# FINAL REPORT
# WIND ENERGY FEASIBILITY STUDY
# NAKNEK AND UNALASKA, ALASKA

**FOR THE**
**STATE OF ALASKA**
**DEPARTMENT OF COMMUNITY**
**AND REGIONAL AFFAIRS**
**DIVISION OF ENERGY**

**May 24, 1999**

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Prepared by:

**DAMES & MOORE, INC.**
5600 B Street
Anchorage, AK 99518
Phone: (907)562-3366
Fax: (907)562-1297

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# 1.0 INTRODUCTION

Dames & Moore was retained by the State of Alaska, Department of Community and Regional Affairs, Division of Energy (DOE) to complete an evaluation of the feasibility of incorporating wind energy with the existing diesel power generation systems in Naknek and Unalaska, Alaska. The work completed as part of this project included collecting existing available data for these two communities regarding wind resources, climate, environmental factors, land use, and other issues which were considered pertinent in each community. Site visits were conducted to each community to gather information, consult with local utilities, and visit potential sites which were considered feasible for installation of a wind turbine generator (WTG) from a wind resource perspective and which would likely be acceptable to community members.

Upon completion of the data collection efforts and the site visits, this report was prepared to document the data collected, discuss the various sites considered in each community, and to evaluate the feasibility of installation of the turbines based on engineering constraints, wind resources, capital cost, and operational cost.

# 2.0 SITE VISIT RESULTS

Deborah Allen of Dames & Moore and Tom Zambrano of AeroVironment Inc., conducted the site visits to Naknek and Unalaska during the week of March 22, 1999. David Lockard of the DOE also attended the Unalaska site visit. The following paragraphs provide a summary description of each community, pertinent information regarding the local electric utility, and descriptions of each individual site considered for installation of a WTG.

## 2.1 NAKNEK SITE VISIT

The Naknek site visit was conducted on March 22 and 23, 1999. The work completed included meeting with Naknek Electric Association (NEA) personnel, including Donna Vukich, the NEA General Manager. Other key contacts include Arne Erickson of the Bristol Bay Borough, Susan Savage and Steve Hill of the US Fish and Wildlife Service (USFWS), and the National Weather Service (NWS) in King Salmon.

**Community Background Information**

Naknek is located on the north bank of the Naknek River near the northeastern end of Bristol Bay as shown on Figure 1. The economy of the community is based primarily on commercial and sport fishing and processing. The community is connected to nearby King Salmon by an approximately 12 mile long road. Naknek is accessible only by air and sea. Most larger commercial airlines operate out of the King Salmon airport, while local residents and small charter operations utilize the Naknek airstrip. Electrical service to King Salmon, Naknek, and South Naknek, which is located on the south side of the river near its mouth, is provided by Naknek Electric Association (NEA). All distribution lines are aerial.

## History of Wind Energy in Naknek

The information presented in this paragraph was compiled based on discussions with NEA personnel and local residents and agency representatives. Several wind projects both private and public have been attempted in Naknek over the years with varying amounts of success. Many of the smaller, privately-owned and maintained installations are still in operation. All operating turbines are connected to the NEA distribution system, and excess energy not used by the generator is compensated with energy credits. One such unit is a 10 kW turbine which has been operating since the mid-1980s. The unit is located in the main residential area of town and is maintained by the homeowner (Einar Bakkar).

Two public wind projects were reported. One included the installation of two WTGs installed as part of the sewage lagoon project in the mid-1980s. There were problems with poor initial installation as well as operation and maintenance, and the project was generally considered a failure by most residents. One turbine was also installed approximately 10 years ago by the Borough. The turbine never worked properly, and the project was soon abandoned. The Borough turbine is still standing.

## Electrical Utility

NEA is a member owned electrical cooperative which serves the Naknek, King Salmon, and South Naknek areas. The power plant is located near the community school and contains 9 diesel powered generators with a total generating capacity of 7,185 kilowatts (kW). One additional generator is scheduled to be on line this June, increasing the total capacity to 8,507 kW. The current total operating efficiency (1998 year) is 15.06 kilowatt-hours (kWh) per gallon of diesel fuel. The utility uses approximately 1.35 million gallons of fuel annually, with recent fuel prices of $0.66 per gallon in 1998 and $0.74 per gallon in 1997. The existing switchgear in the oldest section of the plant is being replaced to maximize capacity of the generating equipment.

Peak loads of 3.1 MW are experienced during the winter, with 5.2 MW peaks during the summer months. Average loads are in the range of 2.5 to 3 MW. The utility deregulated from the Alaska Public Utilities Commission (APUC) in 1982 and only holds a certificate of public convenience from the commission for their territory. The utility hopes to expand its facility to provide the ability to serve several of the canneries which operate during the summer red salmon commercial fishing season. Most of the canneries currently self-generate.

The rate structure per the current NEA tariff is as follows.

| | |
|---|---|
| <u>Residential</u> | |
| Facility Charge | $15.00 |
| First 1000 kWh | 0.18 |
| Over 1000 kWh | 0.165 |
| <u>Commercial – Single Phase</u> | |
| Facility Charge | $30.00 |
| First 1000 kWh | 0.18 |
| Over 1000 kWh | 0.165 |
| <u>Commercial – Three Phase</u> | |
| Facility Charge | $60.00 |
| First 1000 kWh | 0.18 |
| Over 1000 kWh | 0.165 |
| <u>Large Power – Year Round</u> | |
| Facility Charge | $100.00 |
| All kWh | 0.15 |
| Demand per kWh | 10.00 |
| <u>Large Power – Seasonal</u> | |
| Facility Charge | $200.00 |
| All kWh | 0.135 |
| Demand per kWh | 12.00 |
| <u>Wholesale</u> | |
| All kWh | $0.1363 |
| Minimum bill | $15,000.00 |

New services along the Pike Lake and Rapids Camp extensions are required to pay a $3,000 non-refundable fee for connection.

The utility lost 1.5 MW in demand in 1995 with the deactivation of the US Air Force Sir Station at King Salmon. Since that time, they have increased the demand up to 1995 levels by adding new users and completing line extensions.

Long-term construction plans include:

Line extensions to Lake Camp

Line extension to Pederson Point

Possible future customers include canneries, the military, new fishing lodges located a reasonable distance from the existing distribution system, and new residential customers.

## Land Status

The primary landowners in the Naknek area include the Bristol Bay Borough and the Pauq-vik Native Corporation. Although sites owned by both parties were considered during the site visit, the emphasis was placed on Borough lands to minimize capital and operation and maintenance costs for the project.

## Sites Considered

The following paragraphs provide brief descriptions of each of the sites considered for installation of a wind turbine within the project area. The approximate location of each site is shown on Figures 2 and 3.

**Site 1 – Sewage Lagoon Site:** This site is located in Naknek on the bluff near the sewage lagoons at the western end of town. The land is owned by the Borough and the parcel is 112 acres in size. There are two large mounds which resulted from stockpiling of excavated materials during construction of the sewage lagoons approximately 15 years ago. These mounds are approximately 10 to 15 feet higher than the surrounding area and are generally vegetated with grass. The area surrounding the mounds is relatively flat, except for the steep bluff on the western edge of the site which extends to the beach at sea level below. Significant erosion of the bluff has occurred over the years. The soils in the project area are reported to consist of silt and silty sands, and it is believed that an isolated mass of permafrost is present at the site. Vegetation consists of typical tundra plants, with no brush or trees in the immediate vicinity. The wind is reported to blow fairly constantly at the site, and it is likely that some shearing effect is caused by the proximity of the site to the bluff and Bristol Bay waters. Single phase power distribution lines are located nearby and extend past the site for at least one mile, and 3-phase power is available approximately less than one mile from the site.

**Site 2 – Pederson Point:** This site is located approximately 3 miles north of Site 1 and is not accessible by road. The land at Pederson Point is owned by the Pederson Point cannery, whose land is surrounded by Pauq-vik land. A small private airstrip is located at the cannery site. Although we were unable to visit the site, the topography, vegetation, and soil conditions are reported to be similar to those at the lagoon site, except that the bluff is lower in elevation. Power distribution lines are located several miles from Pederson Point; however, extension of a road and power to the site are expected within five to ten years. The cannery at Pederson Point currently self-generates. Because of the site's inaccessibility and distance from the distribution system, this site is not considered feasible for installation of a WTG. However, the site may be suitable for a hybrid wind/fuel cell project.

**Site 3 – KAKN Radio Station**: Site 3 consists of the area surrounding the KAKN Radio station which is located approximately 2 miles from Naknek along the Naknek/King Salmon Highway. The land is owned by the Lutheran Mission. There are two large towers in the immediate area, one owned by the radio station and the other owned by Alaska Rural Communication System (ARCS). The ARCS tower is not currently in use and is scheduled for demolition sometime in the near future. The ARCS tower is estimated to be approximately 100 feet tall. The topography of the site is relatively flat with gently sloping hills in the surrounding area. This area has the highest elevation in the Naknek area. Soils conditions at the project site are unknown, but likely consist of silty sands and gravels similar to the soils observed in the cut banks of the Naknek River. The presence of permafrost is unlikely but may be found in isolated areas. Vegetation consists of typical tundra plants, with clusters of alders and willows. The distribution line between Naknek and King Salmon follows the highway, therefore, the site is very close to the distribution lines. However, installation of a WTG within close proximity to the radio tower would likely cause signal interference and other problems, and site is not considered feasible for further evaluation. The radio station collects and records daily maximum wind speed, and has been doing so since October.

**Site 4 – King Salmon Area/Pike Lake**: Site 4 consists of the entire King Salmon area. Several individual sites were visited, including the Pike Lake area. Reportedly, wind resources in the King Salmon area are usually approximately 10 to 20% less than in Naknek. Therefore, no site in the King Salmon area is considered feasible due to the inadequacy of the wind resource.

**Site 5 – South Naknek:** This site consists of the South Naknek area, which is located across the Naknek River from Naknek. Most of the land in the area is owned by the Pauq-vik native corporation. Several locations within this site were visited, including the area near the airport, a hill south of the airport, and other locations along the road and close to the power distribution system. There is a relatively high hill on which a shop is located which would be considered the best location for a WTG on the south side of the river. The topography of the South Naknek area is characterized by gently rolling hills with some lower, flatter areas. Soils conditions at the project site are unknown, but likely consist of silty sands and gravels similar to the soils in other areas. The presence of permafrost is unlikely but may be present in some isolated locations.

Vegetation consists of typical tundra plants, with clusters of alders and willows, and some small spruce, mostly near the river. The distribution line between Naknek and South Naknek follows the road in most of the areas visited, therefore, the site is very close to the distribution lines. Three phase power has not been extended beyond the main housing area in South Naknek, although single phase aerial lines extend a significant distance along the river to the southwest to serve sparse residential areas and some summer-only cabins. The South Naknek area is accessible only by plane or boat during the summer and by driving on the river ice during the winter. Conducting routine maintenance of a WTG in the South Naknek area would be more costly than for the other side of the river due to these access difficulties. Therefore, installation of a WTG in this area is not considered feasible.

**Site 6 – Borough Landfill:** This site is located at approximately Mile 3 of the Naknek/King Salmon Highway. The land on which the landfill is situated is owned by the Borough, and most surrounding lands are owned by the Pauq-vik corporation. The topography of the area is relatively flat with some low gently rolling hills in the surrounding area. The landfill site itself is a local high point. Based on observations of exposed soils in the surrounding area, the soil conditions at the project site likely consist of silty sands and gravels. Permafrost is unlikely. Vegetation consists of typical tundra plants, with sparse clusters of alders and willows. The distribution line between Naknek and King Salmon follows the highway, and the site is very close to the distribution lines. This site is considered feasible for installation of a WTG, however, the sustainable wind resources are reported to be lower than in other areas by local residents.

**Site 7 – King Salmon Flats:** This site consists of the low area along the Naknek/King Salmon Highway between approximately Mile 8 and 12. Most of the land in the area is owned by the Pauq-vik corporation with some land near the road owned by the Borough. The topography of the area is flat and consists of generally low-lying tundra. Soil conditions at the project site are unknown, but likely consist of soils similar to those found in the rest of the area. Based on the vegetation and topography, there is likely a relatively thick organic layer and permafrost may be present. Vegetation consists of typical tundra plants, with no brush or trees. The distribution line between Naknek and King Salmon follows the highway, and the site is very close to the distribution lines. The area is reportedly subject to significant snow drifting during the winter months. Because the area is generally low, available wind resources are probably lower than at some of the other sites considered.

**Site 8 – Existing 10 kW Turbine Site:** This site is located in a residential area in the main part of town. An existing 10 kW Jacobs turbine is installed on a tower and has been successfully operating for over 10 years. The turbine is maintained by the owner, Einar Bakkar. Although this site is not suitable for installation of a large turbine because the area is primarily residential, it may be cost effective to install a larger, more efficient turbine such as the AOC 15/50 kW on the existing tower to increase output. Nearby residents are accustomed to the turbine as well as to any noise produced.

## 2.2 UNALASKA SITE VISIT

The Unalaska site visit was conducted on March 24 - 26, 1999. The work completed included meeting with Unalaska Electric Utility (UEU) personnel, including Mike Golat, the UEU General Manager. Other key contacts include Karen Blue of UEU and Scott Diener, the Planning Director for the City of Unalaska. There are no USFWS or NWS offices in Unalaska.

### Community Background Information

Unalaska is located on the southern portion of Iliuliuk Bay on Unalaska Island in the eastern Aleutian Islands as shown on Figure 1. The Dutch Harbor area is located on the eastern side of Amaknak Island. The two areas are connected by a bridge. The economy of the community is based primarily on commercial fishing and processing in addition to providing support for the Bering Sea and North Pacific fishing fleets. Unalaska is accessible only by air and sea. Several commercial airlines provide daily flights to Unalaska. Electrical service to the entire area is provided by UEU. All distribution lines are buried.

### History of Wind Energy in Unalaska

According to local sources, two WTGs have been installed in the past in the Unalaska area. Both installations were located on exposed peaks, and high gusts damaged the tower or turbine at each location in a short time. There are currently no operating or non-operating turbines in the Unalaska area.

### Electrical Utility

UEU is a member owned electrical cooperative which serves the Unalaska/Dutch Harbor area. The utility owns 9 diesel powered generators with a total generating capacity of 7,500 kW. Eight of the units are located in the power plant on Amaknak Island, and the ninth is located in a mobile van in Unalaska Valley on Unalaska Island. The Pyramid Valley Hydroelectric Project is scheduled to begin design this year, and should be operational in two years. The Pyramid Valley Project will increase the utility's capacity by 600 kW. The current total operating efficiency (1998 year) is 14.5 kWh per gallon of diesel fuel. The utility uses approximately 2 million gallons of fuel annually, with recent fuel prices of $0.67 per gallon in 1998 and $0.87 per gallon in 1997.

Peak loads of 5.5 to 6.0 MW are experienced routinely. With a current total capacity of 7.5 MW, there is not adequate capacity to add any large customers to the system. Average loads are in the range of 3.5 to 4.0 MW. The utility deregulated from the APUC in 1982 and holds a certificate of public convenience from the commission for their territory. The utility hopes to expand its facility to provide the ability to serve several of the canneries and other industrial users which operate during commercial fishing activities. All of the canneries and many industrial users currently self-generate.

The rate structure per the current UEU tariff is as follows.

Residential

| | |
|---|---|
| Customer Charge | $7.50 per meter per month |
| Energy Charge | 0.20 per kWh |

Small General Services (non-residential with 20 kW demand or less, does not require demand metering.

| | |
|---|---|
| Customer Charge | $10.00 per meter per month |
| Energy Charge | 0.21 per kWh |

Large General Services (all services with demands from 20 to 100 kW for a minimum of 6 months per City fiscal year.)

| | |
|---|---|
| Customer Charge | $50.00 per meter per month |
| Demand Charge | 6.70 per kW |
| Energy Charge | 0.175 per kWh |

Industrial Service (demands exceeding 100 kW for a minimum of 6 months per City fiscal year.)

| | |
|---|---|
| Customer Charge | $100.00 per meter per month |
| Demand Charge | 7.70 per kW |
| Energy Charge | 0.1275 per kWh |

Long-term construction plans include:

Pyramid Creek Hydroelectric Project

Possible future customers include canneries, current industrial users not on City power, and new residential customers.

## Land Status

The primary landowners in the Unalaska area include the City of Unalaska and the Ounalashka Corporation. Although sites owned by both parties were considered during the site visit, the emphasis was placed on City lands to minimize capital and operation and maintenance costs for the project and avoid land lease costs.

**Sites Considered**

The following paragraphs provide brief descriptions of each of the sites within the project area which were considered for installation of a WTG. The approximate location of each site is shown on Figures 4 and 5. Due to heavy snow pack at the time of the site visit, the types of vegetation present at any of the sites could not be determined.

**Site 1 – City Landfill:** This site is located on the eastern side of Iliuliuk Bay at the City landfill. The site is located on a flat area at the base of a steep mountainside. The landfill cells are located on the east side of the access road. The landfill is currently in the process of being expanded. A baler facility was constructed at the southern end of the site several years ago. The land is leased from the Ounalashka Corporation. Although site specific geotechnical data was not obtained, it is expected that the soils in the project area likely consist of gravel and sand with bedrock at a relatively shallow depth. The wind is reported to blow fairly constantly at the site. Three phase power distribution lines extend to the bailer facility. Hundreds of bald eagles and ravens were observed scavenging at the landfill during the site visit. The baler facility was recently constructed to reduce the bird population at the landfill site.

**Site 2 – Haystack Hill:** This site is located on a low hill with a maximum elevation of approximately 375 feet msl. Several communications towers and a small building are also located on the hilltop. An access road leads to the site, and three phase power is also available. Several residences are also located on the hill. Most of the land on Haystack Hill is owned by the Ounalashka Corporation; however, two lots on the southwest side of the hill are owned by the City. Site specific soils information was not located, but it is likely that bedrock is located at a relatively shallow depth. Because of the elevation and exposure at the site, the wind is reported to blow constantly at the site, with extreme high gusts. The proximity of the site to residences and the presence of the communications towers may present a problem. This site is considered feasible for installation of a WTG; however, relocation of the communications towers would be required.

**Site 3 – Mount Ballyhoo Above Airport:** This site is located on the side of Mount Ballyhoo above the Unalaska airport. No access road leads to the site, and three phase power is not available nearby. Most of the land on Mt. Ballyhoo is owned by the Ounalashka Corporation. Because of the proximity of the site to the airport and the distance from power lines, the site is not considered feasible for installation of a WTG.

**Site 4 – Top of Mount Ballyhoo:** This site is located on the top of Mount Ballyhoo. No access road leads to the site, and three phase power is not available nearby. Most of the land on Mt. Ballyhoo is owned by the Ounalashka Corporation. This site is not considered feasible for installation of a WTG for similar reasons to Site 3.

**Site 5 – Strawberry Hill – Old Water Tower Site:** This site is located on a low hill on the west site of Iliuliuk Bay with a maximum elevation of approximately 120 feet msl. An access road is present on the hill; however, it is not maintained during the winter months. Three phase power is not available nearby. Most of the land on Strawberry Hill is owned by the Ounalashka Corporation. Site specific soils information was not identified, but it is likely that bedrock is located at a relatively shallow depth. This site is not considered feasible due to the distance from existing infrastructure.

**Site 6 – Bunker Hill:** This site is located on Bunker Hill which is located on the southern side of Airport Beach Road and the western side of Captains Bay. An access road leads up the hillside, but is not maintained during the winter months, and three phase power is not available nearby. Most of the land on Bunker Hill is owned by the Ounalashka Corporation. This site is not considered feasible for installation of a WTG for similar reasons to Site 3.

**Site 7 – Spit:** This site is located on the low spit which extends from the northern end of Amaknak Island to the southwest approximately two miles. The spit separates Dutch Harbor on the west from Iliuliuk Bay on the east. Power and an access road are available to the end of the spit where the U.S. Coast Guard is reportedly installing navigational aids. The land on the spit is owned by the Ounalashka Corporation. Although site specific soil data was not obtained, the soils likely consists of typical sand and gravel beach deposits. It has also been reported that a midden is located on the spit approximately midway along its length.

**Site 8 – Wastewater Treatment Plant:** This site is located at the site of the existing City wastewater treatment plant. The plant is located along Airport Beach Road north of Bunker Hill. The plant site is relatively flat; however a sheer 30-40 foot cliff is located behind the building. Installation of WTGs at the top of the cliff may be feasible; however, an access road would need to be constructed. Three phase power is available at the plant. The plant site itself and some of the land above the cliff behind the plant is owned by the City, and all surrounding lands are owned by the Ounalashka Corporation. Site specific soil information was not identified, but it is likely that bedrock is located at a relatively shallow depth based on observations at the site.

**Site 9 – Pyramid Valley:** This site is located at Pyramid Valley near the proposed location of the new hydroelectric plant. Due to the heavy snowfall at the time of the site visit, the road to the area had not been plowed and the field team was unable to visit the site. Wind monitoring was completed for one year during the initial studies for the design of the hydro-plant resulting in a mean annual wind speed of 5.2 m/s (11.6 mph) with a 20-foot tower height. All land in the area is owned by the Ounalashka Corporation except for a 200 foot corridor along Icy Creek (for the water treatment plant) and two privately owned lots within Pyramid Valley and extending to Captain's Bay.

## 2.3 PREFERRED SITES

Based on the results of the data collection and site visit tasks, the following sites in each community were selected for further consideration and feasibility analysis.

### Naknek

In Naknek, Site 1 – Sewage Lagoon (Figure 6) is considered the best location for consideration of installation of a WTG. The site already has an industrial use and is owned by the Borough. Based on previous wind monitoring data in the Naknek area, the wind resources are considered feasible for installation of a WTG, although site specific wind monitoring data will be required. The sewage lagoon site is reported to be one of the windiest areas in the community and likely has the best chance of having adequate wind resources to make wind energy feasible in Naknek.

### Unalaska

Several sites are considered feasible for installation of a WTG in the Unalaska area. The preferred site in Unalaska, based solely on land use and ownership and available wind resources, is Site 1 – City Landfill (Figure 7). As with Naknek, the site has industrial use and is leased by the City. The lease is fairly specific as to use as a landfill, and coordination with the Ounalashka Corporation will be required to allow installation of a WTG. The wind resources in Unalaska are greater than that in Naknek, therefore, this factor is not as key to preferred site selection. Actually, some sites in Unalaska may be excluded due to turbulence and high wind gusts. For this reason, sites closest to the water would be preferable over inland or upland sites. The landfill site has open water in the predominant wind direction and is not expected to experience excessive turbulence.

Alternative sites that are acceptable from a wind resource perspective include Haystack Hill (Site 2), the spit (Site 7), the wastewater treatment plant (Site 8), and Pyramid Valley (Site 9). However, Haystack Hill would require relocating the existing communications towers, resulting in significantly higher capital costs. The Ounalashka Corporation was contacted regarding the spit site. It is generally believed that the potential cultural value of the midden site and the visual impact of a wind turbine in this exposed area eliminates the spit from consideration.

# 3.0 WIND RESOURCES

## 3.1 GENERAL INFORMATION

The general background wind feasibility information presented in this section was primarily gathered from the Danish Wind Turbine Manufacturers Association web site (www.windpower.dk) which contains general information and typical calculations for determining the feasibility of wind energy, and the National Renewable Energy Laboratory web site (rredc.nrel.gov) which contains wind resource data for areas throughout the country. According to the data available, wind power density in the Naknek Area is Class 4 and in the Unalaska area is Class 7. According to the NREL site, Class 3 areas or greater are generally suitable for most WTG applications. A summary of the estimated wind power density and wind speed for the various wind power classes is presented on Table 1.

**TABLE 1[(1)]**

**CLASSES OF WIND POWER DENSITY AT 10m AND 50m[(2)]**

| Wind Power Class[(4)] | 10 m (33 ft) | | 50 m (164 ft) | |
|---|---|---|---|---|
| | Wind Power Density (W/m$^2$) | Speed[(3)] m/s (mph) | Wind Power Density (W/m$^2$) | Speed[(3)] m/s (mph) |
| 1 | 0 | 0 | 0 | 0 |
| 2 | 100 | 4.4 (9.8) | 200 | 5.6 (12.5) |
| 3 | 150 | 5.1 (11.5) | 300 | 6.4 (14.3) |
| 4 | 200 | 5.6 (12.5) | 400 | 7.0 (15.7) |
| 5 | 250 | 6.0 (13.4) | 500 | 7.5 (16.8) |
| 6 | 300 | 6.4 (14.3) | 600 | 8.0 (17.9) |
| | 400 | 7.0 (15.7) | 800 | 8.8 (19.7) |
| 7 | 1000 | 9.4 (21.1) | 2000 | 11.9 (26.6) |

Notes:
1. Table from rredc.nrel.gov web site. Product of Pacific Northwest National Laboratory, operated for the US Department of Energy by Battelle Memorial Institute.
2. Vertical extrapolation of wind speed based on the 1/7 power law.
3. Mean wind speed is based on Rayleigh speed distribution of equivalent mean wind power density. Wind speed is for standard sea level conditions. To maintain the same power density, speed decreases 3% per 1000 m (5% per 1000 feet) elevation.

4. Each power wind class should span two power densities. For example, Wind Power Class 3 represents the Wind Power Density range between 150 $W/m^2$ and 200 $W/m^2$. The offset cells in the first column attempt to illustrate this concept.

## General

The feasibility of installing a WTG at any given location is primarily dependent upon the available wind resources at the site. The potential energy content of the wind varies as the cube of the wind speed, meaning that if the wind speed is twice as high in one location as another it contains eight times as much energy. Therefore, it is important to identify the site within each community which has the highest potential wind resources. There are several factors which affect available wind resources and which should be considered in site selection:

**Roughness:** Roughness of the wind is governed by the topography of the surrounding area as well as obstructions to the wind such as buildings or other structures. Since water is very smooth, selection of a site nearest the water will minimize roughness.

**Wind Shear:** The wind is usually at a lower speed at the ground surface than above the ground. The wind speed may be significantly lower on the turbine rotor in the bottom position than in the top position.

**Wind Speed Variability:** Wind is generally higher during the daytime because temperature differences between land and sea are greater during the day. Since power usage is generally higher during the day, wind power can effectively be used to assist utilities in meeting peak loads.

**Turbulence:** Areas with high roughness are often subject to turbulence, which includes irregular wind flows. High turbulence increases operation and maintenance costs and causes excess wear on the turbine and rotor. Towers should be high enough to minimize the effect of turbulence. Obstacles near the turbine often cause localized turbulence.

**Wind Obstacles:** Obstacles such as trees and buildings decrease the downwind speed and can also cause turbulence in the surrounding area. Obstacles within approximately 1 kilometer of the turbine in the primary wind direction should be taken into account when calculating available wind power.

**Wake Effect:** With any WTG, there will be a wake of very turbulent air behind the turbine for some distance. This is particularly important to consider if more than one turbine is being installed, because operation of upstream turbines can affect the production of the downstream turbines.

**Tunnel Effect:** This effect happens when the wind speed is increased due to compression into a smaller area such as a canyon or steep valley. Depending upon the configuration of the "tunnel", wind speed can easily be increased by as much as 30 to 50% due to the tunnel effect. Taking advantage of the tunnel effect may also result in an increase in turbulence.

**Hill Effect:** This effect is similar to the tunnel effect except that the wind becomes compressed on the windward side of the hill rather than in a canyon.

During selection and evaluation of the various sites in each community, the factors above were considered. Sites were selected to minimize obstructions in the project area and to take advantage of the various effects listed above. For example, there are two small hills at the sewage lagoon site in Naknek. Placing a turbine on one of these hills will take advantage of the hill effect. Additionally, roughness and turbulence should be low since the site is adjacent to the Bristol Bay.

## 3.2 SITE SPECIFIC WIND DATA

Various agencies were contacted regarding the availability of wind monitoring data in each community. The following paragraphs provide a summary of the data collected and reviewed and copies of pertinent information are included in Appendix A. Please note that none of this data was collected at the proposed sites under consideration in this study. Site specific monitoring data for the preferred sites should be collected prior to proceeding with the design and construction of a WTG.

**Naknek:** Several sources of wind monitoring data were identified in the Naknek and King Salmon area. The NWS has been collecting wind data at the King Salmon airport for many years at an anemometer height of 11.6 m. During the site visit, data for monthly average wind speeds at the airport were collected for the past year. Based on this data, the average annual wind speed at the King Salmon airport is 10.7 mph (4.8 m/s). It is estimated that the average wind speed in King Salmon is approximately 20 % less than in Naknek, resulting in an average wind speed of approximately 13 mph (5.8 m/s) for Naknek. The KAKN radio station in Naknek has been recording maximum daily wind speed since October 1998. The anemometer is located approximately 1 m above the roof of the building, for a total anemometer height of approximately 5 m. The radio station indicates an average maximum daily wind speed of approximately 23.7 mph (10.6 m/s) over a six-month monitoring period. Over the identical six-month period, King Salmon W.S.O. also monitored for maximum wind speed. Results indicate that the average maximum daily wind speed in King Salmon is 17.6 mph (7.9 m/s) which is 26 % less than Naknek.

AeroVironment, Inc. conducted a wind monitoring program in Naknek in 1981 and 1982 under contract to the US Department of Energy and the Alaska Power Administration. Monitoring was completed at three sites including 1) an area referred to as "Naknek Hill" which is located on a hill south of the airport, 2) south of the sewage lagoon site near the west end of town, and 3) near the cemetery which is located several miles east of town along the Naknek-King Salmon Highway. Monitoring at Naknek Hill was completed for over one year, and monitoring at the west end of town was completed for nearly one year. Monitoring at the cemetery site was discontinued after a few months because of generally low wind speed readings. Anemometer height in all cases was 10 m. The results of the monitoring indicated that the average annual windspeed in the Naknek area is 13.7 mph. Since this monitoring data was obtained at a height of 10m, it can be reasonably assumed that the wind speed at greater heights will be somewhat higher.

Considering these available sources of wind information, it is reasonable to assume that the average annual wind speed for the Naknek area is approximately 14.0 mph (6.25 m/s). Potential power output calculations were prepared based on this value.

**Unalaska:** Very little data was available regarding average annual wind speed in the Unalaska area. The Steiger's Corporation collected data as part of the permitting effort for the Pyramid Valley Hydroelectric Project from July 1995 through June 1996. The anemometer was located at an elevation of 517 feet (158 m) with a tower height of 20 feet (6.1 m). As part of this same effort, data was collected near Rocky Point at an elevation of 100 feet (30m) with a tower height of 30 feet (9 m). The two monitoring efforts resulted in an average annual wind speed of 11.6 mph (5.2 m/s) at Pyramid valley and 12.8 mph (5.7 m/s) at Rocky Point. Considering that the Unalaska area is located within an area reported to have Class 7 wind power density, these results are lower than expected and likely represent data from a somewhat sheltered area. The State of Alaska community profile for Unalaska indicates the mean annual wind speed is 17 mph (7.6 m/s), however, this data was reported by DCRA to possibly be an incorrect conversion from nautical to statute miles. According to the Wind Energy Resource Atlas of the United States, the average annual wind speed for Cold Bay, which is along the Aleutians approximately 180 miles northeast of Unalaska, is 7.5 m/s. Because of the lack of reliable wind monitoring data in Unalaska, the power output calculations for the various turbines presented in the remainder of this section have been prepared for a range of wind speeds. Actual output and optimum turbine selection should be based on monitoring obtained at the preferred site.

## 3.3 ESTIMATED POWER OUTPUT

### Factors Considered

There are several factors which must be considered when estimating the available power at a site. A discussion of some of the key considerations in estimating power output is presented below.

**Wind Variability**: One of the most important factors is the variability of the wind speed. Wind variation along the Aleutian Islands typically follows a Weibull Distribution (NREL) represented by a graph with wind speed on the x-axis and frequency on the y-axis. The shape of this distribution provides a more accurate estimate of the power available from a particular turbine than simply estimating available power using the mean annual wind speed. The shape of the curve is characterized by a "shape parameter". If the shape parameter is exactly 2, it is referred to as a Rayleigh distribution which is used by many turbine manufacturer's to provide standard performance values for their WTGs. Figure 8 presents the annual wind distribution for Naknek, and was prepared using average daily wind speeds resulting from the 1981/1982 wind monitoring data performed by AeroVironment, Inc. This distribution generally corresponds to a shape parameter of 2, which indicates the wind speed is more commonly close to the mean than at significantly higher or lower values. Due to the lack of availability of daily or hourly wind data in Unalaska, and the variation in mean annual wind speed as determined from the various sources, we were unable to obtain a realistic wind distribution for the community. For purposes of estimating theoretical power output for the various turbines, output for a range of wind speeds was calculated using a shape parameter of 1.5. This factor was selected because it is anticipated that wind speeds are more commonly above the mean in Unalaska than in Naknek.

**Power Density:** Since the power of the wind varies with the cube of the wind speed, a significantly higher amount of power is generated during the times the wind speed is higher than the mean. The distribution of energy at different wind speeds is referred to as the power density. It is not possible to accurately estimate the potential wind power available based solely on the average annual wind speed. Site specific monitoring data is required to complete an accurate analysis.

**Temperature and Pressure:** Since the air is denser at lower temperatures, more power is generated by turbines in cold climates than in warm climates. Correcting the density from 58 $^{o}$F to 0 $^{o}$F can result in up to a 13% increase in power. Most standard WTG power curves are prepared for standard temperature and pressure (20 $^{o}$C and 1 atm) and therefore must be corrected for the actual site temperature.

**Loss Factors:** There are several factors which are generally accepted to reduce the actual power production from the theoretical value. Several of these factors include the following.

1. **Availability:** It is important to consider availability of the wind power to the grid. In general, in can be assumed that the turbine is 97% efficient, which represents only a 3% loss of power.

2. **Transmission System Losses:** These losses are generally several percent of the total and consist of the transmission line losses. These losses increase with the distance of the turbine from the distribution point.

3. **Soiling of Blades:** Soiling of blades includes dirt, insects, and other deposits on the blades such as ice. This is generally a loss of a few percent, but can be much higher depending upon specific site conditions.

4. **Control System Losses:** These losses are generally 1 to 3% of the total and include losses related to the reaction time of the turbine during cut in/cut out, reacting to a change in wind direction, or controlled power output reduction due to cold weather.

5. **Turbulence Losses:** These losses vary greatly depending upon the site and turbulence experienced. Standard turbine power curves are based on areas with low turbulence density.

6. **Interference Losses:** Interference losses are generally a few percent and are the result of interference from a variety of sources including the wake effect, roughness, and obstacles.

Considering all of these potential losses which reduce the theoretical output of a turbine, a 25% reduction has been used in this study.

## Turbines Analyzed

Wind turbine generators can be described according to the following controls used to optimize wind energy production.

- variable speed,
- variable pitch,
- stall-regulated, or
- various combinations of the previous.

To provide a representative range of turbine sizes for inclusion in this study, power output for six turbines ranging from 50 kW to 750 kW was estimated. The turbines selected for evaluation were chosen based upon the following criteria.

- Manufactured in the United States,
- Ability to perform in cold regions, and
- Size.

Turbines from several manufacturers with varying output and characteristics were selected for further evaluation based on the criteria above. Brief descriptions of each turbine considered are presented below. Selected manufacturer's data for the various turbines is included in Appendix B, and power curves for each turbine used for power output analysis are presented on Figure 9.

**Zond Z-50 750 kW:** Zond Energy Systems (Zond), subsidiary of Enron Wind Development Corporation (EWDC) developed the Z-50 based on the previously successful Z-40 550 kW (See next section) and on experience gained through the installation and operation of over 2500 wind turbines installed in the USA since 1981. The Z-50 has obtained necessary field verification and is currently available on the market.

The Z-50 is a variable speed, variable pitch wind turbine and can be equipped with a cold weather package that allows operation down to -40º C (-40º F). The cold weather package includes a gearbox heater, generator winding heater, heated anemometer, heated yaw vane, cold weather software, and lower temperature rated parts such as lubricants, steel tower, cables and hydrophobic coating on fiberglass rotor blades [fluorourethane-silicone gel (StaClean®)]. The Z-50 controller software reduces power output to 225 kW (speed variation) when the ambient air temperature drops to -20º C (-4 º F) and shuts down at -40º C (-40º F). The three Z-50 blades result in a rotor diameter of 50 m and a hub height of 53.5-m (175-ft). The rotor is equipped with redundant safety features, an air brake and a fail-safe mechanical brake system.

**Zond Z-40 550 kW:** The Z-40, predecessor to the Z-50, is a constant speed, variable pitch WTG with the same cold weather package and safety features. The Z-40 has three blades that result in a rotor diameter of 40 m and are mounted on a 40-m high (130 ft) tubular tower. One difference between the Z-40 and the Z-50 is in the weight, 132 and 217 kips, respectively. This could be a cost advantage during shipping and installation. Although a Z-40 has recently been installed in the Yukon Territory, the Z-40 is currently off production. Zond indicates that production could be re-initiated if the market exists.

**NEG Micon M750 400/100kW and M700 225/40 kW:** NEG Micon is a Danish company that recently expanded to the USA and Canada. NEG Micon is expected to be established as a USA manufacturer for turbines ranging from 600 to 900 kW by the summer of 1999. Currently, both the M750 and the M700 series are considered Danish products and are planned to be taken out of production in 2000. The purpose of including the 400 kW and 225 kW WTGs is to provide a full range of turbine sizes for evaluation. No USA manufactured turbines of this size class are available and those manufactured elsewhere are being discontinued. For this reason, the only relevant equipment information results from the power curves provided in Figure 9 and the rotor diameter and the hub height. The M700 has a rotor diameter of 29.8-m (97.8 ft) at a height of 36 m (97.8 ft), whereas the M750 is 31 m (101.7 ft) in diameter and 36 m high. The dual ratings (400/100kW and 225/40kW) are provided since the units reduce output in extreme cold weather.

**NPS Northwind 100:** Northern Power Systems (NPS), formerly Northwind Power Company, has been operating in the USA since 1974. NPS has considerable experience with cold region WTG installations. Building upon experience gained during development of a WTG for the harsh climate at the South Pole, NPS designed the Northwind 100 for subarctic and arctic climates and for incorporation in primarily diesel power generation systems. As part of the Wind Turbine Verification Program, Northwind controllers and cold weather package along with a Vestas 225 kW turbine are being incorporated into a high penetration diesel hybrid system for the Tanadgusix Corporation in St. Paul, Alaska. A Northwind 100 is scheduled for installation and testing in Kotzebue, Alaska in 1999, with the first commercial installation scheduled for the year 2000.

The NPS Northwind is a variable speed WTG with a direct drive that does not have a gearbox. The hub height is 24 m and the 16.6 m diameter rotor consists of three blades. The unit does not have blade pitch control, tip brakes, or tip flaps. The brakes are mechanical and electrical. The WTG is rated to -45º C (-50º F) and the simple blade design is intended to minimize problems associated with icing. The Northwind 100 was designed simply and durably specifically for cold regions, small villages, and diesel hybrid applications.

**AOC 15/50 kW:** The Atlantic Orient Corporation (AOC) 15/50 kW WTG has been extensively tested in numerous cold region locations such as central Russian Siberia, Northwest Territory and Northern Ontario in Canada, Vermont, New Hampshire, Maine, and Kotzebue, Alaska. The Kotzebue site, managed by Brad Reeve of Kotzebue Electric Association, is being used to evaluate for the Wind Turbine Verification Program. Mr. Reeve provided cost information from Kotzebue for 1998 that provided a check on the costing methods and assumptions used in this analysis. A summary of the verification test at the Kotzebue site will be published later this year. Although the AOC 15/50 is included in this feasibility study, details will be limited and the reader is encouraged to review the Kotzebue report when it becomes available.

## Power Output Calculations

The power output for the various turbines was estimated using the "Wind Turbine Power Calculator" provided at the Danish Wind Turbine Manufacturers Association web site (www.windpower.dk). A model based on the 1981/1982 wind data for Naknek was prepared by AOC and was used as a check for the validity of the rough calculations obtained from the web site. More accurate calculations should be completed once site specific wind monitoring data is obtained.

Table 2 presents a summary of the estimated annual power output for Naknek and Unalaska. Appendix C includes more detailed tables for each community with the input parameters which were used to calculate the theoretical output at each site. For estimating purposes, mean annual wind speeds of 14 mph (6.25 m/s) and 15 mph (6.7 m/s) were used to generate the data presented in Table 2. Since the actual wind speed in Unalaska may be higher or lower than the assumed 15 mph at a given site, power output was calculated for a range of speeds. Figure 10 presents the power output for the six turbines considered at wind speeds ranging from 6 to 12 m/s.

**TABLE 2**

**ESTIMATED POWER OUTPUT**

| **NAKNEK** | | | | | |
|---|---|---|---|---|---|
| Turbine | Rated capacity (kW) | Theoretical Maximum Output (kWh/yr)(1) | Gross Energy Output (kWh/yr)(2) | Net Energy Output (kWh/yr)(3) | Net Capacity Factor (%) |
| Z50 | 750 | 6,574,500 | 2,908,828 | 2,181,621 | 33.2% |
| Z40 | 550 | 4,821,300 | 1,779,556 | 1,334,667 | 27.7% |
| NEG M750 | 400 | 3,506,400 | 1,177,700 | 883,275 | 25.2% |
| NEG M700 | 225 | 1,972,350 | 776,475 | 582,356 | 29.5% |
| NPS 100 | 100 | 876,600 | 288,015 | 216,011 | 24.6% |
| AOC 15/50 | 50 | 438,300 | 206,028 | 154,521(4) | 35.3% |
| **UNALASKA** | | | | | |
| Turbine | Rated capacity (kW) | Theoretical Maximum Output (kWh/yr)(1) | Gross Energy Output (kWh/yr)(2) | Net Energy Output (kWh/yr)(3) | Net Capacity Factor (%) |
| Z50 | 750 | 6,574,500 | 2,943,252 | 2,207,439 | 33.6% |
| Z40 | 550 | 4,821,300 | 1,905,713 | 1,429,284 | 29.6% |
| NEG M750 | 400 | 3,506,400 | 1,263,712 | 947,784 | 27.0% |
| NEG M700 | 225 | 1,972,350 | 794,817 | 596,112 | 30.2% |
| NPS 100 | 100 | 876,600 | 326,417 | 244,812 | 27.9% |
| AOC 15/50 | 50 | 438,300 | 212,224 | 159,168 | 36.3% |

Notes: (1) Assumes turbine operates at rated capacity for an entire year.
(2) Output calculated based on mean wind speed and site characteristics.
(3) Includes 25% loss factor.
(4) Estimated power output from the AOC model based on hourly data is 163,506 kWh/yr

# 4.0 ENGINEERING CONSIDERATIONS

This section provides a summary of engineering considerations such as foundations, cold weather operations of wind turbines, and potential impacts to the power grid.

## Foundations

Geotechnical conditions at the sewage lagoon site in Naknek consist of silts and silty sands based on observations of the exposed bluff which extends to the beach at the mouth of the Naknek River. Area residents report that permafrost has been encountered in the area at a relatively shallow depth. The two spoil piles which were placed at the site during construction of the lagoons likely consist of uncompacted silts and silty sands and will not provide adequate strength for a concrete foundation. Because of these soil conditions, the most likely suitable foundation for this site consists of a pile system. The most cost effective system will probably consist of a minimum of three piles installed to a suitable depth based on soil conditions (60 to 80 feet). The actual pile foundation design will depend upon the soil properties encountered during a geotechnical investigation. NEA reports drill rigs are available in Naknek for completion of drilling at the proposed site.

Soil conditions in Unalaska most likely consist of a layer of organic and mineral soils underlain by bedrock at a relatively shallow depth. Depending upon the conditions present at the precise site selected for installation of a turbine, these soil conditions are suitable for a concrete foundation anchored to the bedrock.

## Cold Weather Considerations

All of the turbines selected for analysis in this study included cold weather designs and have been installed at other cold region locations. The Zond turbines have an optional cold weather package available which has been included in the estimated capital costs in this study. These cold weather packages include construction materials rated to lower temperatures than those for standard installations, and the addition of heaters to control equipment, gearbox, and hydraulic systems. Software specifically designed for cold weather operations is also included. Special coatings are used on the rotor blades to limit or eliminate ice build-up. For example, the Zond units incorporate a hydrophobic florourethane/silicone substance marketed as “StaClean”. Cold weather rotor blades are specified as black to facilitate shedding of ice when the blades are exposed to sunlight. Under severe icing conditions, it may be necessary to manually shut down the turbine.

The NPS 100 uses durable and simple mechanical systems with cold weather material specifications to counter harsh climatic conditions. The NPS 100 employs a direct, variable speed drive and has no gearbox. Lubrication specifications are important because there are no heaters. Integration into the electrical grid requires an electronic conversion package. The AOC 15/50 is also appropriate for cold region installations. These components include a transmission and enclosure heater, low temperature lubrication, and stearns brake heater. More specifics may be obtained by reading the verification report to be published by KEA.

**Impacts to the Existing Grid and Generation System**

There are several factors which can affect the existing grid and generation system when a wind turbine is installed. Usually, power quality is of most importance to electrical utilities and their customers. Power quality refers to the stability of the voltage and frequency and the absence of flicker and other anomalies which may cause brown-outs or damage the grid. Brown-outs and other items which affect power quality can be caused if the WTG is immediately connected or disconnected from the grid. Modern turbines are “soft-starting” which allows the current to enter the grid gradually, similar to the effect a dimmer switch has on an incandescent light fixture. This prevents large power surges and resulting power quality degradation.

Based on the size of turbines considered in this analysis, and on the average daily loading of both NEA and UEU, the wind turbine installation would be considered “low penetration” which is generally defined as less than 15 to 20% of the total load. Controls on modern wind turbines are designed to control power quality by monitoring the performance of the wind turbine, and by monitoring the voltage and frequency of the grid. The control systems can disconnect the turbine from the grid when conditions are not ideal.

Higher penetration systems (>20%) require much more sophisticated and costly control systems to monitor and control power quality.

**Construction Considerations**

Preliminary research indicates that adequate construction equipment is available for installation of all turbines in each community, except for the Zond Z-40 and Z-50 which will require mobilization of one and two large cranes, respectively. Existing cranes in Naknek and Unalaska are capable of driving the piles, and would only require mobilization of a pile driver if none is available at the time of construction. In both communities, adequate heavy equipment is available to construct the anticipated foundation as described above, and mobilization of the larger cranes will be required only for the erection of the turbine itself. Concrete batch plants and fill materials are available in both communities.

# 5.0 ENVIRONMENTAL CONSIDERATIONS

This section provides a description of the potential environmental and biological issues which were investigated as part of this study and may affect site selection. The data presented in this section is based upon research of previously prepared reports in the project areas, and on initial contacts with agencies who may have an interest in the project. No field work or extensive studies were completed in regard to the environment. The primary purpose of this effort was to identify environmental issues which may require significant consideration and may cause delays or increase the capital cost as the project progresses toward construction. It is anticipated that these environmental and biological issues will be addressed more fully in the Environmental Assessment (EA).

## 5.1 NAKNEK

Very little specific environmental data was identified for the Naknek area specifically. Several reports related to biology and the environment were identified for the King Salmon area. This data is generally assumed to be relevant to Naknek based on the proximity of the two communities. It is assumed that a more in depth analysis of these issues specific to the Naknek area will be conducted during completion of the EA.

**Climate**

The climate in the Naknek area is mainly maritime, and is characterized by cool, humid, and windy weather with relatively little seasonal temperature variation. Average summer temperatures range from 42 to 63 $^{o}$F, with average winter temperatures between 10 and 30 $^{o}$F. Extremes from –40 to 88 $^{o}$F have been recorded. Total precipitation is 20 inches annually, including 44 inches of snowfall. Fog is common during the summer months.

The wind in the King Salmon area is characterized by southeasterly and easterly winds during winter (October through March) that are associated with high pressure over northern Alaska and low pressure over the southern Bering Sea or Gulf of Alaska. Summer winds (June through September) are primarily from the south and southeast and usually result from a blocking ridge of high pressure that extends into Alaska from the southeast and cyclonic storm activity over interior Alaska. Late winter and early spring winds are primarily from the north and northeast.

According to the AeroVironment wind monitoring report, the wind in Naknek is more northerly in the fall and winter and more southerly in the spring and summer.

## Vegetation and Wetlands

Tundra and hills characterize the Bristol Bay lowland region, including the Naknek area. Major plant communities in the region are characterized as dry or moist tundra communities and Subarctic or boreal forest. Vegetation in boreal forest community in this region is characterized by scattered white spruce, paper birch, balsam poplar, and several species of willows. Tundra communities primarily consist of low ericaceous shrubs, such as Labrador tea, blueberry, and crowberry, plus dwarf and shrub birch, and several species of grasses, sedges, and mosses.

The Naknek area supports a wide diversity of wetland communities including palustrine, lacustrine, riverine, and estuarine systems. Wet meadows, shrub bogs, and freshwater marshes occur at poorly-drained sites throughout the area. Riverine wetlands occur in areas adjacent to many of the streams and rivers in the area. In general, wetlands have not been delineated in the Naknek area.

The vegetation surrounding the sewage lagoon area (Site 1), which is considered the primary and preferred site in Naknek consist mostly of tundra. Although the site was frozen and lightly covered with snow at the time of the site visit, the flat topography and local knowledge indicates that the site may be classified as wetlands. No ponds were observed in the area immediately surrounding the site. The Army Corps of Engineers (COE) was contacted for a preliminary determination as to wetlands in the area. A fill permit (404) will be required for construction of and access road to the project site.

## Fish

Bristol Bay is the site of the largest sockeye salmon harvest in the world. Sockeye, chinook, coho, chum, and pink salmon are all present in the Naknek River and local streams. Chinook, chum, and coho salmon spawn in the Naknek River from approximately the lower lagoon near King Salmon to Naknek Lake. Resident fish species found in the Naknek River drainage include rainbow trout, Arctic char, Arctic grayling, lake trout, burbot, and northern pike.

## Birds

Naknek's marsh and aquatic habitats provide rich food sources and staging areas for numerous resident and migratory birds. Waterfowl, cranes, shorebirds, terns, gulls, and jaegers migrate through this area and breed on the wet tundra and at ponds. Common migrant raptor species include osprey, rough-legged hawks, and short-eared owls. Resident raptor species include bald eagles, gyrfalcons, and great-horned owls. The area is also a major migration route for tundra swans. Passerines such as the Lapland longspur, snow bunting, Savanna sparrow, American dipper, and several species of swallows are commonly observed. The varied habitat in the area supports an abundance of bird life. Bird counts have been conducted for a number of years by the US Fish and Wildlife Service (USFWS) during the spring migratory season and around Christmas.

**Threatened and Endangered Species**

The USFWS was contacted regarding the potential presence of threatened or endangered species in the project area. According to Mr. Greg Balough of USFWS, the following three endangered or threatened species are potentially present in the project area.

The entire Alaskan breeding population of Stellar's eider is listed as threatened. The Naknek and King Salmon area are near the northern edge of the molting and wintering range. These birds are diving ducks that spend most of the year in shallow, near-shore marine waters. Molting and wintering flocks congregate in protected lagoons and bays, and along rocky headlands and islets. In summer, they nest on coastal tundra adjacent to small ponds or within drained lake basins. Stellar's eiders have been observed in the Naknek/King Salmon area in recent years according to bird count data provided by the USFWS.

The spectacled eider is threatened throughout its range. Spectacled eiders are diving ducks that spend most of the year in marine waters where they probably feed on bottom-dwelling mollusks and crustaceans. Around spring break-up, breeding pairs move to nesting areas on wet coastal tundra. Spectacled eider's have not been observed in the area in recent years according to bird count data provided by the USFWS.

Three subspecies of peregrine falcon occur in Alaska. The American peregrine falcon is endangered throughout its range, but may be delisted within the next year. The arctic peregrine falcon was removed from the endangered species list in 1994, and the Peale's peregrine falcon has never been listed as threatened or endangered. The Naknek area is located on the southern border of the birds breeding range and on the northern border of the migration range.

Based on our initial contacts with the USFWS, consideration of these threatened and endangered species will be required for this project. These issues should be addressed in more detail in the EA.

**Cultural Resources/ Archaeology**

The state historic preservation office was contacted regarding the potential presence of historic/archaeological sites in the Naknek area. A summary of the historic sites present near the sites considered for installation of a WTG in Naknek area is presented below.

Site 1 – Sewage Lagoon: Near Site Nak-002

Site 2 – Pederson Point: No known sites but contains areas with high potential to contain undiscovered sites, archeological survey may be required.

Site 3 – KAKN Radio Station Area: No known sites, relatively low potential to contain unreported sites.

Site 4 – King Salmon Area: No known sites but contains areas with high potential to contain undiscovered sites, archeological survey may be required.

Site 5 – South Naknek: Contains three known sites, NAK-012, NAK-013, and NAK-022.

Site 6 and 7 – Borough Landfill and Flats: No known sites, relatively low potential to contain unreported sites.

Site 8 – Existing 10kW Turbine Site: Near site NAK-023

Since Site 1 is the primary site considered feasible in this study, a more in depth discussion of the archaeology of the immediate area is provided. NAK-002 is considered one of the first archaeological discoveries in the area. The site was first investigated by Ales Hrdlicka in 1931. During the investigation, human skeletons were excavated near the mouth of the Naknek River on the bluff on the north side of the river. The site was identified as "Pavik", and was determined to be primarily prehistoric in age. The site was further investigated by Helge Larson in 1948 during which time enough trade beads were found to determine that the site had been occupied during the nineteenth century. Further investigations in subsequent years identified housing depressions and artifacts throughout the site. Potential archaeological impacts should be considered in more detail during completion of the EA.

## 5.2 UNALASKA

The information presented in this section was obtained from prior environmental and engineering reports prepared for other projects in the Unalaska area. It is assumed that a more in depth analysis of these issues specific to the Unalaska area will be conducted during completion of the EA.

## Climate

The climate in the Unalaska area is mainly maritime, and is characterized by cool, humid, and windy weather with relatively little seasonal temperature variation. January temperatures range from 25 to 35 $^{o}$F; summers range from 43 to 53 $^{o}$F. Extremes from 12 to 80 $^{o}$F have been recorded. Total precipitation is 64 inches annually, including 21 inches of snowfall.

The wind in the Unalaska area is characterized by southeasterly winds. The Amaknak /Unalaska area is usually characterized by wind, rain, fog, and overcast skies. Moderate to strong winds are recorded throughout the year, with wind velocities of more than 100 knots recorded during strong winter storms. Local topography significantly affects localized wind speed and direction. Icing during cold and windy periods is reported to occur frequently.

## Vegetation and Wetlands

The topography of the area is relatively steep, and most of the land on Amaknak and Unalaska Islands is considered uplands. Because of the topography, wetlands are generally localized and confined to areas near streams and lakes. It is likely that none of the sites considered in this study would be considered wetlands unless the site is adjacent to a water body.

Vegetation in the upland areas generally consists of grasses, willows, alders, and heath-type plants. The vegetation at all of the previously undeveloped sites considered in this study is assumed to be similar to that described above. A thick snow pack and poor weather conditions during the time of the site visit made it impossible to identify the types of vegetation present at each individual site.

The COE was contacted for a preliminary determination as to wetlands in the area and to determine whether a fill permit (404) will be required for construction of a turbine and access road. According to the COE, no wetlands have been delineated in the Unalaska area. It is unlikely that a wetlands permit will be required since the sites considered in this study are generally upland sites or are located at areas previously developed, but the COE should be contacted during the permitting process.

## Fish

The Unalaska/Dutch Harbor port ranks number one in the United States for seafood volume and value. The local economy consists of commercial fishing and support services, as well as for cargo transport to Pacific Rim nations. The waters surrounding the area are abundant with various species of salmon, crab, cod, herring, halibut, pollock, etc. Several streams on the islands support spawning salmon and resident Dolly Varden. Herring feed throughout Unalaska Bay and are generally present in all inner bays in the area. Red king and tanner crab are reportedly distributed throughout Unalaska Bay and contiguous bays.

**Birds**

Emperor geese feed and rest along the entire shoreline of Unalaska Bay and Captains Bay. Migratory waterfowl are present throughout the area, and mallards, green-winged teal, scaup, red-breasted and common merganser, and harlequin duck are reported to nest along streams, lakes, and wetlands. Seabirds also nest in some areas along rocky cliffs. Birds using upland habitats include Savannah and song sparrow, Lapland longspur, snow bunting, gray-crowned rosy finch, winter wren, raven, and bald eagle. Most of these birds use willow-shrub land and grassy areas for feeding and nesting habitat.

At the time of the site visit, upwards of two hundred bald eagles were observed at the community landfill (Site 1). Although not endangered or threatened in Alaska, bald eagles are protected under the Bald Eagle Protection Act. Further environmental study should be conducted during the EA to determine potential effects on bald eagles at the landfill site.

**Threatened and Endangered Species**

The USFWS was contacted regarding the potential presence of threatened or endangered species in the project area. According to Mr. Greg Balough of USFWS, as with Naknek, the Steller's eider, spectacled eider, and peregrine falcon are all potentially present within the Unalaska area. Unalaska is within the molting and wintering range of the Steller's eider, and within the migratory range of the both the spectacled eider and the peregrine falcon.

Based on our initial contacts with the USFWS, consideration of these threatened and endangered species will be required for this project. These endangered species as well as the bald eagle population of the area should be addressed in more detail in the EA.

**Cultural Resources/ Archaeology**

The state historic preservation office was contacted regarding the potential presence of historic/archaeological sites in the Unalaska area. A summary of the historic sites present near the sites considered for installation of a WTG in Unalaska area is presented below.

Site 1 – City Landfill and Site 2 – Haystack Hill: No known sites, relatively low potential to contain unreported sites.

Sites 3 through 8: All within the Dutch Harbor Naval Operating Base National Historic Landmark (UNL-120).

Site 5 – Strawberry Hill and Site 8 – Wastewater Treatment Plant: No known sites but contains areas with high potential to contain undiscovered sites, an archaeological survey may be necessary.

Site 7 – Spit: Although not identified by the State Historic Preservation Office, local sources reported the possible presence of a midden approximately half way down the spit from the main portion of Amaknak Island.

Sites 1, 2, 7, 8, and 9 are all considered feasible from an engineering and land ownership perspective. If site 7 or 8 are selected, a more detailed evaluation of archaeological and cultural resources may be required during completion of the EA.

# 6.0 ECONOMIC ANALYSIS

The cost analysis was completed for the various turbines and sites based on manufacturer provided data, historical cost information provided by the utilities, and typical transportation charges for Alaska. Sites which are considered feasible will generally require construction of minimal site infrastructure, since the feasible sites were selected due to their proximity to existing infrastructure.

Cost spreadsheets and a detailed listing of the assumptions used when preparing the estimates is presented in Appendix D. Table 3 presents a summary of the capital cost estimates prepared for the sewage lagoon site in Naknek, and the landfill, Pyramid Valley, and wastewater treatment plant sites in Unalaska.

**TABLE 3**

**CAPITAL COST ESTIMATE SUMMARY**

| Analysis Results | Turbine | | | | | |
|---|---|---|---|---|---|---|
| | AOC 15/50 kW | NPS Northwind 100 kW | NEG M700 225/40 kW | NEG M750 400/100 kW | Zond Z-40 550 kW | Zond Z-50 750 kW |
| **Naknek Sewage Lagoon Site** | | | | | | |
| Turbine Costs | $133,442 | $251,883 | $403,766 | $674,519 | $924,347 | $1,199,689 |
| Site Development | $41,569 | $42,215 | $47,480 | $47,988 | $53,301 | $56,597 |
| Contingency (10 %) | $17,501 | $29,410 | $45,125 | $72,251 | $97,765 | $125,629 |
| **Site Total** | **$192,511** | **$323,507** | **$496,371** | **$794,758** | **$1,075,413** | **$1,381,914** |

**TABLE 3 Cont.**

**CAPITAL COST ESTIMATE SUMMARY**

| Analysis Results | Turbine | | | | | |
|---|---|---|---|---|---|---|
| | AOC 15/50 kW | NPS Northwind 100 kW | NEG M700 225/40 kW | NEG M750 400/100 kW | Zond Z-40 550 kW | Zond Z-50 750 kW |
| **Unalaska Landfill Site** | | | | | | |
| Turbine Costs | $124,570 | $237,243 | $382,761 | $649,314 | $879,371 | $1,125,666 |
| Site Development | $16,102 | $16,769 | $22,486 | $23,061 | $29,277 | $33,297 |
| Contingency (10 %) | $14,067 | $25,401 | $40,525 | $67,237 | $90,865 | $115,896 |
| **Site Total** | **$154,738** | **$279,413** | **$445,772** | **$739,612** | **$999,513** | **$1,274,859** |
| **Unalaska Pyramid Valley Site** | | | | | | |
| Turbine Costs | $124,570 | $237,243 | $382,761 | $649,314 | $879,371 | $1,125,666 |
| Site Development | $23,826 | $24,493 | $30,210 | $30,785 | $37,001 | $41,021 |
| Contingency (10 %) | $14,840 | $26,174 | $41,297 | $68,010 | $91,637 | $116,669 |
| **Site Total** | **$163,235** | **$287,909** | **$454,269** | **$748,108** | **$1,008,009** | **$1,283,356** |
| **Unalaska Wastewater Treatment Plant Site** | | | | | | |
| Turbine Costs | $124,570 | $237,243 | $382,761 | $649,314 | $879,371 | $1,125,666 |
| Site Development | $38,546 | $39,213 | $44,930 | $45,505 | $51,721 | $55,741 |
| Contingency (10 %) | $16,312 | $27,646 | $42,769 | $69,482 | $93,109 | $118,141 |
| **Site Total** | **$179,427** | **$304,101** | **$470,461** | **$764,300** | **$1,024,201** | **$1,299,548** |

Operations and maintenance costs for the various turbines were obtained from the turbine manufacturer's and from Kotzebue Electric Associations AOC installation. Table 4 provides a summary of the range of estimated annual operation and maintenance costs for the six turbines included in this study. In general, the midpoint of the ranges provided in the table corresponds to double the cost provided by the manufacturer to account for the higher costs in Alaska.

| Turbine | Annual O&M Cost |
|---|---|
| Zond Z-50 750 kW | $17,000-23,000 |
| Zond Z-40550 kW | $15,000-20,000 |
| NEG M750 400/100 kW | $12,000-18,000 |
| NEG M700 225/40 kW | $10,000-15,000 |
| NPS Northwind 100 kW | $7,000-10,000 |
| AOC 15/50 kW | $4,000-7,000 |

# 7.0 CONCLUSIONS AND RECOMMENDATIONS

Based on the information and analysis presented in this document, it appears that wind energy may be feasible in both Naknek or Unalaska, assuming that environmental issues can be addressed in a timely and cost-effective manner. However, there may be economic risks associated with installing larger, heavier wind turbines on poor soils and in severe climatic conditions. Unfortunately, the discontinuation of many of the WTGs in the 100 kW and 500 kW range prevents the selection of moderately priced turbines which may be the best choice. We recommend installation of the largest possible turbine for which capital funding can be obtained and economic risk minimized. Because of the high cost of mobilization of cranes to either community, the best alternative includes installing the largest turbine possible that can be installed using locally available equipment.

In regard to feasible sites in each community, Site 1 – Sewage Lagoon is considered the best site in Naknek based on all factors considered in this analysis. Since the wind resources in Naknek are expected to be marginally feasible, it will be important to monitor the wind for an eighteen month period to verify that the wind resources used in this analysis are representative of conditions at the project site.

In Unalaska, Sites 1, 8, and 9 are considered feasible for installation of a turbine. Some sites may be too turbulent for turbine installations. As with Naknek, site specific monitoring data should be obtained prior to design and installation of the turbine. The actual site selected for turbine installation will be dependent upon the results of the EA and UEU preference. Table 5 provides an overall summary of the issues discussed in this report for each site considered.

**TABLE 5**
**PREFERRED SITE SUMMARY**

| Parameter | Naknek | Unalaska | | |
|---|---|---|---|---|
| | Site 1 – Sewage Lagoon | Site 1 – Borough Landfill | Site 8 – WWTP | Site 9 – Pyramid Valley |
| Land Ownership | BBB | OC–City lease | City & OC | Varies |
| Wetlands Present? | Possible | No | Possible | Possible |
| Impacts to Fisheries? | No | No | No | No |
| Impacts to Birds? | Moderate | High | Moderate | Moderate |
| Endangered Species Considerations? | Yes | Yes | Yes | Yes |

| | | | | |
|---|---|---|---|---|
| Cultural Resources? | Yes | No | Possible | Possible |
| Noise Impacts to Residences? | No | No | Possible | No |
| Visual Impacts? | No | No | Yes | No |
| Site Ranking per community | 1 | 1 | 4 | 5 |

Notes: BBB = Bristol Bay Borough
OC = Ounalashka Corporation

The difficulty in incorporating wind power with a diesel generation system lies in the fact that diesel turbines generally have a narrow operating range at peak efficiency. Operating the generators at other than peak efficiency also results in higher operation and maintenance costs and generator wear. Unless the WTG can generate enough power to allow the utility shut down a diesel generator, savings resulting from diesel displacement will generally be low. The best option is to install the largest turbine possible so that adequate power is generated to displace a turbine. The displacement can be raised by carefully managing the operation of both the WTG and diesel generators. More feasibly, wind power can be used to increase the capacity of the generating system rather than to displace fuel consumption.

Based on the information presented in this report, it is recommended that a wind monitoring station be set up at the Sewage Lagoon site in Naknek in order to verify the assumptions used in this analysis and to gather adequate data to conduct a more in depth analysis of the estimated power to be generated by a WTG at this site. It is also recommended that monitoring stations be set up at a minimum of two of the most feasible sites in Unalaska. Two anemometers should be placed on each tower. Anemometer height should be at the standard 33 feet (10m) and at the hub height of the proposed turbine.

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