12587	20	19	1
11	4500	409872	4876017	44.03177	-124.12475	19	19	0
11	4600	409953	4875961	44.03128	-124.12373	20	19	1
11	4700	410037	4875911	44.03084	-124.12267	24	23	1
11	4800	410134	4875892	44.03068	-124.12146	24	24	0
11	4900	410219	4875848	44.0303	-124.12039	26	25	1
11	5000	410302	4875781	44.0297	-124.11935	26	26	0
11	5100	410372	4875723	44.02919	-124.11846	27	26	1
11	5200	410453	4875650	44.02854	-124.11744	26	26	0
11	5300	410515	4875575	44.02787	-124.11665	25	25	0
11	5400	410576	4875498	44.02719	-124.11588	25	24	1
11	5500	410638	4875420	44.02649	-124.11509	26	24	2
11	5600	410696	4875338	44.02576	-124.11436	26	24	2
11	5700	410795	4875303	44.02546	-124.11311	28	27	1

11	5800	410885	4875288	44.02534	-124.11199	28	26	2
11	5900	410972	4875247	44.02498	-124.1109	28	27	1
11	6000	411025	4875169	44.02428	-124.11022	29	28	1
11	6100	411070	4875068	44.02338	-124.10964	29	28	1
11	6200	411096	4874973	44.02253	-124.1093	28	27	1
11	6300	411097	4874884	44.02172	-124.10928	29	27	2
11	6400	411117	4874785	44.02084	-124.10901	29	28	1
11	6500	411187	4874715	44.02021	-124.10813	28	28	0
11	6600	411257	4874647	44.01961	-124.10724	28	28	0
11	6700	411327	4874565	44.01888	-124.10635	28	28	0
11	6800	411395	4874482	44.01814	-124.10549	30	29	1
11	6900	411478	4874432	44.0177	-124.10445	30	29	1
11	7000	411576	4874429	44.01769	-124.10323	30	29	1
11	7100	411699	4874431	44.01772	-124.10169	32	29	3
11	7200	411688	4874441	44.01781	-124.10183	32	29	3
12	0	411698	4874441	44.01781	-124.10171	32	30	2
12	100	411701	4874544	44.01874	-124.10168	32	30	2
12	200	411715	4874632	44.01953	-124.10152	32	30	2
12	300	411721	4874753	44.02062	-124.10147	33	31	2
12	400	411732	4874836	44.02137	-124.10135	34	32	2
12	500	411739	4874942	44.02232	-124.10128	36	35	1
12	600	411749	4875034	44.02315	-124.10117	36	35	1
12	700	411789	4875138	44.02409	-124.10069	38	35	3
12	800	411768	4875232	44.02494	-124.10096	37	36	1
12	900	411779	4875346	44.02597	-124.10085	38	36	2
12	1000	411788	4875436	44.02678	-124.10075	37	36	1
12	1100	411800	4875539	44.02771	-124.10062	36	36	0
12	1200	411807	4875628	44.02851	-124.10054	36	36	0
12	1300	411814	4875725	44.02938	-124.10047	36	36	0
12	1400	411827	4875825	44.03028	-124.10033	37	36	1
12	1500	411834	4875925	44.03118	-124.10026	38	36	2
12	1600	411844	4876025	44.03209	-124.10015	39	37	2
12	1700	411851	4876135	44.03308	-124.10008	38	37	1
12	1800	411855	4876239	44.03401	-124.10005	37	37	0
12	1900	411867	4876327	44.03481	-124.09991	35	35	0
12	2000	411878	4876424	44.03568	-124.09979	34	33	1
12	2100	411885	4876531	44.03665	-124.09972	33	32	1
12	2200	411897	4876638	44.03761	-124.09959	32	32	0
12	2300	411901	4876723	44.03838	-124.09955	31	30	1
12	2400	411915	4876829	44.03933	-124.0994	30	29	1
12	2500	411923	4876927	44.04021	-124.09931	29	28	1
12	2600	411932	4877024	44.04109	-124.09922	28	27	1
12	2700	411944	4877118	44.04194	-124.09908	28	27	1

12	2800	411953	4877221	44.04287	-124.09899	28	27	1
12	2900	411965	4877322	44.04378	-124.09885	28	27	1
12	3000	411969	4877420	44.04466	-124.09882	27	26	1
12	3100	411986	4877526	44.04561	-124.09863	24	22	2
12	3200	411989	4877637	44.04661	-124.09861	21	18	3
12	3300	412002	4877724	44.0474	-124.09846	18	18	0
12	3400	412079	4877746	44.04761	-124.0975	19	18	1
12	3500	412176	4877743	44.04759	-124.09629	19	18	1
12	3600	412282	4877739	44.04757	-124.09497	19	18	1
12	3700	412380	4877736	44.04755	-124.09374	21	18	3
12	3800	412486	4877732	44.04753	-124.09242	21	18	3
12	3900	412574	4877731	44.04753	-124.09132	21	18	3
12	4000	412680	4877734	44.04757	-124.09	21	20	1
12	4100	412777	4877737	44.04761	-124.08879	26	25	1
12	4200	412882	4877750	44.04774	-124.08748	30	30	0
12	4300	412962	4877792	44.04813	-124.08649	30	26	4
12	4400	413059	4877834	44.04852	-124.08528	30	24	6
12	4500	413164	4877830	44.04849	-124.08397	28	22	6
12	4600	413253	4877822	44.04843	-124.08286	23	15	8
12	4700	413359	4877821	44.04843	-124.08154	23	15	8
12	4800	413445	4877813	44.04837	-124.08046	26	21	5
12	4900	413541	4877753	44.04784	-124.07926	23	17	6
12	5000	413561	4877662	44.04703	-124.07899	18	10	8
12	5100	413704	4877553	44.04606	-124.07719	16	10	6
12	5200	413588	4877587	44.04635	-124.07864	14	12	2
13	1200	412559	4878493	44.05439	-124.09163	15	15	0
13	1300	412477	4878437	44.05387	-124.09265	16	15	1
13	1400	412403	4878370	44.05326	-124.09356	14	14	0
13	1500	412324	4878308	44.05269	-124.09454	14	13	1
13	1800	412063	4878157	44.0513	-124.09777	17	16.5	0.5
13	1900	412038	4878069	44.05051	-124.09807	17	16.5	0.5
13	2000	412026	4877978	44.04969	-124.0982	17	16.5	0.5
13	2100	412013	4877871	44.04872	-124.09835	17	16.5	0.5
13	2200	412002	4877773	44.04784	-124.09847	18	17	1
13	2300	411993	4877672	44.04693	-124.09856	20	19	1
13	2400	411983	4877572	44.04603	-124.09867	23	22	1
13	2500	411974	4877473	44.04514	-124.09877	26	25	1
13	2600	411909	4877470	44.0451	-124.09958	29	28	1
13	2700	411808	4877499	44.04535	-124.10084	29	28	1
13	2800	411735	4877546	44.04576	-124.10176	26	25	1
13	2900	411681	4877630	44.04651	-124.10245	24	23	1
13	3000	411627	4877714	44.04726	-124.10314	23	22	1
13	3100	411576	4877800	44.04803	-124.10379	22	21	1

13	3200	411522	4877885	44.04879	-124.10448	23	21	2
13	3300	411461	4877513	44.04543	-124.10518	29	24	5
13	3400	411369	4878000	44.04981	-124.10641	22	18	4
13	3500	411270	4878040	44.05016	-124.10765	20	16	4
13	3600	411189	4878083	44.05053	-124.10867	21	17	4
13	3700	411138	4878173	44.05134	-124.10932	21	17	4
13	3800	411149	4878262	44.05214	-124.10919	20	16	4
13	3900	411206	4878332	44.05278	-124.1085	18	11	7
13	4000	411269	4878408	44.05347	-124.10772	17	10	7
13	4100	411268	4878506	44.05435	-124.10775	13	6	7
13	4200	411275	4878431	44.05368	-124.10765	16	10	6
13	4300	411214	4878348	44.05292	-124.1084	18	12	6
13	4600	411012	4878357	44.05298	-124.11092	20	10	10
13	4700	410942	4878428	44.05361	-124.11181	20	10	10
13	4800	410902	4878518	44.05441	-124.11232	20	10	10
13	4900	410864	4878611	44.05525	-124.11281	20	10	10
13	5000	410811	4878695	44.056	-124.11349	18	10	8
13	5100	410759	4878772	44.05668	-124.11415	16	9	7
13	5200	410698	4878861	44.05748	-124.11493	16	9	7
13	5300	410642	4878943	44.05821	-124.11564	17	12.5	4.5
13	5400	410583	4879024	44.05893	-124.11639	16	13	3
13	5500	410530	4879108	44.05968	-124.11706	15	11	4
13	5600	410556	4879201	44.06052	-124.11676	13	10	3
13	5700	410521	4879283	44.06125	-124.11721	12	10	2
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13	6000	410308	4879486	44.06305	-124.1199	9	3	6
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13	6200	410246	4879665	44.06466	-124.1207	10	4	6
13	6300	410202	4879762	44.06553	-124.12127	11	5	6
13	6400	410172	4879855	44.06636	-124.12166	10	4	6
13	6500	410141	4879940	44.06712	-124.12206	8	2	6
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14	300	411309	4869070	43.96941	-124.10566	8	6	2
14	400	411251	4869145	43.97008	-124.10639	8	7	1
14	500	411280	4869228	43.97083	-124.10605	8	8	0
14	600	411332	4869319	43.97166	-124.10541	9	8	1
14	700	411384	4869411	43.97249	-124.10478	9	9	0
14	800	411428	4869495	43.97325	-124.10425	10	9	1
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14	1000	411527	4869680	43.97493	-124.10304	10	9	1
14	1100	411588	4869774	43.97578	-124.1023	10	9	1
14	1200	411635	4869864	43.9766	-124.10173	11	10	1

14	1300	411669	4869970	43.97756	-124.10132	11	10	1
14	1400	411678	4870068	43.97844	-124.10123	11	10	1
14	1500	411677	4870175	43.97941	-124.10126	11	10	1
14	1600	411678	4870268	43.98024	-124.10126	12	11	1
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14	1800	411676	4870477	43.98212	-124.10132	13	12	1
14	1900	411676	4870580	43.98305	-124.10134	14	13.5	0.5
14	2000	411681	4870667	43.98383	-124.10129	14	13.5	0.5
14	2100	411681	4870766	43.98473	-124.10131	15	13.5	1.5
14	2200	411683	4870867	43.98564	-124.1013	15	13.5	1.5
14	2300	411677	4870971	43.98657	-124.10139	16	14	2
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14	2500	411677	4871158	43.98825	-124.10142	17	14	3
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14	2900	411681	4871552	43.9918	-124.10144	18	15	3
14	3000	411685	4871655	43.99273	-124.1014	19	16	3
14	3100	411684	4871760	43.99367	-124.10143	19	16	3
14	3200	411685	4871866	43.99463	-124.10144	20	17	3
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14	3700	411687	4872365	43.99912	-124.1015	23	19	4
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14	3900	411687	4872567	44.00094	-124.10153	24	20	4
14	4000	411688	4872664	44.00181	-124.10153	24	20	4
14	4100	411688	4872755	44.00263	-124.10155	25	21	4
14	4200	411688	4872864	44.00361	-124.10157	25	21	4
14	4300	411690	4872965	44.00452	-124.10156	26	22	4
14	4400	411691	4873064	44.00541	-124.10156	27	23	4
14	4500	411690	4873167	44.00634	-124.10159	27	23	4
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14	4700	411691	4873353	44.00801	-124.10161	29	25	4
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14	5000	411695	4873663	44.01081	-124.10161	29	26	3
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14	5500	411696	4874164	44.01532	-124.10168	30	27	3

14	5600	411699	4874251	44.0161	-124.10166	31	27	4
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14	5800	411702	4874457	44.01795	-124.10166	32	30	2
14	5900	411707	4874552	44.01881	-124.10161	32	30	2
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14	6100	411721	4874742	44.02052	-124.10147	33	31	2
14	6200	411735	4874849	44.02149	-124.10131	35	34	1
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14	6500	411760	4875146	44.02416	-124.10105	37	36	1
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14	8100	411909	4876744	44.03857	-124.09946	31	28	3
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15	300	412295	4879138	44.06016	-124.09504	24	23	1
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15	800	412383	4879528	44.06368	-124.094	17	16	1
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16	100	412155	4879740	44.06556	-124.09688	45	44	1
16	200	412254	4879749	44.06566	-124.09565	47	44	3
16	307	412263	4879687	44.0651	-124.09553	41	40	1
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17	100	411802	4880140	44.06912	-124.10136	41	40	1
17	200	411777	4880095	44.06871	-124.10166	34	33	1
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17	400	411762	4880240	44.07002	-124.10187	31	30	1
17	505	411694	4880281	44.07038	-124.10273	32	31	1
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18	200	412015	4880663	44.07386	-124.09879	63	57	6
18	300	412098	4880607	44.07336	-124.09774	62	54	8
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18	500	412222	4880473	44.07217	-124.09617	48	47	1
18	600	412305	4880464	44.0721	-124.09513	43	40	3
18	700	412391	4880424	44.07175	-124.09405	39	35	4
18	800	412488	4880409	44.07163	-124.09284	33	30	3
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18	1100	412581	4880204	44.06979	-124.09164	18	15	3
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19	200	411366	4882193	44.08755	-124.10715	28	25	3
19	300	411290	4882162	44.08726	-124.10809	17	16	1
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19	500	411194	4882312	44.0886	-124.10931	12	10	2
19	600	411095	4882308	44.08855	-124.11055	10	9	1
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19	1100	410606	4882260	44.08806	-124.11665	16	15	1
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19	1335	410488	4882238	44.08785	-124.11812	8	7	1
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20	200	411250	4882172	44.08735	-124.10859	14	13	1
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21	300	411791	4878092	44.05069	-124.10115	14	13	1
21	400	411719	4878092	44.05068	-124.10205	14	14	0
21	500	411649	4878157	44.05125	-124.10294	13	12	1
21	600	411638	4878254	44.05213	-124.10309	14	8	6
21	700	411690	4878300	44.05255	-124.10245	15	9	6
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22	0	411799	4878611	44.05536	-124.10114	16	10	6
22	100	411779	4878399	44.05345	-124.10135	11	10	1
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22	300	411904	4878478	44.05417	-124.09981	21	18	3
22	400	411817	4878470	44.05409	-124.10089	21	18	3
22	500	411780	4878551	44.05482	-124.10137	15	12	3
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22	700	411738	4878377	44.05325	-124.10186	12	9	3
22	800	411646	4878374	44.05321	-124.10301	12	9	3
22	882	411571	4878383	44.05328	-124.10395	12	9	3
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22	1100	411371	4878433	44.05371	-124.10645	13	9	4
22	1200	411319	4878529	44.05456	-124.10712	12	9	3
22	1300	411241	4878529	44.05455	-124.10809	12	9	3
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22	1500	411245	4878718	44.05626	-124.10807	11	8	3
22	1565	411258	4878753	44.05657	-124.10792	11	8	3
23	0	412225	4876282	44.03444	-124.09544	36	35	1
23	100	412144	4876276	44.03438	-124.09645	36	35	1
23	200	412044	4876284	44.03444	-124.0977	35	35	0

23	300	411944	4876293	44.03451	-124.09894	34	34	0
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24	0	412192	4875688	44.02909	-124.09575	40	36	4
24	100	412096	4875705	44.02924	-124.09695	40	36	4
24	200	412059	4875783	44.02993	-124.09742	40	36	4
24	300	411959	4875782	44.02991	-124.09867	39	37	2
24	400	411859	4875794	44.03001	-124.09992	38	37	1
24	500	411760	4875796	44.03001	-124.10116	34	34	0
24	600	411659	4875802	44.03006	-124.10242	33	32	1
24	700	411563	4875816	44.03017	-124.10362	33	32	1
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28	0	409533	4876192	44.03331	-124.12901	14	13	1
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28	200	409332	4876192	44.03328	-124.13152	12	11	1
28	300	409301	4876282	44.03409	-124.13192	11	10	1
28	400	409304	4876381	44.03498	-124.1319	11	10	1
28	500	409310	4876480	44.03587	-124.13184	10	9	1
28	600	409288	4876575	44.03673	-124.13213	8	7	1
28	700	409276	4876644	44.03734	-124.1323	9	7	2
28	744	409304	4876654	44.03744	-124.13195	10	8	2
28	797	409277	4876621	44.03714	-124.13228	8	7	1
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31	100	411796	4872814	44.00318	-124.10021	24	22	2
31	200	411896	4872810	44.00315	-124.09896	24	23	1
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31	500	412191	4872781	44.00293	-124.09528	24	23	1
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31	900	412458	4872889	44.00393	-124.09197	27	26	1
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31	1100	412587	4872823	44.00335	-124.09035	31	27	4
31	1200	412524	4872770	44.00287	-124.09113	29	27	2
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31	1400	412434	4872889	44.00393	-124.09227	25	24	1
31	1500	412370	4872851	44.00358	-124.09306	24	24	0
31	1600	412277	4872859	44.00364	-124.09422	24	24	0
32	0	412293	4873100	44.00581	-124.09406	26	25	1
32	100	412255	4873185	44.00657	-124.09455	27	25	2
32	200	412160	4873198	44.00668	-124.09574	26	25	1
32	300	412060	4873202	44.0067	-124.09698	25	24	1
32	400	411983	4873232	44.00696	-124.09795	26	23	3

32	500	411992	4873330	44.00784	-124.09785	26	23	3
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32	700	412046	4873457	44.00899	-124.0972	27	24	3
32	800	412144	4873438	44.00883	-124.09598	27	24	3
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32	1000	412241	4873310	44.00769	-124.09474	26	24	2
32	1153	412236	4873201	44.00671	-124.09479	25	23	2
33	0	412417	4873110	44.00591	-124.09252	27	25	2
33	100	412325	4873100	44.00581	-124.09366	27	25	2
33	200	412239	4873053	44.00538	-124.09473	25	24	1
33	300	412172	4872990	44.0048	-124.09555	24	23	1
33	400	412198	4872897	44.00397	-124.09521	24	23	1
33	500	412276	4872837	44.00344	-124.09423	23	22	1
33	600	412291	4872740	44.00257	-124.09403	23	22	1
33	700	412293	4872644	44.0017	-124.09399	22	21	1
33	800	412286	4872539	44.00076	-124.09406	22	21	1
33	900	412288	4872440	43.99987	-124.09401	23	21	2
33	1000	412279	4872340	43.99897	-124.09411	21	20	1
33	1100	412214	4872282	43.99844	-124.09491	23	21	2
33	1200	412123	4872272	43.99834	-124.09604	21	20	1
33	1300	412090	4872177	43.99748	-124.09644	21	20	1
33	1400	412067	4872082	43.99662	-124.09671	20	19	1
33	1500	412063	4871987	43.99576	-124.09674	20	19	1
33	1600	412055	4871890	43.99489	-124.09683	19	18	1
33	1700	412044	4871782	43.99392	-124.09695	19	18	1
33	1800	412006	4871719	43.99334	-124.09741	22	20	2
33	1961	411916	4871731	43.99344	-124.09854	22	20	2
34	0	412007	4871631	43.99255	-124.09738	24	18	6
34	100	411943	4871592	43.99219	-124.09818	21	18	3
34	200	411889	4871649	43.9927	-124.09886	20	18	2
34	300	411787	4871650	43.9927	-124.10013	19	16	3
34	400	411688	4871649	43.99268	-124.10136	19	15	4
34	500	411588	4871651	43.99268	-124.10261	19	15	4
34	600	411487	4871650	43.99266	-124.10387	19	16	3
34	700	411407	4871692	43.99303	-124.10488	19	16	3
34	800	411310	4871711	43.99319	-124.10609	19	17	2
34	900	411231	4871656	43.99268	-124.10706	19	16	3
34	977	411214	4871625	43.9924	-124.10727	19	16	3
39	0	412642	4870176	43.97953	-124.08923	12	10	2
39	100	412560	4870175	43.97951	-124.09025	11	9	2
39	200	412460	4870171	43.97946	-124.09149	11	9	2
39	300	412374	4870124	43.97903	-124.09256	11	9	2
39	400	412285	4870077	43.9786	-124.09366	11	9	2

39	500	412198	4870023	43.9781	-124.09474	10	9	1
39	600	412161	4869946	43.9774	-124.09518	11	9	2
39	700	412060	4869950	43.97743	-124.09644	9	8	1
39	800	411957	4869948	43.9774	-124.09773	9	8	1
39	900	411877	4869964	43.97753	-124.09873	9	8	1
39	1000	411879	4870065	43.97844	-124.09872	10	9	1
39	1100	411880	4870159	43.97929	-124.09872	11	10	1
39	1200	411849	4870233	43.97995	-124.09912	11	10	1
39	1300	411744	4870233	43.97994	-124.10043	11	10	1
39	1400	411655	4870233	43.97992	-124.10154	12	10	2
39	1500	411549	4870233	43.97991	-124.10286	13	10	3
39	1600	411452	4870218	43.97977	-124.10407	13	10	3
39	1700	411361	4870169	43.97931	-124.10519	13	10	3
39	1800	411271	4870120	43.97886	-124.10631	14	11	3
39	1900	411188	4870093	43.97861	-124.10734	13	11	2
39	2059	411085	4870107	43.97872	-124.10863	13	11	2
40	0	411070	4870102	43.97867	-124.10881	13	12	1
40	100	411070	4870008	43.97783	-124.1088	15	14	1
40	200	411074	4869907	43.97692	-124.10873	17	15	2
40	300	411074	4869808	43.97603	-124.10871	14	13	1
40	400	411074	4869707	43.97512	-124.1087	9	8	1
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40	600	411072	4869505	43.9733	-124.10869	8	7	1
40	700	411071	4869404	43.97239	-124.10868	8	7	1
40	800	411072	4869306	43.97151	-124.10865	7	6	1
40	900	411030	4869247	43.97097	-124.10917	7	6	1
40	1000	410925	4869246	43.97095	-124.11048	7	6	1
40	1100	410865	4869211	43.97063	-124.11122	6	5	1
40	1200	410875	4869116	43.96978	-124.11108	7	6	1
40	1300	410911	4869048	43.96917	-124.11062	5	4	1
40	1400	410874	4868965	43.96842	-124.11106	4	3	1
40	1500	410941	4868898	43.96782	-124.11022	4	3	1
40	1600	410889	4868818	43.96709	-124.11085	3	2	1
40	1700	410879	4868782	43.96677	-124.11097	3	2	1
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44	100	412283	4872242	43.99808	-124.09404	19	18	1
44	200	412289	4872143	43.99719	-124.09395	18	18	0
44	300	412295	4872044	43.9963	-124.09386	18	17	1
44	400	412304	4871942	43.99539	-124.09373	17	16	1
44	500	412375	4871884	43.99487	-124.09284	16	16	0
44	600	412458	4871829	43.99439	-124.09179	17	16	1
44	700	412539	4871768	43.99385	-124.09077	17	16	1
6	0	410271	4872310	43.99845	-124.11915	18	16	2

6	50	410328	4872291	43.99829	-124.11843	18	16	2
6	150	410409	4872242	43.99786	-124.11741	19	18	1
6	250	410510	4872242	43.99787	-124.11615	21	19	2
6	350	410603	4872212	43.99761	-124.11499	21	19	2
6	450	410696	4872240	43.99788	-124.11383	21	19	2
6	550	410271	4872310	43.99845	-124.11915	18	17	1
6	650	410890	4872252	43.99801	-124.11142	31	28	3
6	750	410927	4872222	43.99774	-124.11095	34	26	8
6	850	411070	4872182	43.9974	-124.10916	31	24	7
6	950	411168	4872160	43.99721	-124.10793	24	21	3
6	1050	411263	4872126	43.99692	-124.10674	21	20	1
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6	1250	411462	4872125	43.99693	-124.10426	21	18	3
6	1350	411563	4872123	43.99693	-124.103	22	18	4
6	1450	411625	4872003	43.99585	-124.10221	21	18	3
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25	50	411580	4874890	44.02184	-124.10325	34	31	3
25	150	411492	4874863	44.02158	-124.10435	31	31	0
25	250	411413	4874919	44.02208	-124.10534	30	30	0
25	350	411379	4875013	44.02292	-124.10578	33	30	3
25	450	411361	4875104	44.02374	-124.10602	31	31	0
25	550	411299	4875181	44.02442	-124.10681	32	31	1
25	650	411252	4875269	44.02521	-124.10741	31	31	0
25	750	411196	4875359	44.02601	-124.10812	33	33	0
25	850	411301	4875032	44.02308	-124.10676	30	30	0
25	950	411093	4875516	44.02741	-124.10943	34	33	1
25	1050	411079	4875551	44.02773	-124.10961	34	32.5	1.5
25	1150	411072	4875575	44.02794	-124.1097	35	34	1
25	1217	411064	4875593	44.0281	-124.10981	36	34	2
26	0	411056	4875084	44.02352	-124.10982	29	26	3
26	100	410964	4875059	44.02328	-124.11097	31	26	5
26	200	410866	4875066	44.02333	-124.11219	30	25	5
26	300	410803	4875020	44.02291	-124.11297	29	24	5
26	400	410841	4874927	44.02208	-124.11248	31	24	7
26	500	410762	4874866	44.02152	-124.11345	31	24	7
27	583	411056	4875084	44.02327	-124.11289	29	24	5
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27	100	410778	4875156	44.02413	-124.1133	29	24	5
27	200	410706	4875209	44.0246	-124.11421	32	23	9
27	300	410622	4875254	44.025	-124.11526	28	24	4
27	400	410363	4875314	44.02551	-124.11851	29	25	4
27	500	410530	4875366	44.02599	-124.11643	27	24	3

27	600	410429	4875367	44.02599	-124.11769	26	25	1
27	700	410362	4875402	44.0263	-124.11853	26	25	1
27	800	410782	4875181	44.02436	-124.11326	30	24	6
27	900	410363	4875599	44.02807	-124.11855	28	22	6
27	1000	410424	4875680	44.02881	-124.11781	27	24	3
29	200	410005	4874799	44.02083	-124.12288	21	20	1
29	300	410054	4874733	44.02024	-124.12226	21	21	0
29	400	410149	4874734	44.02026	-124.12108	22	22	0
29	500	410249	4874752	44.02043	-124.11983	24	24	0
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29	700	410452	4874764	44.02057	-124.1173	26	25	1
29	800	410524	4874712	44.02011	-124.1164	30	29	1
29	900	410609	4874649	44.01955	-124.11532	28	27	1
29	1000	410663	4874598	44.0191	-124.11464	26	26	0
29	1100	410657	4874497	44.01819	-124.1147	26	26	0
29	1200	410575	4874467	44.01791	-124.11572	30	29	1
29	1300	410472	4874468	44.0179	-124.117	27	25	2
29	1400	410438	4874405	44.01733	-124.11742	25	25	0
29	1500	410387	4874331	44.01666	-124.11804	29	28	1
29	1600	410290	4874316	44.01651	-124.11925	28	26	2
29	1700	410186	4874323	44.01656	-124.12055	23	22	1
29	1800	410095	4874343	44.01673	-124.12168	23	23	0
29	1900	410002	4874305	44.01638	-124.12284	21	21	0
29	2000	409960	4874369	44.01695	-124.12337	20	20	0
29	2200	409858	4874373	44.01697	-124.12465	20	19	1
29	2300	409758	4874362	44.01686	-124.12589	15	15	0
29	2400	409694	4874232	44.01568	-124.12667	4	4	0
29	2466	409691	4874239	44.01575	-124.12671	2	2	0
30	0	410185	4873903	44.01278	-124.12049	22	22	0
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30	200	409989	4873901	44.01274	-124.12293	20	19	1
30	266	409936	4873895	44.01268	-124.12359	20	18	2
35	0	410875	4871355	43.98993	-124.11145	18	14	4
35	100	410977	4871366	43.99004	-124.11018	17	14	3
35	200	411073	4871362	43.99002	-124.10899	17	13	4
35	300	411180	4871362	43.99003	-124.10765	18	14	4
35	400	411276	4871364	43.99006	-124.10645	19	15	4
35	500	411336	4871322	43.98969	-124.1057	18	15	3
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35	700	411335	4871121	43.98788	-124.10568	17	15	2
35	800	410394	4871076	43.98736	-124.1174	19	15	4
35	900	411480	4871094	43.98765	-124.10387	17	15	2
35	1000	411483	4871196	43.98857	-124.10385	17	15	2

35	1100	411510	4871270	43.98924	-124.10352	18	15	3
35	1200	411603	4871271	43.98926	-124.10236	18	15	3
35	1300	411688	4871286	43.98941	-124.1013	17	15	2
35	1400	411686	4871385	43.9903	-124.10135	18	15	3
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35	1600	411721	4871556	43.99184	-124.10094	19	15	4
35	1700	411814	4871554	43.99184	-124.09978	19	16	3
35	1800	411887	4871520	43.99154	-124.09886	19	16	3
35	1900	411885	4871422	43.99066	-124.09887	19	16	3
35	2000	411886	4871323	43.98976	-124.09884	17	15	2
35	2100	411885	4871230	43.98893	-124.09884	16	15	1
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35	2300	411949	4871082	43.9876	-124.09802	15	13	2
35	2400	412051	4871089	43.98768	-124.09675	15	12	3
35	2500	412143	4871083	43.98763	-124.0956	15	13	2
35	2600	412247	4871076	43.98758	-124.0943	15	13	2
35	2700	412284	4871074	43.98757	-124.09384	14	12	2
36	100	412297	4870981	43.98673	-124.09366	15	11	4
36	200	412378	4870930	43.98629	-124.09264	12	8	4
36	300	412407	4870836	43.98544	-124.09227	13	9	4
36	400	412472	4870761	43.98478	-124.09144	11	8	3
36	500	412573	4870760	43.98478	-124.09018	11	9	2
36	600	412654	4870720	43.98443	-124.08917	13	7	6
36	637	412657	4870717	43.9844	-124.08913	13	8	5
37	0	412473	4870765	43.98481	-124.09143	11	8	3
37	100	412508	4870664	43.98391	-124.09098	11	7	4
37	200	412499	4870568	43.98304	-124.09107	10	6	4
37	300	412449	4870515	43.98256	-124.09169	11	7.5	3.5
37	400	412347	4870515	43.98255	-124.09296	12	7	5
37	500	412246	4870512	43.98251	-124.09422	13	8.5	4.5
37	600	412148	4870512	43.9825	-124.09544	12	9	3
37	700	412043	4870513	43.98249	-124.09675	13	10	3
37	800	411942	4870513	43.98248	-124.09801	13	9.5	3.5
37	900	411842	4870515	43.98249	-124.09926	13	9	4
37	1000	411747	4870515	43.98247	-124.10044	14	9	5
37	1100	411648	4870516	43.98247	-124.10167	14	9	5
37	1200	411541	4870515	43.98245	-124.10301	14	9	5
37	1300	411444	4870515	43.98244	-124.10422	14	9.5	4.5
37	1364	411435	4870523	43.98251	-124.10433	14	10.5	3.5
38	0	412215	4870699	43.98419	-124.09464	13	11	2
38	100	412137	4870701	43.9842	-124.09561	13	12	1
38	200	412037	4870704	43.98421	-124.09686	13	12	1
38	300	411939	4870706	43.98422	-124.09808	14	13	1

38	400	411883	4870749	43.9846	-124.09878	14	13	1
38	500	411827	4870797	43.98502	-124.09949	15	14	1
38	600	411727	4871799	43.99403	-124.1009	20	15	5
38	700	411679	4870747	43.98455	-124.10133	15	14	1
38	800	411617	4870707	43.98419	-124.10209	14	13	1
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38	1200	411220	4870711	43.98417	-124.10704	15	11	4
38	1300	411123	4870713	43.98418	-124.10825	14	12	2
38	1368	411081	4870716	43.9842	-124.10878	14	12.5	1.5
41	0	410878	4868782	43.96677	-124.11098	3	2.5	0.5
41	100	410925	4868876	43.96762	-124.11041	4	3	1
41	300	410820	4869002	43.96874	-124.11174	4	4	0
41	400	410740	4869060	43.96925	-124.11275	5	4	1
41	500	410717	4869150	43.97006	-124.11305	5	5	0
41	600	410720	4869248	43.97094	-124.11303	8	5	3
41	700	410622	4869248	43.97093	-124.11425	6	6	0
41	800	410520	4869247	43.97091	-124.11552	5	5	0
41	900	410421	4869249	43.97092	-124.11676	7	6	1
41	1000	410322	4869285	43.97123	-124.118	10	7	3
41	1100	410256	4869344	43.97175	-124.11883	12	9	3
41	1200	410190	4869423	43.97246	-124.11967	11	9	2
41	1300	410138	4869501	43.97315	-124.12033	5	5	0
41	1400	410095	4869598	43.97402	-124.12088	8	4.5	3.5
41	1500	410103	4869687	43.97482	-124.1208	12	9.5	2.5
41	1600	410128	4869791	43.97576	-124.1205	12	10	2
41	1700	410146	4869892	43.97667	-124.12029	11	10	1
41	1800	410176	4869984	43.9775	-124.11994	10	10	0
41	1900	410202	4870081	43.97838	-124.11963	9	9	0
41	2000	410210	4870184	43.97931	-124.11955	9	9	0
41	2100	410224	4870289	43.98026	-124.11939	9	9	0
41	2200	410240	4870378	43.98106	-124.1192	10	10	0
41	2300	410240	4870480	43.98198	-124.11922	10	10	0
41	2400	410239	4870583	43.9829	-124.11925	10	10	0
41	2500	410243	4870678	43.98376	-124.11922	10	10	0
41	2600	410246	4870776	43.98464	-124.1192	13	13	0
41	2700	410249	4870879	43.98557	-124.11918	15	14	1
41	2800	410258	4870981	43.98649	-124.11908	12	8	4
41	2900	410260	4871075	43.98733	-124.11907	6	3	3
41	3000	410250	4871177	43.98825	-124.11922	5	4	1
41	3100	410533	4870139	43.97894	-124.11551	12	5.5	6.5
41	3200	410252	4871374	43.99003	-124.11922	5	4	1

41	3300	410259	4871476	43.99094	-124.11915	5	1	4
41	3400	410309	4871434	43.99057	-124.11852	12	9	3
41	3500	410357	4871347	43.9898	-124.11791	16	10	6
41	3600	410371	4871250	43.98892	-124.11772	19	2.5	16.5
41	3700	410386	4871257	43.98899	-124.11753	19	1	18
41	3800	410376	4871295	43.98933	-124.11766	18	2	16
41	3900	410356	4871375	43.99005	-124.11793	16	2	14
41	4000	410259	4871510	43.99125	-124.11916	5	2	3
41	4100	410262	4871611	43.99216	-124.11914	5	2.5	2.5
41	4200	410264	4871710	43.99305	-124.11913	6	4	2
41	4300	410265	4871810	43.99395	-124.11914	6	4	2
41	4400	410251	4871909	43.99484	-124.11933	6	4	2
41	4500	410226	4872004	43.99569	-124.11965	9	7.5	1.5
41	4600	410234	4872101	43.99657	-124.11957	13	9	4
41	4700	410259	4872199	43.99745	-124.11928	17	9.5	7.5
41	4800	410271	4872292	43.99829	-124.11914	18	6	12
41	4905	410278	4872297	43.99834	-124.11906	18	4	14
47	0	411631	4873901	44.01294	-124.10245	28	27	1
47	100	411592	4873860	44.01257	-124.10293	29	27	2
47	200	411493	4873864	44.01259	-124.10417	30	30	0
47	300	411398	4873841	44.01237	-124.10535	32	31	1
47	400	411298	4873828	44.01224	-124.10659	32	31	1
47	500	411199	4873815	44.01211	-124.10782	37	33	4
47	600	411101	4873803	44.01199	-124.10905	27	26	1
47	700	411052	4873871	44.0126	-124.10967	26	26	0
47	800	411021	4873967	44.01346	-124.11007	26	26	0
47	900	410997	4874062	44.01431	-124.11039	26	26	0
47	1000	410977	4874161	44.0152	-124.11065	26	26	0
47	1100	410946	4874120	44.01483	-124.11103	26	26	0
47	1200	410864	4874196	44.0155	-124.11207	27	26.5	0.5
47	1300	410889	4874293	44.01638	-124.11177	29	29	0
47	1350	410859	4874329	44.0167	-124.11215	35	35	0
48	0	410909	4871934	43.99515	-124.11113	31	25	6
48	100	410831	4871916	43.99497	-124.1121	29	25	4
48	200	410773	4871834	43.99423	-124.1128	25	23	2
48	300	410715	4871755	43.99351	-124.11351	23	20	3
48	400	410625	4871726	43.99324	-124.11463	21	19.5	1.5
48	500	410527	4871732	43.99328	-124.11586	18	17	1
48	600	410425	4871706	43.99304	-124.11712	17	16	1
48	700	410441	4871709	43.99306	-124.11692	18	17	1
48	800	410532	4871727	43.99324	-124.11579	18	17	1
48	900	410635	4871724	43.99322	-124.11451	23	22.5	0.5
48	964	410673	4871732	43.9933	-124.11403	23	21	2

49	0	411773	4875127	44.02399	-124.10088	37	36	1
49	100	411856	4875115	44.0239	-124.09985	37	36	1
49	200	411949	4875085	44.02364	-124.09868	36	36	0
49	300	412041	4875038	44.02322	-124.09753	34	34	0
49	400	412127	4874989	44.02279	-124.09644	33	32	1
49	500	412213	4874940	44.02236	-124.09536	32	32	0
49	600	412309	4874904	44.02205	-124.09416	32	32	0
49	700	412406	4874881	44.02186	-124.09295	32	32	0
49	800	412505	4874874	44.0218	-124.09171	32	32	0
49	900	412603	4874865	44.02173	-124.09049	32	32	0
49	1000	412705	4874850	44.02161	-124.08921	33	32	1
49	1100	412784	4874886	44.02195	-124.08823	32	32	0
49	1200	412847	4874967	44.02268	-124.08746	36	36	0
49	1300	412921	4874980	44.02281	-124.08654	42	39	3
49	1400	413004	4874924	44.02231	-124.08549	37	35.5	1.5
49	1500	413065	4874849	44.02165	-124.08472	30	30	0
49	1600	413008	4874909	44.02218	-124.08544	37	36	1
49	1700	413025	4875016	44.02314	-124.08525	37	36.5	0.5
49	1800	413029	4875108	44.02397	-124.08521	36	36	0
49	1900	413028	4875207	44.02486	-124.08524	34	34	0
49	2000	413014	4875305	44.02574	-124.08543	37	34	3
49	2100	413036	4875393	44.02654	-124.08517	38	32	6
49	2200	413102	4875466	44.0272	-124.08436	40	34	6
49	2300	413169	4875539	44.02787	-124.08354	43	42	1
49	2400	413239	4875615	44.02856	-124.08267	42	40	2
49	2500	413311	4875693	44.02927	-124.08179	48	41	7
49	2600	413262	4875733	44.02963	-124.08241	49	44	5
49	2700	413163	4875767	44.02992	-124.08365	46	42.5	3.5
49	2800	413076	4875797	44.03018	-124.08474	40	40	0
49	2900	412975	4875832	44.03048	-124.086	36	36	0
49	3000	412879	4875868	44.0308	-124.08721	37	37	0
49	3100	412787	4875865	44.03076	-124.08836	36	35	1
49	3168	412737	4875850	44.03062	-124.08898	36	35	1
50	100	413014	4875817	44.03035	-124.08552	36	34	2
50	200	413012	4875715	44.02943	-124.08552	36	33	3
50	300	413011	4875616	44.02854	-124.08552	36	33	3
50	500	413007	4875419	44.02677	-124.08554	36	34	2
50	800	412880	4875191	44.0247	-124.08708	35	28	7
50	900	412850	4875096	44.02384	-124.08744	34	27	7
50	1000	412820	4875002	44.02299	-124.0878	33	27	6
50	1100	412800	4874909	44.02215	-124.08804	32	26	6
50	1300	412776	4874722	44.02047	-124.0883	33	28	5
50	1500	412785	4874531	44.01875	-124.08816	32	27	5

50	1600	412801	4874435	44.01789	-124.08795	31	26	5
50	1700	412800	4874336	44.017	-124.08794	34	27	7
50	1800	412792	4874230	44.01604	-124.08802	36	31	5
50	1886	412853	4874106	44.01493	-124.08724	32	27	5
51	0	412853	4874106	44.01493	-124.08724	32	31	1
51	100	412914	4874188	44.01568	-124.08649	34	33	1
51	200	412965	4874274	44.01646	-124.08587	44	41	3
51	300	413000	4874363	44.01726	-124.08545	53	43	10
51	400	413001	4874464	44.01817	-124.08545	55	44.5	10.5
51	500	413078	4874522	44.0187	-124.0845	42	40	2
51	600	413102	4874517	44.01866	-124.0842	37	36	1
51	700	413015	4874486	44.01837	-124.08528	55	44	11
51	800	412999	4874389	44.0175	-124.08547	53	42	11
51	900	412975	4874295	44.01665	-124.08575	47	41	6
51	1000	412930	4874206	44.01584	-124.0863	35	34	1
51	1100	412868	4874130	44.01515	-124.08706	32	31	1
51	1200	412815	4874041	44.01434	-124.08771	31	30	1
51	1300	412773	4873958	44.01359	-124.08822	31	30	1
51	1400	412764	4873851	44.01263	-124.08831	31	30	1
51	1500	412766	4873756	44.01177	-124.08827	31	30	1
51	1600	412766	4873660	44.01091	-124.08825	30	29	1
51	1700	412763	4873556	44.00997	-124.08827	31	29	2
51	1800	412666	4873548	44.00989	-124.08948	30	29	1
51	1900	412602	4873477	44.00924	-124.09027	32	30	2
51	1977	412594	4873406	44.0086	-124.09036	29	28	1
52	0	410088	4874103	44.01457	-124.12173	21	21	0
52	100	410194	4874102	44.01458	-124.12041	22	21	1
52	200	410294	4874097	44.01454	-124.11916	23	22	1
52	300	410389	4874064	44.01426	-124.11797	24	23	1
52	400	410484	4874047	44.01412	-124.11678	25	24	1
52	500	410586	4874046	44.01412	-124.11551	26	25	1
52	600	410652	4874089	44.01451	-124.11469	27	25	2
52	700	410595	4874171	44.01525	-124.11542	28	26	2
52	800	410531	4874248	44.01593	-124.11623	28	27	1
52	900	410467	4874325	44.01662	-124.11704	29	28	1
52	1000	410395	4874340	44.01674	-124.11794	29	28	1
52	1100	410299	4874314	44.0165	-124.11914	28	27	1
52	1200	410201	4874319	44.01653	-124.12036	24	23	1
52	1300	410196	4874219	44.01563	-124.1204	22	22	0
53	0	413068	4871963	43.99567	-124.08421	13	12	1
53	100	412956	4871943	43.99547	-124.0856	19	18	1
53	200	412909	4872015	43.99612	-124.0862	25	23	2
53	300	412874	4872118	43.99704	-124.08665	27	24	3

53	400	412871	4872206	43.99783	-124.08671	27	25	2
53	500	412874	4872116	43.99702	-124.08665	27	24	3
53	600	412906	4872021	43.99617	-124.08624	25	22	3
53	700	412955	4871943	43.99547	-124.08561	19	18	1
53	800	412960	4871871	43.99483	-124.08554	19	18	1
53	900	412930	4871784	43.99404	-124.0859	18	18	0
53	1000	412935	4871682	43.99312	-124.08582	18	18	0
53	1100	412943	4871651	43.99284	-124.08572	19	18	1
53	1200	412931	4871750	43.99373	-124.08588	18	18	0
53	1300	412937	4871847	43.99461	-124.08582	18	18	0
53	1400	411937	4871932	43.99525	-124.09831	26	25	1
53	1500	413058	4871950	43.99555	-124.08433	13	12	1
53	1579	413065	4871951	43.99556	-124.08424	13	12	1
54	0	412699	4870737	43.98459	-124.08861	17	16	1
54	100	412685	4870843	43.98554	-124.0888	17	16	1
54	200	412684	4870937	43.98638	-124.08883	19	16	3
54	300	412694	4871034	43.98726	-124.08872	22	18	4
54	400	412698	4871135	43.98817	-124.08869	26	18	8
54	500	412696	4871234	43.98906	-124.08873	32	18	14
54	600	412699	4871333	43.98995	-124.08871	31	17	14
54	700	412699	4871432	43.99084	-124.08872	32	18	14
54	800	412692	4871530	43.99172	-124.08883	30	18	12
54	900	412688	4871635	43.99267	-124.08889	26	15	11
54	1000	412687	4871728	43.9935	-124.08892	26	18	8
54	1100	412706	4871823	43.99436	-124.0887	34	27	7
54	1200	412695	4871927	43.9953	-124.08885	33	22	11
54	1300	412694	4872024	43.99617	-124.08888	31	20	11
54	1400	412698	4872119	43.99703	-124.08885	30	21	9
54	1500	412706	4872221	43.99795	-124.08877	34	27	7
54	1600	412742	4872166	43.99874	-124.08893	29	25	4
54	1700	412737	4872072	43.99823	-124.0881	29	21	8
54	1800	412738	4871971	43.99834	-124.08726	30	27	3
54	1900	412745	4871866	43.99774	-124.08763	32	25	7
54	2000	412692	4871781	43.9971	-124.08838	29	21	8
54	2100	412738	4871971	43.99834	-124.08726	20	16	4
54	2300	412736	4872127	43.9971	-124.08838	29	26	3
54	2400	412721	4871977	43.99575	-124.08854	32	27	5
54	2500	412695	4871796	43.99412	-124.08883	30	24	6
54	2600	412690	4871582	43.99219	-124.08886	26	17	9
54	2700	412683	4871421	43.99074	-124.08892	34	23	11
54	2800	412681	4871254	43.98924	-124.08892	29	19	10
54	2900	412693	4871156	43.98836	-124.08875	27	20	7
54	3000	412692	4871869	43.99477	-124.08888	31	24	7

Appendix B- Groundwater Groundtruthing Locations and Elevations

ID	UTM E	UTM N	DTW(m)	Z	Latitude	Longitude
1	411829	4869625	3.7	4	43.97447	-124.099
2	411881	4869930	6	6	43.97722	-124.099
3	411881	4869979	3.3	5	43.97767	-124.099
4	411894	4872320	3.5	21	43.99874	-124.099
5	411941	4872405	3	22	43.99951	-124.098
6	411009	4868803	2	3	43.96697	-124.109
7	412626	4873393	2.4	30	44.00849	-124.09
8	412972	4872772	1.5	26	44.00294	-124.086
9	413195	4870802	1.5	5	43.98523	-124.082
10	412339	4871184	2	13	43.98857	-124.093
11	412282	4871079	3	15	43.98762	-124.094
12	410870	4871355	3	22	43.98993	-124.112
15	410628	4875418	1.5	30	44.02647	-124.115
16	411053	4875083	3.5	31	44.02351	-124.11
17	411114	4874779	1.5	33	44.02078	-124.109
18	413588	4877587	4	17	44.04635	-124.079
19	412590	4878505	3.7	15	44.0545	-124.091
20	411184	4878285	1.5	21	44.05235	-124.109
21	411281	4878505	1.2	21	44.05434	-124.108
23	411420	4868823	3	6	43.9672	-124.104
24	411703	4869753	6.8	5	43.97561	-124.101
27	412390	4869599	2.5	25	43.97431	-124.092
28	411694	4870281	4.6	38	43.98036	-124.101
29	410858	4882317	1	6	44.08861	-124.114
30	410779	4872314	1	6	43.99855	-124.113
31	411285	4872024	3	11	43.996	-124.106
32	411379	4871684	2	10	43.99295	-124.105
33	411808	4870646	7	53	43.98366	-124.1
34	411819	4879899	4	37	44.06696	-124.101
35	411936	4878906	4	16	44.05803	-124.099
37	412056	4878352	5.7	11	44.05306	-124.098
38	411886	4878050	3	26	44.05032	-124.1
39	411585	4875805	3	35	44.03007	-124.103
40	410399	4875648	2	30	44.02852	-124.118
41	409691	4874239	1.8	5	44.01575	-124.127
42	412220	4872779	2	23	44.00291	-124.095

43	412253	4873192	2.8	25	44.00663	-124.095	
44	412070	4872137	2	19	43.99711	-124.097	
45	412285	4871069	3	15	43.98753	-124.094	
46	412306	4870967	3.7	13	43.98661	-124.094	
47	412435	4870520	2.9	10	43.9826	-124.092	
48	410879	4868782	2	0	43.96677	-124.111	
49	410266	4861484	4.2	6	43.901	-124.117	
50	412325	4871185	2.8	13	43.98857	-124.093	
51	411077	4873805	1	36	44.01201	-124.109	
52	413059	4874839	1	31	44.02155	-124.085	
53	411819	4879899		37	44.06696	-124.101	Dune Lake
54	411353	4871435		19	43.99071	-124.106	Lake Marr
55	411595	4870820		30	43.9852	-124.102	Nott Lake
56	411560	4870596		43	43.98318	-124.103	Mussel Lake a
57	411560	4870543		44	43.9827	-124.103	Mussel Lake b
58	411720	4870575		48	43.98301	-124.101	Mussel Lake c
59	411633	4870345		37	43.98093	-124.102	Alder Lake
60	411930	4879712		37	44.06529	-124.1	Buck Lake
61	412211	4878773		10	44.05687	-124.096	Sutton Lake
62	413818	4877772		10	44.04805	-124.076	Mercer Lake
63	413604	4876813		36	44.03939	-124.078	North Collard Lake
64	413575	4876518		37	44.03673	-124.079	Central Collard Lake
65	413594	4876166		37	44.03356	-124.078	South Collard Lake
66	413442	4874949		30	44.02259	-124.08	Clear Lake
67	413269	4874014		30	44.01415	-124.082	Ackerly Lake
68	413019	4873206		28	44.00685	-124.085	Munsel Lake
69	410526	4872662		21	44.00165	-124.116	Golf Course Lake 1
70	410814	4872516		25	44.00037	-124.112	Golf Course Lake 2
71	410935	4874761		37	44.0206	-124.111	Heceta Beach Road
72	411056	4875277		32	44.02526	-124.11	Lake Point Drive
73	410261	4876033		29	44.03197	-124.12	Unnamed Lake

Appendix C- GPR Line Metadata

Line	Distance (m)	Date Collected	Antennae Frequency
3	1855	June 13 2011	50 mHz
4	3730	June 13 2011	50 mHz
5	3645	June 13 2011	50 mHz
6	1650	June 13 2011	50 mHz
8	1410	June 13 2011	50 mHz
11	7200	June 13 2011	50 mHz
12	5200	June 13 2011	50 mHz
13	6600	June 13 2011	50 mHz
14	9200	June 29 2011	50 mHz
15	917	June 29 2011	50 mHz
16	307	June 29 2011	50 mHz
17	505	June 29 2011	50 mHz
18	1300	June 29 2011	50 mHz
19	1335	June 29 2011	50 mHz
20	4620	June 29 2011	50 mHz
21	778	June 29 2011	50 mHz
22	1565	June 29 2011	50 mHz
23	364	June 29 2011	50 mHz
24	757	June 29 2011	50 mHz
25	1217	June 29 2011	50 mHz
26	583	June 29 2011	50 mHz
27	1000	June 29 2011	50 mHz
28	797	June 29 2011	50 mHz
29	2466	June 29 2011	50 mHz
30	266	June 29 2011	50 mHz
31	1600	June 29 2011	50 mHz
32	1153	June 29 2011	50 mHz
33	1961	June 29 2011	50 mHz
34	977	June 29 2011	50 mHz
35	2700	June 29 2011	50 mHz
37	1364	June 29 2011	50 mHz
38	1368	June 29 2011	50 mHz
39	2059	June 29 2011	50 mHz
40	1700	June 29 2011	50 mHz
41	4905	September 6 2011	100 mHz
44	700	September 6 2011	100 mHz
47	1350	September 6 2011	100 mHz
48	964	September 7 2011	100 mHz
49	3168	September 7 2011	100 mHz
50	1886	September 7 2011	100 mHz
51	1977	September 7 2011	100 mHz
52	1300	September 7 2011	100 mHz
53	1579	September 7 2011	100 mHz
54	3000	September 7 2011	100 mHz

Appendix D- GPR Subsurface Images

Line 3

Line 4

Line 5

Line 6

Line 8

Line 11

Line 12

Line 13

Line 14

Line 15

Line 16

Line 17

Line 18

Line 19

Line 20

Line 21

Line 22

Line 23

Line 24

Line 25

Line 26

Line 27

Line 28

Line 29

Line 30

Line 31

Line 32

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Line 34

Line 35

Line 36

Line 37

Line 38

Line 39

Line 40

Line 41

Line 42

Line 43

Line 44

Line 45

Line 46

Line 47

Line 48

Line 49

Line 50

Line 51

Line 52

Line 53

Line 54