SURFACE CURRENTS IN THE FOREBAY AT ROUND BUTTE DAM DURING SPRING 1996

PELTON ROUND BUTTE HYDROELECTRIC PROJECT

FERC NO. 2030

Prepared by

Scott A. McCollister and Don E. Ratliff
Portland General Electric Company

November 1996

Prepared for Portland General Electric Company

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ABSTRACT

Surface currents in Lake Billy Chinook were studied during the initial evaluation of the fish facilities (Korn et al. 1967; Mullarkey 1967). These studies showed the surface currents tended to move down the Deschutes and Crooked river arms, and up the Metolius River Arm. However, little attention was given to the surface currents in the Round Butte Dam forebay near the downstream fish facilities. During the months of April and May 1996, surface current studies were conducted in the forebay of Round Butte Dam to provide information to help design and orientation of potential downstream-migrant fish facilities. During the sample test days, 5-meter depth drogues drifted with the surface currents. When the dam was operating under normal conditions, the drogues drifted in one of four patterns. They either drifted clockwise (downstream on the west bank and upstream on the east bank), upstream, downstream, or in no distinguishable pattern. There was a high correlation between surface current patterns and wind direction. During a controlled 2,000 cfs surface spill, the drogues drifted strongly toward the spillway, with an eddy created on each bank. This demonstrated that a large surface attraction flow could overcome existing surface currents.

INTRODUCTION

This study was conducted as part of a proposed plan to reintroduce anadromous fish upstream of the Pelton Round Butte Hydroelectric Project. Upstream passage of returning adult salmonids was successful, but efforts to maintain the wild runs above the dams was abandoned in 1968 when the downstream-migrant fish facility at Round Butte proved to be ineffective in capturing enough smolts from Lake Billy Chinook. Hatchery production began in 1969. With the federal relicensing of the Pelton Round Butte Project, reintroducing wild salmon and steelhead runs upstream of the project is being considered. This study was conducted to help with the design and orientation of possible new downstream-migrant fish facilities. Since migrating smolts tend to follow water currents near the surface, drogues were used to determine the direction of the water movements near the surface in the forebay at the Round Butte Dam during the normal spring smolt emigration period in April and May. A study in 1995 using a boat-mounted "acoustic doppler current profiler" captured information on currents throughout the water column, but only during very short durations (Truebe 1996). This study was conducted to learn about surface water movements in the forebay over a longer duration. A cooperative spill-for-generation trade with the Bonneville Power Administration (BPA) made it possible to study surface currents with one-third of the water leaving the reservoir pulled from the surface via the spillway. The goal of BPA was to reduce dissolved gas levels in the mainstem Columbia River.

METHODS

Study Area

Lake Billy Chinook is located in Central Oregon on the Deschutes River, 179 km (110 mi) upstream of the confluence with the Columbia (Figure 1). Created by the construction of Round Butte Dam in 1964, the reservoir has a surface area of approximately 1,585 ha (4,000 acre-feet). Water normally leaves the reservoir at the bottom of the intake tower via the power intake for Round Butte Dam at a depth from 60 to 85 m below the surface. The intake tower is located in the forebay upstream of the west abutment of the dam (Figure 1). Lake Billy Chinook is formed by the impoundment of the Metolius, Deschutes and Crooked rivers that have lengths of 10.5, 14, and 19.5 km respectively. Current studies in Lake Billy Chinook were focused on surface water movements in the forebay at Round Butte Dam. The southern boundary of the study area was an imaginary line from a southwestern point on the corner into the Metolius Arm east across the Deschutes channel to the most easterly point below the cliff area southwest of the Round Butte Dam observatory (Figure 1).

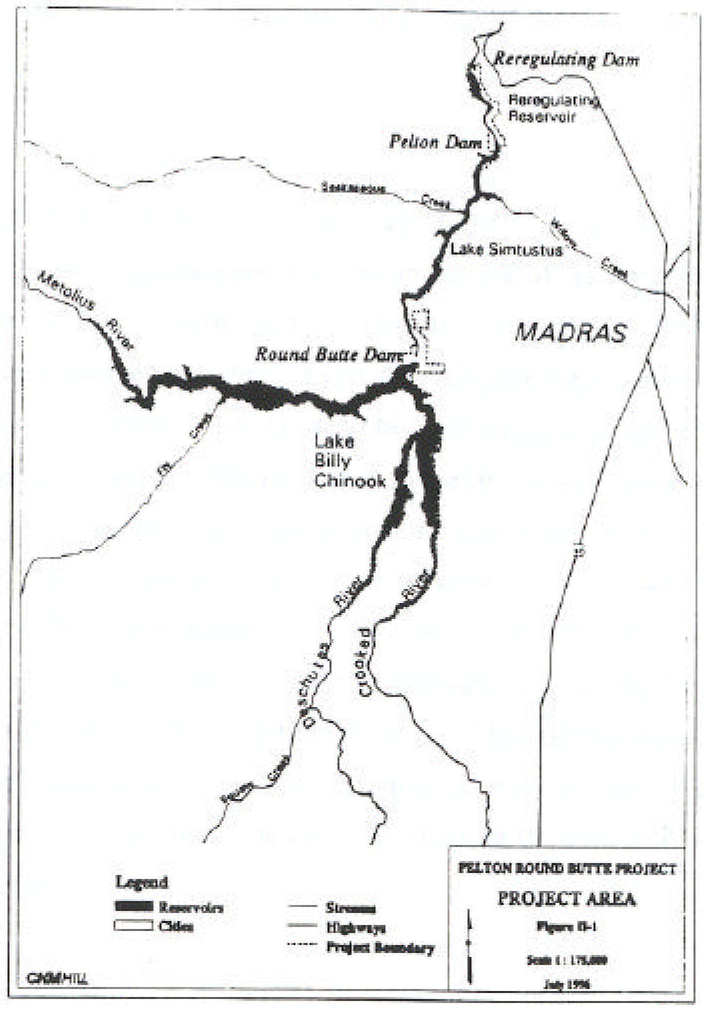

Figure 1. General location map and study area Lake Billy Chinook.

Drogues

Two types of marked drogues were deployed in the forebay of Round Butte Dam. The first was hand-constructed from masonite similar to those used by Korn et al. (1967). The crossed vanes of the drogue were made from two rectangular boards of equal size and dimension (59 cm L. by 60 cm W.). The boards were cut and slotted together, which made an (X) if viewed from the top. The vane was suspended 5 m below the surface of the water by nylon twine from a cylindrical float of polystyrene (10 cm D. by 25 cm L.). The float was cut to minimize the amount of material needed to keep the drogue afloat. From 3 to 5 cm of float extended above the water's surface. Approximately 1 lb of lead was hung below the vane to offset the buoyancy of the masonite.

The second type of drogue was commercially constructed. The crossed vanes (40 cm L. by 30 cm W.) were constructed with polyethylene oblong disks. The vane was suspended 5 m below the surface of the water by nylon twine from a float of the same material, but smaller than those used by the other drogues (10 cm D. by 10 cm L.). From 3 to 5 cm of float extended above the water's surface. Approximately 1.5 lb of lead was hung below the vane to offset the buoyancy of the polyethylene disk.

Procedures

During April and May, 5-m-depth drogues were placed in the forebay of Round Butte Dam early on calm mornings. Their positions were recorded at the time of placement and throughout the course of the day while they drifted with the surface currents. Drogues which became grounded or drifted outside the study area were repositioned. Typically, drogues were placed in the water to drift in the morning, and the trial terminated when the wind became strong enough to form significant waves on the reservoir. When there were significant waves on the lake, it was thought that any surface currents would be overridden by the strong wave action against the drogue floats. Between 10 and 15 drogues were used during each trial. The drogues' locations were recorded using a Global Positioning System (GPS) unit when they were first put out and then about every hour.

On April 30, 2,000 cfs was spilled from 0500 through 1015 hours. Fifteen drogues were placed in the water at 0600 hours and their positions were recorded approximately every hour with the use of standard survey equipment from a fixed location above the dam. The 2,000-cfs spill began at 0500 hours and ended at 1015 hours on April 30. During the spill test, a constant generation flow of 4,000 cfs was maintained.

Analysis

Drogue movements were compared with wind direction, wind speed, and reservoir outflow for the 48 hours prior to and during the sample periods to see if there was a correlation between these three factors and the surface current patterns. Wind speed and direction were recorded on 5-minute intervals from a weather station mounted on the intake tower located in the middle of the study area. Wind data was unavailable for some time periods due to anemometer malfunction. Due to the nature of wind in canyons, wind direction was categorized into either traveling downstream or upstream. Wind from the west, southwest, south, and southeast formed waves traveling downstream. Wind from the east, northeast, north and northwest formed waves traveling upstream. Wind direction, wind speed, and reservoir outflow were graphically presented together to qualitatively sum the effects of these three factors on the surface currents (see Appendices 1-12).

RESULTS AND DISCUSSION

There was no consistent pattern in the direction for water movements in the top 5 m in the forebay of Round Butte Dam. Monitoring of the wind indicated that even on the days when the wind was very slight, the surface water appeared to move in relation to the wind. On May 1, May 8, and May 16, the water moved in a clockwise direction, downstream on the west bank and upstream on the east bank (Figures 2, 3, and 4). On April 26, May 2, and May 8, the surface water moved in a southerly, or upstream, direction (Figures 5, 6, and 7). On May 6 and May 9, the surface water moved in a northerly, or downstream, direction (Figures 8 and 9). On May 13, May 20, and May 21, the water moved in a nondistinguishable pattern (Figures 10, 11, and 12). On April 30, the controlled spill day of 2,000 cfs, the drogues in the mid portions of the forebay moved rapidly toward the spillway gate (Figure 13).

Clockwise Rotational Movements

On May 1, drogues moved in a clockwise pattern from 0630 to 0930 hours (Figure 2). The positions of the drogues were recorded at 0630, 0800, and 0930 hours. During the sample period, wind was generally in the upstream direction around 3 mph. Reservoir outflow for the same time period ranged between 4,000 and 9,000 cfs. During the 48 hours prior to the sample period, wind shifted between the upstream and downstream directions. Wind speed fluctuated between 2 and 12 mph. Wind data was unavailable for a 6- and 12-hour time block 18 and 48 hours prior to the sample period. Reservoir outflow ranged between 2,500 and 9,800 cfs (see Appendix 1 for wind direction, wind speed, and reservoir outflow for the 48 hours prior wind direction, wind speed, and reservoir outflow to and during the sample period on May 1).

On May 8, drogues moved in a clockwise pattern from 0600 to 0900 hours (Figure 3). The positions of the drogues were recorded at 0600, 0700, 0800, and 0900 hours. During the sample period, wind was in the upstream direction less then 5 mph. Reservoir outflow for the same period ranged between 3,800 and 6,300 cfs. During the 48 hours prior to the sample period, wind shifted between the upstream and the downstream directions. Wind speed fluctuated between 2 and 10 mph, except for a 12-hour time period 20 hours prior to the sample period. Reservoir outflow ranged between 0 and 7,000 cfs (see Appendix 2 for wind direction, wind speed, and reservoir outflow for the 48 hours prior wind direction, wind speed, and reservoir outflow to and during the sample period on May 8).

On May 16, drogues moved in a clockwise pattern from 0700 to 0900 hours (Figure 4). The positions of the drogues were recorded at 0700 and 0900 hours. During the sample period, wind was in the upstream direction less then 2 mph. Reservoir outflow for the same time period was 6,200 cfs. During the 48 hours prior to the sample period, the majority of the wind was in the downstream direction less than 5 mph, except for a 10-hour time period 20 hours prior to the sample period. During that time period, wind was in the downstream direction between 15 and 20 mph. Reservoir outflow ranged between 3,800 and 7,000 cfs, except for a 7-hour time period 32 hours prior to the sample period. During that time period, reservoir outflow ranged between 1,000 and 3,000 cfs (see Appendix 3 for wind direction, wind speed, and reservoir outflow for the 48 hours prior wind direction, wind speed, and reservoir outflow to and during the sample period on May 16).

Upstream Movements

On April 26, drogues moved upstream from 0600 to 0800 hours (Figure 5). The positions of the drogues were recorded at 0600 and 0800 hours. During the sample period, wind was in the upstream direction around 4 mph. Reservoir outflow for the same time period ranged between 5,000 and 5,800 cfs. During the 48 hours prior to the sample period, wind direction and speed data were unavailable. Reservoir outflow ranged between 4,000 and 6,900 cfs, except for a 3-hour time period when reservoir outflow dropped below 1,000 cfs 14 hours prior to the sample period. (see Appendix 4 for wind direction, wind speed, and reservoir outflow for the 48 hours prior wind direction, wind speed, and reservoir outflow to and during the sample period on April 26).

On May 2, drogues moved upstream from 0630 to 0830 hours (Figure 6). The positions of the drogues were recorded at 0630 and 0830 hours. During the sample period, wind was in the upstream direction around 5 mph. Reservoir outflow for the same time period ranged between 4,000 and 5,500 cfs. During the 48 hours prior to the sample period, wind shifted between the upstream and the downstream directions around 4 mph, except for a 10-hour time period 12 hours prior to the sample period. During that time period, wind was in the downstream direction between 12 and 17 mph. No wind data was available for a 12-hour time period 30 hours prior to the sample period. Reservoir outflow ranged between 2,500 and 10,000 cfs. The majority of the time, reservoir outflow was 5,000 cfs (see Appendix 5 for wind direction, wind speed, and reservoir outflow for the 48 hours prior wind direction, wind speed, and reservoir outflow to and during the sample period on May 2).

On May 8, the drogues were repositioned at 1000 hours after the trial showing clockwise movements earlier in the morning. The drogues then moved upstream from 1000 to 1400 hours (Figure 7). The positions of the drogues were recorded at 1000, 1100, 1200, 1300, and 1400 hours. During the sample period, the majority of the wind was in the upstream direction around 5 mph. Reservoir outflow for the same time period ranged between 4,000 and 6,000 cfs. During the 48 hours prior to the sample period, the wind shifted between the upstream and the downstream directions. Wind speed was around 5 mph, except for a 12-hour time period 18 hours prior to the sample period. During that time period, wind speed increased to 15 mph in the downstream direction. Reservoir outflow ranged between 4,000 and 7,000 cfs, except for two time period blocks 14 and 30 hours prior to the sample period. During these two 6-hour time periods, there was no reservoir outflow (see Appendix 6 for wind direction, wind speed, and reservoir outflow for the 48 hours prior wind direction, wind speed, and reservoir outflow to and during the sample period on May 8).

Downstream Movements

On May 6, drogues moved downstream from 0800 to 1100 hours (Figure 8). The positions of the drogues were recorded at 0800, 0900, and 1100 hours. During the sample period, wind was in the downstream direction around 4 mph. Reservoir outflow for the same time period ranged between 2,000 and 7,000 cfs. During the 48 hours prior to the sample period wind shifted between the upstream and the downstream directions. Wind speed was between 1 and 11 mph. Reservoir outflow ranged between 1,800 and 8,200 cfs (see Appendix 7 for wind direction, wind speed, and reservoir outflow for the 48 hours prior wind direction, wind speed, and reservoir outflow to and during the sample period on May 6).

On May 9, drogues moved downstream from 0600 to 0930 hours (Figure 9). The positions of the drogues were recorded at 0600, 0730, and 0930 hours. During the sample period, wind was in the downstream direction around 5 mph. Reservoir outflow for the same time period ranged between 500 and 3,100 cfs. During the 48 hours prior to the sample period, wind shifted between the upstream and the downstream directions. Wind speed was around 5 mph, except for two 12-hour time periods 18 and 40 hours prior to the sample period. During these time periods, wind speed was between 10 and 20 mph. Reservoir outflow ranged between 4,000 and 9,000 cfs, except for three 4-hour time periods 4, 28, and 48 hours prior to the sample period. There was no reservoir outflow during these three time periods. (see Appendix 8 for wind direction, wind speed, and reservoir outflow for the 48 hours prior wind direction, wind speed, and reservoir outflow to and during the sample period on May 9).

No Distinguishable Pattern

On May 13, drogues moved in different directions in which no patten was distinguishable from 1000 to 1330 hours (Figure 10). The positions of the drogues were recorded at 1000, 1130, and 1330 hours. During the sample period, wind shifted between the upstream and the downstream directions around 3 mph. Reservoir outflow for the same time period ranged between 3,800 and 8,000 cfs. During the 48 hours prior to the sample period, wind shifted between the upstream and the downstream directions around 5 mph, except for a 12-hour time period when wind speed was between 10 and 16 mph in the upstream direction. Reservoir outflow was between 2,500 and 10,000 cfs, except for two 8-hour time periods when there was no outflow 10 and 30 hours prior to the sample period. (see Appendix 9 for wind direction, wind speed, and reservoir outflow for the 48 hours prior wind direction, wind speed, and reservoir outflow to and during the sample period on May 13).

On May 20, drogues moved in different directions in which no pattern was distinguishable from 0900 to 1400 hours (Figure 11). The positions of the drogues were recorded at 0900, 1000, 1200, and 1400 hours. During the sample period, the wind shifted between the upstream and the downstream directions around 4 mph. Reservoir outflow, for the same time period, ranged between 6,000 and 7,000 cfs. During the 48 hours prior to the sample period, wind was in the downstream direction, except for a 6-hour time period when the wind shifted to the upstream direction 12 hours prior to the sample period. Wind speed fluctuated between 2 and 25 mph. Reservoir outflow ranged between 2,000 and 7,000 cfs (see Appendix 10 for wind direction, wind speed, and reservoir outflow for the 48 hours prior wind direction, wind speed, and reservoir outflow to and during the sample period on May 20).

On May 21, drogues moved in different directions in which no pattern was distinguishable from 0700 to 1100 hours (Figure 12). The positions of the drogues were recorded at 0700, 0900, and 1100 hours. During the sample period, wind was in the downstream direction less then 2 mph. Reservoir outflow for the same time period ranged between 3,200 and 8,900 cfs. During the 48 hours prior to the sample period, wind shifted between the upstream and the downstream directions around 5 mph, except for a 12-hour time period when the wind speed was between 10 and

20 mph in the upstream direction 46 hours prior to the sample period. Reservoir outflow ranged between 1,000 and 7,000 cfs (see Appendix 11 for wind direction, wind speed, and reservoir outflow for the 48 hours prior wind direction, wind speed, and reservoir outflow to and during the sample period on May 21).

Controlled Surface Spill

On April 30, surface currents were studied from 0600 to 1015 hours while 2,000 cfs was pulled out of the spillway about 4 m below the surface. Drogues in the mid portion of the forebay moved rapidly toward the spillway. Drogues on the east side of the forebay moved in a clockwise rotation while drogues on the west side of the forebay moved in a counterclockwise rotation (Figure 13). During the sample period, the winds were very light, shifting between the upstream and downstream directions at less then 5 mph. Wind data was only available for 14 hours prior to the sample period. (see Appendix 12 for wind direction, wind speed, and reservoir outflow data prior to and during the sample period on April 30).

As opposed to the confusing water movements during normal operating conditions, the trial with the 2,000-cfs controlled spill demonstrated strong downstream movement of surface water in the forebay. Because of wind during other arranged spill days, this trial could not be repeated during 1996; however, it would be informative to measure surface currents with lesser amounts of water being pulled from the surface. The use of spilled water for downstream-migrant attraction would be cost-prohibitive; however, using the spillway as a test device allows the determination of the amount of water that must be pulled from the surface to maintain a consistent pattern of forebay surface currents toward the dam.

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Mullarkey, W.G. 1967. Observations on the Limnology of the Round Butte Reservoir, Oregon Research Briefs, Volume 13(1):60-86. FCO, Research Division (now ODFW). Clackamas, Oregon.

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Figure 2. Movements of individual 5-meter depth drogues in the forebay of Round Butte Dam on May 1, from 0630 to 0930 hours. Drogue positions were recorded at 0630, 0830, and 0930 hours (see Appendix 1 for additional wind and flow data).

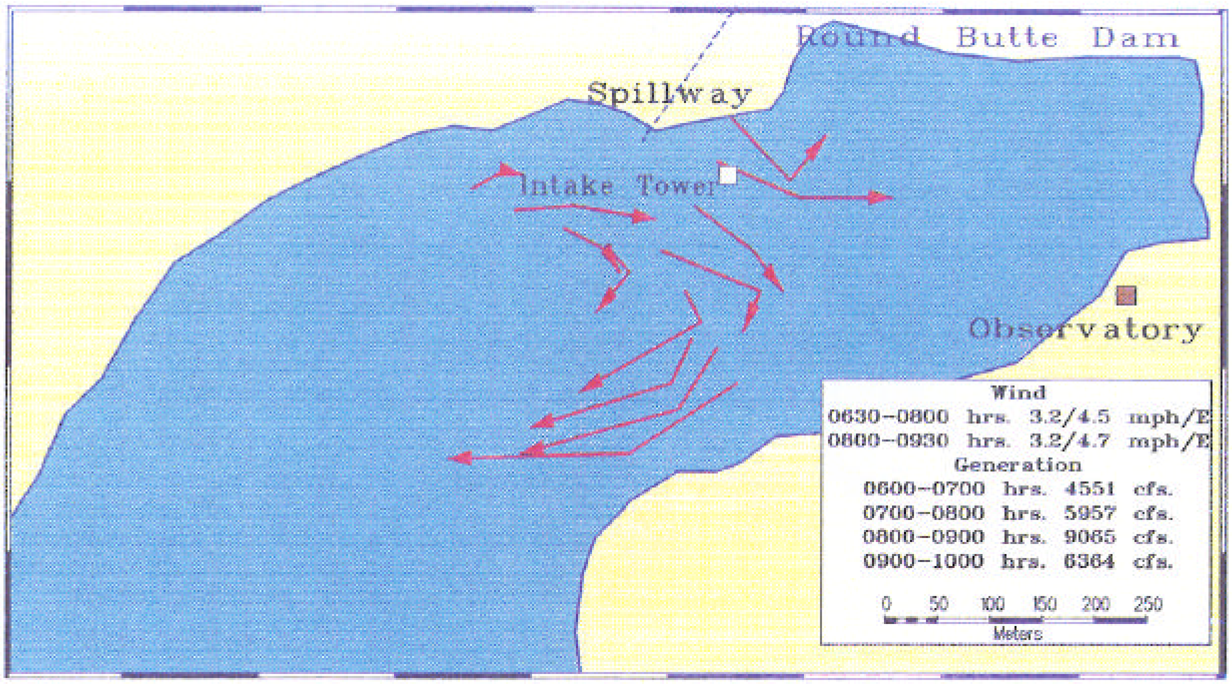
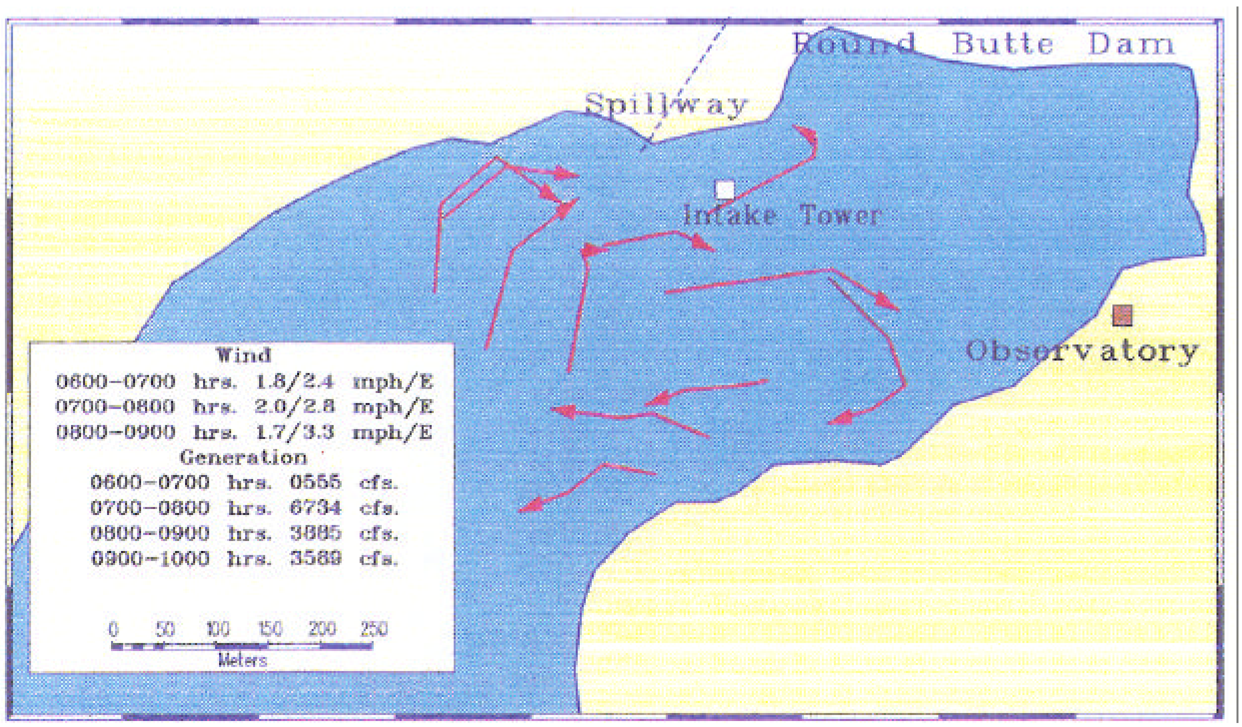


Figure 3. Movements of individual 5-meter depth drogues in the forebay of Round Butte Dam on May 8, from 0600 to 0900 hours. Drogue positions were recorded at 0600, 0700, 0800, and 0900 hours (see Appendix 2 for additional wind and flow data).



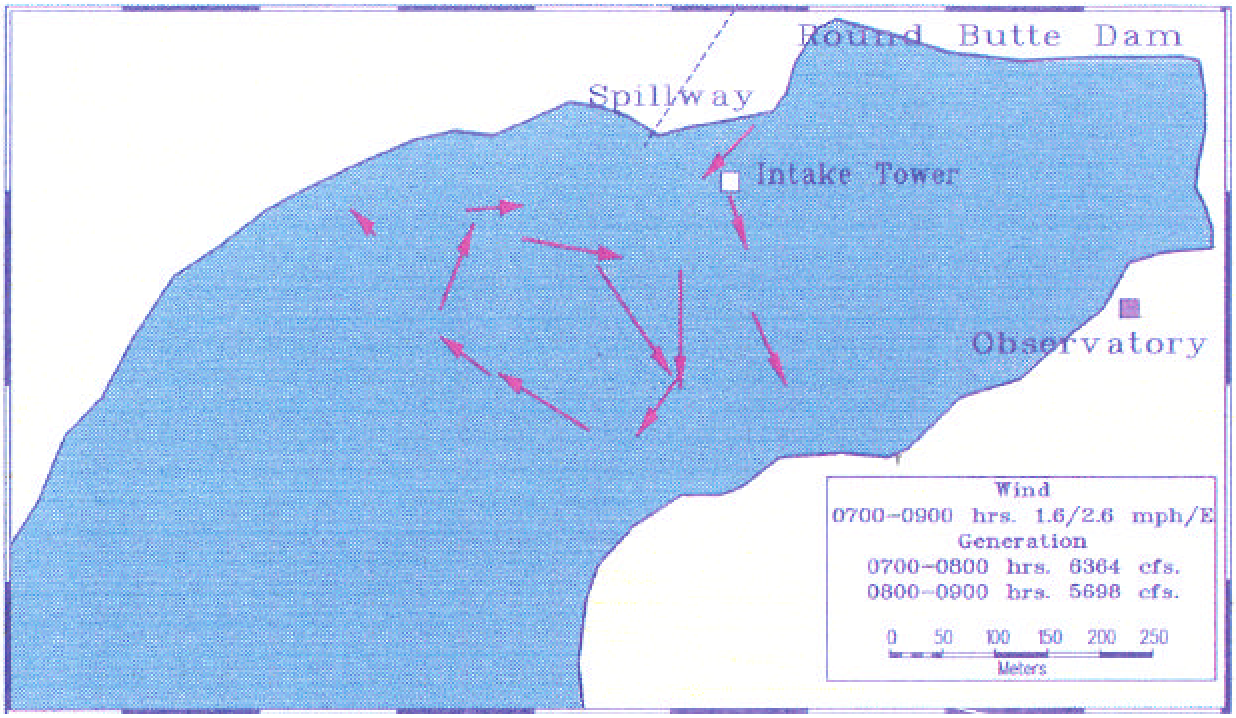


Figure 4. Movements of individual 5-meter depth drogues in the forebay of Round Butte Dam on May 16, from 0700 to 0900 hours. Drogue positions were recorded at 0700 and 0900 hours (see Appendix 3 for additional wind and flow data).

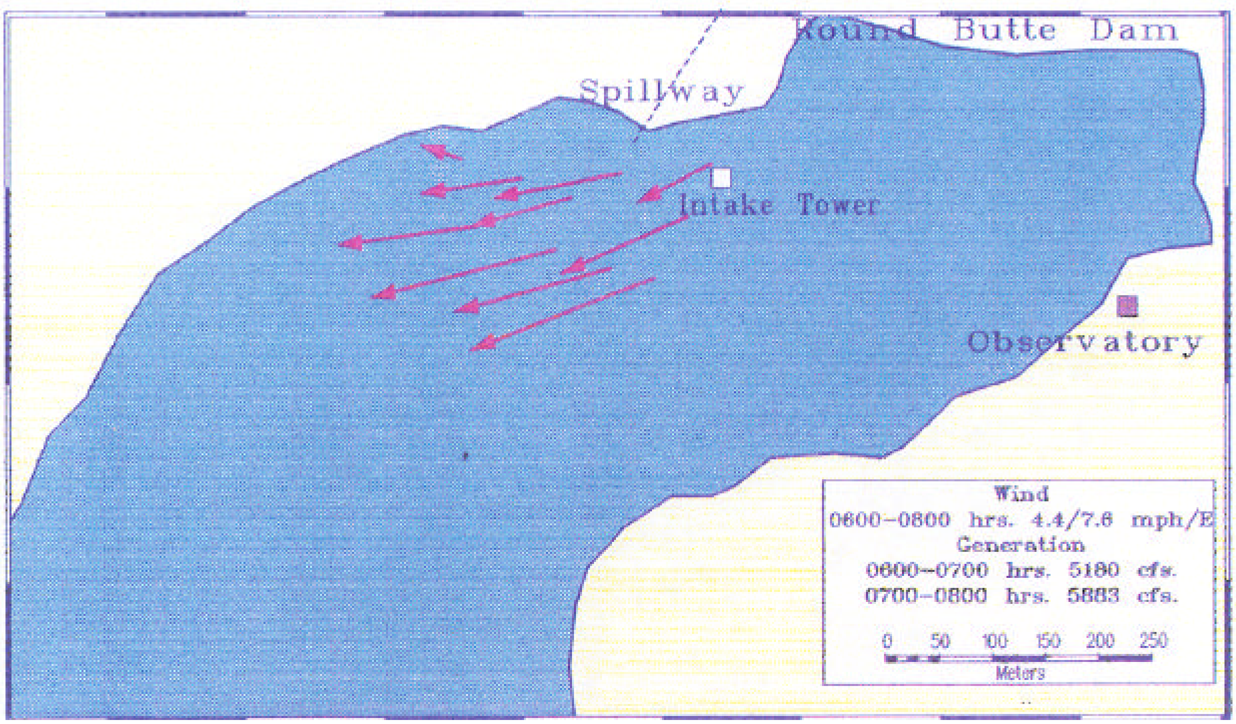


Figure 5. Movements of individual 5-meter depth drogues in the forebay of Round Butte Dam on April 26, from 0600 to 0800 hours. Drogue positions were recorded at 0600 and 0800 hours (see Appendix 4 for additional wind and flow data).

Figure 6. Movements of individual 5-meter depth drogues in the forebay of Round Butte Dam on May 2, from 0630 to 0830 hours. Drogue positions were recorded at 0630 and 0830 hours (see Appendix 5 for additional wind and flow data).

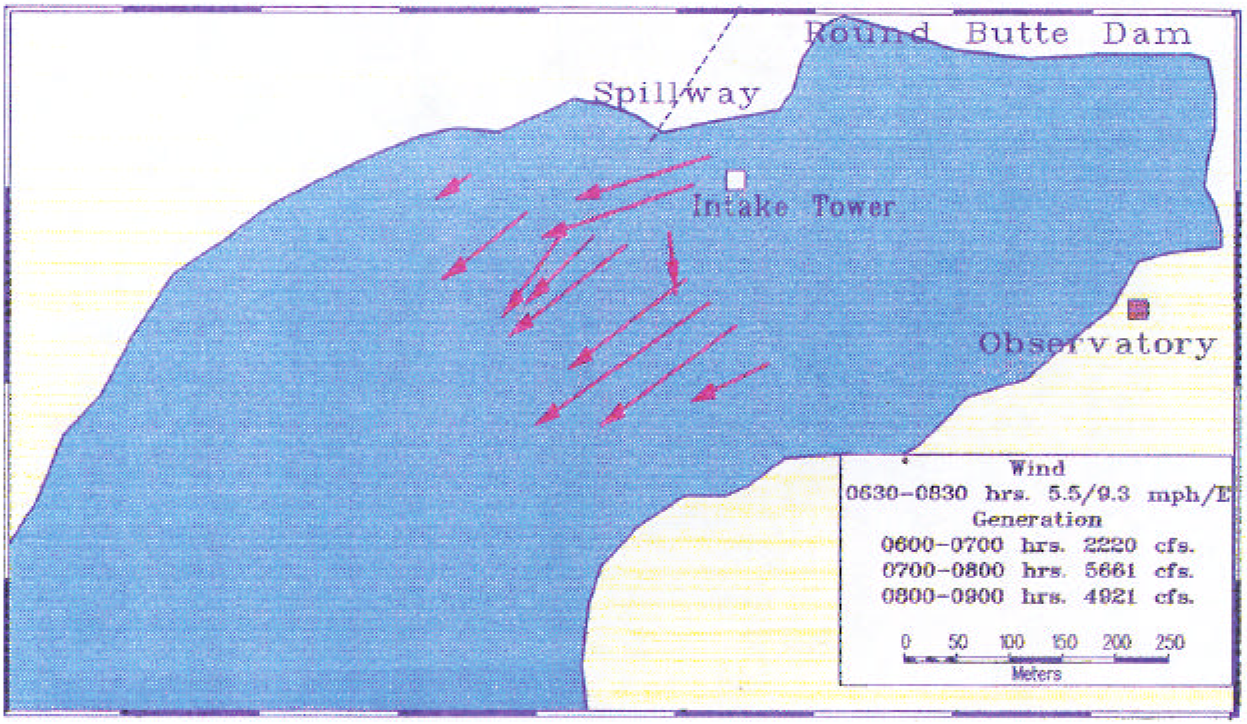


Figure 7. Movements of individual 5-meter depth drogues in the forebay of Round Butte Dam on May 8, from 1000 to 1400 hours. Drogue positions were recorded at 1000, 1100, 1200, 1300, and 1400 hours (see Appendix 6 for additional wind and flow data).

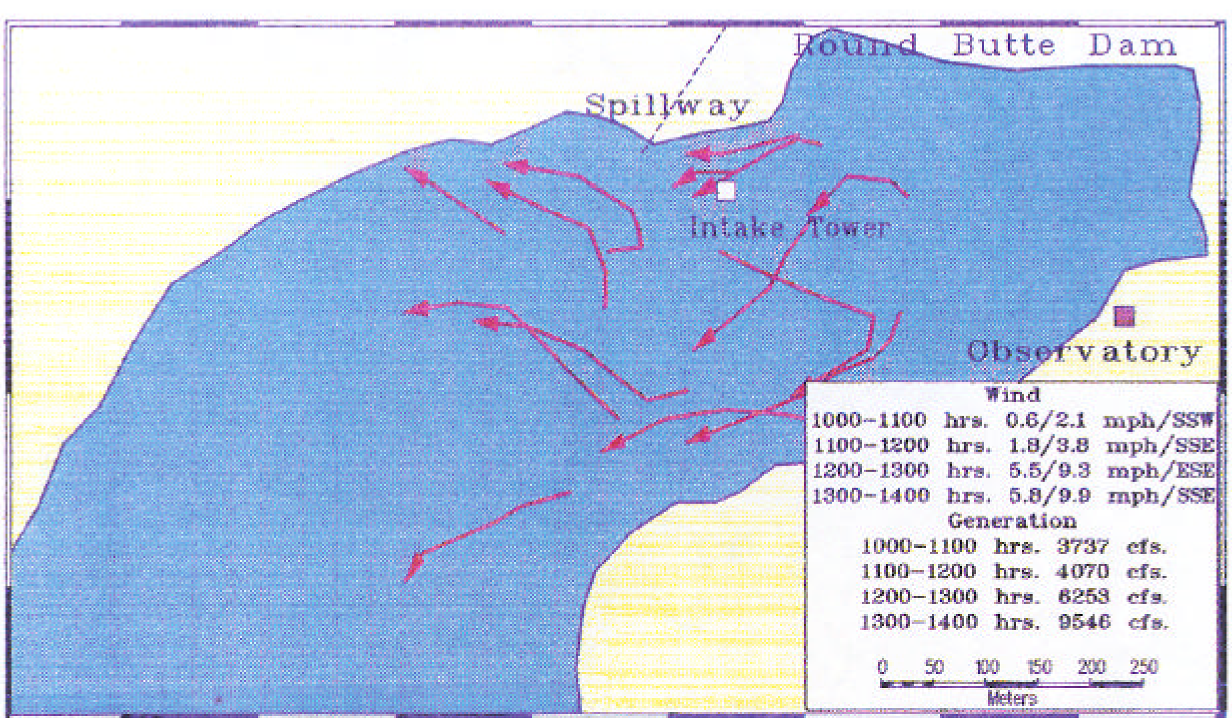


Figure 8. Movements of individual 5-meter depth drogues in the forebay of Round Butte Dam on May 6, from 0800 to 1100 hours. Drogue positions were recorded at 0800, 0900, and 1100 hours (see Appendix 7 for additional wind and flow data).

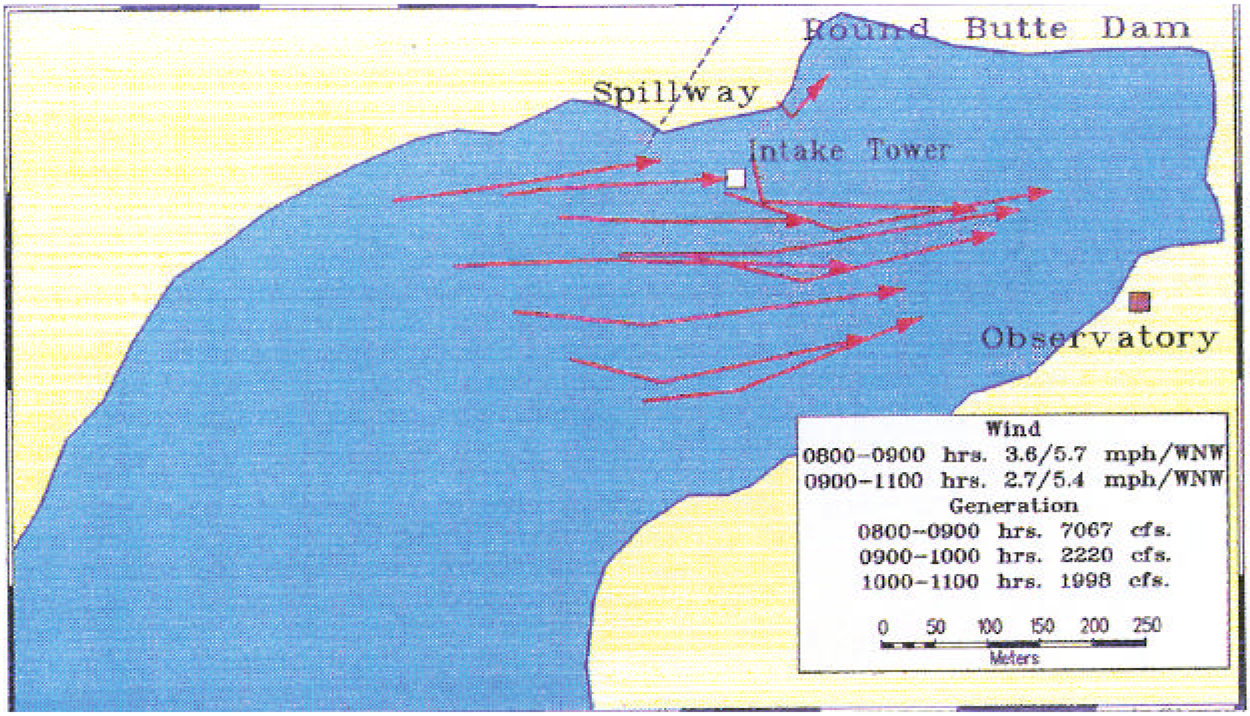


Figure 9. Movements of individual 5-meter depth drogues in the forebay of Round Butte Dam on May 9, from 0600 to 0900 hours. Drogue positions were recorded at 0600, 0730, and 0930 hours (see Appendix 8 additional wind and flow data).

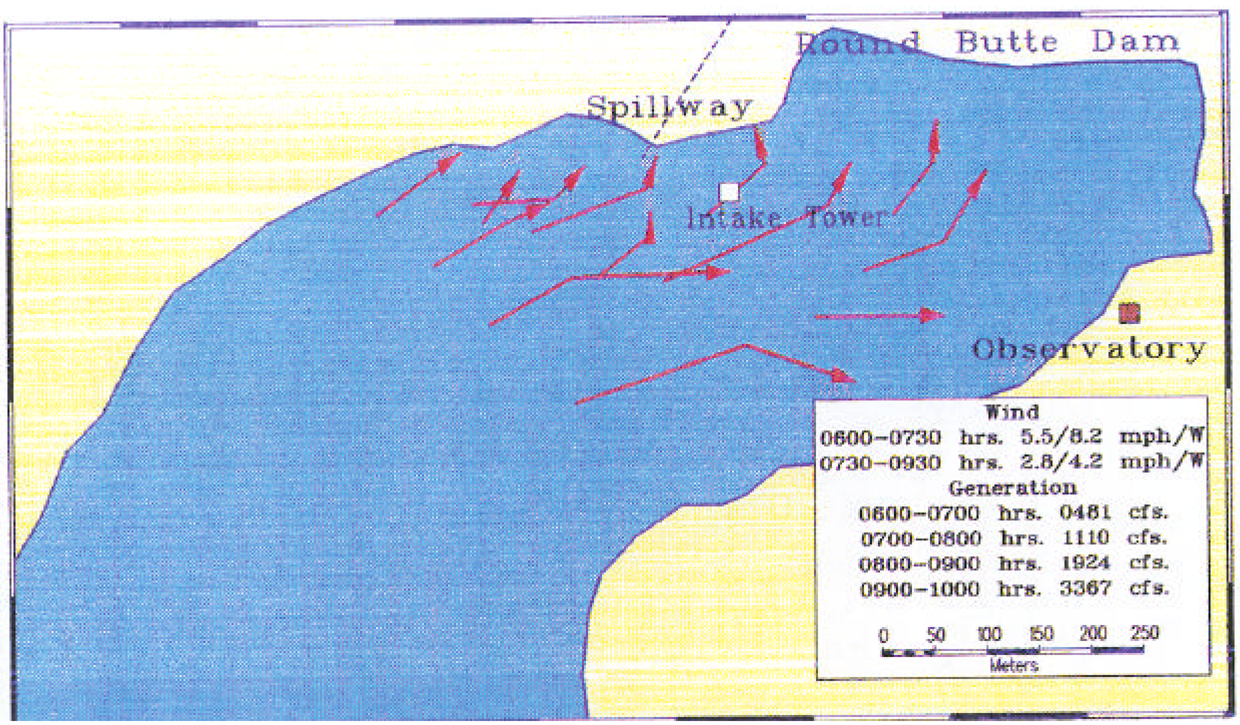


Figure 10. Movements of individual 5-meter depth drogues in the forebay of Round Butte Dam on May 13, from 1000 to 1330 hours. Drogue positions were recorded at 1000, 1130, and 1330 hours (see Appendix 9 for additional wind and flow data).

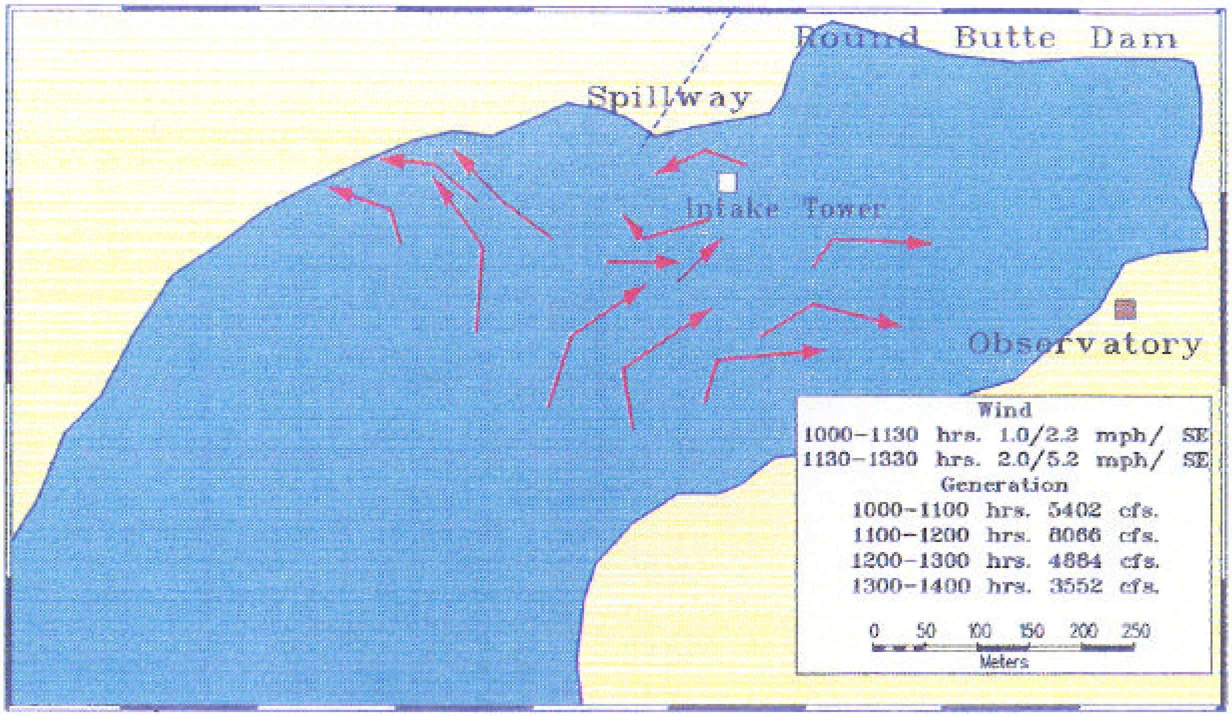


Figure 11. Movements of individual 5-meter depth drogues in the forebay of Round Butte Dam on May 20, from 0900 to 1400 hours. Drogue positions were recorded at 0900, 1000, 1200, and 1400 hours (see Appendix 10 for additional wind and flow data).

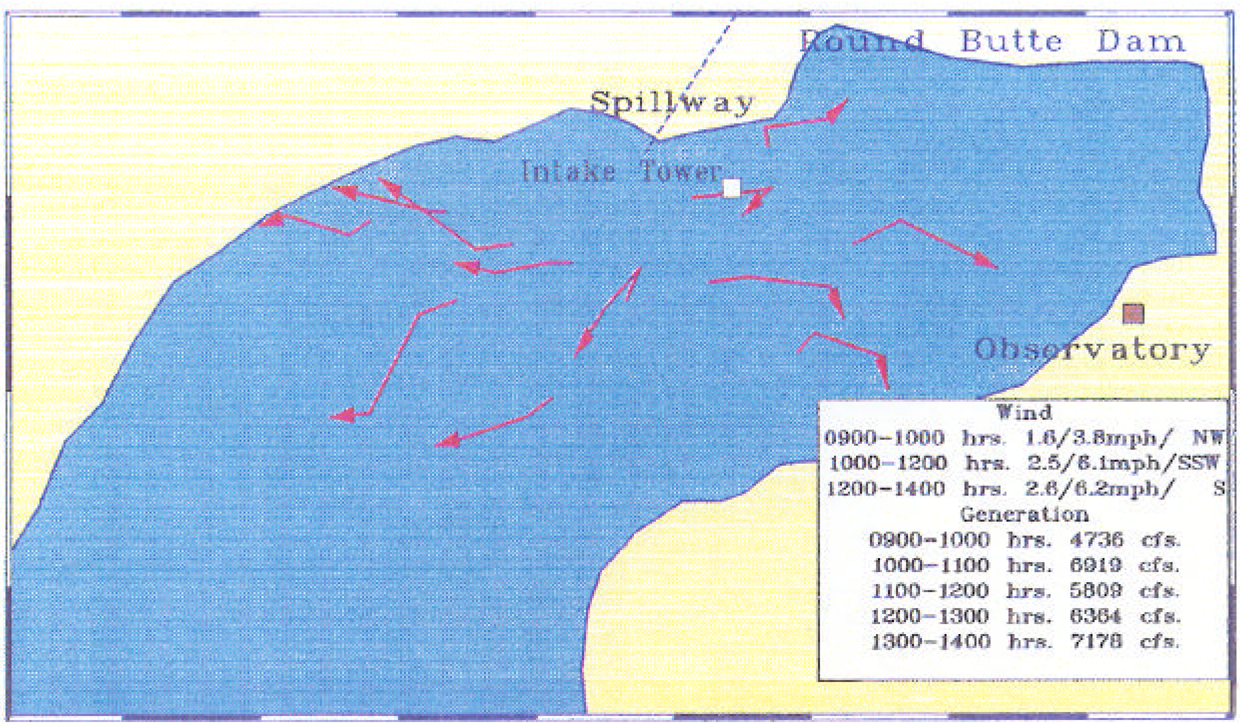


Figure 12. Movements of individual 5-meter depth drogues in the forebay of Round Butte Dam on May 21, from 0700 to 1100 hours. Drogue positions were recorded at 0700, 0900, and 1100 hours (see Appendix 11 for additional wind and flow data).

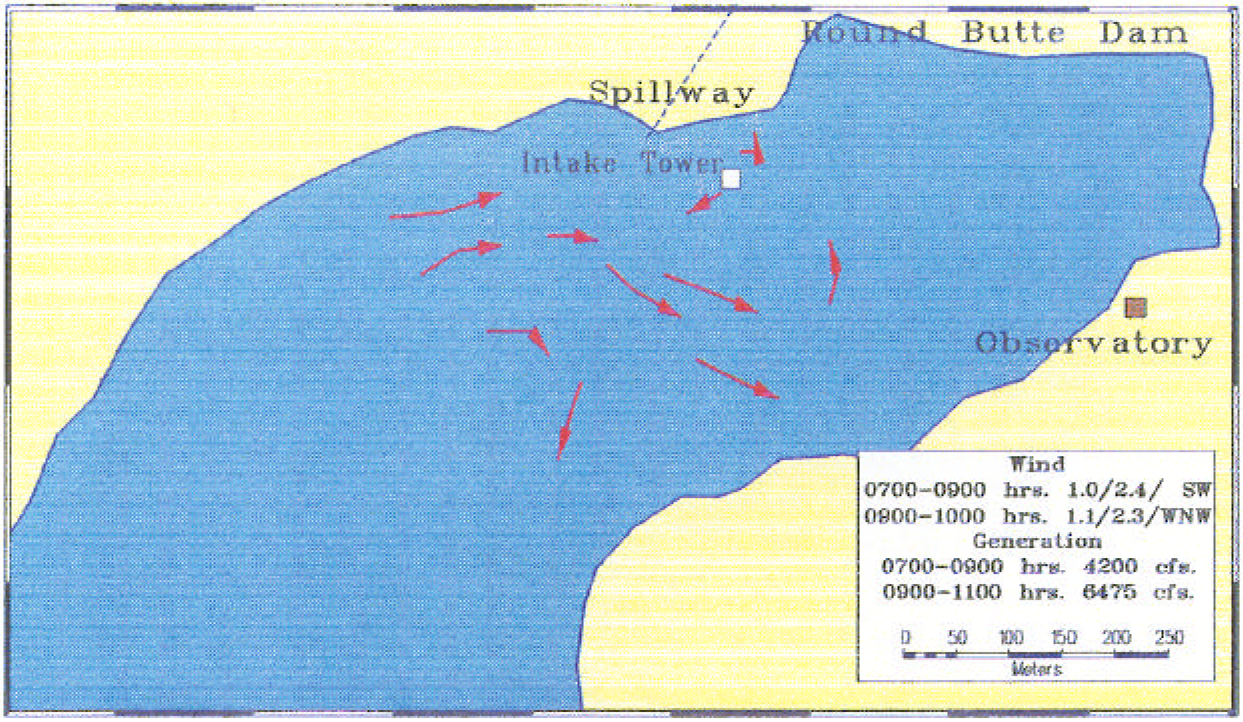
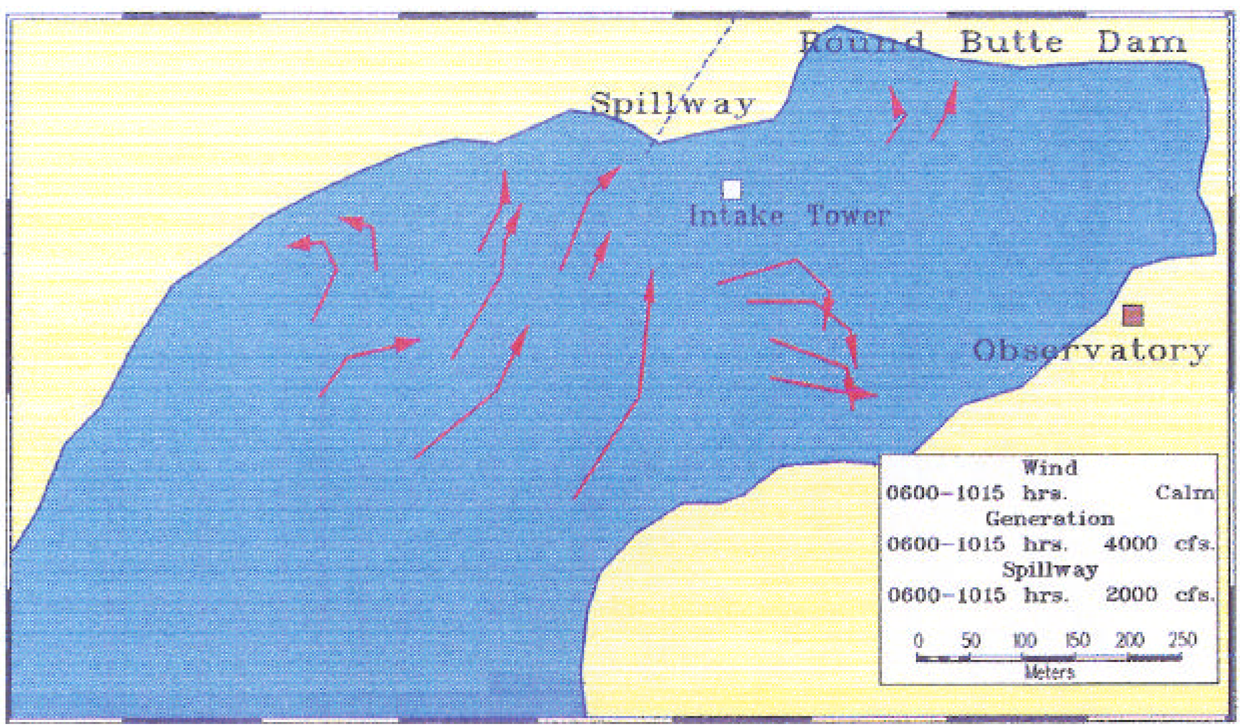
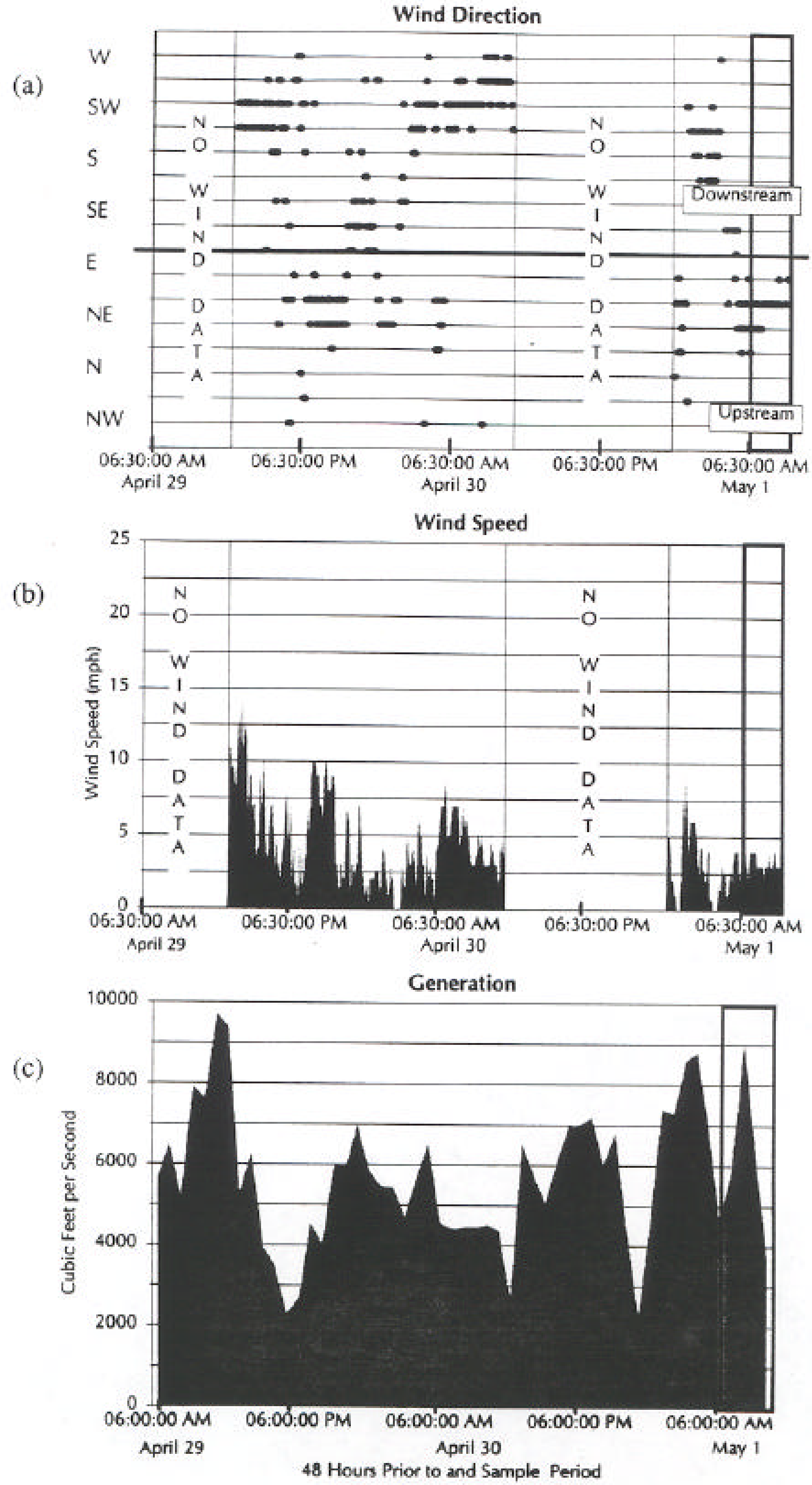


Figure 13. Movements of individual 5-meter depth drogues during a 2,000 cfs. controlled surface spill in the forebay of Round Butte Dam on April 30, from 0600 to 1015 hours (see Appendix 12 for additional wind and flow data).



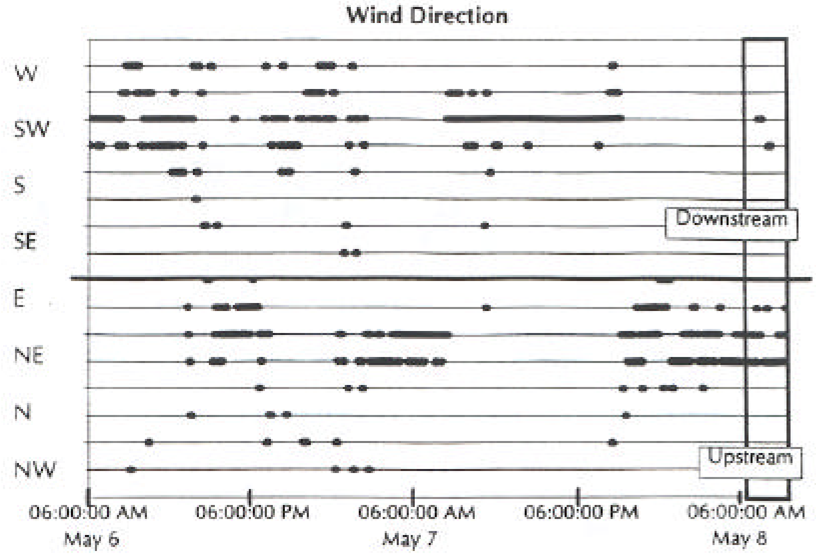
Appendix 1



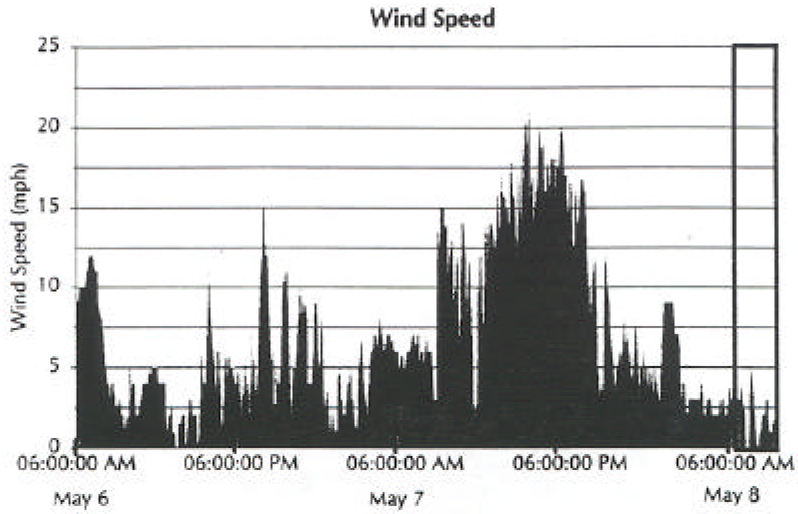
Wind Direction (a), Wind Speed (b), and Reservoir Outflow (c) for the 48 hours prior wind direction, wind speed, and reservoir outflow to, and during the sample period on May 1. Sample period enclosed in the bold box on the right side of figures.

Appendix 2

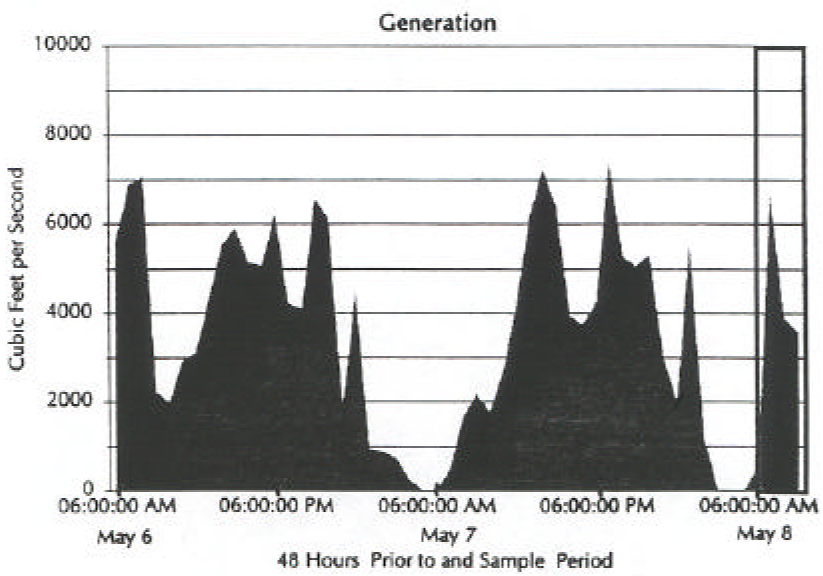
(a)



(b)



(c)



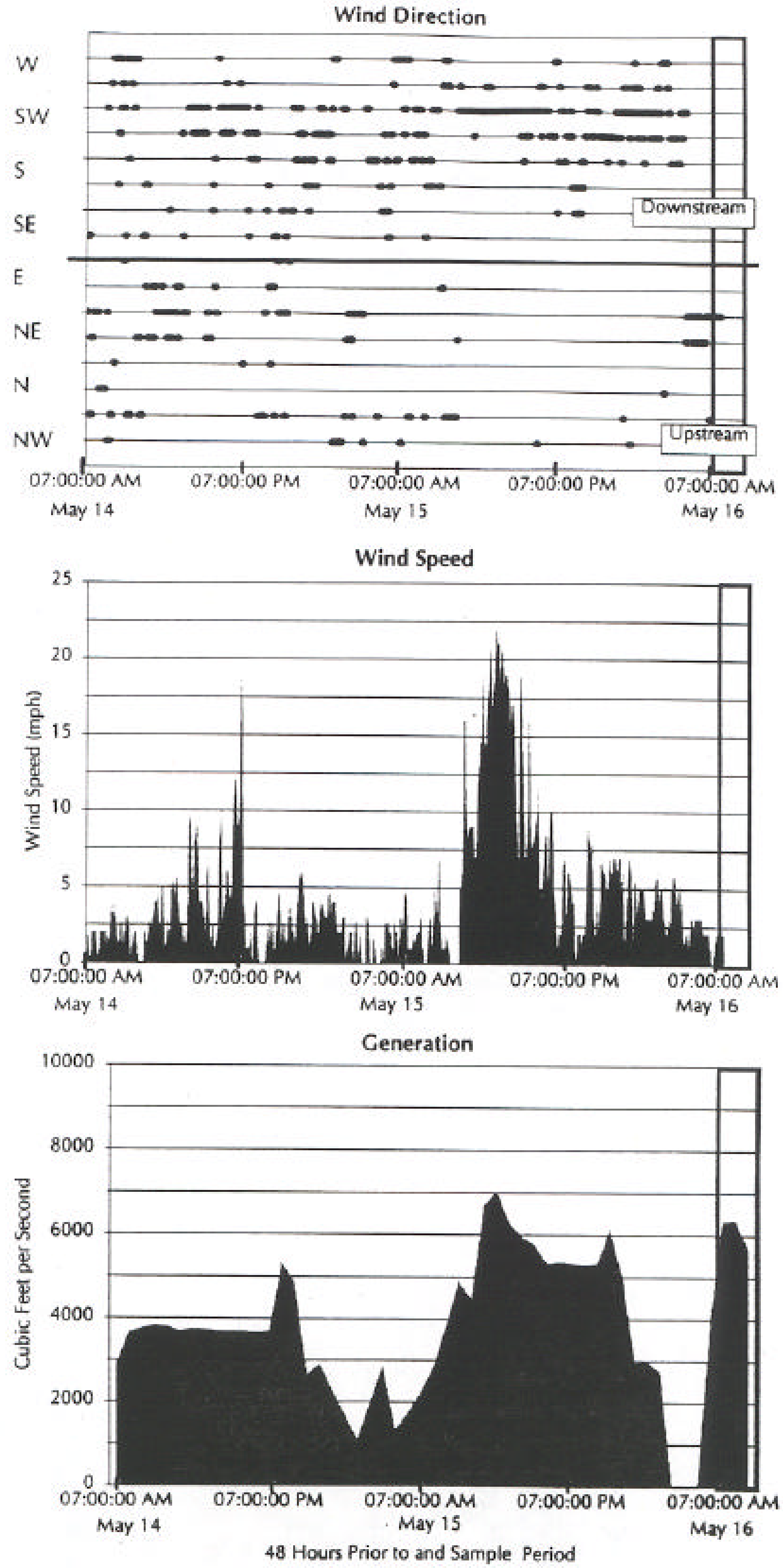
Wind Direction (a), Wind Speed (b), and Reservoir Outflow © for the 48 hours prior wind direction, wind speed, and reservoir outflow to, and during the sample period on May 8. Sample period enclosed in the bold box on the right side of figures.

Appendix 3

(a)

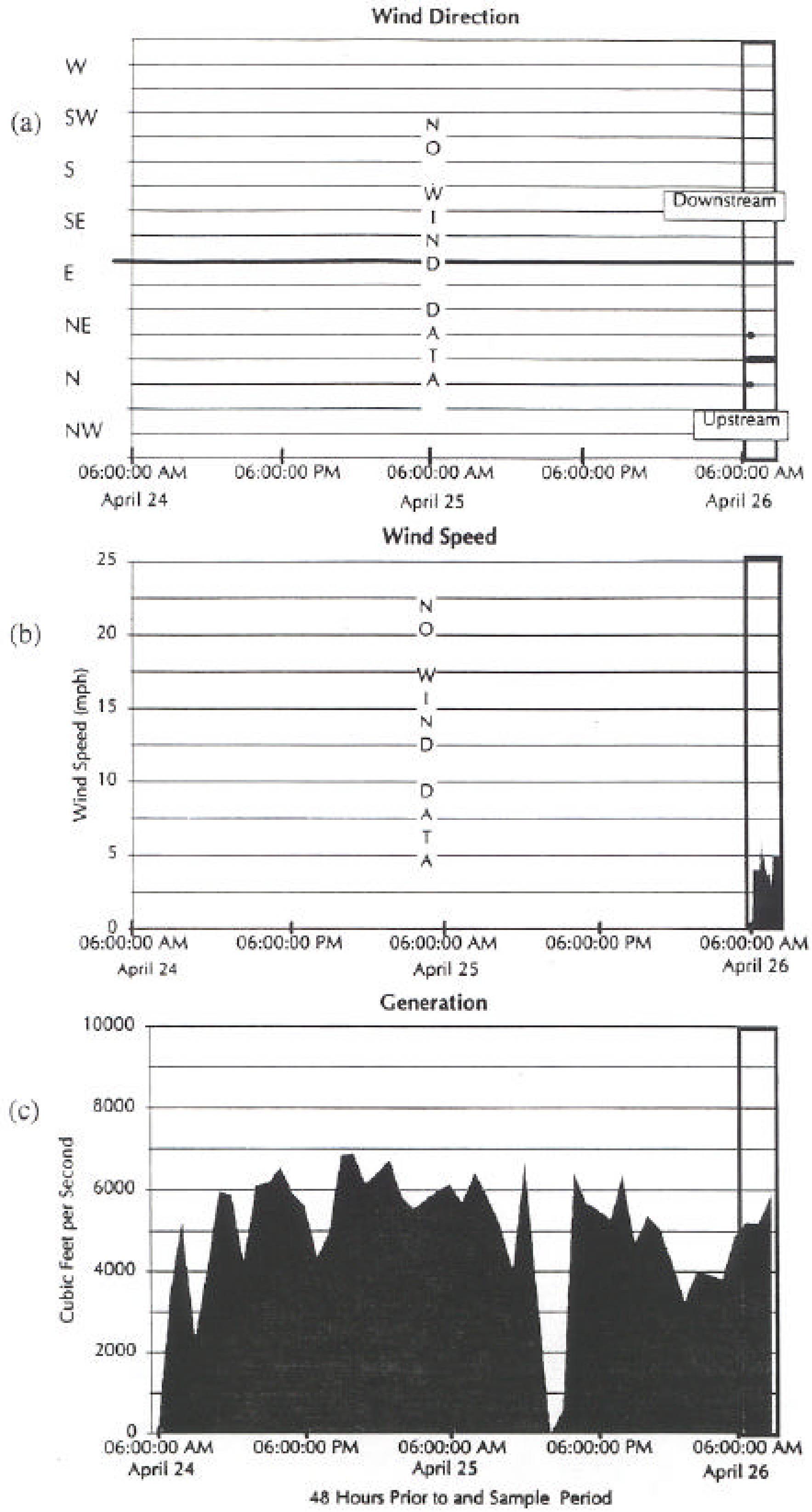
(b)

(c)



Wind Direction (a), Wind Speed (b), and Reservoir Outflow (c) for the 48 hours prior wind direction, wind speed, and reservoir outflow to, and during the sample period on May 16. Sample period enclosed in the bold box on the right side of figures.

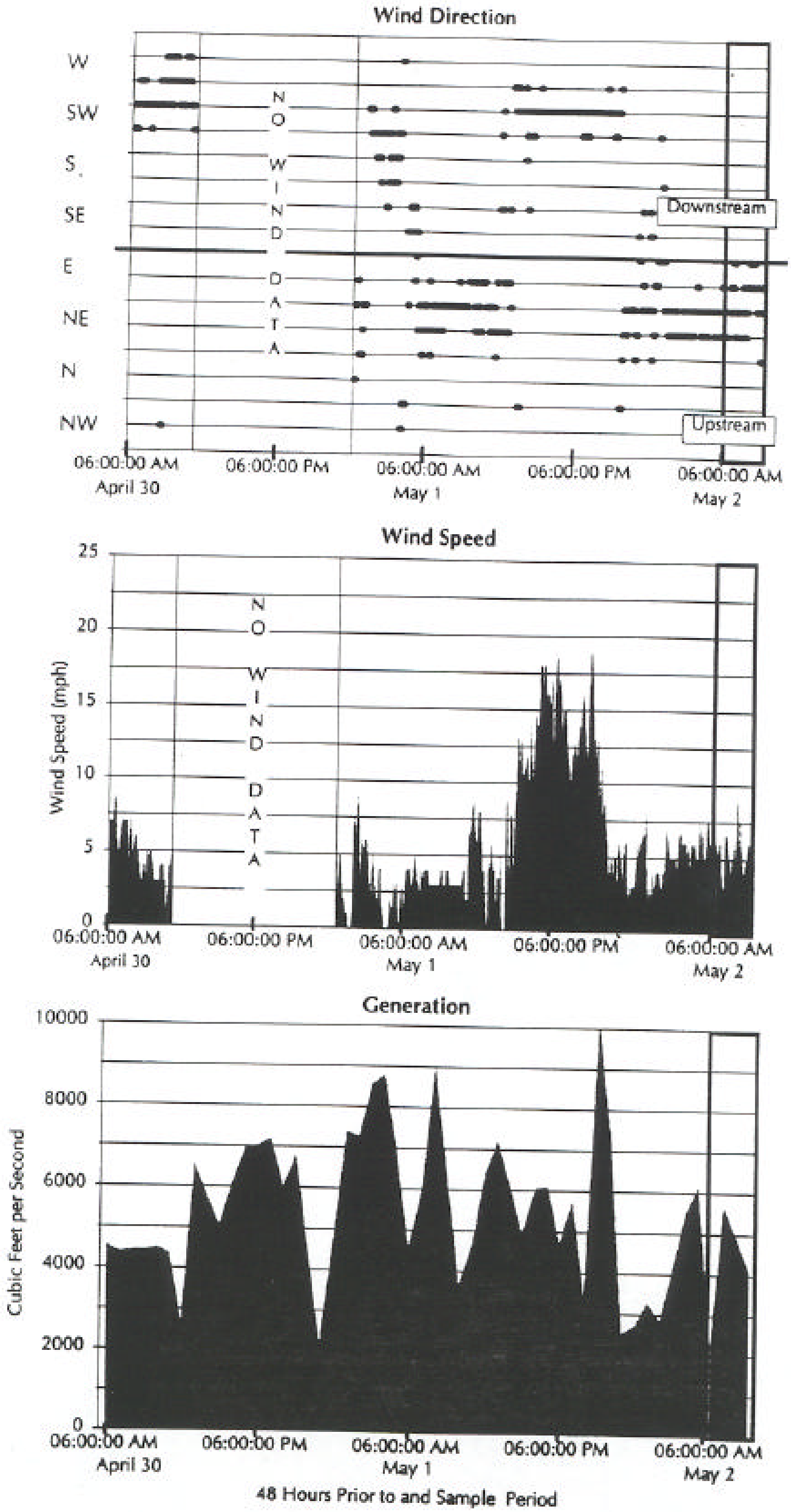
Appendix 4



Wind Direction (a), Wind Speed (b), and Reservoir Outflow (c) for the 48 hours prior wind direction, wind speed, and reservoir outflow to, and during the sample period on April 26. Sample period enclosed in the bold box on the right side of figures.

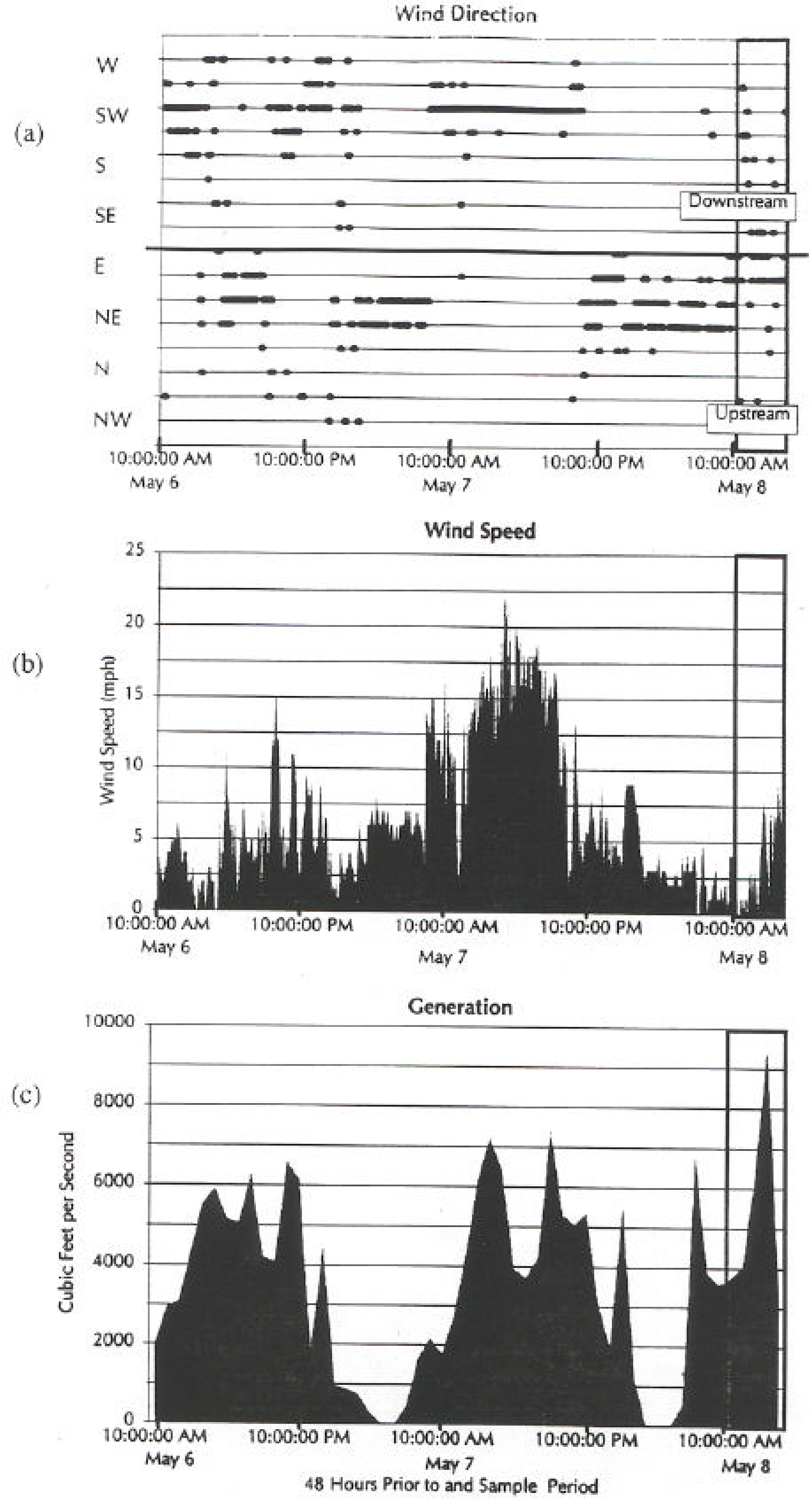
Appendix 5

(a)
(b)
(c)



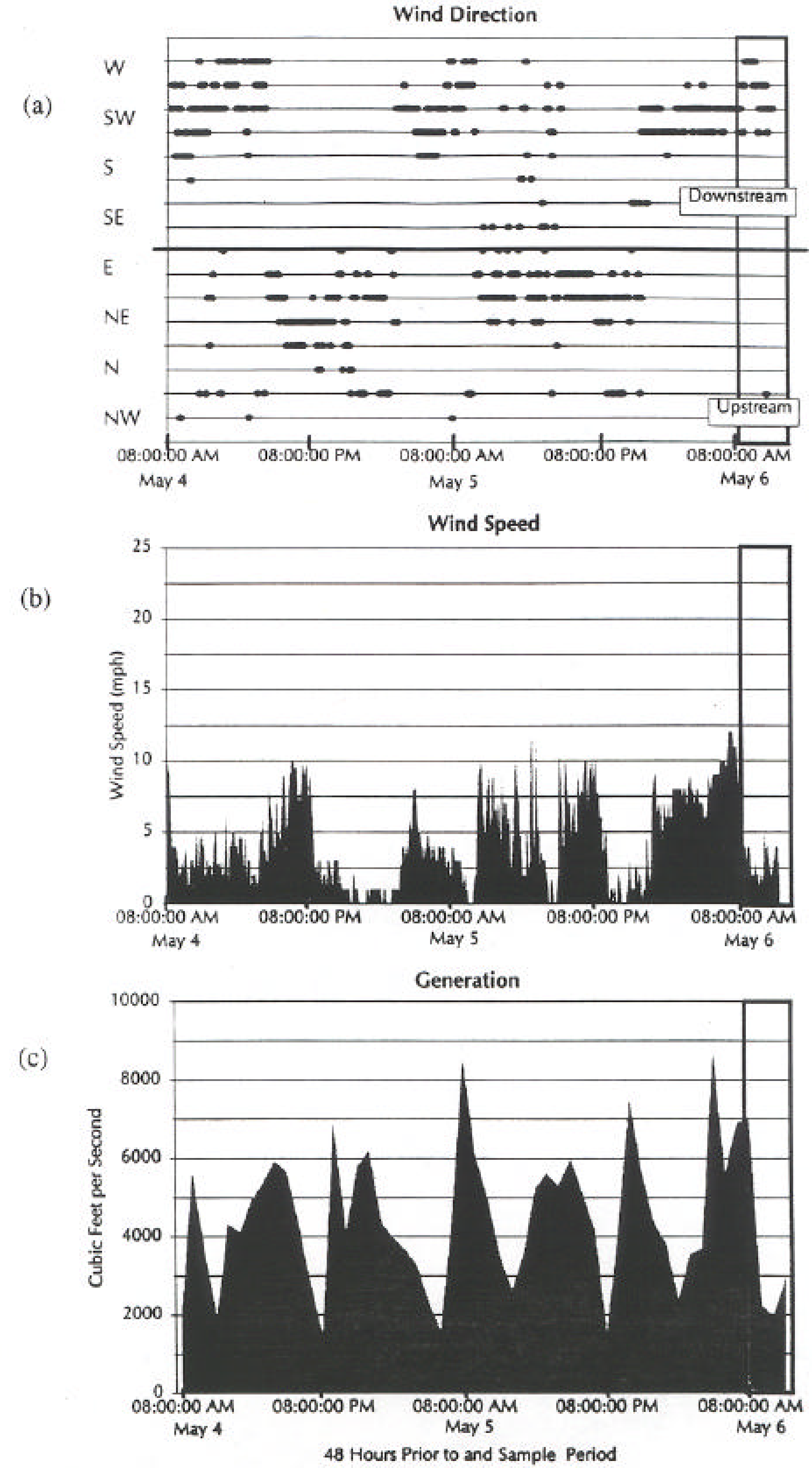
Wind Direction (a), Wind Speed (b), and Reservoir Outflow (c) for the 48 hours prior wind direction, wind speed, and reservoir outflow to, and during the sample period on May 2. Sample period enclosed in the bold box on the right side of figures.

Appendix 6



Wind Direction (a), Wind Speed (b), and Reservoir Outflow (c) for the 48 hours prior wind direction, wind speed, and reservoir outflow to, and during the sample period on May 8. Sample period enclosed in the bold box on the right side of figures.

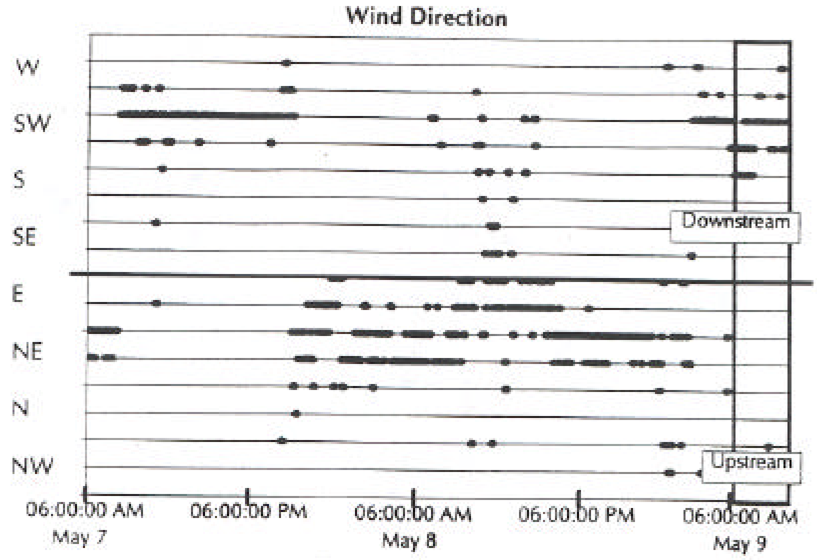
Appendix 7



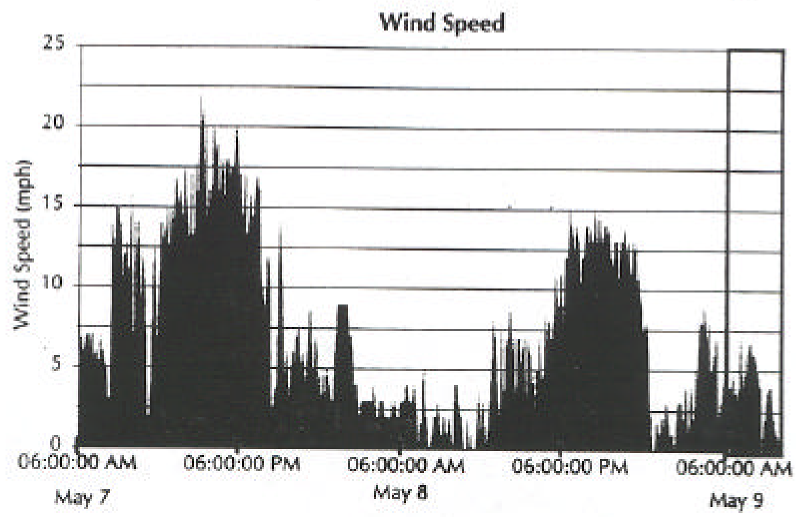
Wind Direction (a), Wind Speed (b), and Reservoir Outflow (c) for the 48 hours prior wind direction, wind speed, and reservoir outflow to, and during the sample period on May 6. Sample period enclosed in the bold box on the right side of figures.

Appendix 8

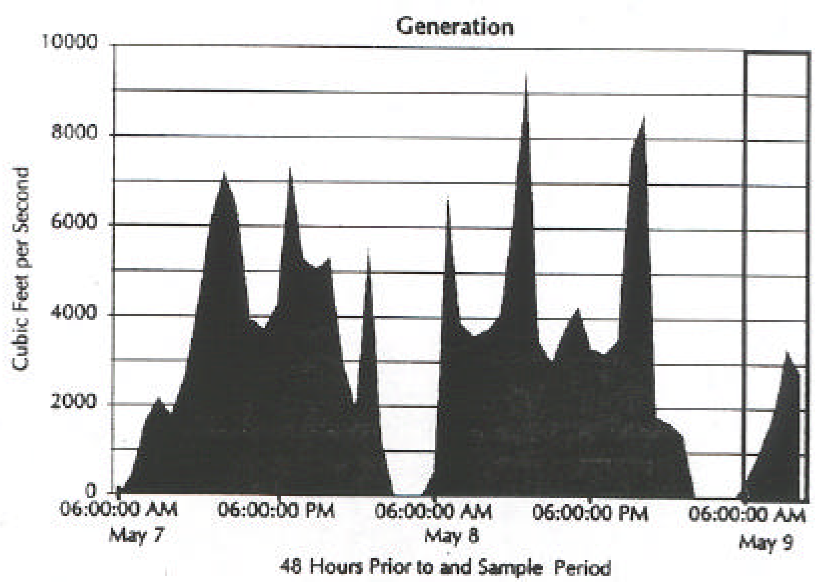
(a)



(b)



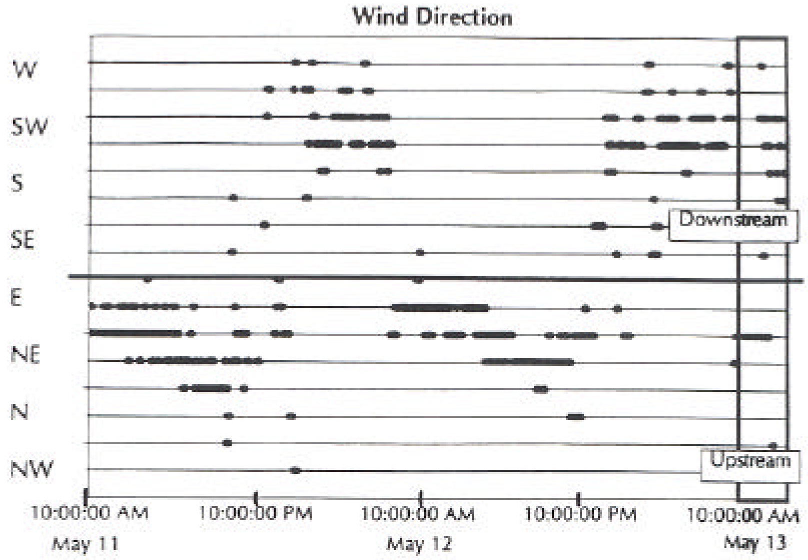
(c)



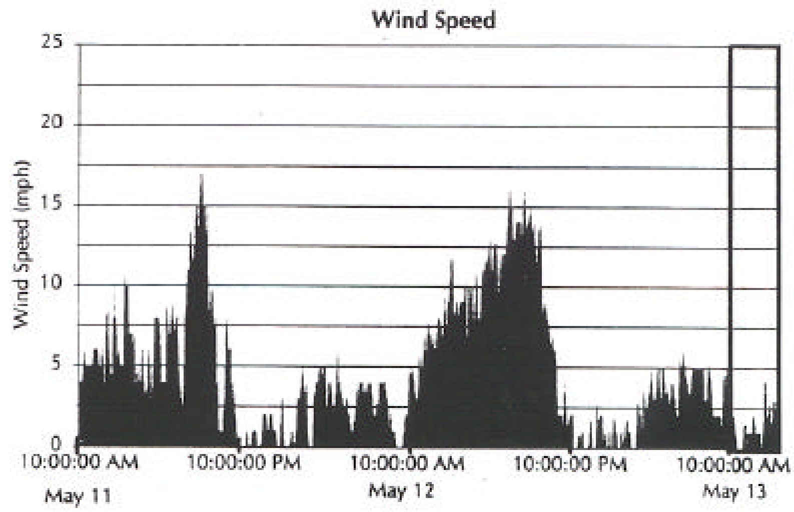
Wind Direction (a), Wind Speed (b), and Reservoir Outflow (c) for the 48 hours prior wind direction, wind speed, and reservoir outflow to, and during the sample period on May 9. Sample period enclosed in the bold box on the right side of figures.

Appendix 9

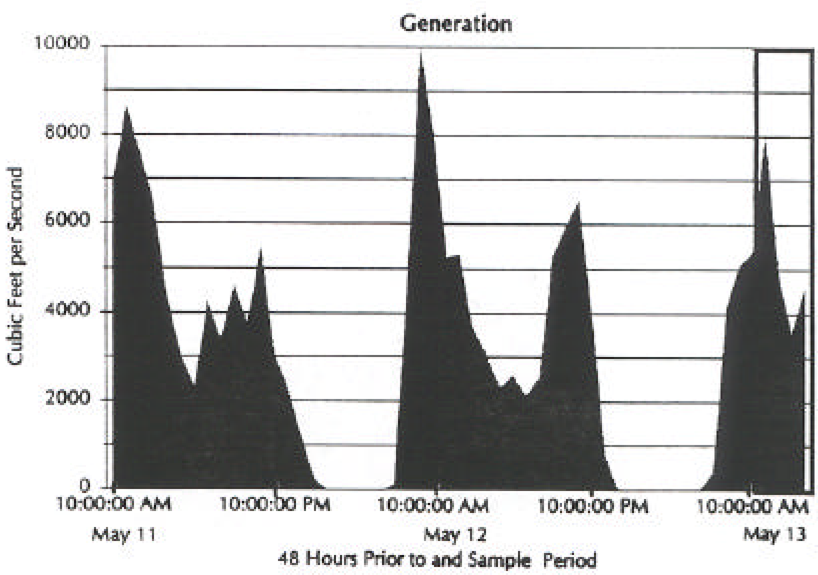
(a)



(b)

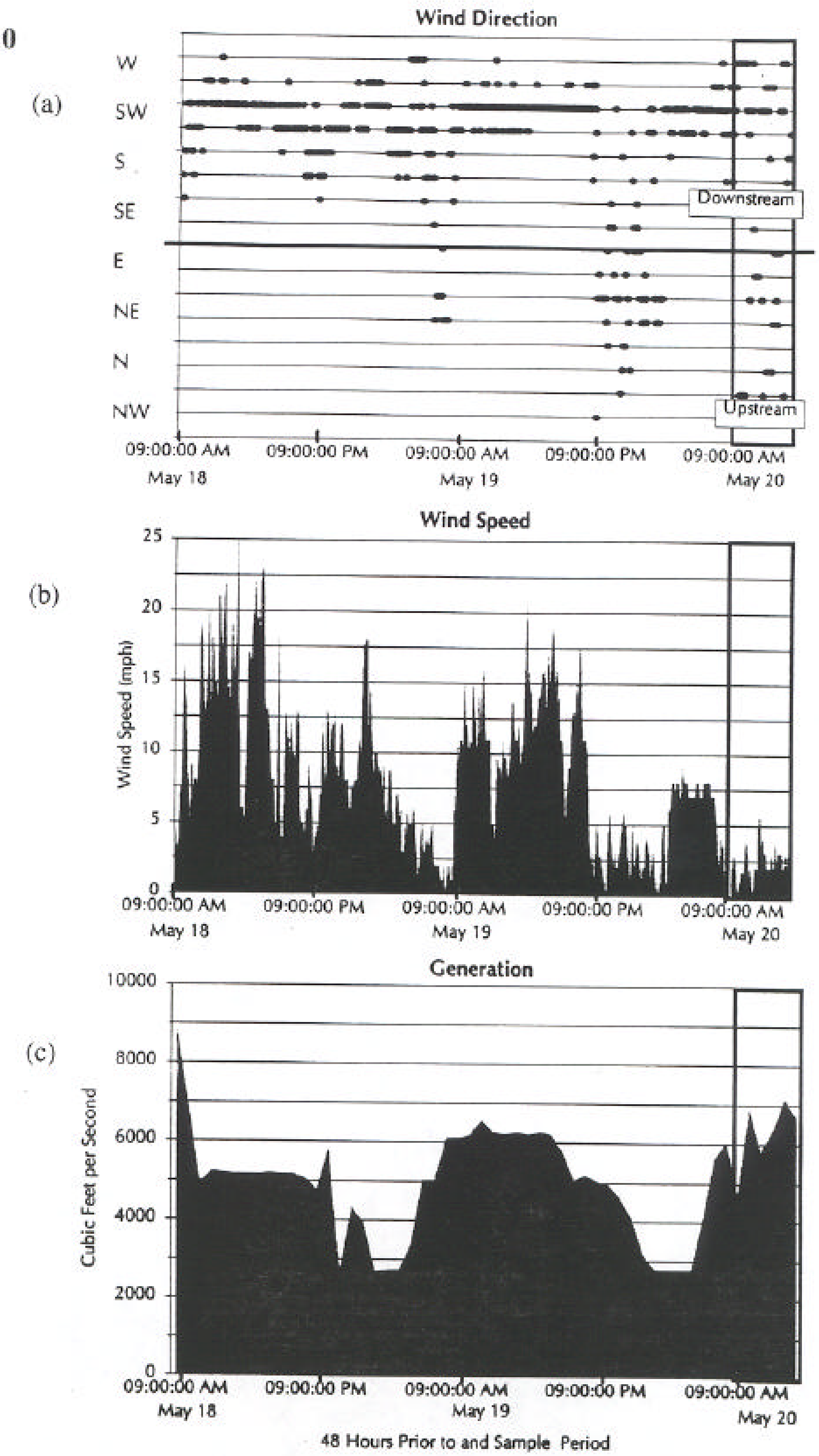


(c)



Wind Direction (a), Wind Speed (b), and Reservoir Outflow (c) for the 48 hours prior wind direction, wind speed, and reservoir outflow to, and during the sample period on May 13. Sample period enclosed in the bold box on the right side of figures.

Appendix 10



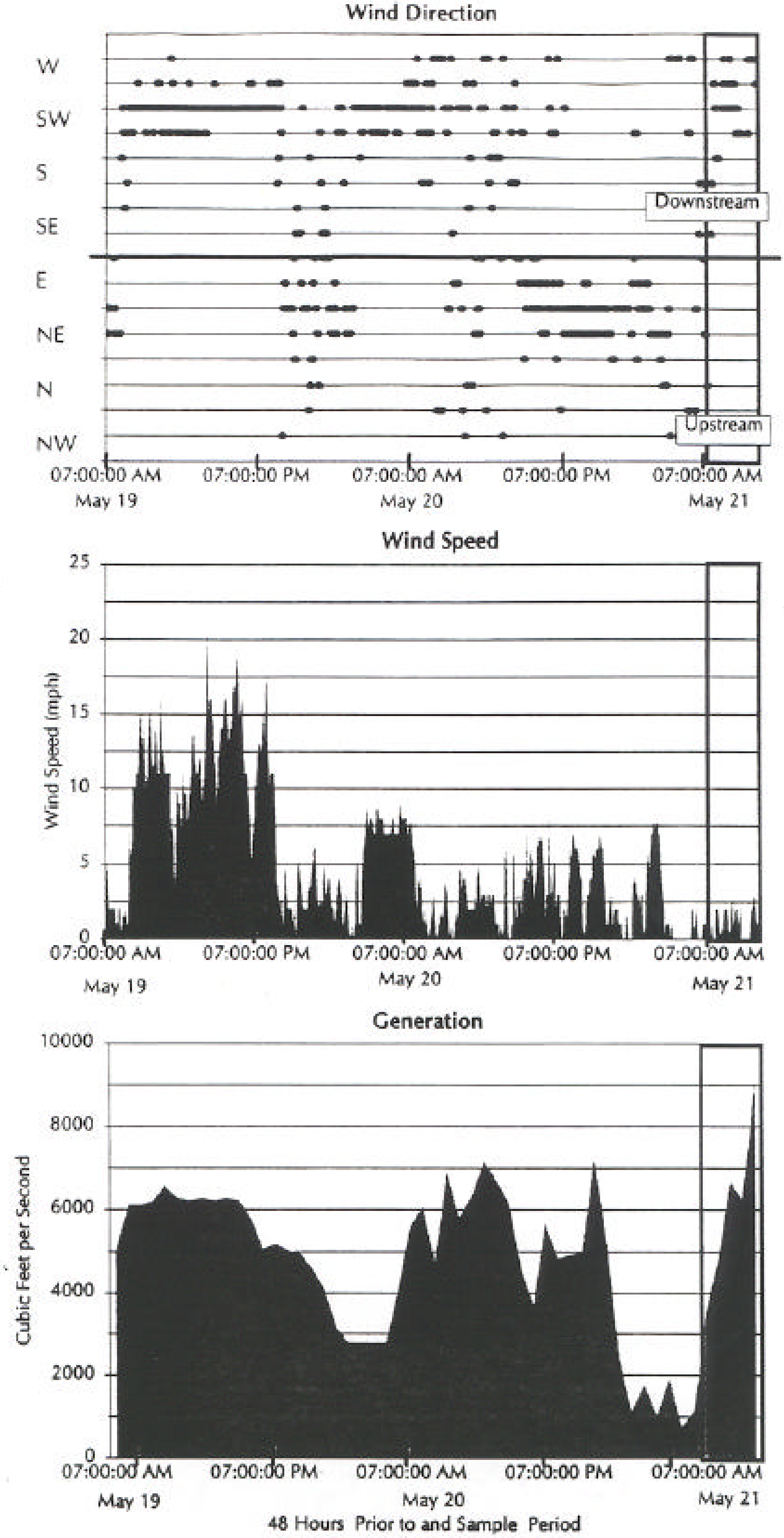
Wind Direction (a), Wind Speed (b), and Reservoir Outflow (c) for the 48 hours prior wind direction, wind speed, and reservoir outflow to, and during the sample period on May 20. Sample period enclosed in the bold box on the right side of figures.

Appendix 11

(a)

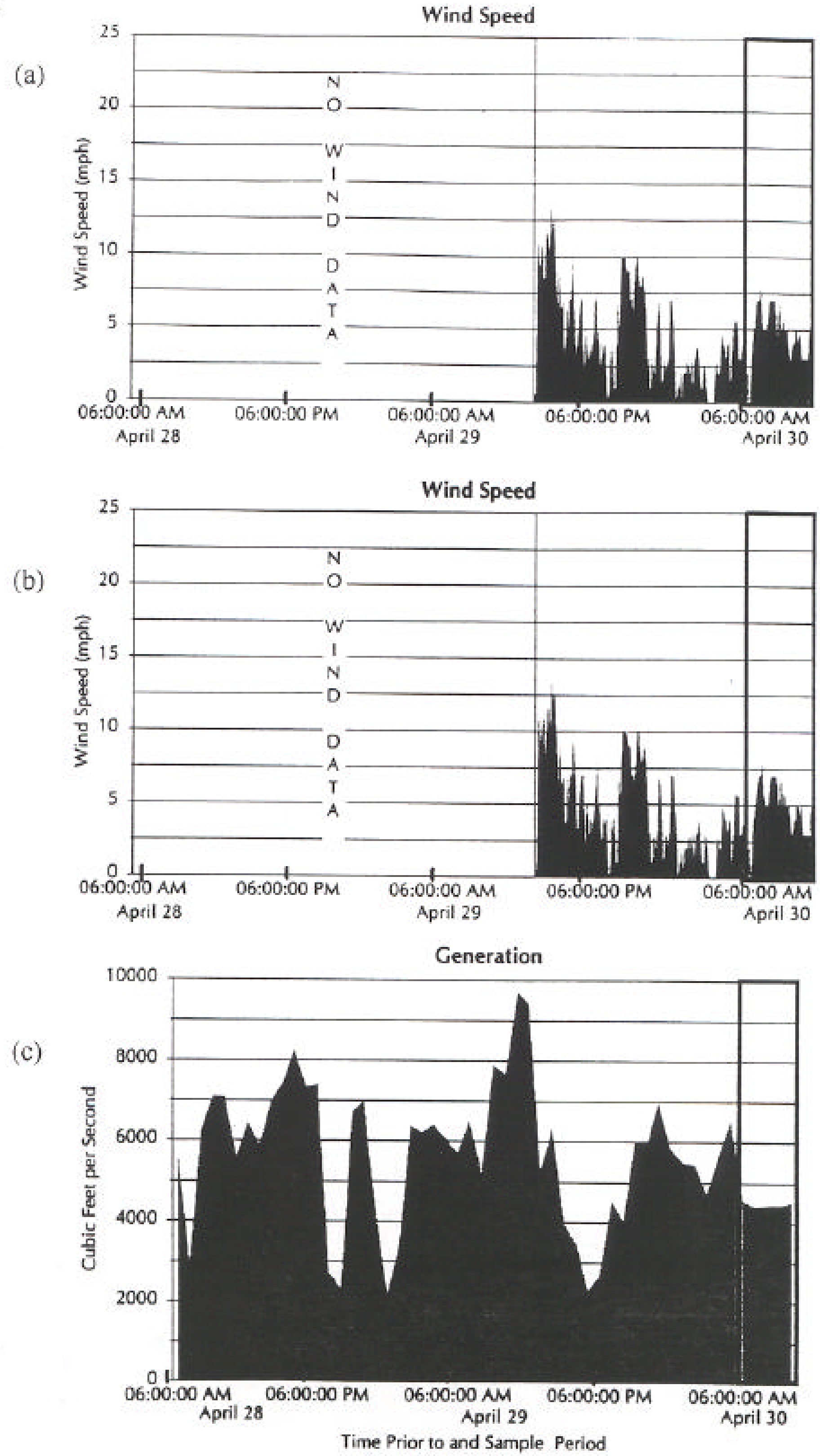
(b)

(c)



Wind Direction (a), Wind Speed (b), and Reservoir Outflow (c) for the 48 hours prior wind direction, wind speed, and reservoir outflow to, and during the sample period on May 21. Sample period enclosed in the bold box on the right side of figures.

Appendix 12



Wind Direction (a), Wind Speed (b), and Reservoir Outflow (c) for the 48 hours prior wind direction, wind speed, and reservoir outflow to, and during the sample period on April 26. Sample period enclosed in the bold box on the right side of figures.