Pacific Connector Gas Pipeline Least-Cost Path Analysis
(By Dongmei Chen)

1. Project Overview

The Pacific Connector Gas Pipeline (PCGP) project, sponsored by the Jordan Cove LNG, LLC., and managed by the Bureau of Land Management (BLM), originally presented a 229-mile gas pipeline route from Malin to Coos Bay, that passes through some land area in the southwestern parts of Rogue River and Umpqua national forests in Oregon. To search for an alternative least-cost path that avoids national forest land, the nonprofit organization Forest Service Employees for Environmental Ethics (FSEEE) consulted an independent contractor, Dr. Dongmei Chen, who provided services on GIS analysis and mapping as well as writing the relevant technical documents for an alternative PCGP route. This document explains the data collection and GIS analysis processes used for the proposed alternative route shown in Figure 1.

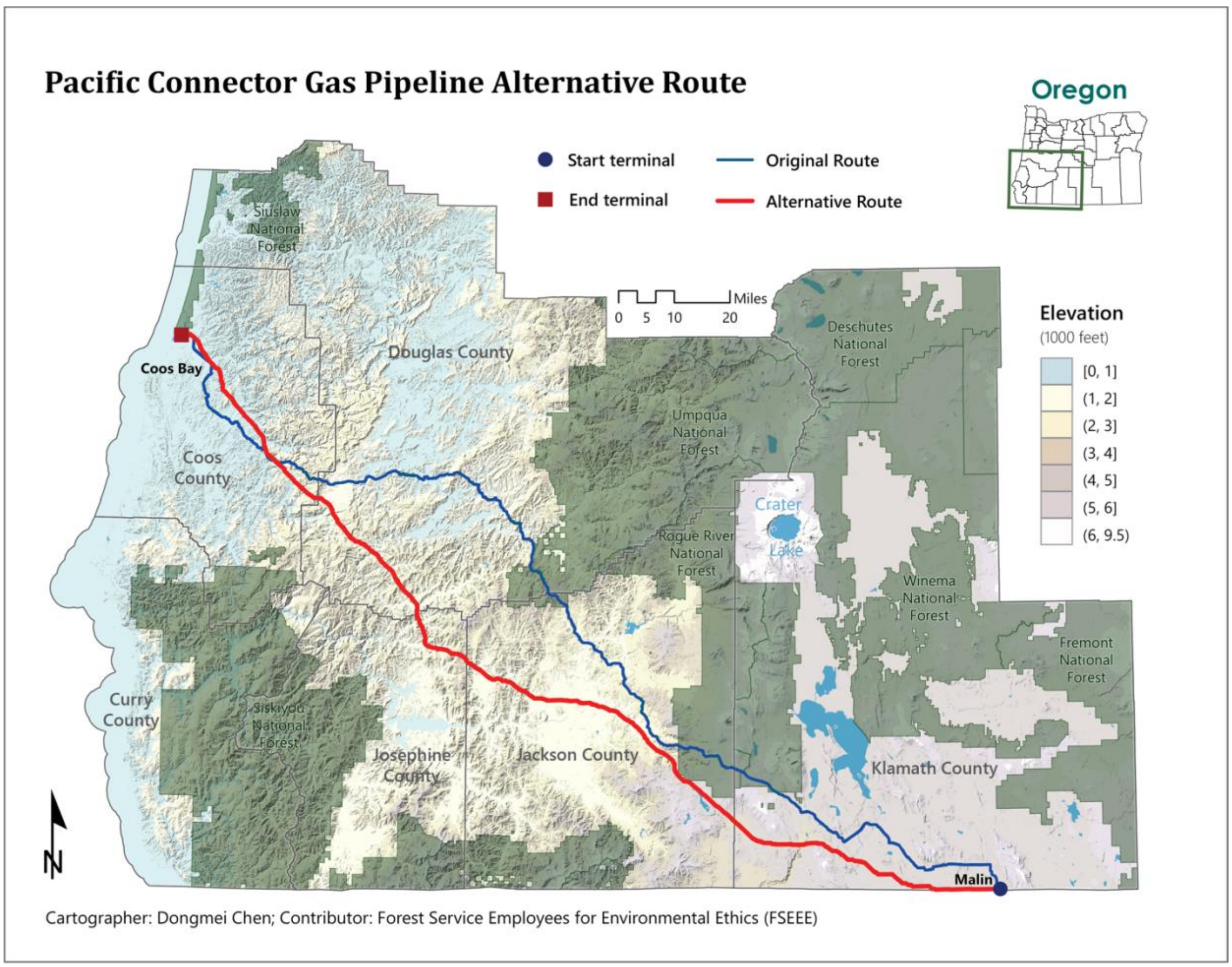

Figure 1. An alternative route for the Pacific Connector Gas Pipeline project based the least-cost path analysis using a multicriteria selection method

The selection of a gas pipeline route requires consideration of multiple criteria, including engineering, environmental and social constraints. The route avoids engineering constraints such as high elevations, steep terrain slopes, and high risk of geohazards. Minimizing distance to roads was also preferred due to logistic convenience. The route also avoids environmentally sensitive areas including protected and natural areas, parks, lakes, and national forests, and socially sensitive areas such as urban areas. The least-cost path analysis (LCPA) is a common GIS approach for the pipeline route selection based on multicriteria evaluation to minimize social and environmental impacts. This project presents an alternative PCGP route using the LCPA approach and the detailed descriptions of data and GIS steps are included as following.

2. Least-Cost Path Analysis

2.1 Study area and data

The study area is set within the boundary of six counties in southwest Oregon, including Klamath, Jackson, Coos, Douglas, Josephine, and Curry counties. The GIS processing extent was determined by the study area. The original pipeline route data was collected from a data set for the proposed and existing utility corridors with the Resource Management Plans for Western Oregon, downloaded from the BLM website, which may have been revised. The start and end terminals were created from the two original PCGP route end points. The data sets used in this project were primarily collected from the Oregon Spatial Data Library in vector format. According to the data needs on engineering, environmental and social constraints, a list of variables, datasets, and data sources is included in Table 1. The spatial resolution of the digital elevation model (DEM) is 1/3 arc-second or 10 meters, which sets the raster cell size for the project. Topographic variables in the raster data format include DEM and slope, which was calculated from DEM. Polygon data for landslide deposit, wilderness, national parks, natural areas, protected areas, lakes, national forests, and urban growth boundaries, line data for the Oregon transportation network and streams, and point data for the historical landslide locations were used to identify the environmental and social constraints for the pipeline route selection.

2.2 GIS Analysis and Mapping

Datasets from different projections were converted to the same projection. The data preprocessing steps including reprojection, data merge and conversion were completed in ArcMap 10.5. Wilderness areas, national parks, natural areas and protected areas were merged to be a complete natural-area layer. To account for boundary uncertainties, all polygon and line data were buffered at a 100-meter distance, while the historical landslide points were buffered at a 200-meter distance. The buffered historical landslide points and landslide deposit were merged to be a complete input as geohazards. A pixel value field was added to mask the vector boundary data including the merged natural areas, lakes, streams, national forests, and urban growth boundaries, which were further converted to raster format and the pixel values were stored as the cell values at the 10-meter resolution. For the geohazard data, the historical landslide points were filled with a pixel value of 10 (greatest risk of landslide), while the areas with a confidence level of high, moderate and low landslide risk were filled with a pixel value of 5, 3, and 1, respectively. The numbers for landslide risk levels are somewhat arbitrary and indicate a relatively high or low risk based on the confidence level. Distance to road was calculated from the Oregon transportation network using the Euclidean Distance tool in ArcMap 10.5.

A scale from 1 to 10 was used to determine the cost from low to high. The existing and converted raster data were then reclassified to the same scale. The DEM, slope and distance to road were reclassified to 10 classes using the Jenks natural breaks classification method. The values within classes of these three variables from low to high were scaled from 1 to 10. The restricted areas (or 'no-go' areas), including the merged natural areas, national forests, lakes, urban areas, steep slopes (> 35 degrees), and historical landslide points, were set as 100. Streams were set as 10. The Weighted Sum tool was applied to calculate the cost surface, in which the weights for elevation and slope were doubled and the rest reclassified data remain weighted as 1 in the default setting. The tools Cost Distance and Cost Path were used to get the least-cost path in the raster format, which was then converted to a polyline. Lastly, the cartographic design of the final map was completed using ArcMap, Illustrator and Photoshop. The workflow for the LCPA can be summarized as the steps of rasterization, reclassification, cost surface, cost distance and cost path in GIS analysis.

3. Concluding Remarks

The results of LCPA depends on the input data and weights of the input variables. The alternative route presented in this document shows an example of PCGP route that avoids national forests, which is based on the above GIS analysis. Other variables including erosion hazard ratings, wildfire risk, climate, mining concessions, defense areas, and archaeological sites were also considered, but these variables were not included due to data limitations or the fact that the variables are not applicable in this study area. The project was completed under deadline constraints, but may be modified with more data, variables, or different parameter settings. The alternative route is about 200 miles.

Table 1. Datasets used in the least-cost path analysis of the Pacific Connector Gas Pipeline alternative route

No.	Constraint	Variable category	Variable	Dataset
1	Engineering	Topography	Elevation, Slope	National Elevation Dataset
2		Logistics	Distance to road	Oregon Transportation Network
3		Geohazads	Landslide	Statewide Landslide Information Database for Oregon
4	Environmental	Environmental sensitivity	Wilderness	National Wilderness Preservation System
5			National parks	Administrative Boundaries of National Park System Units
6			Natural areas	Oregon's Natural Areas
7			Protected areas	World Database on Protected Areas
8			Lakes	Oregon Water Quality Streams and Lakes
9			Streams	Oregon Water Quality Streams and Lakes
10			National forests	Administrative Forest Boundaries
11	Social	Residential boundaries	Urban area	Oregon Urban Growth Boundaries

Table 1 Continued

No.	Source	Access date	Download link
1	Oregon Geospatial Enterprise Office	11/27/19	https://spatialdata.oregonexplorer.info/geoportal/details;id=7a82c1be50504f56a9d49d13c7b4d9aa
2	Oregon Spatial Data Library	12/1/19	https://spatialdata.oregonexplorer.info/geoportal/details;id=12d99bf70d064391b5f487ed6bce4133
3	Oregon Department of Geology and Mineral Industries	11/26/19	https://www.oregongeology.org/slido/data.htm
4	Oregon Spatial Data Library	12/8/19	https://spatialdata.oregonexplorer.info/geoportal/details;id=111616dcb4014ed8a966f775e995debf
5	National Park Service	12/6/19	https://irma.nps.gov/DataStore/Reference/Profile/2225713
6	Oregon Spatial Data Library	12/1/19	https://spatialdata.oregonexplorer.info/geoportal/details;id=d2e844f814c34b4f97dc2ffe0eab7fd2
7	Protected Planet	12/4/19	https://www.protectedplanet.net/c/world-database-on-protected-areas
8	Oregon Spatial Data Library	12/1/19	https://spatialdata.oregonexplorer.info/geoportal/details;id=7bee41a81cdb4eb99d71cdd2217ee3da
9	Oregon Spatial Data Library	12/1/19	https://spatialdata.oregonexplorer.info/geoportal/details;id=7bee41a81cdb4eb99d71cdd2217ee3da
10	FSGeodata Clearinghouse	11/21/19	https://data.fs.usda.gov/geodata/edw/datasets.php?dsetCategory=boundaries
11	Oregon Spatial Data Library	12/1/19	https://spatialdata.oregonexplorer.info/geoportal/details;id=394740b8fffc44a78b3747ca03acb34a