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WIND POWER

OREGON STATE UNIVERSITY
Department of Atmospheric Sciences

REPORT NO. BPA 79-4
1979

OCTOBER 1979

NETWORK WIND POWER OVER THE
PACIFIC NORTHWEST

APPENDIX 1

WIND POWER SITE SURVEY REPORTS

AC 80-78 BPO 1310

prepared by

E. WENDELL HEWSON and ROBERT W. BAKER

PRINCIPAL INVESTIGATORS

Submitted to
BONNEVILLE POWER ADMINISTRATION
Portland, Oregon

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Submitted to
BONNEVILLE POWER ADMINISTRATION
Portland, Oregon

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Northwest Washington Wind Survey Field Trip Reports

NORTHWEST WASHINGTON WIND SURVEY FIELD TRIP REPORTS

6-8 March 1979

A wind survey field trip was made in the mountainous area of the Northwest Washington Coast on 6-8 March 1979 by OSU meteorologists John Wade and Bob Baker. The locations that were visited are shown in the site map, Figure 1. Station number 9, Mt. Octopus, was not surveyed but communications company personnel that frequently visit this area claim that the wind flow is strong, especially in the winter. Detailed topography maps showing the promising potential wind power sites are shown in Figures 2 and 3. Site photographs are given in Figures 4-13. Wind measurements were taken with the kite anemometer at Sekiu Mountain Lookout, Bahokus Peak, Striped Peak, and Ellis Mountain. These data are summarized in Table 1.

On the first day, 6 March, we drove from Corvallis to Neah Bay. We stopped along the Washington Coast at Kalalock, location 1 in Figure 1, and took photographs of the wind swept trees. Figure 8 is a picture of a well deformed Spruce that displays northwest wind flagging. The mean annual wind speed based on this external deformation is estimated at 6.2 m/s (13.9 mph). Ship data off the Central Washington Coast indicate mean annual wind speeds of 6.0 m/s (13.4 mph).

We arrived at Neah Bay late in the afternoon and met Jerry Lucas, a Makah tribal councilman. The weather was very poor with heavy rain and poor visibility. So plans were made to survey the Makah reservation the next day.

The first location visited on 7 March was Sekiu Mountain. The roads are in good condition and Sekiu Mountain and the adjacent ridges are well exposed as noted in Figures 2 and 4. Many well flagged trees were noted on the south and west side of the mountain (see Figure 4). The south-

southwest flagged trees indicate about 6.3 m/s (14.0 mph) mean annual wind speed. The wind measurements taken indicated a slight increase in the wind speed with height from the 65 to 350 ft. level (see Table 1). The wind flow below 65 ft. was too unsteady to measure on the road near the lookout. Turbulence intensity values varied between 0.08 and 0.11, and the wind direction changed 30 degrees between the 65 and 150 ft. level.

Wind measurements are taken once a day at Sekiu Mountain from June through September by the fire lookout. However, more detailed measurements are needed to better define the wind flow in this area. It is suggested that a wind-run anemometer be mounted on a well exposed 40 ft. mast near the lookout.

Next we met with Jerry Lucas and visited the Makah Air Force Station. We talked with the base commander, Major Freeman, about the wind energy assessment work in the BPA service area and the potential wind resource in northwest Washington. He escorted us up to Bahokus Peak. The peak is well exposed and has numerous poles and small towers along the ridge that runs east to west (see Figure 2). The trees are well flagged by south-southwest winds as noted in Figure 6. The estimated mean annual wind speed from the tree flagging is 6.2 m/s (13.9 mph). Long term wind records from Tatoosh Island nearby indicate a mean annual speed of 6.5 m/s (14.6 mph). Kite anemometer measurements were taken at the 50, 150, 250, and 350 ft. levels. There was little wind speed increase with height in the 20 mph south-southwest winds that were monitored.

Although there are many wood poles and a 120 ft. tower that will be installed soon at Bahokus Peak by the Navy, a better location to monitor the wind flow would be at Cheeka Peak, location 4 in Figure 2. This area is well exposed and has very good winds according to Jerry Lucas.

Unfortunately, we were unable to drive up to the new FAA facility there because the road was temporarily blocked in order to lay an underground utility cable. Coordination will be made with the FAA people to obtain permission to install a recording anemometer at their facility. It is suggested that an Aerovane sensor and a strip chart recorder be placed there.

After leaving the Makah reservation we drove east towards Port Angeles down Highway 112 and surveyed two points on Striped Peak, location 5 in Figure 3. The western most point was first visited where wind measurements were taken at the 50 and 150 ft. levels. This point is labeled Striped Peak West in Table 1. West winds were measured at 21 and 22 mph. The west wind flagged trees are shown in Figure 10 and indicated a mean annual wind speed of 6.0 m/s (13.4 mph).

Next the winds were measured close to the 95 ft. utility pole on the eastern end of Striped Peak (see Figure 9). The west winds measured at the Striped Peak East site noted in Table 1 averaged 19.7 mph at the 95 ft. level. Although the winds may be slightly lighter at this location than at the point further west, the existing facilities to install an anemometer on and house a wind-run recorder in make this location attractive. West wind tree deformation is apparent at this spot also as noted in Figure 5. The estimated mean annual wind speed is 5.5 m/s (12.3 mph). Coordination will be made with the owners of the facility on Striped Peak to install wind measuring equipment.

The last place visited for the day was the Port Angeles Airport, location 11 in Figure 3. A picture of a slightly flagged tree was taken in a well exposed field next to the airport runway. Mean annual wind speed recorded at the airport is 3.8 m/s (8.5 mph). A slightly

deformed northwest wind flagged tree agreed quite well with this speed (see Figure 13). The Griggs-Putnam Index predicted 3.6 m/s, Deformation Ratio 3.5 m/s and a Compression Ratio of 1.1 indicated 3.4 m/s for an average error of 8% for the three indices.

The next morning we drove to Mt. Pleasant, location 10 in Figure 3, but were unable to drive up to it because of a locked gate. However, the trees observed at the top of the 2700 ft. mountain did not appear well flagged.

We next took Highway 101 west of Port Angeles and proceeded to Snider Peak and Deadman Hill, location 6 in Figure 2. Unfortunately the road was blocked by wind fall. The ridge top area is very well exposed from Deadmans Hill east to Snider Peak and North Point and should be investigated when the road becomes passable.

After leaving the Snider Peak area we drove up to Ellis Mountain, location 7 in Figure 2. A strong northeast wind was measured at over 20 mph at all levels as noted in Table 1. There was little wind speed increase with height and turbulence intensity values varied between 0.04 and 0.10. The area is very well exposed and there are many communications facilities there. One that looks particularly attractive is the abandoned facility shown in Figure 7. The 60 ft. utility pole is well exposed to the northeast and southwest flow. It is recommended that a wind-run anemometer be mounted on this pole and the odometer be housed in the building. This small shelter does not have a door so one should be installed. Contact will be made with the owner of this facility to get permission to install wind equipment. The Noble Fir trees display slight northeast flagging. The estimated mean annual wind speed is 6.7 m/s (15.0 mph).

On the return trip we stopped by North Head, location 8 in Figure 1, and took numerous pictures of the wind deformed Spruce trees. Photographs of this flagging are shown in Figures 11 and 12. Wind data from this area indicate a mean annual wind speed of 7.0 m/s (15.6 mph) which agrees quite well with the deformed Spruce tree in Figure 11. These trees indicate a 7.4 m/s (16.6 mph) wind. The carpeted Spruce tree along the slope in Figure 12 resembles a bush as it is forced to grow along the ground by the persistent and strong winds. The mean annual wind speed along the slope appears to be in the 8-10 m/s (18-22 mph) range as indicated by the tree deformation. This undoubtedly is a very local acceleration phenomena.

Northwest Washington, being remote from electrical generating facilities and within 100 miles of the major load center in the Pacific Northwest appears to be a prime area for wind power development. A small 69/115 KV BPA transmission line runs from Port Angeles through Sappho to Forks and a Callam County PUD line runs from Sappho through Sekiu and out to Neah Bay.

Although the winds in northwest Washington appear to be significantly weaker during the summer, the strong winter and fall winds in this area will complement other locations we are now investigating where the strongest winds occur during the spring and summer. Table 2 presents the seasonal distribution of winds at three levels 150, 300, and 1000 meters (492, 984, and 3280 feet) of upper level winds measured by balloon tracking from Tatoosh Island and Quillayute. The strong east wind at the lower levels usually occurs during the winter when a cold core anticyclone positions itself over the Pacific Northwest. Wind power potential is significantly reduced in most areas of the BPA region. However in the west end of the Columbia Gorge and in Strait of Juan De Fuca strong northeast to east winds are experienced. These winds usually last for several days. This

easterly wind flow is quite shallow both in the Gorge and in the Straits. Northeast to east winds at Augspurger Mt. (877m) average 5-7 m/s, while the same winds at 1000m at Tatoosh/Quillayute average 3-8 m/s. At Crown Point (218m) easterly winds average 9-13 m/s while at Tatoosh/Quillayute at 150m and 300m they average 8-12 m/s.

In summary the trip proved very successful in locating many sites to install wind measuring equipment. A real time recording system should be installed at Cheeka Peak and wind-run units should be placed at Sekiu Mountain, Ellis Mountain, and Striped Peak. The Snider Peak area also looks promising but must be visited to locate the placement of a wind-run system. Also, another area that appears well exposed and windy according to forest service and communications company personnel is Mt. Octopus. Contact will be made with the State Department of Natural Resources to get permission to install a wind-run system there.

Table 1. Wind velocity profile measurements taken at several locations in northwest Washington. $\bar{V}$ is the mean wind speed in mph and I is the turbulence intensity.

Location (Elevation)	Date	Altitude (ft.)	65	150	250	350
		Time (PST)	0920-0925	0910-0915	0900-0905	0850-0855
Sekiu Mtn.	3/7/79	$\bar{V}$	19.4	20.3	19.9	21.5
Lookout		I	.09	.10	.08	.11
(1930')		Direction	300°	270°	270°	270°
		Altitude (ft.)	50	150	250	350
Bahokus Peak		Time (PST)	1145-1150	1155-1200	1205-1210	1215-1220
(1200')	3/7/79	$\bar{V}$	19.0	20.1	20.6	20.6
		I	.16	.13	.13	.10
		Direction	220°	220°	220°	220°
		Altitude (ft.)	50	150		
		Time (PST)	1630-1635	1640-1645		
Striped Peak		$\bar{V}$	21.1	22.2		
West	3/7/79	I	.10	.09		
(1000')		Direction	270°	270°		
		Altitude (ft.)	95	150		
		Time (PST)	1710-1715	1720-1725		
Striped Peak		$\bar{V}$	19.7	21.1		
East	3/7/79	I	.10	.11		
(930')		Direction	270°	270°		
		Altitude (ft.)	60	150	250	350
Ellis Mtn.		Time (PST)	1030-1035	1040-1045	1050-1055	1100-1105
(2600')	3/8/79	$\bar{V}$	22.5	23.4	23.6	22.9
		I	.07	.04	.10	.07
		Direction	040°	040°	040°	040°

Table 2. Upper air data for Tatoosh/Quillayute at three levels for direction (D) and speed (S) in m/s

LEVEL 150 METERS

SEASON/TIME	4AM	10AM	4PM	10PM	AVG
	D/S	D/S	D/S	D/S	D/S
Winter	E/9.7	E/8.8	ENE/9.3	SE/8.3	E/9.0
Spring	S/6.7	E/6.3	SSW/7.0	W/5.8	SSW/6.5
Summer	SSW/5.1	SSW/4.9	WSW/5.6	WSW/4.7	SW/5.1
Fall	E/8.0	E/8.2	E/7.5	E/7.0	E/7.7
Average Speed					7.1

LEVEL 300 METERS

SEASON/TIME	4AM	10AM	4PM	10PM	AVG
	D/S	D/S	D/S	D/S	D/S
Winter	S/10.3	SSE/9.6	E/10.1	SSW/8.8	S/9.7
Spring	SSW/7.3	E/6.5	W/7.4	WSW/6.3	SW/6.9
Summer	W/5.0	W/4.8	WNW/5.7	WNW/5.5	W/5.3
Fall	E/8.5	E/8.4	S/7.9	S/7.8	SE/8.2
Average Speed					7.5

LEVEL 1000 METERS

SEASON/TIME	4AM	10AM	4PM	10PM	AVG
	D/S	D/S	D/S	D/S	D/S
Winter	S/11.0	S/10.2	S/11.3	S/10.6	S/10.8
Spring	WSW/8.1	SSE/7.2	SSW/7.7	S/7.1	SSW/7.5
Summer	W/5.4	WNW/5.2	W/5.1	WNW/5.7	WNW/5.4
Fall	S/9.1	S/8.9	S/8.9	S/8.6	S/8.9
Average Speed					8.2

Figure 1. Wind survey locations (1 - Kalalock, 2 - Sekiu Mtn., 3 - Bahokus Peak, 4 - Cheeka Peak, 5 - Striped Peak, 6 - Snider Peak, 7 - Ellis Mtn., 8 - North Head, 9 - Mt. Octopus, 10 - Mt. Pleasant, 11 - Port Angeles Airport)

Figure 2. Wind power site survey areas (2 - Sekiu Mtn., 3 - Bahokus Peak, 4 - Cheeka Peak, 6 - Deadmann Hill and Snider Peak, 7 - Ellis Mtn.)

Figure 3. Wind power site survey areas (5 - Striped Peak, 10 - Mt. Pleasant, 11 - Port Angeles Airport)

Figure 4. Sekiu Mtn. Lookout

Figure 5. Wind deformed trees on Bahokus Peak

Figure 6. Wind deformed trees on Striped Peak East

Figure 7. Abandoned communications facility on Ellis Mtn.

Figure 8. Wind deformed tree at Kalalock

Figure 9. Communications facility at Striped Peak East

Figure 10. Wind deformed trees on Striped Peak West

Figure 11. Wind deformed Spruce trees
at North Head

Figure 12. Wind deformed Spruce tree at North Head

Figure 13. A slightly flagged Douglas-fir at the Port Angeles, Washington Airport.

NORTHWEST WASHINGTON WIND SURVEY FIELD TRIP

5-6 June 1979

A follow-up visit to Northwest Washington was made on 5-6 June by OSU personnel Robert Baker and Peter Maule. Three areas were surveyed that were not visited on the initial wind power prospecting trip made to this region on 6-8 March 1979. Reference "Northwest Washington Wind Survey Field Trip Report" that was sent to BPA on 3 April 1979. Cheeka Peak, the Snider Peak area, and the hills east of Queets were inspected for exposure and wind deformed vegetation, photographs were taken and wind profile measurements were made at each site. These sites are located on the map, Figure 1, along with the previously surveyed sites. This map and the site photographs are in the back of this report.

The FAA TACAN facility at Cheeka Peak is well exposed (see Figure 2). The area has been logged off for some 30 years and the planted trees have not survived due to the strong winds according to the Forest Service. East wind flagging was noticeable on most of the trees in this area, and south wind flagging was also very apparent as noted in Figures 3 and 4.

There is a well exposed landing about 250 yards south of the FAA building where an anemometer could be installed on a 40' mast. This region is shown in the photograph in Figure 5. It would be good to get real time data from this location so a strip chart recording system is suggested. There is A.C. power in the FAA facility and the technicians could service the recorder monthly. If a D.C. recording system is used it could also be checked at least monthly if not more often. Preliminary coordination has been made with the FAA people in Seattle for their personnel to monitor the wind equipment.

Kite anemometer measurements were taken under moderate west flow. The results are listed in Table 1. The wind speed change with height was negli-

Figure 1. Wind survey locations (1 - Kalalock, 2 - Sekiu Mtn., 3 - Bahokus Peak, 4 - Cheeka Peak, 5 - Striped Peak, 6 - Snider Peak, 7 - Ellis Mtn., 8 - North Head, 9 - Mt. Octopus, 10 - Mt. Pleasant, 11 - Port Angeles Airport, 12 - Queets Hills)

gible and the turbulence intensities were moderate.

Table 1. Kite anemometer data for Cheeka Peak on 5 June 1979 (speeds in mph)

Altitude (ft)	40	150	250	350
Time (PST)	1450-1455	1500-1505	1508-1513	1517-1522
Wind Direction	250-290	280	270	280
$\bar{v}$	20.6	20.5	19.7	20.4
I	.16	.20	.16	.16

After leaving the Neah Bay area we drove to Snider Peak and surveyed the ridge, the ridge top is heavily wooded with 50-150' trees. The entire ridge is very well exposed and south wind flagging is very noticeable in the trees along the ridge line as noted in Figures 6 and 7. The lookout east of Snider Peak is in a semi-logged off area and is very well exposed (see Figure 8). The lookout is abandoned and has been vandalized. There is room enough next to the lookout to install a 40 ft. mast. There is also a concrete pad with an 18" triangular tower mounting base next to the lookout. It is recommended that a wind-run anemometer be installed there. The wind deformed trees indicate a $7-8 \text{ m s}^{-1}$ mean annual wind speeds. There is the Olympic National Forest Snider Work Center at the base of the ridge. Perhaps one of the workers there could check the installation on a weekly basis. The lookout is at the 3300 ft. level and probably gets some snow and ice during the winter. It may be advisable to remove the unit in the late fall before the weather gets bad and then install it again in the spring.

Kite anemometer measurements taken at the lookout indicated a noticeable increase in the wind speed from the 40 to 250 ft. level. The results are listed in Table 2. Very smooth westerly flow was measured above the 150 ft. level.

Table 2. Kite anemometer measurements taken at the Snider Peak Lookout on 5 June 1979. (wind speeds are in mph)

Altitude (ft)	40	150	250	350
Time (PST)	1900-1905	1907-1912	1914-1919	1923-1928
Wind Direction	240-280	260	260	260
$\bar{v}$	19.6	21.8	26.1	25.6
I	.15	.09	.08	.04

The well exposed hills just east of Queets Washington were surveyed on 6 June. (The area is shown in Figure 9). There is a radio and TV transmitter station on one of the hills about 300 ft. above the town. This station is shown in Figures 10 and 11. Trees in the area display northwest wind flagging (see Figures 12 and 13). The area is mostly logged off and the ridges adjacent to the TV/radio station are well exposed and display numerous flagged trees. A wind-run anemometer could be placed next to the station on a 40' mast. The trees indicate a $5-6 \text{ m s}^{-1}$ annual mean wind speed near the station. The hills north and east of the station are better exposed and the trees indicate winds in the $5-7 \text{ m s}^{-1}$ range.

TALA measurements taken under northwest flow indicate a fairly turbulent wind at the radio/TV station. The readings are summarized in Table 3.

Table 3. TALA kite anemometer data for Queets Hill on 6 June 1979. (wind speeds in mph)

Altitude (ft.)	40	150	250	350
Time (PST)	0852-0857	0845-0850	0837-0842	0830-0835
Wind Direction	290	310	310	320
$\bar{v}$	15.5	16.0	14.1	15.9
I	.22	.29	.19	.20

Figure 2. Cheeka Peak FAA facility

Figure 3. East wind flagged Hemlocks and Pacific Silver Fir at Cheeka Peak.

Figure 4. South wind flagged Hemlock at Cheeka Peak.

Figure 5. Proposed landing to install an anemometer at Cheeka Peak.

Figure 6. Ridgeline east of Snider Peak. The lookout is on the logged-off hill in the left side of the photograph.

Figure 7. South wind flagged trees on Snider Peak ridge.

Figure 8. Abandoned lookout east of Snider Peak. South wind flagged trees are also evident.

Figure 9. Hills east of Queets Washington.

Figure 10. Radio/TV station east of Queets.

Figure 11. Proposed site east of Queets to install a 40' mast with anemometer.

Figure 12. Northwest wind flagged trees on the Queets hills.

Figure 13. Northwest wind flagged trees on the hills east of Queets.

Southern Oregon Coast Wind Survey Field Trip Reports

SOUTHERN OREGON COAST WIND POWER PROSPECTING
FIELD TRIP - 12-14 JUNE 1979

A site survey was made by OSU personnel John Wade, Ray Whitney, and Bob Baker along the southern Oregon coast on 12-14 June 1979. Two sites were looked at east and north of Florence and eight sites were visited in the Cape Blanco area. Most of the figures and tables of the site locations and wind data are attached in the back of this report.

The Siuslaw National Forest radio facility on Cummins Peak was visited on 12 June (see Figure 1, site A). A Windco wind charger is used to power the radios. Figure 2 is a photograph of this system. The charger is on a 70 ft. tower and is near tree top level to the south and is about 20-30 ft. above the trees to the north. Mr. Van Orden of the U.S. NFS accompanied us and said they have lost three blades due to high winds, so they cut each blade down by 6 inches and have not had any problems. The trees show very little flagging. The wind charger has kept the radio system charged for the past two years. Although the winds appear not to be persistent, they are strong enough when they do blow to keep at least a one week charge on the battery bank.

All of the ridges in eye sight of Cummins Ridge are tree covered as shown in Figure 3. A 100-150 ft. tower would be needed to get well exposed wind flow in this area. Mr. Van Orden had no objection to installing a wind-run anemometer just below the wind charger. Although the south wind exposure is not the best, wind data from this area would be helpful.

The next area visited was above Cape Perpetua where a well flagged (north wind) tree was photographed (see Figure 4). We met a technician from the Yaquina Cable TV Company and he said they had a translator station and tower in the approximate location of point B in Figure 1. However, a

four-wheel drive vehicle is needed to drive to their facility. This site will be surveyed at a later date.

On the return from Cape Blanco on 14 June the BPA facility at Goodwin Peak was visited. This is labeled Site C in Figure 1 and a photograph of the facility is shown in Figure 5. The BPA tower is about 50 ft. high. A wind-run anemometer should be mounted on a 10-15 ft. mast above the tower. The trees show little flagging but the peak is well exposed in all directions. This would be an interesting location to collect data from.

Unfortunately, the winds were very light at all three locations just described so TALA measurements were not taken.

After leaving the Florence area we drove south to Langlois Mountain, Site 8 in Figure 6. A cup and vane anemometer with a strip chart recorder was installed on a 25 ft. mast next to the BPA anemometer. A temporary wind-run unit was installed on an 18 ft. mast to use in the kite anemometer measurements. The anemometers are shown in Figure 20. The TALA unit was flown at four levels and the data are given in Table 1. The wind speed steadily increased with height under the moderate northwest flow up to the 250 ft. level. The turbulence intensity values were highest below the 150 ft. level. The Cape Blanco BPA anemometer recorded a 13 mph north wind for this period. The strip chart recorder at Langlois Mountain also recorded 13 mph winds.

Table 1. Kite anemometer data for Langlois Mountain on 12 June 1979
(wind speeds are in mph, I = Turbulence Intensity)

Altitude (ft)	50	150	250	350
Time (PDT)	1655-1700	1706-1711	1717-1722	1726-1731
$\bar{V}$	13.7	16.6	19.9	20.1
I	.25	.19	.08	.16
Direction	310°	310°	310°	310°

The following day wind profiles were taken at eight locations. These sites are shown in Figure 6. Photographs of the sites are contained in Figures 9-24.

Wind velocity profiles were taken on the hour from 1200-1600 PDT near the Cape Blanco BPA station, Site 1. The five profiles are tabulated in Table 2 along with the average of all of the profiles. The most notable increase in the wind speed under the moderate north flow was from the 50-150 ft. levels. The general increase above the 150 ft. level was slight. The power law, α , between the 50 and 150 ft. level averaged about 0.13. Also, the 50 ft. level experienced the most turbulence, $I = 0.138$, and relatively smooth flow was measured aloft.

The five minute Stewart anemometer averages taken off the 16 ft. mast were compared to the 150 ft. level winds at Site 1. The results indicated there was little correlation between the near ground wind speed changes over the TALA measurement period and the wind speed changes at the 150 ft. level. It appears that small scale eddy movement near the ground will prevent using wind-run anemometer measurements to determine short term wind speed changes as related to the change in the wind profile from 50-350 ft. Another method which is now being tested is to make two profiles at the four levels and average the data at each level to filter out the short term fluctuations.

The wind profiles taken at Sites 2-8 are compared to those taken at the base station, Site 1. The site profile data are given in Tables 3 and 4 and the comparisons in Table 5. A relative ranking is also given for each site compared to Site 1. The ratio V_n/V_1 is a comparison of the speeds at all four levels at each site to those at Site 1. Sites 2 and 3 south of the Cape Blanco BPA station had the strongest relative flow. The north winds measured at the Knapp Farm, Site 2, were stronger in the lower levels than those measured at the BPA station. The sharp cliff just north of Site 2 caused considerable acceleration of the flow. Turbulence intensity values varied from 0.12 at the 50 ft. level to 0.08 at the 350 ft. level. Site 3, the Wahl Farm, also appears to have very good winds. The wind profile at the

Cape Blanco BPA station was estimated. The general wind flow measured by the BPA anemometer decreased from an afternoon steady 16 mph to 12 mph at 1830 PDT, the time the Site 3 profile was taken. A factor of .75 was multiplied times the average Site 1 profile to obtain the estimated profile. Turbulence intensity values were quite high at the Wahl Farm and varied from 0.27 at 50 ft. to 0.12 at 350 ft. The wind flow at Sites 4, 6, and 8 was about 80% of that at Site 1. Site 4 had high turbulence intensity values at the 50 and 150 ft. levels as the average was 0.29 and 0.20 respectively. Moderate turbulence intensity values were measured at Sites 6 and 8. The wind flow measured at Sites 5 and 7 was very turbulent below the 200 ft. level and averaged about 70% of that measured at Site 1.

Figure 7 shows the hourly wind speed variations at Langlois Mountain and the Cape Blanco BPA station on 12-14 June. The wind speed traces tracked quite closely and showed a definite diurnal trend on the 12th and 13th. On the 14th south winds prevailed. The wind speed maximum occurred about two hours later at Langlois Mountain than at the Cape Blanco station on 13 June.

The Stewart anemometer data taken at the eight sites during the kite anemometer runs also shows a diurnal trend as noted in Figure 8. There was also amazingly close similarity in the wind-run five minute variations taken at the base station, Site 1, and the other sites. The 50 ft. level kite measurements at Site 1 also showed a gradual wind speed decrease but the 150, 250, and 350 ft. level readings did not.

To better define the wind flow in the Cape Blanco area wind-run units should be placed at the following sites: the Wahl Farm - the north exposure is fair and the south exposure is excellent; the area west of Langlois (Site 6) - the Knapps own much of this land and said they would be willing to monitor a wind station. If possible, the Langlois Mountain anemometer should be kept in service to correlate the wind flow in the lowlands and hill

area. It would be a good idea to install the MS 778 units at each location for the same time period for one month during the winter and summer to get comparisons under the prevailing south and north flow regimes.

Locked gates prevented getting to the Stone Butte Microwave, Site 9 in Figure 6. The ridge area from Stone Butte to Edson Butte is mostly tree covered but well exposed to north and south flow. The Edson Butte area will be visited at a later date.

Figure 1. Topography map showing Cummins Peak, A, approximate location of the Yaquina Cable TV Tower, B, and Goodwin Peak, C.

Figure 2. USFS wind charger at Cummins Peak.

Figure 3. Tree covered ridges northeast and east of Cummins Peak.

Figure 4. North wind flagged trees at Cape Perpetua.

Figure 5. BPA Goodwin Peak facility.

Figure 6. Topography map of the Cape Blanco area showing Sites 1-8 where wind measurements were taken. Sites 9 and 10 were not visited. the sites are as follows: 1 - Cape Blanco BPA, 2 - Knapp's Farm, 3 - Wahl's Farm, 4 - log pond, 5 - Cape Blanco Airport, 6 - Langlois, 7 - Lower Four Mile Road, 8 - Langlois Mtn., 9 - Stone Butte Micro-wave, 10 - Edson Butte Lookout.

Table 2. TALA II prototype wind profile measurements at the Cape Blanco BPA station, Site 1, taken on 13 June 1979 (wind speeds in mph, I = Turbulence Intensity, times are in PDT)

Level (ft)	<u>50</u>	<u>150</u>	<u>250</u>	<u>350</u>
Time	1227-1232	1219-1224	1210-1215	1200-1205
$\bar{V}$	23.9	26.9	28.0	28.3
DIR	315-345	310	340	340
I	.117	.064	.029	.022
Stewart	21.1	21.6	19.2	--
Time	1325-1330	1317-1322	1309-1314	1300-1305
$\bar{V}$	23.2	24.4	25.1	27.8
DIR	310-335	330	330	340
I	.125	.049	.033	.034
Stewart	18.7	20.2	19.9	20.2
Time	1426-1431	1418-1423	1410-1415	1400-1405
$\bar{V}$	23.2	27.9	24.4	24.8
DIR	315-335	330	330	340
I	.150	.047	.020	.012
Stewart	19.2	18.7	19.0	20.8
Time	1523-1528	1515-1520	1508-1513	1500-1505
$\bar{V}$	21.9	24.5	27.2	28.5
DIR	315-340	330	330	330
I	.158	.144	.038	.025
Stewart	17.8	15.8	15.4	19.4
Time	1625-1630	1617-1622	1607-1612	1600-1605
$\bar{V}$	21.0	26.5	26.7	26.7
DIR	330	330	330	335
I	.141	.064	.034	.022
Stewart	16.1	15.4	17.3	15.1

Average of the Five Profiles

	50	150	250	350
$\bar{V}$	22.6	26.0	26.3	27.2
I	1.38	.074	.031	.023

Table 3. TALA II kite anemometer measurements at Sites 3, 4, 6, and 7 (wind speeds are in mph, I = Turbulence Intensity) taken on 13 June 1979 in the Cape Blanco area.

Site #4. Log Pond (1200-1235 PDT 6/13/79)

Level (ft)	<u>50</u>	<u>150</u>	<u>250</u>	<u>350</u>
Time	1230-1235	1220-1225	1210-1215	1200-1205
$\bar{V}$	20.0	20.5	23.9	22.5
DIR	330-350	350	350	350
I	.290	.201	.122	.123
Stewart	16.6	13.9	15.8	13.2

Site #6. Langlois (1400-1432 PDT 6/13/79)

Level (ft)	<u>50</u>	<u>150</u>	<u>250</u>	<u>350</u>
Time	1427-1432	1417-1422	1409-1414	1400-1405
$\bar{V}$	19.1	20.2	18.0	20.0
DIR	320	340	340	335
I	.150	.166	.199	.145
Stewart	12.7	12.2	12.2	13.0

Site #7. Lower 4 mile road (1600-1640 PDT 6/13/79)

Level (ft)	<u>50</u>	<u>150</u>	<u>250</u>	<u>350</u>
Time	1635-1640	1625-1630	1610-1615	1600-1605
$\bar{V}$	13.8	17.1	20.5	20.7
DIR	330	330	330	330
I	.320	.203	.092	.091
Stewart	9.8	10.0	11.0	9.4

Site #3. Wahls Farm (1816-1844 6/13/79)

Level (ft)	<u>50</u>	<u>150</u>	<u>250</u>	<u>350</u>
Time	1839-1844	1832-1837	1824-1829	1815-1820
$\bar{V}$	15.1	15.6	18.6	21.1
DIR	340	340	340	340
I	.266	.181	.146	.115
Stewart	13.0	11.8	13.2	13.9

Table 4. TALA spring scale wind profile measurements at Sites 2, 5, and 8 taken on 13 June 1979 in the Cape Blanco area. (wind speeds are in mph, I = Turbulence Intensity)

Site 5. Cape Blanco Airport (1203-1236 PDT 6/13/79)

Level (ft)	<u>50</u>	<u>150</u>	<u>250</u>	<u>350</u>
Time	1231-1236	1222-1227	1213-1218	1203-1208
$\bar{V}$	17.4	17.9	20.0	23.2
DIR	310-340	320	330	340
I	.201	.212	.166	.117
Stewart	11.3	9.8	11.8	11.3

Site 8. Langlois Mountain (1337-1406 PDT 6/13/79)

Level (ft)	<u>50</u>	<u>150</u>	<u>250</u>	<u>350</u>
Time	1401-1406	1353-1358	1345-1350	1337-1342
$\bar{V}$	19.0	18.8	19.9	20.9
DIR	330-340	330	340	350
I	.143	.152	.121	.131
Stewart	16.1	15.1	15.1	18.5

Site 2. Knapp Farm (1500-1540 PDT 6/13/79)

Level (ft)	<u>50</u>	<u>150</u>	<u>250</u>	<u>350</u>
Time	1535-1540	1517-1522	1509-1514	1500-1505
$\bar{V}$	26.0	25.8	25.9	27.1
DIR	290-340	320	320	320
I	.123	.093	.103	.076
Stewart	17.5	18.2	17.5	17.8

Table 5. Comparison of the wind speeds (mph) at each site to that at the base station, Site 1, for the same time period. (13 June 1979)

Site No.	<u>50</u>	<u>150</u>	<u>250</u>	<u>350</u>	$\frac{V_n}{V_1}$	Relative Ranking
2	26.0	25.8	25.9	27.1	1.03	1
1	21.9	24.5	27.2	28.5		
3	15.1	15.6	18.6	21.1	.92	2
1 (estimated)	17.0	19.5	19.7	20.4		
4	20.0	20.5	23.9	22.5	.81	3
1	23.9	26.9	28.0	28.3		
5	17.4	17.9	20.0	23.2	.71	6
1	23.9	26.9	28.0	28.3		
6	19.1	20.2	18.0	20.0	.77	5
1	23.2	27.9	24.4	24.8		
7	13.8	17.1	20.5	20.7	.71	7
1	21.0	26.5	26.7	26.7		
8	19.0	18.8	19.9	20.9	.79	4
1	23.2	27.9	24.4	24.8

Figure 7. Wind speed data from the Cape Blanco BPA anemometer and the Langlois Mountain anemometer. Times are in PDT.

Figure 8. A comparison of low level data collected at the survey sites to wind data collected at base station Site 1 at Cape Blanco.

Figure 9. Headland of Cape Blanco.

Figure 10. North wind flagged trees on Knapp's Farm, Site 2.

Figure 11. Wahl's Farm, Site 3.

Figure 12. North wind flagged tree at Site 3.

Figure 13. Proposed anemometer location at Site 3 as shown by the arrow.

Figure 14. Looking south over the Wahl Farm, Site 3.

Figure 15. Photograph of Site 4.

Figure 16. Photograph of north wind flagged trees at Site 6.

Figure 17. Looking south from Site 6.

Figure 18. Looking south from Site 7.

Figure 19. Hills east of Cape Blanco showing Langlois Mountain (arrow) Site 8.

Figure 20. Anemometer set-up at Langlois Mountain, Site 8. The temporary strip chart recording system is at the left, and the wind-run anemometer used for TALA measurements is at the right.

Figure 21. Lowland area north of Langlois, Site 6.

Figure 22. Cape Blanco headland.

Figure 23. Stone Butte Microwave Tower noted by the arrow.

Figure 24. Edson Butte Lookout shown by the arrow.

CAPE BLANCO SITE INSTRUMENTATION

TRIP REPORT

21-22 August 1979

Wind-run anemometers (AO - PG systems) were installed near Langlois and on the headland of Cape Blanco. Max Holder from BPA and Bob Baker from OSU installed the wind systems on 30 ft masts. The site locations are shown in Figures 1 and 2. The unit near Langlois is on the Knapp Ranch and was placed in a well exposed area near the beach. A barbed-wire fence was put up around the system to keep the cattle out. Mr. Knapp said he would check the unit weekly. The kite anemometer was flown and measured south winds of 13.8 mph at the 40 ft level and 14.0 mph at the 200 ft level. The turbulence intensities measured were 0.21 and 0.13 respectively. The winds for the same time period at Cape Blanco measured by the 40 ft level anemometer were out of the south at 19 mph. The resulting ratio of the 40 ft level winds at the two locations was 0.73.

On 22 August a wind-run unit was installed on the Wahl Ranch about 3 miles southeast of the BPA anemometer at the Cape. The unit is on a well exposed grass-covered bench about .2 miles from the ocean, as shown in Figure 1. Mrs. Wahl accompanied us and said she would check the system weekly. A barbed-wire fence was installed around the tower. Kite anemometer measurements were taken at the 40 and 200 ft levels under moderate south winds. The mean wind speed at the 40 ft level was 16 mph while that at the 200 ft level was 16.5 mph. The turbulence intensity values were 0.09 and 0.08 respectively. The BPA anemometer at Cape Blanco recorded a south wind of 17.5 mph for the same period. The ratio of the Wahl and Cape Blanco speed measurements was .91.

Wind speed profiles were also taken next to the BPA anemometer at Cape Blanco. Measurements were taken for 5 minutes with the hand-held TALA unit at the 40, 200 and 350 ft levels. Two profiles were taken and the readings were averaged. These data are summarized in Table 1. The south flow measured was very smooth at all levels as noted by the low turbulence intensity values. The kite fluctuated very little in both speed and direction. The weather was clear and warm and the characteristics of the south flow measured on this day

may not represent the turbulence and wind shear experienced under more typical storm conditions. There was a gradual wind speed increase with height and the wind direction changed slightly to a more southwest orientation at the 350 ft level. The TALA unit was in good agreement with the tower anemometer being within $\pm 4\%$ at the 40 ft level as noted in Table 2.

Table 1. Wind profile data taken at the Cape Blanco BPA station on 22 August 1979. Wind speeds are in mph and I is Turbulence Intensity.

Time (PST)		Altitude (ft)		
		40	200	350
1033-1119	$\bar{V}$	18.5	18.8	19.8
	I	.05	.03	.04
	Direction	180°	185°	190°

Table 2. Comparison of the hand-held TALA anemometer five minute average speed to the recording anemometer at the BPA wind station at Cape Blanco, 22 August 1979.

Time (PST)	Wind Speed (mph)		Percent Error
	<u>BPA Anem.</u>	<u>TALA</u>	
1033-1038	19.5	19.3	-1.0
1100-1105	17.0	17.6	+3.5

Figure 1. Newly installed wind-run anemometer units at site 2, the Wahl Ranch and at site 3, the Knapp Ranch. Site 1 is the Cape Blanco BPA site and site 4 is the Langlois Mountain anemometer location.

Figure 2. Cape Blanco area anemometer sites: 1 - Cape Blanco BPA,
2 - Wahl Ranch, 3 - Knapp Ranch, 4 - Langlois Mountain.

Central Columbia River Gorge Wind Power Prospecting Field Trip

CENTRAL COLUMBIA RIVER GORGE

Wind Power Prospecting Field Trip

31 May - 5 June 1979

A wind power prospecting field survey was made on 31 May and 1 June 1979 in the central part of the Columbia River Gorge by Robert Baker and Ray Whitney of O.S.U. A follow-up visit west of Hood River was made by John Wade and Ray Whitney on 5 June. The region covered is shown on the map in Figure 1 with all the sites noted.

The microwave tower west of Augspurger Mountain and north of Beacon Rock (site 1) is well exposed in all directions as noted in Figure 2. The trees in the area are 30-50 feet high. The tower is about 100 feet tall and has four round dishes on top. The blockhouse at the base of the tower is not completed and appears to be under construction. There is also a large square tower belonging to Pacific Northwest Bell about .25 miles north of the microwave tower. This tower is not as well exposed and has four large square dishes on top.

The trees in this area show some flagging which is mostly due to the east wind. The mean annual wind speed is estimated at 6 m s^{-1} . Some of the trees had very stubby branches like those at Crown Point which probably indicates limb breakage due to ice loading. The west winds at this 3200 foot site are probably fair and the east winds are moderate to strong. It is recommended that a wind-run anemometer be put about 70 feet up on the microwave tower to record the flow.

An east wind was measured by the TALA kite anemometer near the microwave tower. The flow was moderately turbulent and varied from 6.8 m s^{-1} at the 15 m level to 9.2 m s^{-1} at the 105 m level, as noted in Table 1.

Table 1: TALA kite measurements at Site 1

31 May 1979

0846 - 0914 PST

(wind speed is in m s^{-1})

Altitude (m)	15	45	75	105
$\bar{V}$	6.8	6.9	5.9	9.2
I	.14	.16	.16	.15
Direction	090°	090°	090°	090°

Field Trip - Central Columbia River Gorge

We next drove west of site 1 to a well exposed area, labeled site 1A in Figure 1, next to the BPA transmission lines and noted east wind flagged trees (see Figure 3). The winds were blowing about the same as those measured at site 1. There are many well exposed ridges running north/south in the area as noted in Figure 4.

After leaving the Beacon Rock area we drove up to Red Mountain but were unable to make it all the way up due to snow at the 4300 ft. level. There was no noticeable flagging in the trees on the sides of the mountain, but there probably are deformed trees at the top. The conical mountain is shown in the background in Figure 5.

From Red Mountain we drove up the west side of the ridge about 5 miles northwest of Augspurger Mountain and noted many well flagged Douglas Firs at the top of the ridge (see Figures 6a-c). Photographs taken at sites 3, 4, and 5 indicate strong west wind flagging. The mean annual wind speed in this area is estimated at $5-7 \text{ m s}^{-1}$.

A view of Augspurger Mountain, site 6 in Figure 1, from the north is shown in Figure 7. The wind velocity measured at the 21 m level on the Augspurger Mountain tower from 0900 - 1600 PST averaged $4.5 - 5.5 \text{ m s}^{-1}$ from 070 degrees.

Next we drove up to Peterson Ridge and Flattop Mountain about 20 miles north of Augspurger Mountain. The west wind flagged trees on Peterson Ridge are shown in Figure 8 and those on Flattop Mountain in Figure 9. The Flattop Mountain Lookout is not well exposed except to the east and north (see Figure 10). The trees indicate that the mean annual wind speed in this area is $6-7 \text{ m s}^{-1}$.

Except for the microwave facility west of Augspurger, site 1, the rest of the area surveyed north of the Columbia River was heavily forested with 50-100 ft. trees. A few of the areas were logged off, but there were no well exposed ridge top areas where an anemometer could be installed. It will be difficult to get good wind measurements north of Augspurger due to the high tree canopy unless a 100-150 ft. tower is installed. A well exposed logged-off area may be located to install a portable 40-ft. mast with further surveying. A possible area would be Peterson Ridge. However, such a monitoring station could only give reliable data during the accessible months, but short term data would be valuable in assessing the extent of the winds north of Augspurger Mountain.

Figure 1. Topography map of the central part of the Columbia River Gorge showing the wind power site survey areas. (1: Beacon Rock Microwave; 1A: exposed ridge southwest of site 1; 2: Red Mountain; 3, 4 and 5: areas investigated near Grassy Knoll; 6: Augspurger Mountain; 7: Peterson Ridge; 8: Flattop Mountain; 9: Hood River Mountain Microwave; 10: area west of Bald Butte next to BPA transmission lines; 11: Bald Butte; 12: Springhill Fish Hatchery; 13: Blue Ridge; 14: Blowdown Ridge; 15: Mt. Defiance; 16: Mt. Talapus)

Field Trip - Central Columbia River Gorge

On 1 June, Hood River Mountain was surveyed. The microwave station owned by Pacific Power and Light* was visited on the north end of Hood River Mountain, site 9 in Figure 1. There is a relatively well exposed 50 ft tower where an anemometer could be mounted on the north side. This tower is shown in Figure 15. Pacific Northwest Bell also has a facility there but it is not as well exposed. The trees show very good flagging due to west wind, as noted in Figures 11 and 12. The mean annual wind speed is estimated at $7 - 8 \text{ m s}^{-1}$. There is also a well exposed field just south of the Bell facility where a 40 ft mast could be installed if the PP&L tower is not used.

After leaving the north end of Hood River Mountain we drove to a logged-off area 10 miles south of site 9. This area is on top of the ridge next to the BPA transmission lines and is noted in site 10, Figure 1. The Douglas-fir trees are well flagged as shown in Figure 13. TALA kite measurements at the 45 m level indicated an east/southeast wind of 6.5 m s^{-1} . Due to light and gusty winds below the 100 ft level, measurements were not taken. The tree flagging indicates a mean annual wind speed in the $6 - 7 \text{ m s}^{-1}$ range.

The next stop was at Bald Butte, site 11 in Figure 1. West wind flagging was very apparent in the trees (see Figures 14a and b). Kite anemometer measurements taken at the 15 and 45 m level indicated 7.1 and 8.0 m s^{-1} winds, respectively (see Table 2). The wind velocity at the 45 m level on the Sevenmile Hill tower for the same time period was 140° at 3.0 m s^{-1} . That measured by the Augspurger Mountain anemometer was $4.5 - 5.5 \text{ m s}^{-1}$ at 070° . The Bald Butte area is very well exposed. Unfortunately the lookout tower has been removed, so a portable 40 ft mast should be installed to correlate the flow with that at Augspurger Mtn. and Sevenmile Hill during the summer and fall. The system should be removed before poor weather sets in. The tree flagging indicates the mean annual winds speed in the $7 - 8 \text{ m s}^{-1}$ range.

Table 2. TALA kite measurements at Bald Butte,
Site 11, 1 June 1979, 1003 - 1015 PST.
(Wind speeds are in m s^{-1} .)

Altitude (m)	15	45
$\bar{V}$	7.1	8.0
I	.27	.15
Direction	100°	110°

* It was recently discovered that this microwave station is actually owned by the Union Pacific Railroad.

Field Trip - Central Columbia River Gorge

On June 5, 1979, Ray Whitney and John Wade site-surveyed the ridge areas west of Hood River Valley. This region is shown in Figure 1 and also in the photograph in Figure 15. Mt. Defiance is the tallest point. The first stop was at the Springhill Fish Hatchery where a Stewart anemometer was installed (site 12 in Figure 1). Next, the Parkdale Ranger Station, was visited to get maps and permission to set up an anemometer at Bald Butte. Permission was granted.

The first area visited was Blue Ridge. Blue Ridge is about 3600 ft high and is heavily covered with second growth Douglas-fir. The very tops of the 60 ft trees were west wind flagged. However, there were no well exposed locations to put up anemometers (see Figure 16). The tree flagging indicates mean annual winds in the $5 - 6 \text{ m s}^{-1}$ range.

The next area visited was Blowdown Ridge, Site 14 in Figure 1. We tried to get on Blowdown Ridge from three different roads; all were blocked or locked because they allow access to the Bull Run Water Shed. Blowdown Ridge appears to be well exposed to the wind but again covered with trees (see Figure 17).

Next, Mt. Defiance was visited. This is site 15 in Figure 1. Mt. Defiance had snow in the shady areas near the top so the last .5 mi had to be walked. The Noble Fir trees were flagged by west northwest winds and appeared to be damaged by ice and severe wind (see Figure 18). The trees indicate moderate to strong wind flagging (an annual mean speed of $7 - 9 \text{ m/s}$). Figure 19 shows the large microwave tower at this site. We met a technician there who told us that access to areas within the Bull Run watershed required permission and a key from the Springdale Forest Service Office. From Mt. Defiance we drove past Rainy Lake to Black Lake which was as far as we could go in this survey.

The main conclusion we arrived at was that access in this area is difficult. Trees would have to be cleared at all locations visited just to get good anemometer data. One of the sites not visited that is within Bull Run is Mt. Talapus, site 15 in Figure 1. Lionell Mitchell, who maintains three Winco wind chargers for the MHNF, says Mt. Talapus has good east winds in the winter but poor summer winds. He said the site also has problems with ice.

Figure 2.

Microwave tower
north of Beacon
Rock (site 1) is
noted by the arrow.

Figure 3.

East wind flagged
trees southeast of
site 1.

Figure 4.

Well exposed
ridges near site 1.

Figure 5.
Red Mountain
in background.

Figure 6a.
West wind flagged
trees at site 5.

Figure 6b.
West and east wind
flagged trees at site 6.

Figure 6c.
West flagged
trees at site 7.

Figure 7.
Photograph of
Augsburger Mountain
from the north.

Figure 8.
West wind flagged
trees at Peterson Ridge.

Figure 9.
West wind flagged
trees at Flattop
Mountain.

Figure 10.
Flattop Mountain
Lookout.

Figure 11. UPRR tower on Hood River Mountain. The arrow points to a possible location to install a wind-run anemometer, about 6 feet away from the support structure.

Figure 12. West wind flagged trees on Hood River Mountain.

Figure 13. West wind flagged trees at site 10.

Figure 14a. West wind flagged trees at site 11
(Bald Butte).

Figure 14b. West wind flagged trees at site 10 (Bald Butte).

Figure 15. Photograph of the ridges west of Hood River Valley.
Mt. Defiance is the highest point in the background.

Figure 16. West wind flagged trees on Blue Ridge.

Figure 17. Photograph of Blowdown Ridge.

Figure 18. West wind flagged trees on Mt. Defiance.

Figure 19. Microwave tower on Mt. Defiance.

Columbia Hills Wind Power Prospecting Area Survey

COLUMBIA HILLS WIND POWER PROSPECTING

AREA SURVEY

27 - 29 June 1979

Wind measurements were taken in an area of approximately 24 square miles (4 mi x 6 mi) over the Columbia Hills north of The Dalles, Oregon, on 27 and 28 June. On 29 June wind measurements were taken at Juniper Point. These areas are shown on the topographic map in Figure 1. West winds prevailed for the entire three days being in the 10 - 15 mph range the first day and increasing to 25 - 50 mph on the 29th. Details of the daily flow regimes are given in the rest of this text and are graphically depicted in Figure 2.

The wind flow was measured by the TALA kite anemometer at nine locations in The Dalles area on 27 and 28 June. These sites are noted on the topographic map in Figure 3. A recording anemometer was installed at the start of the survey on a 25 ft mast at site 1, about 3 miles southwest of KCIV. This knoll is well exposed and is the same location that TALA measurements were made on 13 October 1977 and reported in BPA Report No. 77-2, January 1979. Anemometer records from KCIV and the Dallesport Airport were also gathered to use as base station measurements. Hourly wind data from these three stations plus hourly data from Juniper Point are given in Figure 2. Additional photographs of some of these sites are given in figures 4 - 8 in the back of this report.

On 27 June the west wind flow was shallow and quite variable in The Dalles area. Moderate west winds were recorded on the floor of the Gorge from sites 5, 6 and Dallesport. The west winds decreased with elevation and were generally less than 10 mph at sites 1 and 2 on top of the Columbia Hills. TALA measurements were taken at sites 5 and 6 on the afternoon of the 27th. The data are summarized in Table 1. Two profiles were taken at each site and the readings at the 50, 150, 250, and 350 ft levels were averaged.

Figure 1. The Dalles and Juniper Point wind power survey sites (Site 2 is KCIV, site 9 is Murdock, site 10 is the Dallesport Airport, site 11 is Juniper Pt., and site 12 is the Hctor Farm).

FIGURE 2. Hourly wind speed plots for KCIV, site 1, the Dallesport Airport, and Juniper Pt. for 26-29 June 1979.

Table 1. Wind profile measurements taken at sites 5 and 6 on 27 June 1979 (wind speeds are in mph, I = Turbulence Intensity)

Site 5 (1543-1638 PST)	Altitude (ft)			
	50	150	250	350
$\bar{V}$	14.5	16.2	16.1	16.7
I	.07	.10	.09	.07
Direction	250 ⁰	250 ⁰	250 ⁰	250 ⁰
Site 6 (1548-1639 PST)				
	50	150	250	350
$\bar{V}$	15.3	16.8	17.1	16.9
I	.14	.11	.10	.07
Direction	290	290	290	290

Moderate west winds were measured and were slightly stronger at site 6 than at site 5. Turbulence intensity values were not high. Winds measured at the Dallesport Airport by the 15 ft high anemometer were northwest at 15 mph during the kite measurements.

On the 28th the west wind flow deepened during the early morning hours and was felt at KCIV and at site 1, as noted in Figure 2. The west winds probably decreased to less than 10 mph at the Dallesport Airport during this time due to the low level inversion that formed under clear skies. TALA wind profile measurements were taken at KCIV almost hourly from 0800 - 1400 PST. These data are shown in Table 2 and indicate a general increase in wind speed with height. The kite was flown about 200 ft west of the KCIV anemometer and recorded higher winds than the 45 ft sensor. Wind speed changes were most noticeable in the lowest 150 ft as these differences varied from .4 - 5.5 mph from the 50 - 150 ft level. The average shear from the six profiles indicated a 2.8 mph difference. The corresponding α values for a .4 - 5.5 mph shear are 0.02 - 0.32 and the average value was .17.

In the morning of 28 June three TALA recording units were flown at KCIV at the 150, 250 and 350 ft levels while a profile was taken by the hand-held spring scale unit for five minute intervals at these levels, plus the 50 and 100 ft level. Two profiles were taken and compared to the stationary TALA units. These data are summarized in Table 3.

Table 2. Kite anemometer profiles taken at KCIV on 28 June 1978 indicating wind speed (mph) and turbulence intensity values. The KCIV anemometer speed at 45 ft is noted by the asterick (*).

<u>Time (PST)</u>	<u>50</u>	<u>100</u>	<u>150</u>	<u>250</u>	<u>350</u>	<u>Mean</u> <u>Direction</u>
0836-0914	14.9/.17 13.5*	17.6/.07	17.9/.09	18.0/.05	18.5/.05	280°
0922-0956	13.2/.18 11.0*	15.0/.11	18.7/.07	20.7/.04	19.6/.03	280°
1100-1127	12.7/.14 11.0*		16.7/.06	17.5/.05	20.2/.03	290°
1200-1229	13.8/.07 12.0*		15.1/.09	16.5/.05	15.8/.05	280°
1300-1329	13.5/.14 11.0*		15.9/.09	16.4/.09	17.7/.08	280°
1412-1439	15.9/.09 12.0*		16.3/.09	18.6/.03	18.5/.05	280°
<u>Average of the Six Profiles</u>						
	<u>50</u>	<u>150</u>	<u>250</u>	<u>350</u>	<u>Mean</u> <u>Direction</u>	
	14.0/.13	16.8/.08	18.0/.05	18.4/.05	280°	
	11.8*					

The hand-held 5 minute profiles compared quite closely with the stationary TALA units. The agreement with the average of the two profiles was within 1 mph. It appears that taking two consecutive profiles with one kite anemometer is a reasonable method of approximating the true wind profile.

After this experiment was completed wind profile measurements were taken at sites 1, 3, 4, 5, and 7 while hourly kite profile measurements were made at the base station, KCIV. The wind profile at KCIV was estimated when the profile was taken at site 8 at 1730 PST. The wind speed recorded by the KCIV anemometer at 1730 PST was 15 mph. The wind speed recorded by the KCIV anemometer at 1400 PST when the last wind profile was taken there was 12 mph. Therefore, a multiplication factor of 15/12 or 1.25 was used to correct the 1400 PST profile speed observations to the estimated 1730 PST profile.

Table 3. Hand-held spring scale profiles compared to stationary TALA units at KCIV on 28 June 1979. Wind speed (mph) and Turbulence Intensity values are given.

0830-0913 PST:	Altitude (ft)			
	<u>50</u>	<u>150</u>	<u>250</u>	<u>350</u>
Hand-held Spring Scale	14.9/.17	17.9/.09	18.0/.05	18.5/.05
TALA II Prototype		17.6/.06		
TALA II			18.6/.03	
TALA 151				19.5/.03
0922-0956 PST:	Altitude (ft)			
	<u>50</u>	<u>150</u>	<u>250</u>	<u>350</u>
Hand-held Spring Scale	13.2/.18	18.7/.07	20.7/.04	19.6/.03
TALA II Prototype		17.4/.04		
TALA II			20.2/.02	
TALA 151				20.5/.03
<u>Average of the two Profiles</u>				
	<u>50</u>	<u>150</u>	<u>250</u>	<u>350</u>
Hand-held Spring Scale	14.0/.18	18.3/.08	19.3/.05	19.1/.04
Recording TALA's		17.5/.05	19.4/.03	20.0/.03

The results of this site survey are given in Table 4. The overall strength of the wind speed over the entire profile was higher at all but one of the sites compared to KCIV as noted by the ratio V_s/V_{KCIV} . The overall wind speed measured at site 1 was about 7% higher than that measured at KCIV. The most notable difference was at the 50 ft level where a 2.8 mph difference was measured. TALA measurements at site 3 along the ridge southeast of KCIV indicated about a 6% difference in the overall wind speed. At this site a significant speed difference from KCIV occurred at the 350 ft level where a 3.6 mph difference was measured. The wind profile taken at site 7, about .5 mile south of KCIV, indicated about 12% stronger winds than those measured at KCIV. Higher winds were measured at the 50, 150, and 250 ft levels, and the most significant departure was a 4.9 mph difference measured at the 50 ft level. The wind flow measured at site 4, a well exposed ridgeline about

Table 4. Comparisons of the wind speed (mph) and turbulence intensity measurements at six sites to those at KCIV for 28 June 1979.

Site	Time (PST)	Mean Dir.	Altitude (ft)				Ratio V_s/V_{kciv}
			50	150	250	350	
1	1100-1158	290 ⁰	15.5/.11	16.1/.11	19.1/.04	20.3/.02	1.07
KCIV	1100-1158	290 ⁰	12.7/.14	16.7/.06	17.5/.05	20.2/.03	
3	1300-1401	280 ⁰	14.2/.08	14.7/.10	16.8/.08	19.4/.09	1.06
KCIV	1300-1401	290 ⁰	13.8/.08	15.1/.09	16.5/.05	15.8/.07	
4	1301-1355	280 ⁰	14.8/.19	11.6/.28	12.4/.24	8.0 (est)	.77
KCIV	1301-1355	280 ⁰	13.8/.08	15.1/.09	16.5/.05	15.8/.07	
5	1431-1534	290 ⁰	23.3/.12	20.4/.13	20.6/.10	19.6/.12	1.22
KCIC	1431-1534	280 ⁰	15.9/.19	16.3/.09	18.6/.03	18.5/.05	
7	1108-1209	290 ⁰	17.6/.11	17.9/.10	19.8/.09	19.7/.07	1.14
KCIV	1108-1309	290 ⁰	12.7/.14	16.7/.06	17.5/.05	20.2/.03	
8	1653-1733	300 ⁰	38.1/.19	41.2/.07	43.7/.03	45.4/.04	1.95
KCIV*	1653-1733	280 ⁰	19.8	20.4	23.2	23.1	

* The KCIV profile was estimated

2 miles southeast of KCIV was much lighter than that measured at KCIV. The west winds were very gusty and decreased with height. The kite anemometer could not be flown at the 350 ft level due to the light and turbulent flow. The wind speed at this level was estimated at 8 mph. The ratio of the wind speeds at this site to those at KCIV was .77.

The overall strength of the wind increased further down the slope. Wind speeds at site 5 were 1.22 times as high as those measured at KCIV. The differences ranged from 7.4 mph to the 50 ft level to a 1.1 mph difference at the 350 ft level. The west wind measured at site 8 on the floor of the valley near the Columbia River was almost twice as strong as that estimated at KCIV for all four levels.

After leaving the Smith Ranch, site 8, a wind profile was taken at Murdock, site 9 in Figure 3. This is a proposed site for a small WTG unit. The wind flow was measured at the 100 ft level and the data are shown in

Table 5. The kite broke twice at the 50 ft level due to turbulent winds with gusts over 50 mph, so measurements were not made.

Table 5. Wind profile measurements taken at Murdock on 28 June 1979.

<u>Altitude</u>	<u>Time (PST)</u>	<u>Direction</u>	<u>Speed (mph)</u>	<u>Turbulence Intensity</u>
100 ft	1923-26	320 ⁰	42.9	.09

Although the results of this survey on 28 June indicated stronger flow on the valley floor than at KCIV, more kite anemometer measurements should be made to determine spatial variations on a seasonal basis. Previous comparison of the winds at KCIV to those at the Dallesport Airport indicated stronger flow at KCIV, especially during the winter. (Reference BPA Report 77-2) The winds at Dallesport and KCIV are fairly close in the summer. However, the valley land just north of the Dallesport Airport does experience much stronger west winds than those measured at the more sheltered airport. In fact, the difference measured on 28 June between the airport and site 8 was about a factor of 2! It could be that summer west winds in this well exposed area of the valley are stronger than the flow higher up on the ridge. Wind-run anemometers should be installed at sites 8, 5, and 1 to verify this. Seasonal data collection with the MS 778 unit at these sites is also suggested. Site 3 should also be instrumented since it is easily accessible and there is a Washington State Patrol communications station there with a 100 ft tower.

On 29 June wind measurements were taken at Juniper Point under very strong west winds. The 50 mph plus winds proved very difficult to work in as two people were needed to operate the TALA II and TALA II Prototype equipment. The line must be yarded in by hand! Wind measurements were taken at the 200 and 300 ft levels next to the 100 ft tower that is instrumented at the 33 and 100 ft levels. The wind profile data are contained in Table 6 and indicate little change of wind speed with height and very smooth flow above the 100 ft level.

At times the wind speeds exceeded the upper limit of the recorders 25 m s^{-1} (55 mph) so the 200 and 300 ft readings may be in error slightly. One kite also broke during the testing. Wind measurements taken by the TALA II Prototype next to the 100 ft level anemometer read about 5% lower than the

tower. An adjustment was made to the TALA readings at the 200 and 300 ft levels given in Table 6.

Table 6. Wind profile measurements taken at Juniper Point 29 June 1979, 0930-0957 PST. (Wind speeds are in mph, I = Turbulence Intensity).

	Altitude (ft)			
	33	100	200	300
$\bar{V}$	45.0 ¹	50.5 ¹	51.0	49.9
I	--	.06	.03	.02
Direction	--	290 ⁰	300 ⁰	310 ⁰

¹ The wind speed was measured by the tower anemometer.

Due to the difficulty in operating the TALA equipment in such strong winds at Juniper Point, further measurements were not taken. Wind profile measurements were taken though under 40 mph west flow at the Hocter Farm (site 12) and at Murdock (site 9), the two prime sites for small wind turbines. The profile data are listed in Table 7. The winds were moderately turbulent at both locations, both in speed and direction. There was also a noticeable wind speed increase with height from the 50 to 100 ft levels at both sites.

Table 7. Wind profile data taken at the Hocter Farm and Murdock on 29 June 1979. (Wind speeds are in mph and I = Turbulence Intensity.)

Hocter Farm (1155-1208 PST)			
Altitude	$\bar{V}$	I	Direction
50 ft	40.5	.10	240-300 ⁰
100 ft	46.7	.12	260-290 ⁰

Murdock (1320-1334 PST)			
Altitude	$\bar{V}$	I	Direction
50 ft	37.8	.18	260-300 ⁰
100 ft	43.9	.11	260-290 ⁰

Figure 4.

Flagged trees
west of site 1
(ref. Fig. 3)

Figure 5.

Base station
anemometer at
site 1.

Figure 6.

Abandoned
facility at
site 1.

Figure 7. Photographs of the KCIV area taken from site 4, showing four wind profile measurement sites noted in Figure 3.

Figure 8. Photograph of the KCIV area showing sites 3 & 4 (reference Figure 3).

Goodnoe Hills Wind Profile Survey

GOODNOE HILLS WIND PROFILE SURVEY

6 JUNE 1979

Wind profile measurements were taken with the TALA kite anemometer at three locations near the Goodnoe Hills anemometer on 6 June. The measurement sites are shown in Figure 1. Site 1 is the proposed WTG site and site 2 is .5 miles west of site 1 and site 3 is .8 miles east of site 1. Moderate west winds were measured at all three sites as noted in Table 1. The wind velocity recorded by the Goodnoe Hills anemometer, 45 feet above the ground, is shown in Figure 2 and indicates an increase in the wind speed during the measurement period. The mean wind speed increased from 20 mph when measurements were taken at site 1 to 28 mph when site 3 was surveyed. While five minute wind velocity measurements were taken at the four levels, the wind speed was recorded by a wind-run anemometer on a 16 ft. mast to note any wind speed changes with time. The TALA data were adjusted to compensate for temporal speed fluctuations.

The TALA data are given in Table 1. There was an increase in wind speed with height measured at all sites and wind speed increases were about 5 mph between the 50 and 350 ft. level. The turbulence intensity values were moderate and remained fairly constant at all four levels. The wind direction measured by the Goodnoe Hills anemometer was more northwesterly than that measured by the TALA anemometer at all three sites. The rapid drop off in topography just south of the Goodnoe Hills anemometer undoubtedly influences the wind flow to spill down the slope and thus veer more to the south than further north on the ridge.

In assessing the relative strength of the wind flow over this small area the wind data in Table 1 indicated the strongest overall winds were measured at sites 3 and 1. But when considering the temporal change in the winds measured by the Goodnoe Hills anemometer, from the time site 1 was measured to when site 3 was measured, it appears that the site 1 wind flow may be about 30% higher than that measured at site 3 and about 40% higher than that measured at site 2. Further surveys will be made to determine the spatial variations in this area.

Table 1. Wind profile measurement data taken at three locations in the Goodnoe Hills area on 6 June 1979. Wind speed (mph) and turbulence intensity (I) data are given for the four levels.

	Altitude (ft)				Goodnoe Hills $\bar{V}$
	50	150	250	350	
<u>Site 1</u>					
(0925-0958 PST)					
$\bar{V}$	24.8	26.7	29.8	30.0	20.0
I	.20	.14	.12	.18	
Direction	230-260 ⁰	240-250 ⁰	260 ⁰	250 ⁰	
<u>Site 2</u>					
(1030-1100 PST)					
$\bar{V}$	20.6	21.5	24.3	25.7	24.0
I	.19	.14	.17	.16	
Direction	230-280 ⁰	270 ⁰	260 ⁰	260 ⁰	
<u>Site 3</u>					
(1132-1201 PST)					
$\bar{V}$	25.8	25.9	28.3	31.6	28.0
I	.16	.17	.14	.20	
Direction	260-300 ⁰	250-280 ⁰	280 ⁰	270 ⁰

Figure 1. Wind power site survey locations in the Goodnoe Hills area. (Site 1 is the proposed WTG site, and site 4 is the anemometer site)

Figure 2. Goodnoe Hills wind velocity trace for 6 June 1979. A mean direction is plotted over the faint ink trace.

Horse Heaven Hills Wind Power Prospecting Field Trip

HORSE HEAVEN HILLS WIND POWER PROSPECTING

FIELD TRIP

10 - 13 July 1979

Wind flow measurements were taken in the eastern part of the Horse Heaven Hills near the Kennewick BPA anemometer site to investigate the spatial and temporal changes in the wind field. A survey team composed of four OSU personnel performed the survey and the area surveyed is shown in Figure 1. The area surveyed covers about 100 square miles and encompasses the estimated WTG area described in BPA Report 77-2.

Enroute to the Horse Heaven Hills a stop was made near Boardman, Oregon, to install a recording anemometer on a 30 ft mast. A photograph of this unit is shown in Figures 2 and 3. The unit is located on the top of a small hill in very open and exposed flat terrain. The site location is marked on the topography map, Figure 4. The kite anemometer was flown, but the southwest winds were too erratic to take reliable measurements. The kite would not fly steady at any level for more than a minute or two. The speed varied from 5 - 15 mph and the direction varied about 90° . It was very hot and thermal convection controlled the wind flow.

We arrived in the Kennewick area late in the afternoon on 10 July and looked at an area west of the Kennewick anemometer site, site 1 in Figure 1, to locate a base station with a recording anemometer. We got permission at the Quillan farm to put up a strip chart anemometer on a 25 ft mast. This is site 2 in Figure 1. Photographs of both base stations, sites 1 and 2, are given in Figures 5, 6 and 7. That evening and following morning the rest of the area was visited and sites 3 - 6 were located at which wind profile measurements would be taken.

It was discovered upon arriving at the Kennewick microwave station that the existing anemometer was recording inaccurately. The kite anemometer was flown next to the cup anemometer mounted on the tower. The tower sensor recorded a wind speed of 16.5 mph while that measured by the kite anemometer was 23.3 mph. The measurement period was for five minutes and the ratio between the kite and tower anemometer speed was 1.41. Due to this discrepancy a recording anemometer (Climatronics) was installed next to the existing unit to make a longer term comparison of the difference. A photograph of the two sensors

on the tower is shown in Figure 5. Comparisons of the hourly average wind speeds over a two-day period gave a ratio of 1.44 between the Climatronics unit and the existing anemometer. The hourly mean wind speed varied from 12 - 29 mph and the standard deviation of the ratio was 0.131. The variation between the speeds measured by these two anemometers is graphically depicted in Figure 8.

Kite anemometer measurements were taken at the six sites on 11 and 12 July. Profile data were taken continuously at the two base stations, sites 1 and 2, while kite measurements were made at sites 4 - 6. These data are contained in Tables 1 and 2. The wind velocity was measured using the spring scale hand-held TALA units every 10 seconds for a five-minute period at the 50, 200, and 350 ft levels. Two profiles were taken at each site and the data for each level were averaged to reduce errors due to temporal variations in the speed while the profile was being taken. This technique was suggested from earlier studies investigating proper measurement techniques.

On 11 July a wind survey was made during the midday under 20 - 30 mph southwest winds. A comparison of the profile data taken at site 1 to those taken at sites 2 - 6 is given in Table 1. A ratio of the average of the speeds at all three levels at site 1 to the average at sites 2 - 6 is also given. The overall strength of the wind at sites 2 - 6 was about 75 - 85% of that measured at the Kennewick site on the east edge of the Horse Heaven Hills. The flow at sites 2, 3, and 4 was about 80 - 84% as strong as that measured at site 1. The wind flow at site 5 was about 75% of that at site 1. The strength of the wind at site 6 on top of the ridge was about 75% as strong as that measured on the ridge crest at site 1, about 4 miles north of site 6. The turbulence intensity values at all of the sites were moderate as they generally ranged from 0.10 to 0.15.

During the morning of the next day a similar survey was taken at the six sites. These data are tabulated in Table 2. The wind flow was lighter at site 1 than that measured the previous day. Also, the overall wind speed decreased during the morning. The mean wind direction was from 210° . Winds from 230° were measured the day before. As noted in Table 2 the strength of the flow measured on this morning at sites 2 - 6 was about 55 - 75% of that measured at site 1. Sites 3 and 6 on the ridge crest measured flow about 75% as strong as that at site 1 while the lower elevation sites west of site 1 measured much lighter winds.

Figure 1. Topography map showing the six survey sites and also the possible area for WTG development documented in BPA Report 77-2.

Figure 2. Boardman anemometer mounted on a 30 ft mast.

Figure 3. Topography at the Boardman site showing the anemometer.

Figure 4. Topography map showing the Boardman anemometer site (A).

Figure 5.

Kennewick anemometer site showing the existing anemometer, A, and the temporary Climatronics unit, B.

Figure 6.

Kennewick anemometer site, 1, noted by the arrow.

Figure 7.

Quillan anemometer site, 2, noted by the arrow.

Figure 8. Hourly average wind speed readings comparing the Kennewick base station anemometers at site 1 and the Quillan base station anemometer, site 2, for the period 10-13 July '79.

In summary, the wind profile measurements taken over the two-day period revealed some interesting relationships on the spatial variation in the wind field. These include:

1. Under south to southwest flow, stronger winds occur along the ridge crest from sites 6 to 3 than along the gently rising slope to the west. Highest winds appear to occur near the Kennewick anemometer site, 1.
2. Under the stronger wind field measured on 11 July the wind speed differences between sites 2 - 6 were not large being less than 10%, and the difference between these sites and site 1 was about 20%.
3. Under lighter southwest winds the wind speed difference between the sites was more pronounced. The difference between the ridge sites 1, 3, and 6 and the slope sites 2, 4, and 5 was between 20 and 45%. Of the ridge sites the winds were about 25% stronger at site 1.

However, more testing should be done in this area to verify the conclusions derived from the two days of testing. The other prevailing wind direction as measured by the Kennewick anemometer is northwest. This flow should also be investigated to determine the spatial variation in the wind field.

During the afternoon on 12 July the kite anemometer was flown against the 400 ft. Hanford meteorological tower. Three Battelle Northwest Laboratory scientists accompanied the OSU scientists. The results of the experiment were sent under separate cover on 26 July in the report "Comparison Study of the TALA-150 Kite Anemometer and the Hanford 1 Meteorological Tower."

On the morning of 13 July wind profiles were taken to investigate the spatial variation in the wind flow immediately adjacent to the Kennewick anemometer. Two kites were flown 300 ft. apart with the Kennewick anemometer half way between the two TALA units. Two profiles were taken at each site at the 50, 200 and 350 ft. levels and the data were averaged and summarized in Table 3. The difference in the strength of the profiles at sites A and B was about 10%. The wind speed differences were greatest near the ground at the 50 ft. level and had the closest agreement at the 350 ft level. The surface roughness upwind of site B was greater than that near site A, as noted by the

inspection of the terrain. The Kennewick anemometer at the 105-ft level recorded a wind speed of about 15 mph. This spatial variation in the horizontal appears to be as great or greater than the wind variation in the vertical at this site. More investigations of the spatial variation in the horizontal within 350 ft will be made at other potential WTG sites.

Table 1. Comparisons of the wind speed (mph) and turbulence intensity measurements at five sites to those at Kennewick, site 1, on 11 July 1979.

Site	Time (PST)	Mean Dir.	Altitude (ft)			V_s/V_1
			50	200	350	
1	1140-1230	230°	28.9/.13	29.4/.13	29.9/.13	1.00
2	1140-1230	230°	20.2/.13	22.8/.12	26.4/.12	.79
4	1140-1230	220°	22.0/.15	21.6/.14	24.2/.13	.77
1	1140-1230	230°	28.9/.13	29.4/.13	29.9/.13	1.00
2	1140-1230	230°	20.2/.13	22.8/.12	26.4/.12	.79
5	1140-1230	240°	20.1/.13	22.6/.13	21.4/.15	.73
1	1300-1340	230°	31.0/.12	31.3/.08	30.3/.11	1.00
2	1300-1340	230°	25.3/.10	24.8/.14	26.3/.09	.83
3	1300-1340	240°	24.6/.12	25.9/.11	27.6/.12	
1	1340-1430	230°	30.9/.11	31.6/.08	31.2/.11	1.00
2	1349-1430	230°	26.9/.10	24.7/.12	25.7/.11	.83
6	1340-1430	270°	23.5/.15	24.1/.14	25.4/.13	

Table 2. Comparisons of the wind speed (mph) and turbulence intensity measurements at five sites to those at Kennewick, site 1, on 12 July 1979.

Site	Time (PST)	Mean Dir.	Altitude (ft)			V_s/V_1
			50	200	350	
1	0820-0900	210°	25.9/.08	25.6/.09	24.9/.09	1.00
2	0820-0900	230°	15.9/.25	12.6/.32	12.6/.26	.54
4	0820-0900	230°	14.7/.24	14.5/.18	14.1/.17	.57
1	0820-0900	210°	25.9/.08	25.6/.09	24.9/.09	1.00
2	0820-0900	230°	15.9/.25	12.6/.32	12.6/.26	.54
5	0820-0900	240°	15.1/.10	16.2/.11	16.0/.14	.62
1	0950-1030	210°	20.3/.08	22.1/.09	22.3/.09	1.00
2	0950-1030	230°	v < 10	12.3/.20	12.6/.18	.56
3	0950-1030	240°	15.9/.12	16.7/.15	16.9/.14	.77
1	0950-1030	210°	20.3/.08	22.1/.09	22.3/.09	1.00
2	0950-1030	230°	v < 10	12.3/.20	12.6/.18	.56
6	0950-1030	270°	18.9/.15	16.5/.27	14.5/.24	.78

Table 3. Comparison of kite profiles taken next to the Kennewick tower on 13 July 1979 from 0715-0900 PST. Site A is 150 ft north of the tower and site B is 150 ft south of the tower. Wind speed (mph) and turbulence intensity data are given.

Altitude (ft)	50	200	350	DIR.
Site A	17.4/.09	17.6/.07	17.8/.09	200°
Site B	15.2/.11	16.6/.11	17.0/.10	200°