A GIS Site Exploration to Locate Washington's Next Ski Resort:

Proposed **WinterRidge** *Resort Location Study*

Prepared by:
Mark Raleigh
Allied Alpine Engineers, Inc.

Prepared for:
Team Zurshaus, LLC
CEE 424

Submitted
December 7, 2007

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1. Objectives

This study was conducted to determine the most favorable and economical location for a new ski resort in the State of Washington. Team Zurshaus, LLC ("The client") has a set of requirements that must be satisfied with the selection of the proposed resort site, WinterRidge. They are as follows:

- The resort must be within 125 miles (as the crow flies) of Seattle to accommodate "day trip" skiers
- The land for the proposed resort will be rented from the U.S. government on National Forest land in the Cascade Mountains of Washington
- The resort must be located off a major U.S. Interstate or State Highway
    - To minimize new roadway construction, the maximum distance from this thoroughfare will not exceed 5 miles
- The resort will be located a minimum of 10 miles from any existing resorts
- The average winter temperature shall be below 32°F
- The annual snowfall shall meet or exceed 200 inches
- The vertical rise from base to summit shall be 2000 ft minimum
- The terrain should have a variety of slopes for skiers of different abilities

The main tool of analysis was through the use of the ArcInfo program, which is a component of ESRI ArcGIS. After collecting complete and relevant data, the above constraints were applied using ArcInfo in order to spatially determine an ideal location for the proposed WinterRidge resort location. This study summarizes the data, analysis procedure, and conclusions of using ArcInfo to locate Washington's newest ski resort.

2. Data Collection

Data was utilized from a variety of organizations to provide detailed information for the spatial analysis in ArcInfo. A collection of sample metadata is referenced in the Appendix of this report, and further metadata information is available for select sources on the included data CD. The following is a detailed description of the main data sources and the layers attributed to each source.

United States Geological Survey (USGS)

Description: The USGS National Elevation Dataset (NED) is mainly a data bank of vertical and geological features of the United States. 30m vertical digital elevation models (DEMs) of the Cascade Mountains were downloaded from the USGS NED website[1] with a resolution of 1:24,000. The data had no projection, and the geographic coordinate system was NAD83. Additionally, a dataset for the streams and rivers of Washington was acquired from the USGS site, as well as one for the state boundary.

The following layers were created from USGS data:

- "Cascades DEM" – This layer was the main basis of vertical information in the area of interest, and was used to create hillshade and slope layers. This layer was the product of a chain of ArcInfo commands (see data analysis for details).
- "Streams" – This layer was extracted from the USGS site, and used as a visual check in the final site determination to ensure that no major rivers interfered with the resort location. All streams and rivers were displayed as line features.
- "State Boundaries" – This layer was extracted from the National Atlas within the USGS site. This displays the limits of the state of Washington, as well as Oregon and Idaho for reference.

Washington State Department of Transportation (WSDOT)

WSDOT provides and maintains a GIS Data Distribution Catalog[2] that is readily available to the general public. The WSDOT catalog includes not only transportation features, but also hydrologic and political layers. A variety of layers were downloaded from the WSDOT site. Unless otherwise designated in the metadata, all layers from WSDOT were based on the NAD83 HARN coordinate system.

The following layers were created from WSDOT data:

- "Interstates" & "US Highways" – These layers included the major interstates (I-90, I-5, etc) and major US Highways (US-2, US-12, etc). These roadways were displayed as line features.
- "Mile Markers" – This layer displayed the mile markers for all major roadways in Washington. This was used to determine the mile marker location of the proposed ski resort. These mile markers were displayed as point features.
- "Seattle" and "Washington Cities" – The "Seattle" feature was extracted from the "Washington Cities" layer. Seattle is displayed on several maps as a point feature to show the proximity of the analysis to Seattle.
- "National Forests" – This layer was a collection of all National Forest areas in the state of Washington. The National Forests were displayed with polygon features.
- "Washington Counties" – This layer was comprised of all counties within Washington, and was used purely for reference (no analysis). These counties were illustrated with polygon features.
- "Lakes" – This layer was a collection of all lakes in Washington, and was used to visually check the final site determination to ensure that no lakes interfered with the proposed site location. Lakes were displayed as polygon features.

Western Regional Climate Center

The Western Regional Climate Center (WRCC) was a resource that provided data from weather stations across the State of Washington. The WRCC was partnered with the National Weather Service (NWS) of the National Oceanographic and Atmospheric Administration (NOAA) to make statewide climate data available online[3] to the public. This was the best available source of climate data available, and the major disadvantage was that it was not readily

available to import into ArcInfo. As a result, the data had to be manually inputted into a text file, and caution was utilized to ensure that the data was accurately transcribed.

The following layer was created from WRCC data:

- "Weather Stations" – This encompassed 68 selected weather stations across the Cascade Mountains east of Seattle. Horizontal locations were given in latitude and longitude and the stations were displayed as point features.

Google Earth & Ski Resort-Specific Websites

A data source for the locations of existing ski resorts in the state of Washington was not readily available. The next logical step was to identify the address of each resort and use geocoding to establish the horizontal locations. Unfortunately, many ski resorts do not provide an address at the resort itself but supply a P.O. Box in the city of their business headquarters for all correspondence. Thus, geocoding was not an alternative to determine the locations of existing ski resorts.

The best available method to determine the locations of existing ski resorts was by using the Google Earth[4] program. A search was executed to find the known ski resorts and the latitude and longitude of each resort was recorded into a manually created text file. Attributes of each ski resort, such as vertical rise and annual snowfall, were acquired directly from the website[5] of each resort. Those additional attributes were then manually combined into the same text file.

The following layers were created from Google Earth data:

- "WA Ski Resorts" – This included the locations of the 12 major ski resorts in Washington and displayed the locations as point features. The coordinates were derived from latitude and longitude.

3. Data Analysis

Using ArcInfo, the collected data was analyzed to determine potential ski resort locations according to the client's specifications. Four collective analyses were utilized to evaluate the range of possible ski resort locations.

Proximity Analysis

The data was first analyzed by means of proximity. After bringing all relevant data into ArcInfo, a 125 mile buffer was initialized around Seattle. That buffer was then intersected with the "National Forests" layer to determine the available land within 125 miles of Seattle (the resulting layer was "National Forests within 125 Miles of Seattle"). 10 mile buffers were then executed at each existing ski resort, and 5 mile buffers were initiated along the Interstates and US Highways. A combination of erase and intersect commands yielded viable corridors that were within 5 miles of a major roadway, at least 10 miles away from existing ski resorts, and on National Forest land within 125 miles of Seattle. The resulting layers were named "Possible Ski

Resort Base off US Highway" and "Possible Ski Resort Base off US Interstate." This proximity analysis essentially isolated three potential areas of location, along I-90, US-2, and US-12, all east of Seattle near the Cascade ridge.

Annual Snowfall Analysis

After adding the "Weather Stations" layer to the GIS, the 3d analyst toolbox was used to create a TIN surface of the average annual snow depth at the 68 weather stations. This was done twice – once for the weather stations west of the ridge, and separately for the weather stations east of the ridge. Contours were then produced for each TIN surface by using the 3d analyst toolbox. The creation of TIN surfaces was divided between east and west slopes instead of a single surface so that the interpolation process would not create snowfall values along the ridge irrespective of elevation change. After those contours were generated, a select command was utilized for each contour set to create a new contour sets for snowfalls greater than 200 inches. These final sets of contours were then visually inspected over the three potential areas for the new ski resort. This showed that there was either not enough snow or not enough available data to justify building along US-12. As a side note, while areas in the Olympic peninsula qualified for consideration after the proximity analysis, the annual snowfall records did not show consistent enough data to provoke attention.

Average Maximum Temperature Analysis

Colder temperature zones were preferred to provide a stable source of snow and to ensure long term vitality for the ski resort against the forces of climate change[6]. The interpolation command within the spatial analysis toolbox was used to create separate "temperature" surfaces for the east and west slopes. The average maximum temperature was considered during the months of December and January to visualize the spatial temperature variations during the height of winter and ski season. These "temperature" surfaces were visually inspected to further the analysis, and two smaller areas were considered. One was along I-90 east of Snoqualmie Pass, and the other was along US-2 east of Steven's Pass.

Terrain Slope Analysis

Originally, six USGS DEMs (too large to fit on the data CD – contact me if they are required) were combined to form a single DEM using the mosaic tool. This large raster was then clipped, and then re-projected to convert the cell widths from arc-seconds to meters. The spatial analyst tool was then used to produce a hillshade layer and a slope layer. The hillshade layer aided in visualization of the terrain, and the slope layer provided a way of visualizing the contrast of slopes in an area. According to a USDA study[7], "Beginner Slopes" range from 6%-25%, "Intermediate Slopes" range from 26%-40%, and "Advanced Slopes" range from 40%-80%. These values of slope were used in the symbology of the slope raster to evaluate the diversity of slopes in an area. Constructability of a new access road, parking facilities, and a "village resort area" at the base of the resort was also factored into the site selection. Quantitatively, this dictated the need for slopes on the order of 0-5% to minimize the use of retaining walls and grading operations.

The orientation of slopes in those final two areas showed that the US-2 corridor east of Steven's Pass was largely prohibitive to producing a diversity of ski-able slopes. Conversely, an area 3 miles SE of Lake Keechelus off I-90 had a diversity of slopes, most of which were facing

north or northwest. This site also had a large area of 0%-5% slopes, which could easily provide for an access road, parking lot, and "village resort area."

4. Results and Conclusion

Upon execution of the described ArcInfo analysis, it has been determined that an ideal location for a new ski resort is located south of I-90 near milepost 63. This location is on the east side of Snoqualmie Pass, and is relatively close to Lake Keechelus. Allied Alpine Engineers suggests that the client conducts a site visit to become familiar with the selected area. The following lists the statistics and details of the selected site location.

- Latitude: 47° 17' 12.5"
- Longitude: -121° 18' 54.4"
- Proximity: 63 roadway miles east of Seattle
- Location: On National Forest Land
    - Front Face: Wenatchee NF
    - Back Bowl: Mt. Baker – Snoqualmie NF
- 3 miles SE of Lake Keechelus
- Access: Off I-90 at MP 63
- New Road Construction ~ 1.5 miles
- Closest Resort: The Summit (~11 miles)
- Orientation – North by Northeast facing slopes
- Average Max Temperature: 30.6°F (Dec), 29.5°F (Jan)
- Annual Snowfall: 350 in - 400 in
- Vertical Rise: 2290 ft from base to summit
- Slopes: Diversity of slopes

5. References

1. USGS Ned Website. http://ned.usgs.gov/
2. WSDOT GIS Catalog. http://www.wsdot.wa.gov/mapsdata/geodatacatalog/default.htm
3. Western Regional Climate Center. http://www.wrcc.dri.edu/summary/Climsmwa.html
4. Google Earth. http://earth.google.com/
5. Map of Downhill Ski Areas in Washington State. http://www.gonorthwest.com/washington/ski-map-wa.htm
6. Nolin, Anne W and Daly, C. *Journal of Hydrometeorology*. "Mapping At Risk' Snow in the Pacific Northwest." 2006.
7. Appendix G: Mountain Specifications Summary, Draft Environmental Impact Statement for The Timberline Express Proposal. USDA, U.S. Forest Service, Mount Hood National Forest (March 2005), 26.

Appendix
Sample of Metadata