



**U.S. Army Corps of Engineers
Walla Walla District**

Two-Dimensional Hydrodynamic, Water Quality, and Fish Exposure Modeling of the Columbia and Snake Rivers.

Part 5: Ice Harbor Reservoir

FINAL REPORT

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**M.C. Richmond
W.A. Perkins**

**Battelle Pacific Northwest Division
P.O. Box 999
Richland, Washington 99352
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Abstract

One of the major goals for the U.S. Army Corps of Engineers Dissolved Gas Abatement Study is to identify measures that could reduce levels of dissolved gas supersaturation in the Columbia and Snake Rivers caused by spillway discharges. Attaining this goal could contribute significantly to meeting water quality criteria and lowering gas bubble trauma in resident and migrating fish in these rivers. To achieve this goal, the Corps of Engineers is studying various operational and structural alternatives using field investigations and computational modeling tools to simulate the transport of dissolved gas in the river system.

Part 5 of the report series summarizes the development and application of a two-dimensional depth-averaged hydrodynamic and water quality model (MASS2) to the Ice Harbor Reservoir of the Lower Snake River system.

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Two-Dimensional Hydrodynamic, Water Quality, and Fish Exposure Modeling of the Columbia and Snake Rivers. Part 5: Ice Harbor Reservoir

Under Biological Services Contract DACW68-96-D-0002, Delivery Order No. 8, Battelle, Pacific Northwest Division is developing and applying a two-dimensional hydrodynamic, transport model, and fish exposure model to the Lower Columbia and Snake River systems. This work is an element of the U.S. Army Corps of Engineers Dissolved Gas Abatement Program (DGAS).

Part 5 of the report series describes the application of the model to the Ice Harbor Pool of the Snake River. The modeled domain encompasses the following region:

- Lower Monumental Dam, at Snake rivermile (RM) 40
- Ice Harbor Dam, at Snake RM 9.8

1 Application of the Hydrodynamics and Water Quality Models to Ice Harbor Pool

A two-dimensional-depth averaged hydrodynamics and transport model has been developed and applied to the part of the Snake River that forms the Ice Harbor Dam pool. The model simulates time-varying distributions of the depth-averaged velocities, water temperature, and total dissolved gas. Further details concerning the model including the governing equations and solutions procedures are provided in Part 1 of the report series (Richmond, Perkins, and Scheibe, 1998).

The section discusses the general aspects of the application of the models to Ice Harbor Pool. The data used to assign the bathymetry and boundary conditions are described in Appendix A. Summaries of the field data in the calibration and verification simulations are provided in Appendix B through Appendix C.

Hydrodynamics were verified using Spring 1996 and Spring 1997 Acoustic Doppler Current Profiler (ADCP) data. Dissolved gas and temperature verification used the Spring 1996 and Spring 1997 pool study data.

1.1 Model Grid

The computational grid was generated using the Gridgen 9.1 code. Gridgen 9.1 is software for the generation of 3D, multiple block, structured grids. The code was developed for NASA Ames Research Center (Steinbrenner and Chawner, 1995).

To create the grid, a data file containing discrete geographical locations that outline the river shoreline was imported to Gridgen. In Gridgen, curves containing the data points

were created and joined to enclose 2-dimensional flow regions. Grid spacing was set in each flow region and the grids were smoothed using the Gridgen elliptic solver. The elliptic solver was used to minimize grid twist and skew. The flow regions were then joined end to end in the downstream direction to make up the entire flow domain and the entire 2-dimensional grid was written to file. Once the grid was created bottom elevations in each cell were assigned using the bathymetric data and procedure described in Appendix A.

The model grid for Ice Harbor pool is shown in Figure 1. Larger scale maps of the model grid near the Lower Monumental dam and Ice Harbor dam boundaries are shown in Figure 3. Note that several small islands were not included in the model and these were replaced with bottom elevation approximately 2 ft below the low water surface elevation (the water is about 2 ft deep where the islands are).

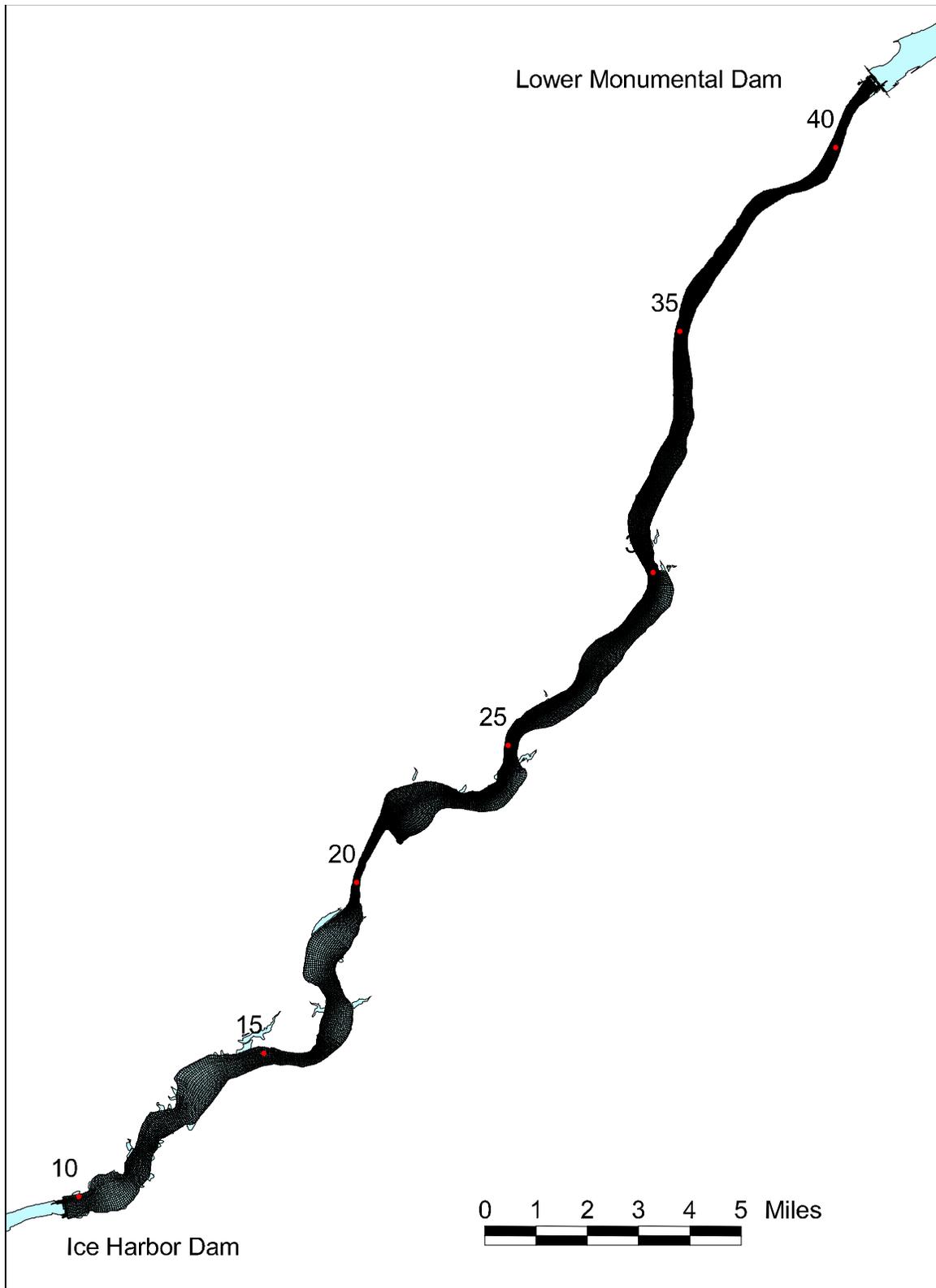


Figure 1. Model grid for Ice Harbor pool.

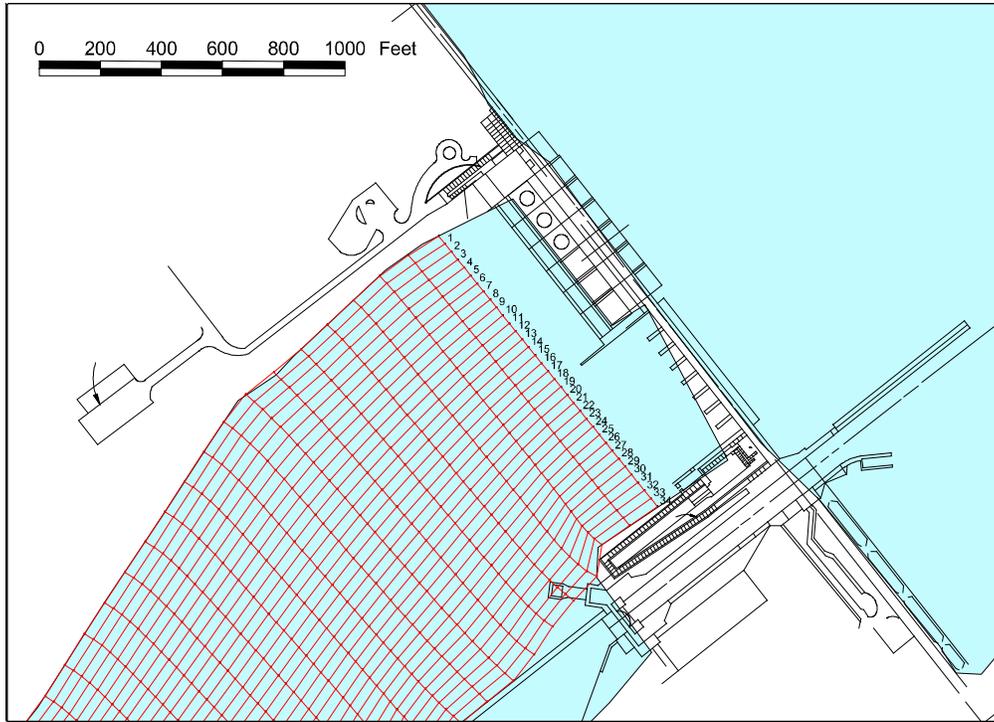


Figure 2. Model grid near Lower Monumental Dam.

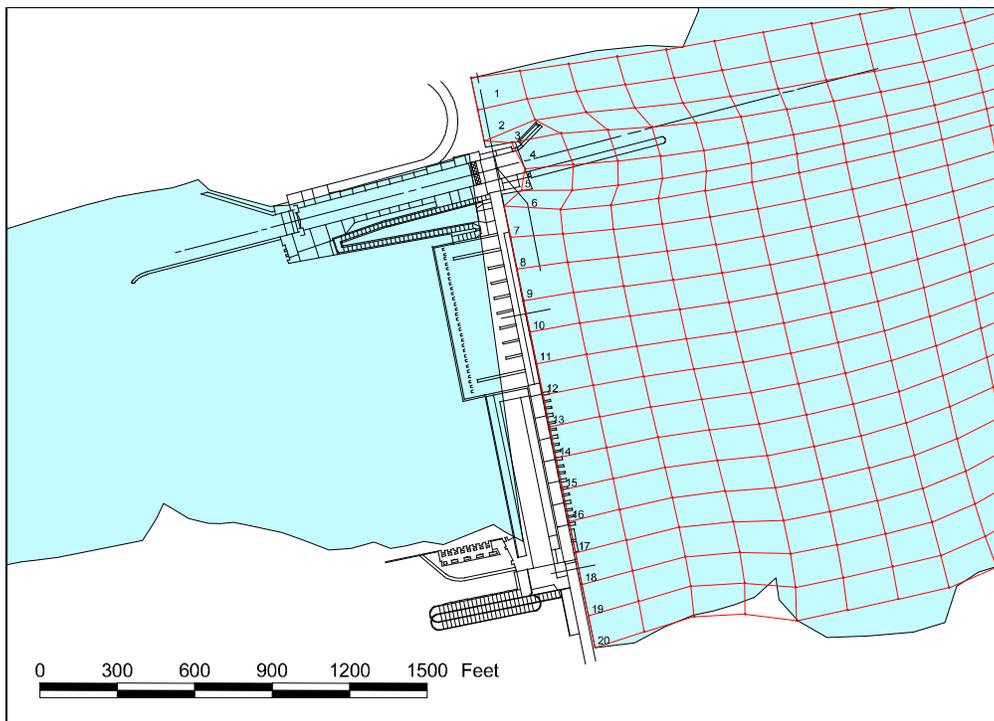


Figure 3. Model grid near Ice Harbor Dam.

1.2 Boundary Conditions

1.2.1 Lower Monumental Dam Sourcing Function

Spillway TDG concentrations were estimated using the Lower Monumental dam TDG sourcing function presented by Schnieder and Wilhelms (1997):

$$131.0 - 26.9 \exp(-2.56 \times 10^{-5} Q_s) \quad (1)$$

where

S_s = TDG saturation of spillway flow, percent; and

Q_s = spillway flow, cfs.

Forebay temperatures and barometric pressures were used to compute concentration from the saturation estimated using equation (1).

1.3 Hydrodynamics Calibration and Verification

The model hydrodynamics were calibrated primarily using the Lower Monumental dam tailwater elevation gage. ADCP velocity measurements were available for both Little Goose pool study periods. Due to instrumentation problems the coordinates of the ADCP data were subject to uncertain errors. Therefore, at this time, use of the ADCP data was restricted to qualitative comparisons with the model simulations.

In all simulations in this report a time step of 50 seconds was used. The simulations also used constant longitudinal and lateral turbulent eddy viscosities of $0.2 \text{ ft}^2/\text{s}$.

1.3.1 Lower Monumental Tailwater

The first step in the calibration procedure was to select a spatially uniform value of the Manning roughness coefficient that would yield computed water surface elevations in satisfactory agreement with the Lower Monumental Dam tailwater gage. The Spring 1997 pool study period was selected for calibration. Simulations were performed using Manning n values in the range of 0.021 to 0.029. Figure 5 compares the model simulation and measured tailwater elevation for a n-value of 0.021 which was chosen as the final parameter value to be used in the remainder of the Ice Harbor Pool simulations.

The selected n-value was verified for the Summer 1997 study period. The verification results are shown in Figure 5.

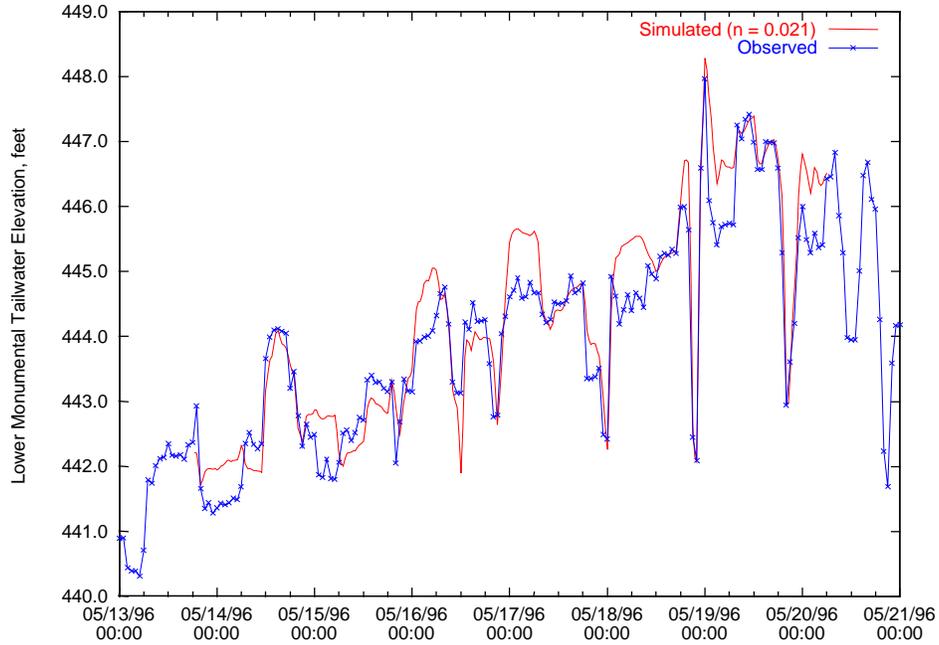


Figure 4. Comparison of simulated (Manning’s $n = 0.021$) and measured water surface elevation at the Lower Monumental dam tailwater gage during the Spring 1996 study period

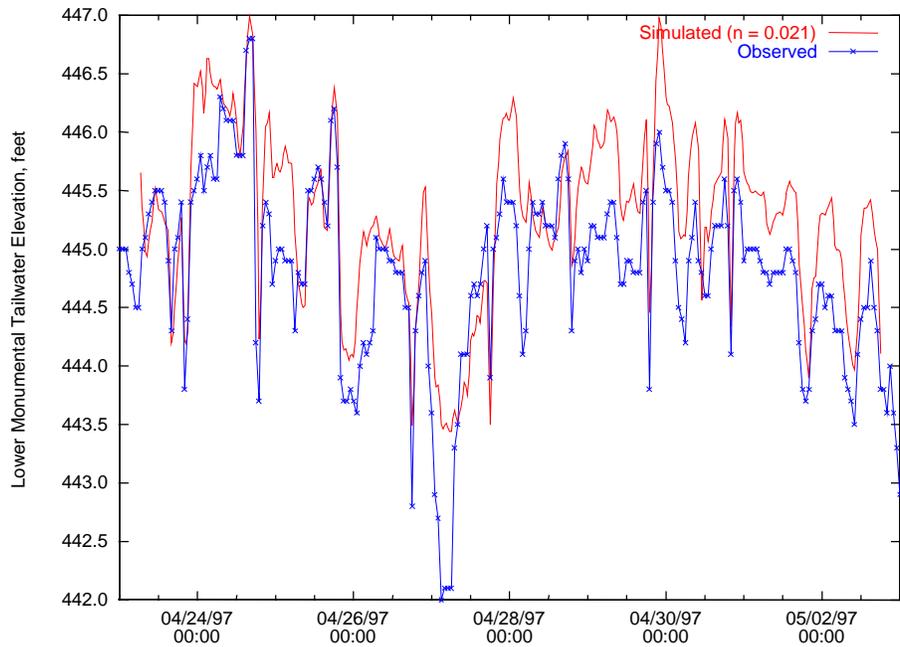


Figure 5. Comparison of simulated (Manning’s $n = 0.021$) and measured water surface elevation at the Lower Monumental dam tailwater gage during the Spring 1997 study period

1.3.2 Spring 1996 ADCP Data

Once the Manning n value was selected, the model was run for the operational conditions that existed when the Spring 1996 ADCP measurements were performed. The Manning n value was not altered from the value of 0.021 selected from the tailwater calibration. Simulated velocities are compared to the depth-averaged ADCP data in Figure 6 through Figure 28.

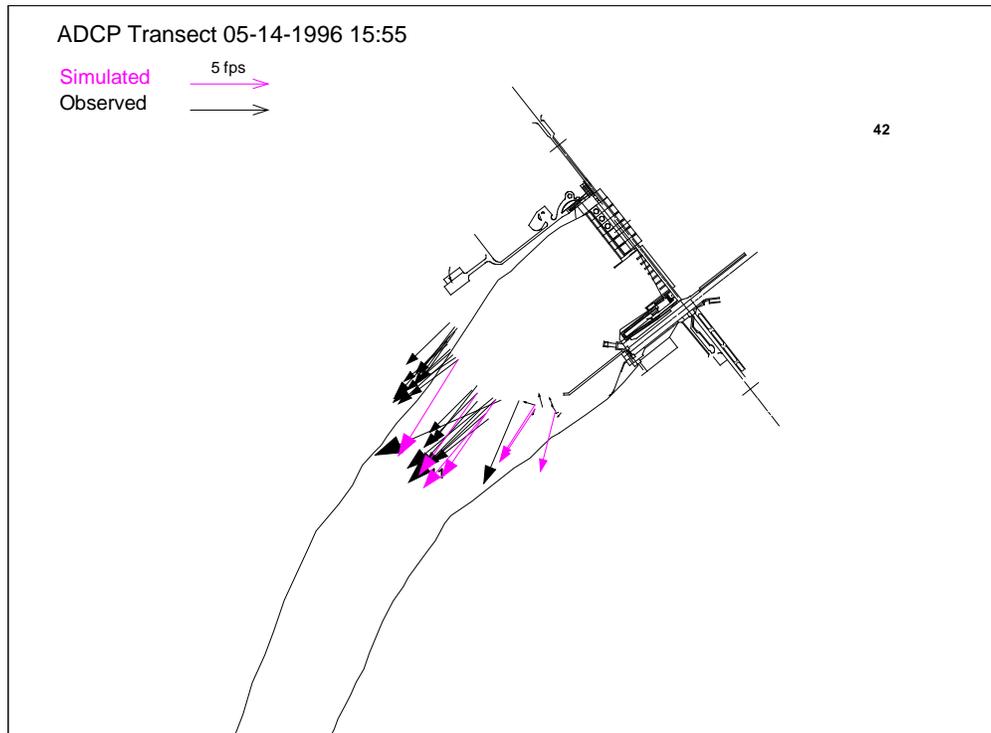


Figure 6. Simulated and observed depth-averaged velocities near Lower Monumental Dam on 5-14-1996.

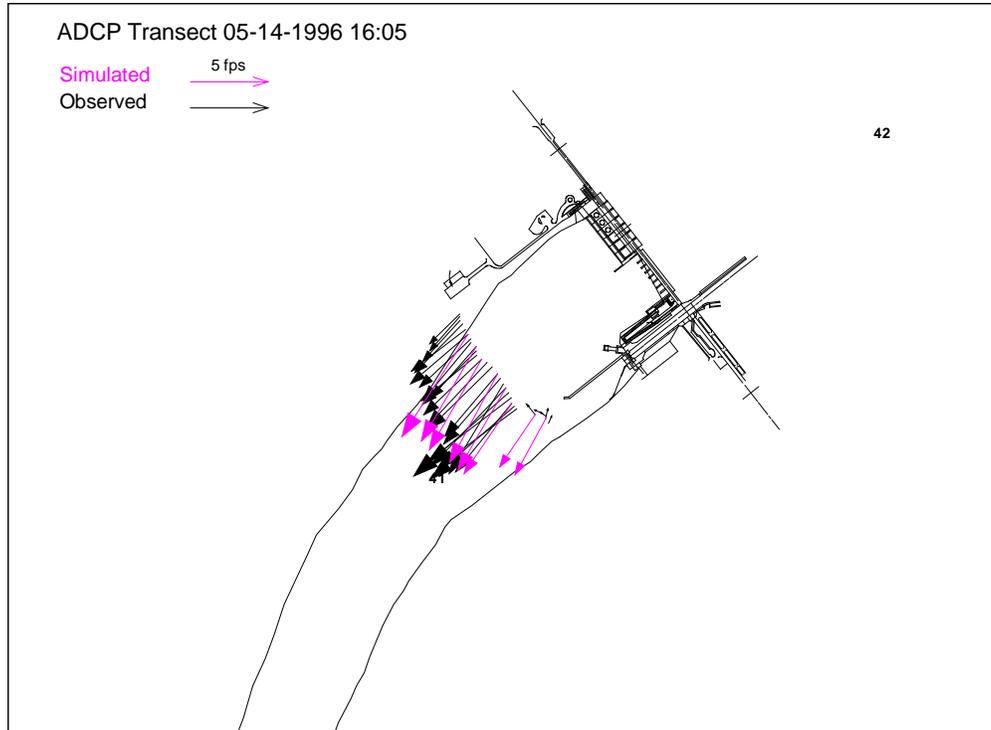


Figure 7. Simulated and observed depth-averaged velocities near Lower Monumental Dam on 5-14-1996.

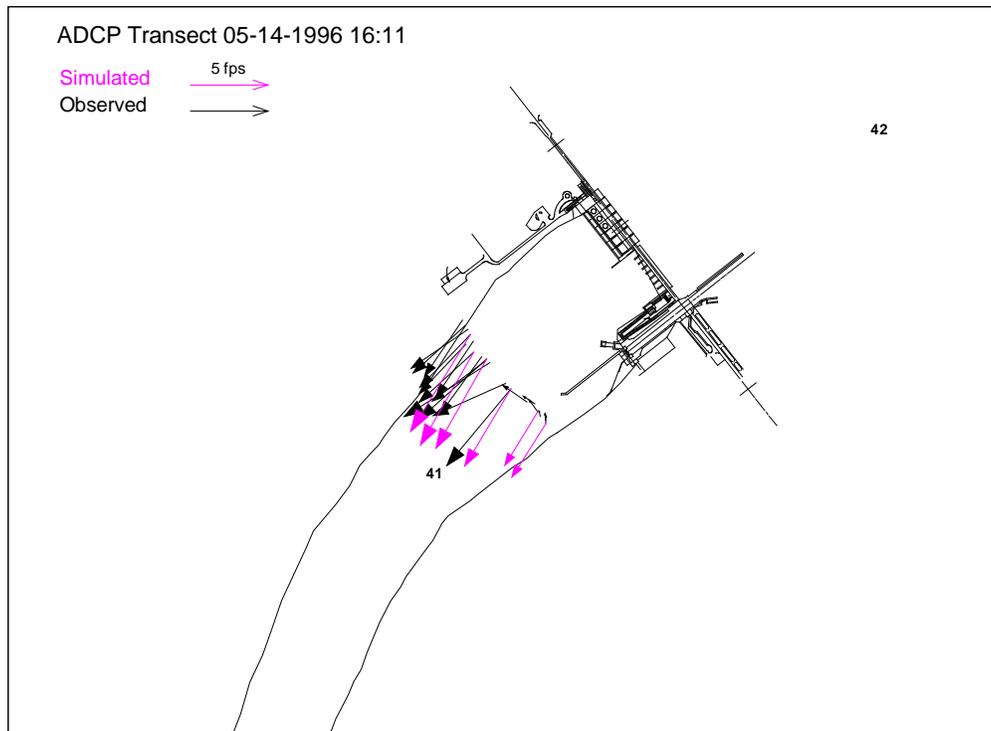


Figure 8. Simulated and observed depth-averaged velocities near Lower Monumental Dam on 5-14-1996.

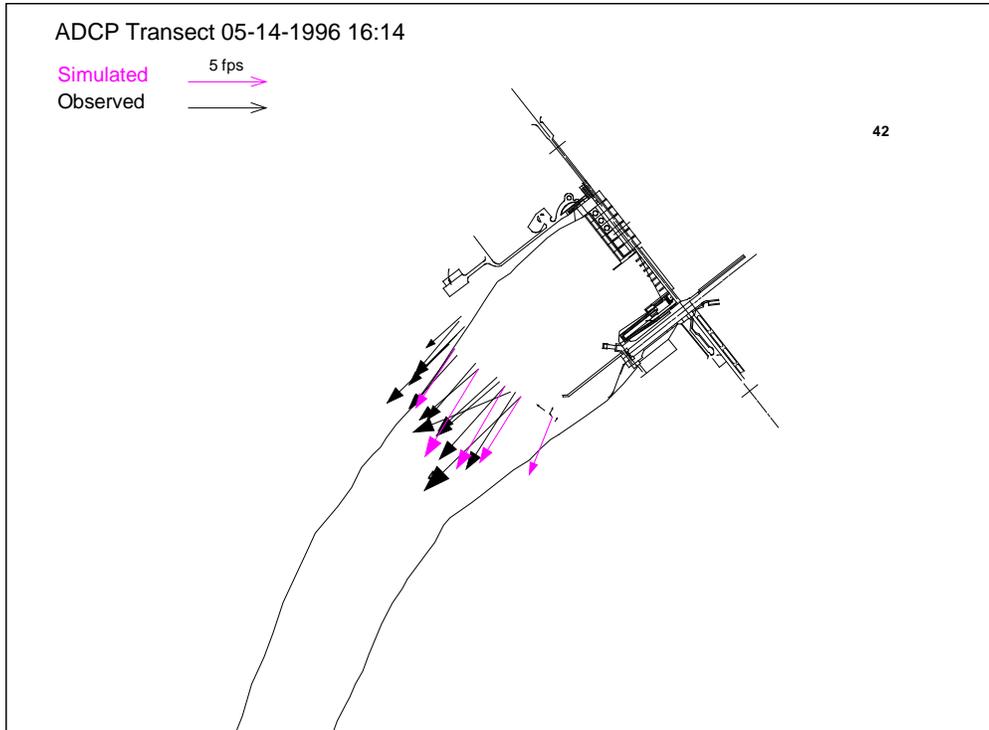


Figure 9. Simulated and observed depth-averaged velocities near Columbia River Mile 41 on 5-14-1996.

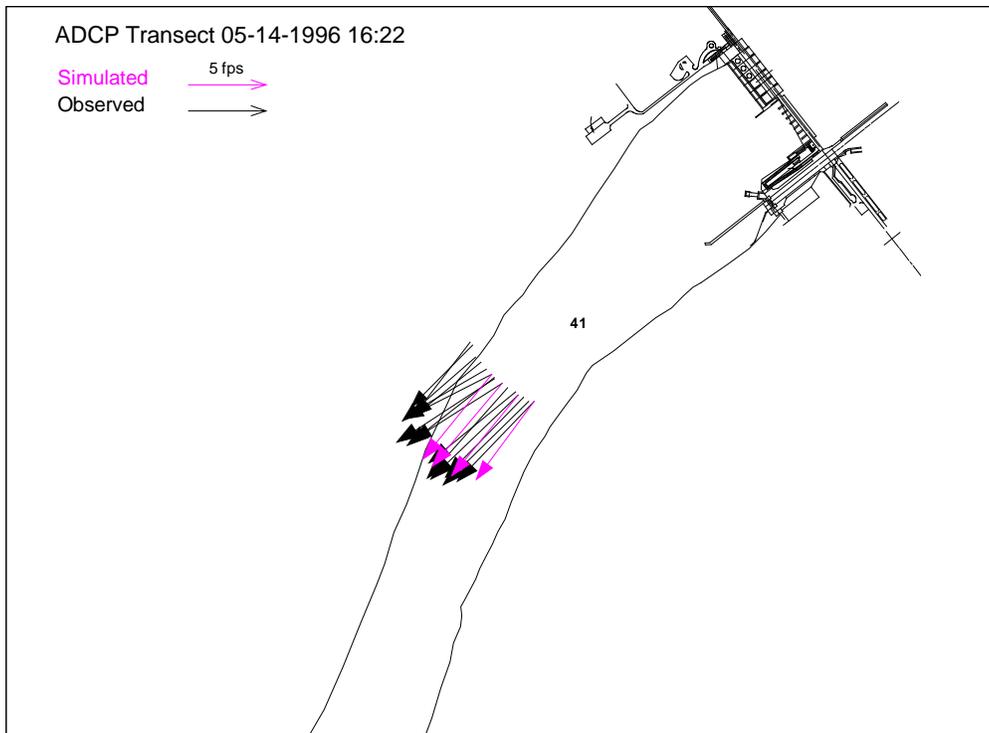


Figure 10. Simulated and observed depth-averaged velocities near Columbia River Mile 41 on 5-14-1996.

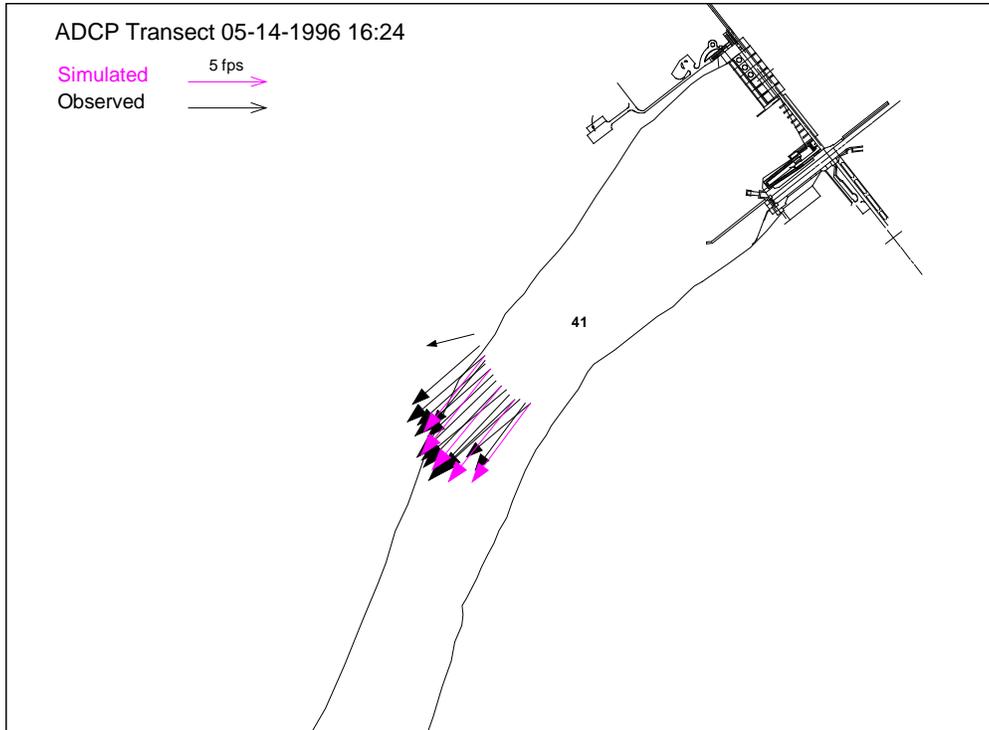


Figure 11. Simulated and observed depth-averaged velocities near Columbia River Mile 41 on 5-14-1996.

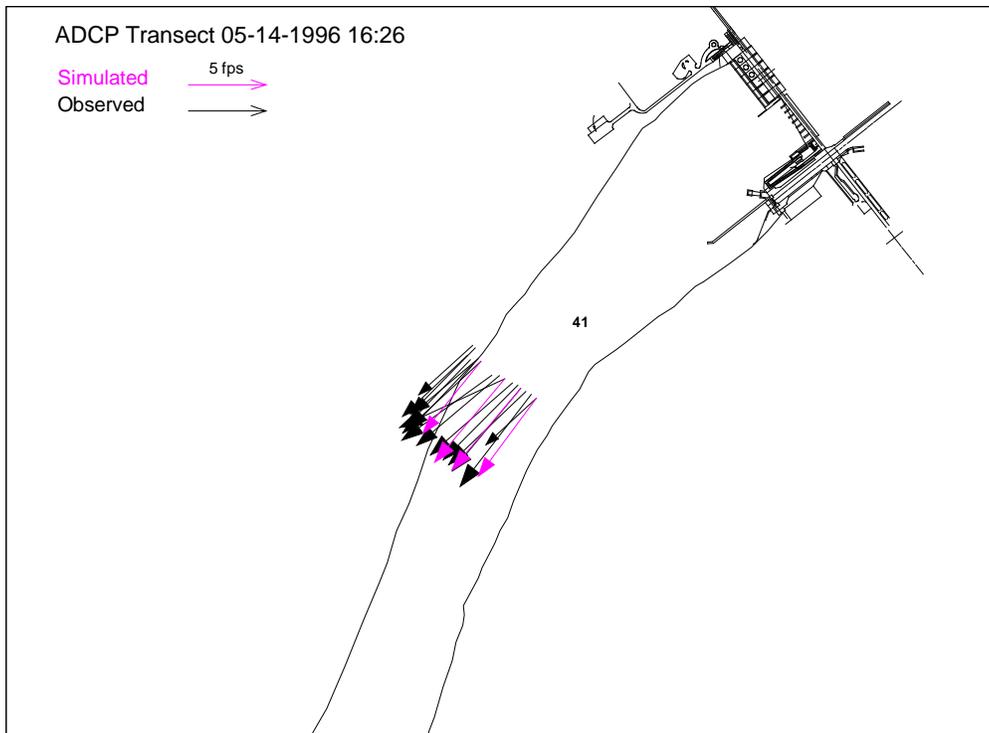


Figure 12. Simulated and observed depth-averaged velocities near Columbia River Mile 40.5 on 5-14-1996.

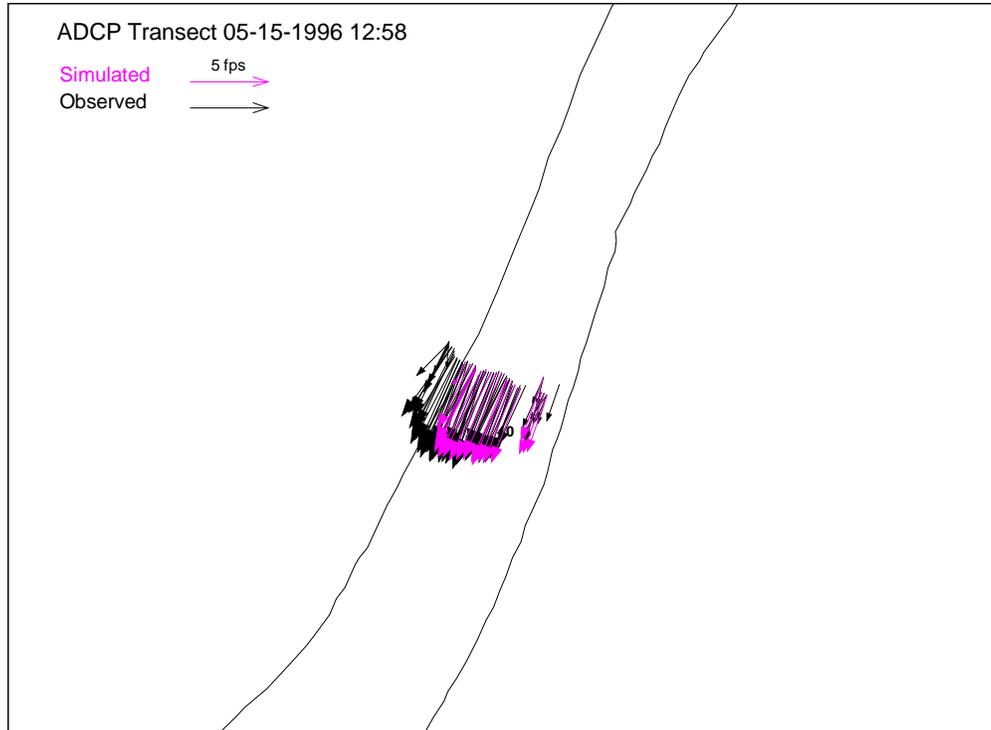


Figure 13. Simulated and observed depth-averaged velocities near Columbia River Mile 40 on 5-15-1996.

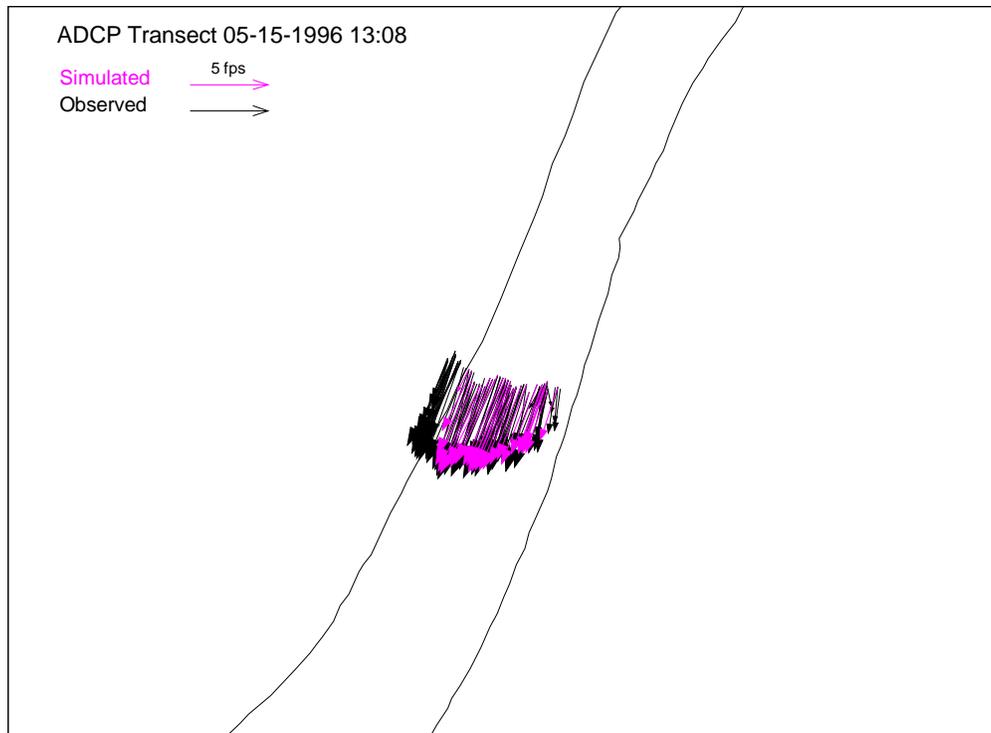


Figure 14. Simulated and observed depth-averaged velocities near Columbia River Mile 40 on 5-15-1996.

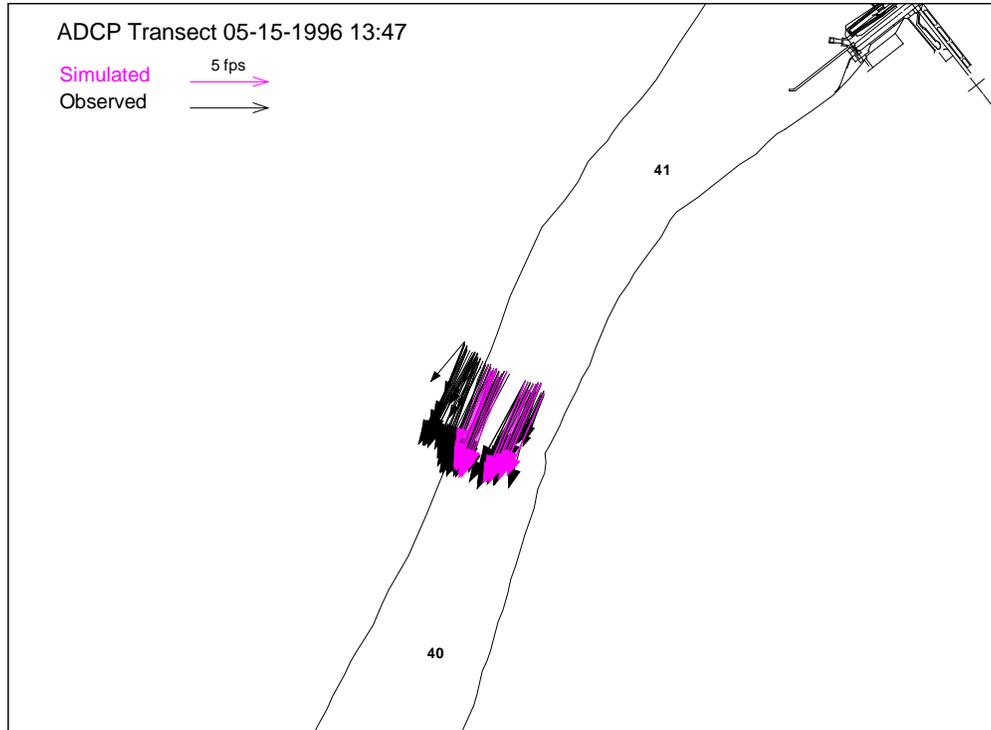


Figure 15. Simulated and observed depth-averaged velocities near Columbia River Mile 40.5 on 5-15-1996.

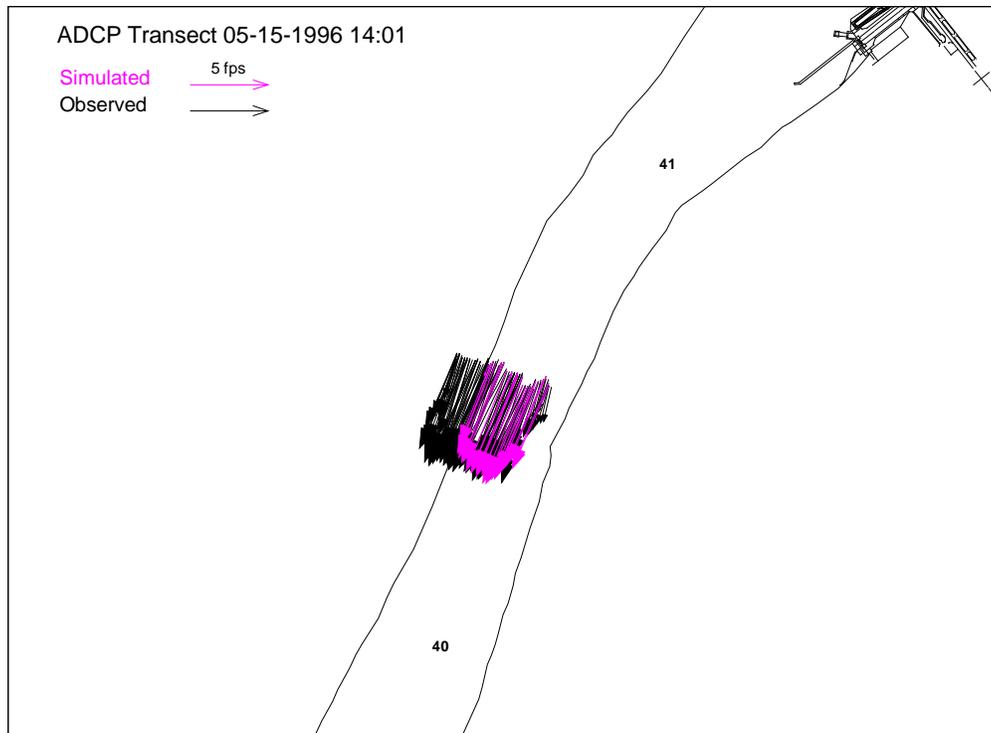


Figure 16. Simulated and observed depth-averaged velocities near Columbia River Mile 40.5 on 5-15-1996.

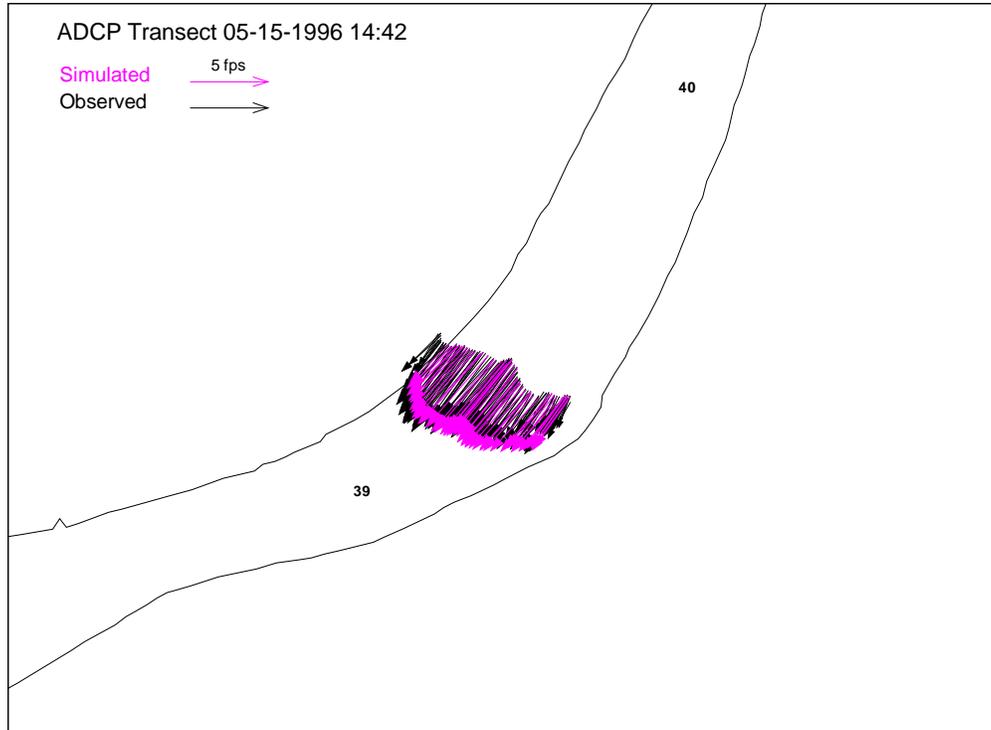


Figure 17. Simulated and observed depth-averaged velocities near Columbia River Mile 39 on 5-15-1996.

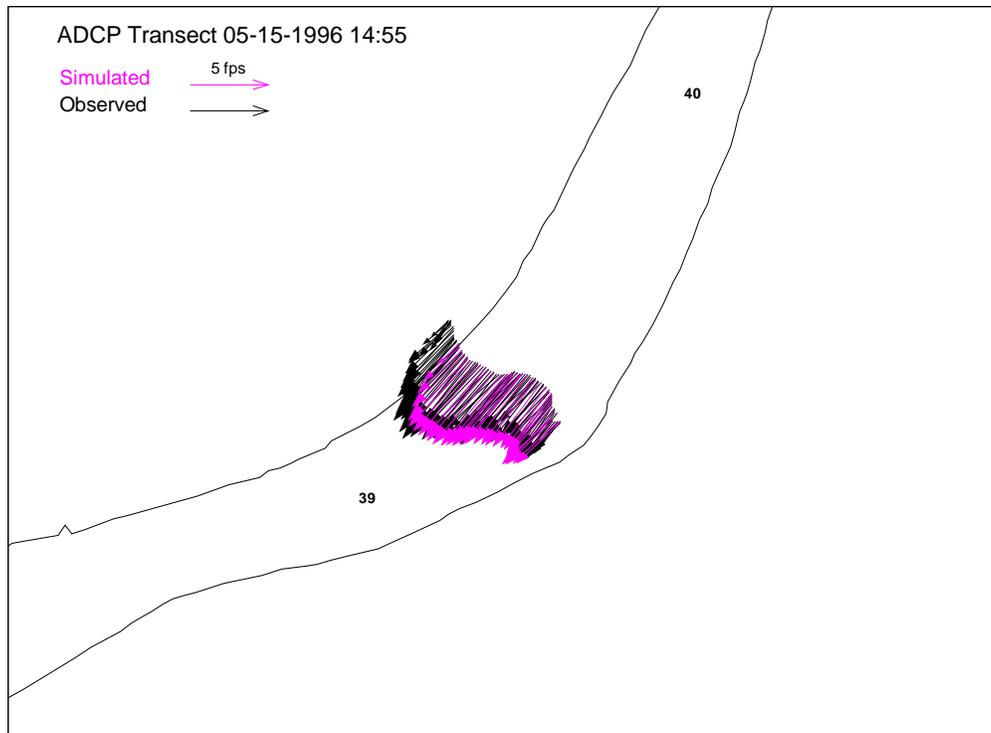


Figure 18. Simulated and observed depth-averaged velocities near Columbia River Mile 39 on 5-15-1996.

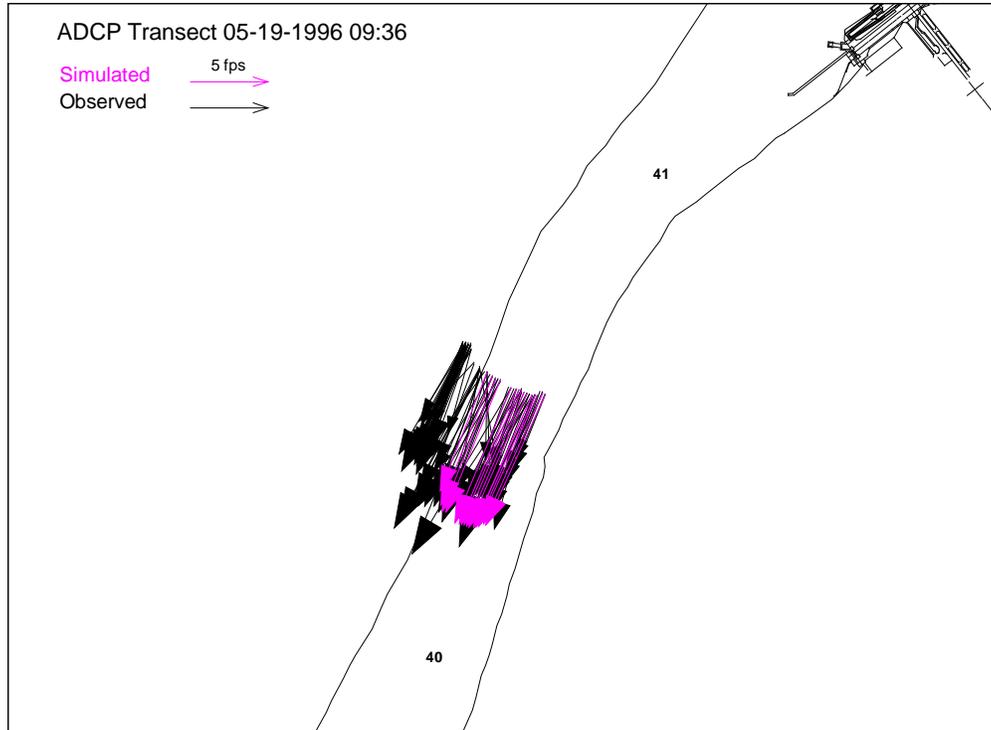


Figure 19. Simulated and observed depth-averaged velocities near Columbia River Mile 40.5 on 5-19-1996.

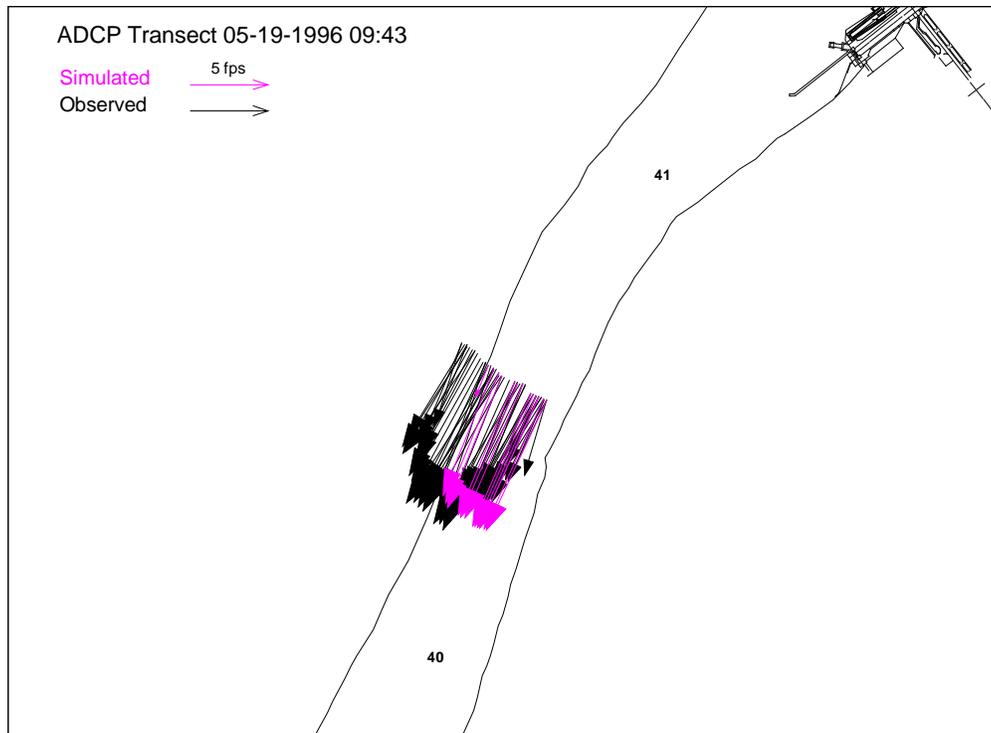


Figure 20. Simulated and observed depth-averaged velocities near Columbia River Mile 40.5 on 5-19-1996.

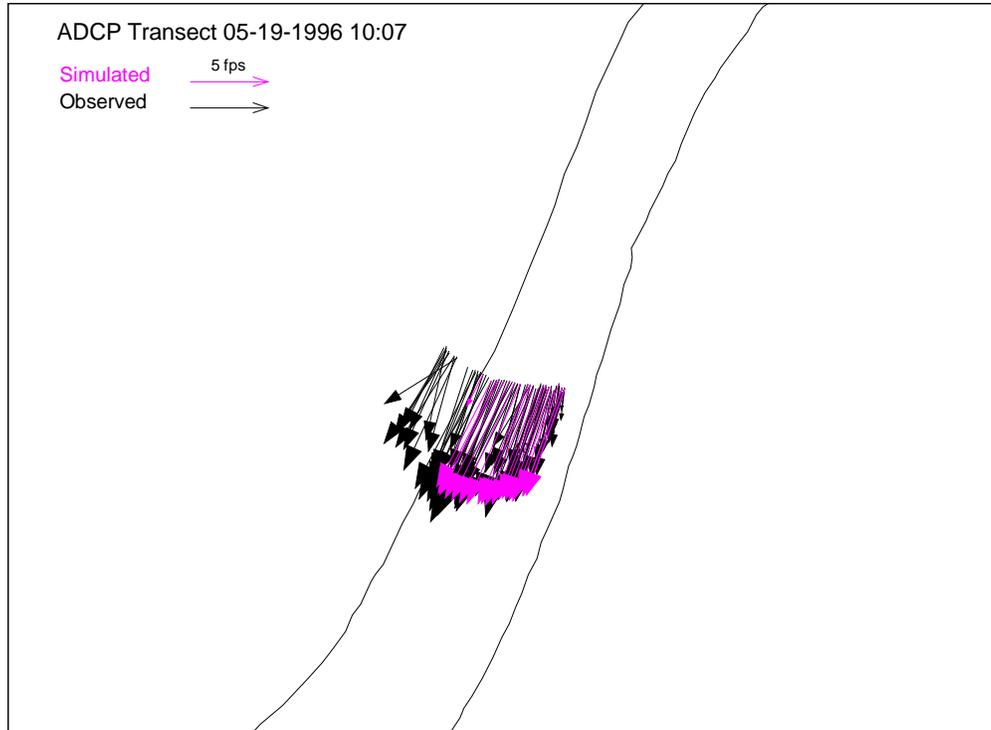


Figure 21. Simulated and observed depth-averaged velocities near Columbia River Mile 40 on 5-19-1996.

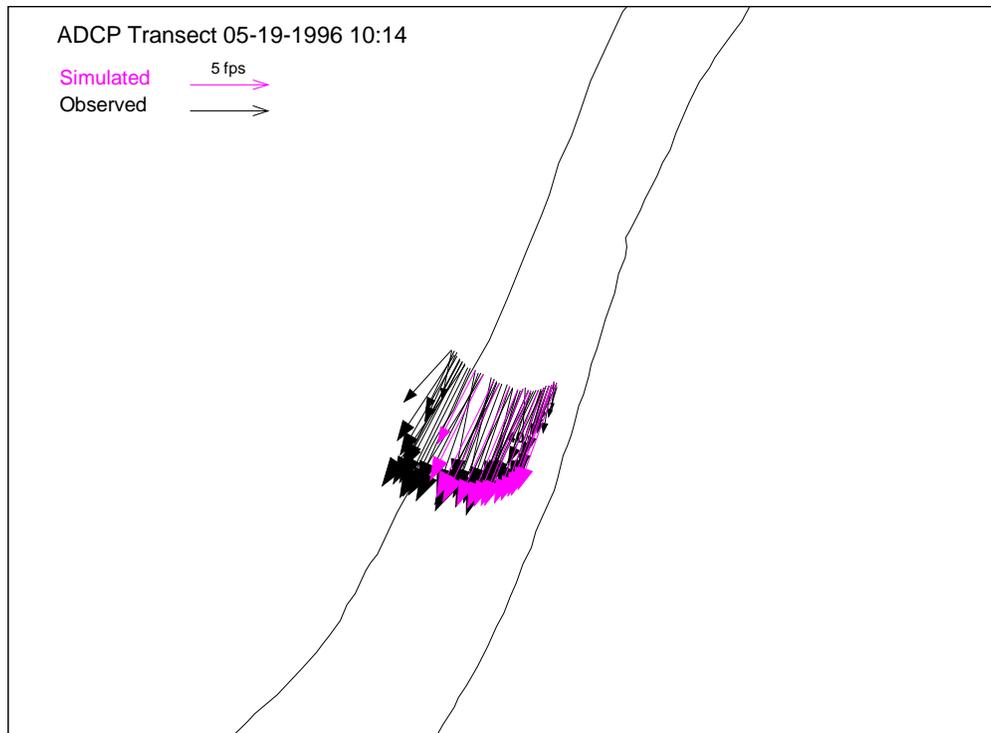


Figure 22. Simulated and observed depth-averaged velocities near Columbia River Mile 40 on 5-19-1996.

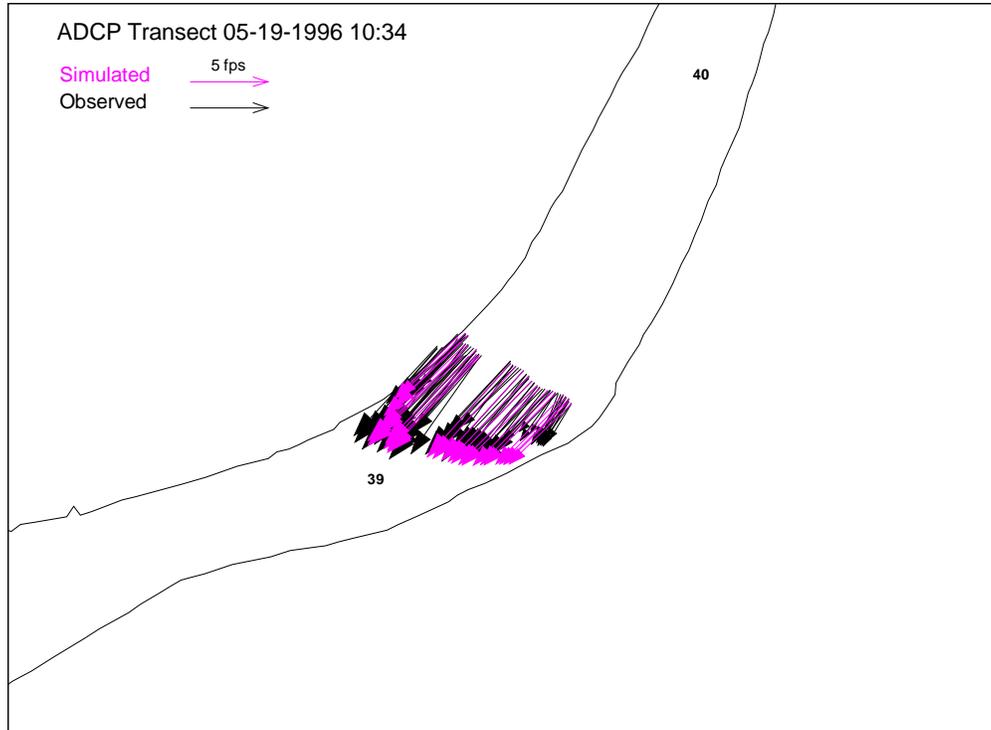


Figure 23. Simulated and observed depth-averaged velocities near Columbia River Mile 39 on 5-19-1996.

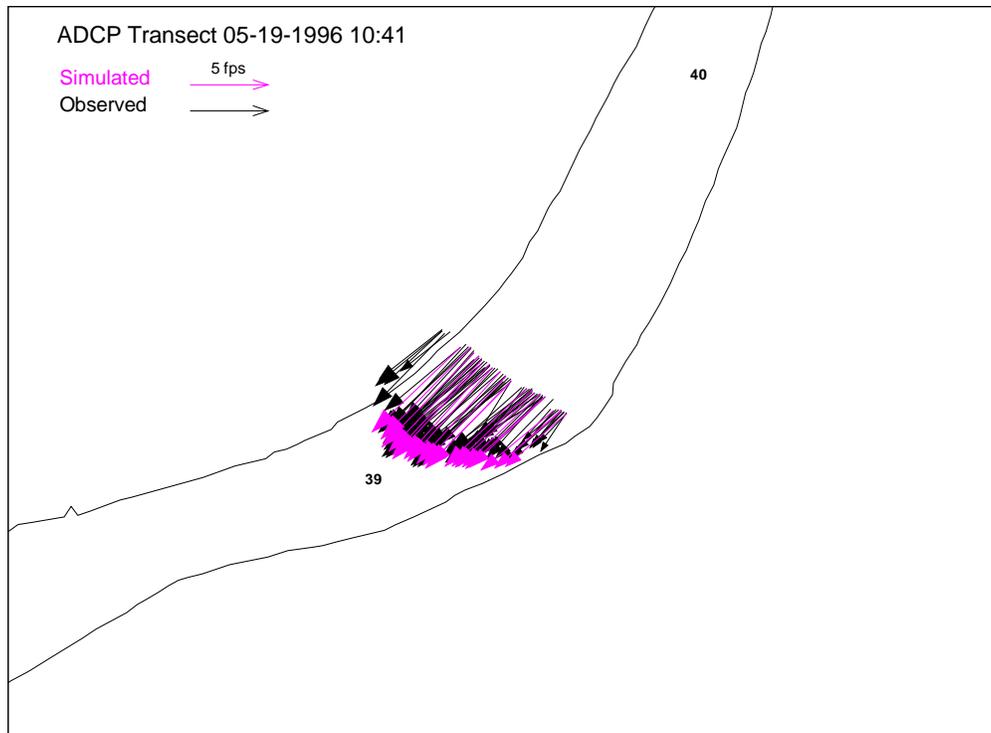


Figure 24. Simulated and observed depth-averaged velocities near Columbia River Mile 39 on 5-19-1996.

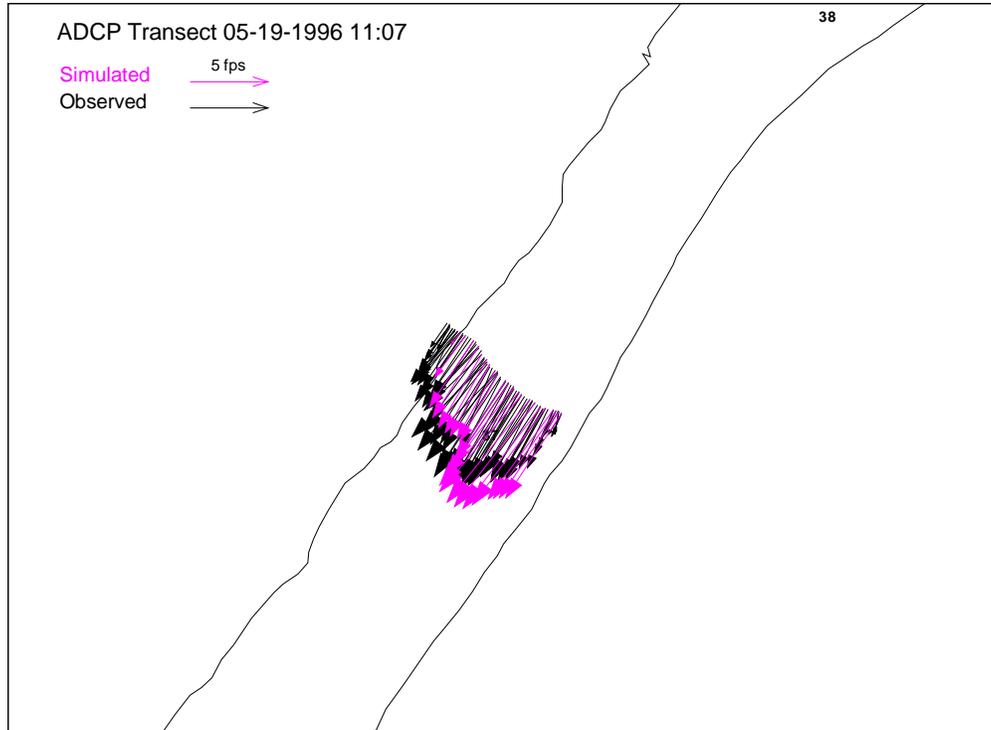


Figure 25. Simulated and observed depth-averaged velocities near Columbia River Mile 37 on 5-19-1996.

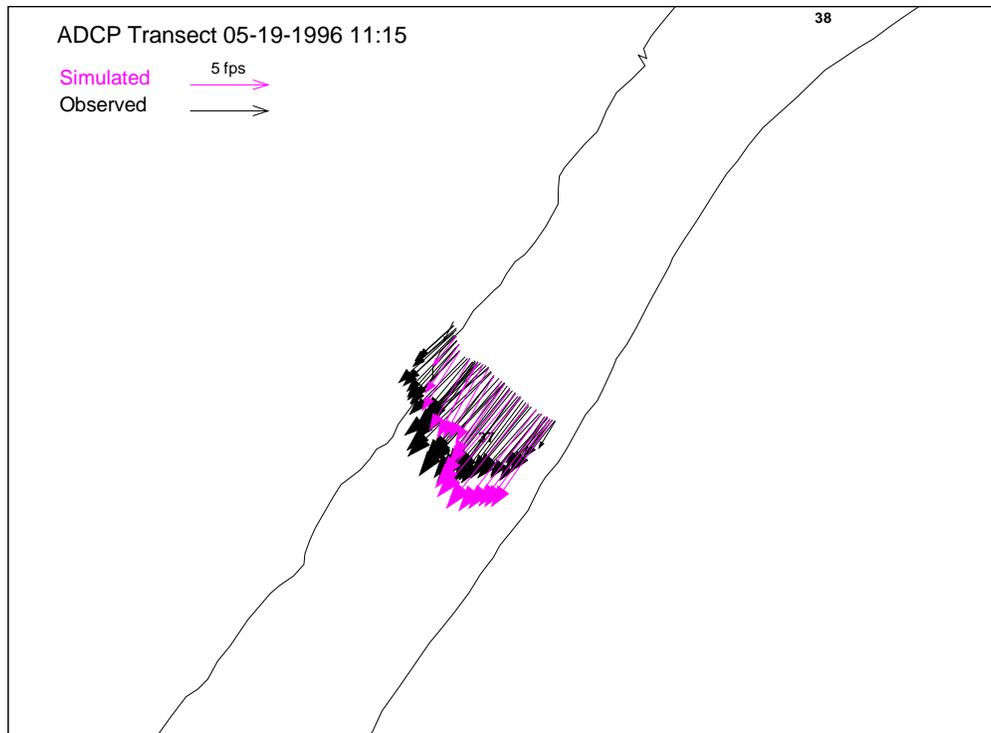


Figure 26. Simulated and observed depth-averaged velocities near Columbia River Mile 37 on 5-19-1996.

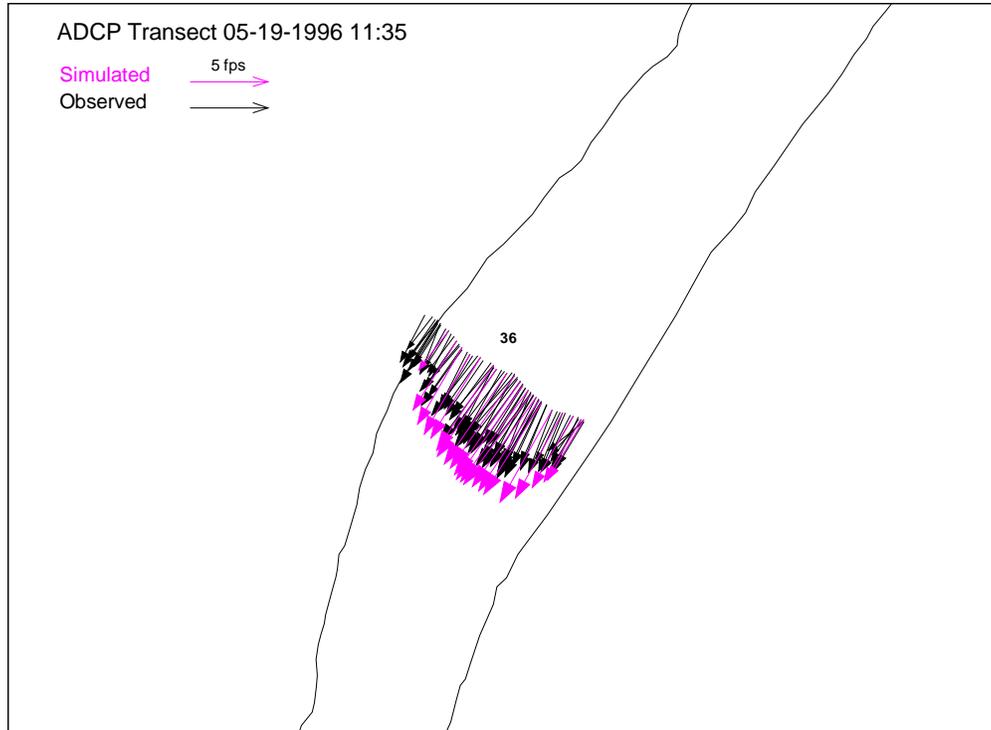


Figure 27. Simulated and observed depth-averaged velocities near Columbia River Mile 36 on 5-19-1996.

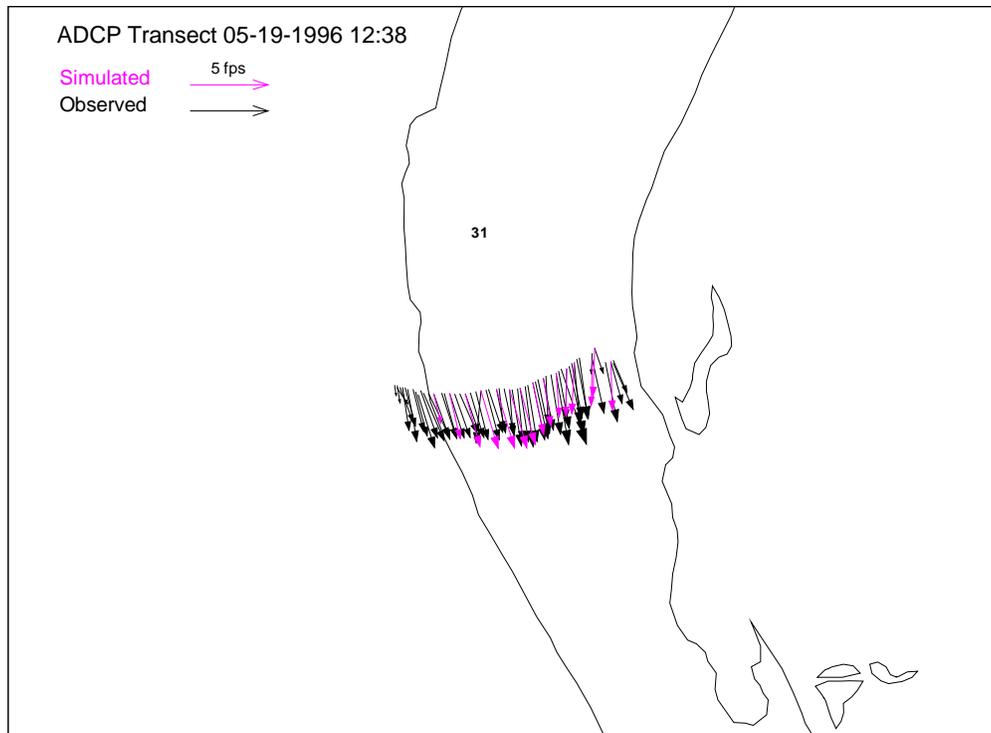


Figure 28. Simulated and observed depth-averaged velocities near Columbia River Mile 30.5 on 5-19-1996.

1.3.3 Spring 1997 ADCP Data

The model was run for the operational conditions that existed when the Spring 1997 ADCP measurements were performed. The manning n value was not altered from the value of 0.021 selected from the tailwater calibration. Simulated velocities are compared to the depth-averaged ADCP data in Figure 29 through Figure 62.

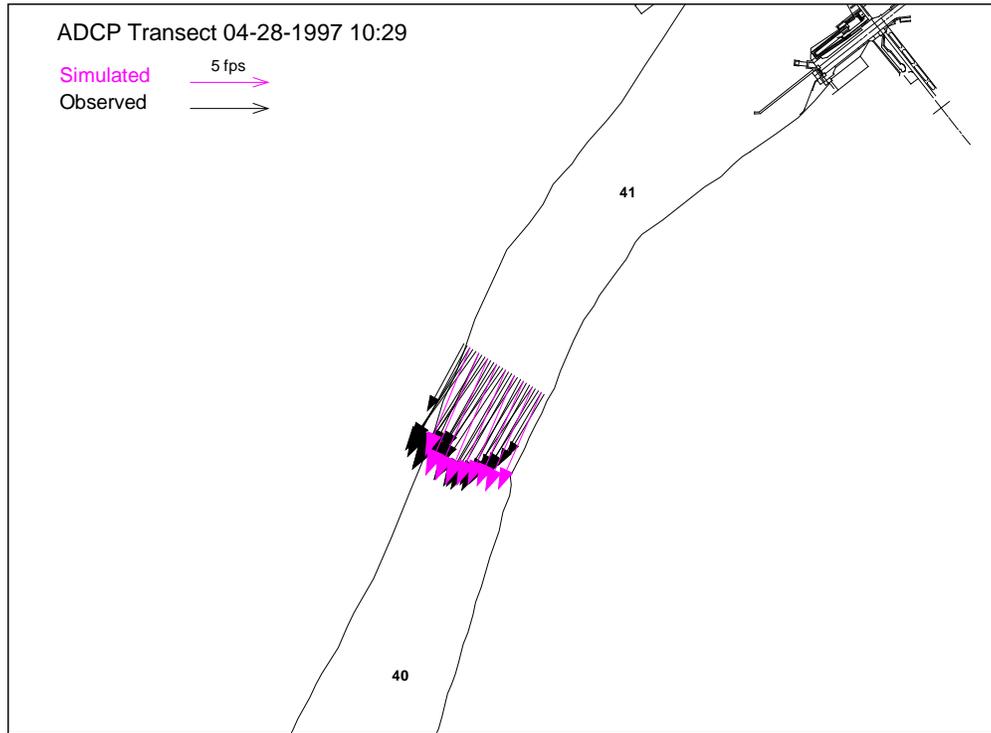


Figure 29. Simulated and observed depth-averaged velocities near Columbia River Mile 40.5 on 4-28-1997.

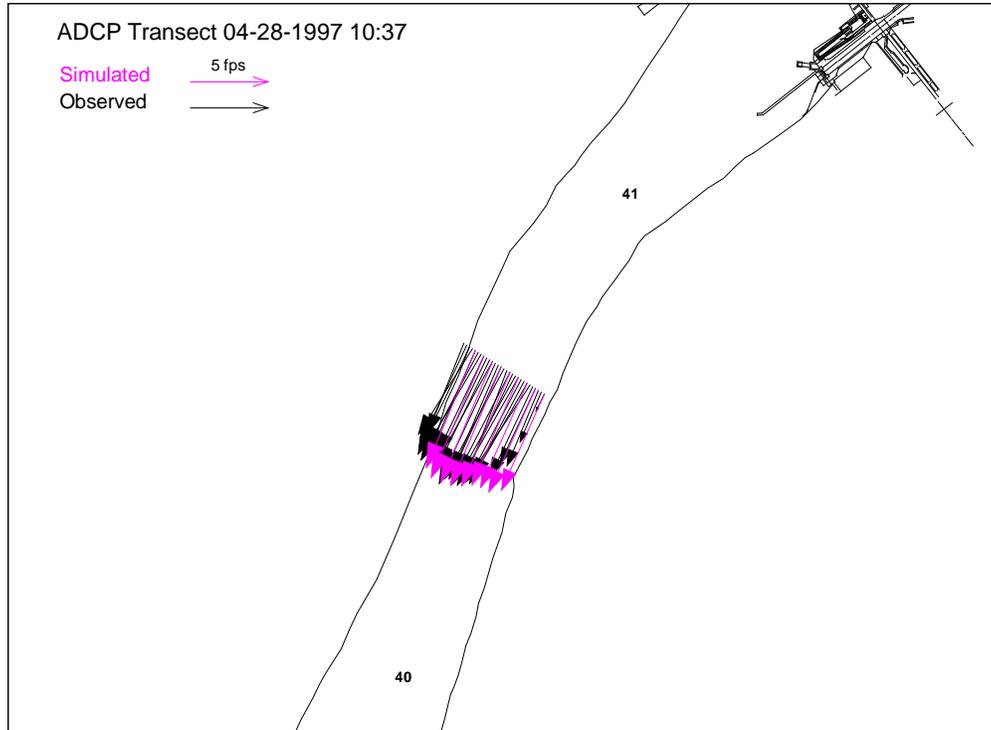


Figure 30. Simulated and observed depth-averaged velocities near Columbia River Mile 40.5 on 4-28-1997.

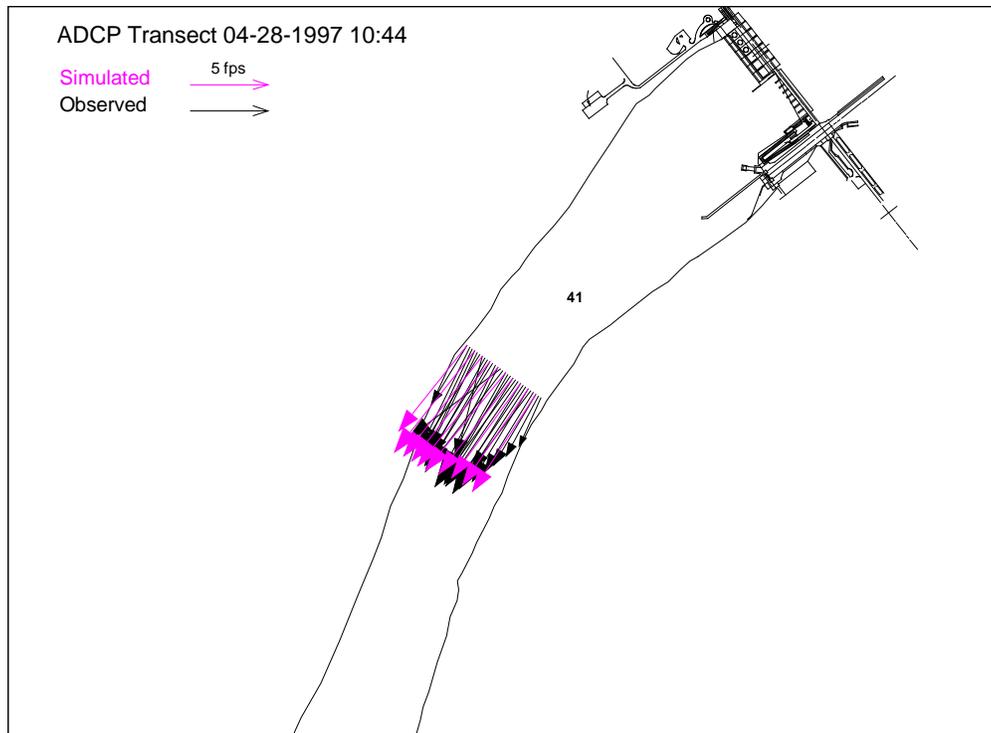


Figure 31. Simulated and observed depth-averaged velocities near Columbia River Mile 40.5 on 4-28-1997.

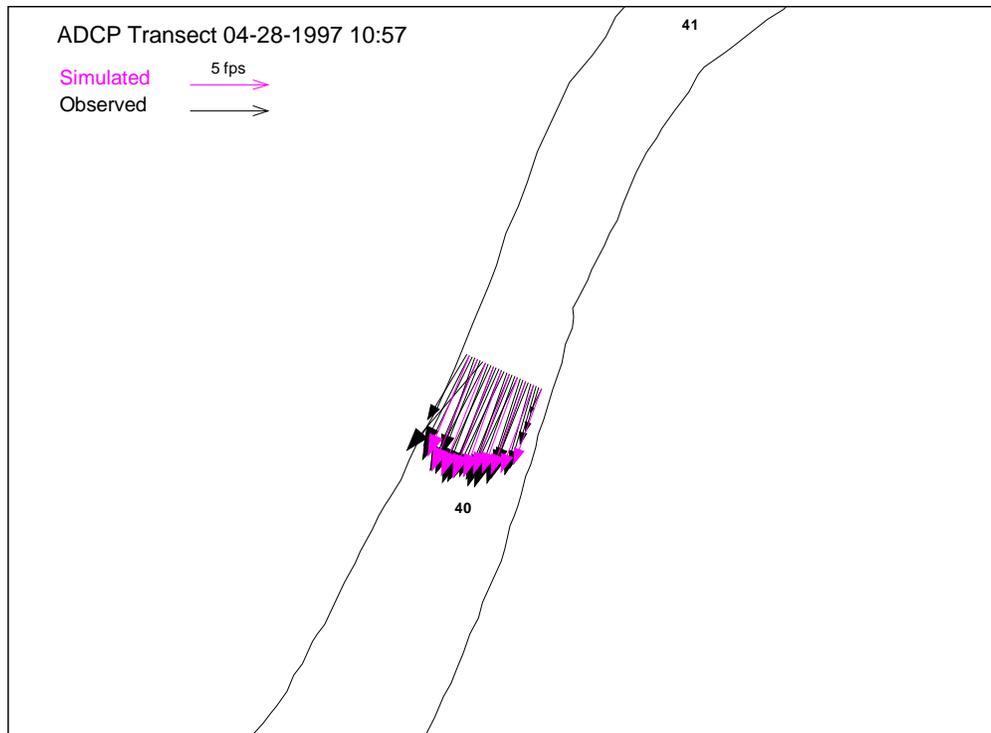


Figure 32. Simulated and observed depth-averaged velocities near Columbia River Mile 40 on 4-28-1997.

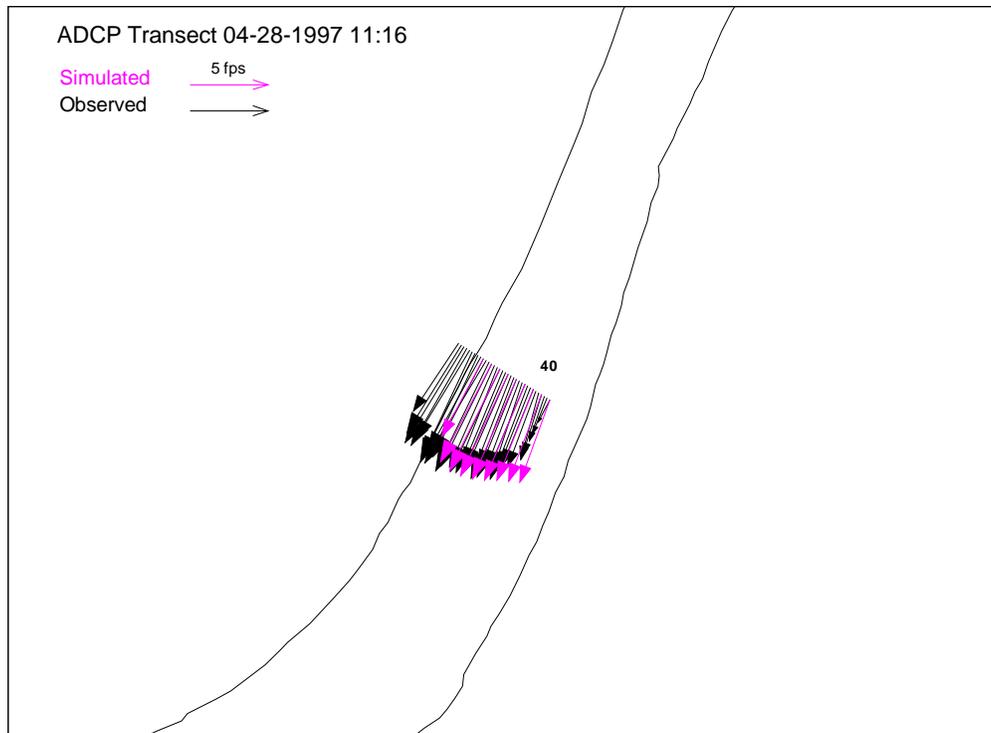


Figure 33. Simulated and observed depth-averaged velocities near Columbia River Mile 40 on 4-28-1997.



Figure 34. Simulated and observed depth-averaged velocities near Columbia River Mile 40 on 4-28-1997.

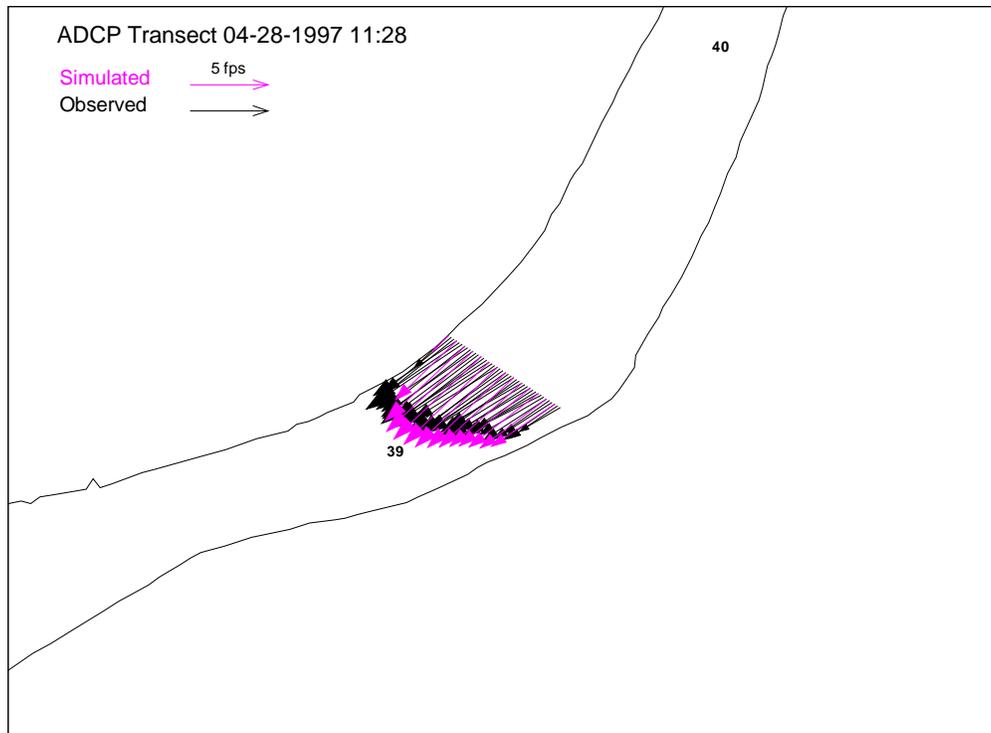


Figure 35. Simulated and observed depth-averaged velocities near Columbia River Mile 39 on 4-28-1997.

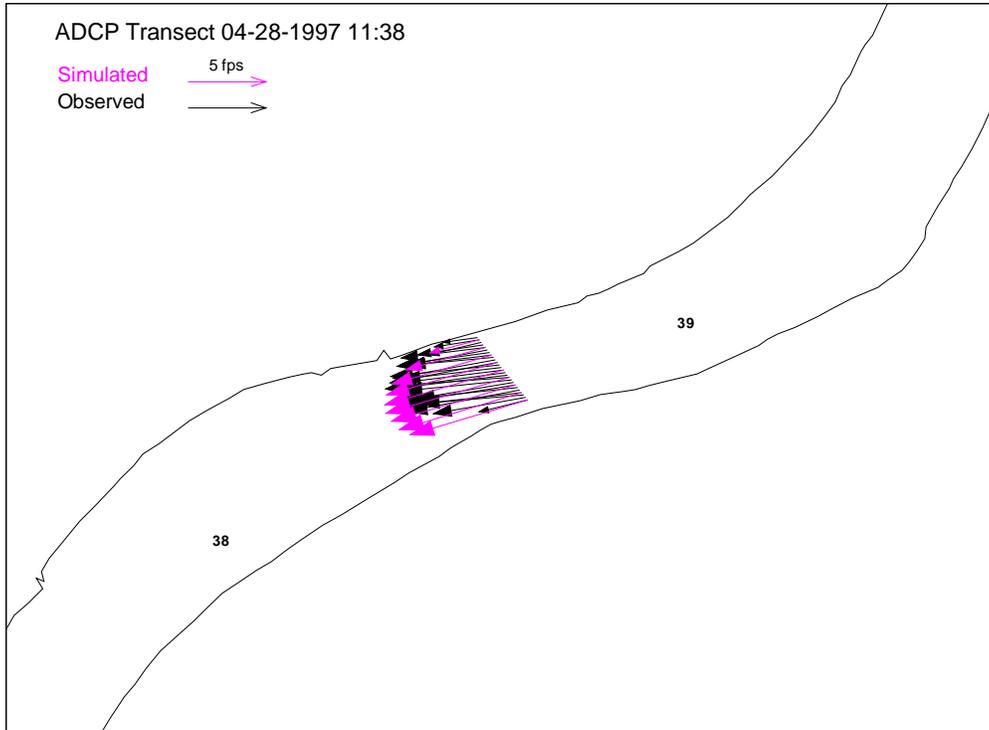


Figure 36. Simulated and observed depth-averaged velocities near Columbia River Mile 38.5 on 4-28-1997.

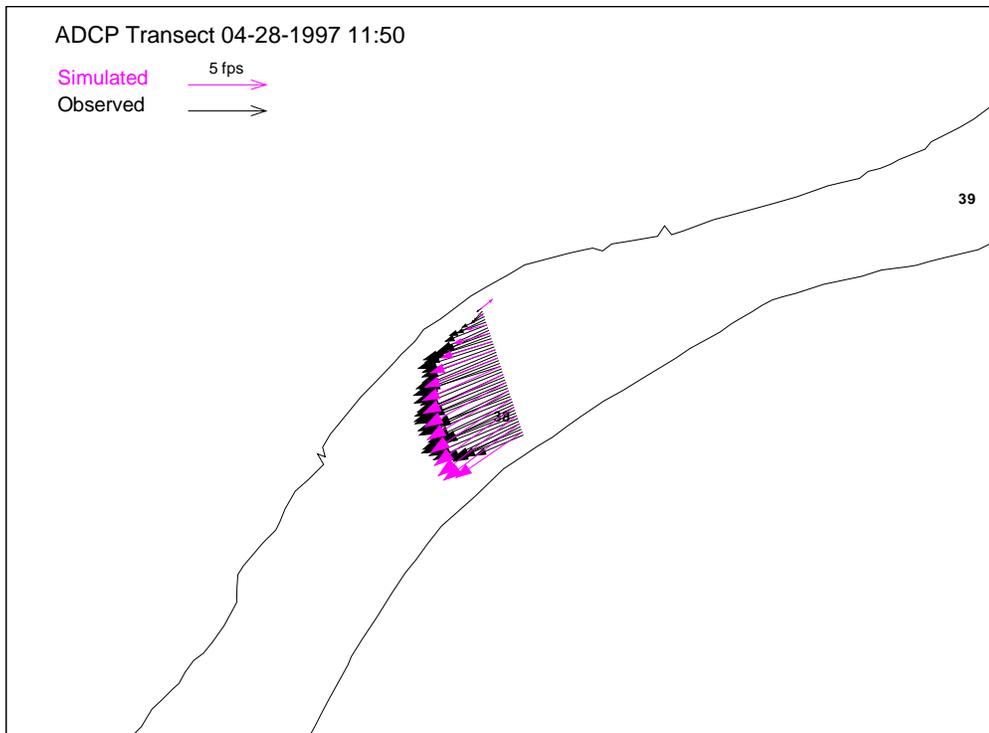


Figure 37. Simulated and observed depth-averaged velocities near Columbia River Mile 37 on 4-28-1997.

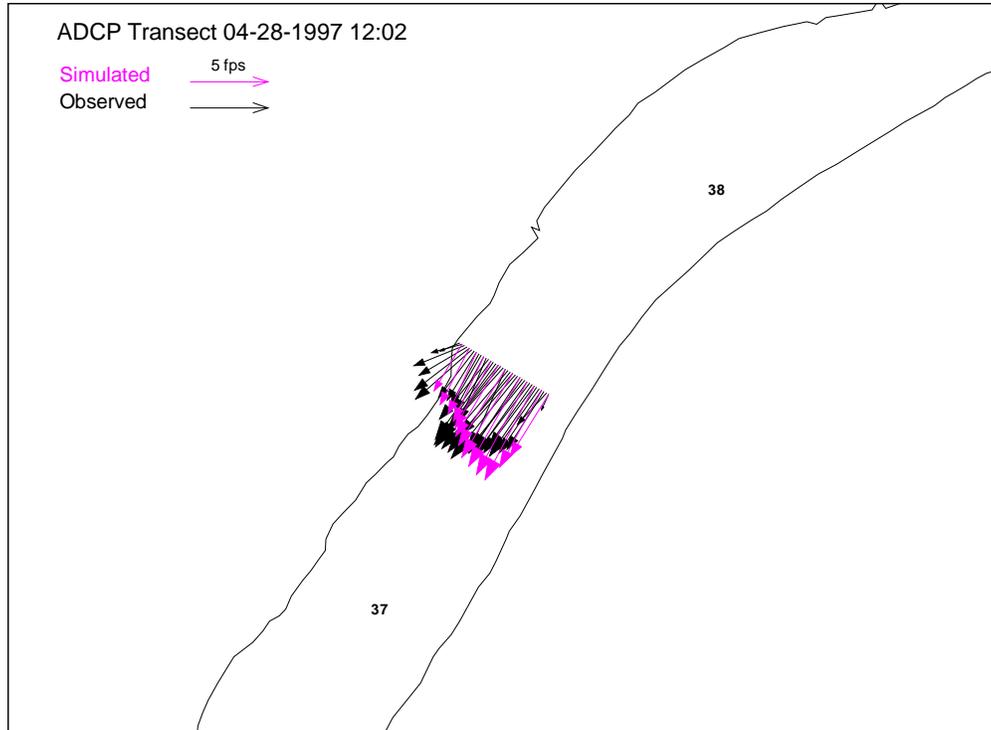


Figure 38. Simulated and observed depth-averaged velocities near Columbia River Mile 37.5 on 4-28-1997.

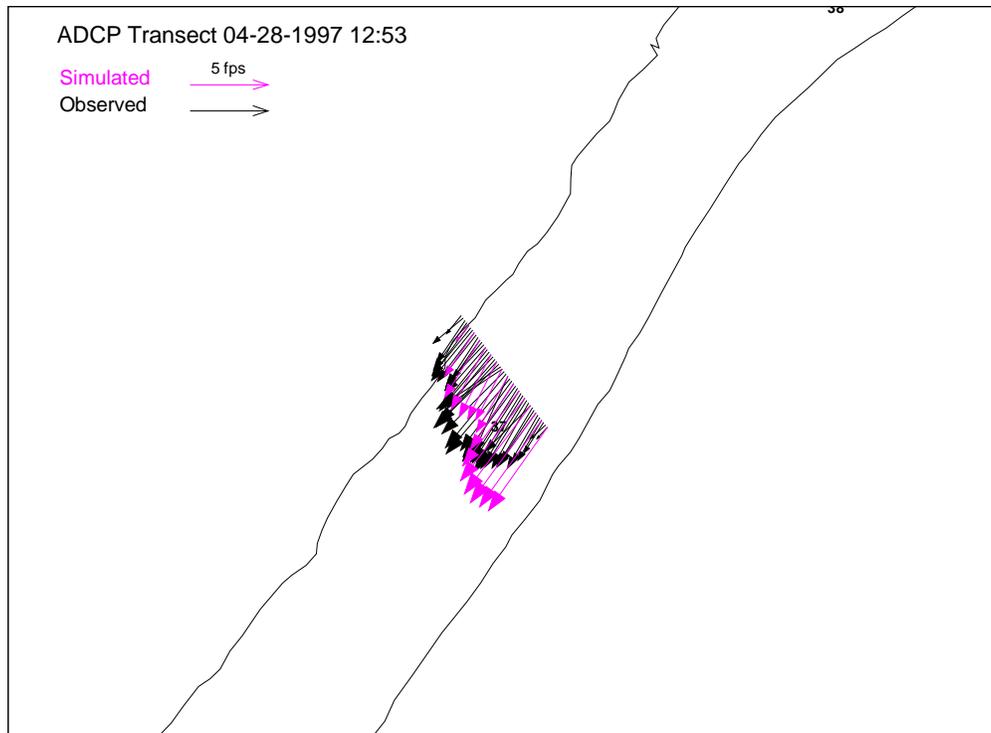


Figure 39. Simulated and observed depth-averaged velocities near Columbia River Mile 37 on 4-28-1997.

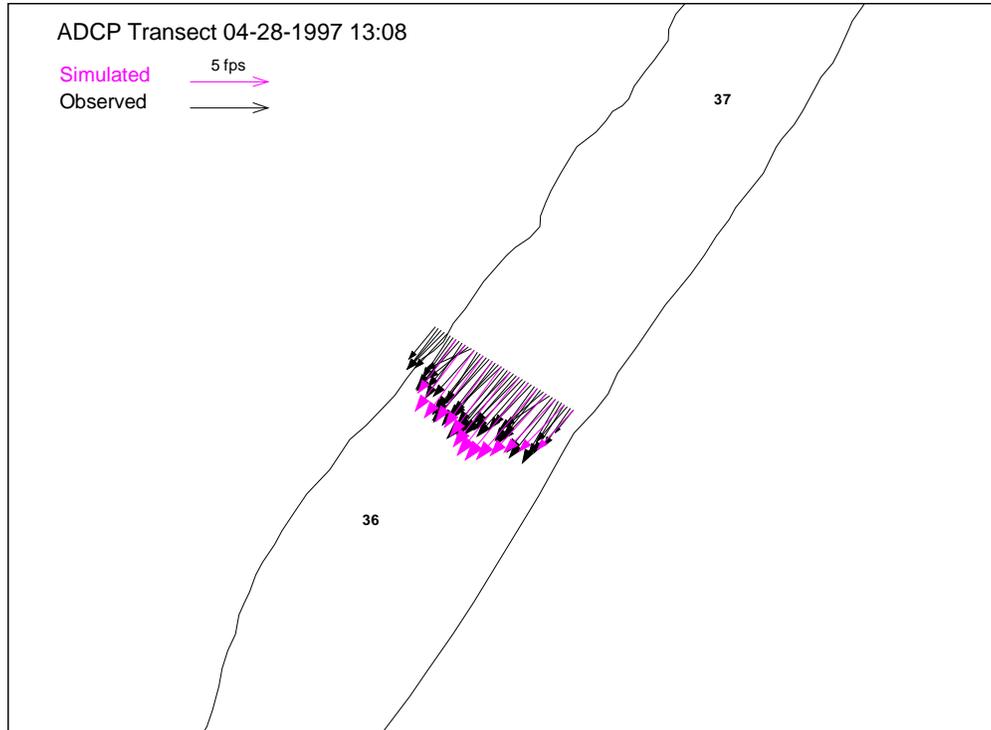


Figure 40. Simulated and observed depth-averaged velocities near Columbia River Mile 36 on 4-28-1997.

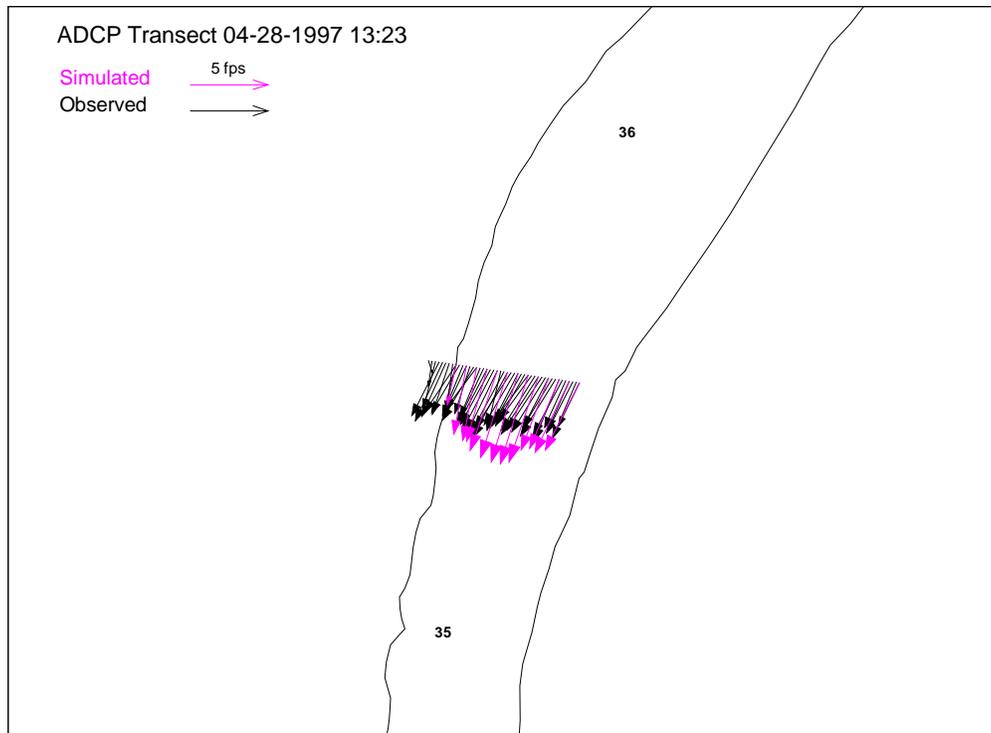


Figure 41. Simulated and observed depth-averaged velocities near Columbia River Mile 35.5 on 4-28-1997.

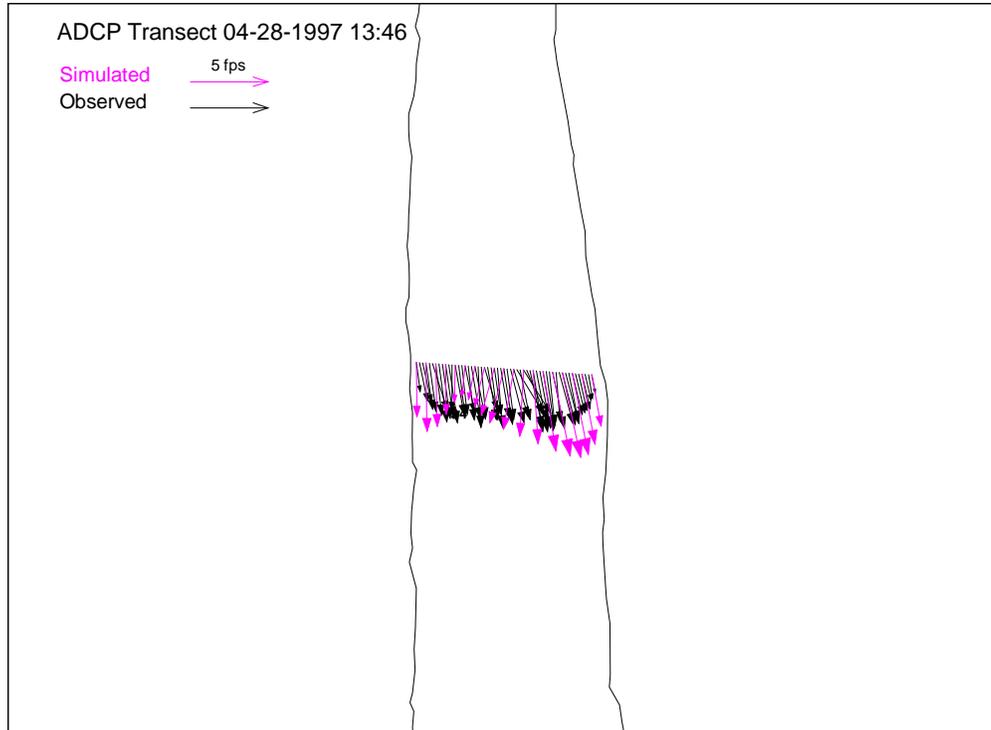


Figure 42. Simulated and observed depth-averaged velocities near Columbia River Mile 34 on 4-28-1997.

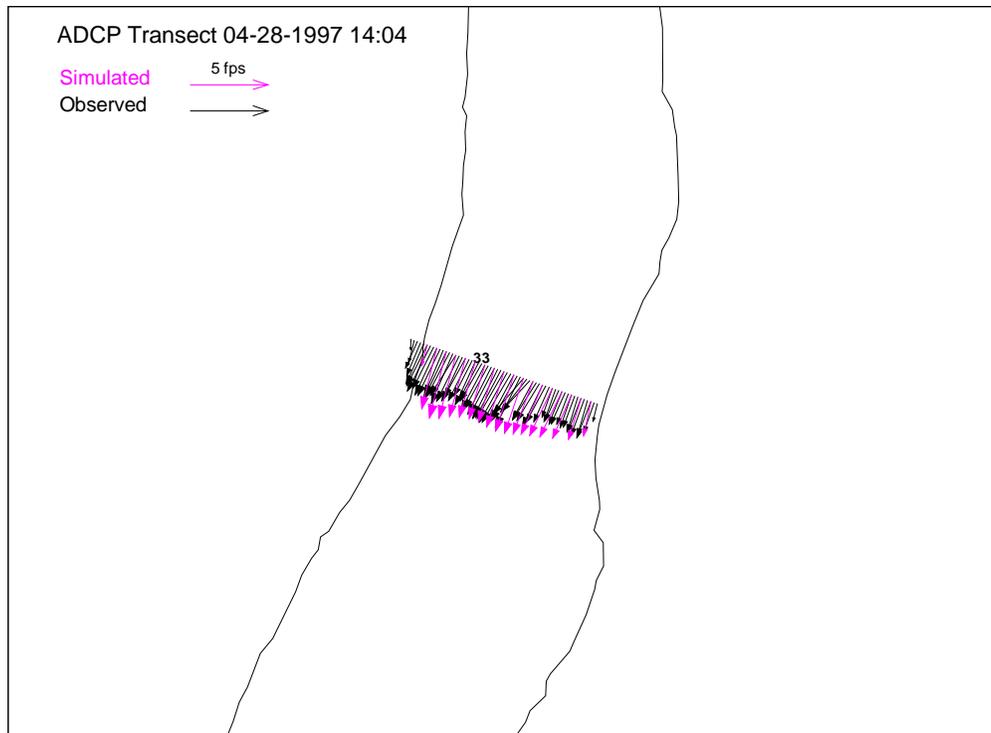


Figure 43. Simulated and observed depth-averaged velocities near Columbia River Mile 33 on 4-28-1997.

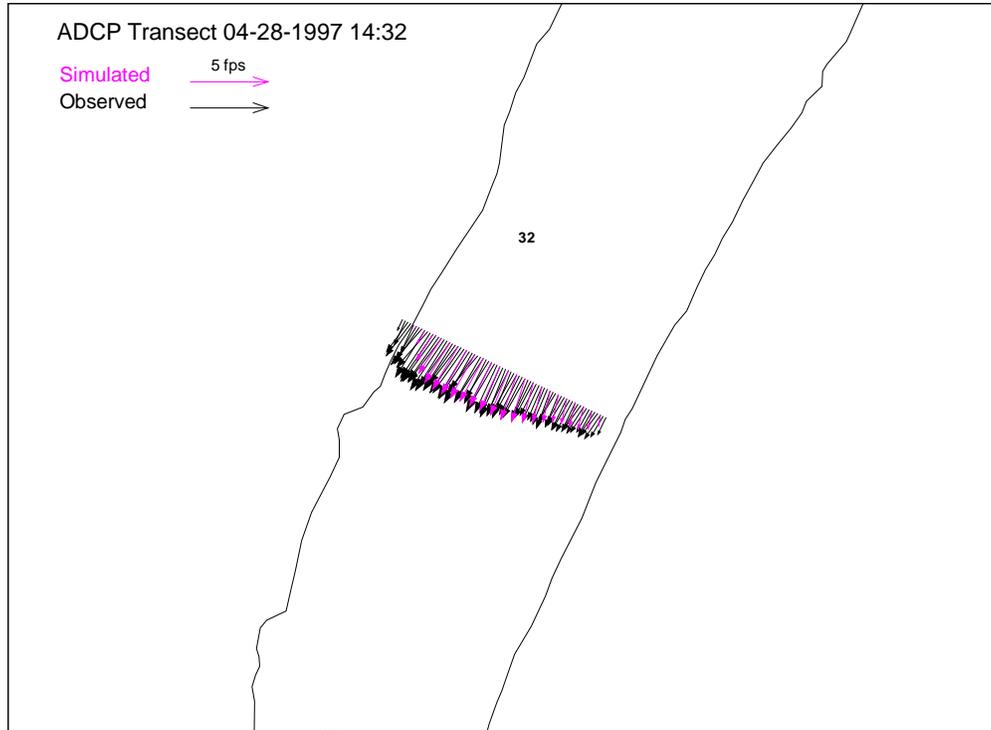


Figure 44. Simulated and observed depth-averaged velocities near Columbia River Mile 32 on 4-28-1997.

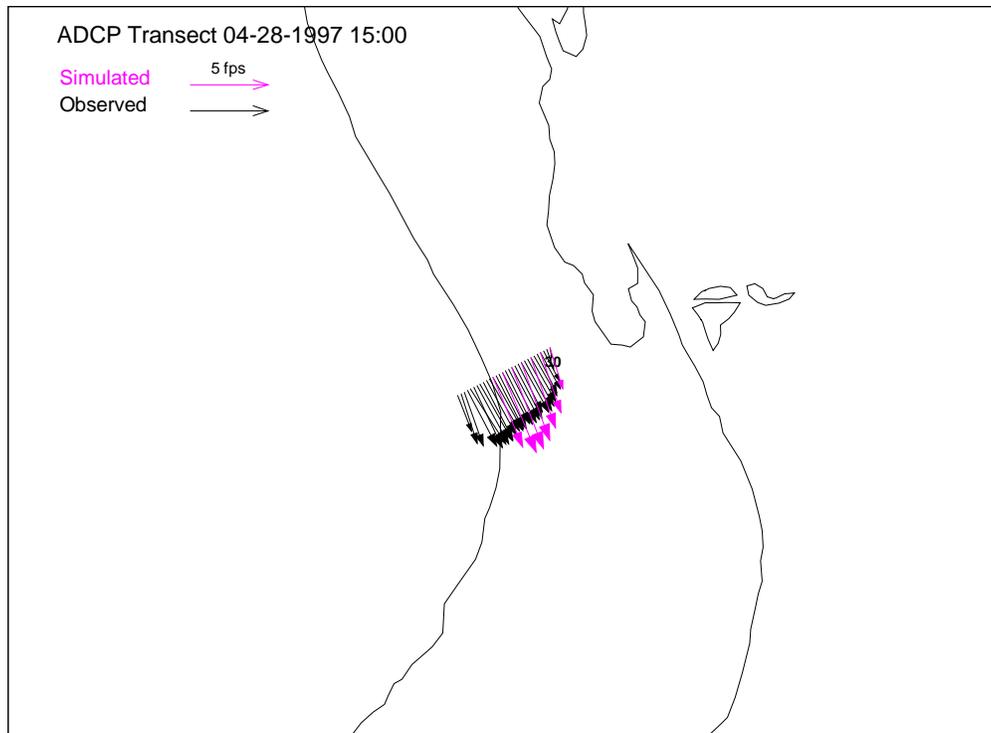


Figure 45. Simulated and observed depth-averaged velocities near Columbia River Mile 30 on 4-28-1997.

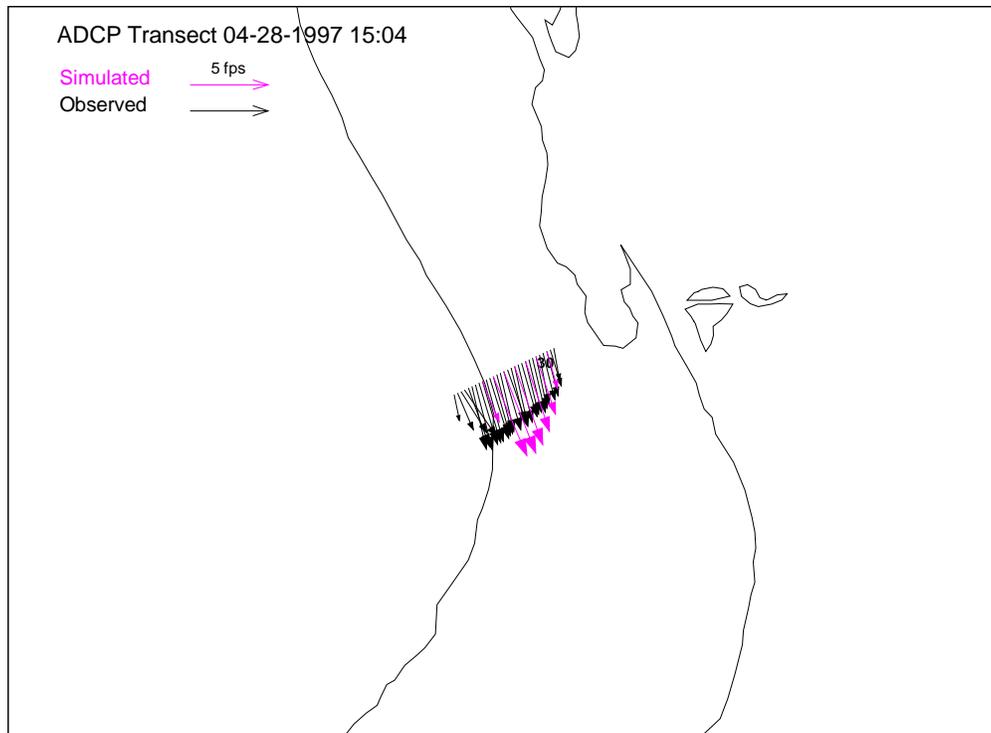


Figure 46. Simulated and observed depth-averaged velocities near Columbia River Mile 30 on 4-28-1997.

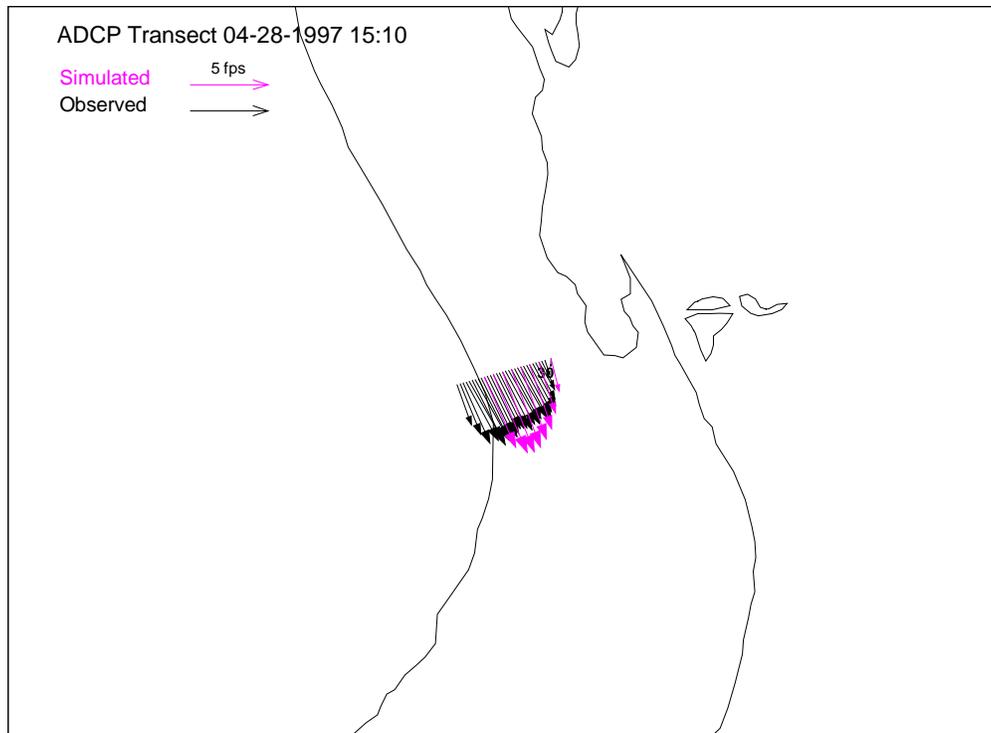


Figure 47. Simulated and observed depth-averaged velocities near Columbia River Mile 30 on 4-28-1997.

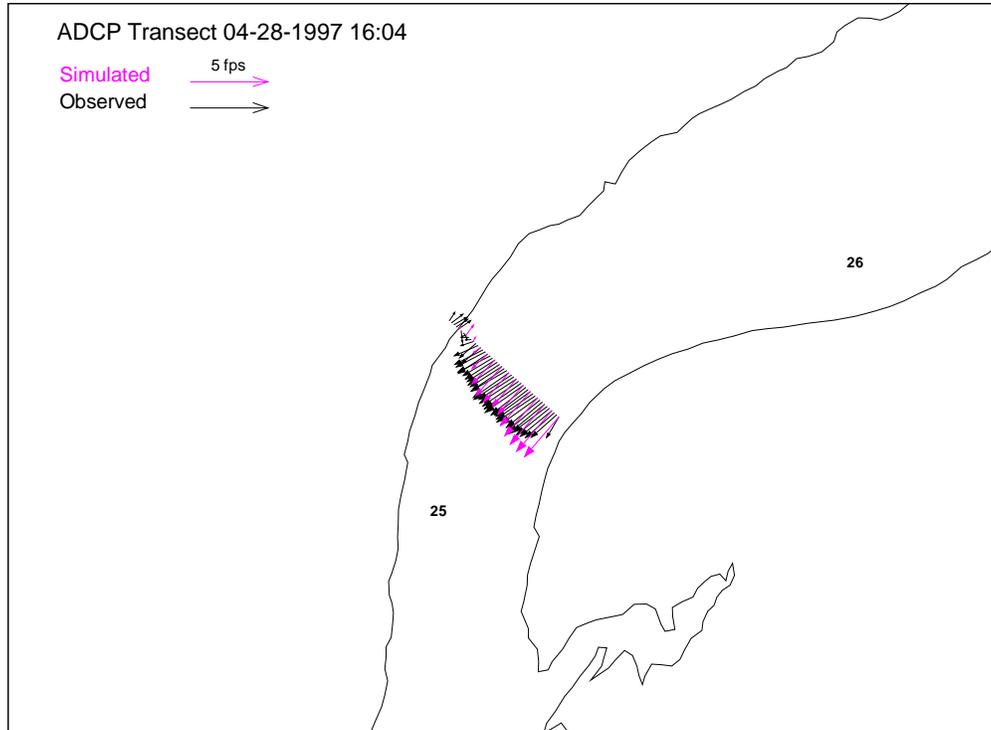


Figure 48. Simulated and observed depth-averaged velocities near Columbia River Mile 25 on 4-28-1997.

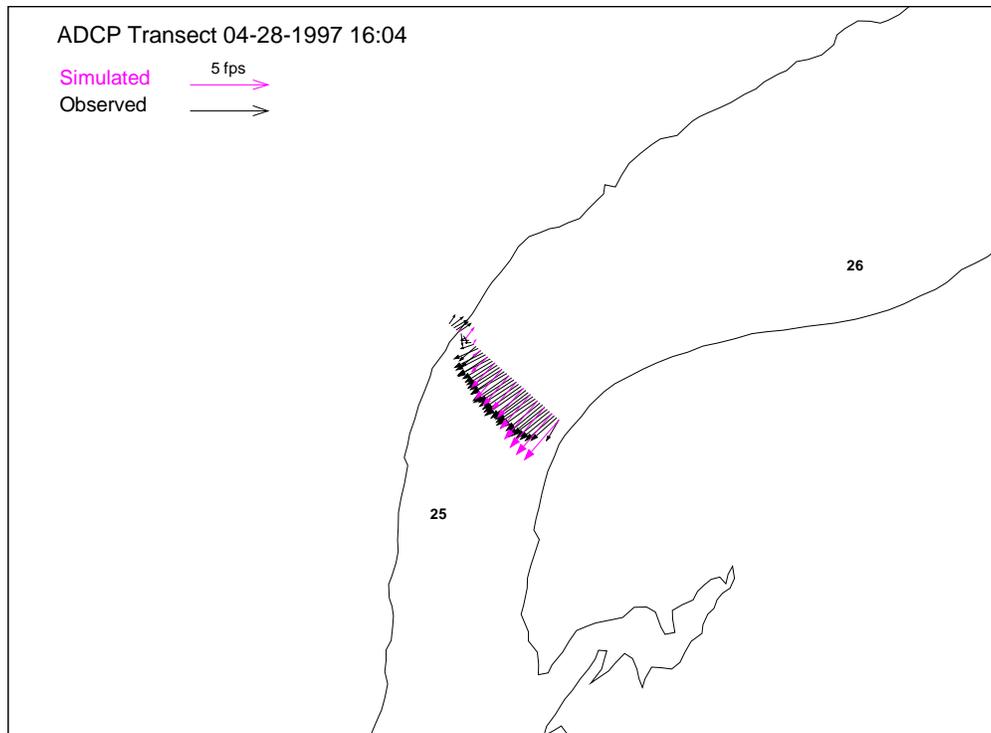


Figure 49. Simulated and observed depth-averaged velocities near Columbia River Mile 25 on 4-29-1997.

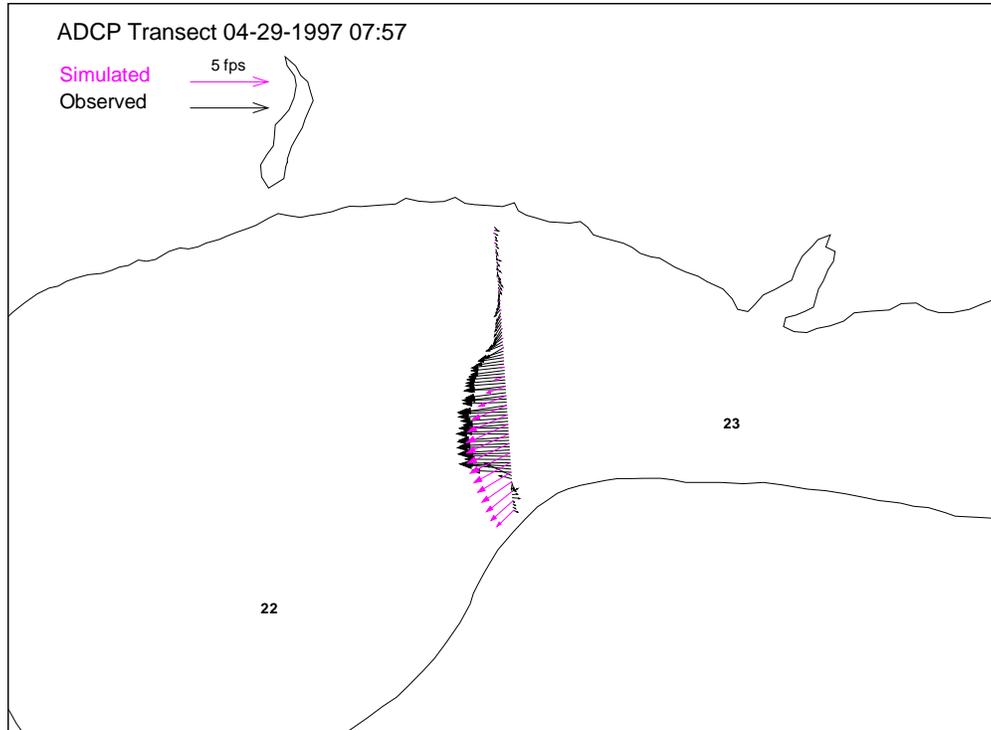


Figure 50. Simulated and observed depth-averaged velocities near Columbia River Mile 22.5 on 4-29-1997.

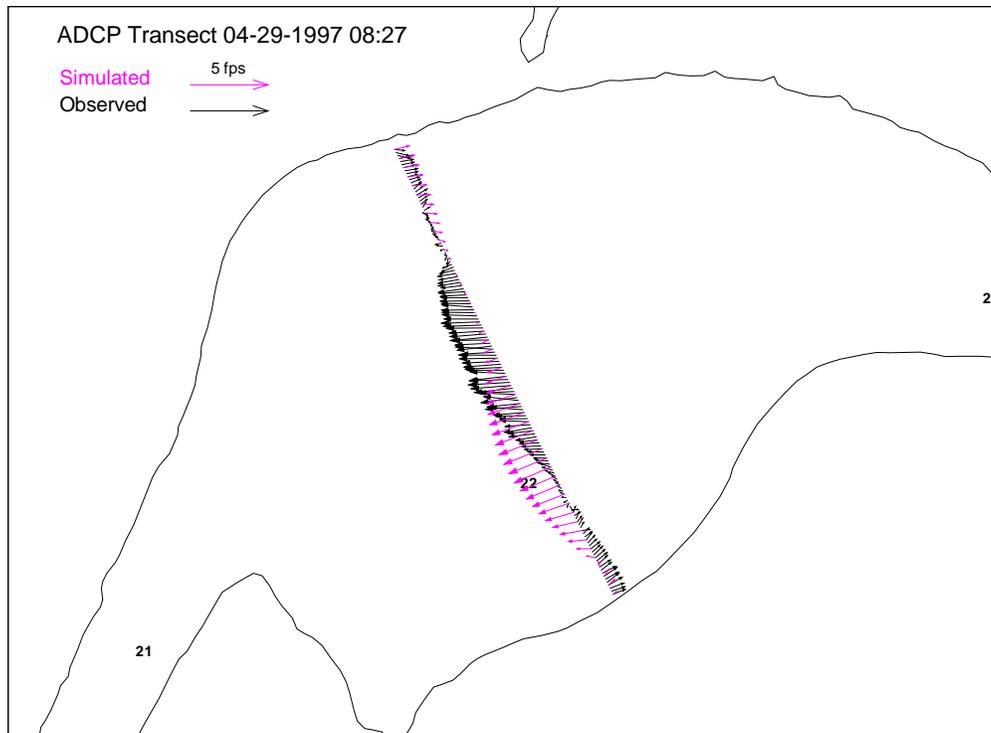


Figure 51. Simulated and observed depth-averaged velocities near Columbia River Mile 22 on 4-29-1997.

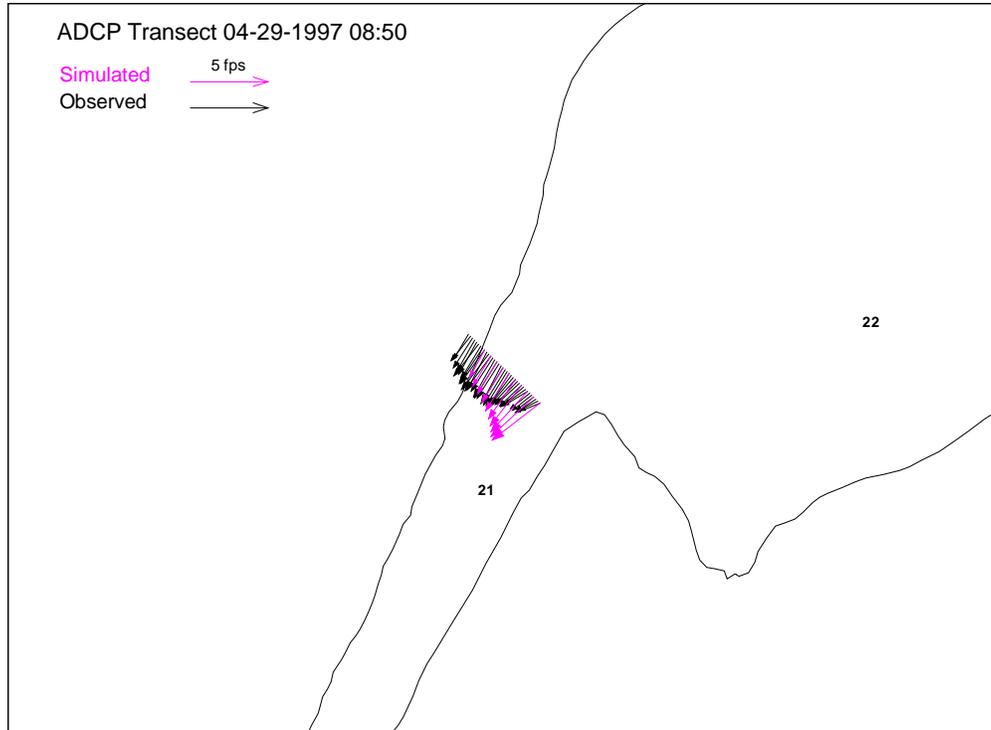


Figure 52. Simulated and observed depth-averaged velocities near Columbia River Mile 21 on 4-29-1997.

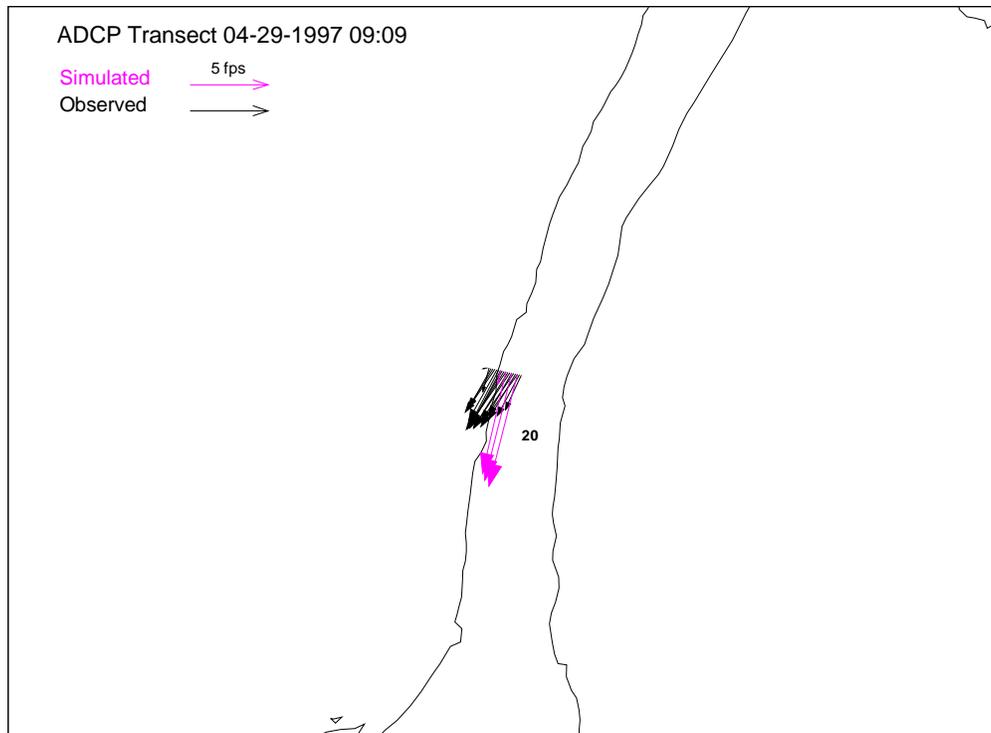


Figure 53. Simulated and observed depth-averaged velocities near Columbia River Mile 20 on 4-29-1997.

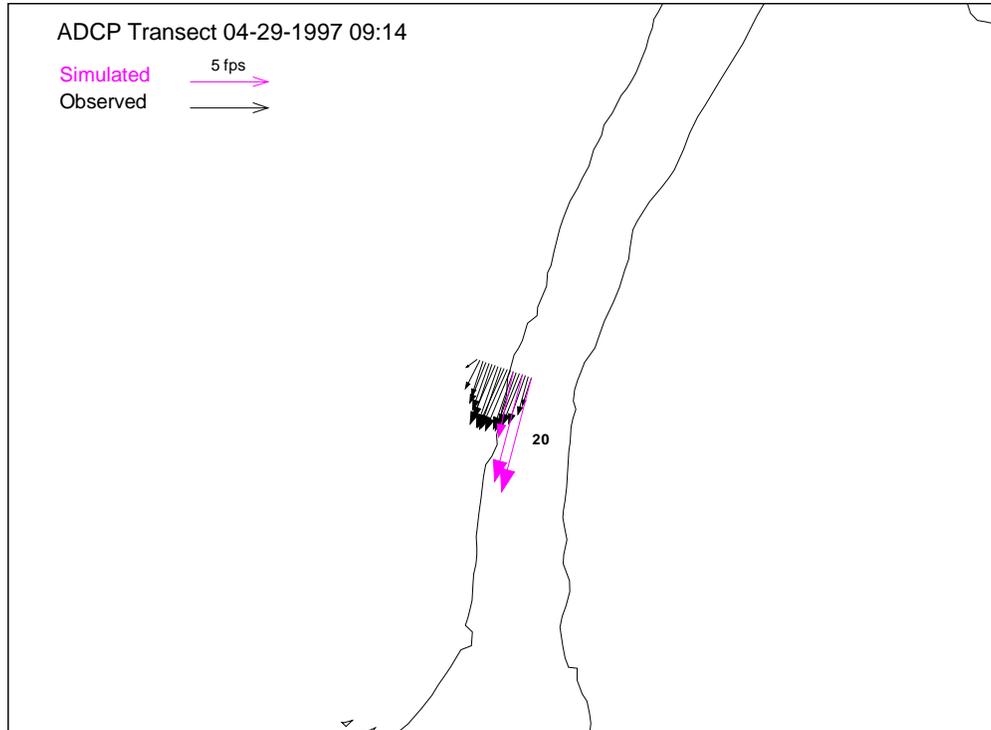


Figure 54. Simulated and observed depth-averaged velocities near Columbia River Mile 20 on 4-29-1997.

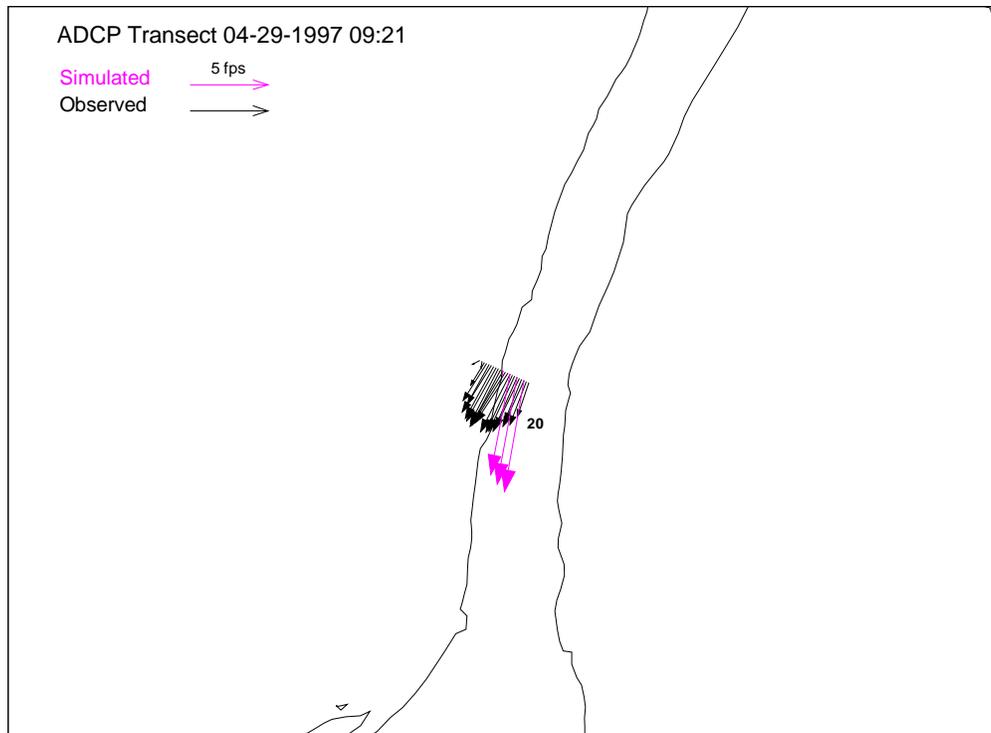


Figure 55. Simulated and observed depth-averaged velocities near Columbia River Mile 20 on 4-29-1997.

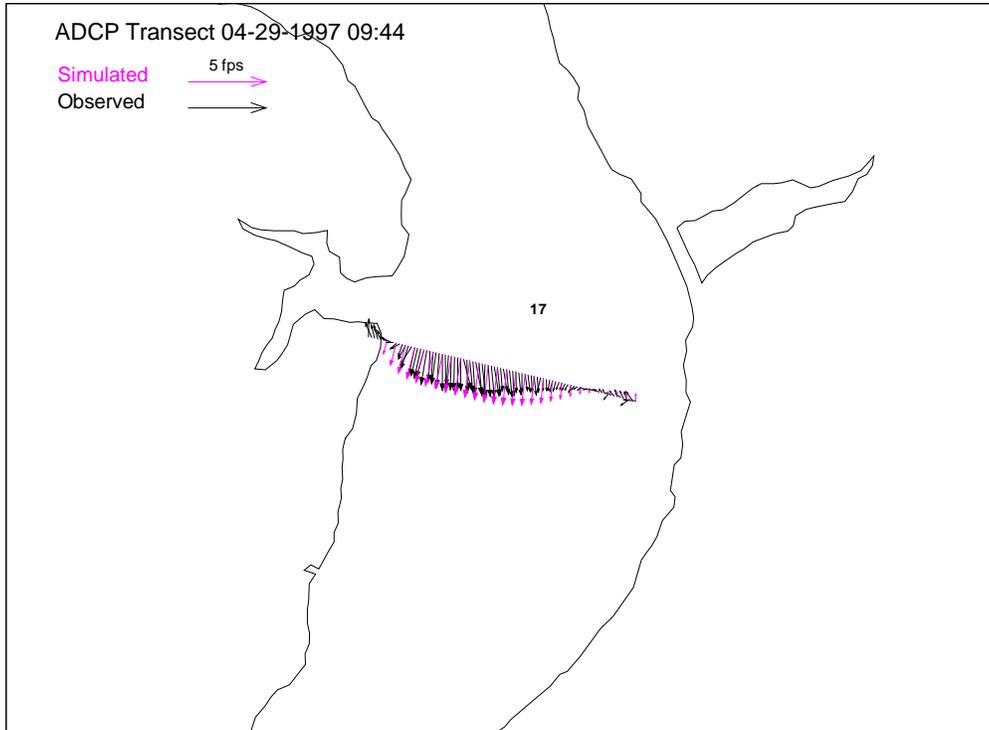


Figure 56. Simulated and observed depth-averaged velocities near Columbia River Mile 17 on 4-29-1997.

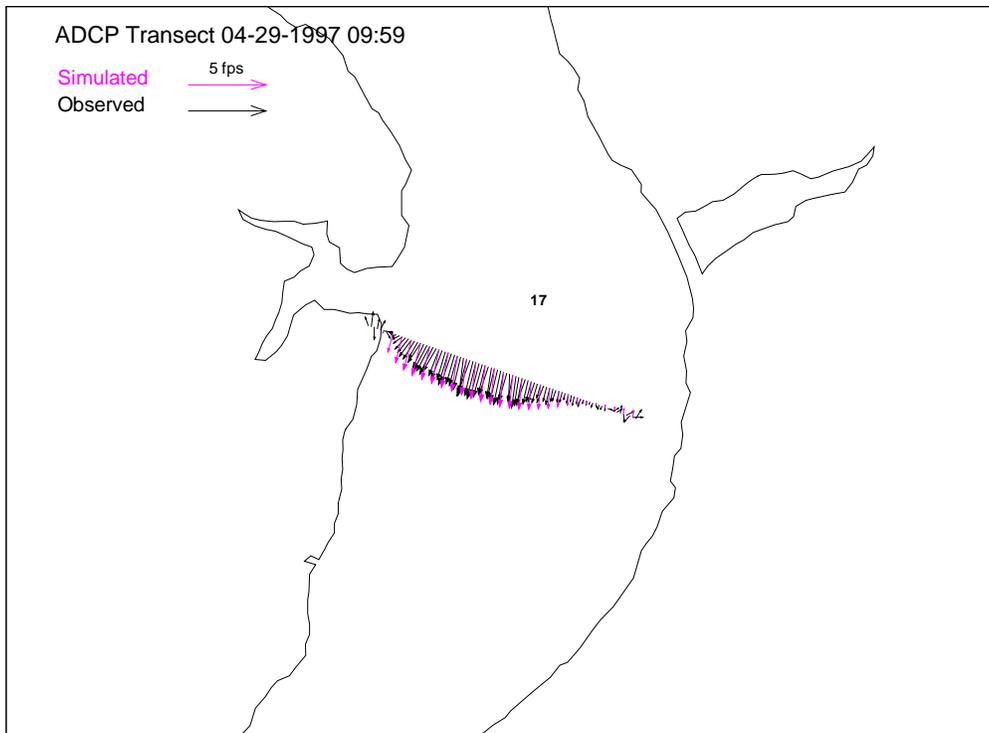


Figure 57. Simulated and observed depth-averaged velocities near Columbia River Mile 17 on 4-29-1997.

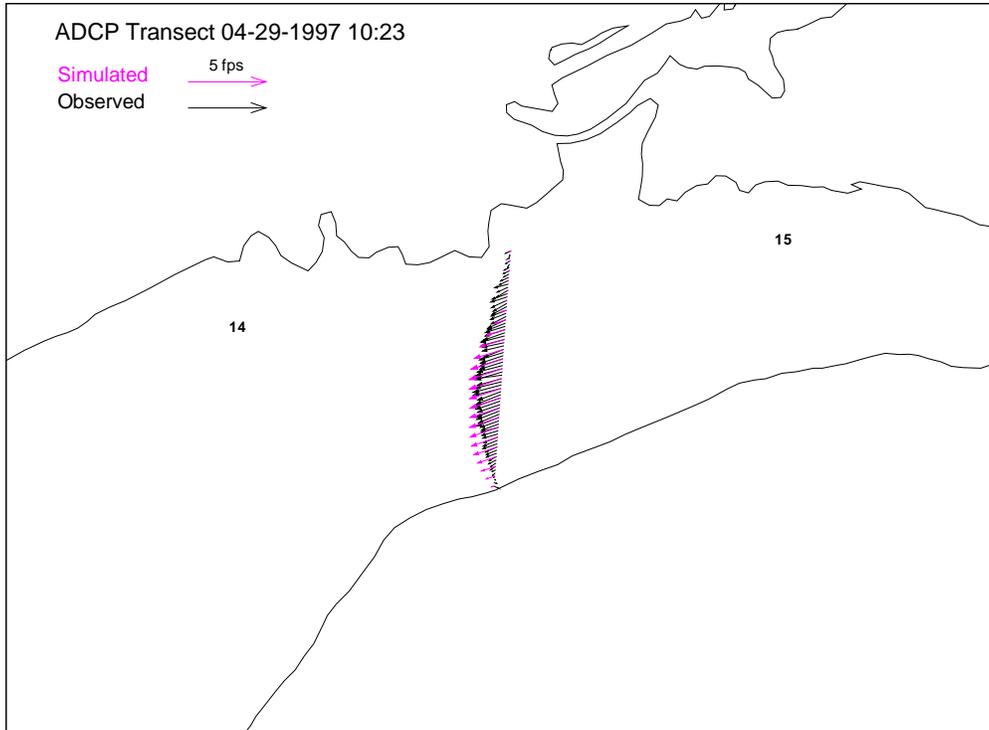


Figure 58. Simulated and observed depth-averaged velocities near Columbia River Mile 14 on 4-29-1997.

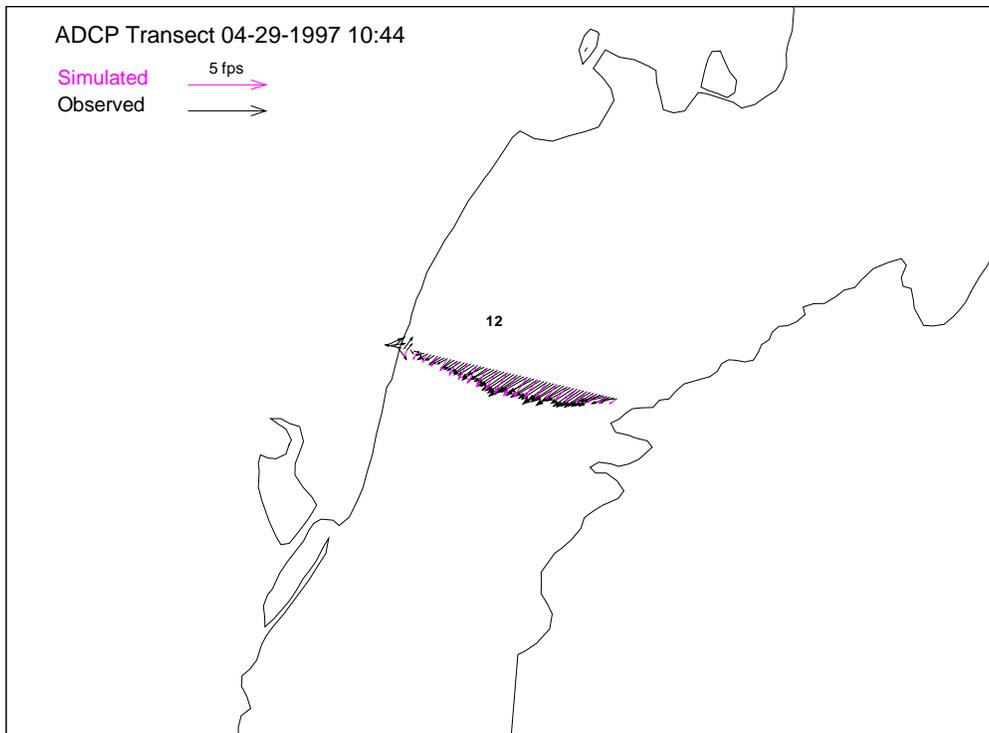


Figure 59. Simulated and observed depth-averaged velocities near Columbia River Mile 12 on 4-29-1997.

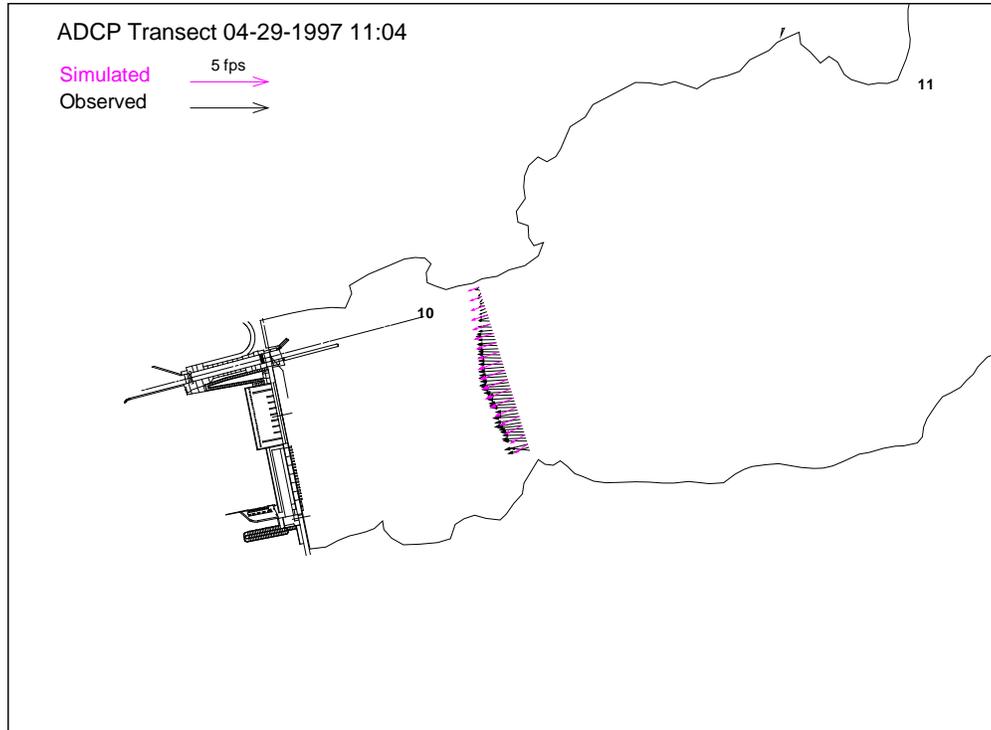


Figure 60. Simulated and observed depth-averaged velocities near Columbia River Mile 10 on 4-29-1997.

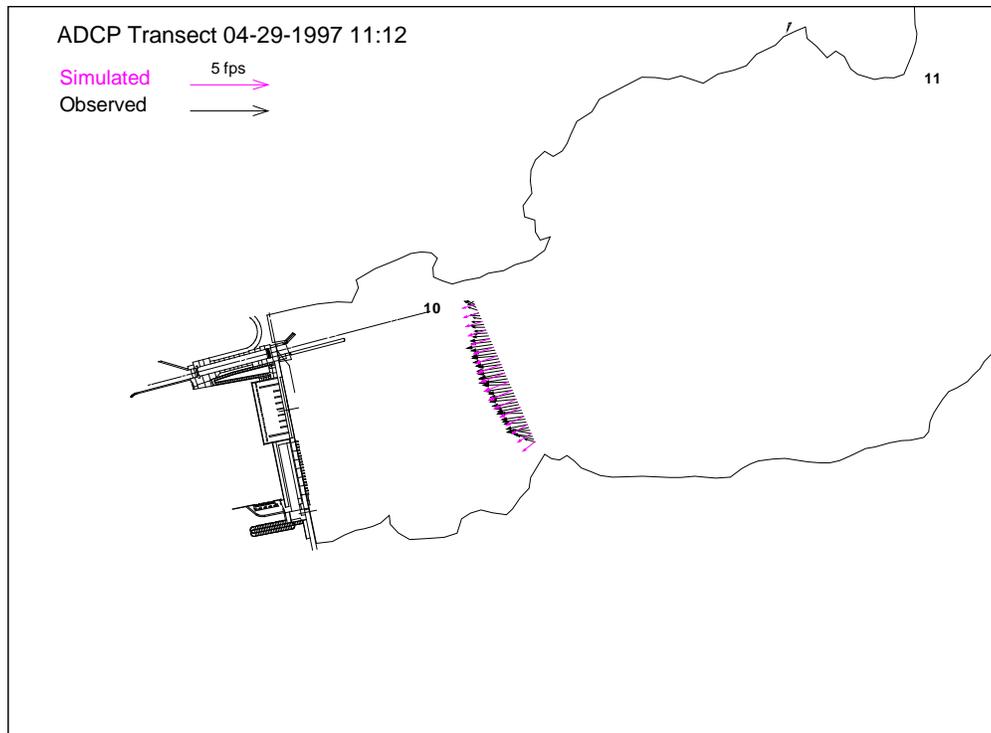


Figure 61. Simulated and observed depth-averaged velocities near Columbia River Mile 10 on 4-29-1997.

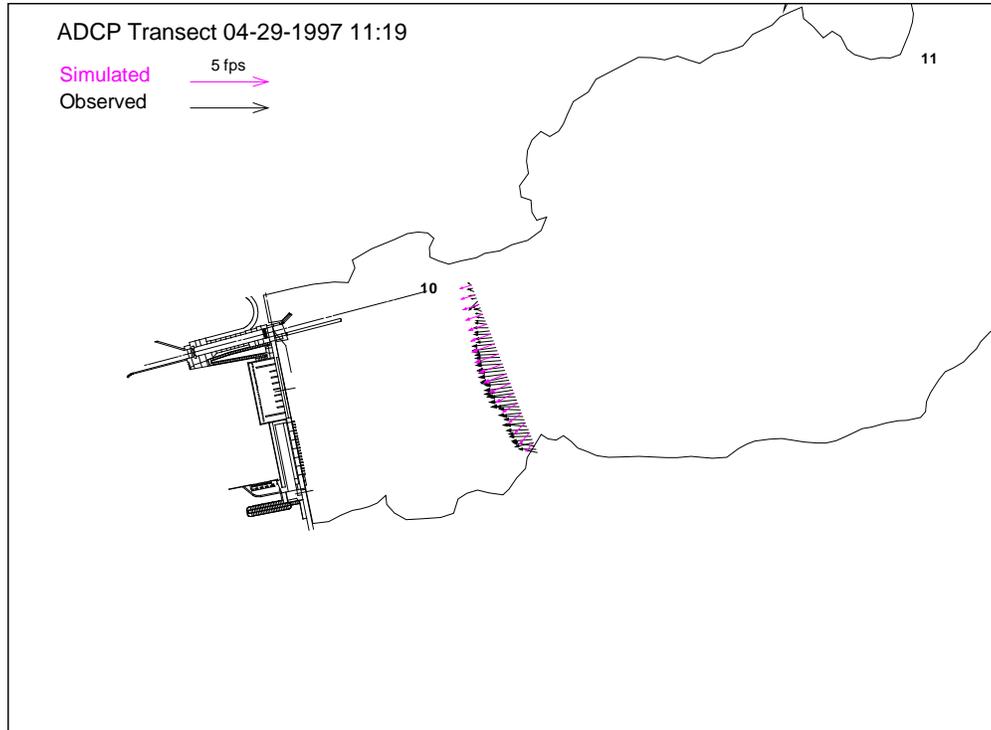


Figure 62. Simulated and observed depth-averaged velocities near Columbia River Mile 10 on 4-29-1997.

1.3.4 Simulated spatial velocity distribution during the Spring 1996 study.

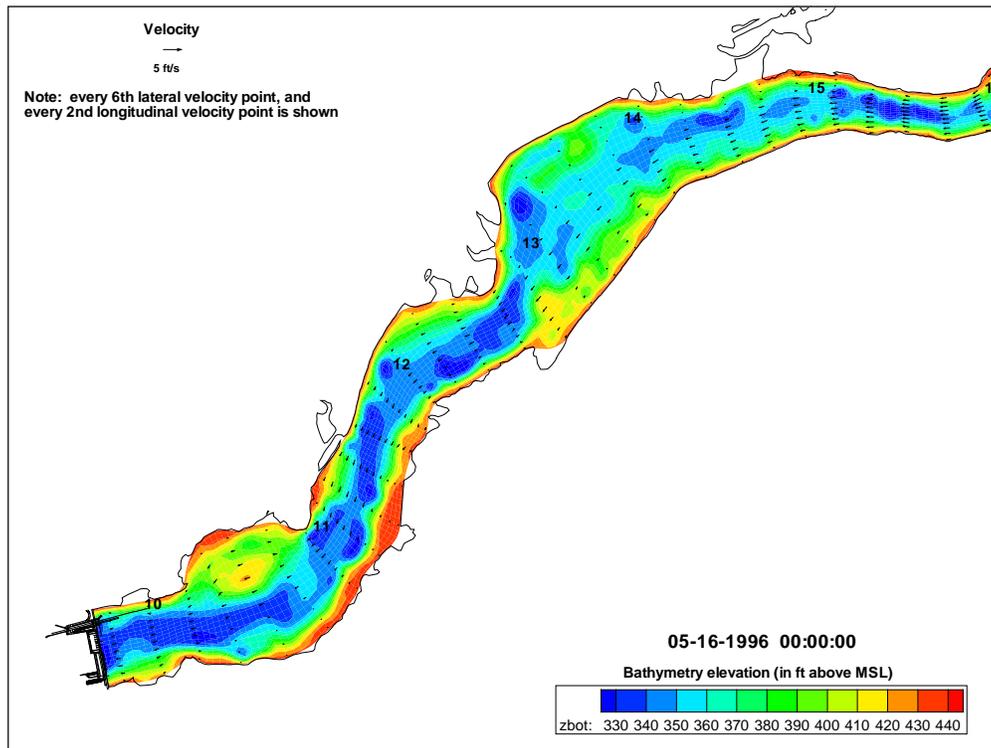


Figure 63. Spatial velocity distribution during the Spring 1996 study period.

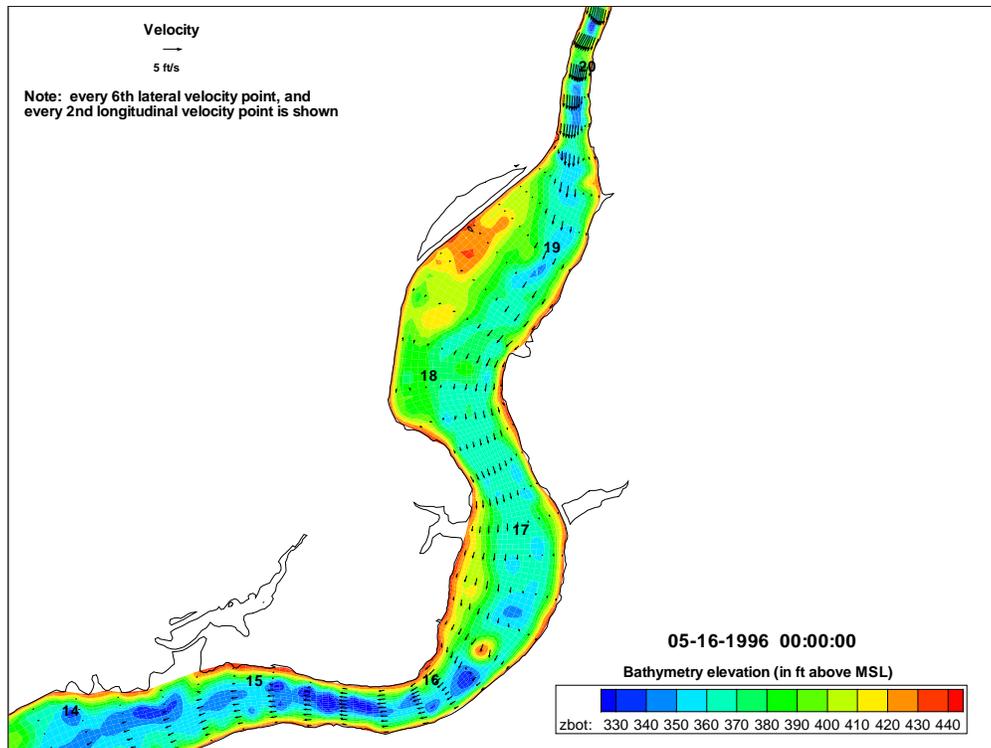


Figure 64. Spatial velocity distribution during the Spring 1996 study period.

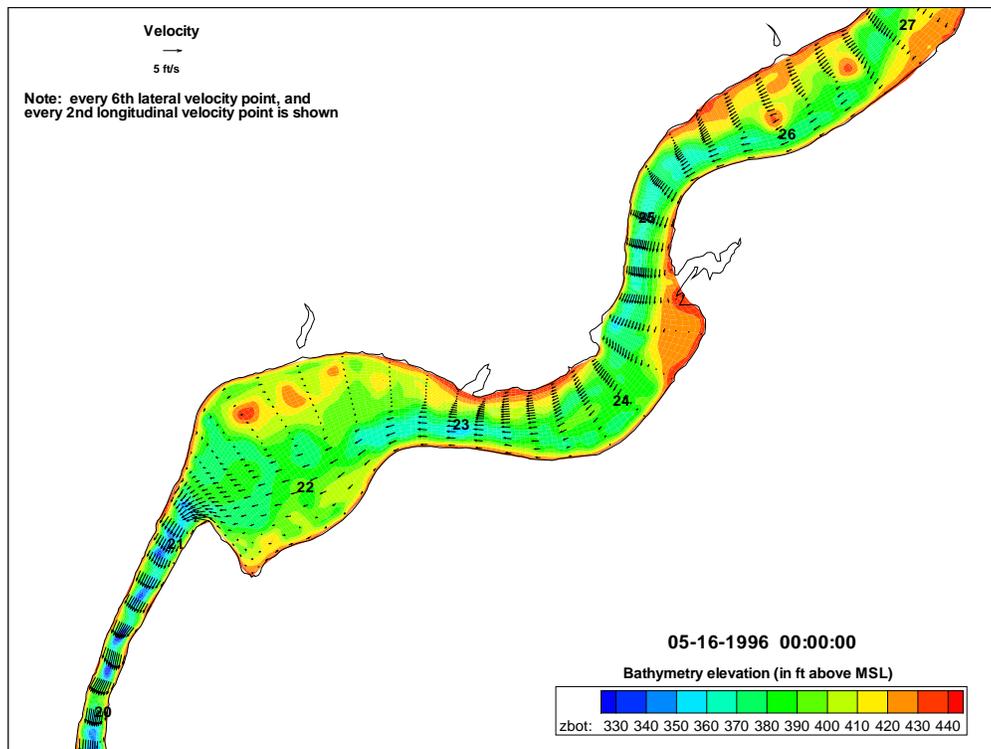


Figure 65. Spatial velocity distribution during the Spring 1996 study period.

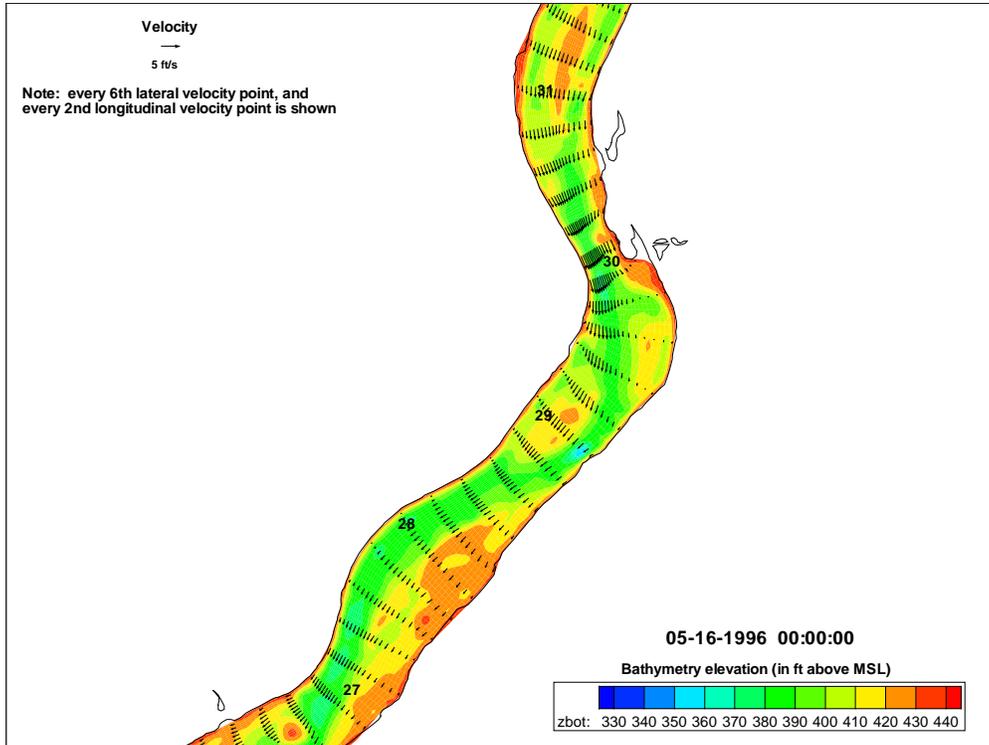


Figure 66. Spatial velocity distribution during the Spring 1996 study period.

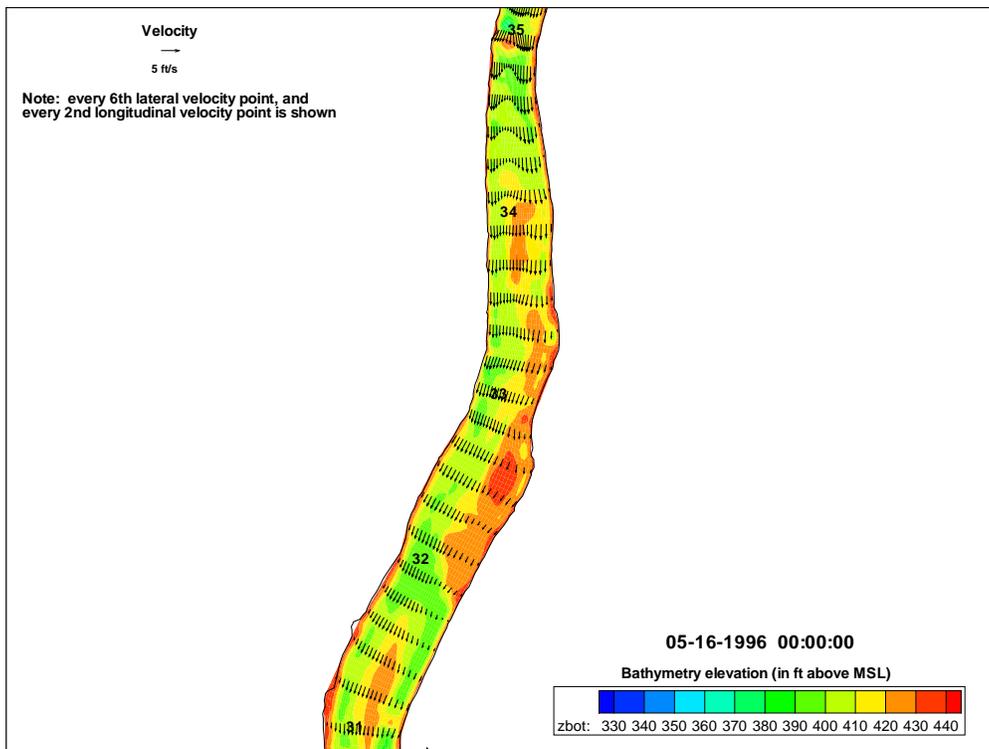


Figure 67. Spatial velocity distribution during the Spring 1996 study period.

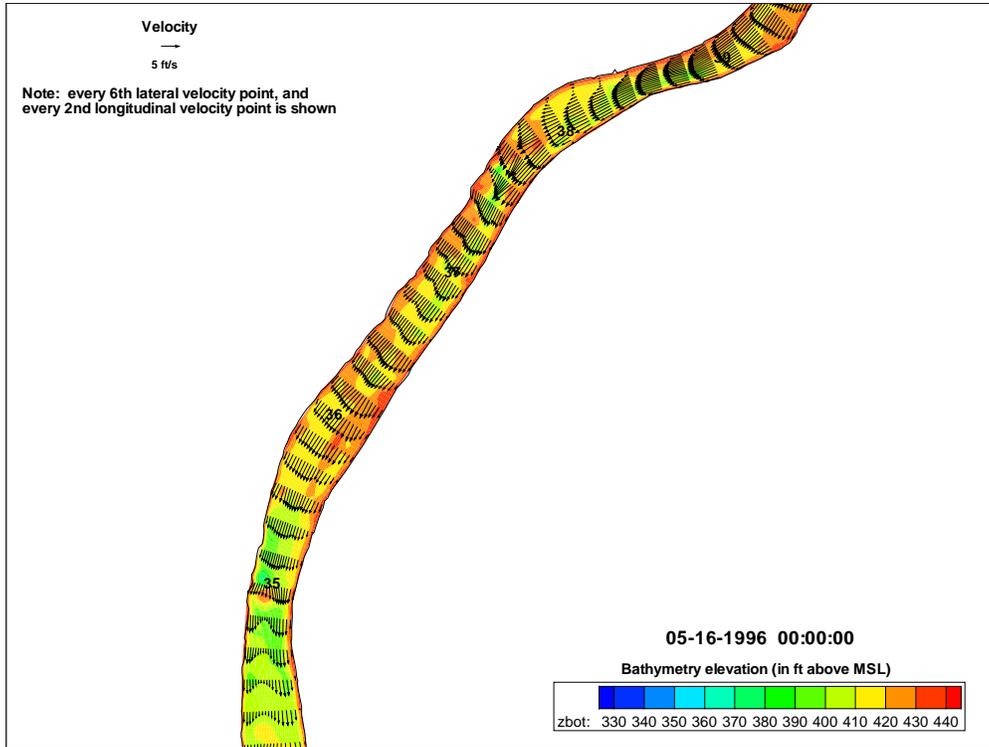


Figure 68. Spatial velocity distribution during the Spring 1996 study period.

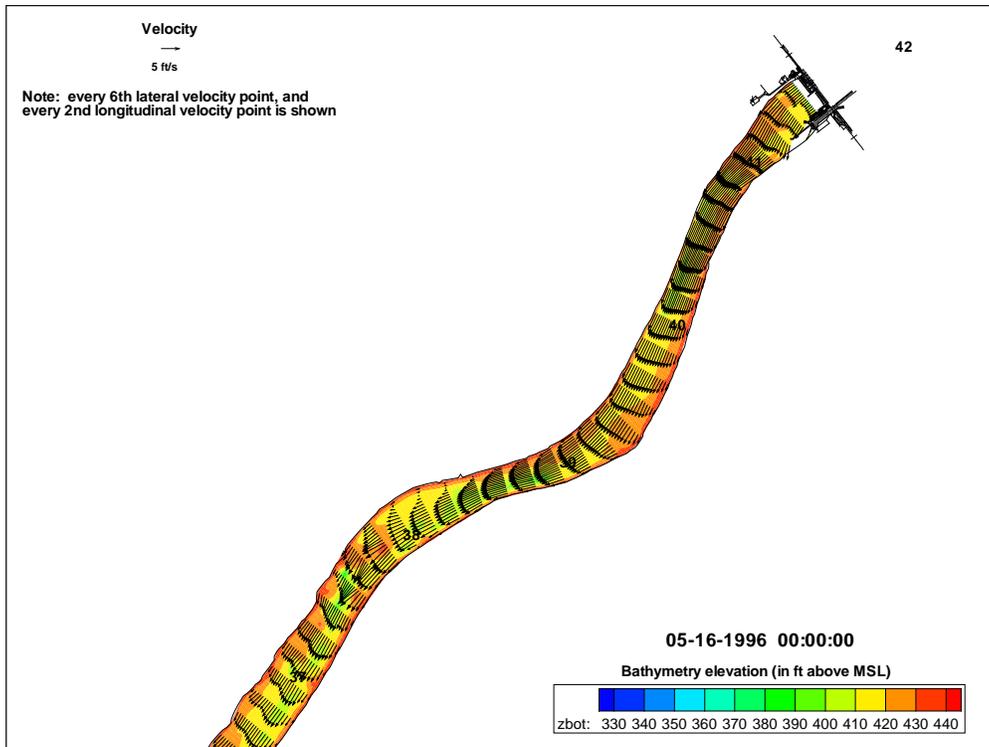


Figure 69. Spatial velocity distribution during the Spring 1996 study period.

1.4 Water Quality Calibration and Verification

1.4.1 1996 Spring Simulation

Boundary Conditions using Lower Granite Sourcing Function and Forebay FMS Data

Comparisons between the measurements and simulations using an upstream boundary condition developed from the empirical project gas sourcing function and the forebay FMS are shown in the figures below. Statistics on comparisons between measured and simulated temperatures and total dissolved gas are also presented. The case is denoted as FMS-BC in the figure and table captions.

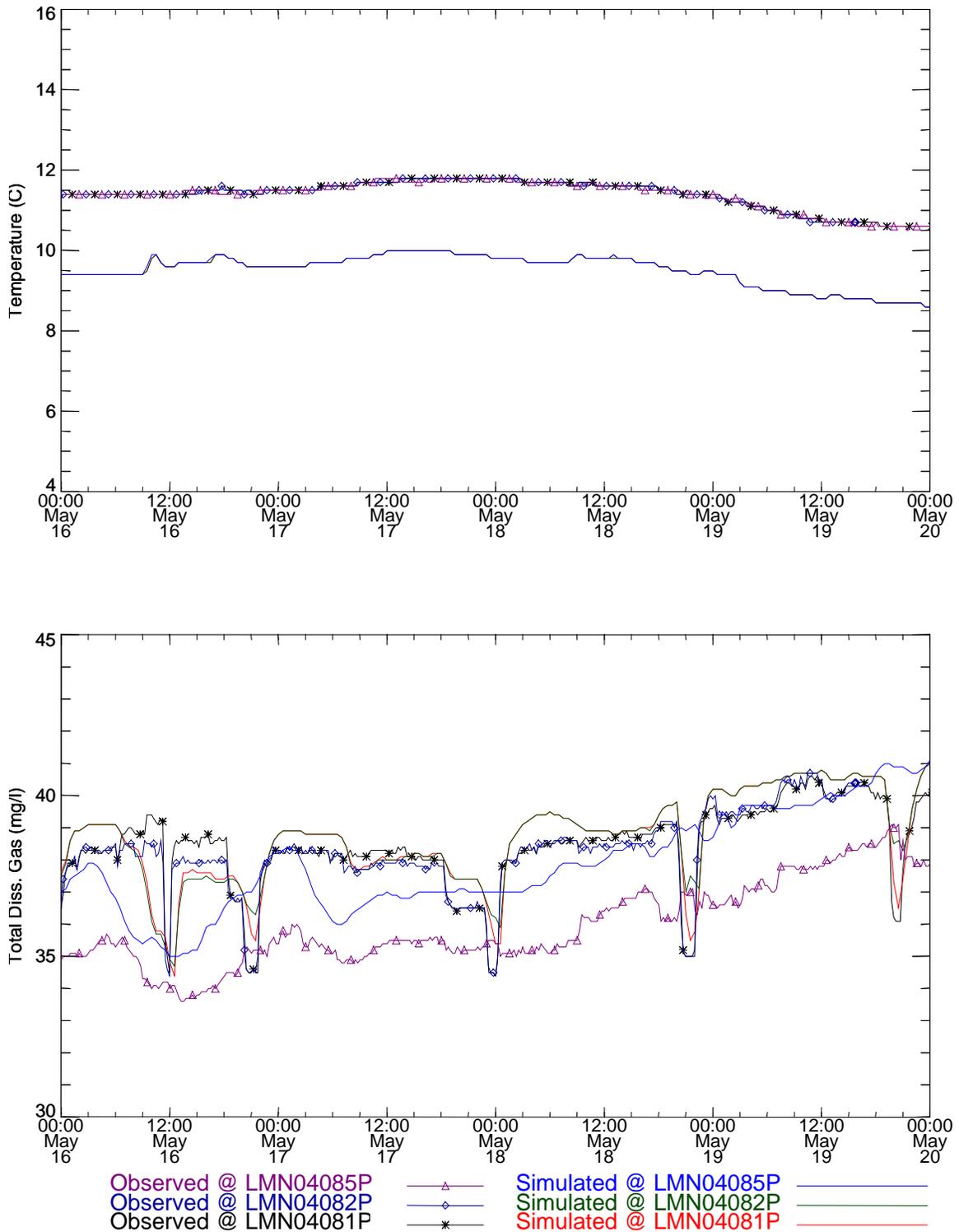


Figure 70. Temperature and total dissolved gas time series comparisons near the Snake River Mile 040.8 for the Spring 1996 study period. (FMS-BC).

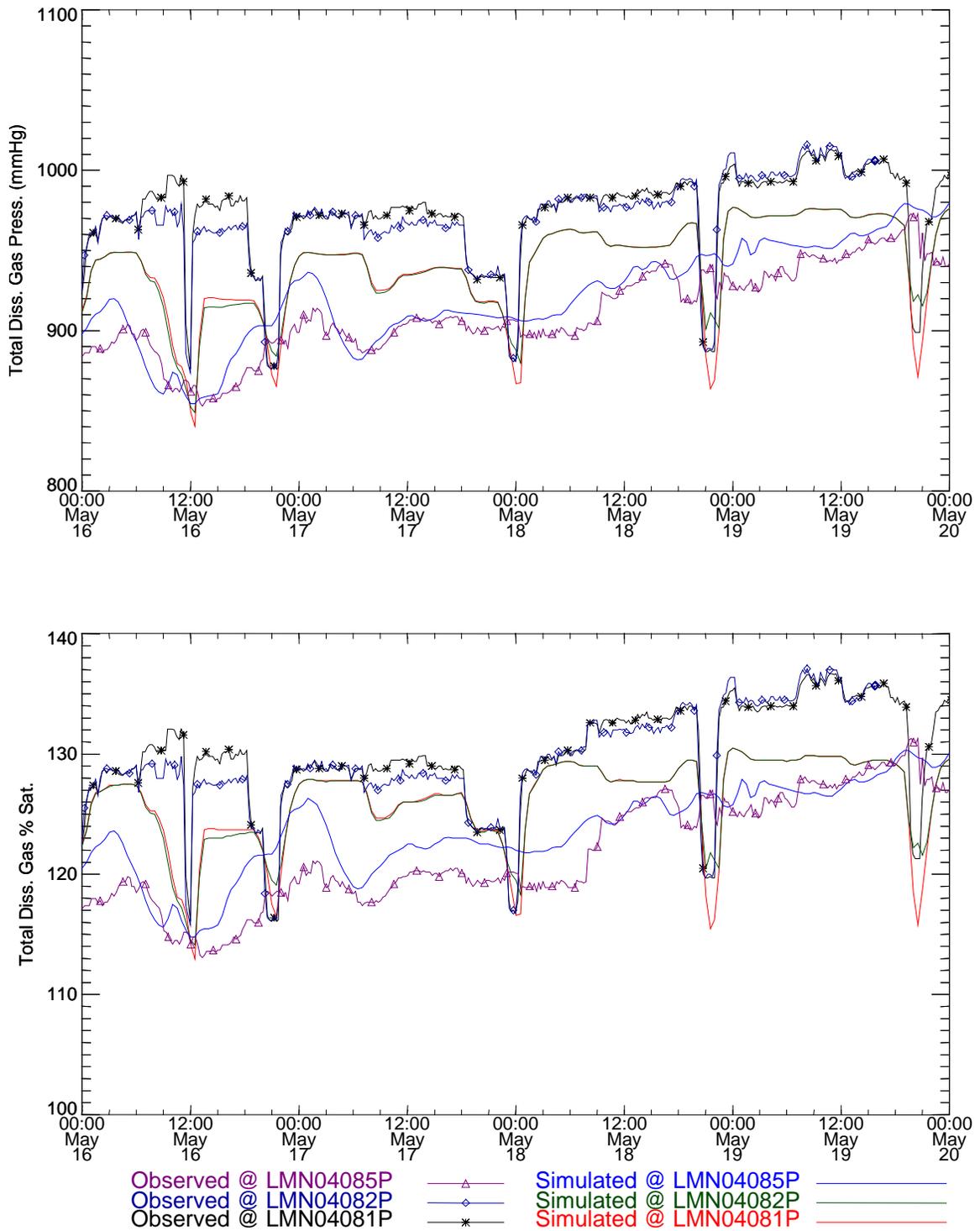


Figure 71. Total dissolved gas pressure and saturation time series comparisons near Snake River Mile 040.8 for Spring 1996 study period (FMS-BC).

Table 1. Statistical summary of measurements and simulations near the Snake River Mile 040.8 for the Spring 1996 study period (FMS-BC).

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature					
LMN04081P	11.39	9.51	0.36	0.39	1.89
LMN04082P	11.39	9.51	0.35	0.39	1.89
LMN04085P	11.39	9.51	0.36	0.4	1.88
Concentration					
LMN04081P	38.41	38.66	1.29	1.4	0.88
LMN04082P	38.41	38.7	1.38	1.33	0.87
LMN04085P	35.97	37.88	1.3	1.55	1.97
Gas Pressure					
LMN04081P	972.7	940.6	28.79	29.56	37.57
LMN04082P	972.59	941.55	29.5	27.25	36.69
LMN04085P	911.49	921.79	27.28	30.94	15.29
% Saturation					
LMN04081P	129.92	126.14	4.42	3.73	4.75
LMN04082P	129.9	126.27	4.67	3.37	4.86
LMN04085P	121.75	123.61	4.59	3.7	2.7

Table 2. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements. Stations near the Snake River Mile 040.8 for the Spring 1996 study period (FMS-BC).

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat.
LMN04081P	0	87.56	78.24	66.32
LMN04082P	0	87.05	79.27	73.58
LMN04085P	0	4.15	100	93.26

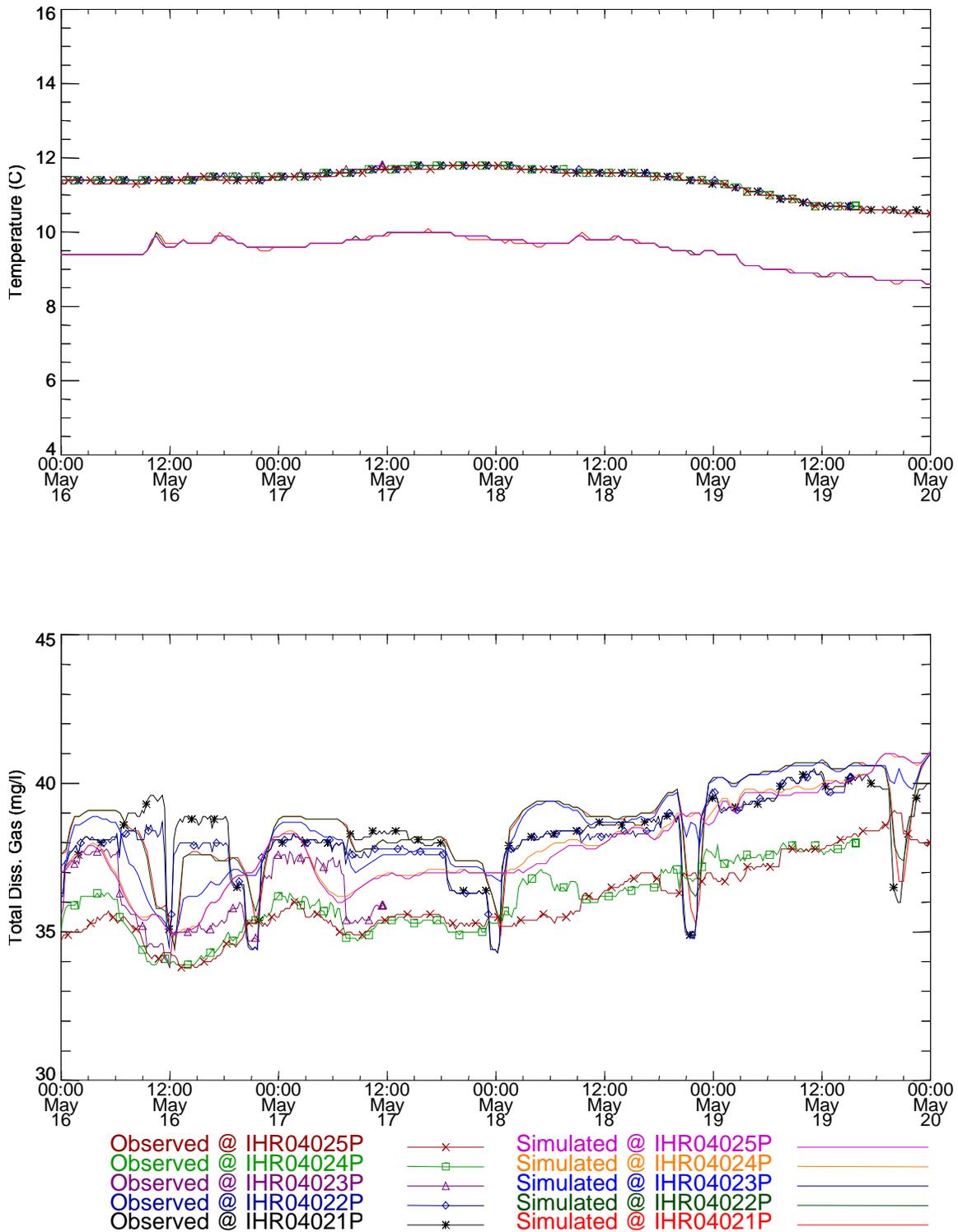


Figure 72. Temperature and total dissolved gas time series comparisons near the Snake River Mile 040.2 for the Spring 1996 study period. (FMS-BC).

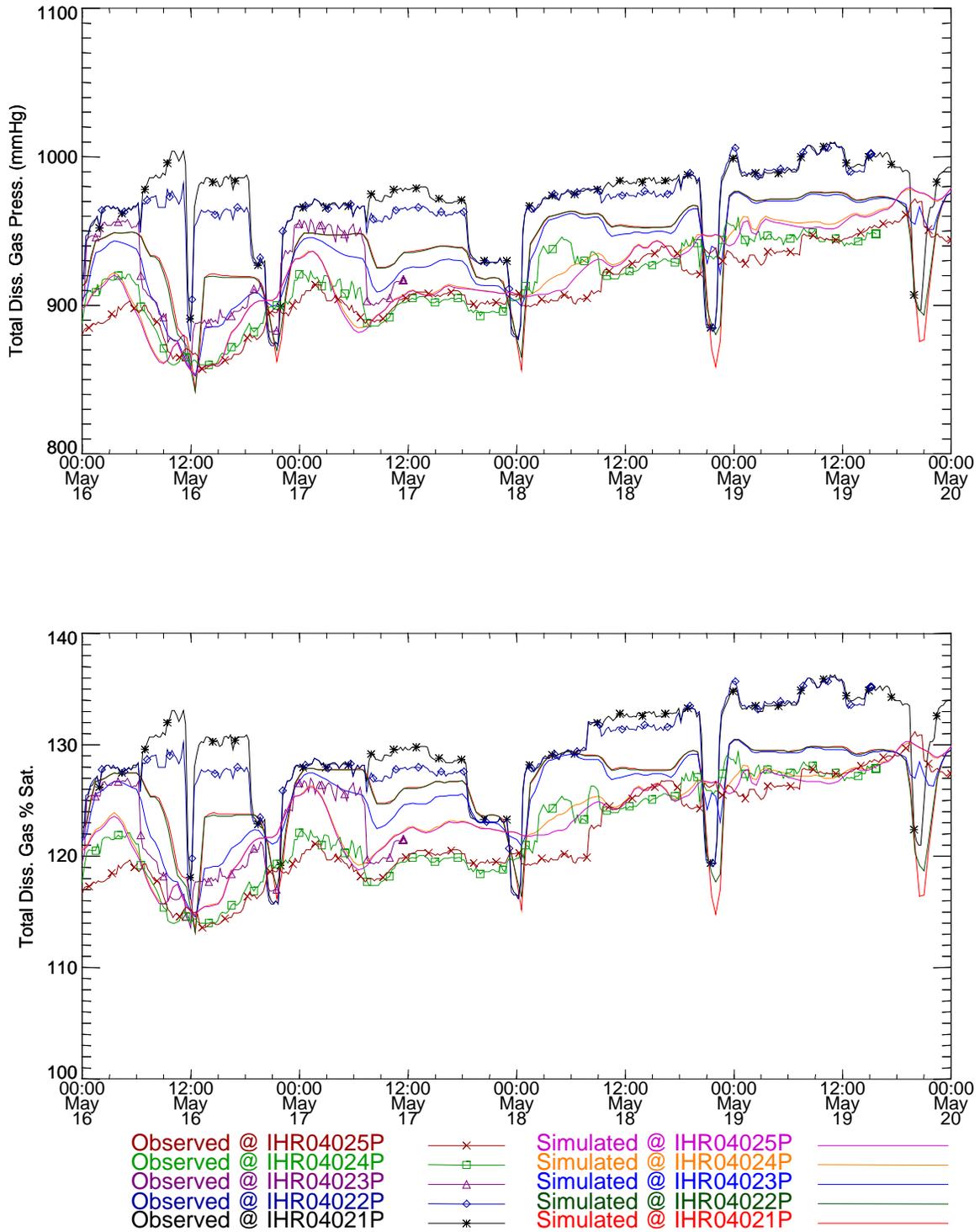


Figure 73. Total dissolved gas pressure and saturation time series comparisons near Snake River Mile 040.2 for Spring 1996 study period (FMS-BC).

Table 3. Statistical summary of measurements and simulations near the Snake River Mile 040.2 for the Spring 1996 study period (FMS-BC).

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature					
IHR04021P	11.38	9.51	0.37	0.39	1.87
IHR04022P	11.4	9.51	0.35	0.39	1.89
IHR04023P	11.69	9.51	0.16	0.39	2.23
IHR04024P	11.4	9.51	0.35	0.39	1.89
IHR04025P	11.36	9.51	0.37	0.39	1.85
Concentration					
IHR04021P	38.33	38.66	1.28	1.38	1.01
IHR04022P	38.23	38.67	1.33	1.34	0.96
IHR04023P	36	38.53	0.71	1.43	2.88
IHR04024P	36.19	37.94	1.21	1.54	1.83
IHR04025P	36.03	37.87	1.26	1.54	1.9
Gas Pressure					
IHR04021P	970.58	940.83	28.64	28.93	37.16
IHR04022P	968.32	941.07	28.37	28.01	34.05
IHR04023P	917.81	937.53	17.68	28.86	32.93
IHR04024P	917.24	923.31	26.02	30.94	13.29
IHR04025P	912.58	921.68	26.22	30.78	14.18
% Saturation					
IHR04021P	129.63	126.18	4.37	3.65	4.68
IHR04022P	129.33	126.21	4.52	3.5	4.58
IHR04023P	121.62	125.73	2.34	3.49	5.14
IHR04024P	122.51	123.81	4.35	3.7	2.09
IHR04025P	121.89	123.6	4.46	3.68	2.5

Table 4. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements. Stations near the Snake River Mile 040.2 for the Spring 1996 study period (FMS-BC).

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat.
IHR04021P	0	75.52	78.13	73.18
IHR04022P	0	77.08	82.29	78.13
IHR04023P	0	9.9	66.41	55.47
IHR04024P	0	9.64	100	99.48
IHR04025P	0	5.99	100	94.53

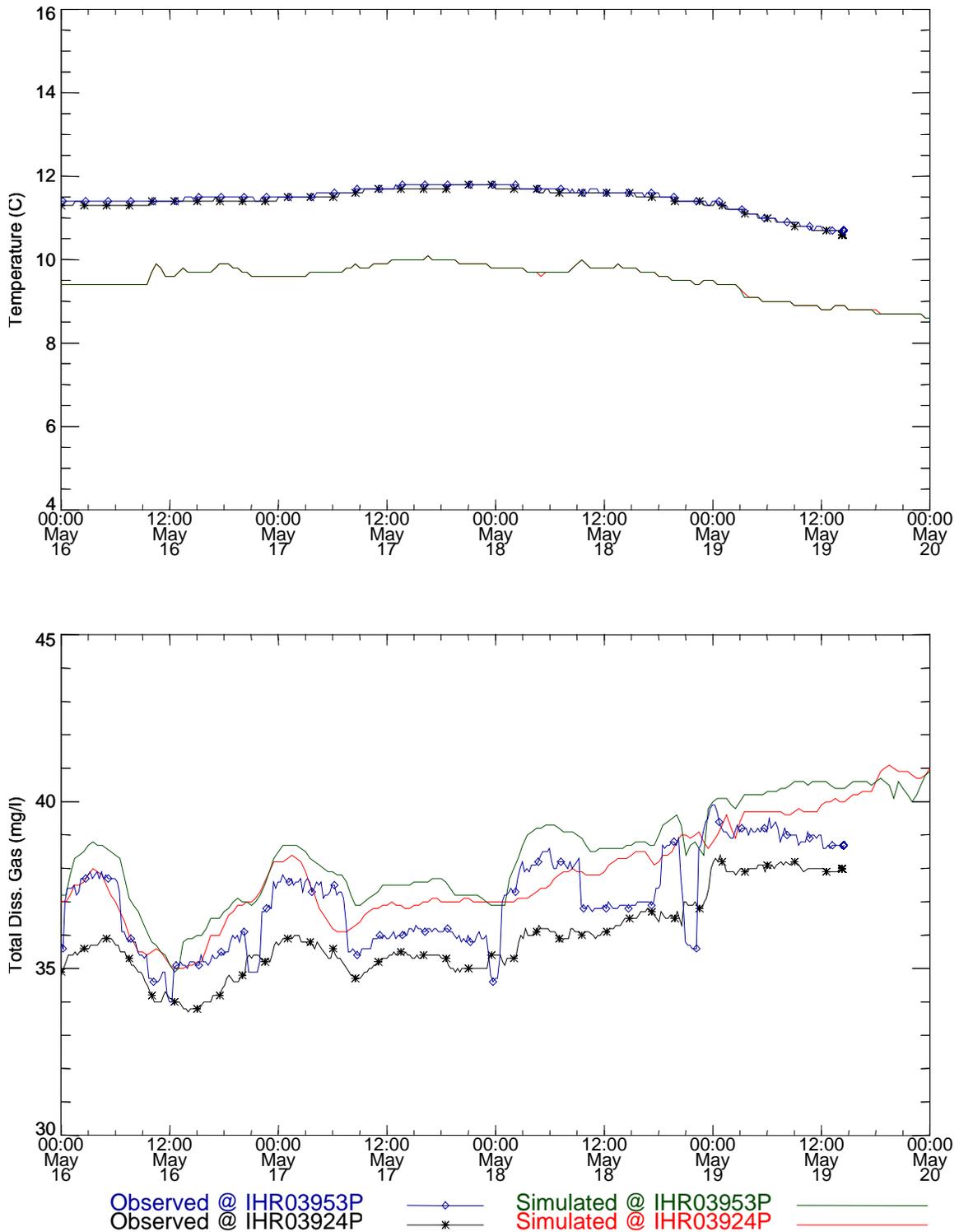


Figure 74. Temperature and total dissolved gas time series comparisons near the Snake River Mile 039.2 for the Spring 1996 study period. (FMS-BC).

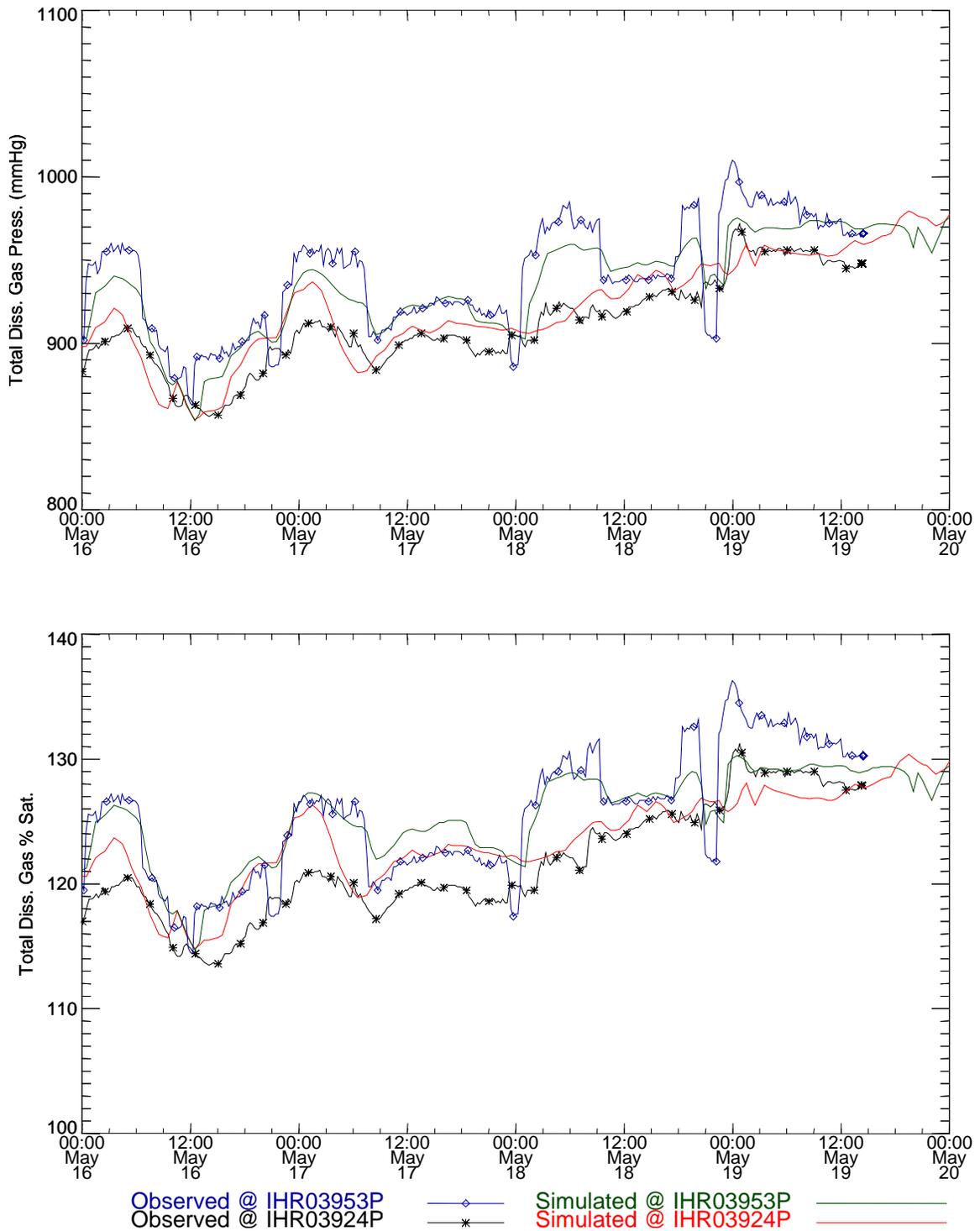


Figure 75. Total dissolved gas pressure and saturation time series comparisons near Snake River Mile 039.2 for Spring 1996 study period (FMS-BC).

Table 5. Statistical summary of measurements and simulations near the Snake River Mile 039.2 for the Spring 1996 study period (FMS-BC).

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature					
IHR03924P	11.35	9.51	0.36	0.39	1.84
IHR03953P	11.4	9.51	0.35	0.4	1.89
Concentration					
IHR03924P	36.12	37.89	1.3	1.54	1.84
IHR03953P	37.21	38.45	1.41	1.46	1.36
Gas Pressure					
IHR03924P	914.71	922.03	27.81	30.86	13.65
IHR03953P	942.74	935.63	31.64	29.65	15.51
% Saturation					
IHR03924P	122.18	123.64	4.66	3.68	2.51
IHR03953P	125.91	125.47	4.97	3.57	2.24

Table 6. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements. Stations near the Snake River Mile 039.2 for the Spring 1996 study period (FMS-BC).

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat.
IHR03924P	0	7.25	100	96.37
IHR03953P	0	32.64	98.45	97.41

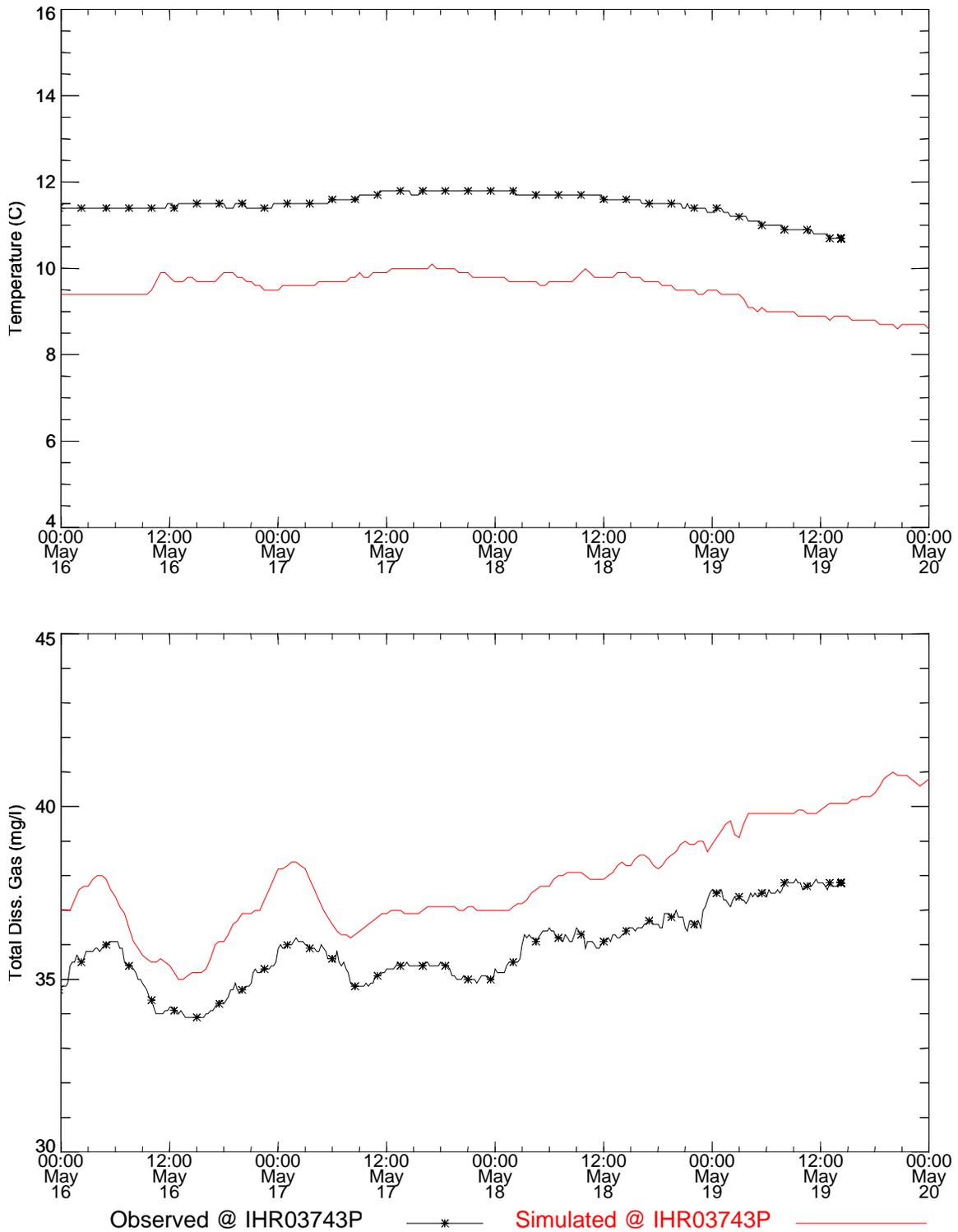


Figure 76. Temperature and total dissolved gas time series comparisons near the Snake River Mile 037.4 for the Spring 1996 study period. (FMS-BC).

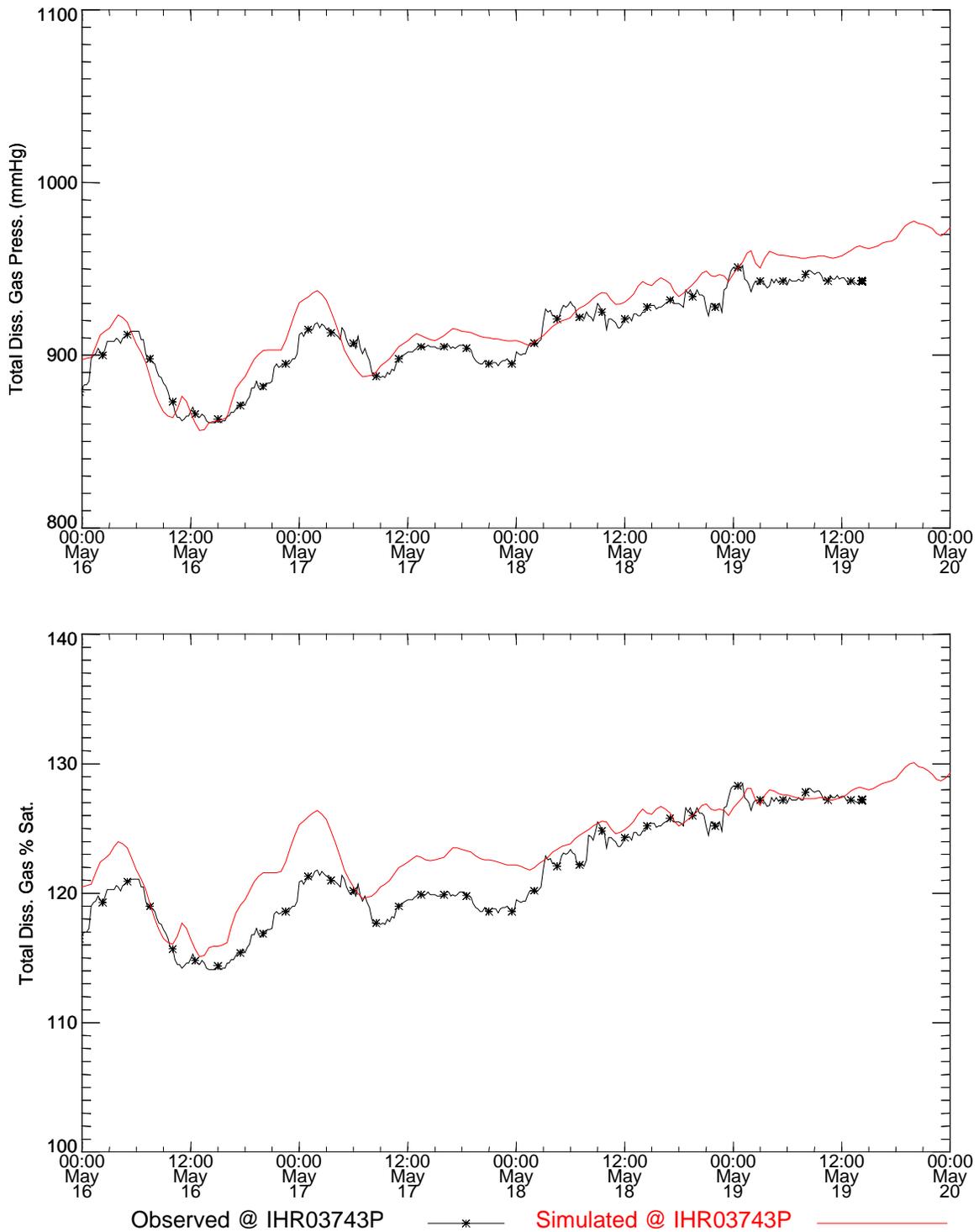


Figure 77. Total dissolved gas pressure and saturation time series comparisons near Snake River Mile 037.4 for Spring 1996 study period (FMS-BC).

Table 7. Statistical summary of measurements and simulations near the Snake River Mile 037.4 for the Spring 1996 study period (FMS-BC).

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature IHR03743P	11.4	9.51	0.35	0.39	1.89
Concentration IHR03743P	36.06	37.94	1.16	1.52	1.94
Gas Pressure IHR03743P	914.08	923.75	24.56	30.4	14.55
% Saturation IHR03743P	122.08	123.87	4.2	3.62	2.37

Table 8. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements. Stations near the Snake River Mile 037.4 for the Spring 1996 study period (FMS-BC).

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat.
IHR03743P	0	5.18	100	99.48

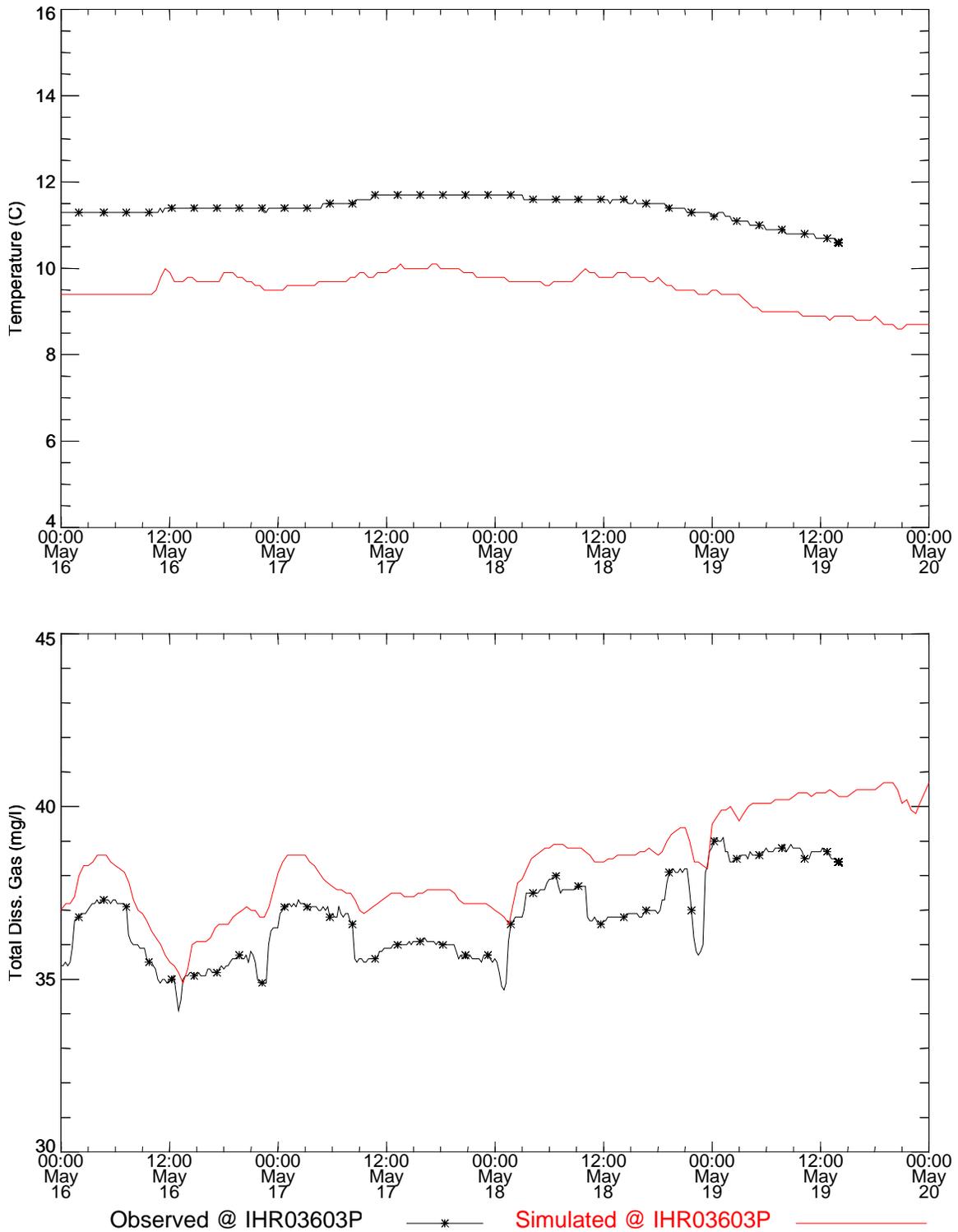


Figure 78. Temperature and total dissolved gas time series comparisons near the Snake River Mile 036.0 for the Spring 1996 study period. (FMS-BC).

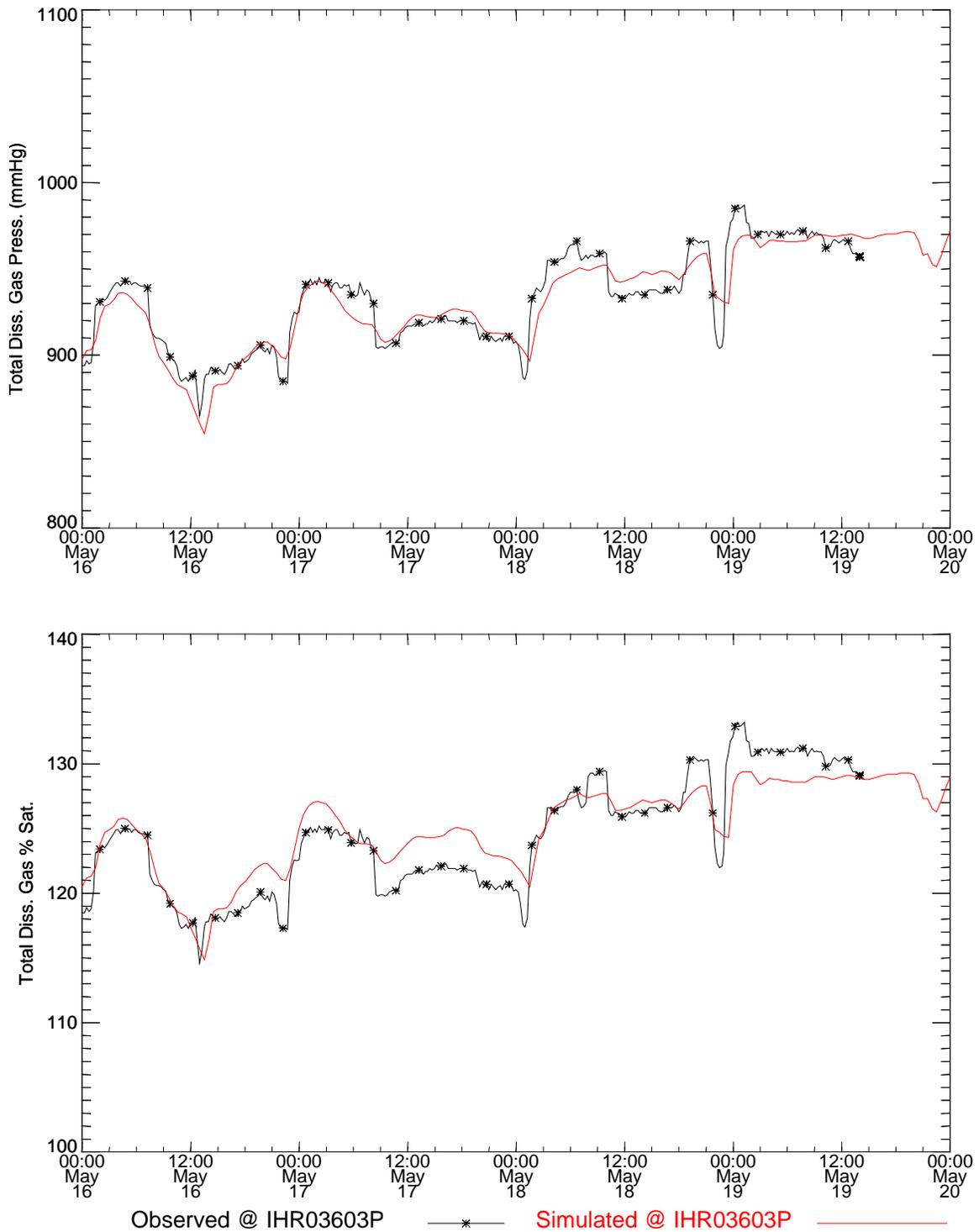


Figure 79. Total dissolved gas pressure and saturation time series comparisons near Snake River Mile 036.0 for Spring 1996 study period (FMS-BC).

Table 9. Statistical summary of measurements and simulations near the Snake River Mile 036.0 for the Spring 1996 study period (FMS-BC).

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature IHR03603P	11.32	9.52	0.35	0.39	1.81
Concentration IHR03603P	36.94	38.33	1.24	1.39	1.46
Gas Pressure IHR03603P	934.41	933.23	26.8	27.75	10.44
% Saturation IHR03603P	124.8	125.15	4.42	3.3	1.87

Table 10. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements. Stations near the Snake River Mile 036.0 for the Spring 1996 study period (FMS-BC).

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat.
IHR03603P	0	17.62	99.48	99.48

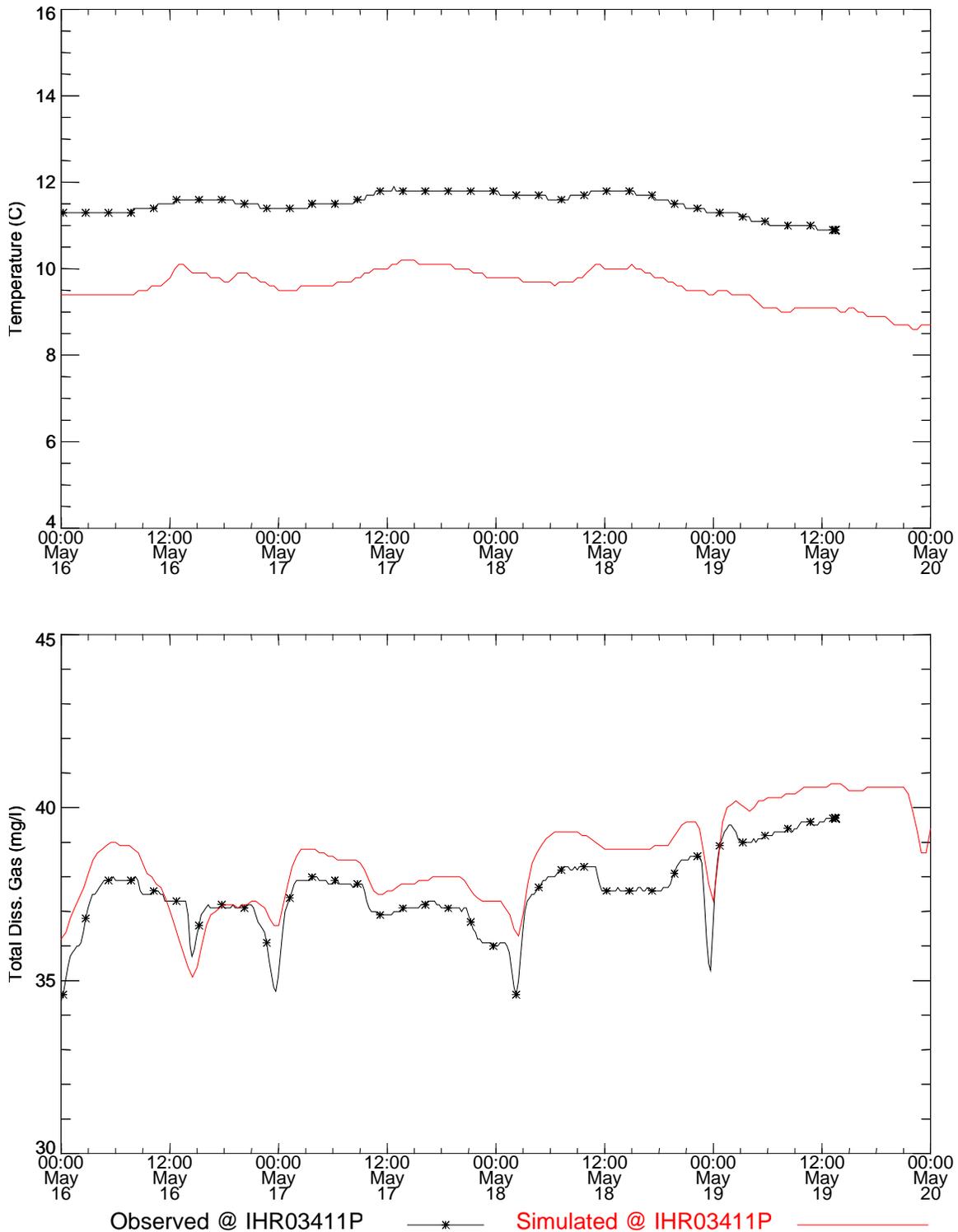


Figure 80. Temperature and total dissolved gas time series comparisons near the Snake River Mile 034.1 for the Spring 1996 study period. (FMS-BC).

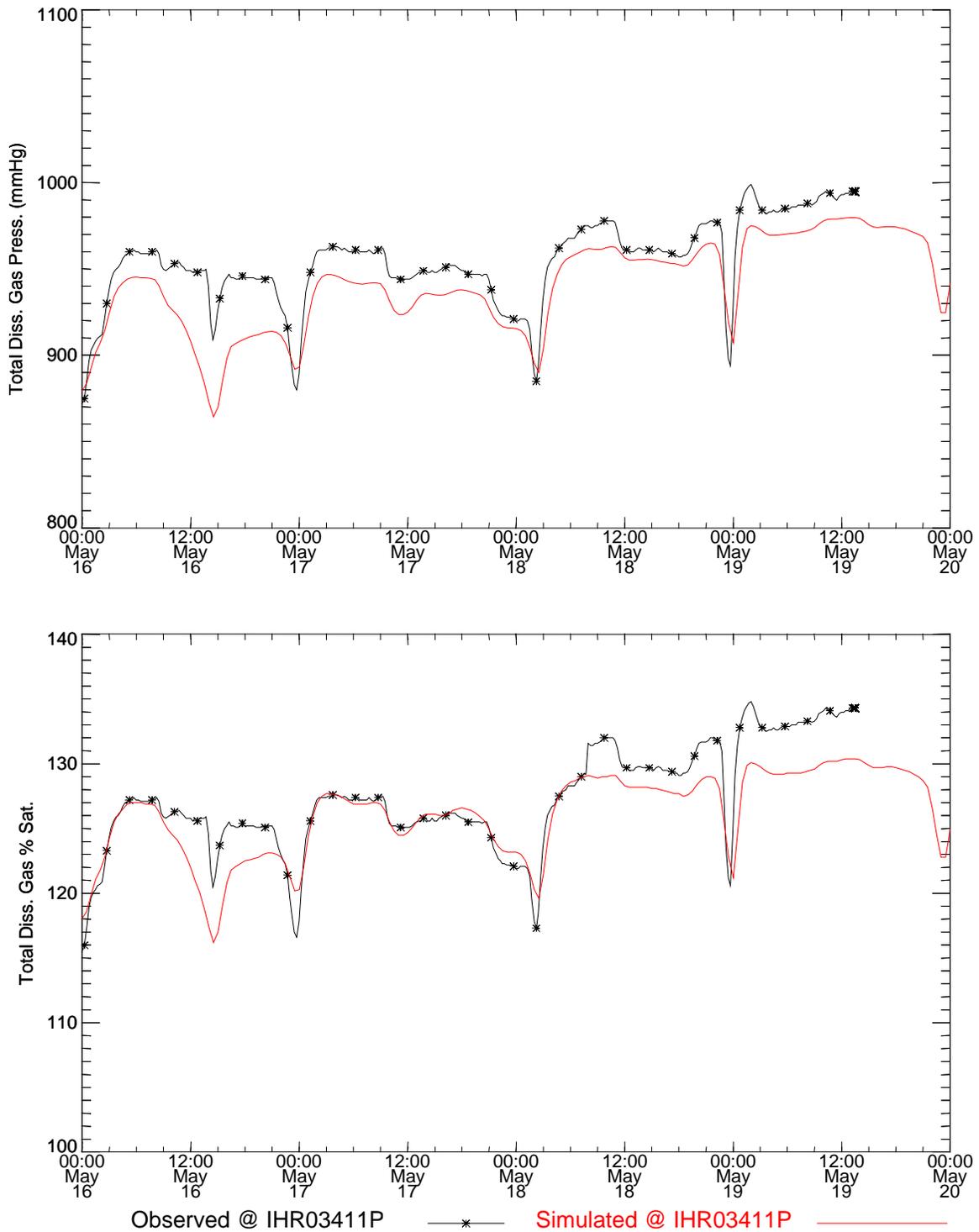


Figure 81. Total dissolved gas pressure and saturation time series comparisons near Snake River Mile 034.1 for Spring 1996 study period (FMS-BC).

Table 11. Statistical summary of measurements and simulations near the Snake River Mile 034.1 for the Spring 1996 study period (FMS-BC).

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature IHR03411P	11.44	9.58	0.3	0.39	1.86
Concentration IHR03411P	37.8	38.57	1.21	1.31	0.95
Gas Pressure IHR03411P	958.6	940.48	26.46	26.69	22.64
% Saturation IHR03411P	128.04	126.12	4.41	3.23	3.13

Table 12. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements. Stations near the Snake River Mile 034.1 for the Spring 1996 study period (FMS-BC).

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat.
IHR03411P	0	66.84	91.71	92.23

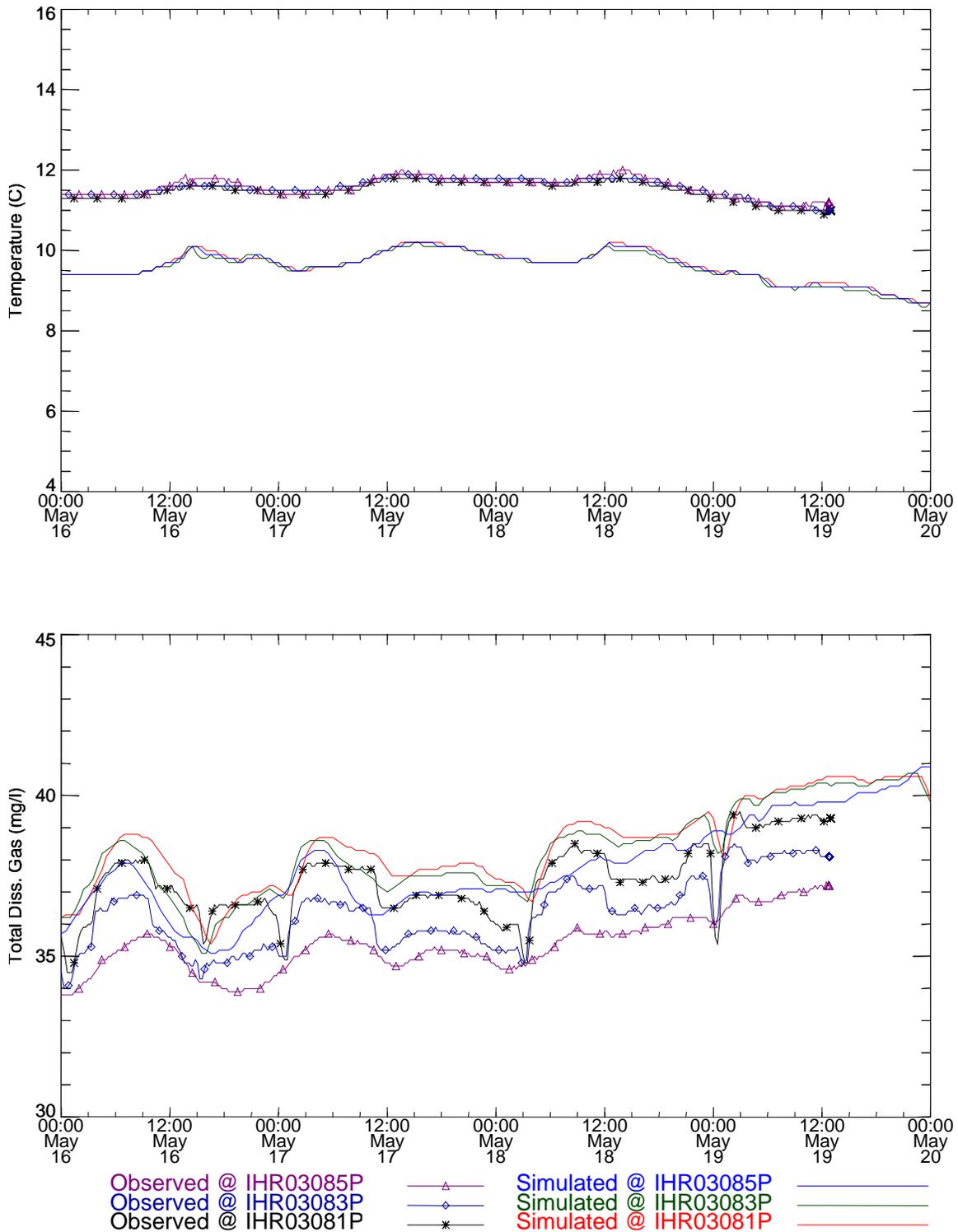


Figure 82. Temperature and total dissolved gas time series comparisons near the Snake River Mile 030.8 for the Spring 1996 study period. (FMS-BC).

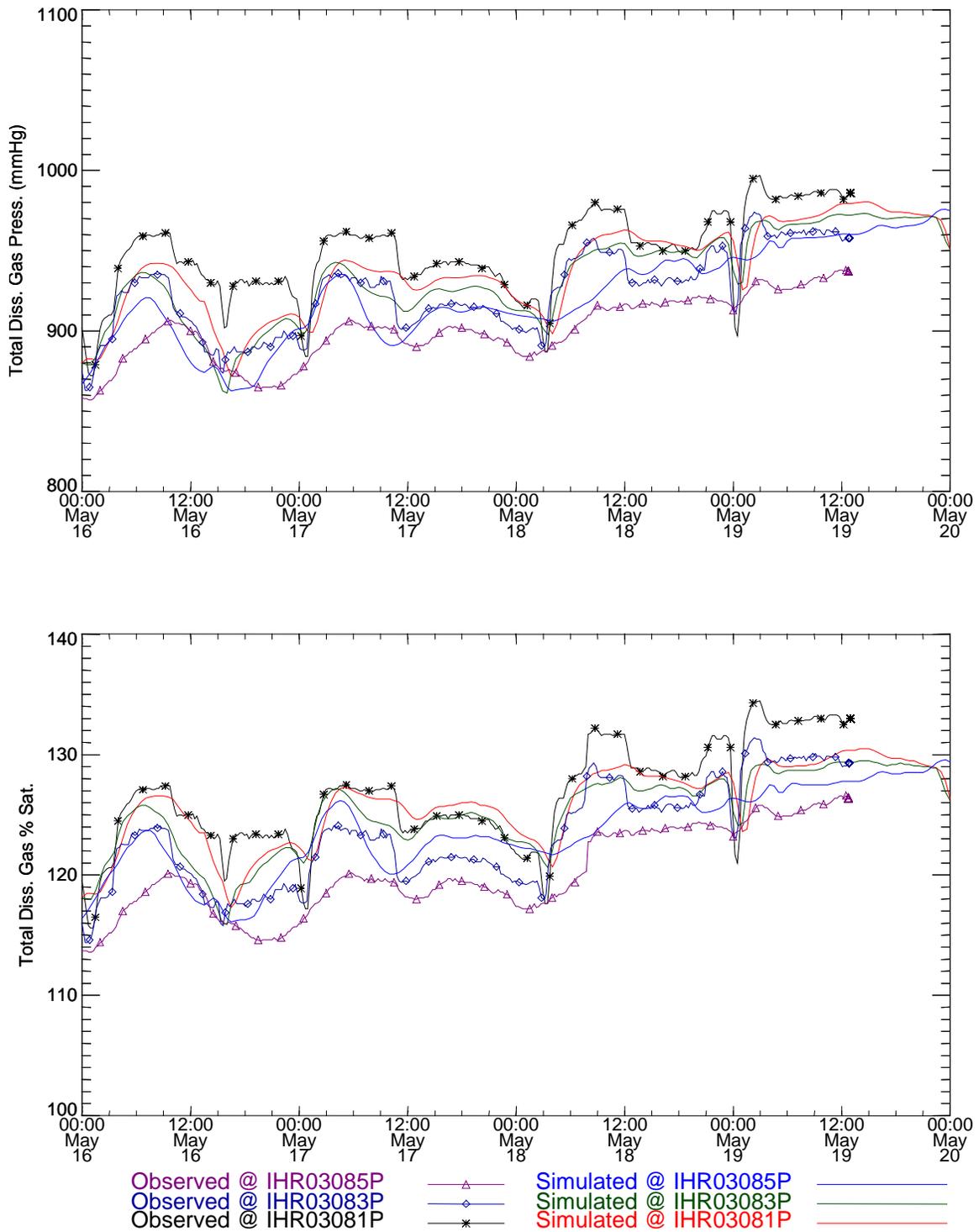


Figure 83. Total dissolved gas pressure and saturation time series comparisons near Snake River Mile 030.8 for Spring 1996 study period (FMS-BC).

Table 13. Statistical summary of measurements and simulations near the Snake River Mile 030.8 for the Spring 1996 study period (FMS-BC).

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature					
IHR03081P	11.43	9.63	0.26	0.38	1.81
IHR03083P	11.5	9.58	0.28	0.38	1.93
IHR03085P	11.54	9.61	0.25	0.38	1.94
Concentration					
IHR03081P	37.58	38.46	1.21	1.32	1.04
IHR03083P	36.52	38.28	1.17	1.38	1.81
IHR03085P	35.58	37.78	1	1.45	2.29
Gas Pressure					
IHR03081P	952.77	938.69	26.97	27.36	19.65
IHR03083P	927.79	933.34	26.02	27.94	10.31
IHR03085P	904.71	922.03	22.12	29.47	21.61
% Saturation					
IHR03081P	127.25	125.88	4.46	3.26	2.64
IHR03083P	123.93	125.16	4.38	3.31	2.12
IHR03085P	120.84	123.64	3.89	3.48	3.28

Table 14. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements. Stations near the Snake River Mile 030.8 for the Spring 1996 study period (FMS-BC).

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat.
IHR03081P	0	60.62	95.85	95.34
IHR03083P	0	4.66	100	100
IHR03085P	0	6.22	98.45	89.12

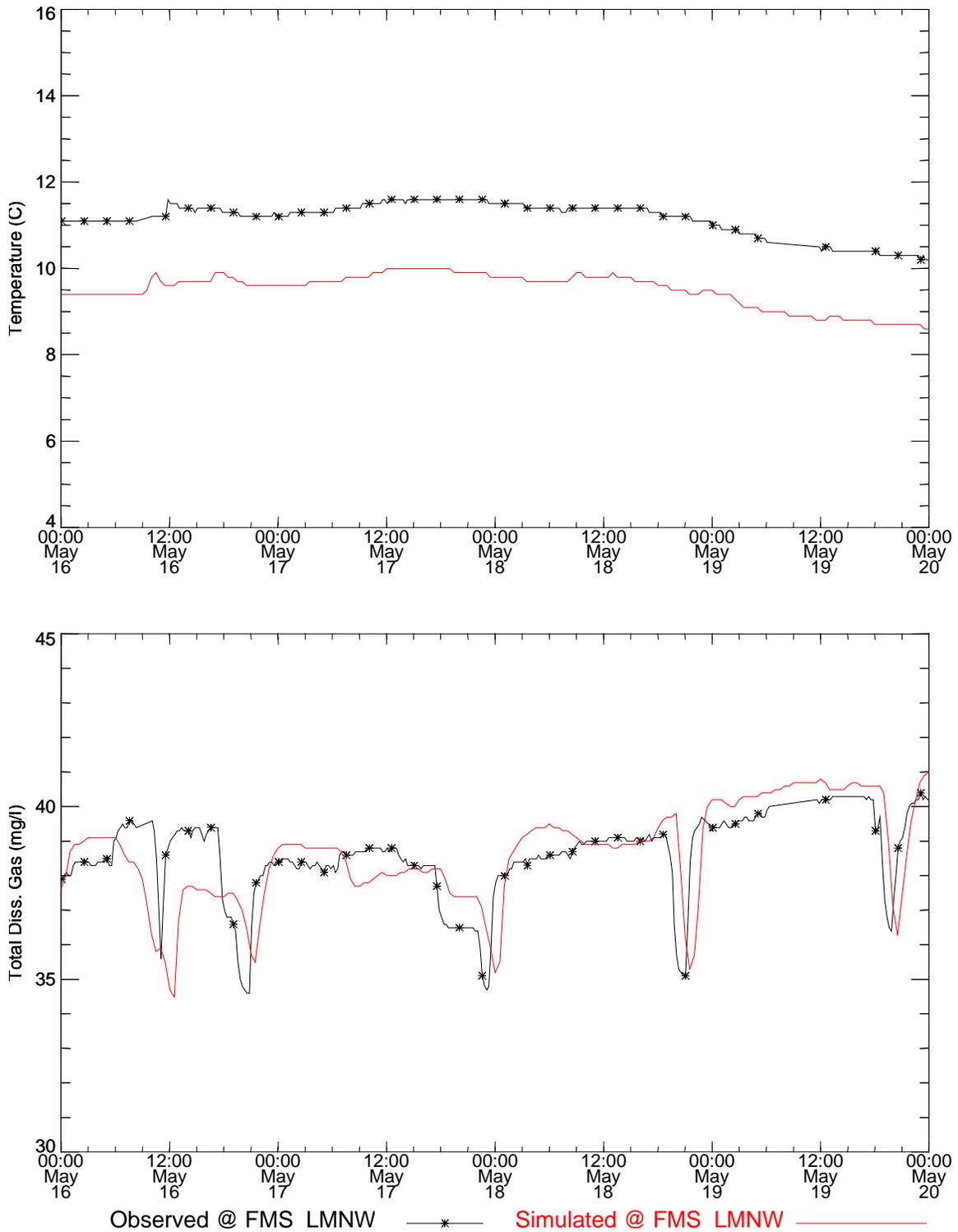


Figure 84. Temperature and total dissolved gas time series comparisons near fixed monitor LMNW for the Spring 1996 study period. (FMS-BC).

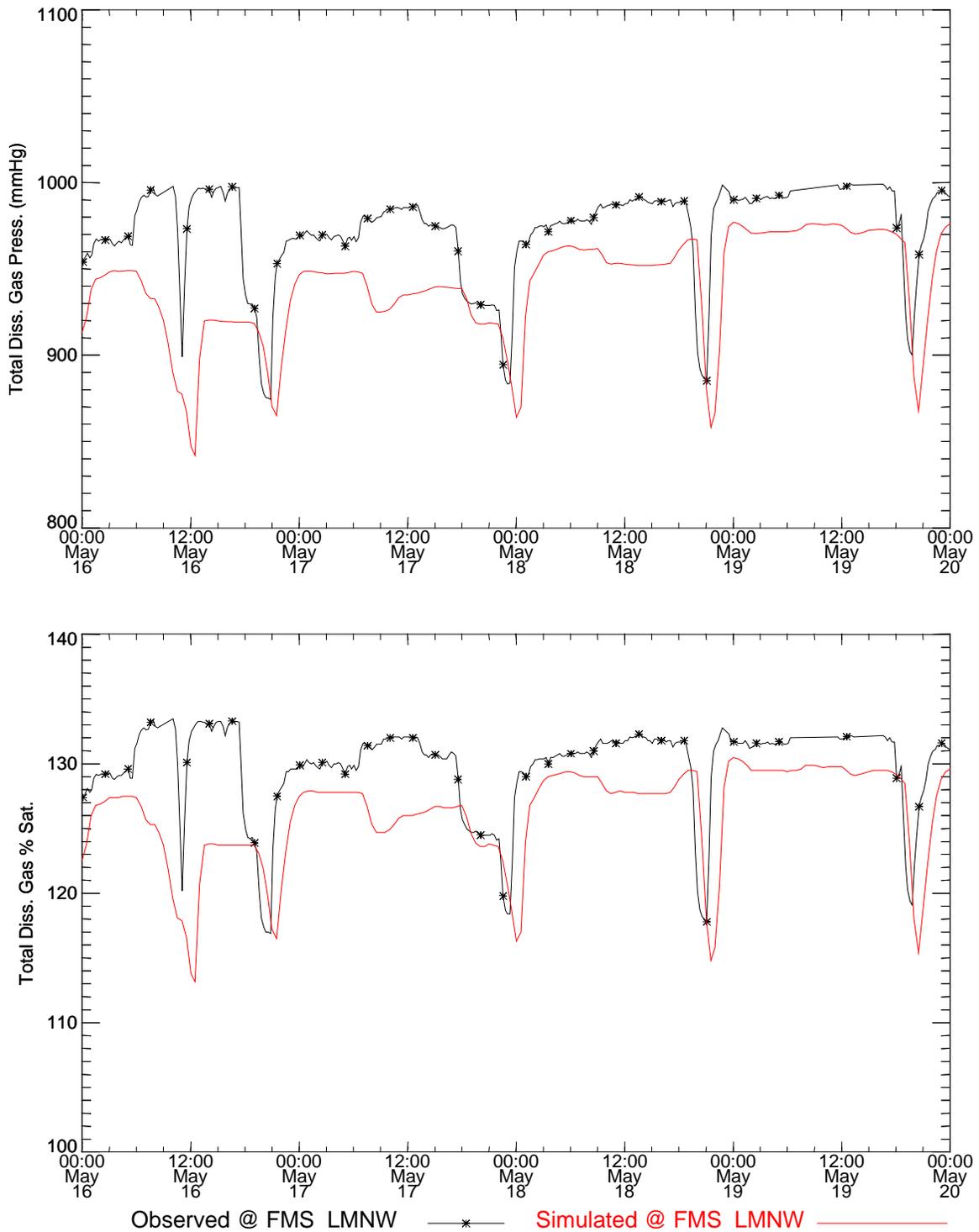


Figure 85. Total dissolved gas pressure and saturation time series comparisons near fixed monitor LMNW for Spring 1996 study period (FMS-BC).

Table 15. Statistical summary of measurements and simulations near fixed monitor LMNW for the Spring 1996 study period (FMS-BC).

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature FMS_LMNW	11.14	9.51	0.4	0.39	1.64
Concentration FMS_LMNW	38.64	38.66	1.22	1.41	1.19
Gas Pressure FMS_LMNW	973.5	940.5	26.98	29.81	44.06
% Saturation FMS_LMNW	129.87	126.12	3.46	3.76	5.42

Table 16. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements. Stations fixed monitor LMNW for the Spring 1996 study period (FMS-BC).

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat.
FMS_LMNW	0	77.2	70.98	74.61

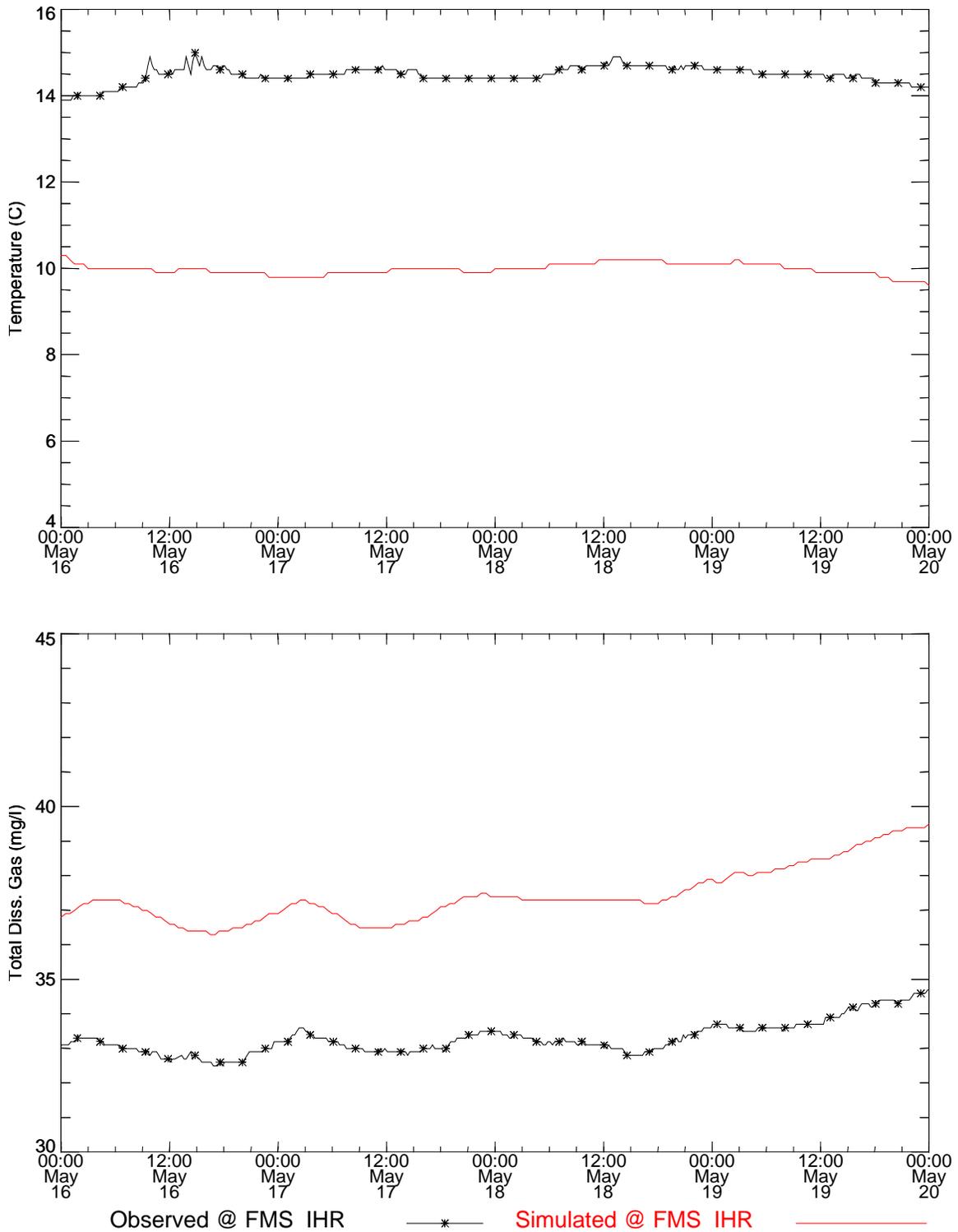


Figure 86. Temperature and total dissolved gas time series comparisons fixed monitor IHR for the Spring 1996 study period. (FMS-BC).

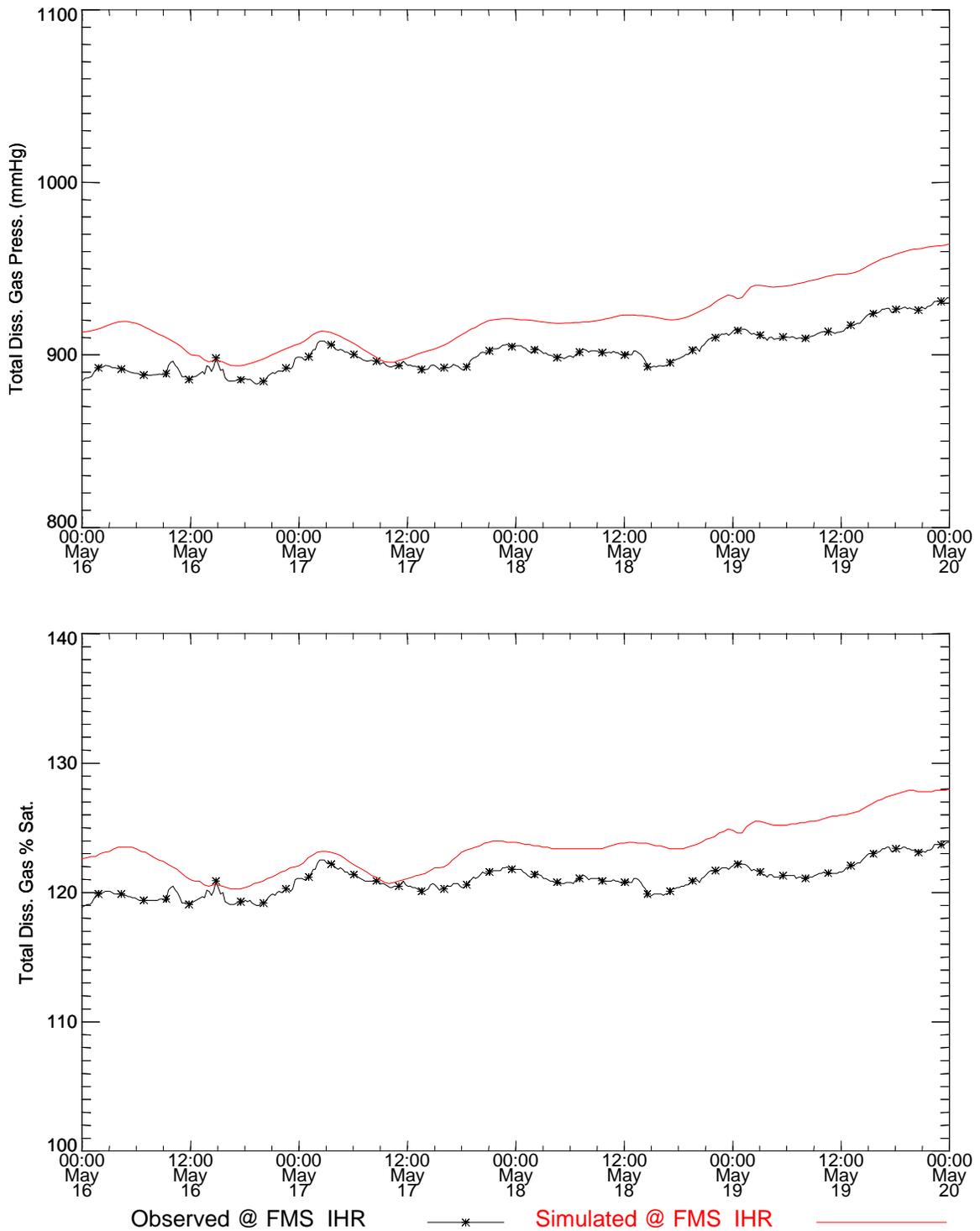


Figure 87. Total dissolved gas pressure and saturation time series comparisons near fixed monitor IHR for Spring 1996 study period (FMS-BC).

Table 17. Statistical summary of measurements and simulations near fixed monitor IHR for the Spring 1996 study period (FMS-BC).

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature					
FMS_IHR	14.48	9.98	0.19	0.13	4.5
Concentration					
FMS_IHR	33.3	37.43	0.48	0.79	4.16
Gas Pressure					
FMS_IHR	902.01	921.45	11.85	18.87	21.57
% Saturation					
FMS_IHR	121	123.57	1.15	1.99	2.85

Table 18. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements. Stations near fixed monitor IHR for the Spring 1996 study period (FMS-BC).

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat.
FMS_IHR	0	0	100	100

Boundary Conditions using Temporary Monitored Field Data

Comparisons between the measurements and simulations using an upstream boundary condition developed from water temperatures and TDG pressures measured by temporary monitors are shown in the figures below. Statistics on comparisons between measured and simulated temperatures and total dissolved gas are also presented. The case is denoted as TM-BC in the figure and table captions.

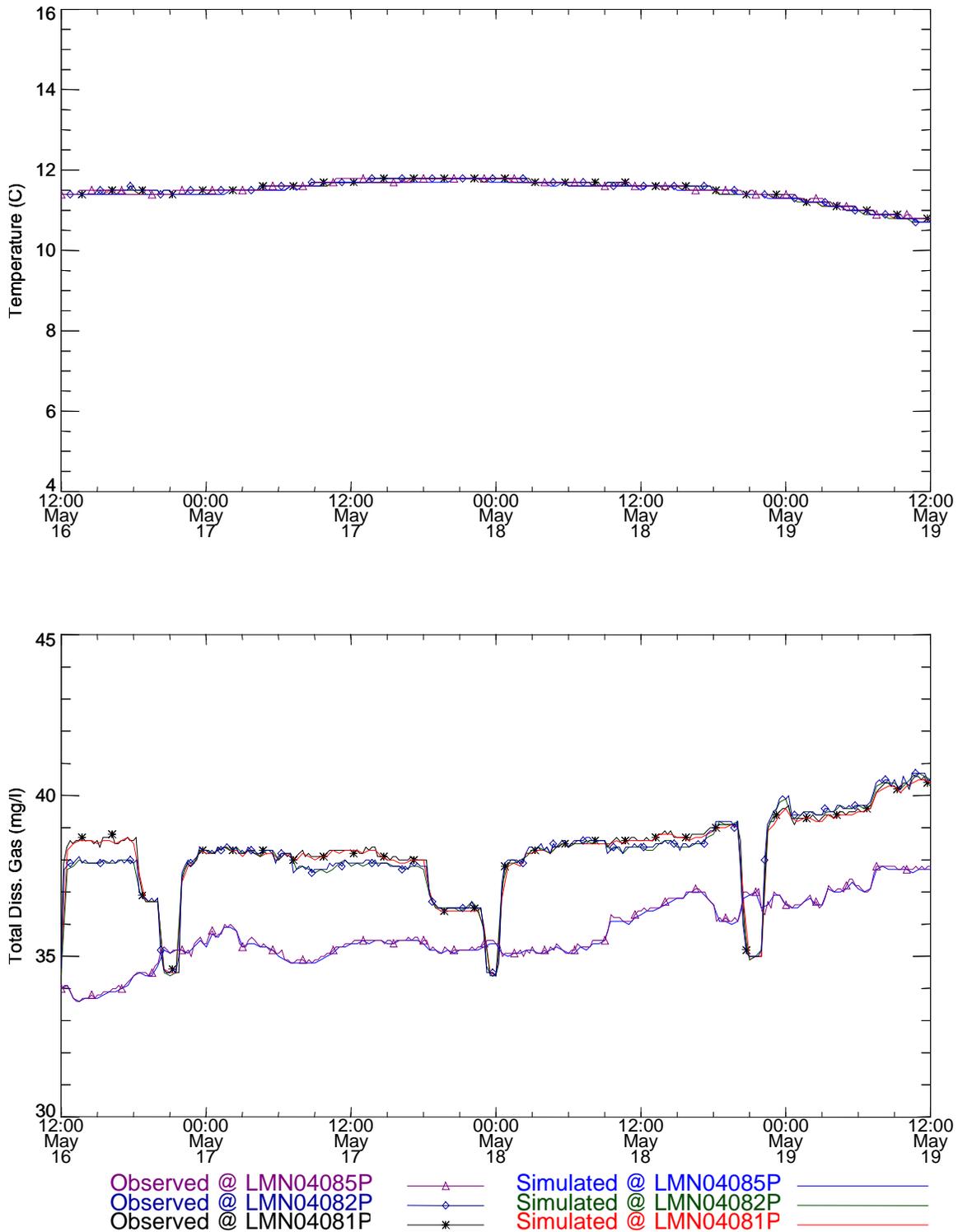


Figure 88. Temperature and total dissolved gas time series comparisons near the Snake River Mile 040.8 for the Spring 1996 study period. (TM-BC).

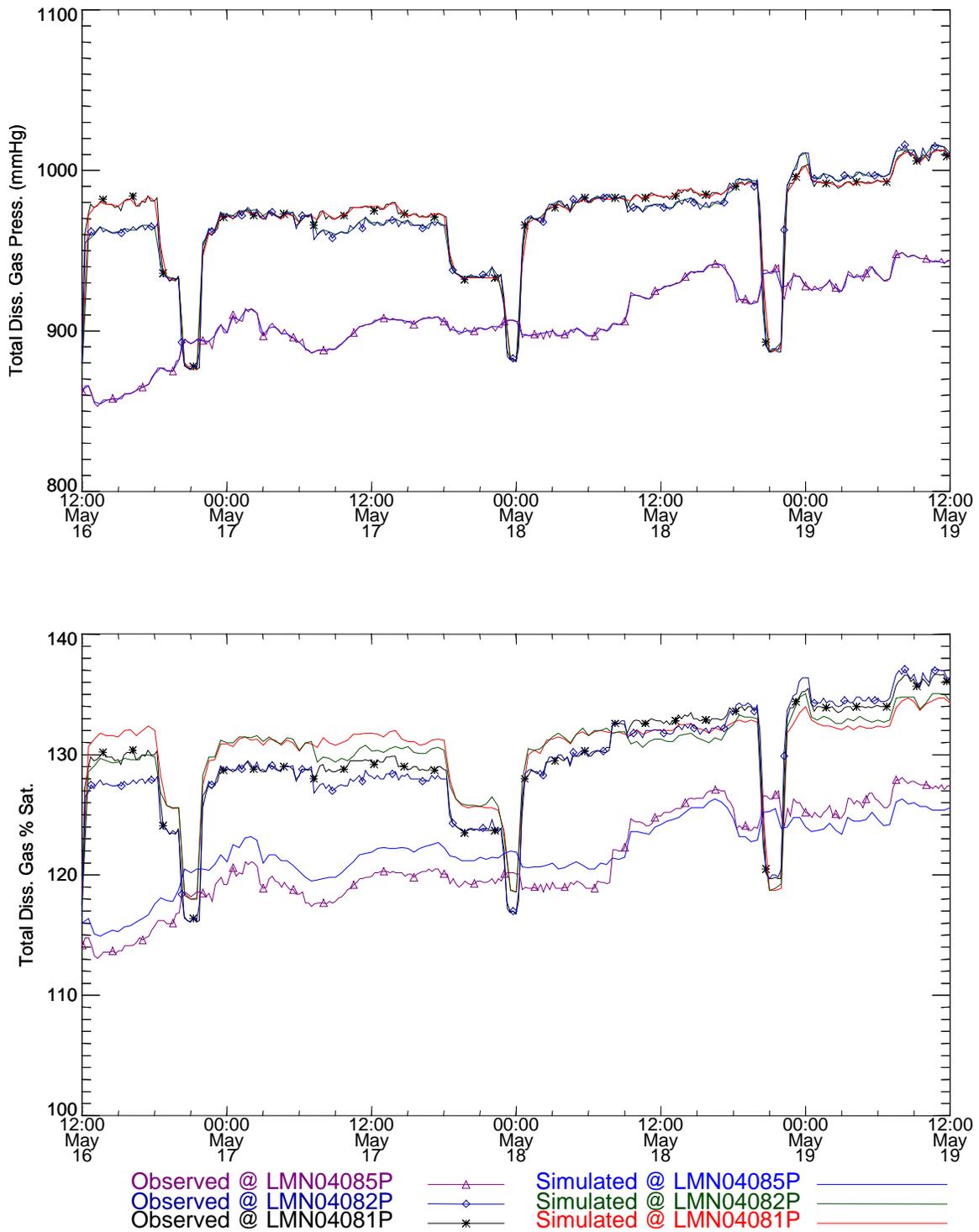


Figure 89. Total dissolved gas pressure and saturation time series comparisons near Snake River Mile 040.8 for Spring 1996 study period (TM-BC).

Table 19. Statistical summary of measurements and simulations near the Snake River Mile 040.8 for the Spring 1996 study period (TM-BC).

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature					
LMN04081P	11.51	11.47	0.27	0.27	0.06
LMN04082P	11.51	11.47	0.27	0.27	0.06
LMN04085P	11.51	11.46	0.25	0.25	0.07
Concentration					
LMN04081P	38.24	38.19	1.27	1.28	0.08
LMN04082P	38.15	38.1	1.32	1.32	0.07
LMN04085P	35.76	35.71	1.02	1.02	0.07
Gas Pressure					
LMN04081P	971.13	971.05	29.27	29.44	0.96
LMN04082P	968.8	968.74	30.04	30.16	0.81
LMN04085P	908.63	908.54	23.01	22.97	0.38
% Saturation					
LMN04081P	129.65	130.37	4.51	3.74	1.79
LMN04082P	129.33	130.06	4.66	3.79	1.79
LMN04085P	121.3	121.98	3.98	2.73	1.68

Table 20. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements. Stations near the Snake River Mile 040.8 for the Spring 1996 study period (TM-BC).

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat.
LMN04081P	100	100	100	100
LMN04082P	100	100	100	100
LMN04085P	100	100	100	100

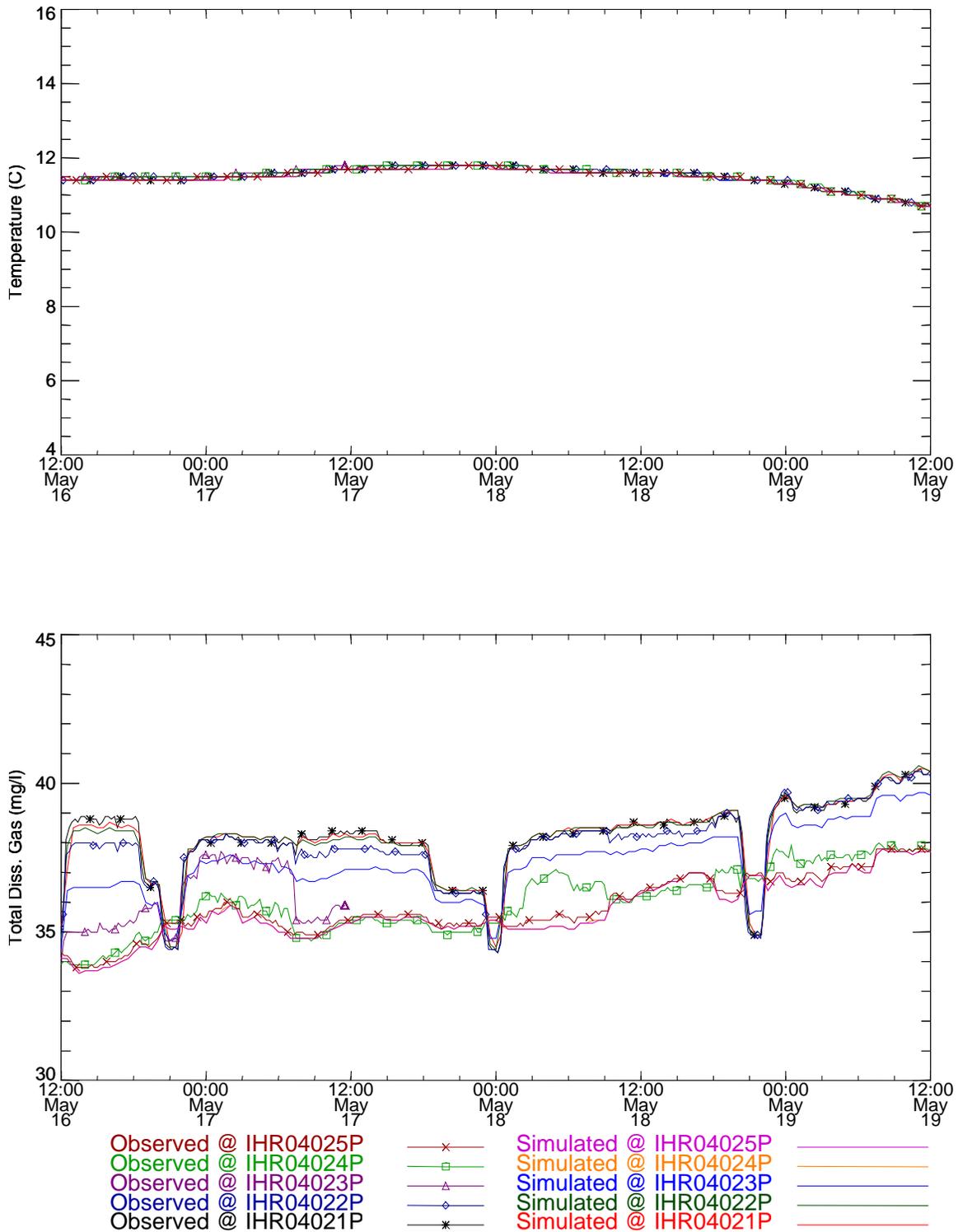


Figure 90. Temperature and total dissolved gas time series comparisons near the Snake River Mile 040.2 for the Spring 1996 study period. (TM-BC).

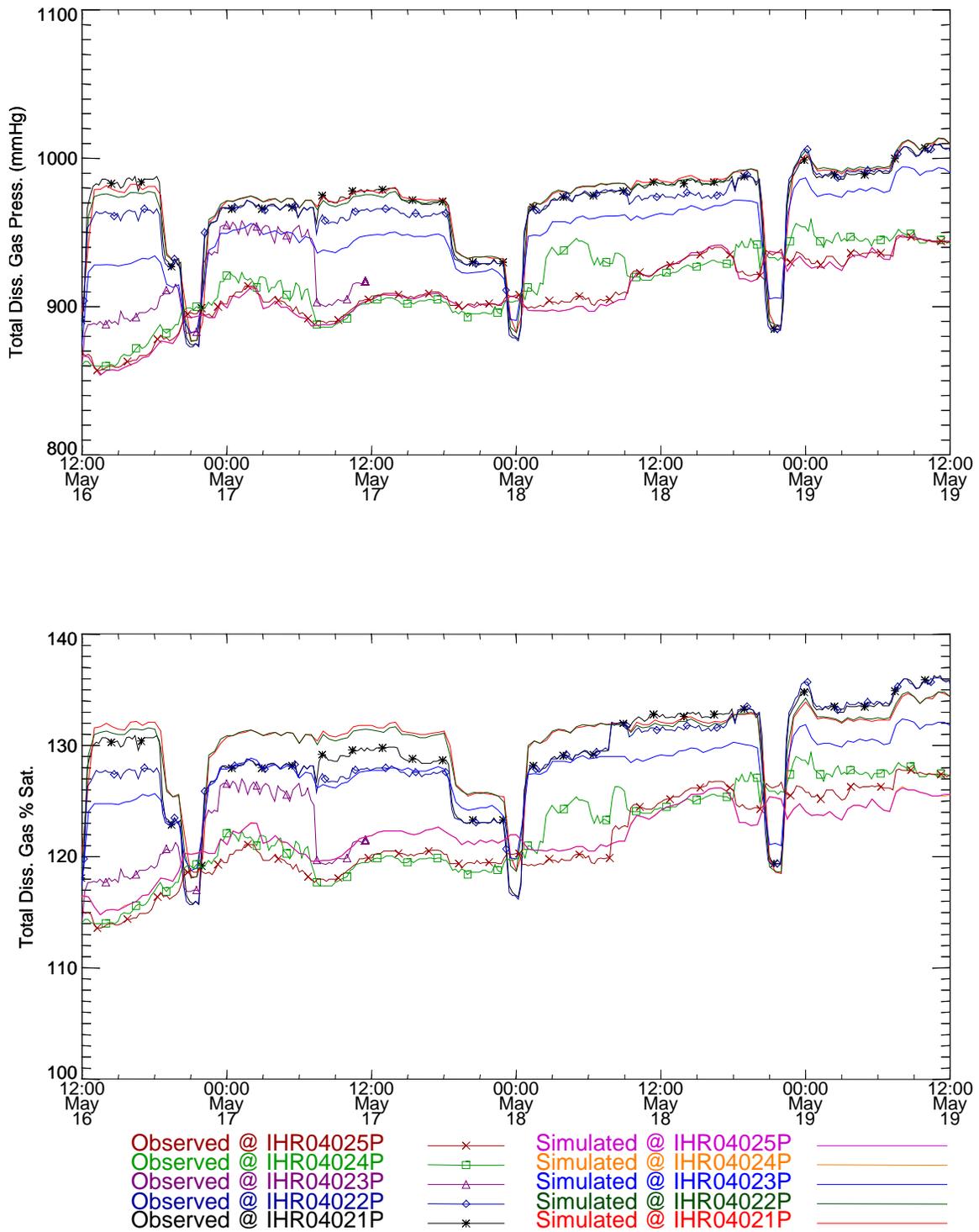


Figure 91. Total dissolved gas pressure and saturation time series comparisons near Snake River Mile 040.2 for Spring 1996 study period (TM-BC).

Table 21. Statistical summary of measurements and simulations near the Snake River Mile 040.2 for the Spring 1996 study period (TM-BC).

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature					
IHR04021P	11.5	11.48	0.26	0.26	0.05
IHR04022P	11.52	11.47	0.26	0.26	0.07
IHR04023P	11.72	11.47	0.12	0.26	0.38
IHR04024P	11.51	11.46	0.26	0.25	0.07
IHR04025P	11.48	11.46	0.25	0.25	0.04
Concentration					
IHR04021P	38.16	38.17	1.26	1.23	0.24
IHR04022P	37.96	38.16	1.25	1.23	0.29
IHR04023P	35.96	37.36	0.6	1.09	1.8
IHR04024P	36.04	35.7	1.08	1.01	0.62
IHR04025P	35.83	35.69	0.99	1	0.16
Gas Pressure					
IHR04021P	968.91	970.96	28.86	28.23	6.39
IHR04022P	964.32	970.48	28.62	28.04	8.12
IHR04023P	917.39	950.25	15.13	24.21	40.99
IHR04024P	915.92	908.42	24.34	22.69	15.02
IHR04025P	910.16	908.41	22.1	22.69	2.61
% Saturation					
IHR04021P	129.34	130.36	4.43	3.57	2.01
IHR04022P	128.73	130.3	4.47	3.53	2.46
IHR04023P	121.56	127.57	2	2.91	6.68
IHR04024P	122.27	121.97	4.08	2.7	2.32
IHR04025P	121.5	121.96	3.87	2.7	1.57

Table 22. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements. Stations near the Snake River Mile 040.2 for the Spring 1996 study period (TM-BC).

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat.
IHR04021P	100	98.61	100	100
IHR04022P	100	99.65	100	100
IHR04023P	97.92	29.86	53.13	29.51
IHR04024P	100	88.54	94.79	99.65
IHR04025P	100	100	100	100

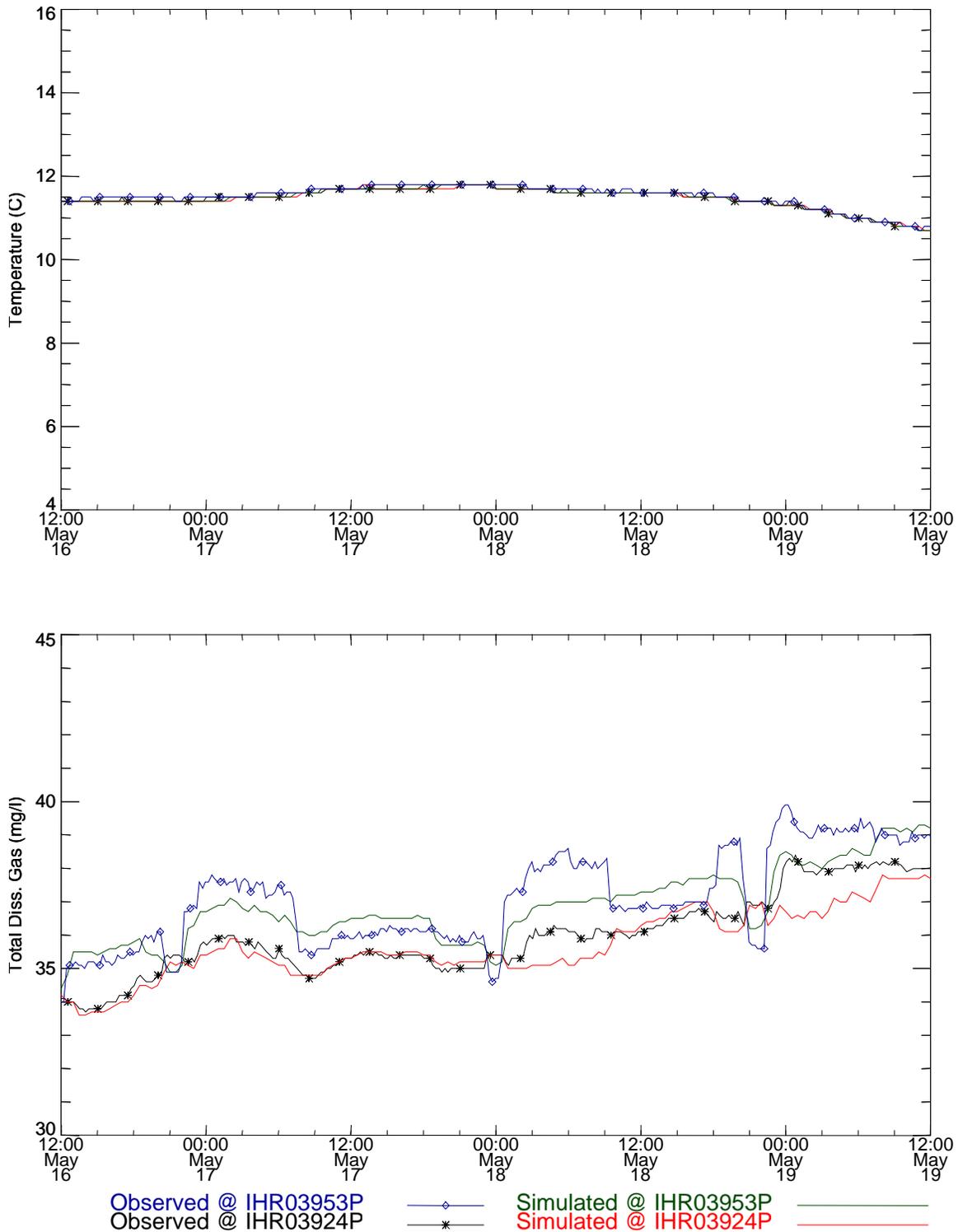


Figure 92. Temperature and total dissolved gas time series comparisons near the Snake River Mile 039.2 for the Spring 1996 study period. (TM-BC).

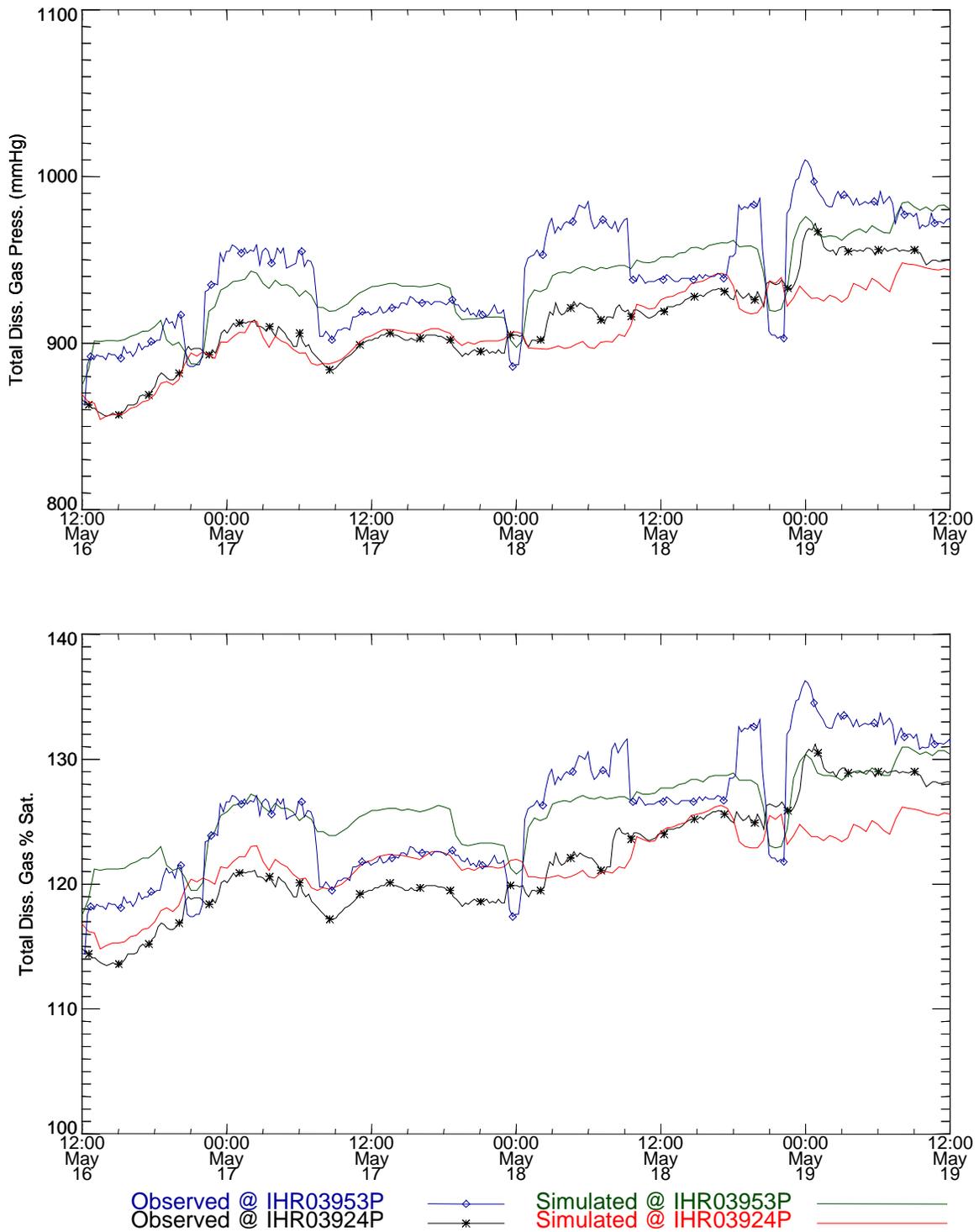


Figure 93. Total dissolved gas pressure and saturation time series comparisons near Snake River Mile 039.2 for Spring 1996 study period (TM-BC).

Table 23. Statistical summary of measurements and simulations near the Snake River Mile 039.2 for the Spring 1996 study period (TM-BC).

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature					
IHR03924P	11.47	11.46	0.26	0.25	0.04
IHR03953P	11.52	11.46	0.27	0.26	0.07
Concentration					
IHR03924P	35.96	35.69	1.2	1.02	0.52
IHR03953P	37.07	36.85	1.4	1.11	0.71
Gas Pressure					
IHR03924P	913.13	908.17	26.85	22.93	12.14
IHR03953P	941.76	937.34	32.35	24.61	17.67
% Saturation					
IHR03924P	121.91	121.93	4.49	2.73	2.47
IHR03953P	125.73	125.84	5.03	2.93	2.83

Table 24. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements. Stations near the Snake River Mile 039.2 for the Spring 1996 study period (TM-BC).

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat.
IHR03924P	100	91.72	98.62	95.17
IHR03953P	100	84.83	99.31	96.55

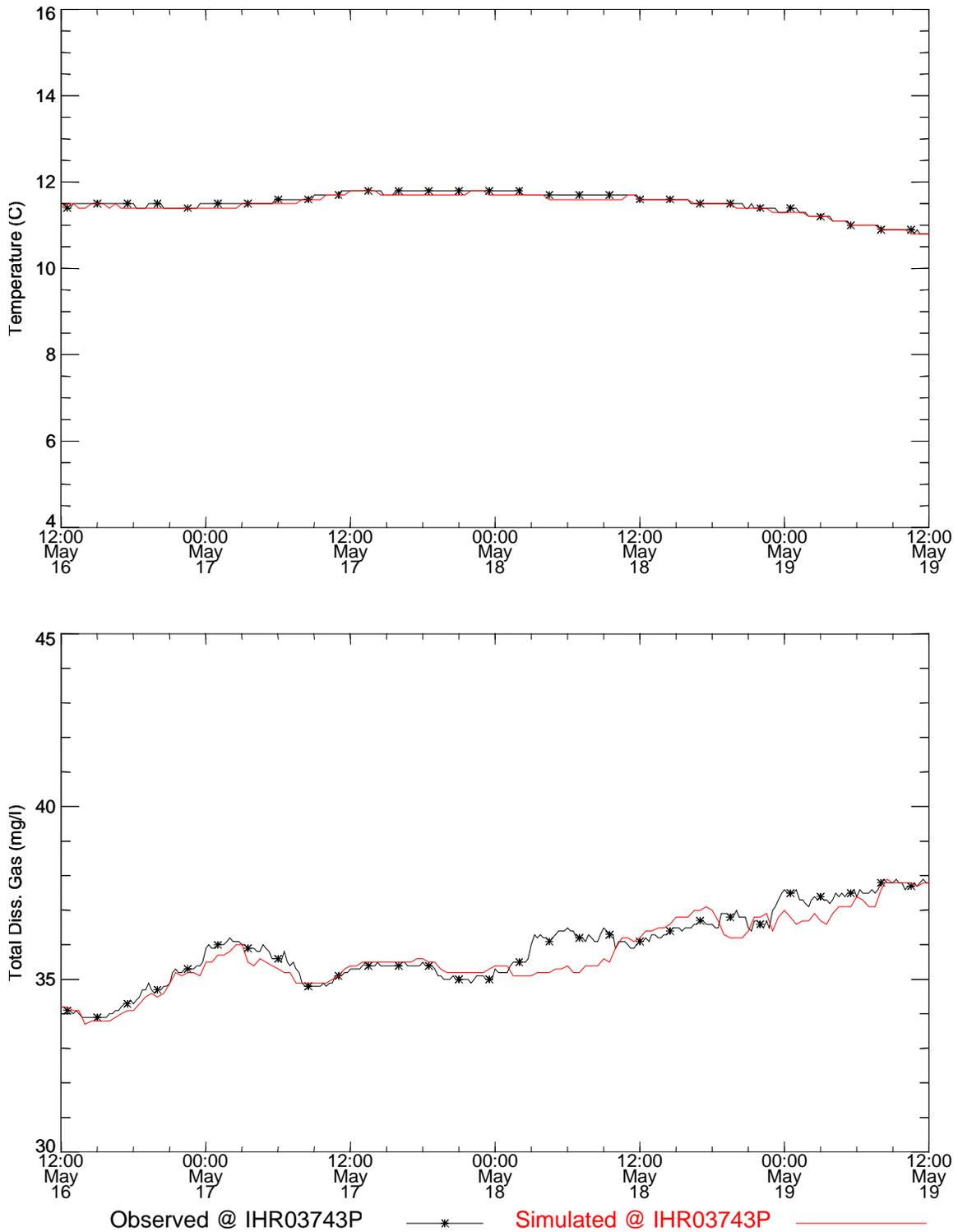


Figure 94. Temperature and total dissolved gas time series comparisons near the Snake River Mile 037.4 for the Spring 1996 study period. (TM-BC).

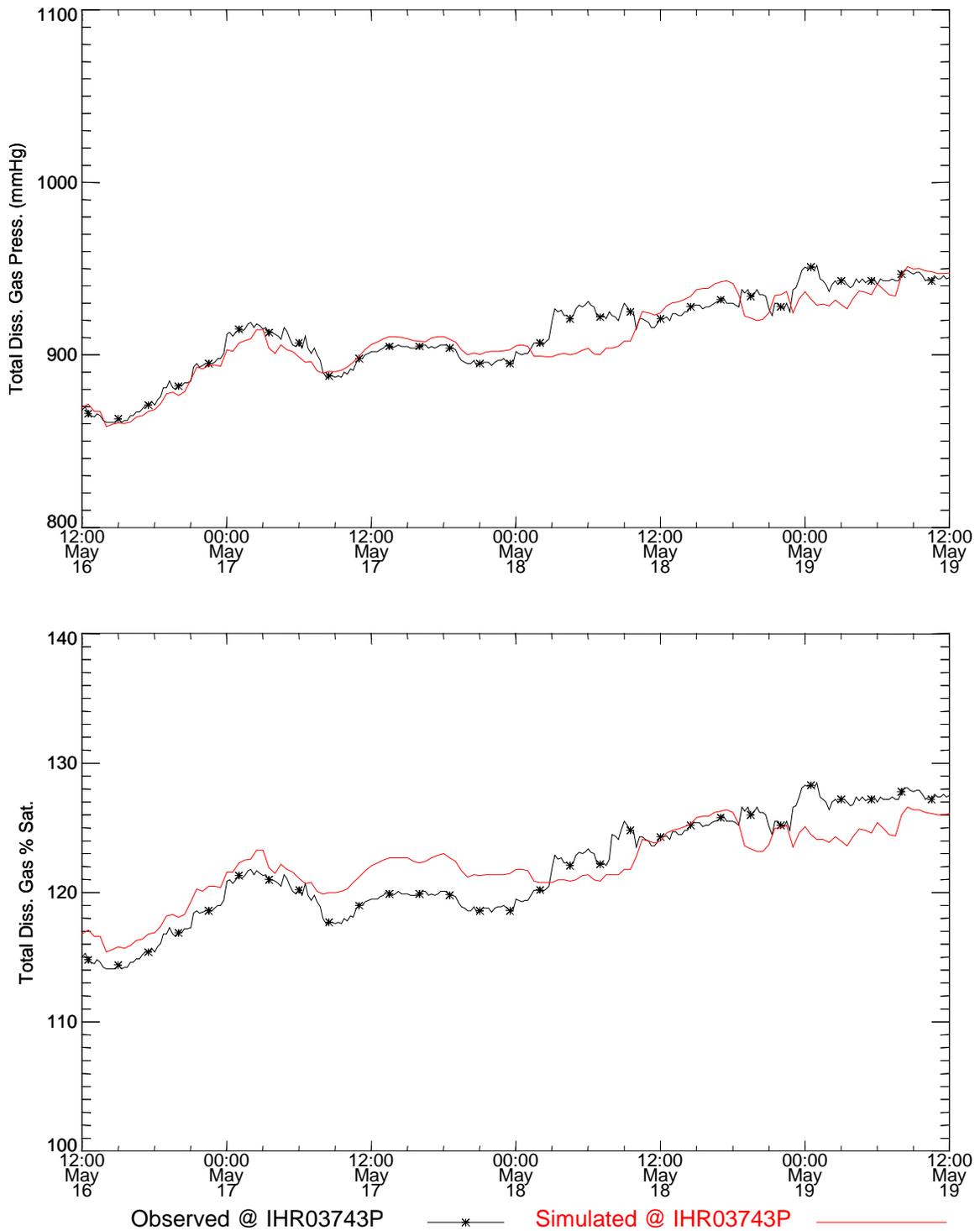


Figure 95. Total dissolved gas pressure and saturation time series comparisons near Snake River Mile 037.4 for Spring 1996 study period (TM-BC).

Table 25. Statistical summary of measurements and simulations near the Snake River Mile 037.4 for the Spring 1996 study period (TM-BC).

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature IHR03743P	11.52	11.47	0.26	0.24	0.07
Concentration IHR03743P	35.91	35.74	1.05	1.01	0.41
Gas Pressure IHR03743P	912.59	909.82	23.52	22.89	9.86
% Saturation IHR03743P	121.83	122.15	4.02	2.72	2.03

Table 26. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements. Stations near the Snake River Mile 037.4 for the Spring 1996 study period (TM-BC).

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat.
IHR03743P	100	97.93	100	100

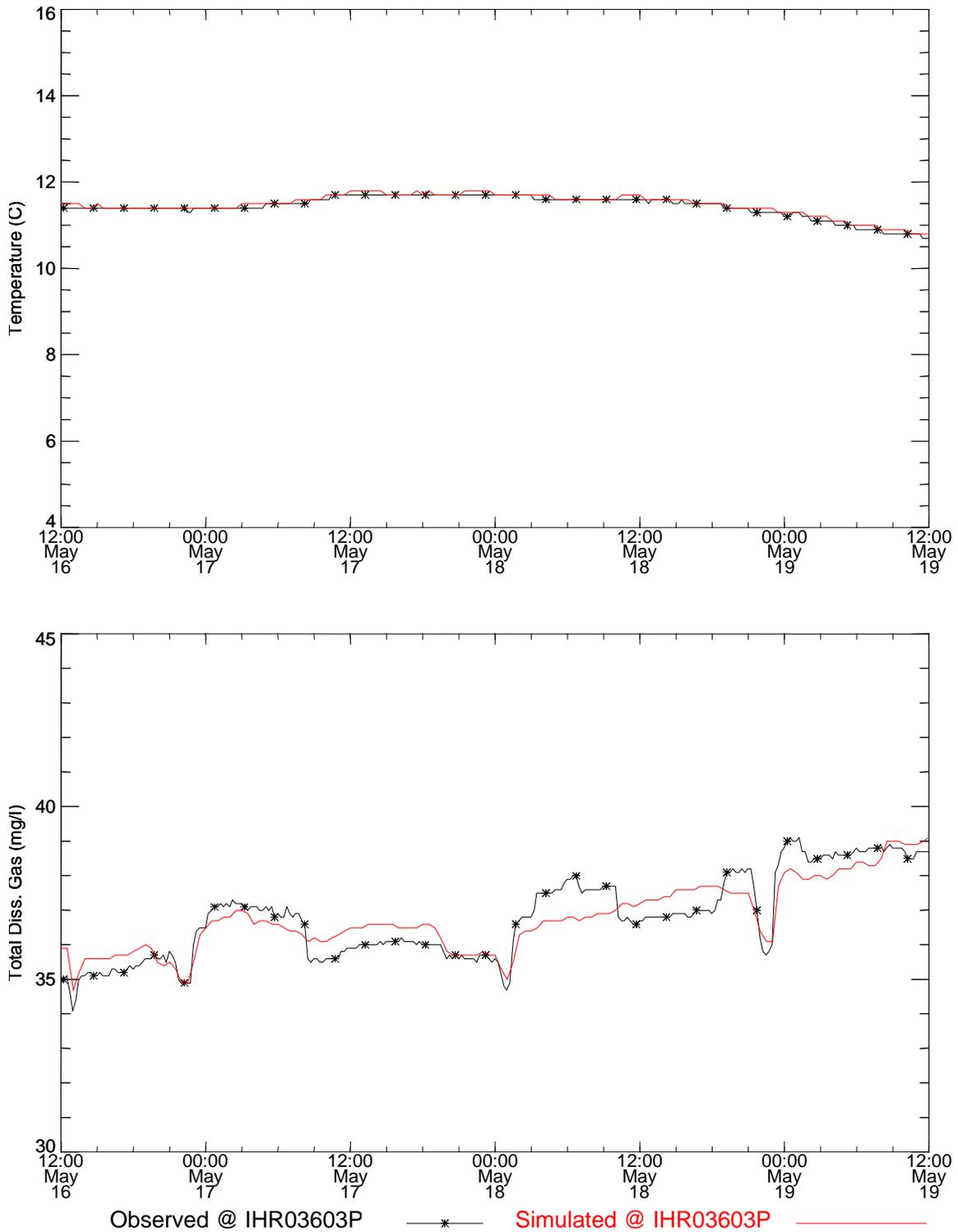


Figure 96. Temperature and total dissolved gas time series comparisons near the Snake River Mile 036.0 for the Spring 1996 study period. (TM-BC).

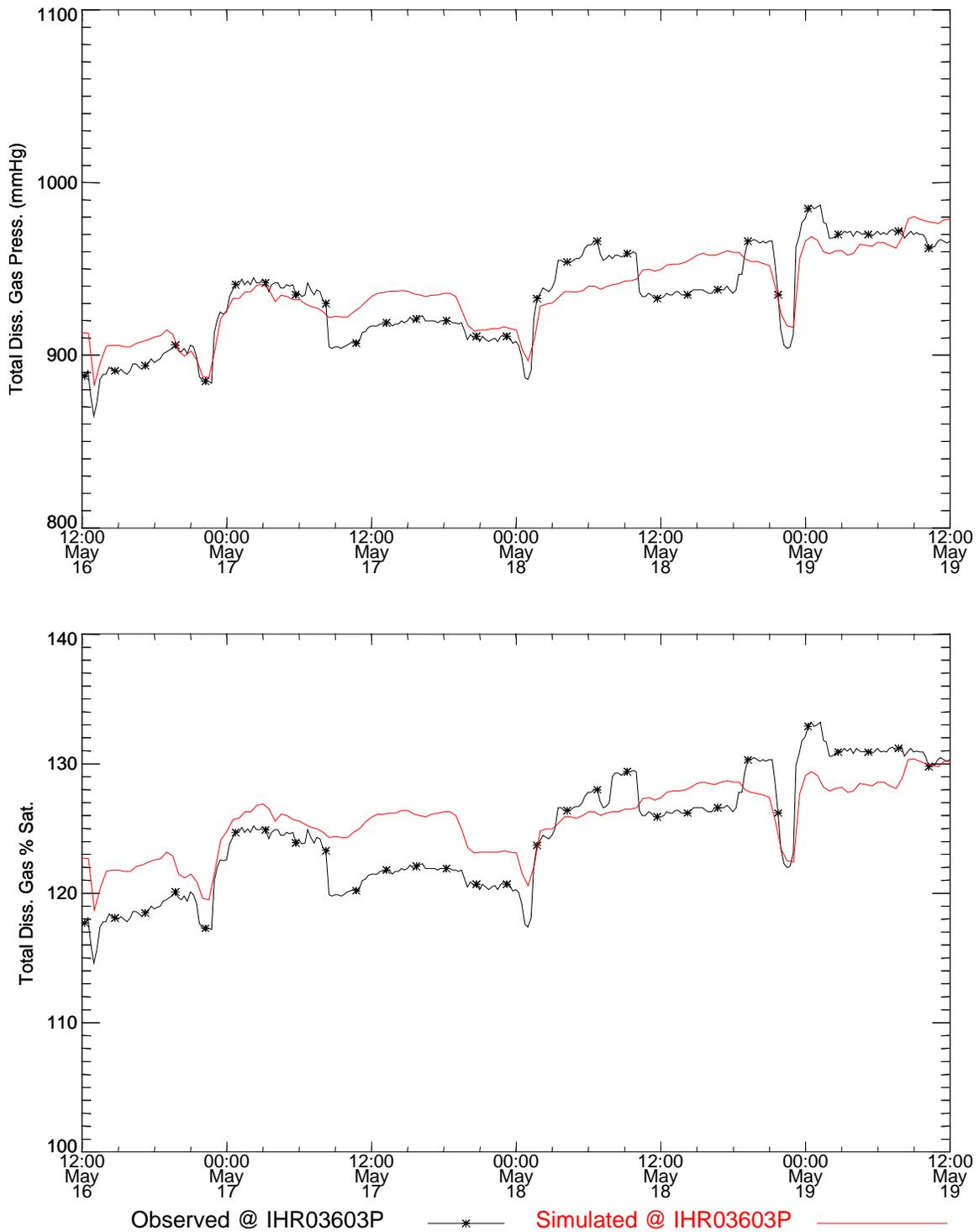


Figure 97. Total dissolved gas pressure and saturation time series comparisons near Snake River Mile 036.0 for Spring 1996 study period (TM-BC).

Table 27. Statistical summary of measurements and simulations near the Snake River Mile 036.0 for the Spring 1996 study period (TM-BC).

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature IHR03603P	11.44	11.48	0.26	0.25	0.06
Concentration IHR03603P	36.79	36.79	1.22	1	0.53
Gas Pressure IHR03603P	933.13	936.21	27.48	22.22	13.63
% Saturation IHR03603P	124.57	125.69	4.48	2.62	2.76

Table 28. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements. Stations near the Snake River Mile 036.0 for the Spring 1996 study period (TM-BC).

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat.
IHR03603P	100	98.62	100	100

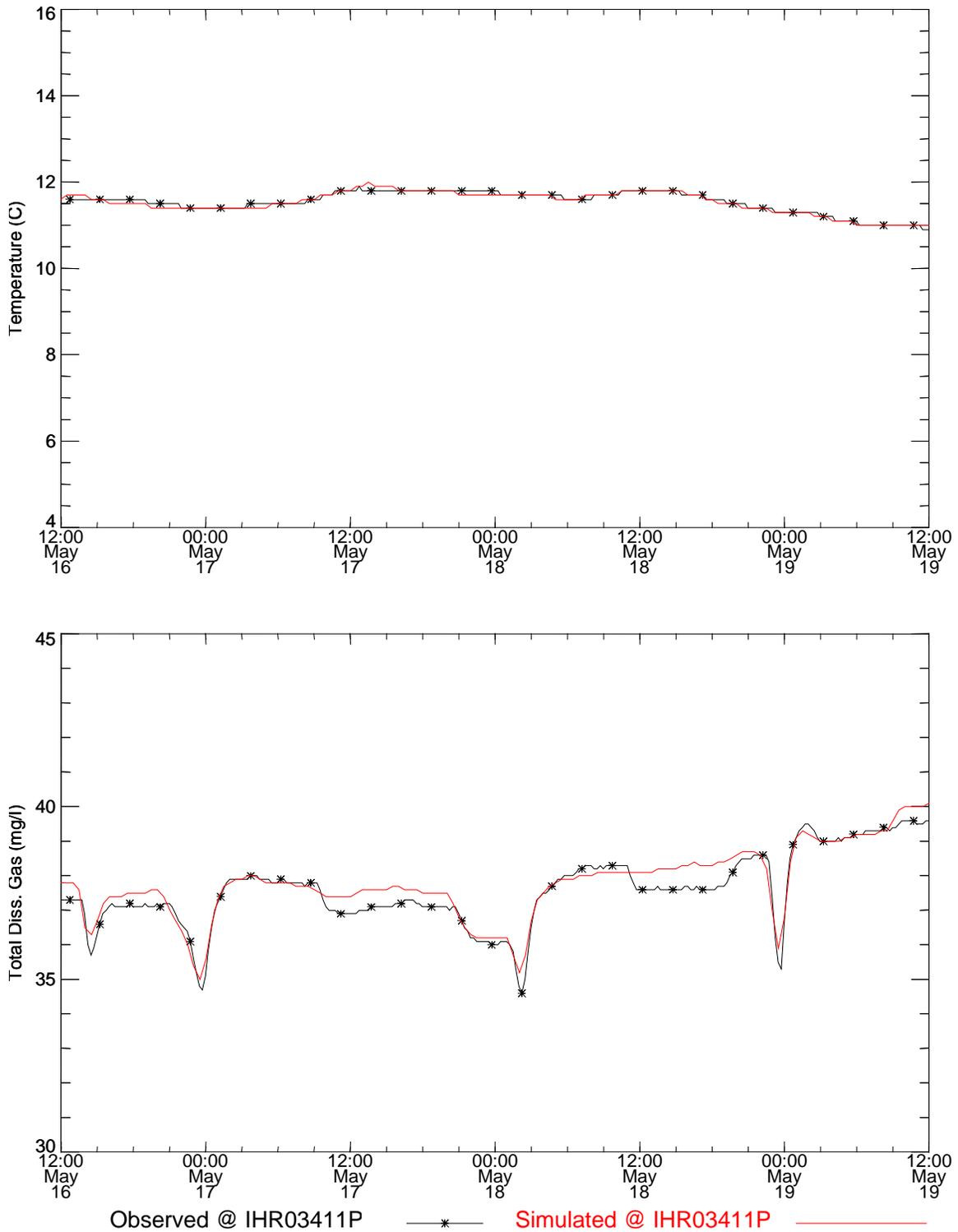


Figure 98. Temperature and total dissolved gas time series comparisons near the Snake River Mile 034.1 for the Spring 1996 study period. (TM-BC).

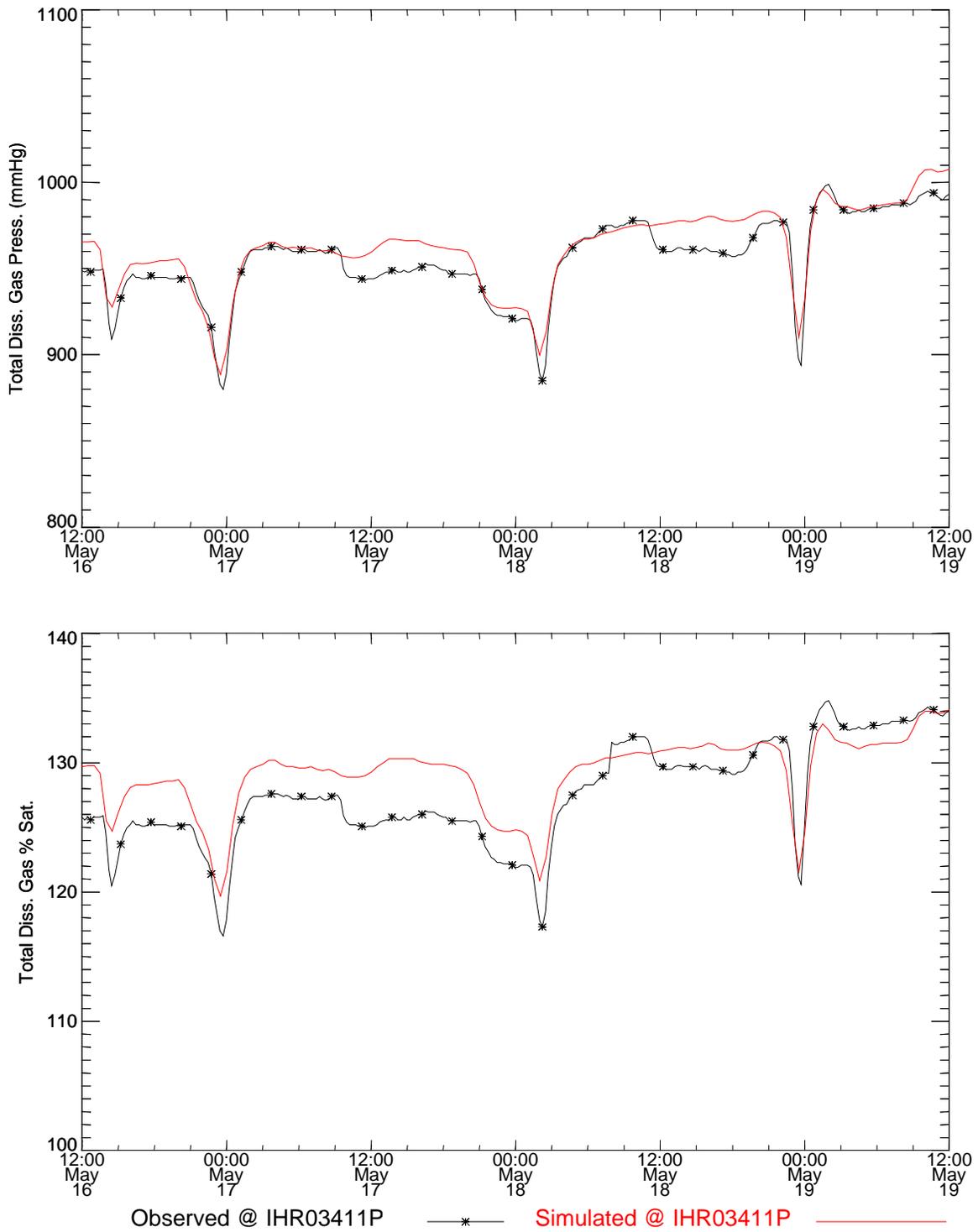


Figure 99. Total dissolved gas pressure and saturation time series comparisons near Snake River Mile 034.1 for Spring 1996 study period (TM-BC).

Table 29. Statistical summary of measurements and simulations near the Snake River Mile 034.1 for the Spring 1996 study period (TM-BC).

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature IHR03411P	11.54	11.53	0.25	0.25	0.06
Concentration IHR03411P	37.6	37.78	1.05	1.01	0.35
Gas Pressure IHR03411P	955.52	962.41	23.37	23.26	10.23
% Saturation IHR03411P	127.55	129.21	3.93	2.82	2.53

Table 30. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements. Stations near the Snake River Mile 034.1 for the Spring 1996 study period (TM-BC).

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat.
IHR03411P	100	100	100	100

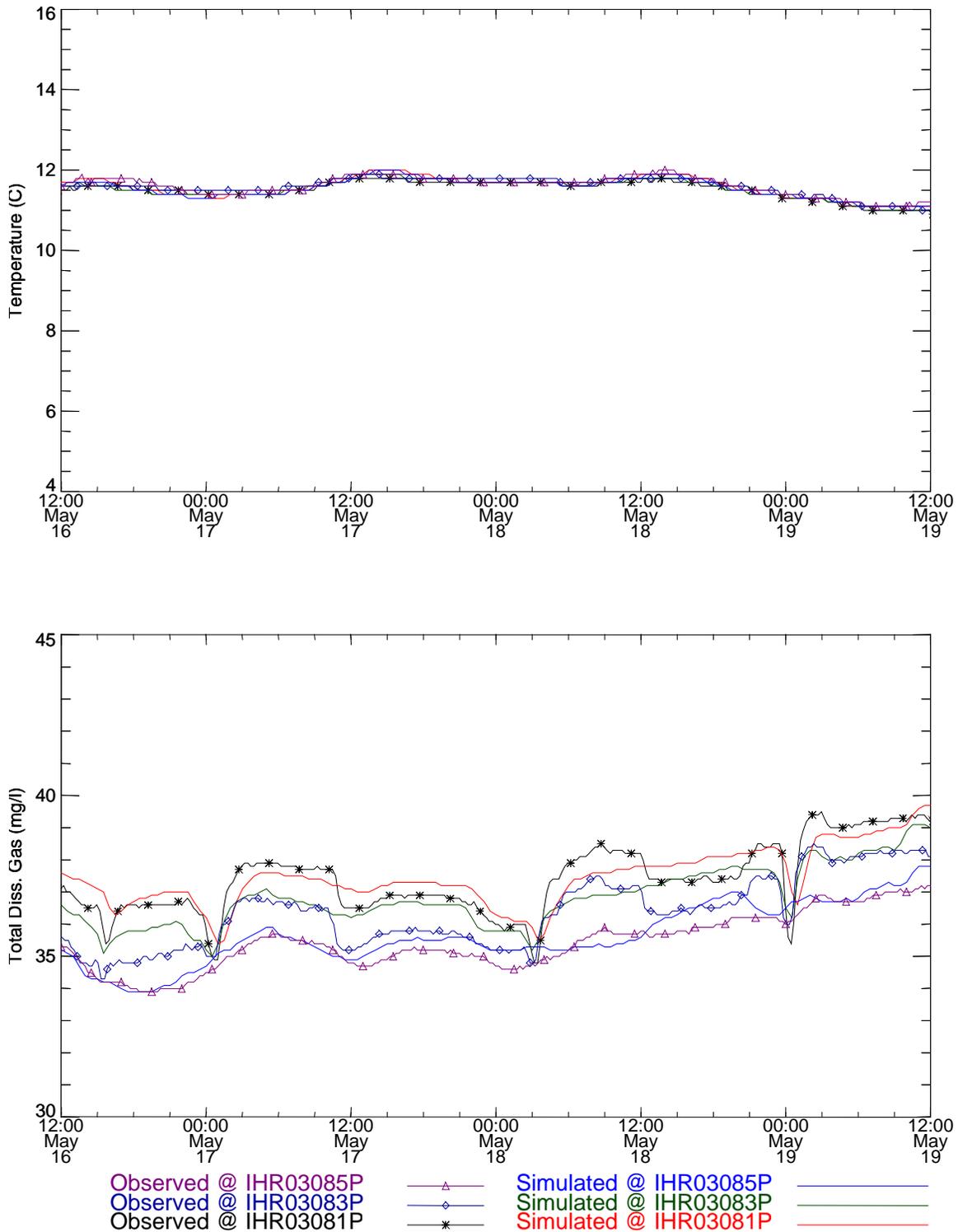


Figure 100. Temperature and total dissolved gas time series comparisons near the Snake River Mile 030.8 for the Spring 1996 study period. (TM-BC).

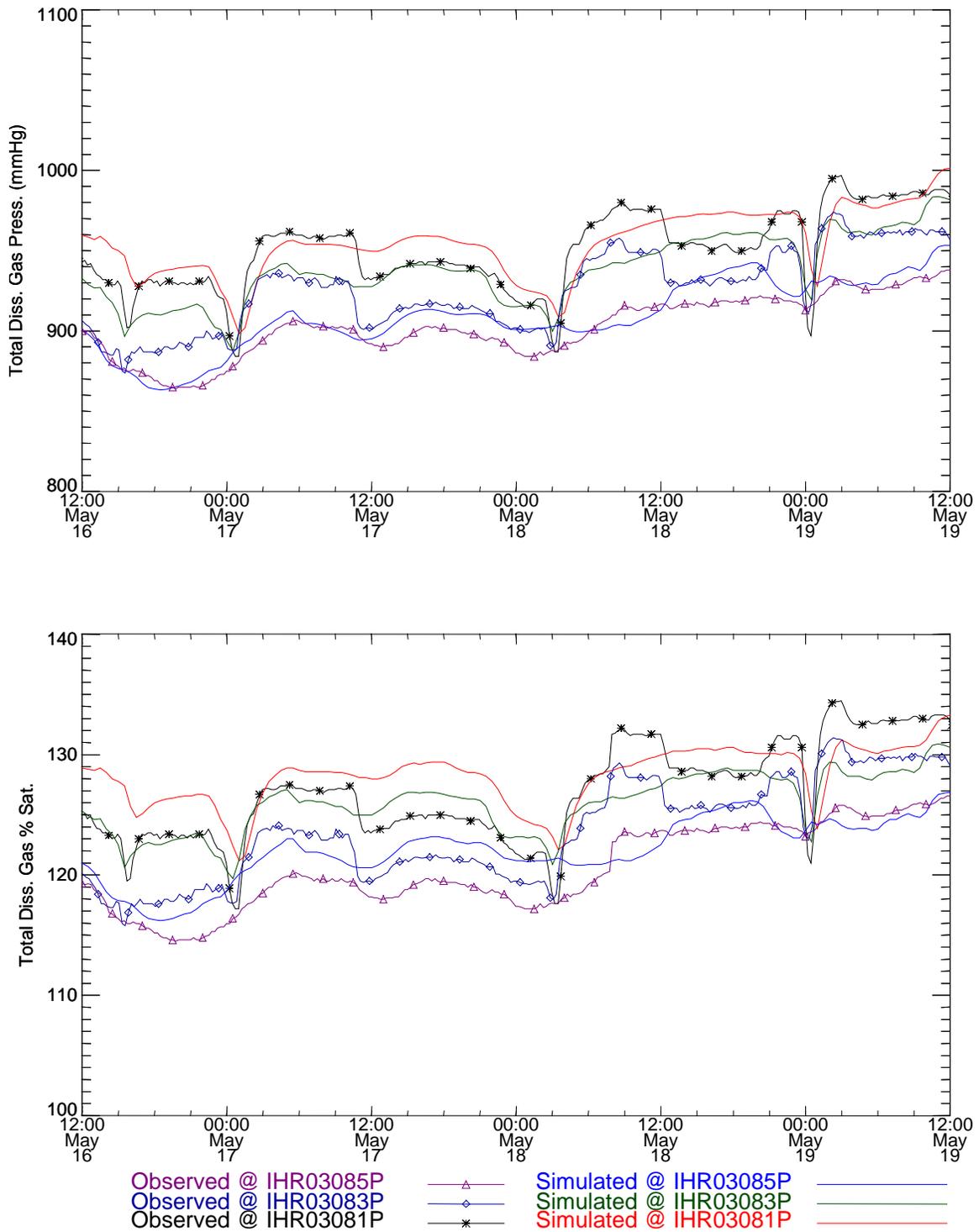


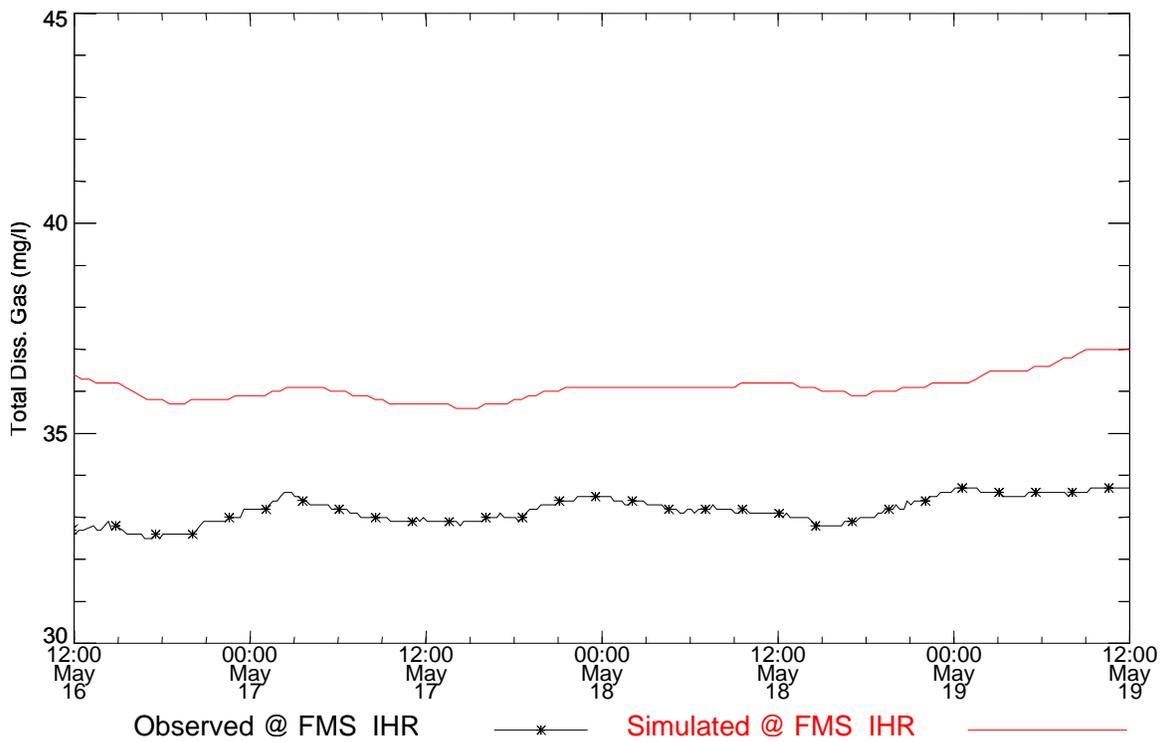
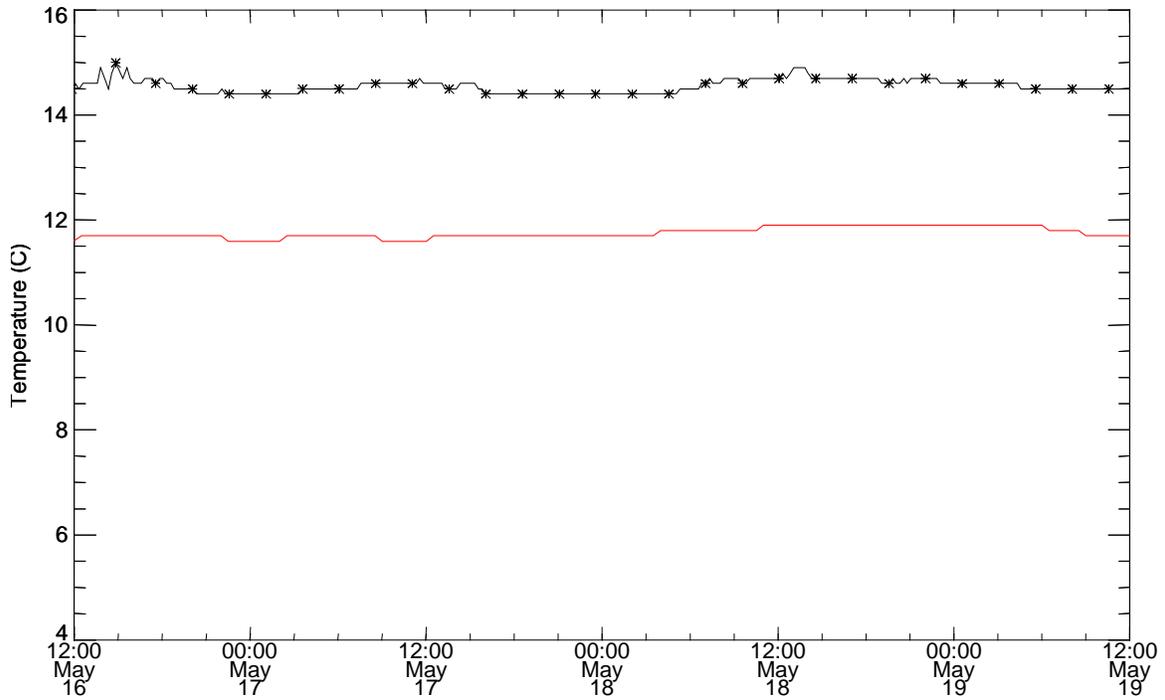
Figure 101. Total dissolved gas pressure and saturation time series comparisons near Snake River Mile 030.8 for Spring 1996 study period (TM-BC).

Table 31. Statistical summary of measurements and simulations near the Snake River Mile 030.8 for the Spring 1996 study period (TM-BC).

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature					
IHR03081P	11.52	11.58	0.23	0.26	0.1
IHR03083P	11.6	11.54	0.23	0.24	0.08
IHR03085P	11.62	11.56	0.24	0.24	0.09
Concentration					
IHR03081P	37.4	37.46	1.07	0.88	0.56
IHR03083P	36.35	36.83	1.09	0.92	0.67
IHR03085P	35.43	35.65	0.85	0.94	0.38
Gas Pressure					
IHR03081P	950.35	955.04	24.25	20.19	15.4
IHR03083P	925.41	938.23	24.82	20.93	17.72
IHR03085P	902.63	908.96	18.92	21.85	10.08
% Saturation					
IHR03081P	126.87	128.22	4.06	2.38	3
IHR03083P	123.55	125.96	4.19	2.44	3.46
IHR03085P	120.5	122.03	3.46	2.58	2.3

Table 32. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements. Stations near the Snake River Mile 030.8 for the Spring 1996 study period (TM-BC).

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat.
IHR03081P	100	93.79	99.31	95.86
IHR03083P	100	89.66	99.31	79.31
IHR03085P	100	100	100	100



Observed @ FMS IHR * Simulated @ FMS IHR —

Figure 102. Temperature and total dissolved gas time series comparisons fixed monitor IHR for the Spring 1996 study period. (TM-BC).

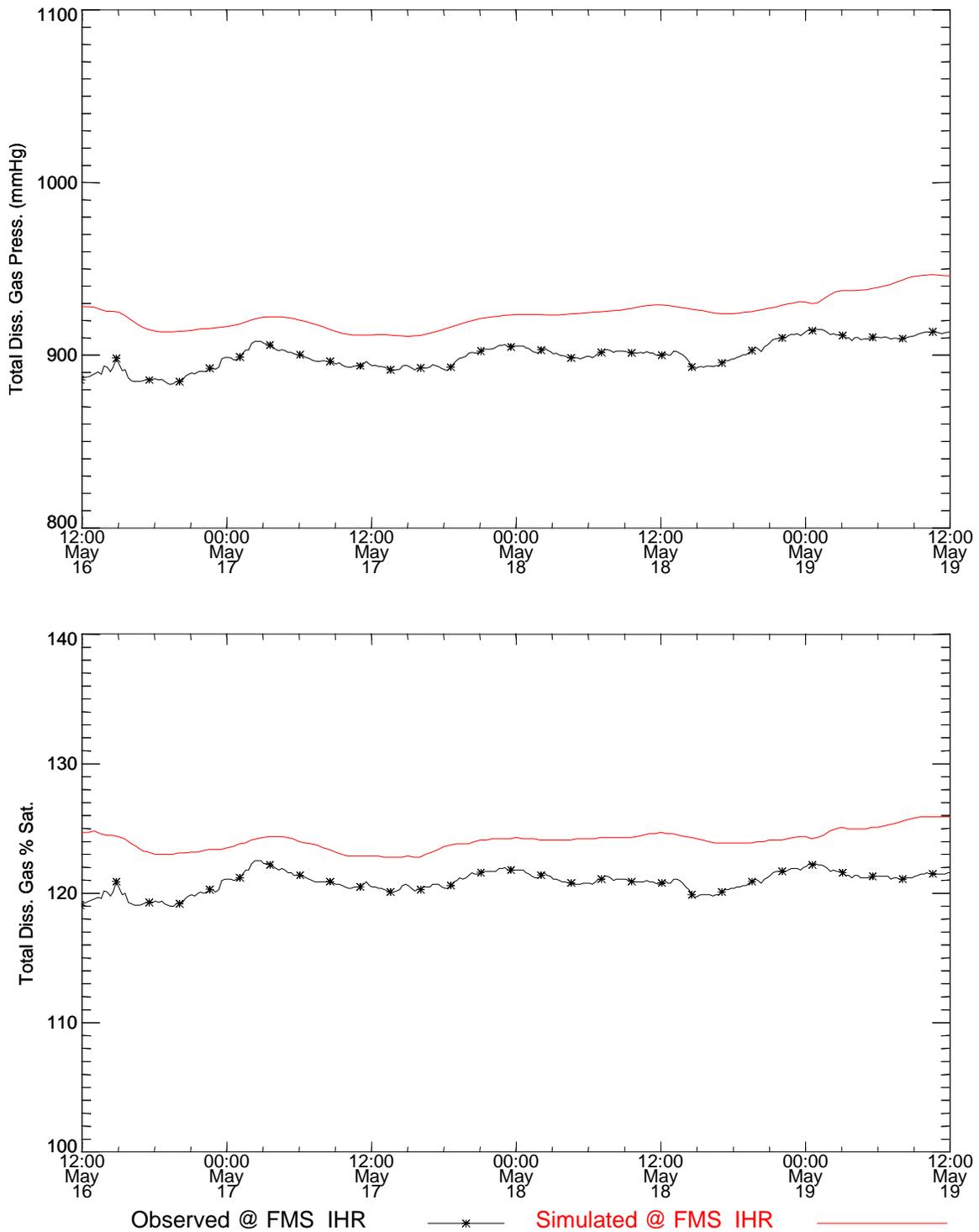


Figure 103. Total dissolved gas pressure and saturation time series comparisons near fixed monitor IHR for Spring 1996 study period (TM-BC).

Table 33. Statistical summary of measurements and simulations fixed monitor IHR for the Spring 1996 study period (TM-BC).

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature					
FMS_IHR	14.55	11.76	0.12	0.1	2.8
Concentration					
FMS_IHR	33.17	36.09	0.32	0.32	2.93
Gas Pressure					
FMS_IHR	900.06	924.27	8	9.1	24.95
% Saturation					
FMS_IHR	120.88	124.09	0.79	0.76	3.31

Table 34. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements. Stations fixed monitor IHR for the Spring 1996 study period (TM-BC).

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat.
FMS_IHR	0	0	97.93	97.93

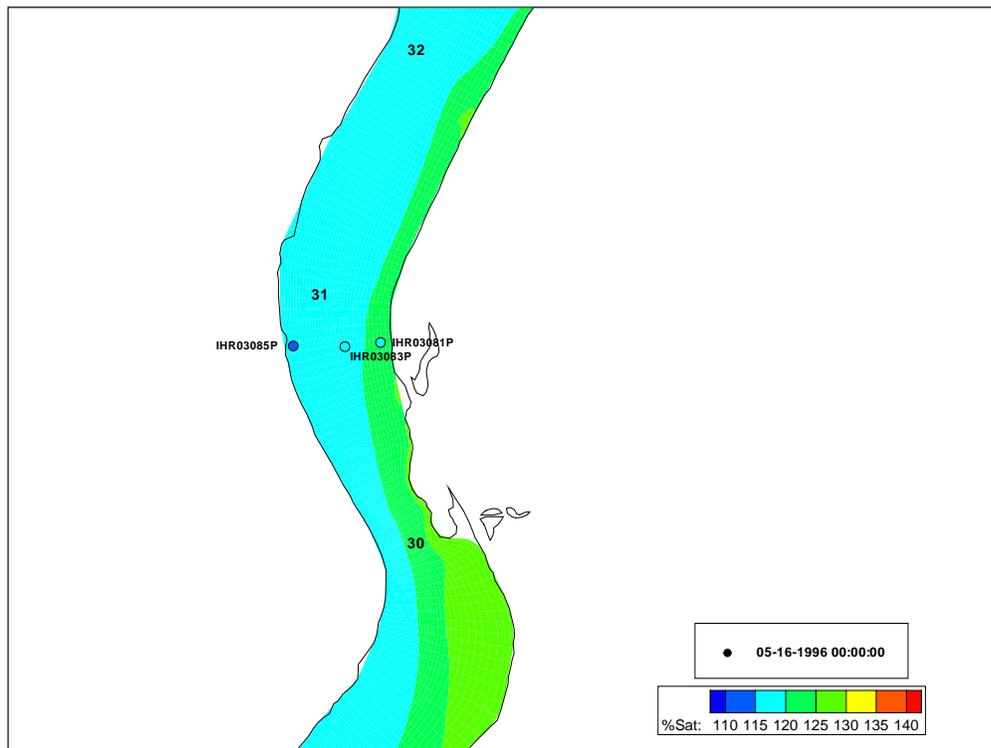


Figure 104. Spatial distribution of dissolved gas near Snake river mile 31 during the Spring 1996 study period.

1.4.2 1997 Spring Simulation

Boundary Conditions using Lower Granite Sourcing Function and Forebay FMS Data

Comparisons between the measurements and simulations using an upstream boundary condition developed from the empirical project gas sourcing function and the forebay FMS are shown in the figures below. Statistics on comparisons between measured and simulated temperatures and total dissolved gas are also presented. The case is denoted as FMS-BC in the figure and table captions.

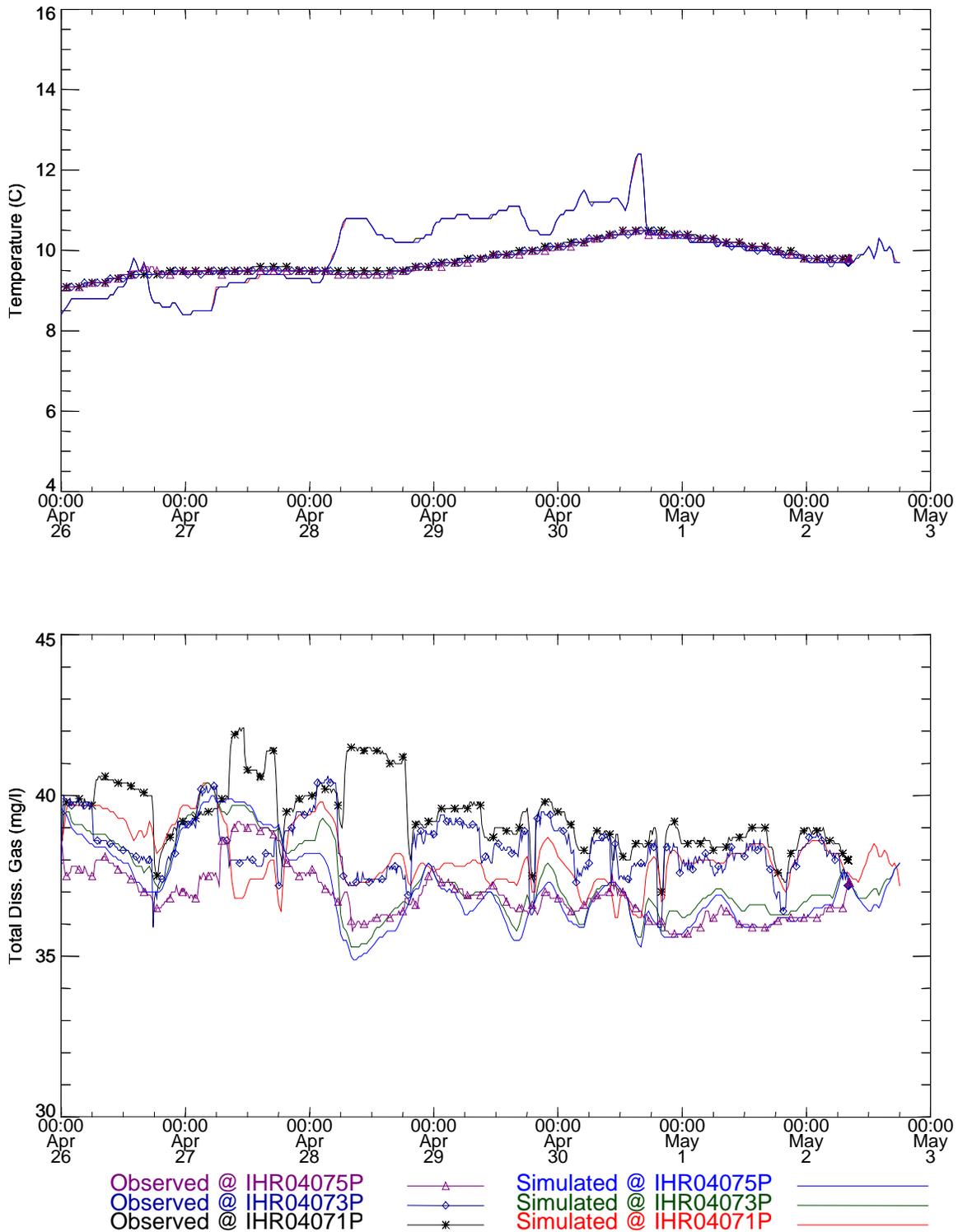


Figure 105. Temperature and total dissolved gas time series comparisons near the Snake River Mile 040.7 for the Spring 1997 study period. (FMS-BC).

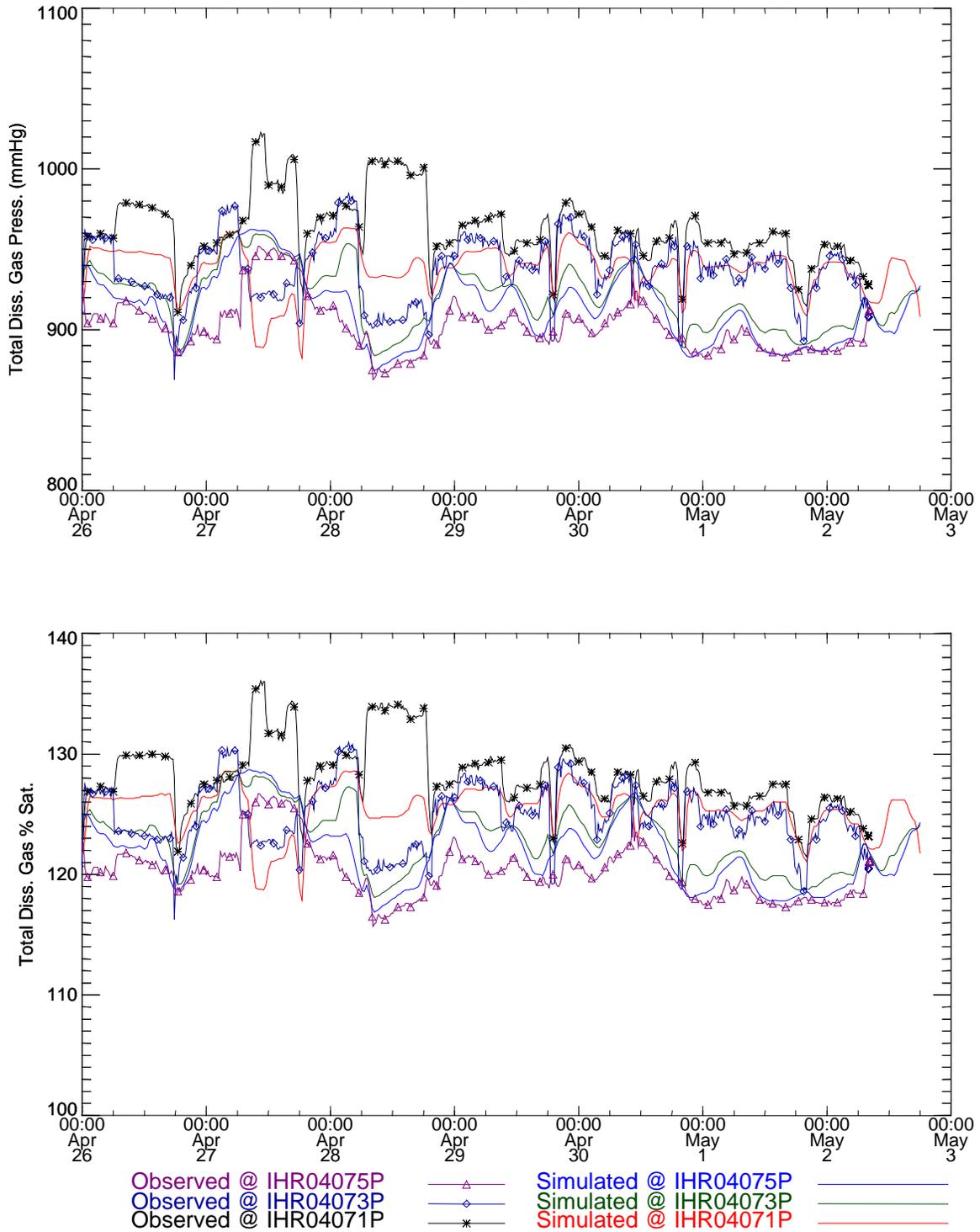


Figure 106. Total dissolved gas pressure and saturation time series comparisons near Snake River Mile 040.7 for Spring 1997 study period (FMS-BC).

Table 35. Statistical summary of measurements and simulations near the Snake River Mile 040.7 for the Spring 1997 study period (FMS-BC).

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature					
IHR04071P	9.8	10	0.38	0.85	0.68
IHR04073P	9.76	10	0.38	0.86	0.7
IHR04075P	9.77	10	0.38	0.86	0.71
Concentration					
IHR04071P	39.4	38.15	1.03	0.93	1.75
IHR04073P	38.38	37.43	0.86	1.22	1.38
IHR04075P	36.92	37.13	0.83	1.29	0.76
Gas Pressure					
IHR04071P	962.91	938.57	20.8	14.38	34.64
IHR04073P	937.53	920.98	19.97	19.66	25.54
IHR04075P	902.45	913.58	16.73	22.09	15.3
% Saturation					
IHR04071P	128.27	125.45	2.8	1.93	4.33
IHR04073P	124.88	123.1	2.67	2.69	3.15
IHR04075P	120.21	122.11	2.26	3.03	2.37

Table 36. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements. Stations near the Snake River Mile 040.7 for the Spring 1997 study period (FMS-BC).

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat.
IHR04071P	83.91	49.26	84.73	84.89
IHR04073P	83.74	37.6	86.86	87.52
IHR04075P	82.27	86.04	98.36	96.06

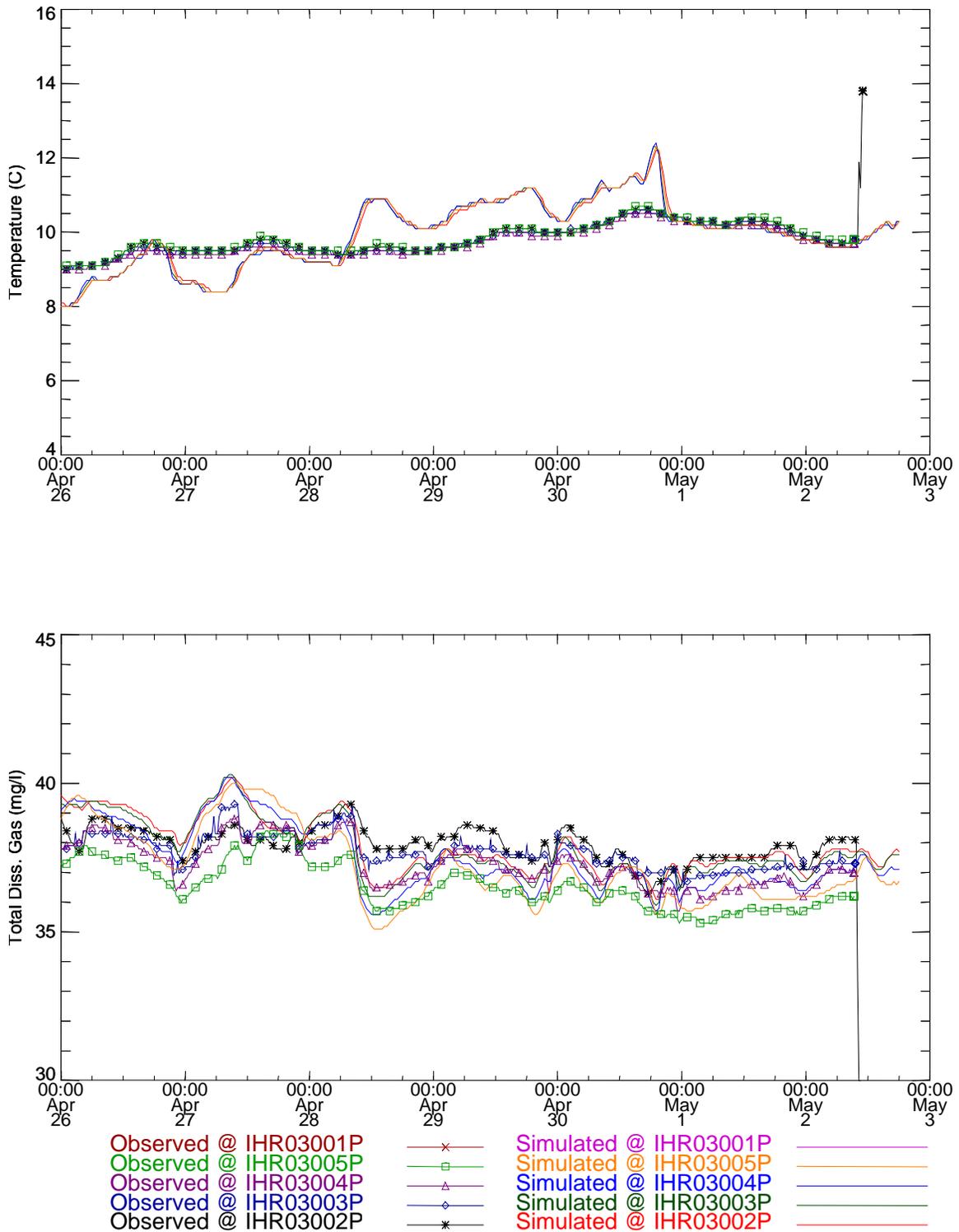


Figure 107. Temperature and total dissolved gas time series comparisons near the Snake River Mile 030.0 for the Spring 1997 study period. (FMS-BC).

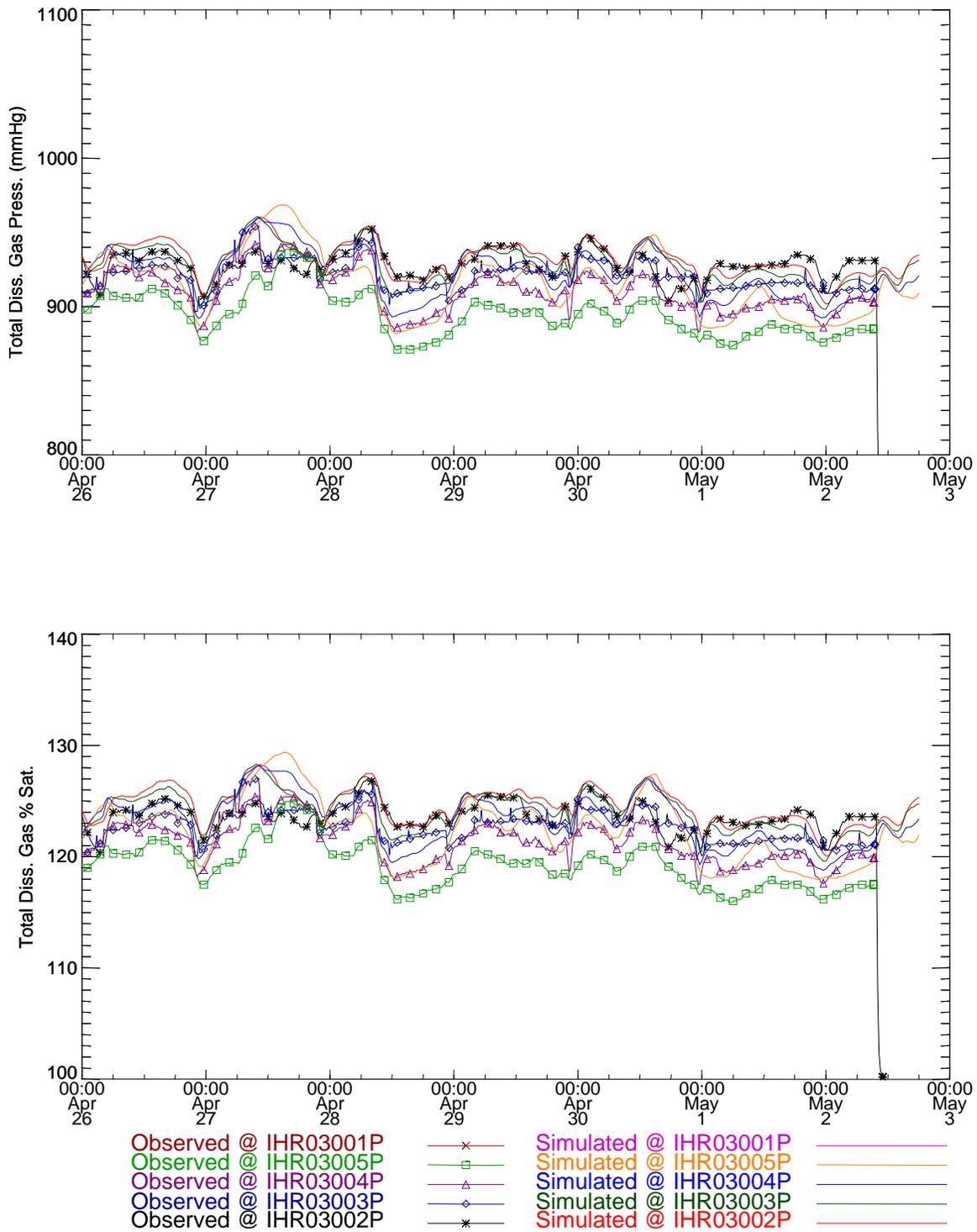


Figure 108. Total dissolved gas pressure and saturation time series comparisons near Snake River Mile 030.0 for Spring 1997 study period (FMS-BC).

Table 37. Statistical summary of measurements and simulations near the Snake River Mile 030.0 for the Spring 1997 study period (FMS-BC).

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature					
IHR03002P	9.84	9.95	0.45	0.89	0.71
IHR03003P	9.78	9.95	0.39	0.9	0.69
IHR03004P	9.73	9.95	0.39	0.9	0.7
IHR03005P	9.84	9.95	0.39	0.9	0.68
Concentration					
IHR03002P	37.88	37.92	0.92	0.94	0.99
IHR03003P	37.67	37.8	0.56	1	0.66
IHR03004P	37.3	37.52	0.75	1.14	0.65
IHR03005P	36.55	37.24	0.79	1.29	0.97
Gas Pressure					
IHR03002P	926.93	932.2	17.14	11.64	17.06
IHR03003P	921.1	929.42	10.41	13	10.71
IHR03004P	910.85	922.53	14.12	17.02	13.81
IHR03005P	895	915.66	15.31	21.74	23.08
% Saturation					
IHR03002P	123.46	124.6	2.3	1.65	2.45
IHR03003P	122.69	124.22	1.46	1.82	1.78
IHR03004P	121.32	123.3	1.89	2.34	2.22
IHR03005P	119.21	122.38	2.06	2.97	3.47

Table 38. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements. Stations near the Snake River Mile 030.0 for the Spring 1997 study period (FMS-BC).

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat.
IHR03002P	87.92	84.06	99.19	99.19
IHR03003P	84.7	85.83	100	100
IHR03004P	84.54	88.41	100	99.84
IHR03005P	85.19	76.01	93.24	89.37

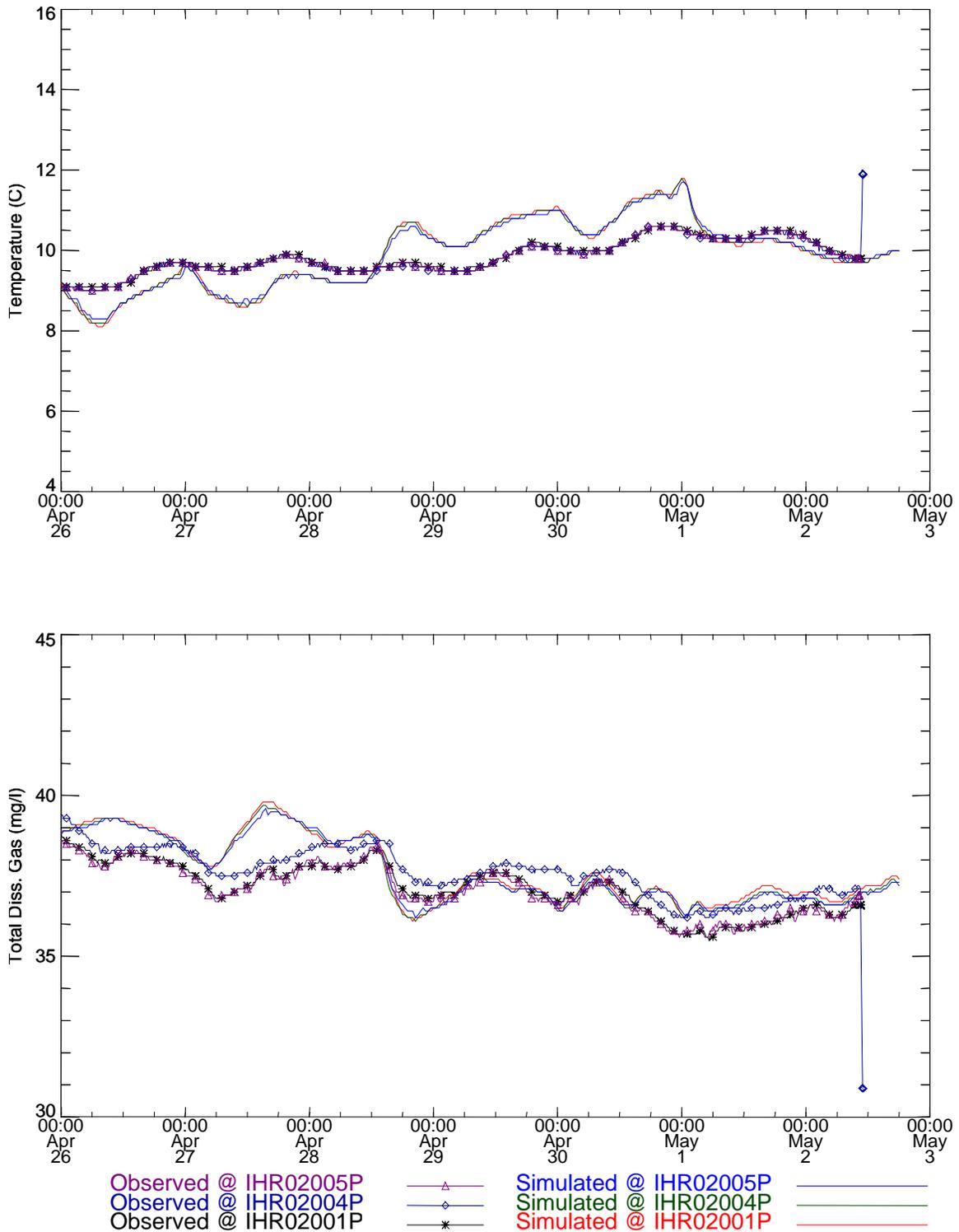


Figure 109. Temperature and total dissolved gas time series comparisons near the Snake River Mile 020.0 for the Spring 1997 study period. (FMS-BC).

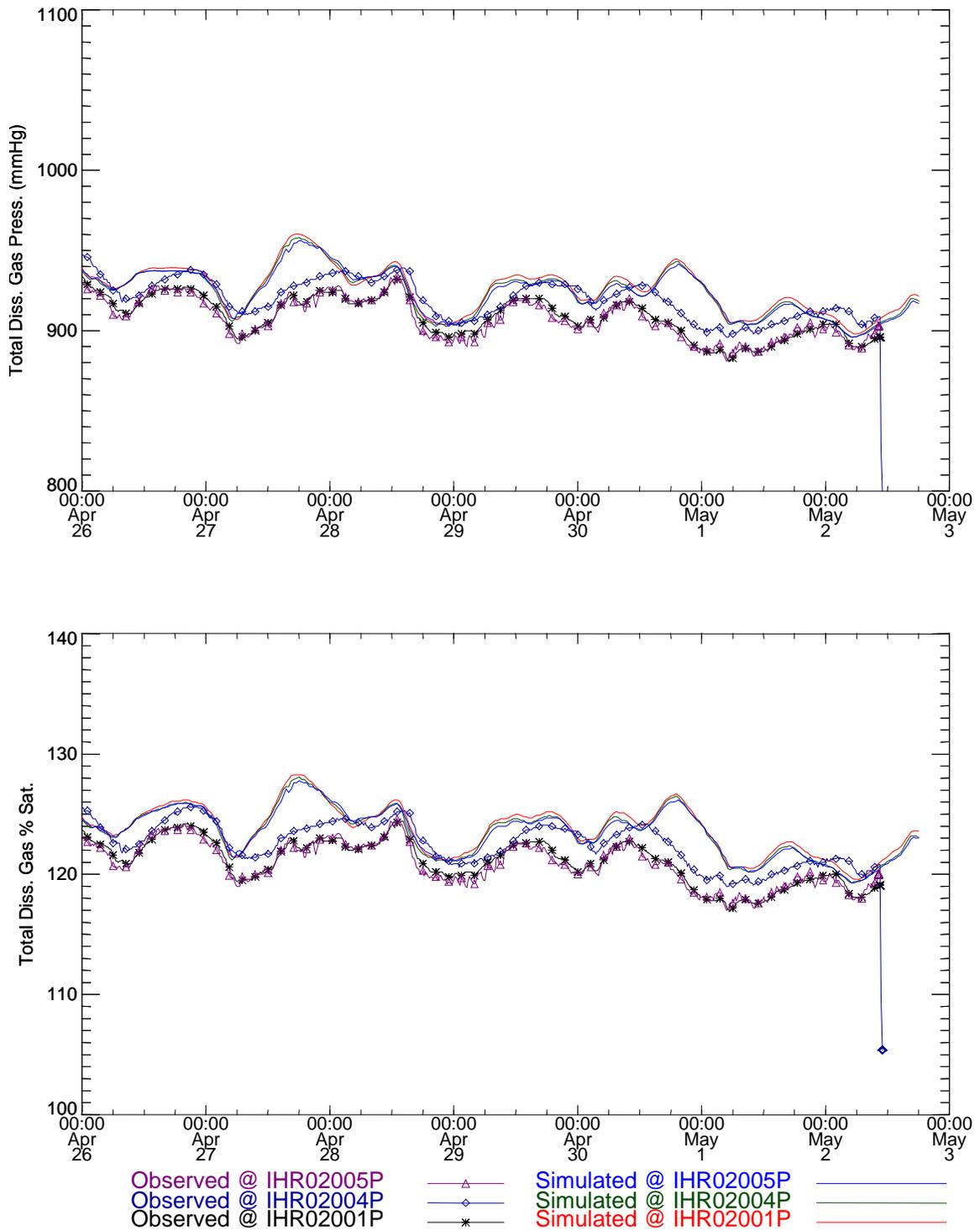


Figure 110. Temperature and total dissolved gas time series comparisons near the Snake River Mile 020.0 for the Spring 1997 study period. (FMS-BC).

Table 39. Statistical summary of measurements and simulations near the Snake River Mile 020.0 for the Spring 1997 study period (FMS-BC).

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature					
IHR02001P	9.85	9.92	0.41	0.88	0.63
IHR02004P	9.83	9.92	0.41	0.86	0.61
IHR02005P	9.84	9.92	0.41	0.84	0.59
Concentration					
IHR02001P	37.11	37.7	0.78	1.05	0.89
IHR02004P	37.6	37.63	0.74	1.06	0.7
IHR02005P	37.07	37.63	0.76	1.04	0.82
Gas Pressure					
IHR02001P	908.79	926.31	12.79	14.34	20.16
IHR02004P	920.01	924.63	12.1	14.5	11.83
IHR02005P	907.45	924.42	12.64	14.13	19.44
% Saturation					
IHR02001P	121.05	123.8	1.84	2.03	3.07
IHR02004P	122.54	123.58	1.75	2.05	1.8
IHR02005P	120.87	123.55	1.8	2	2.97

Table 40. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements. Stations near the Snake River Mile 020.0 for the Spring 1997 study period (FMS-BC).

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat.
IHR02001P	98.55	79.81	93.7	89.82
IHR02004P	97.25	83.52	100	100
IHR02005P	98.71	82.07	94.18	92.57

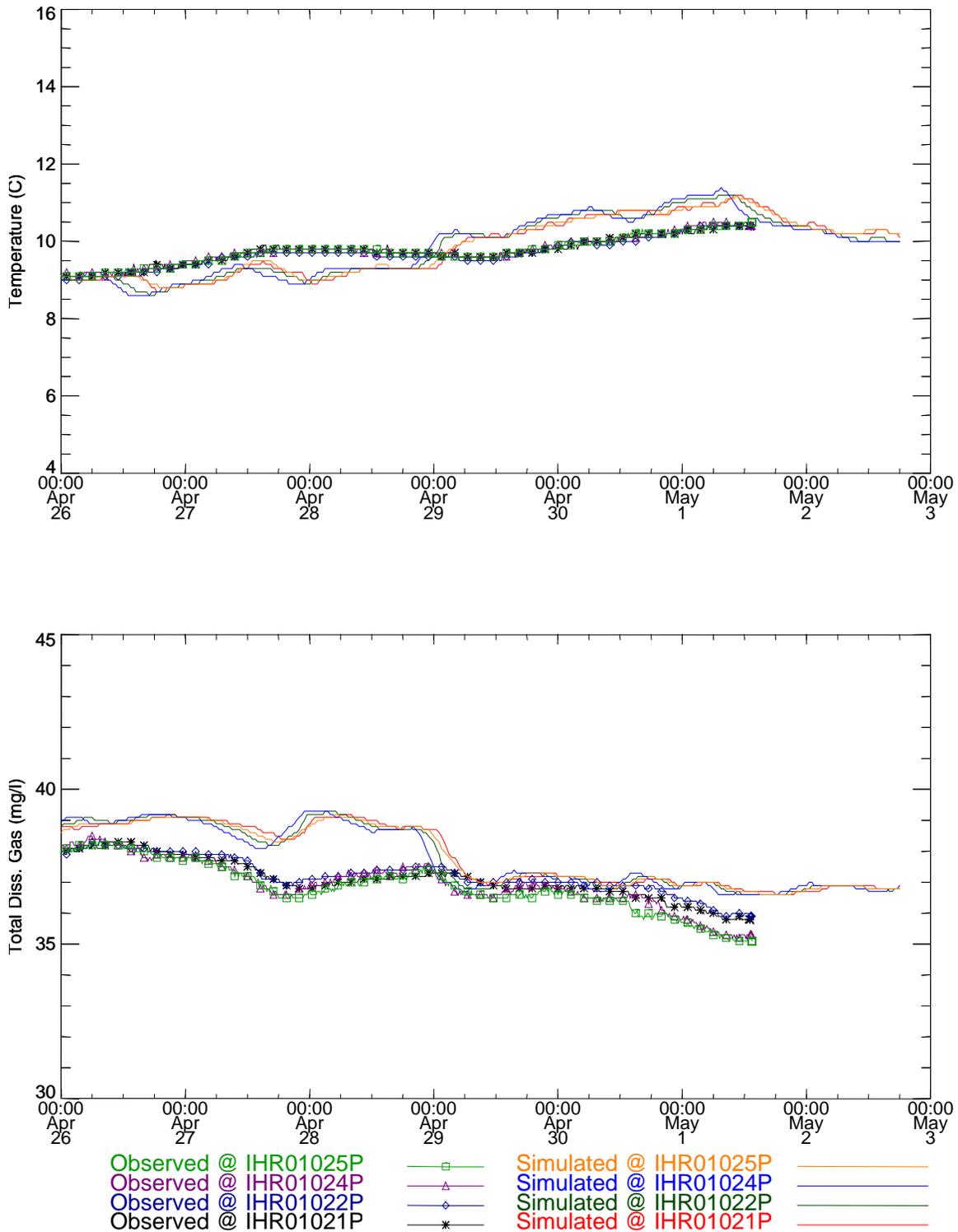


Figure 111. Temperature and total dissolved gas time series comparisons near the Snake River Mile 010.2 for the Spring 1997 study period. (FMS-BC).

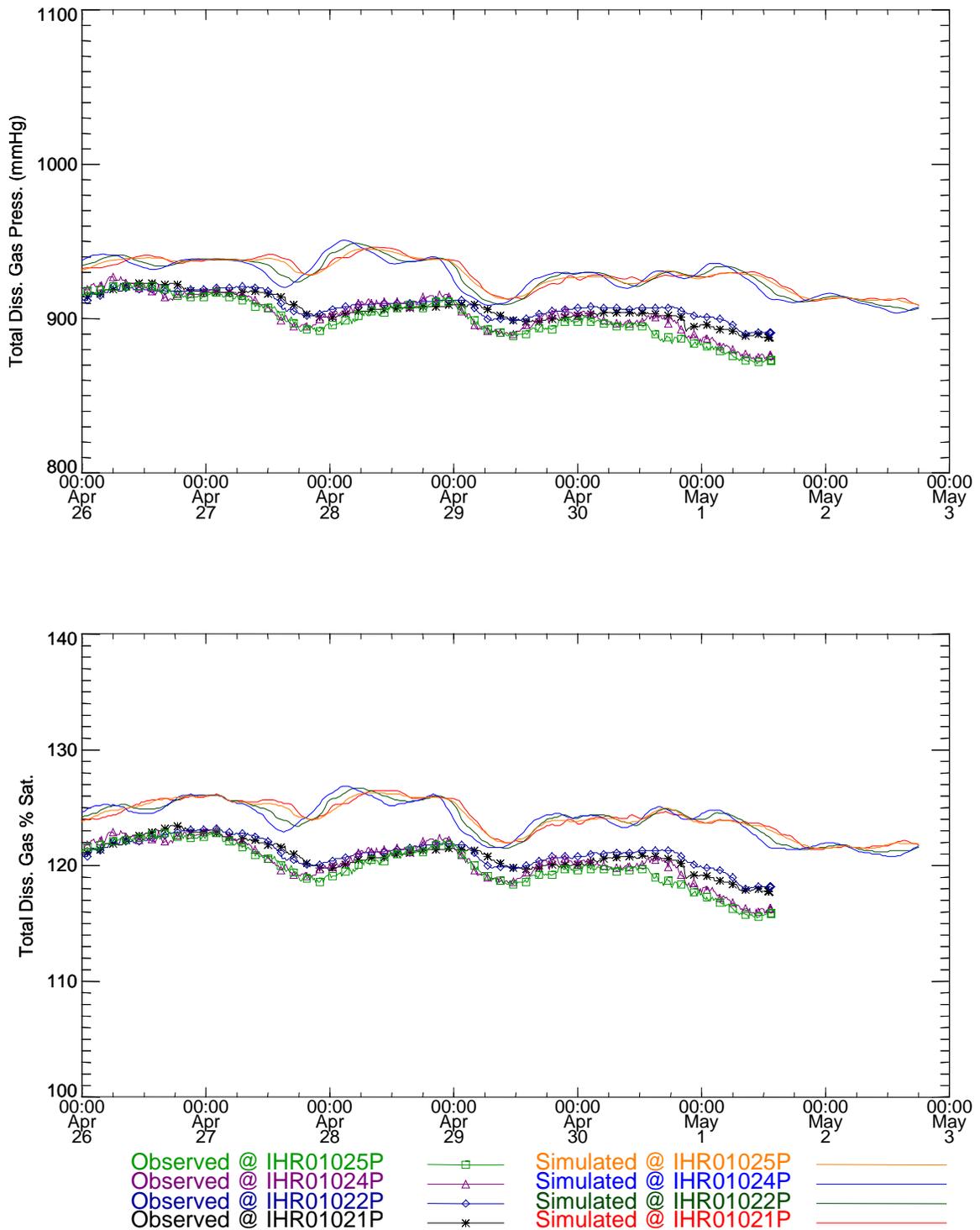


Figure 112. Total dissolved gas pressure and saturation time series comparisons near Snake River Mile 010.2 for Spring 1997 study period (FMS-BC).

Table 41. Statistical summary of measurements and simulations near the Snake River Mile 010.2 for the Spring 1997 study period (FMS-BC).

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature					
IHR01021P	9.74	9.76	0.35	0.77	0.54
IHR01022P	9.69	9.8	0.36	0.82	0.57
IHR01024P	9.76	9.82	0.35	0.83	0.58
IHR01025P	9.74	9.77	0.35	0.76	0.51
Concentration					
IHR01021P	37.12	38.09	0.65	0.92	1.14
IHR01022P	37.25	38.03	0.58	0.96	0.99
IHR01024P	36.98	37.99	0.78	0.97	1.17
IHR01025P	36.87	38.06	0.81	0.91	1.31
Gas Pressure					
IHR01021P	906.8	932.32	9.08	8.13	26.81
IHR01022P	908.76	931.66	7.81	8.9	24.19
IHR01024P	903.75	931.12	12.34	9.36	29.27
IHR01025P	900.66	932.02	13	7.87	32.97
% Saturation					
IHR01021P	120.85	124.67	1.32	1.14	3.98
IHR01022P	121.11	124.59	1.18	1.2	3.63
IHR01024P	120.44	124.52	1.75	1.26	4.31
IHR01025P	120.03	124.64	1.83	1.1	4.81

Table 42. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements. Stations near the Snake River Mile 010.2 for the Spring 1997 study period (FMS-BC).

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat.
IHR01021P	100	55.35	89.49	80.11
IHR01022P	100	65.1	93.81	87.62
IHR01024P	100	47.65	81.8	78.99
IHR01025P	100	41.65	74.86	66.79

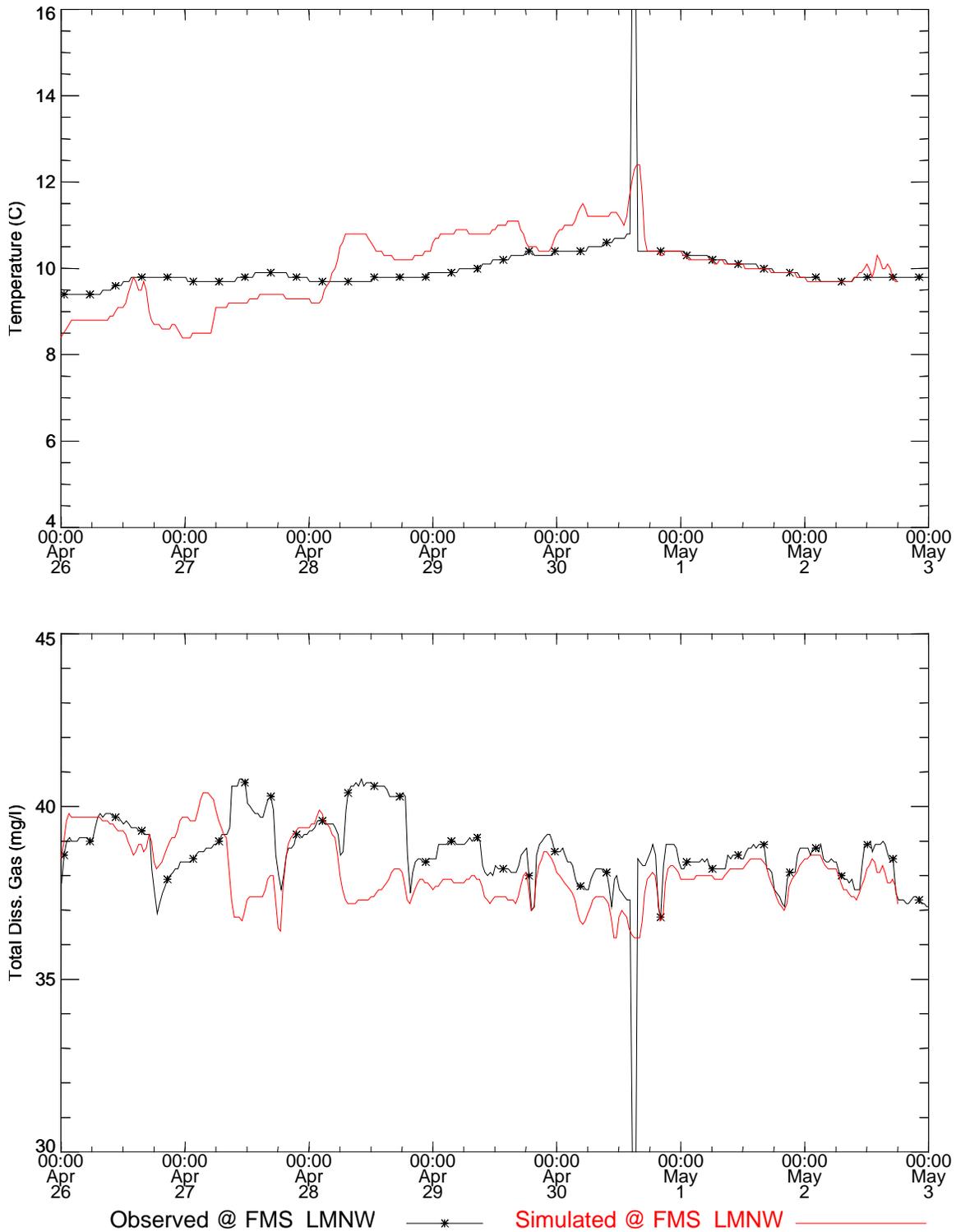


Figure 113. Temperature and total dissolved gas time series comparisons fixed monitor LMNW for the Spring 1997 study period. (FMS-BC).

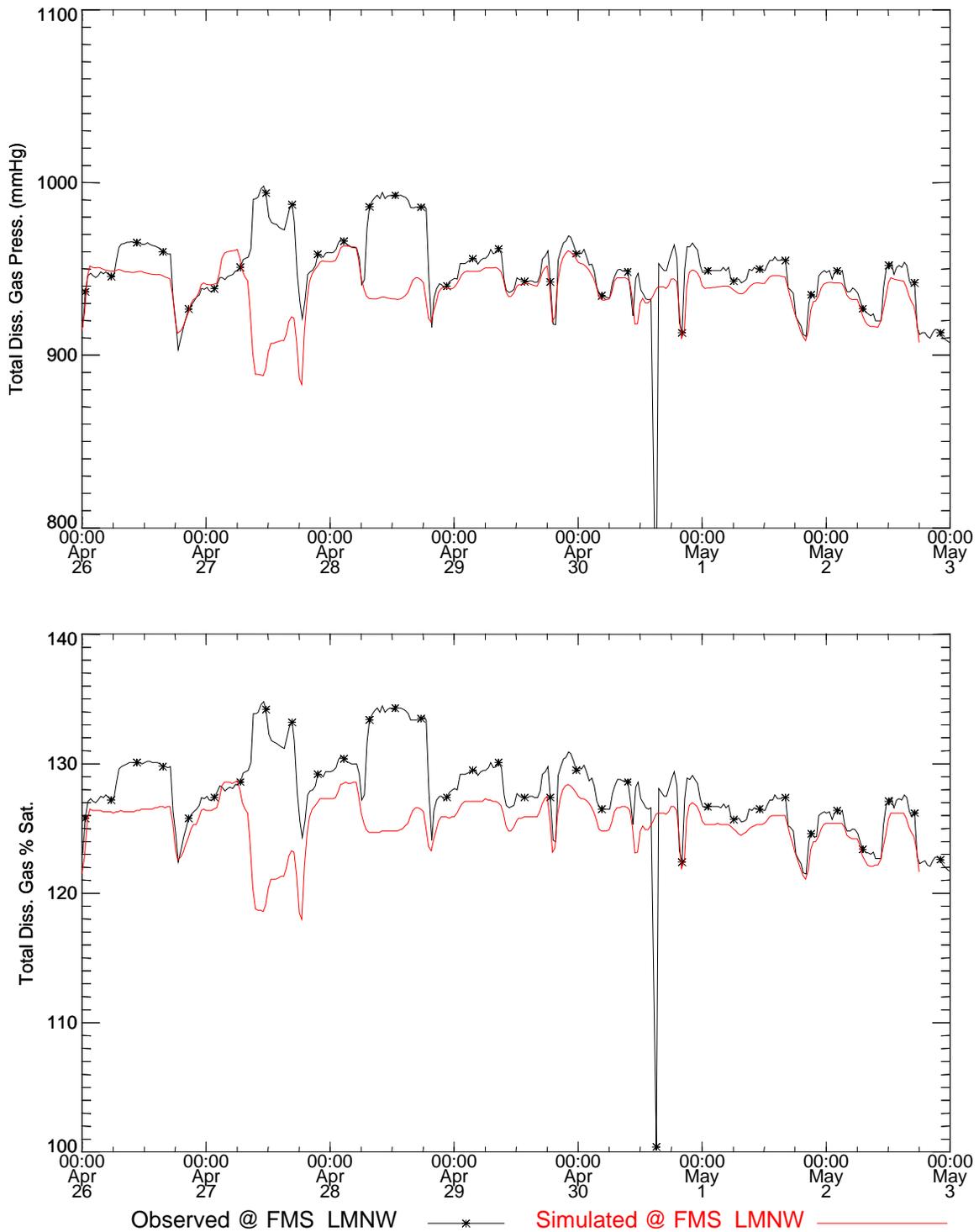


Figure 114. Total dissolved gas pressure and saturation time series comparisons near fixed monitor LMNW for Spring 1997 study period (FMS-BC).

Table 43. Statistical summary of measurements and simulations fixed monitor LMNW for the Spring 1997 study period (FMS-BC).

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature FMS_LMNW	10.01	10	0.78	0.83	0.82
Concentration FMS_LMNW	38.71	38.13	1.21	0.91	1.42
Gas Pressure FMS_LMNW	950.55	938.04	21.56	14.54	27.45
% Saturation FMS_LMNW	128	125.38	3.17	1.96	4.35

Table 44. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements. Stations fixed monitor LMNW for the Spring 1997 study period (FMS-BC).

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat.
FMS_LMNW	88.62	72.62	86.15	84.92

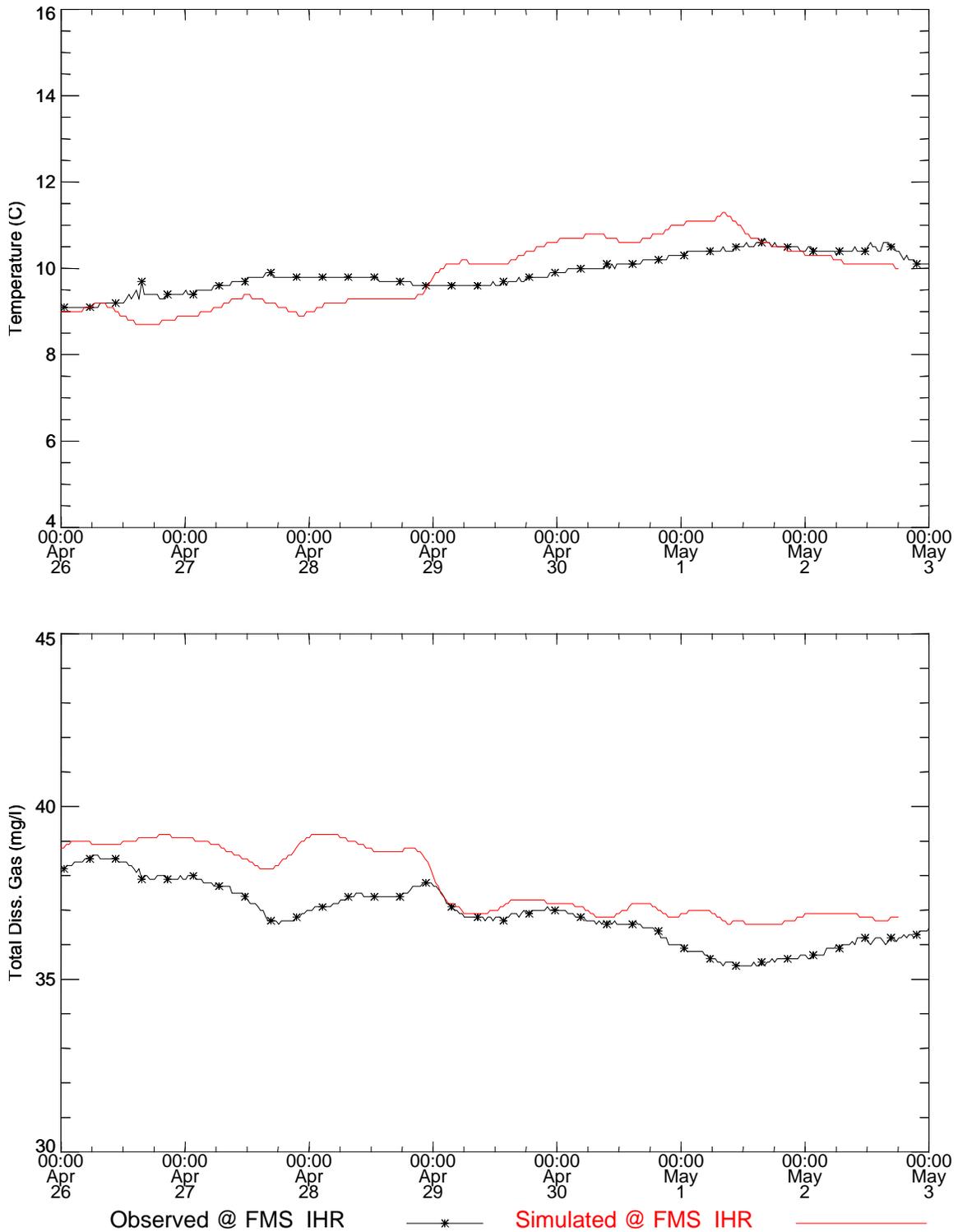


Figure 115. Temperature and total dissolved gas time series comparisons fixed monitor IHR for the Spring 1997 study period. (FMS-BC).

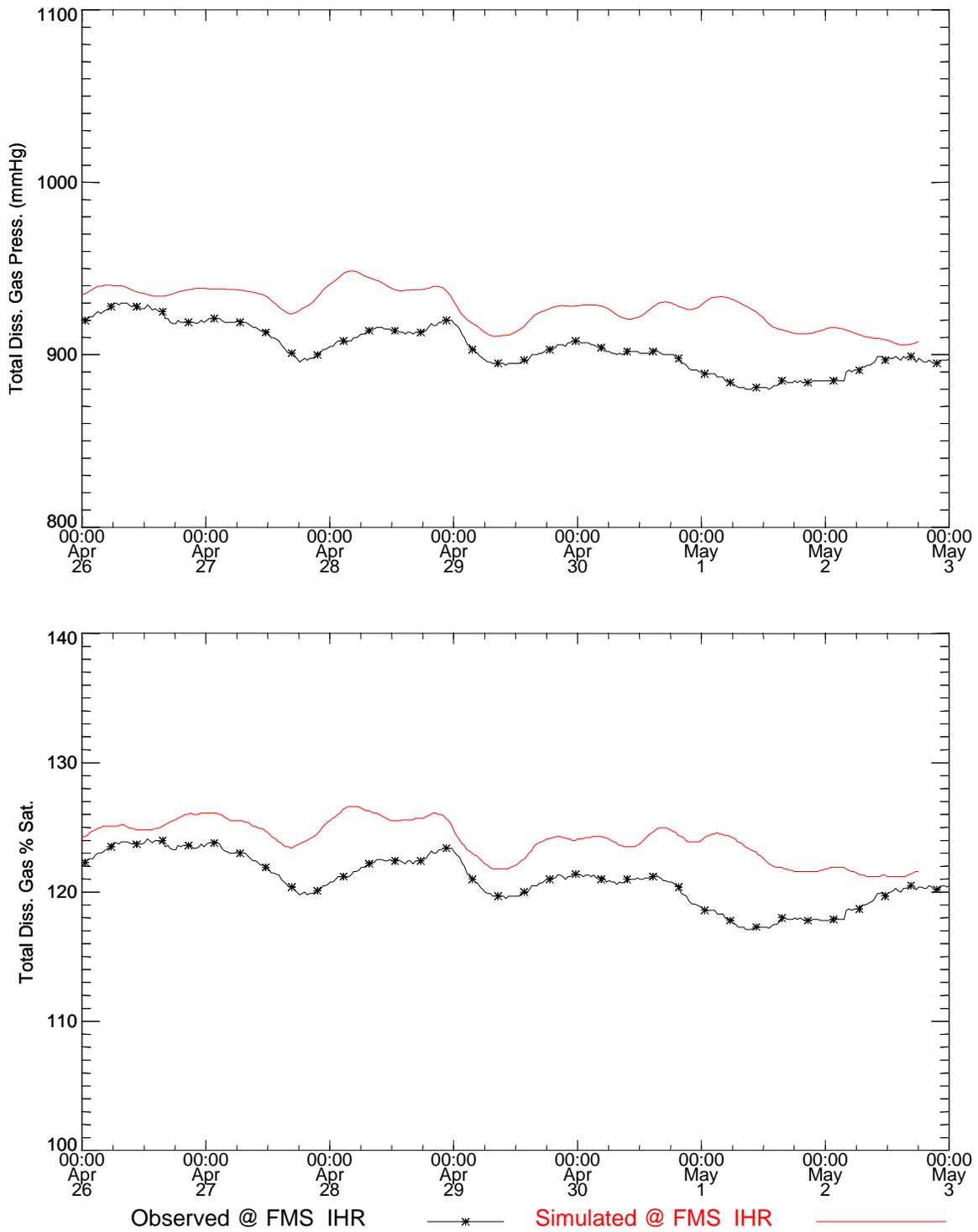


Figure 116. Total dissolved gas pressure and saturation time series comparisons near fixed monitor IHR for Spring 1997 study period (FMS-BC).

Table 45. Statistical summary of measurements and simulations fixed monitor IHR for the Spring 1997 study period (FMS-BC).

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature					
FMS_IHR	9.89	9.89	0.42	0.76	0.52
Concentration					
FMS_IHR	36.9	37.8	0.88	0.98	1.04
Gas Pressure					
FMS_IHR	904.27	927.93	13.46	10.9	25.68
% Saturation					
FMS_IHR	120.91	124.02	1.95	1.56	3.39

Table 46. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements. Stations fixed monitor IHR for the Spring 1997 study period (FMS-BC).

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat.
FMS_IHR	100	51.69	90.15	90.46

Boundary Conditions using Temporary Monitored Field Data

Comparisons between the measurements and simulations using an upstream boundary condition developed from water temperatures and TDG pressures measured by temporary monitors are shown in the figures below. Statistics on comparisons between measured and simulated temperatures and total dissolved gas are also presented. The case is denoted as TM-BC in the figure and table captions.

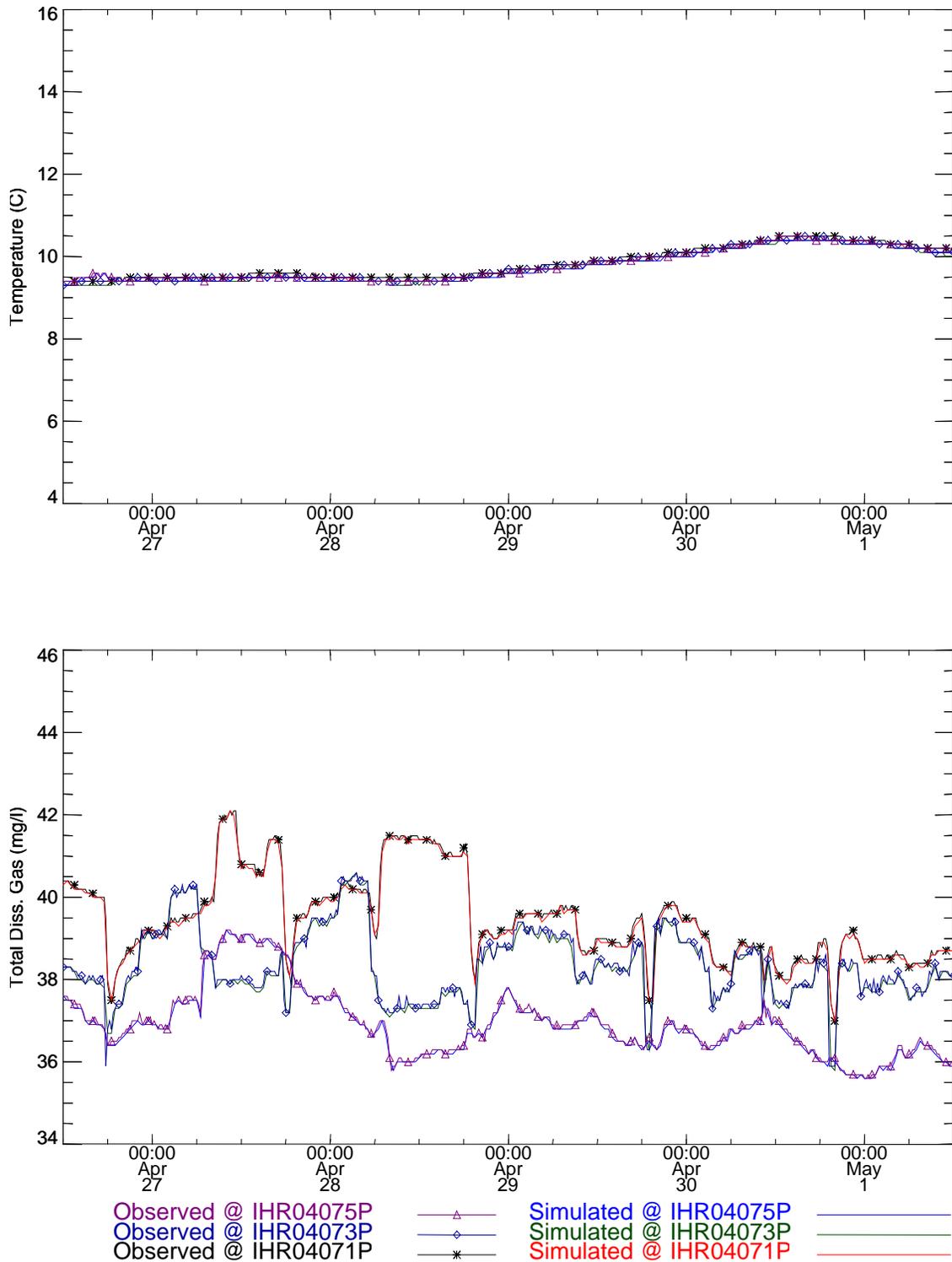


Figure 117. Temperature and total dissolved gas time series comparisons near the Snake River Mile 040.7 for the Spring 1997 study period. (TM-BC).

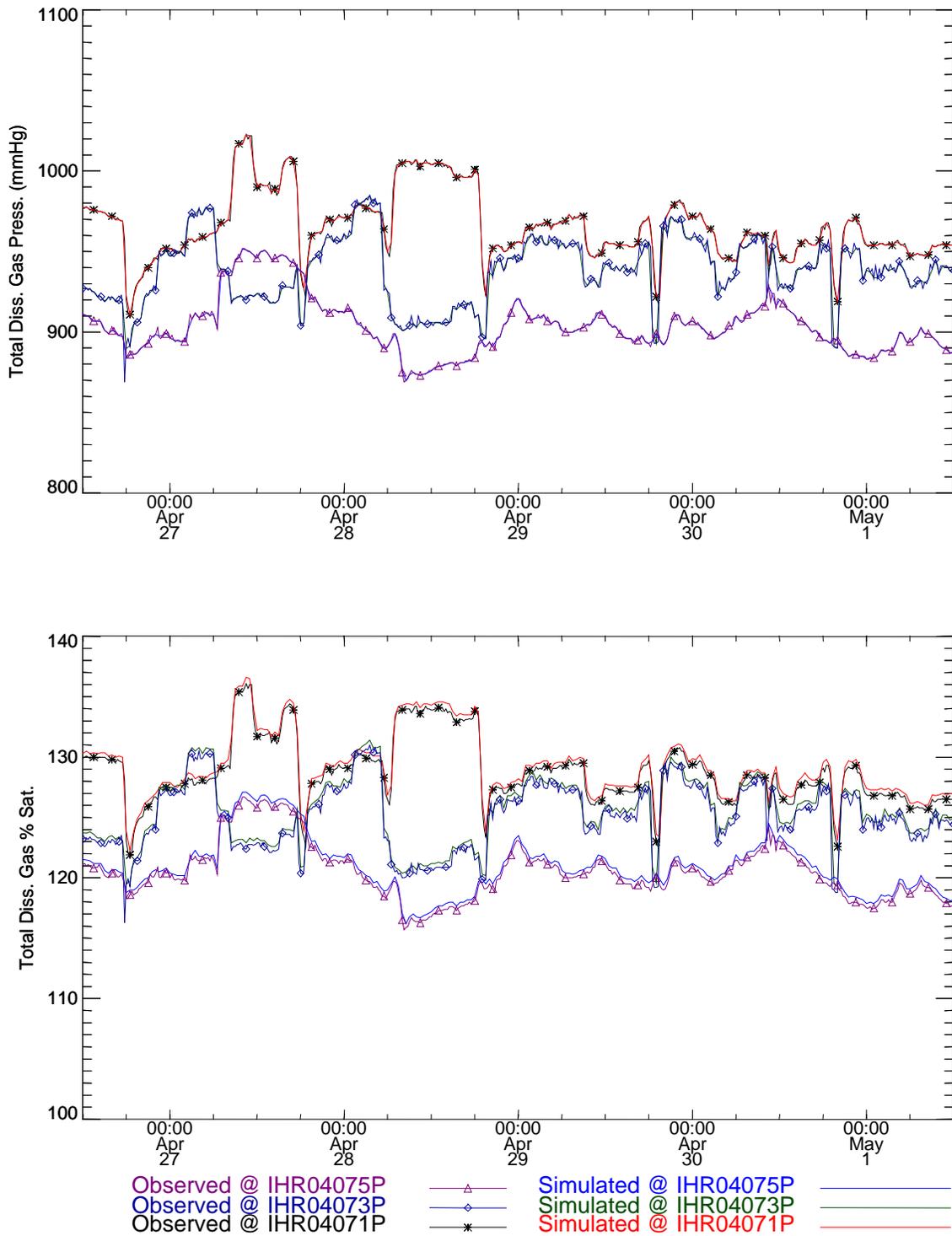


Figure 118. Total dissolved gas pressure and saturation time series comparisons near Snake River Mile 040.7 for Spring 1997 study period (TM-BC).

Table 47. Statistical summary of measurements and simulations near the Snake River Mile 040.7 for the Spring 1997 study period (TM-BC).

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature					
IHR04071P	9.83	9.78	0.37	0.38	0.08
IHR04073P	9.8	9.75	0.38	0.38	0.07
IHR04075P	9.8	9.75	0.38	0.37	0.07
Concentration					
IHR04071P	39.48	39.44	1.05	1.03	0.1
IHR04073P	38.36	38.32	0.86	0.84	0.16
IHR04075P	36.95	36.9	0.83	0.83	0.08
Gas Pressure					
IHR04071P	965.75	965.72	20.95	20.59	1.95
IHR04073P	938.06	937.92	20.87	20.38	3.67
IHR04075P	903.9	903.81	17.44	17.4	1.06
% Saturation					
IHR04071P	128.77	129.21	2.73	2.69	0.51
IHR04073P	125.08	125.49	2.78	2.72	0.64
IHR04075P	120.52	120.92	2.31	2.31	0.43

Table 48. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements. Stations near the Snake River Mile 040.7 for the Spring 1997 study period (TM-BC).

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat
IHR04071P	100	100	100	100
IHR04073P	100	99.58	100	100
IHR04075P	100	100	100	100

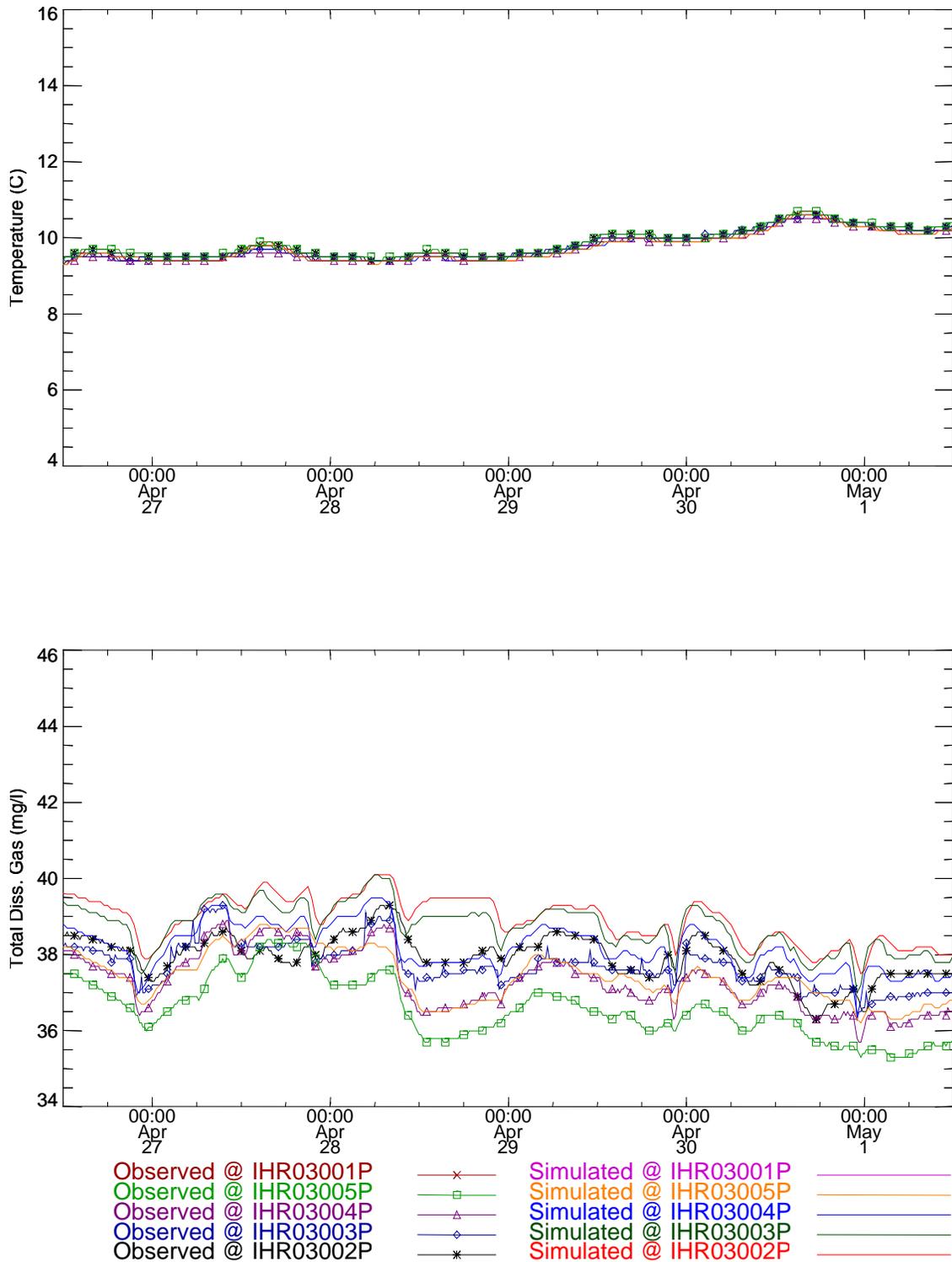


Figure 119. Temperature and total dissolved gas time series comparisons near the Snake River Mile 030.0 for the Spring 1997 study period. (TM-BC).

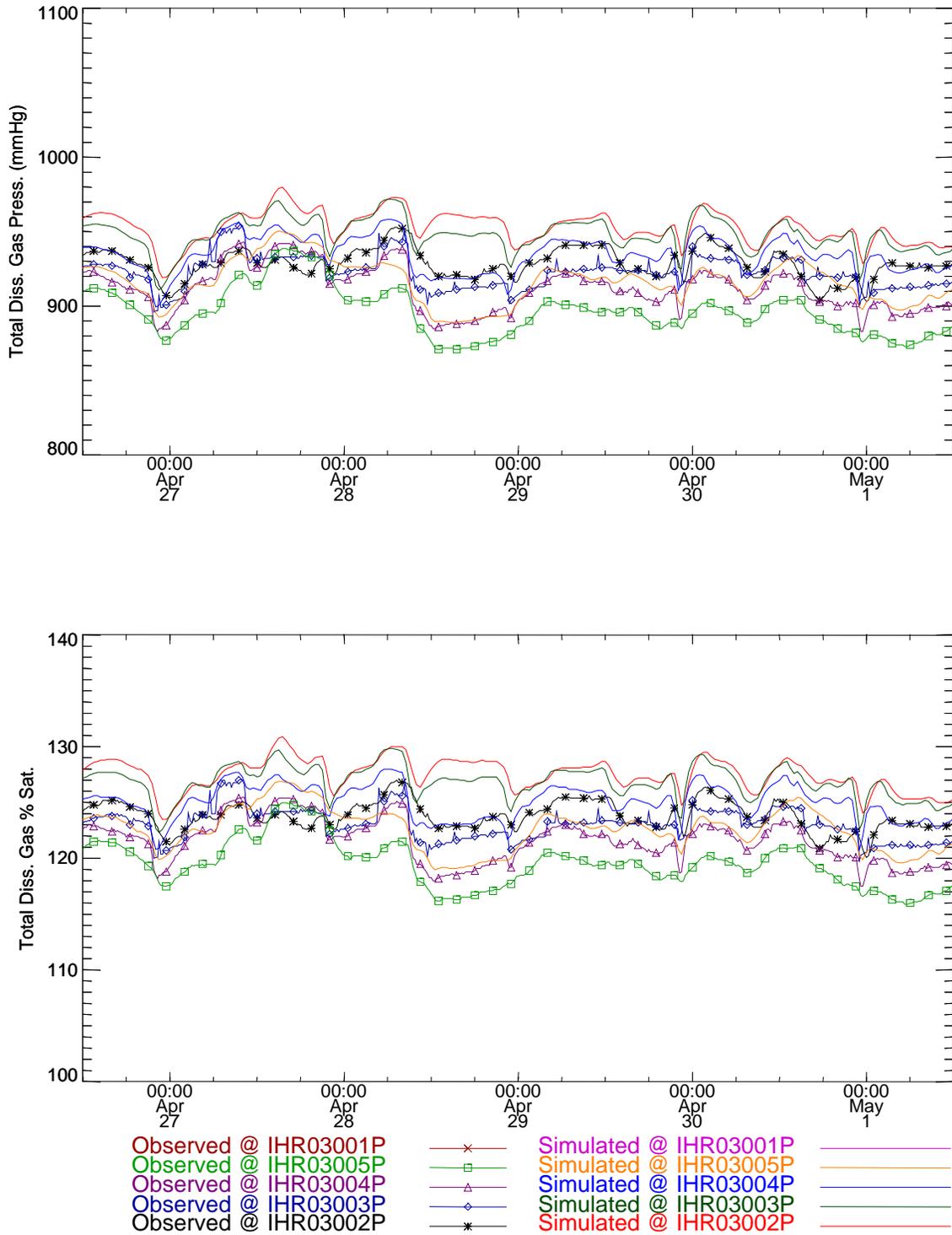


Figure 120. Total dissolved gas pressure and saturation time series comparisons near Snake River Mile 030.0 for Spring 1997 study period (TM-BC).

Table 49. Statistical summary of measurements and simulations near the Snake River Mile 030.0 for the Spring 1997 study period (TM-BC).

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature					
IHR03002P	9.85	9.77	0.36	0.37	0.1
IHR03003P	9.82	9.76	0.37	0.37	0.08
IHR03004P	9.76	9.75	0.37	0.37	0.05
IHR03005P	9.87	9.75	0.36	0.36	0.13
Concentration					
IHR03002P	37.92	38.92	0.59	0.6	1.06
IHR03003P	37.71	38.73	0.57	0.61	1.07
IHR03004P	37.31	38.18	0.75	0.61	0.91
IHR03005P	36.58	37.42	0.79	0.67	0.87
Gas Pressure					
IHR03002P	928.41	953.03	10.09	10.9	26.14
IHR03003P	922.69	948.26	10.91	11.12	26.69
IHR03004P	911.83	934.7	14.82	12.17	23.74
IHR03005P	896.25	916.33	16.12	14.56	20.78
% Saturation					
IHR03002P	123.78	127.51	1.29	1.44	3.92
IHR03003P	123.03	126.87	1.44	1.44	3.98
IHR03004P	121.58	125.06	1.93	1.57	3.59
IHR03005P	119.5	122.6	2.11	1.92	3.18

Table 50. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements. Stations near the Snake River Mile 030.0 for the Spring 1997 study period (TM-BC).

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat
IHR03002P	100	63.83	87.53	79.63
IHR03003P	100	49.27	94.8	87.73
IHR03004P	100	69.23	100	98.54
IHR03005P	100	82.33	100	100

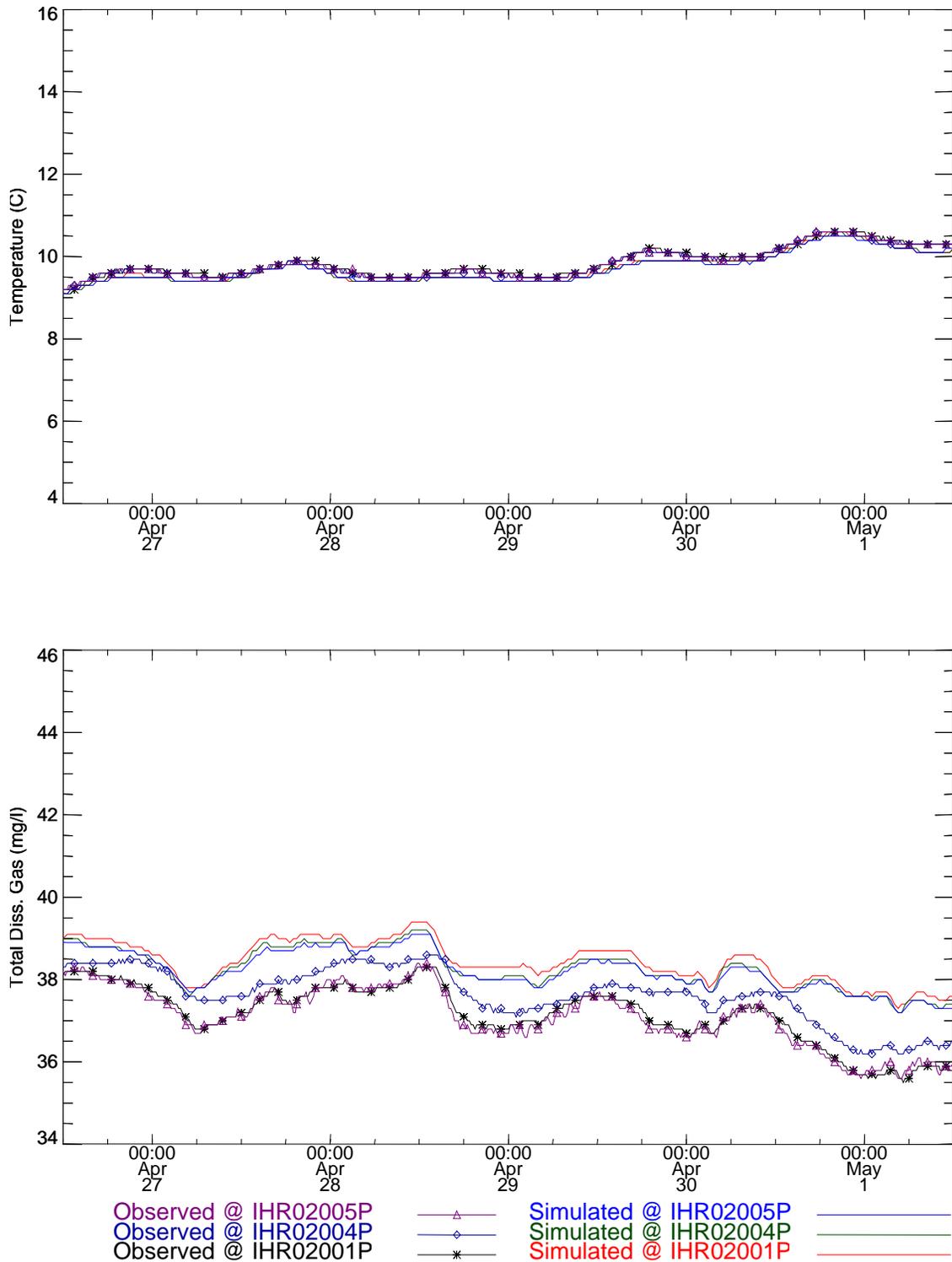


Figure 121. Temperature and total dissolved gas time series comparisons near the Snake River Mile 020.0 for the Spring 1997 study period. (TM-BC).

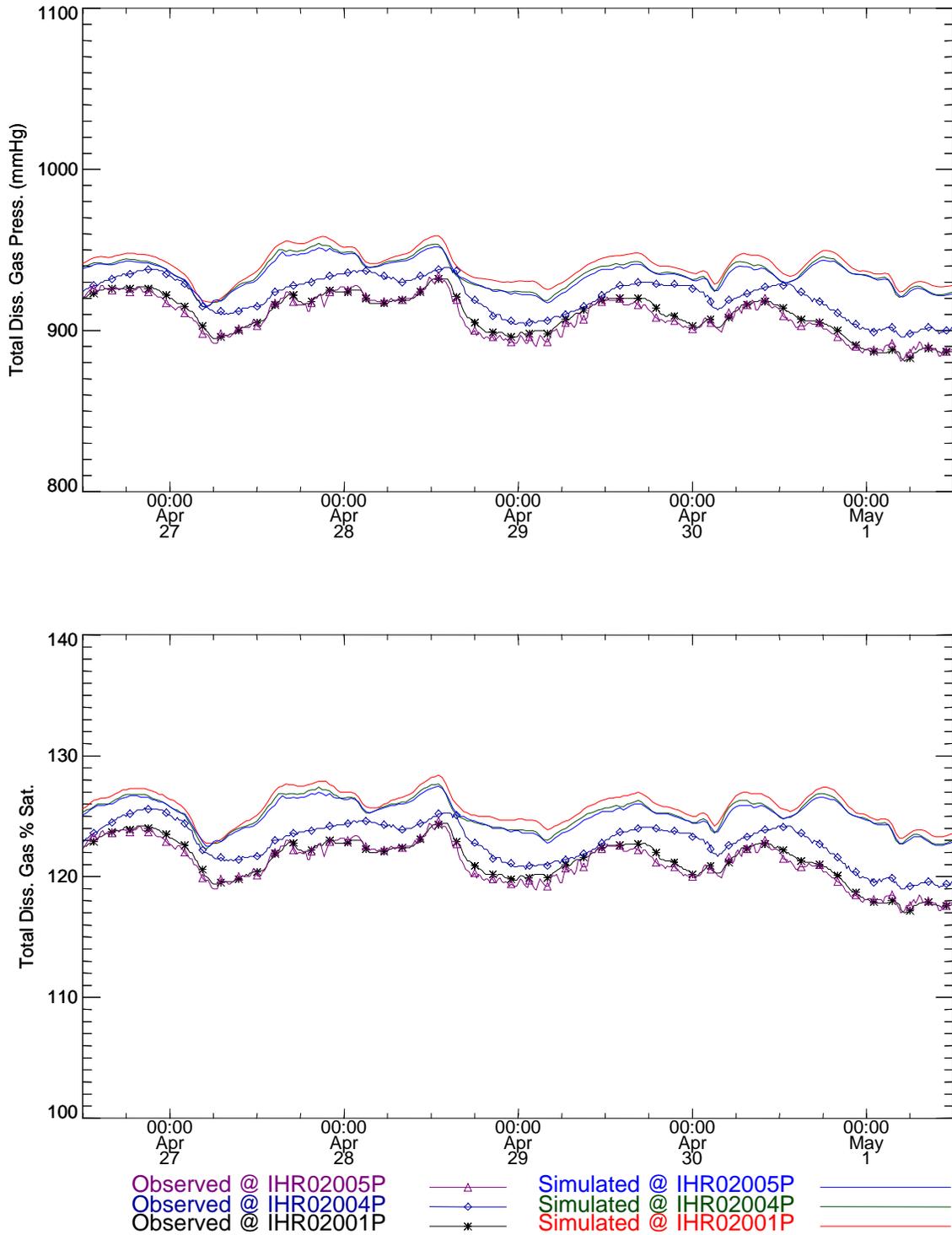


Figure 122. Total dissolved gas pressure and saturation time series comparisons near Snake River Mile 020.0 for Spring 1997 study period (TM-BC).

Table 51. Statistical summary of measurements and simulations near the Snake River Mile 020.0 for the Spring 1997 study period (TM-BC).

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature					
IHR02001P	9.86	9.73	0.35	0.35	0.14
IHR02004P	9.84	9.72	0.35	0.35	0.13
IHR02005P	9.85	9.71	0.35	0.34	0.14
Concentration					
IHR02001P	37.16	38.43	0.71	0.51	1.31
IHR02004P	37.64	38.27	0.66	0.49	0.71
IHR02005P	37.11	38.23	0.71	0.47	1.16
Gas Pressure					
IHR02001P	910.04	940.13	12.6	9.51	31.14
IHR02004P	921.12	936.03	11.92	9.38	17.13
IHR02005P	908.45	934.99	12.81	8.92	27.66
% Saturation					
IHR02001P	121.34	125.78	1.8	1.33	4.58
IHR02004P	122.82	125.23	1.72	1.3	2.67
IHR02005P	121.13	125.1	1.8	1.24	4.11

Table 52. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements. Stations near the Snake River Mile 020.0 for the Spring 1997 study period (TM-BC).

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat.
IHR02001P	100	22.25	83.37	75.68
IHR02004P	100	88.57	100	99.79
IHR02005P	100	46.57	90.44	84.62

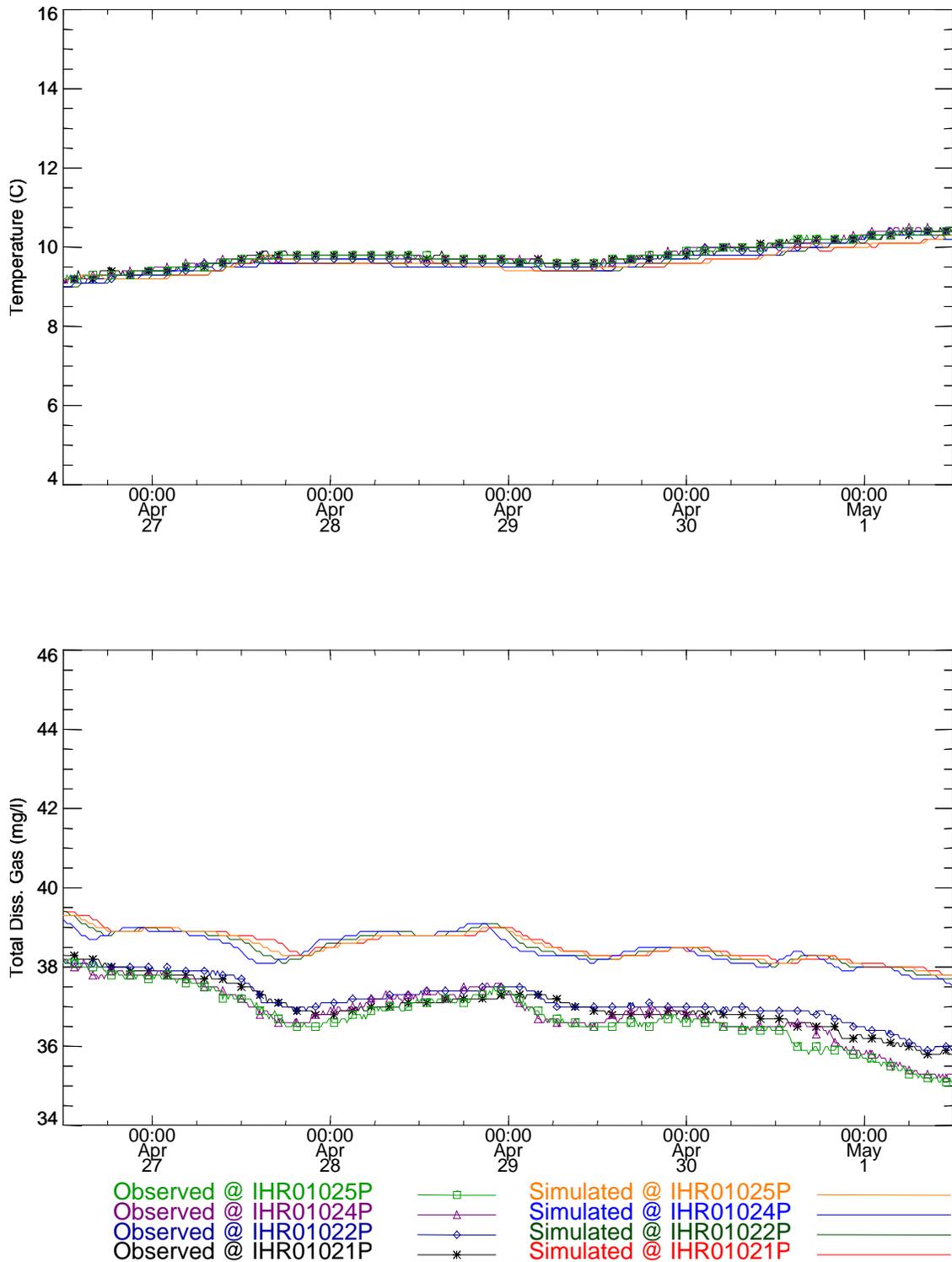


Figure 123. Temperature and total dissolved gas time series comparisons near the Snake River Mile 010.2 for the Spring 1997 study period. (TM-BC).

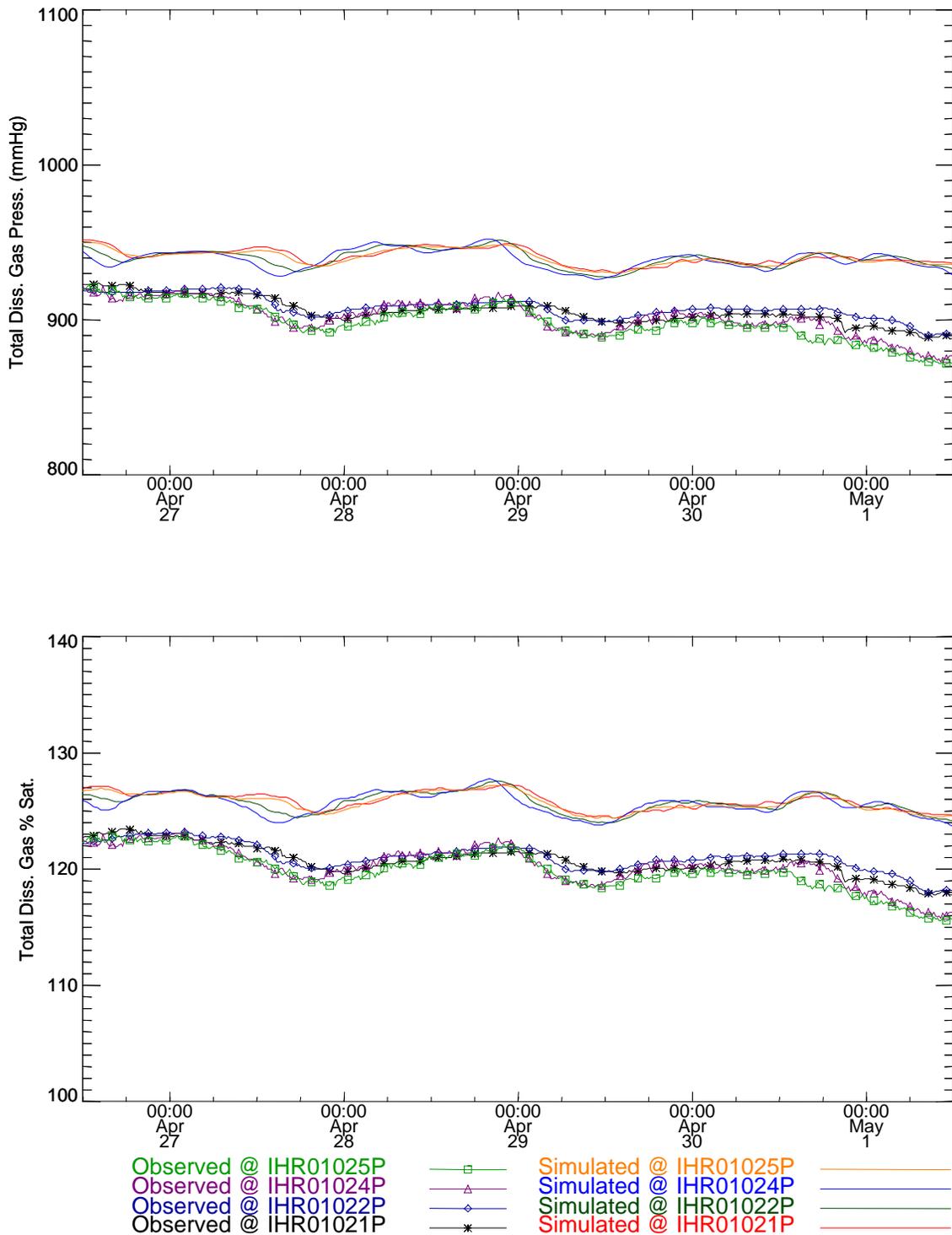


Figure 124. Total dissolved gas pressure and saturation time series comparisons near Snake River Mile 010.2 for Spring 1997 study period (TM-BC).

Table 53. Statistical summary of measurements and simulations near the Snake River Mile 010.2 for the Spring 1997 study period (TM-BC).

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature					
IHR01021P	9.8	9.61	0.3	0.28	0.2
IHR01022P	9.74	9.62	0.32	0.31	0.13
IHR01024P	9.81	9.64	0.31	0.31	0.18
IHR01025P	9.8	9.62	0.3	0.27	0.2
Concentration					
IHR01021P	37.03	38.56	0.58	0.35	1.55
IHR01022P	37.17	38.5	0.52	0.38	1.35
IHR01024P	36.87	38.46	0.68	0.39	1.63
IHR01025P	36.75	38.53	0.72	0.36	1.82
Gas Pressure					
IHR01021P	905.77	940.9	8.49	5.01	35.77
IHR01022P	907.99	939.87	7.42	5.67	32.51
IHR01024P	902.1	939.07	11.08	6.15	38.11
IHR01025P	899	940.24	11.92	4.98	42.28
% Saturation					
IHR01021P	120.77	125.89	1.31	0.77	5.2
IHR01022P	121.07	125.75	1.19	0.86	4.76
IHR01024P	120.28	125.64	1.67	0.94	5.5
IHR01025P	119.87	125.8	1.78	0.8	6.06

Table 54. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements. Stations near the Snake River Mile 020.2 for the Spring 1997 study period (TM-BC).

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat.
IHR01021P	100	4.78	62.99	46.36
IHR01022P	100	17.88	81.91	59.25
IHR01024P	100	6.03	63.83	33.06
IHR01025P	100	1.04	29.52	18.92

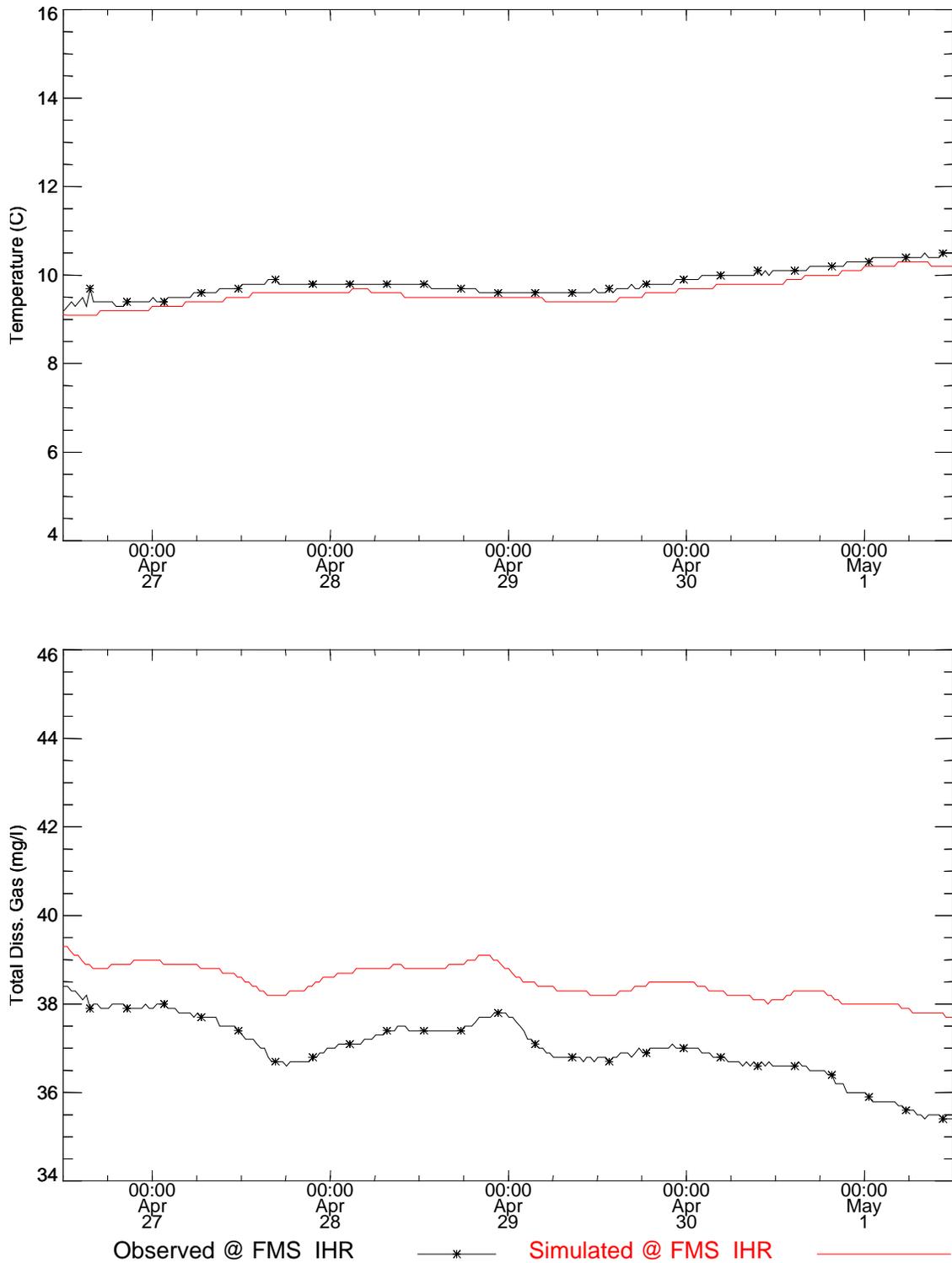


Figure 125. Temperature and total dissolved gas time series comparisons fixed monitor IHR for the Spring 1997 study period. (TM-BC).

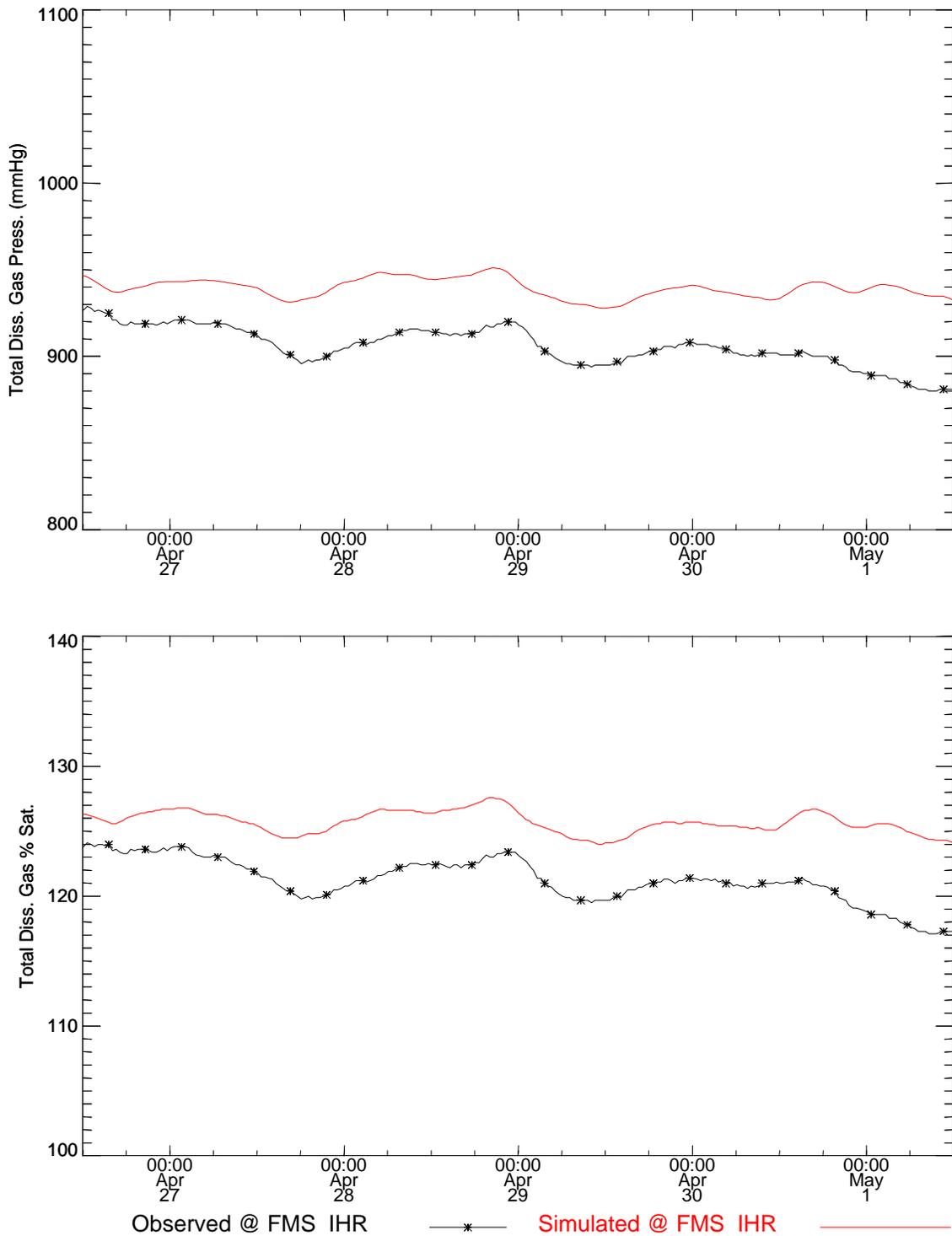


Figure 126. Total dissolved gas pressure and saturation time series comparisons near fixed monitor IHR for Spring 1997 study period (TM-BC).

Table 55. Statistical summary of measurement's and simulations fixed monitor IHR for the Spring 1997 study period (TM-BC).

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature FMS_IHR	9.82	9.62	0.3	0.3	0.21
Concentration FMS_IHR	37.01	38.49	0.69	0.37	1.52
Gas Pressure FMS_IHR	905.71	939.46	11.42	5.43	34.98
% Saturation FMS_IHR	121.22	125.7	1.71	0.85	4.64

Table 56. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements. Stations fixed monitor IHR for the Spring 1997 study period (TM-BC).

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat.
FMS_IHR	100	11.2	78.42	78.01

2 References

Richmond, M.C., W.A. Perkins, and T.D. Scheibe. 1998. *Two-Dimensional Hydrodynamic, Water Quality, and Fish Exposure Modeling of the Columbia and Snake Rivers. Part 1: Summary and Model Formulation*. Draft Final Report submitted to U.S. Army Corps of Engineers, Walla Walla District. Battelle Pacific Northwest Division, Richland, Washington.

Schneider, M.L., and S.C. Wilhelms, 1997. *Total Dissolved Gas Production at Spillways on the Snake and Lower Columbia Rivers*. Memorandum for Record, CEWES-HS-L, U.S. Army Corps of Engineers, Available (limited access): limnos.wes.army.mil
Directory: /data3/dgas/Documents/reports/ File: dgasprod.exe.

Steinbrenner J.P., and J.R. Chawner, 1995. *The GRIDGEN Version 9 Multiple Block Grid Generation Software*. MDA Engineering, Inc., Arlington, Texas.

Appendix A. Ice Harbor Pool Data Sources

A.1 Bathymetry

Bathymetric data for Ice Harbor pool was gathered from the various sources shown in Table 57. The primary source was digitized NOAA navigation, which are relatively coarse. The charts were supplemented with dense surveys in Ice Harbor dam forebay and Lower Monumental dam tailrace. Using the Arc/Info® GIS software system, the data was converted to a consistent coordinate system and datum, and combined to build a triangular irregular network (TIN), which represented the river bottom and shore as a three-dimensional surface. The resulting surface for Ice Harbor pool is shown in Figure 127. Once the surface was produced, it was “sampled” at the necessary grid locations to produce the bathymetry required by the hydrodynamic model grid.

Table 57. Columbia River bathymetry data sets used to create the Ice Harbor pool bathymetric surface. Listed Figure numbers refers to the map which shows the survey location(s).

Bathymetric Data Set	Source	Survey Date	Approximate Rivermile	
			Start	End
Lower Monumental Dam Tailrace (Figure 128)	Julie Davin (Walla Walla)	1992	40.4	41.5
Ice Harbor Dam Tailrace (Figure 129)	Julie Davin (Walla Walla)	1993	8.5	9.7
Ice Harbor Dam Forebay (Figure 129)	Julie Davin (Walla Walla)	1993	9.7	10.4
NOAA Navigation Charts (Figure 128 and Figure 129)	Battelle	unknown	0.0	107.2

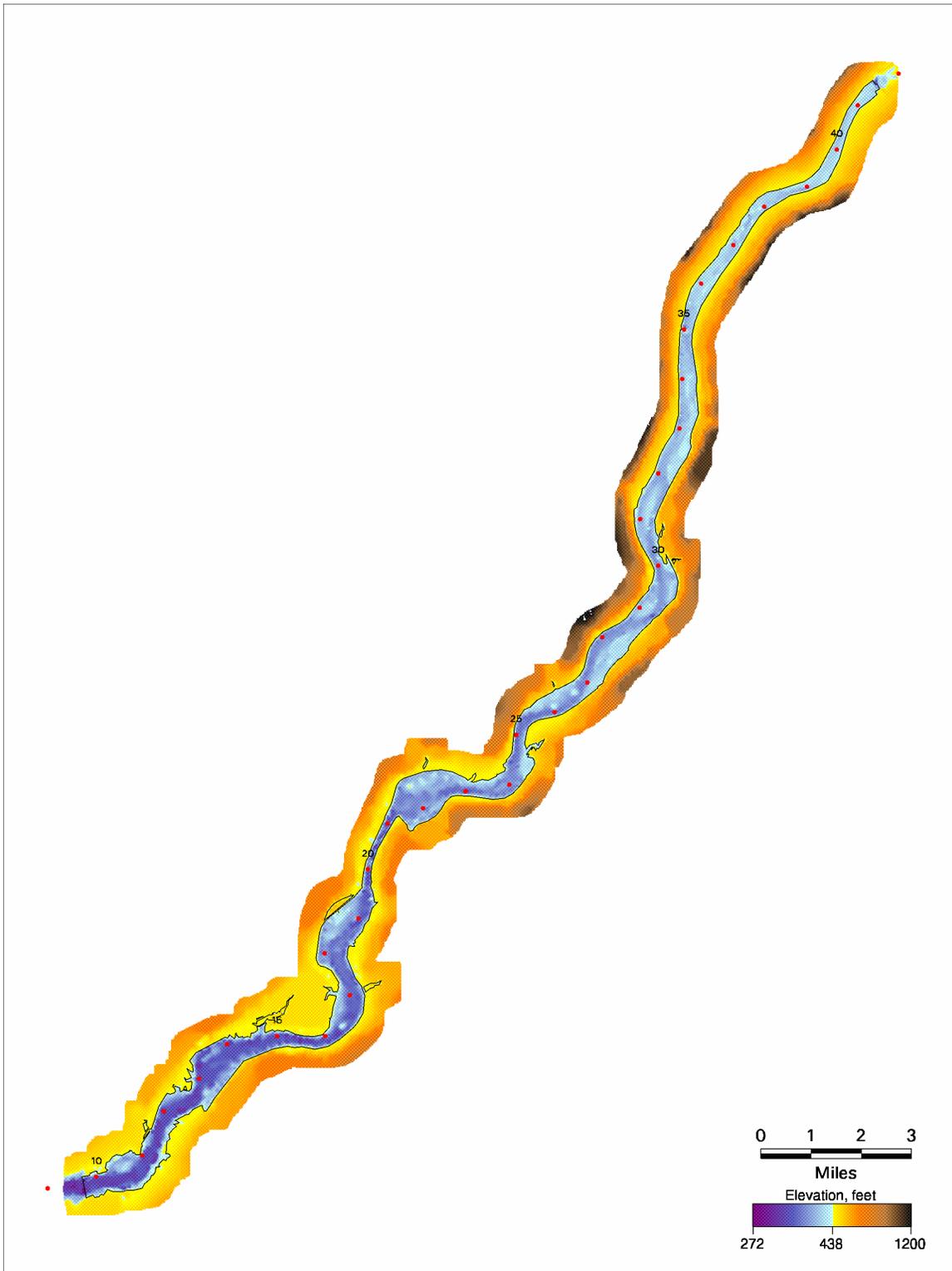


Figure 127. Color representation of Ice Harbor pool bathymetric surface.

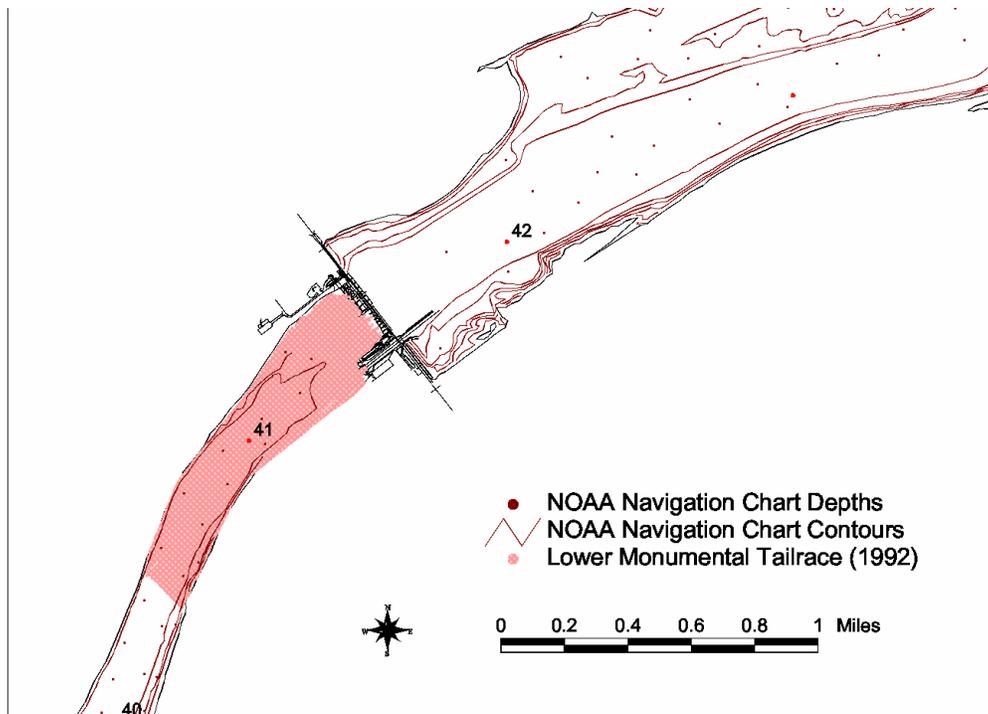


Figure 128. Bathymetric data near Lower Monumental Dam.

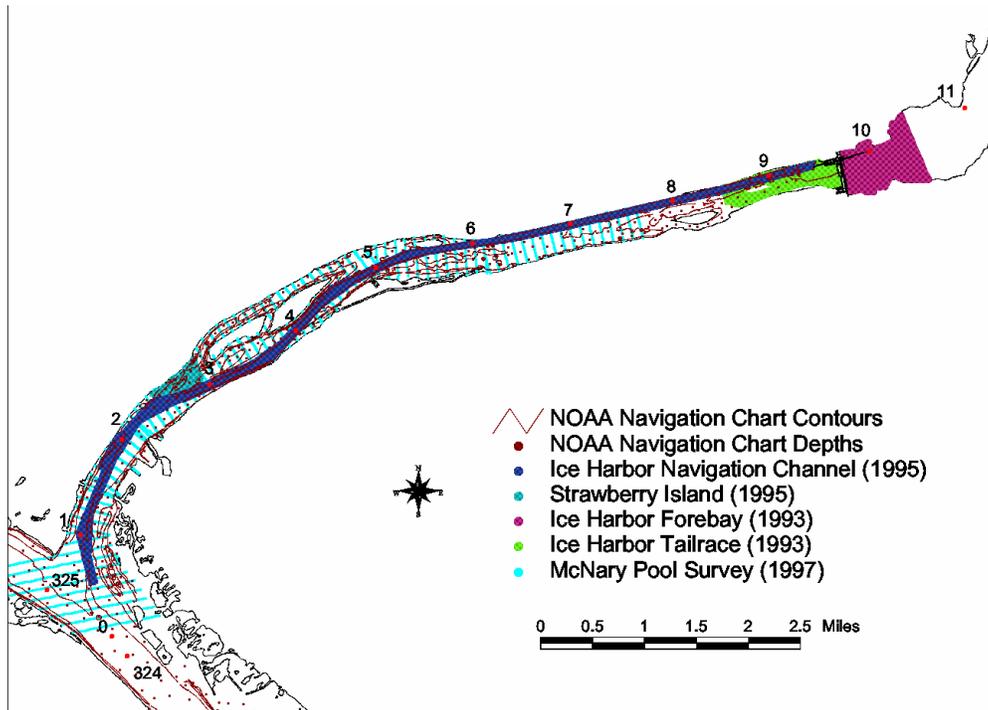


Figure 129. Bathymetric data near Ice Harbor dam.

A.2 Calibration/Verification Data Sources

A.2.1 Dissolved Gas Measurements

Dissolved gas measurements were available from two sources: permanent fixed monitors and dissolved gas pool studies which used temporary monitors. Fixed monitor stations (FMS) in Ice Harbor pool area are shown in Figure 131. The water quality data recorded by the FMS included total dissolved gas (TDG) pressure, barometric pressure, and temperature, and was obtained from the DGAS team ftp server, `limnos.wes.army.mil`, in the file `/data3/dgas/database/FMS_data/FMS_data.zip`, dated August 25, 1998. Fixed monitor data was used to establish temperature and TDG concentration in powerhouse flow at the Lower Monumental dam model boundary.

The dissolved gas pool studies performed in Ice Harbor Pool to date are shown in Table 58 and their durations are shown graphically in Figure 130. During these studies water temperature and TDG pressures were measured at several locations within Ice Harbor pool. These periods were used for model calibration and verification and are discussed individually below. The water quality data gathered during these studies was obtained from the DGAS team ftp server, `limnos.wes.army.mil`, in the file `/data3/dgas/database/field_data/field_data.zip`, dated August 25, 1998.

Table 58. Dates of dissolved gas field studies in Ice Harbor pool.

STUDY SET	Start	End
IHR MCN SPR 97	4/22/97 10:58:00 PM	5/3/97 11:00:00 AM
IHR SPR 96	5/13/96 11:28:00	5/20/96 2:38:00 PM

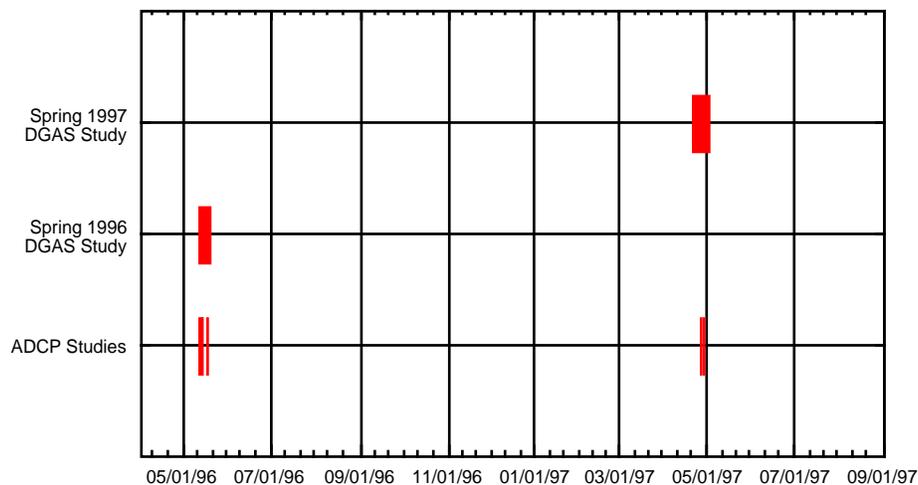


Figure 130. Dates and durations of dissolved gas and ADCP velocity studies in Ice Harbor Pool

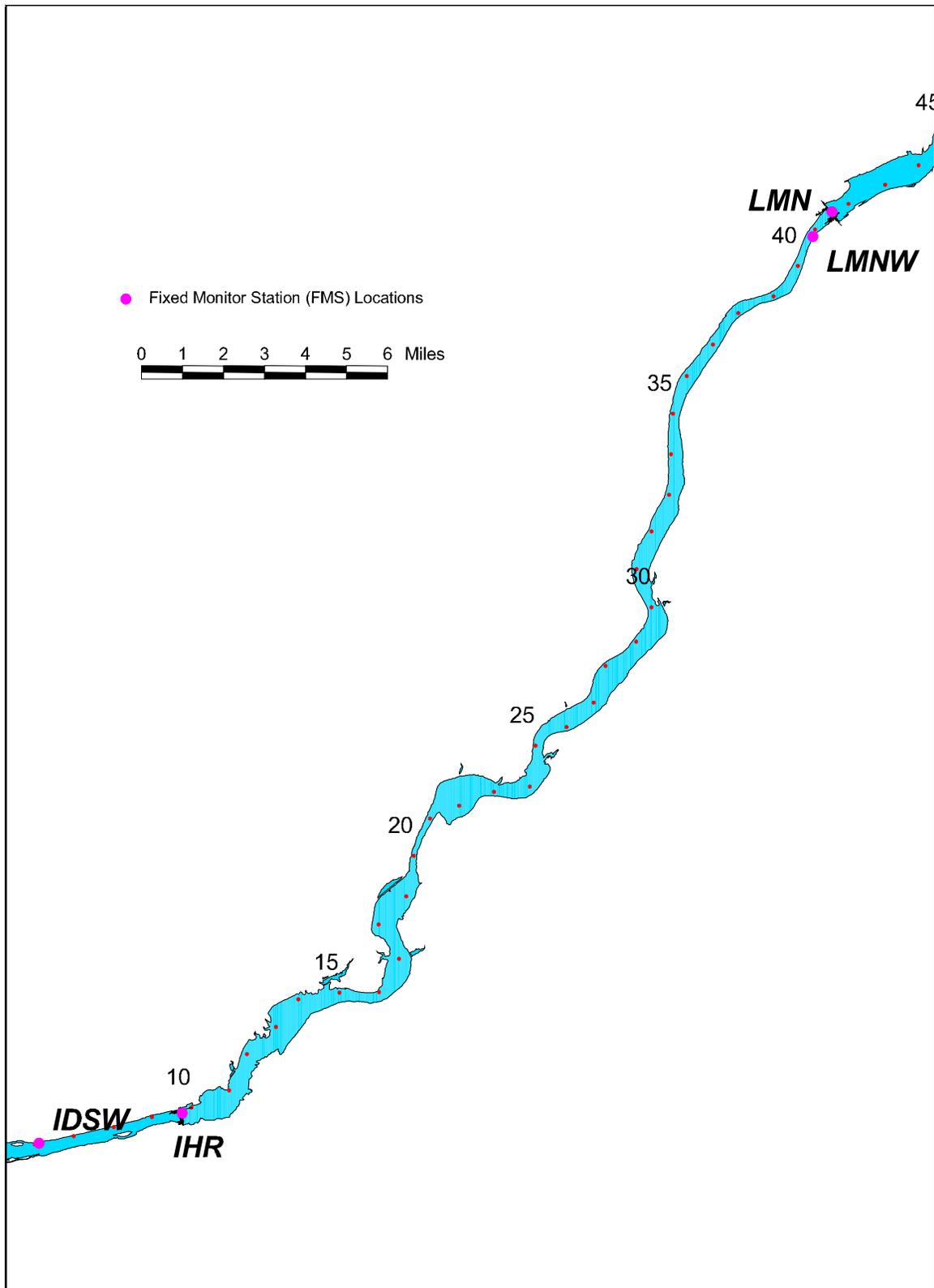


Figure 131. FMS locations in and around Ice Harbor pool.

A.2.2 ADCP Velocity Measurements

As shown in Figure 130, velocity measurements were taken using ADCP (Acoustic Doppler Current Profiler) instruments during two of the dissolved gas pool studies: Spring 1996 and Summer 1997. The ADCP data was obtained from the DGAS team FTP server, `limnos.wes.army.mil`, in the files `/data3/dgas/database/ADCP data/96ADCP.zip` and `/data3/dgas/database/ADCP data/97ADCP.zip`, dated April 10, 1998 and July 15, 1998, respectively. Figure 138 through show the measurements made as small arrows. The measurements were thinned for clarity in those figures: only one arrow in three was drawn.

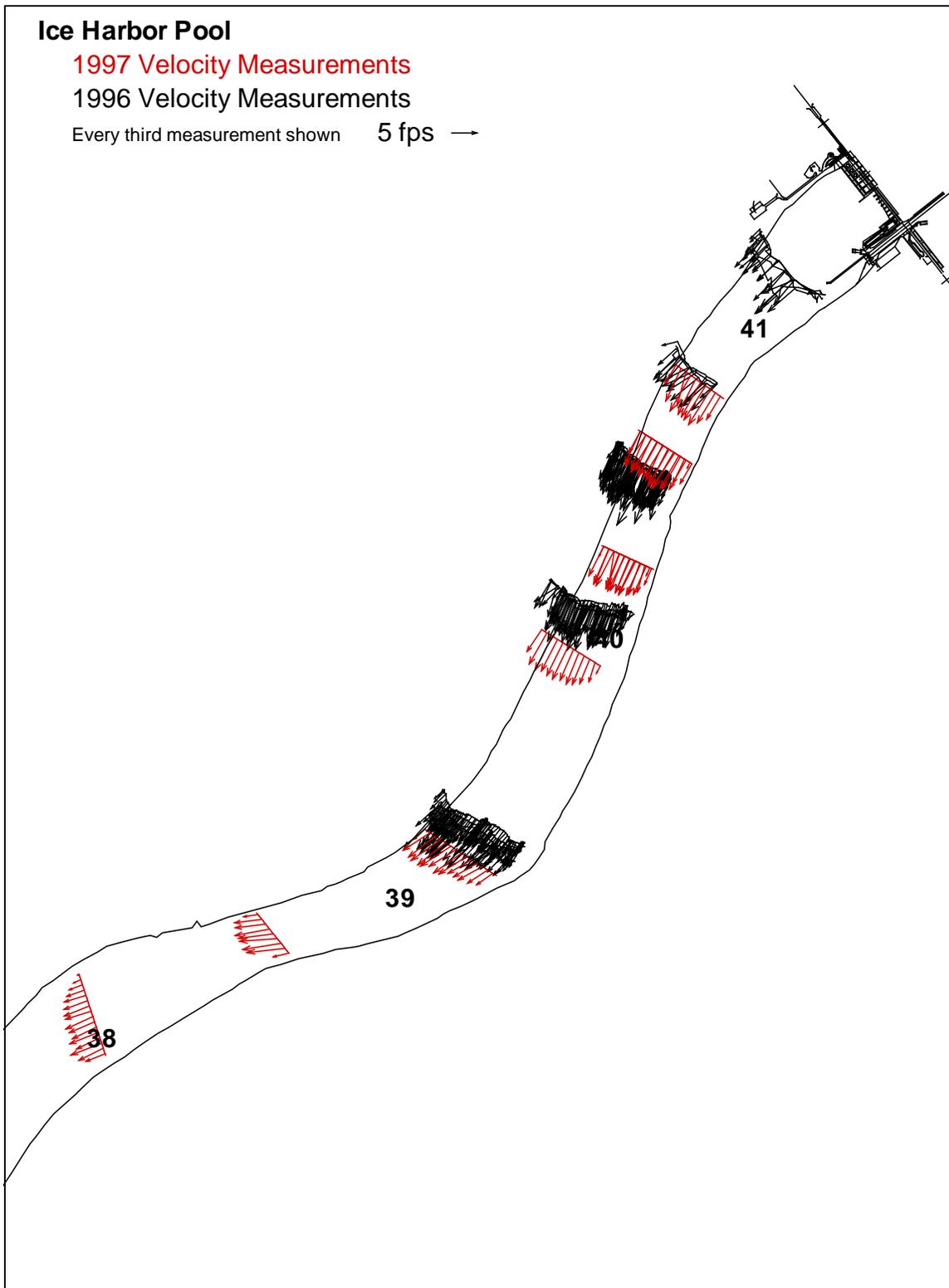


Figure 132. Ice Harbor pool ADCP velocity measurements near Lower Monumental dam.

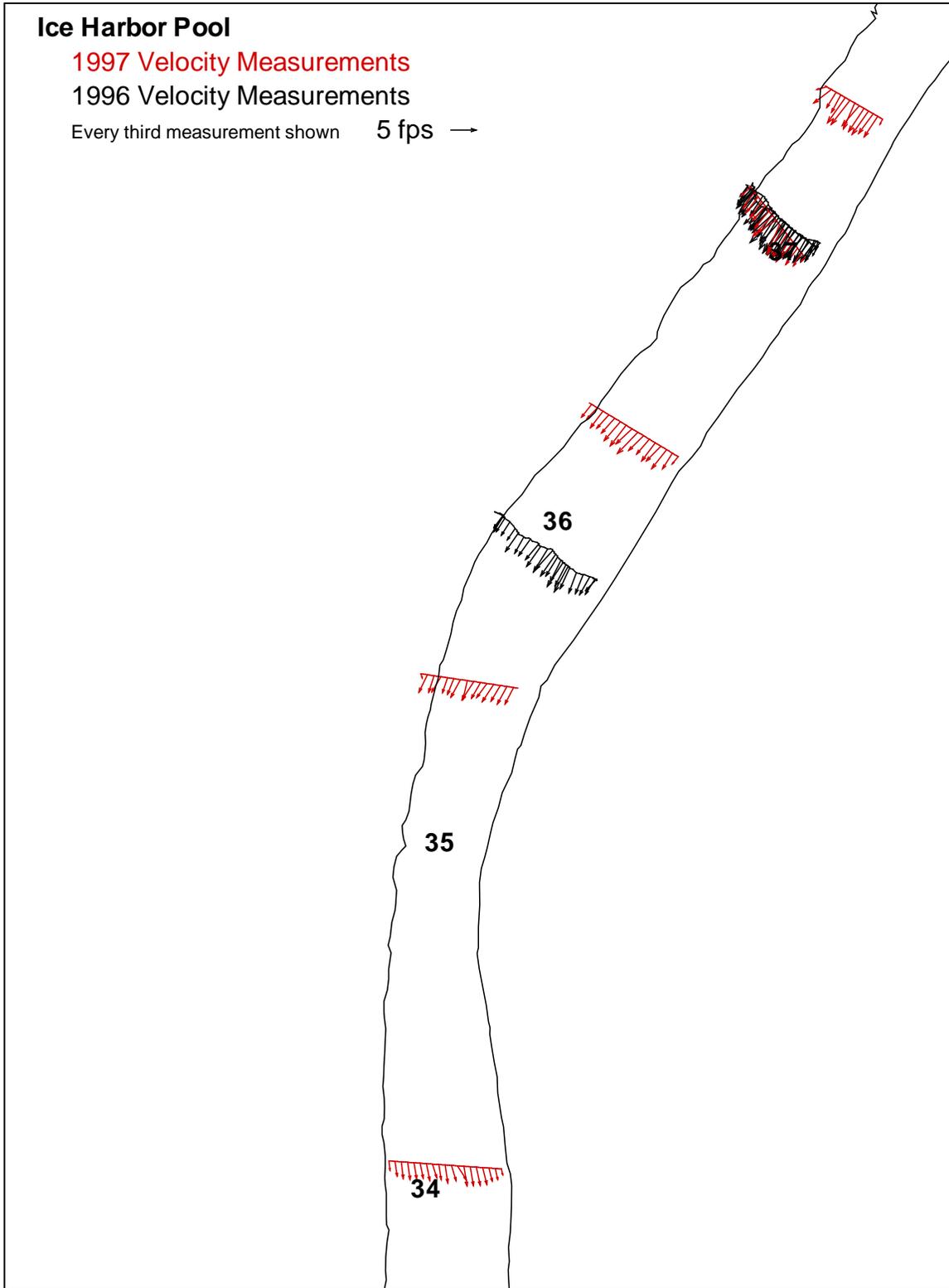


Figure 133. Ice Harbor pool ADCP velocity measurements near river mile 36.

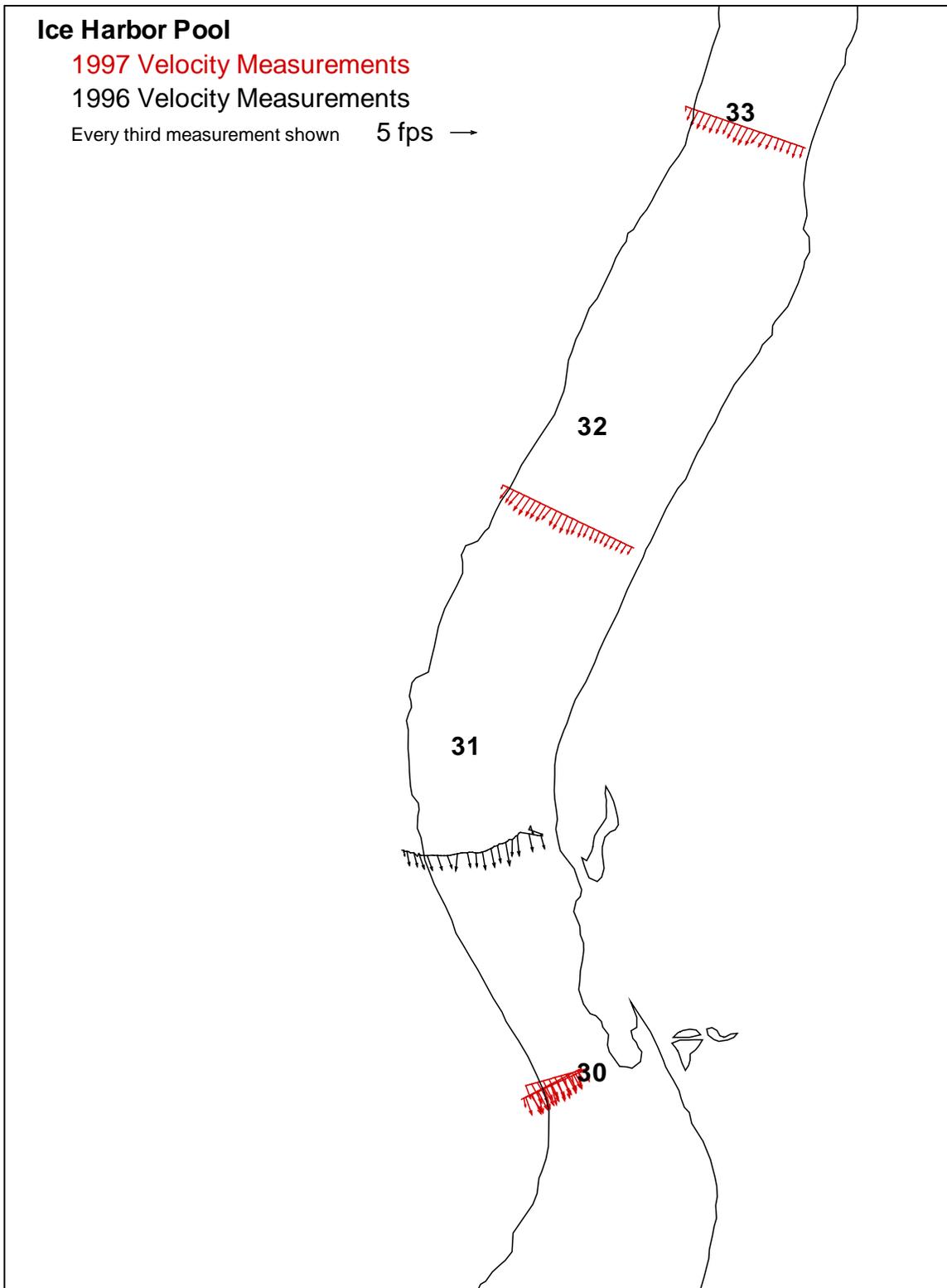


Figure 134. Ice Harbor pool ADCP velocity measurements near river mile 32.

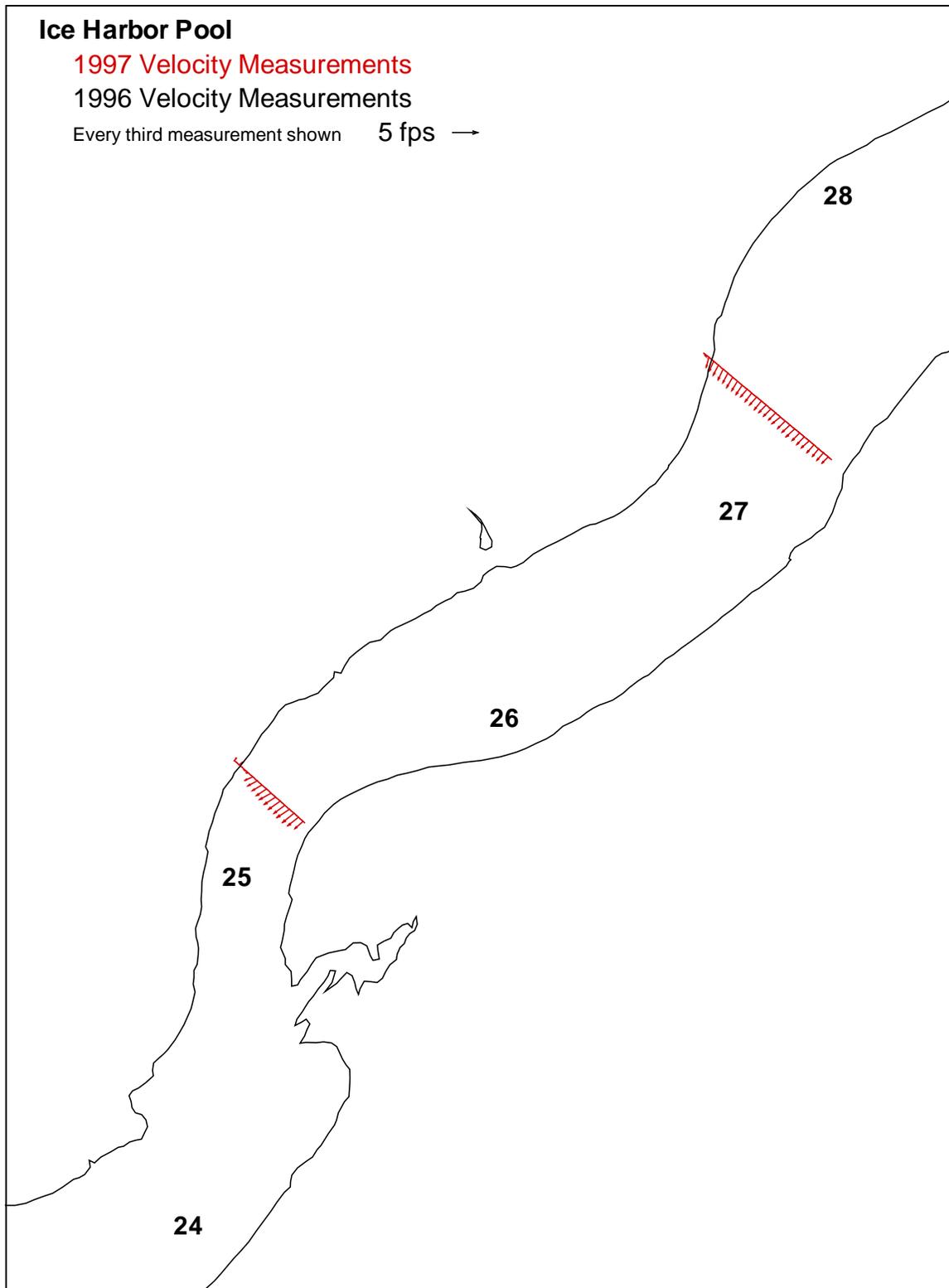


Figure 135. Ice Harbor pool ADCP velocity measurements near river mile 26.

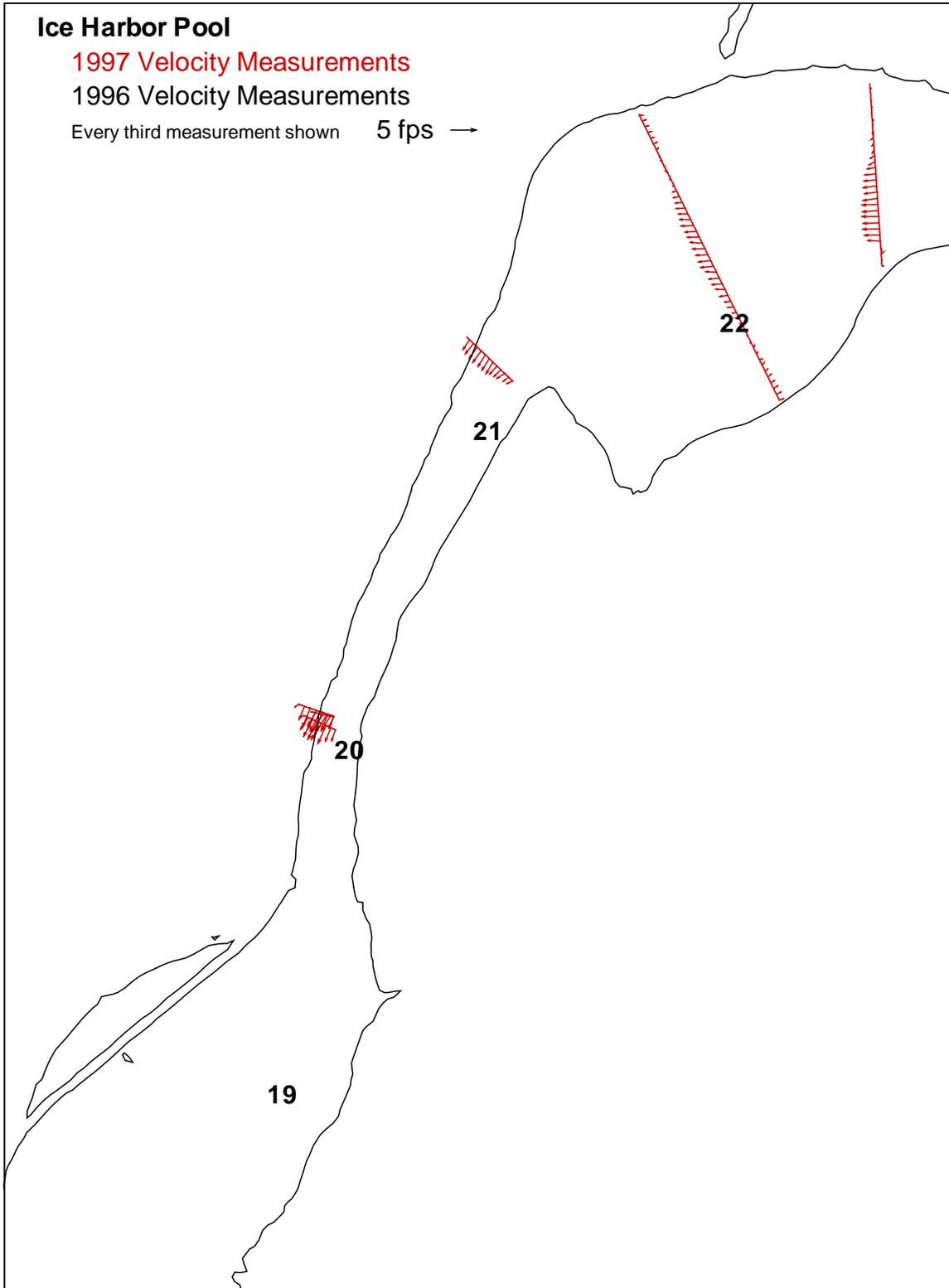


Figure 136. Ice Harbor pool ADCP velocity measurements near Fishhook park.

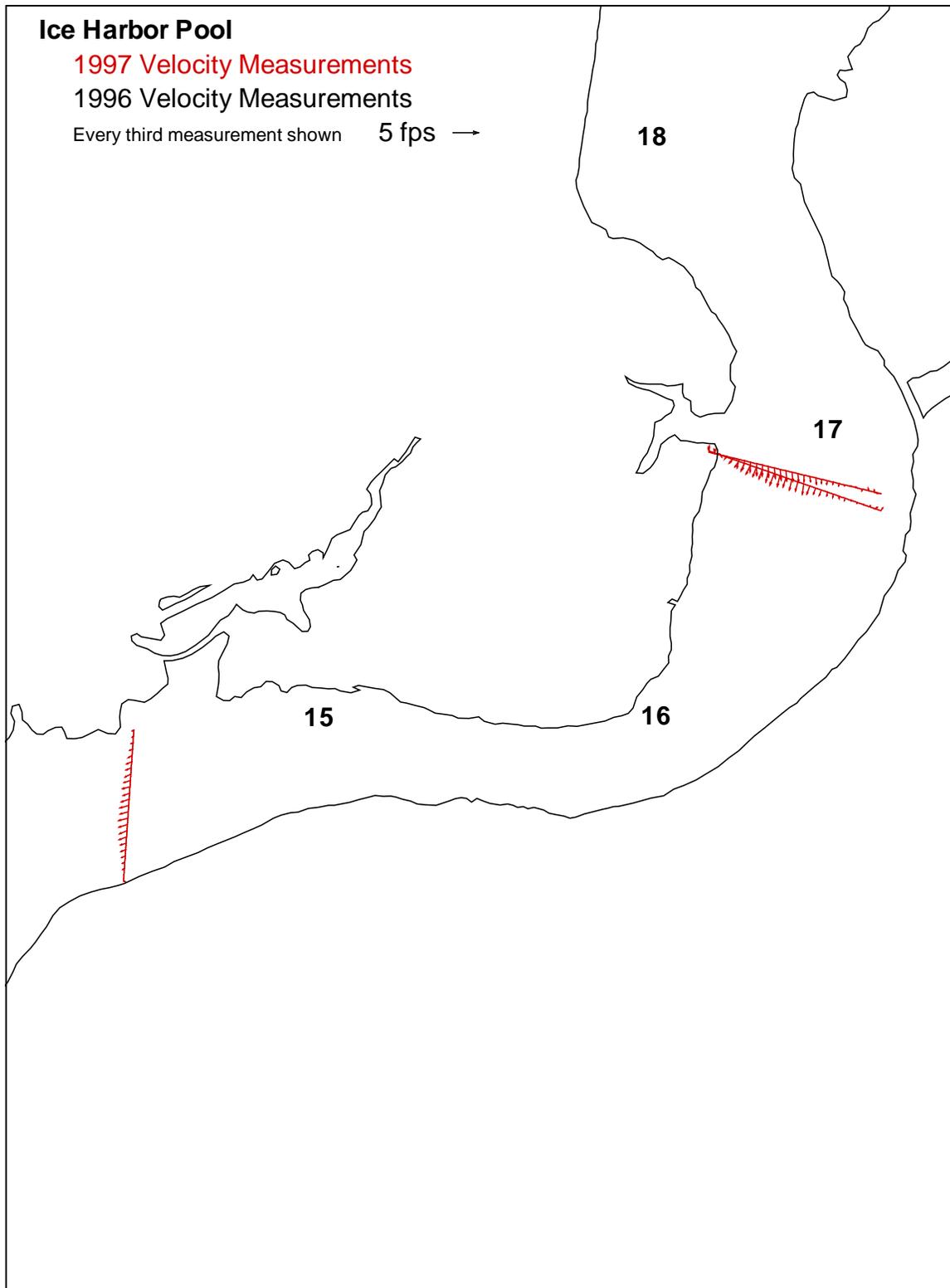


Figure 137. Ice Harbor pool ADCP velocity measurements near Dalton Lake.

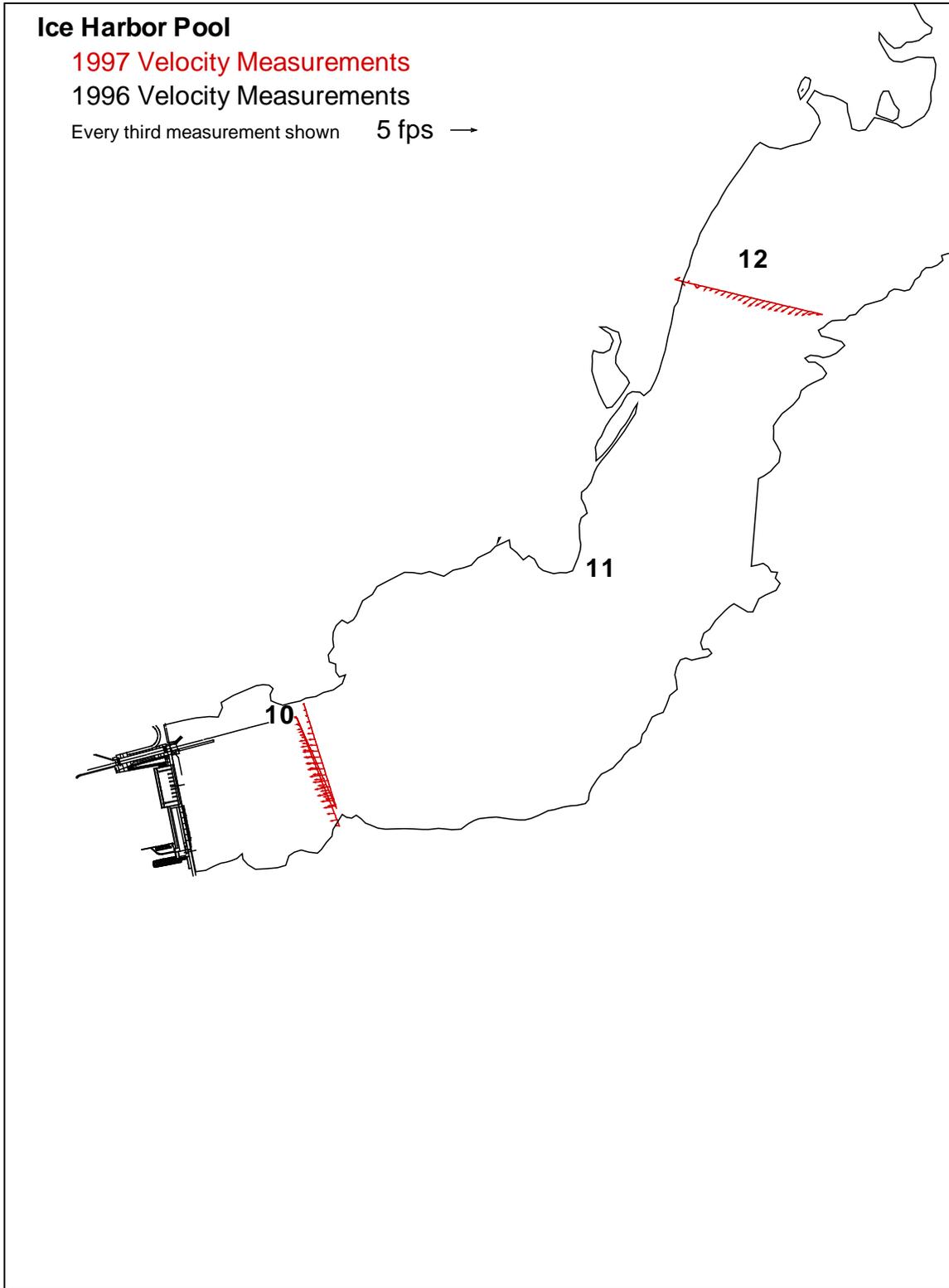


Figure 138. Ice Harbor pool ADCP velocity measurements near Ice Harbor dam.

A.2.3 Dam Operations Data

Dam operations data was used to establish model boundary conditions. Hourly CHROMS data was obtained from the DGAS team FTP server, limnos.wes.army.mil, in the file `/data3/dgas/database/ops_data/ops_data.zip`, dated August 25, 1998. The CHROMS operations data provided hourly aggregate spill and powerhouse flows and forebay and tailwater stages.

A.2.4 Weather Data

Weather data was obtained from two DGAS team databases: one containing data from National Weather Service (NWS) stations, the other from WeatherPak instrumentation used for short periods during the pool studies. Both NWS and WeatherPak data was obtained from the DGAS team FTP server, limnos.wes.army.mil, in the file `/data3/dgas/database/weather_data/weather_data.zip`, dated June 11, 1998.

Appendix B. Spring 1996 Ice Harbor Pool Study

B.1 Dissolved Gas Data

The Spring 1996 Ice Harbor pool dissolved gas study started on May 13 and ended on May 20. A total of 18 water quality monitors were used. These stations, and their records, are listed in Table 59. Station locations are shown in Figure 139.

Table 59. Dissolved gas monitor stations, and their records, used during the Spring 1996 Ice Harbor pool study.

Station	Record Start	Record End	Temperature Records	Pressure Records
IHR03603P	5/13/96 11:28:00 AM	5/19/96 1:58:00 PM	586	586
IHR03743P	5/13/96 11:45:00 AM	5/19/96 2:15:00 PM	586	586
IHR03924P	5/13/96 12:02:00 PM	5/19/96 2:17:00 PM	578	578
IHR03953P	5/13/96 12:12:00 PM	5/19/96 2:27:00 PM	586	586
IHR03411P	5/13/96 12:13:00 PM	5/19/96 1:28:00 PM	582	582
IHR03083P	5/13/96 12:49:00 PM	5/19/96 12:49:00 PM	577	577
LMN04081P	5/13/96 1:13:00 PM	5/20/96 10:28:00 AM	662	662
IHR03081P	5/13/96 1:27:00 PM	5/19/96 12:57:00 PM	574	574
IHR03085P	5/13/96 1:59:00 PM	5/19/96 12:44:00 PM	572	572
LMN04085P	5/13/96 2:01:00 PM	5/20/96 11:01:00 AM	661	661
LMNDTDP	5/14/96 6:42:00 PM	5/20/96 2:38:00 PM	554	554
IHR04025P	5/15/96 9:45:00 AM	5/20/96 11:15:00 AM	486	486
IHR04021P	5/15/96 10:54:00 AM	5/20/96 11:24:00 AM	483	483
IHR04023P	5/15/96 12:58:00 PM	5/19/96 3:43:00 PM	374	187
IHR04024P	5/15/96 12:58:00 PM	5/19/96 3:43:00 PM	389	389
IHR04022P	5/15/96 1:39:00 PM	5/19/96 3:09:00 PM	390	390
LMN04082P	5/15/96 2:14:00 PM	5/19/96 3:44:00 PM	391	391
LMN04132P	5/16/96 11:52:00 AM	5/16/96 11:37:00 PM	48	48

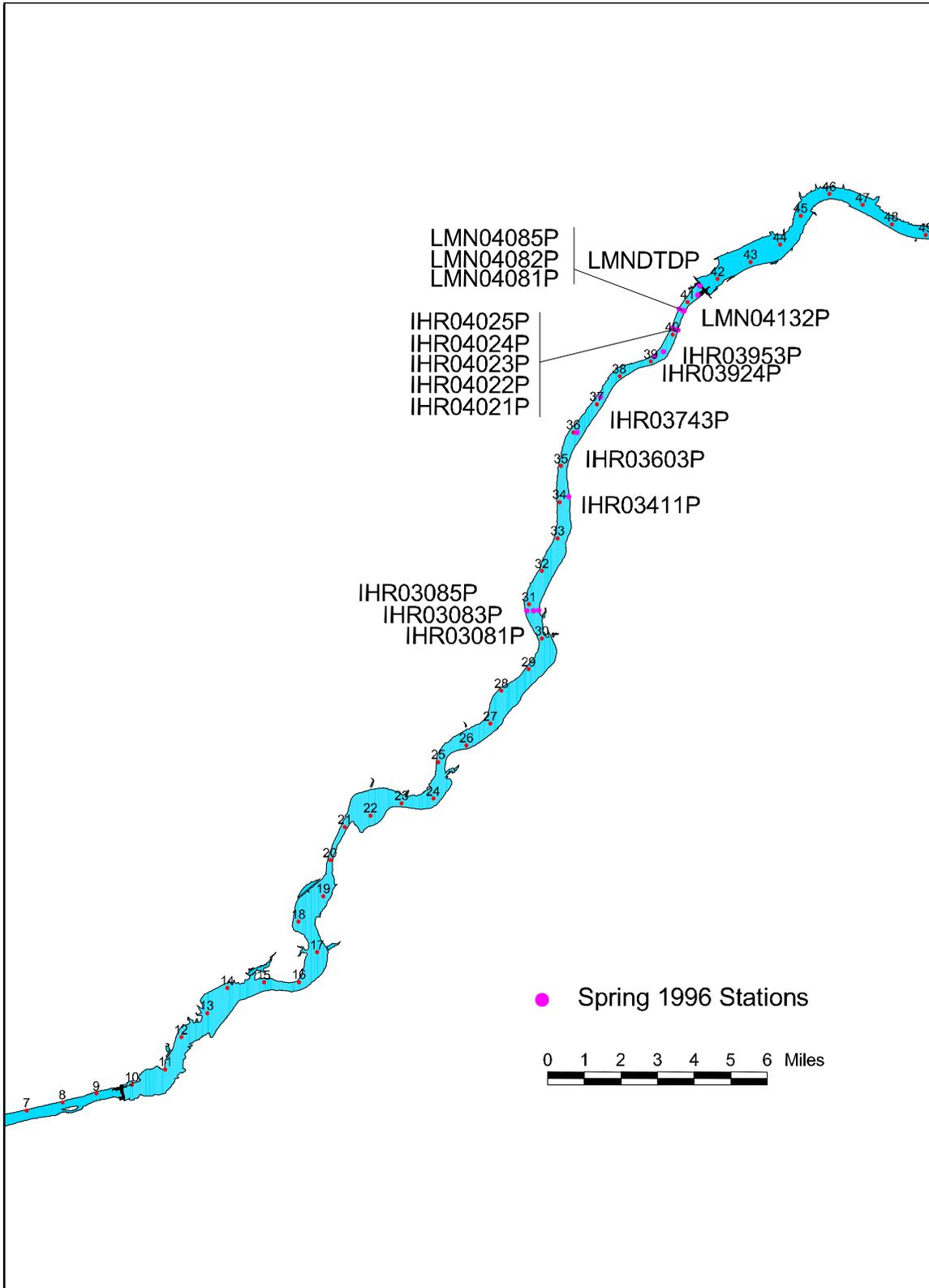


Figure 139. Dissolved gas monitor locations during the Spring 1996 study.

B.2 Velocity Data

Velocity measurements were made along a total of 23 transects during the Spring 1996 study period. The transects are summarized in Table 60. Supplied measurement locations are shown in Figure 140.

Table 60. Summary of ADCP transects made during the Spring 1996 study period.

Date Label	Average		Number of Measurements
	Velocity	Depth	
05-14-1996 15:55:00	3.9	21.1	30
05-14-1996 16:05:00	4.4	20.5	28
05-14-1996 16:11:00	3.6	20.9	19
05-14-1996 16:14:00	4.2	20.2	19
05-14-1996 16:22:00	6.8	24.0	15
05-14-1996 16:24:00	6.2	22.8	15
05-14-1996 16:26:00	6.3	23.4	16
05-15-1996 12:58:00	5.0	23.7	76
05-15-1996 13:08:00	5.0	23.6	114
05-15-1996 13:47:00	5.8	23.1	117
05-15-1996 14:01:00	5.9	22.7	136
05-15-1996 14:42:00	4.2	20.2	184
05-15-1996 14:55:00	4.4	20.7	119
05-19-1996 09:36:00	7.7	28.2	102
05-19-1996 09:43:00	7.8	25.1	56
05-19-1996 10:07:00	6.4	24.8	83
05-19-1996 10:14:00	6.4	24.9	57
05-19-1996 10:34:00	6.1	23.6	84
05-19-1996 10:41:00	6.2	23.0	69
05-19-1996 11:07:00	5.0	26.3	78
05-19-1996 11:15:00	5.2	26.6	67
05-19-1996 11:35:00	4.3	26.3	72
05-19-1996 12:38:00	3.1	29.1	56

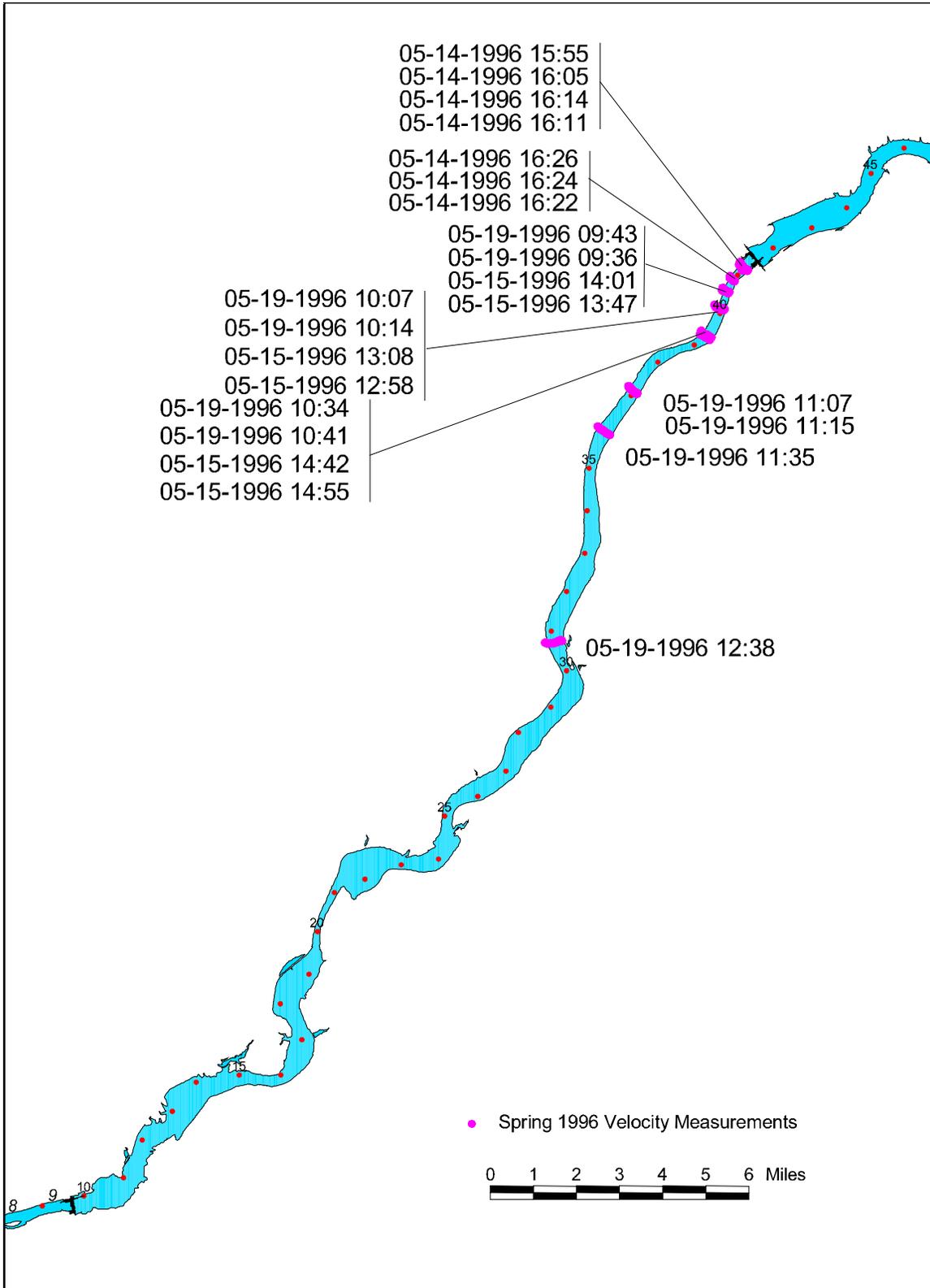


Figure 140. Locations of ADCP velocity measurements during the Spring 1996 study period.

B.3 Lower Monumental Dam Model Boundary

B.3.1 Dam Operations

CHROMS operations data was used to establish the flow at the Lower Monumental dam model boundary and stage at Ice Harbor dam model boundary. This data provided hourly spillway flow and powerhouse flow. Hourly total spill and powerhouse flows for the Spring 1996 study period are shown in Figure 141. These flows were uniformly distributed across the corresponding part of the model grid.

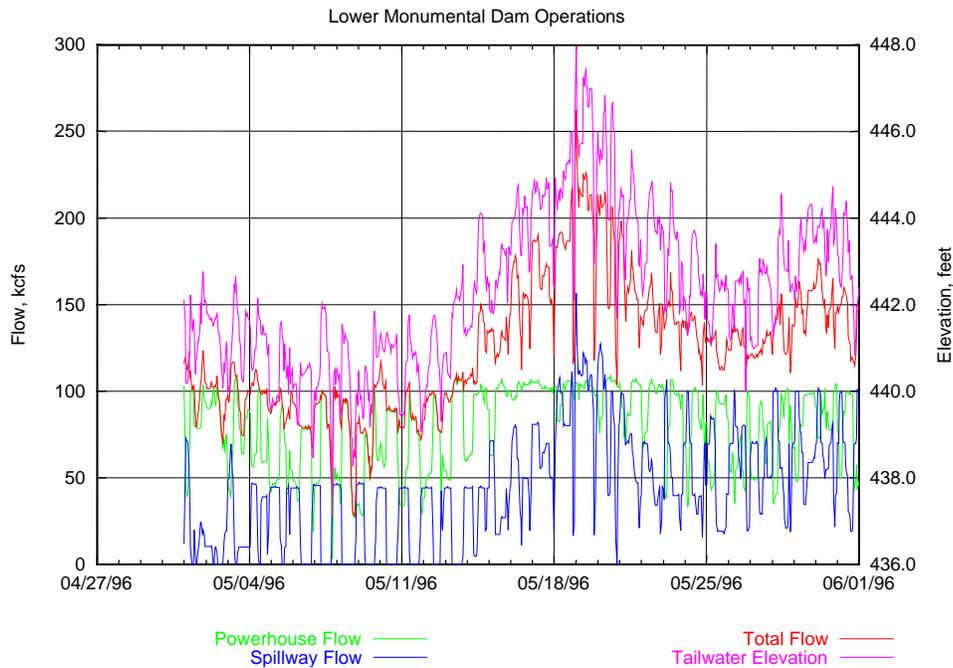


Figure 141. Lower Monumental dam operations during the Spring 1996 study.

B.3.2 Water Quality

Initially, data from the permanent fixed monitor located in the Lower Monumental dam forebay (station name "LMN") was used to establish temperature at the Lower Monumental dam boundary. Station data was taken from the FMS database. Temperature measured by the station (Figure 142) was used for both spillway and powerhouse flow. TDG pressures measured by the station (Figure 143) was used to compute TDG concentrations (Figure 144) for the powerhouse flow. Spillway TDG gas pressures and concentrations (also shown in Figure 143 and Figure 144, respectively) were estimated using the TDG sourcing function for Lower Monumental dam.

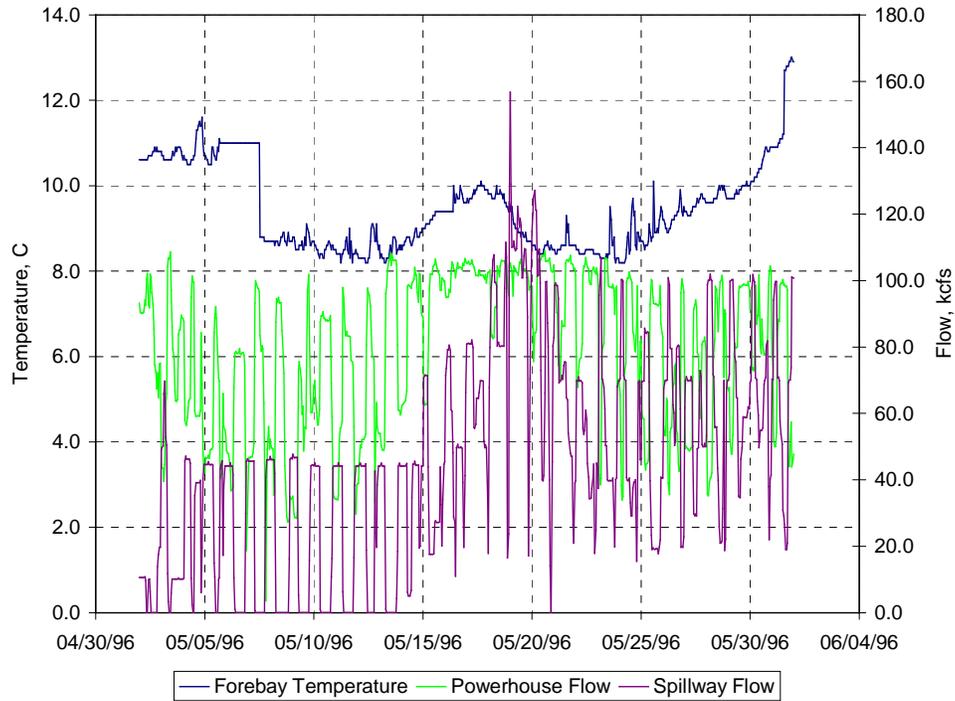


Figure 142. Lower Monumental forebay water temperature during the Spring 1996 study period.

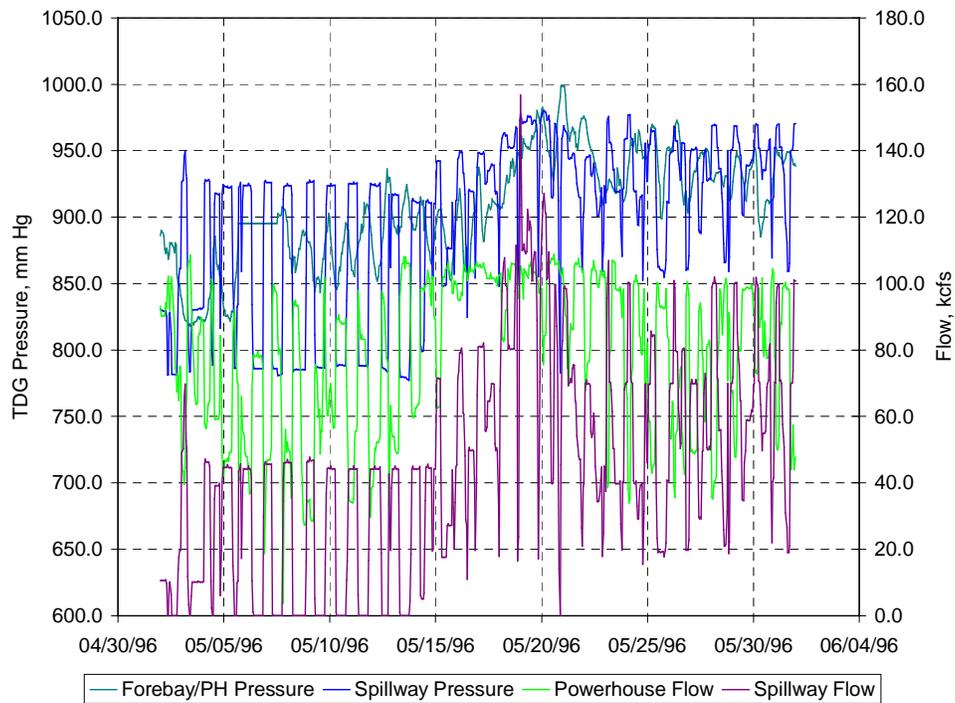


Figure 143. Lower Monumental forebay TDG pressure during the Spring 1996 study period.

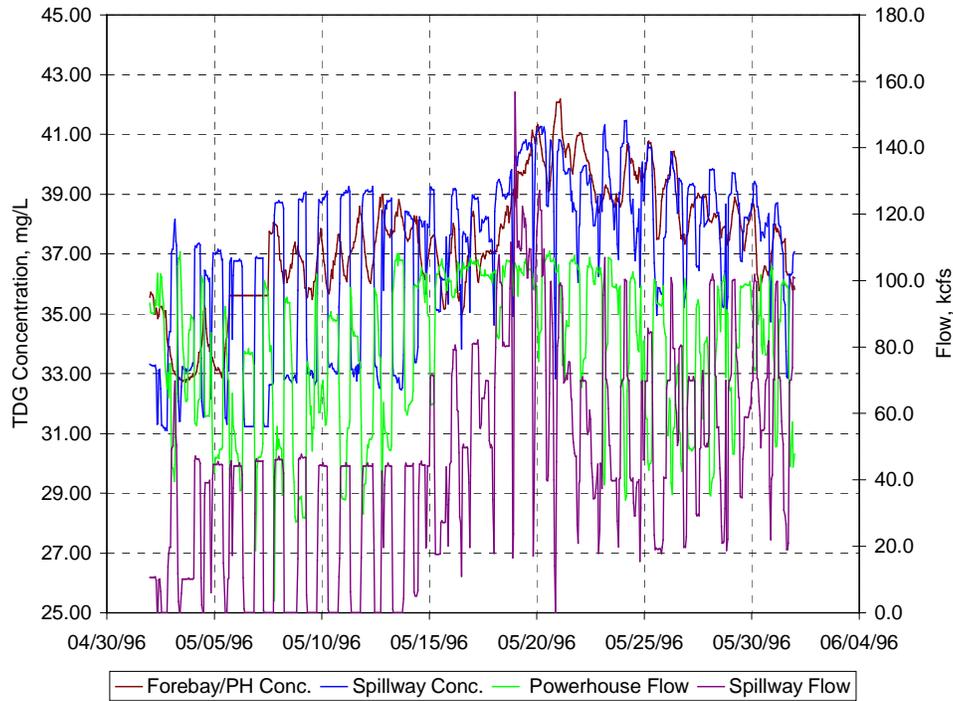


Figure 144. Computed TDG concentration in the Lower Monumental forebay during the Spring 1996 study.

Model boundary temperature and dissolved gas concentrations were also established at the Lower Monumental dam boundary using the temporary pool study monitors. Three temporary monitors were located in the Lower Monumental tailrace during Summer 1997 study period, as shown in Figure 145. The temperatures and TDG pressures recorded by these monitors are shown in Figure 146 and Figure 147, respectively. TDG concentrations computed from the measured TDG pressures and temperatures are shown in Figure 148. The transport simulation boundary was established at grid row 26 of block 1 (shown in red in Figure 145). Temporary monitor TDG concentrations and temperatures as follows along the model grid:

- LMN04085P: columns 1 to 18;
- LMN04082P: columns 19 to 27; and
- LMN04081P: columns 28 to 34.

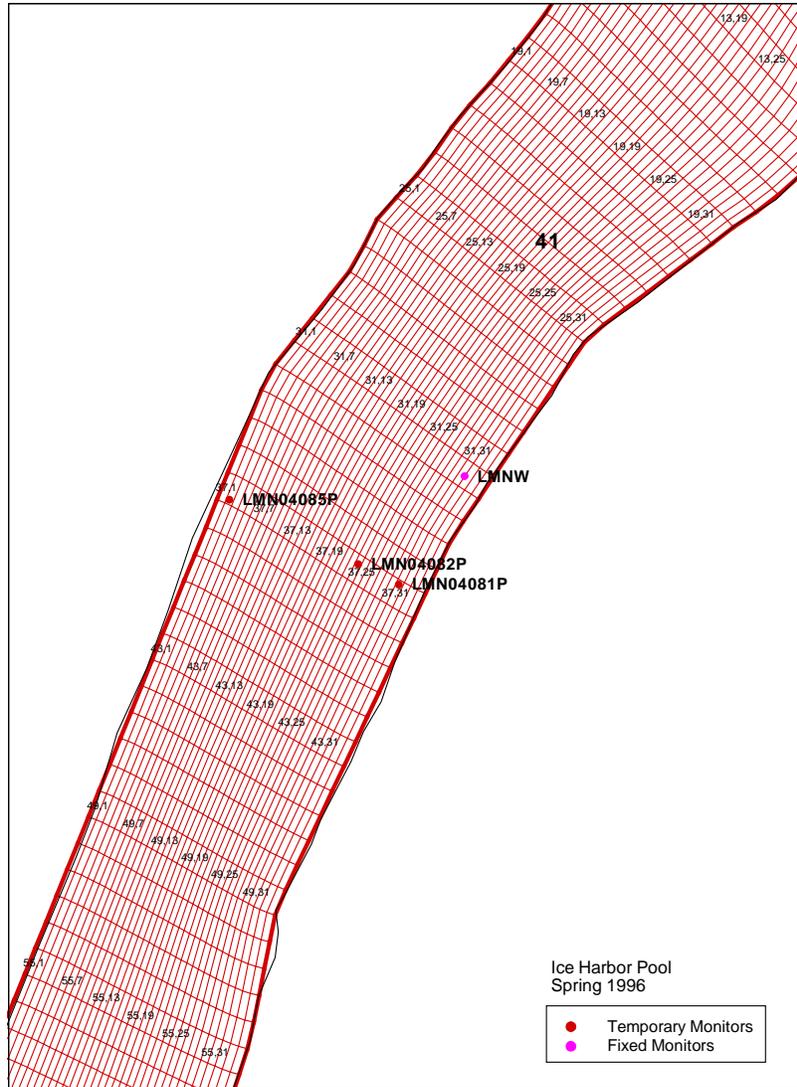


Figure 145. Locations, relative to the model grid, of upstream temporary monitors during the Spring 1996 study period.

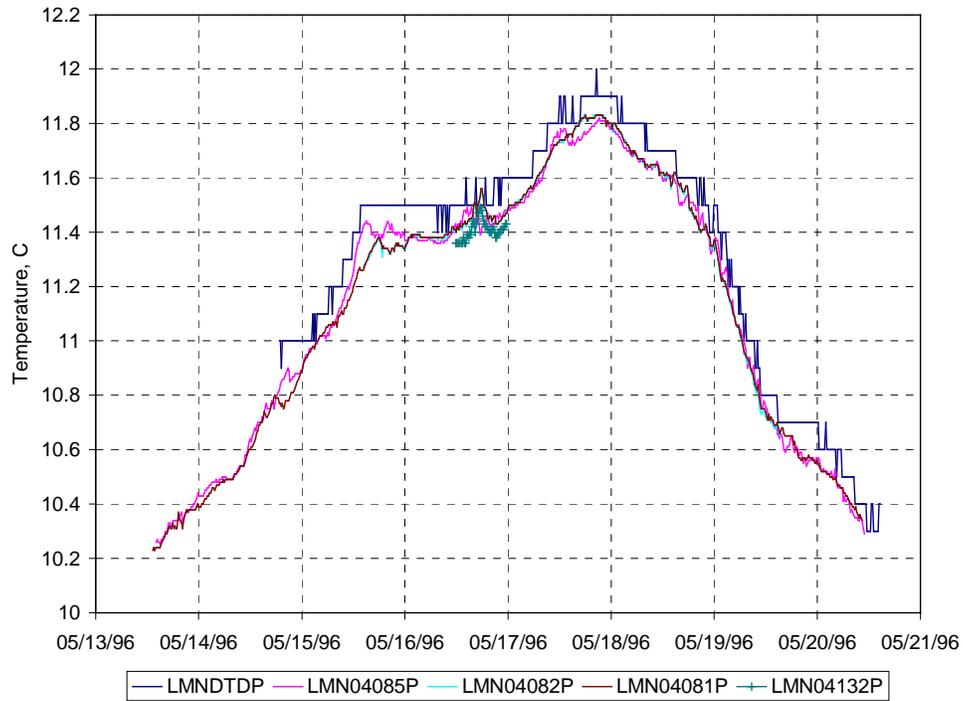


Figure 146. Temperatures measured by temporary monitors near Lower Monumental dam during the Spring 1996 study period.

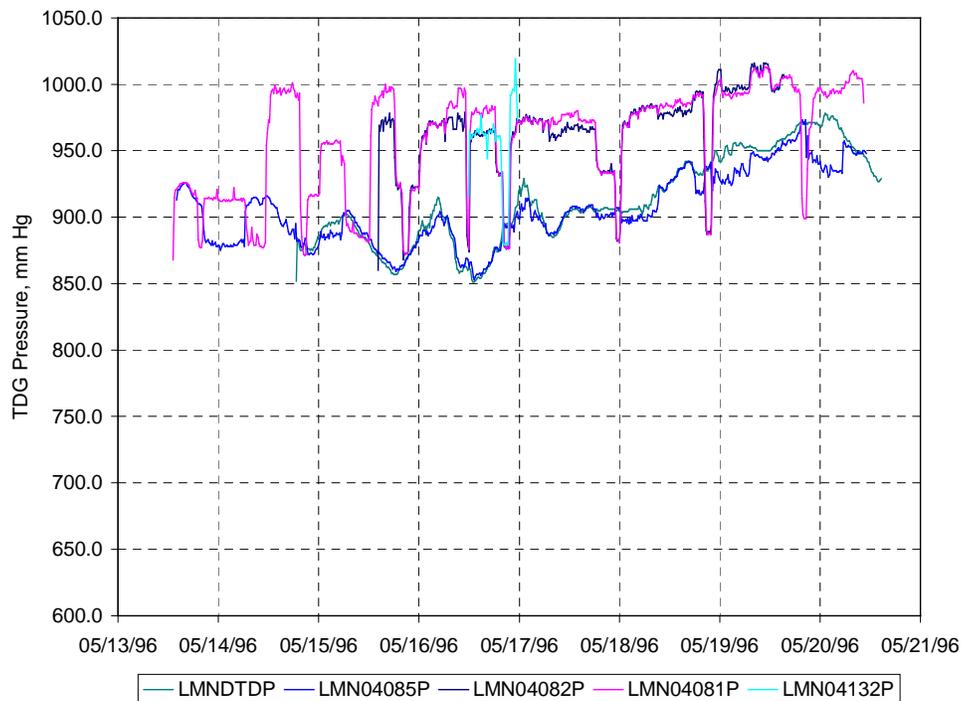


Figure 147. TDG pressures measured by temporary monitors near Lower Monumental dam during the Spring 1996 study period.

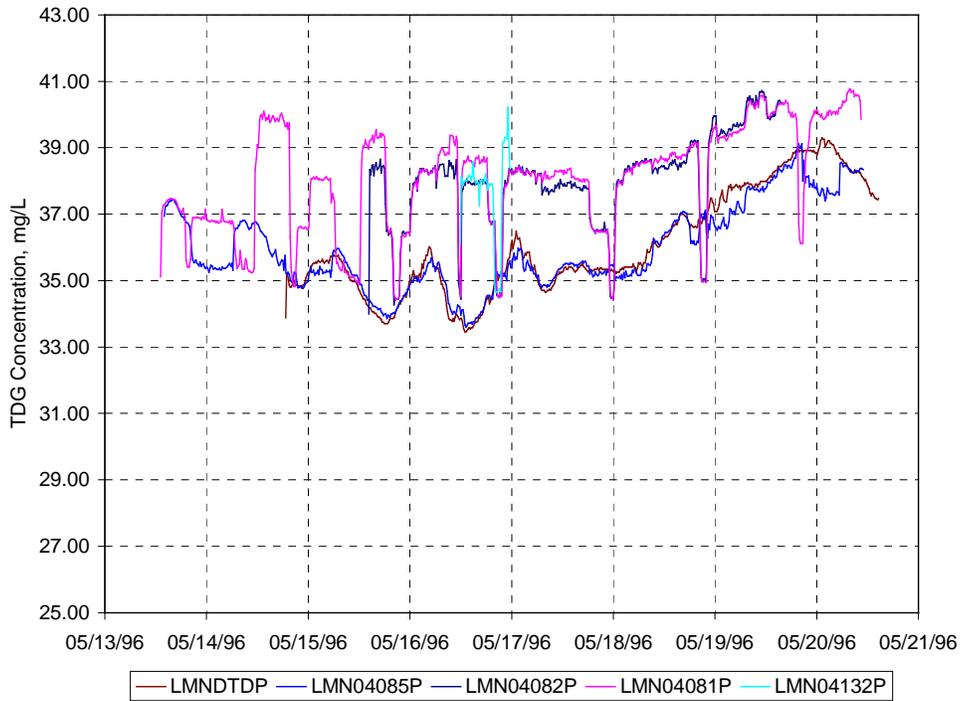


Figure 148. TDG concentrations computed from temporary monitor data near Lower Monumental dam during the Spring 1996 study period.

B.4 Ice Harbor Dam Boundary Operations

Forebay stage for Ice Harbor dam was obtained from hourly CHROMS operations data and is shown in Figure 149.

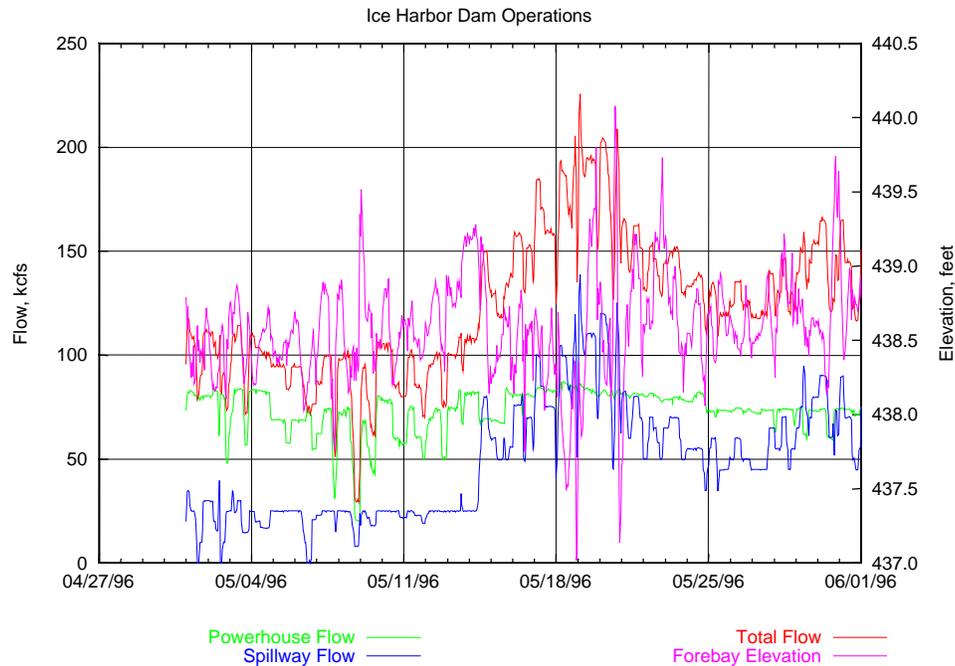


Figure 149. Ice Harbor dam operations during the Spring 1996 study.

B.5 Weather

Atmospheric conditions were considered constant over the entire pool. Pasco, Washington, air and dew point temperature (Figure 150) and wind speed (Figure 151) were used from the NWS weather database. Barometric pressure measured by the IHR FMS (also shown in Figure 150) was considered to apply over the entire modeled area. Measured short-wave radiation was available from the WeatherPak database for the spring 1996 study. The available radiation data was extended using NWS Pasco dew point and cloud cover data. Net incoming solar radiation based both on the measured and estimated total solar radiation is shown in Figure 152.

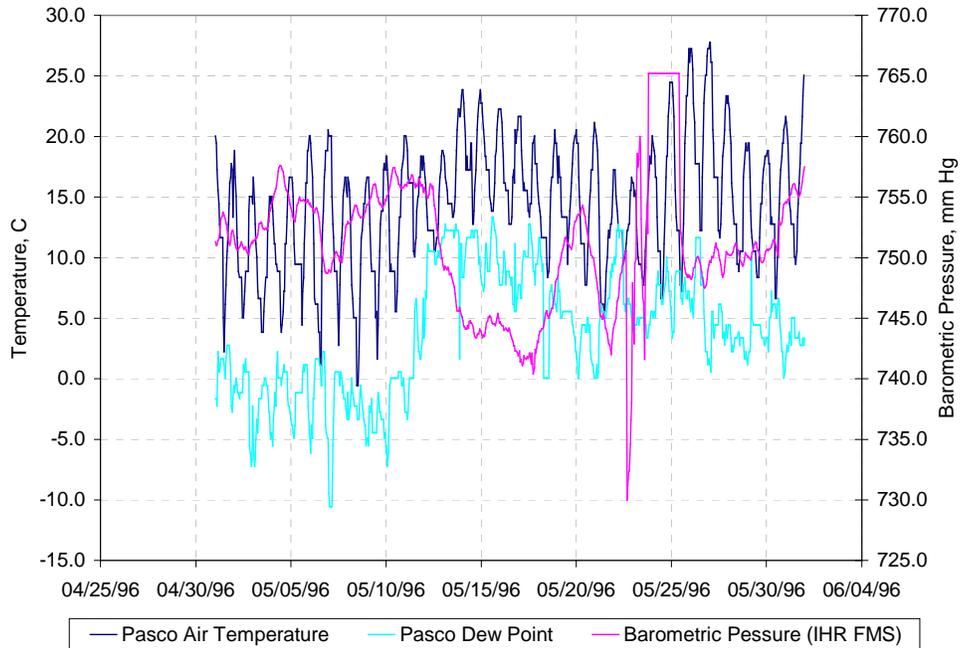


Figure 150. Air temperature, dew point, and barometric pressure used during the Spring 1996 study period.

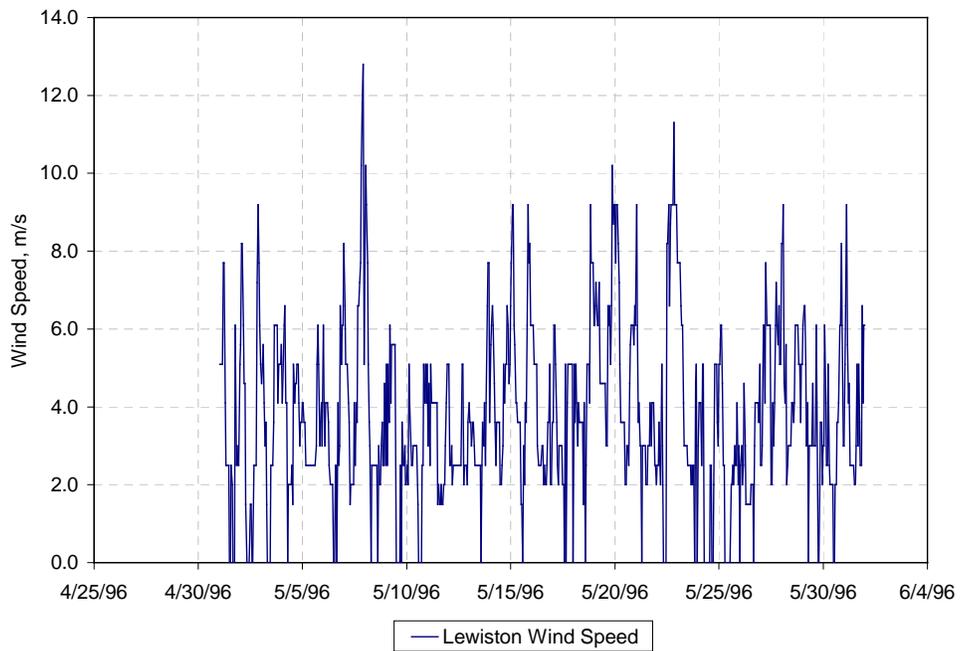


Figure 151. Wind speed used during the spring 1996 study period.

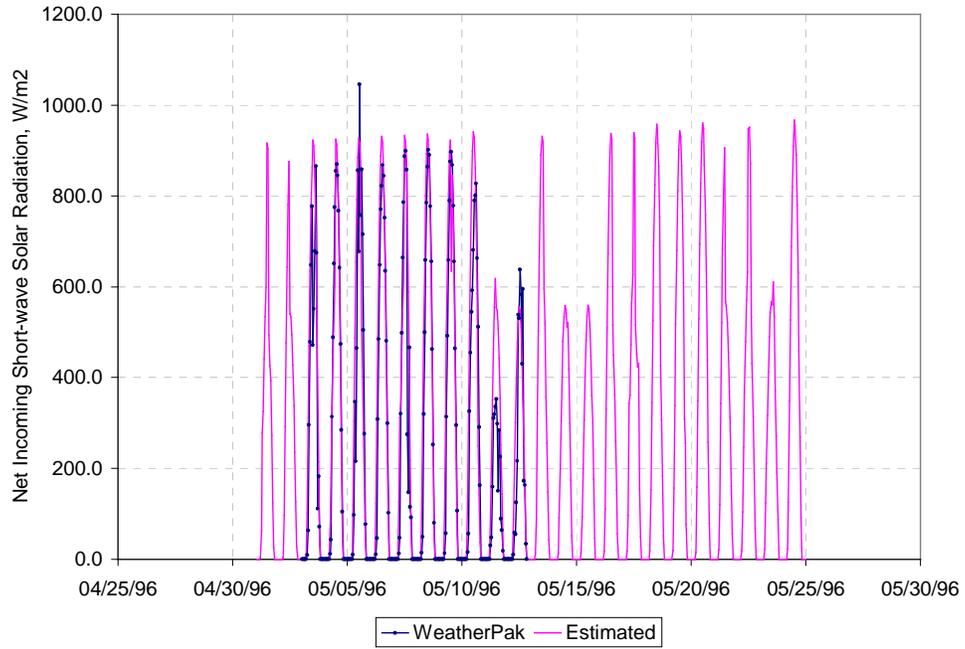


Figure 152. Net incoming short-wave solar radiation based on observed and estimated total radiation during the Spring 1996 study period.

Appendix C. Spring 1997 Ice Harbor Pool Study

C.1 Dissolved Gas Data

The Spring 1997 Ice Harbor pool dissolved gas study started on April 23 and ended on May 2. A total of 16 water quality monitors were used. These stations, and their records, are listed in Table 61. Station locations are shown in Figure 153.

Table 61. Dissolved gas monitor stations, and their records, used during the Spring 1997 Ice Harbor pool study.

Station	Record Start	Record End	Temperature Records	Pressure Records
IHR03002P	4/23/97 11:00:00 PM	5/2/97 11:00:00 AM	817	817
IHR01022P	4/23/97 11:00:00 PM	5/1/97 1:15:00 PM	730	730
IHR01024P	4/23/97 11:00:00 PM	5/1/97 1:15:00 PM	730	730
IHR01025P	4/23/97 11:00:00 PM	5/1/97 1:30:00 PM	731	731
IHR02001P	4/23/97 11:00:00 PM	5/2/97 10:30:00 AM	815	815
IHR02004P	4/23/97 11:00:00 PM	5/2/97 11:00:00 AM	817	817
IHR01021P	4/23/97 11:00:00 PM	5/1/97 1:00:00 PM	729	729
IHR03001P	4/23/97 11:00:00 PM	5/2/97 11:00:00 AM	817	37
IHR03003P	4/23/97 11:00:00 PM	5/2/97 9:30:00 AM	811	811
IHR03004P	4/23/97 11:00:00 PM	5/2/97 9:30:00 AM	810	810
IHR03005P	4/23/97 11:00:00 PM	5/2/97 9:15:00 AM	810	810
IHR04071P	4/23/97 11:00:00 PM	5/2/97 8:00:00 AM	805	805
IHR04073P	4/23/97 11:00:00 PM	5/2/97 8:00:00 AM	801	801
IHR04075P	4/23/97 11:00:00 PM	5/2/97 8:15:00 AM	806	806
IHR02005P	4/23/97 11:00:00 PM	5/2/97 10:15:00 AM	814	814
LMNDTUDU2P	4/24/97 4:00:00 PM	5/2/97 11:00:00 AM	188	188

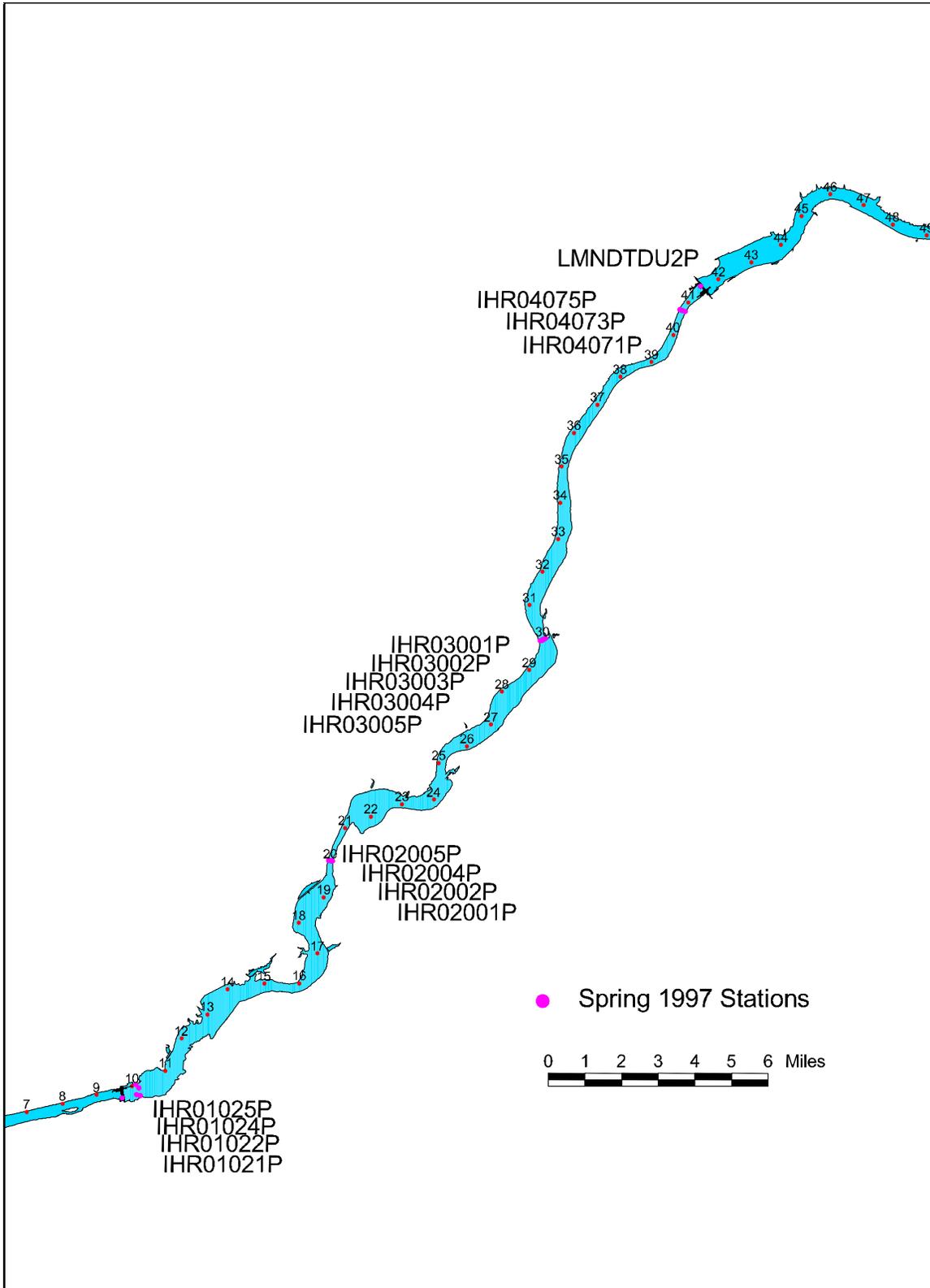


Figure 153. Dissolved gas monitor locations during the Spring 1997 study.

C.2 Velocity Data

Velocity measurements were made along a total of 34 transects during the Spring 1997 study period. The transects are summarized in Table 62. Supplied measurement locations are shown in Figure 154.

Table 62. Summary of ADCP transects made during the Spring 1997 study period.

Date Label	Average		Number of Measurements
	Velocity	Depth	
04-28-1997 10:29:00	7.4	26.3	28
04-28-1997 10:37:00	7.0	26.0	29
04-28-1997 10:44:00	7.2	26.3	30
04-28-1997 10:57:00	6.6	26.9	29
04-28-1997 11:04:00	6.4	26.5	29
04-28-1997 11:16:00	6.2	24.7	34
04-28-1997 11:28:00	5.9	21.8	42
04-28-1997 11:38:00	6.1	31.8	26
04-28-1997 11:50:00	4.8	24.4	47
04-28-1997 12:02:00	4.9	29.6	38
04-28-1997 12:53:00	4.3	26.3	47
04-28-1997 13:08:00	4.1	27.4	47
04-28-1997 13:23:00	3.7	31.9	45
04-28-1997 13:46:00	3.2	30.1	55
04-28-1997 14:04:00	2.7	33.5	59
04-28-1997 14:32:00	2.7	27.3	74
04-28-1997 15:00:00	3.4	47.4	30
04-28-1997 15:04:00	3.5	48.2	29
04-28-1997 15:10:00	3.5	46.2	31
04-28-1997 15:41:00	2.0	33.9	81
04-28-1997 16:04:00	2.1	55.5	47
04-29-1997 07:57:00	1.4	48.7	90
04-29-1997 08:27:00	1.1	48.1	148
04-29-1997 08:50:00	2.2	74.3	36
04-29-1997 09:09:00	3.4	86.8	19
04-29-1997 09:14:00	3.3	87.4	19
04-29-1997 09:21:00	3.2	85.2	22
04-29-1997 09:44:00	1.1	55.3	88
04-29-1997 09:59:00	1.2	56.3	88
04-29-1997 10:23:00	1.0	68.5	73
04-29-1997 10:44:00	1.3	81.8	70
04-29-1997 11:04:00	1.2	80.7	54
04-29-1997 11:12:00	1.3	86.9	50
04-29-1997 11:19:00	1.2	83.5	52

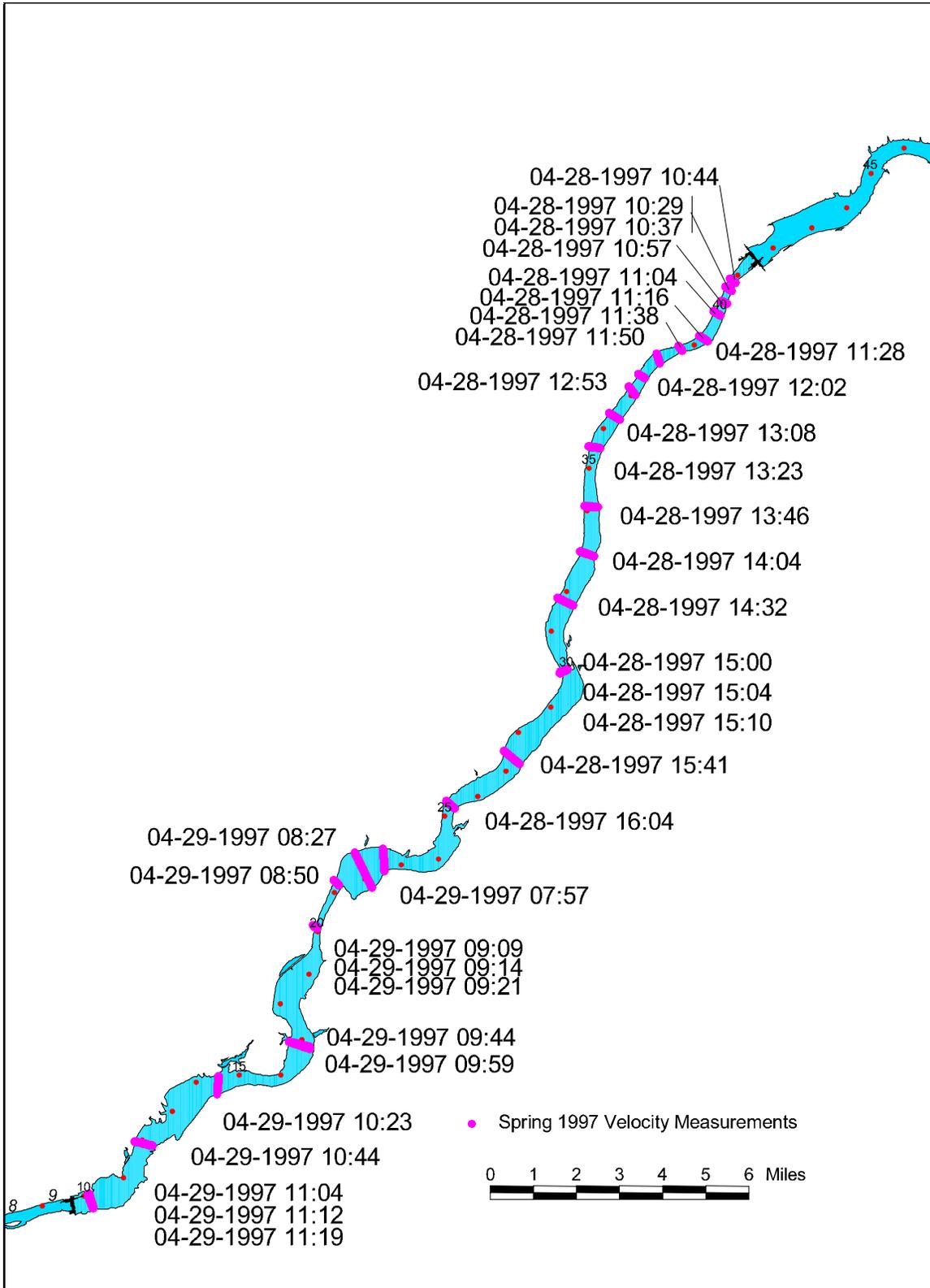


Figure 154. Locations of ADCP velocity measurements during the Spring 1997 study period.

C.3 Lower Monumental Dam Model Boundary

C.3.1 Dam Operations

CHROMS operations data was used to establish the flow at the Lower Monumental dam model boundary and stage at Ice Harbor dam model boundary. This data provided hourly spillway flow and powerhouse flow. Hourly total spill and powerhouse flows for the Spring 1997 study period are shown in Figure 155. These flows were uniformly distributed across the corresponding part of the model grid.



Figure 155. Lower Monumental dam operations during the Spring 1997 study.

C.3.2 Water Quality

Initially, data from the permanent fixed monitor located in the Lower Monumental dam forebay (station name "LMN") was used to establish temperature at the Lower Monumental dam boundary. Station data was taken from the FMS database. Temperature measured by the station (Figure 156) was used for both spillway and powerhouse flow. TDG pressures measured by the station (Figure 157) were used to compute TDG concentrations (Figure 158) for the powerhouse flow. Spillway TDG gas pressures and concentrations (also shown in Figure 157 and Figure 158, respectively) were estimated using the TDG sourcing function for Lower Monumental dam.

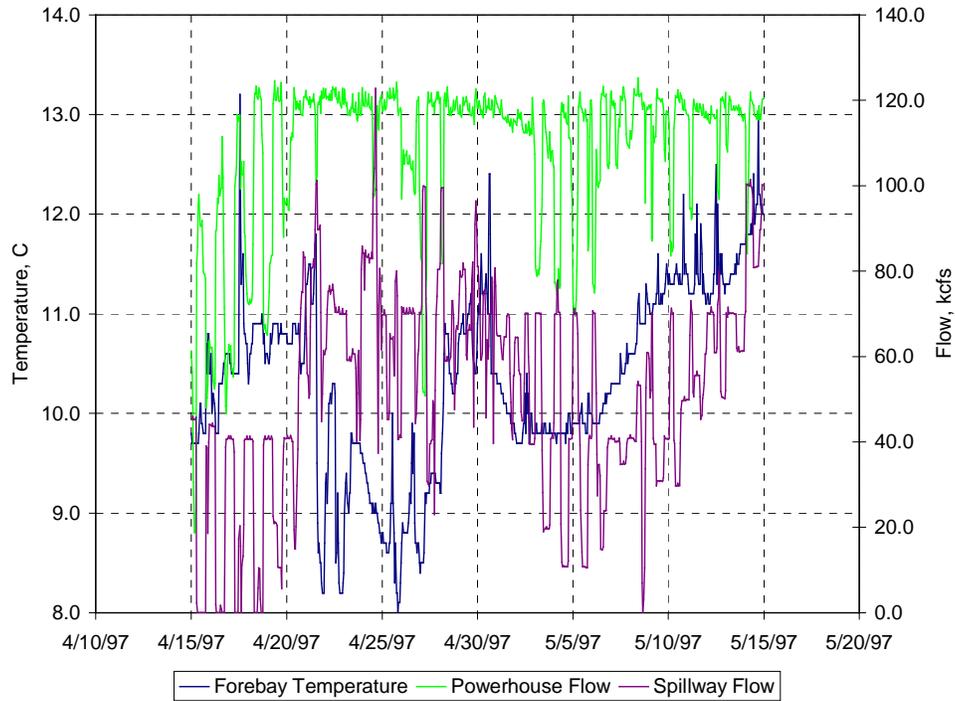


Figure 156. Lower Monumental forebay water temperature during the Spring 1997 study period.

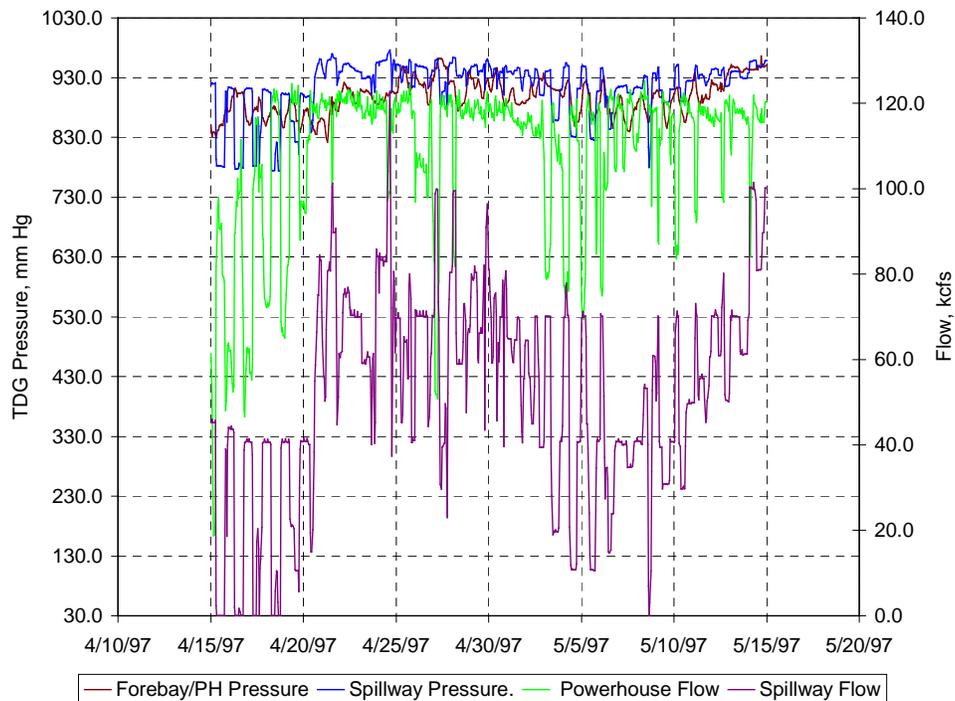


Figure 157. Lower Monumental forebay TDG pressure during the Spring 1997 study period.

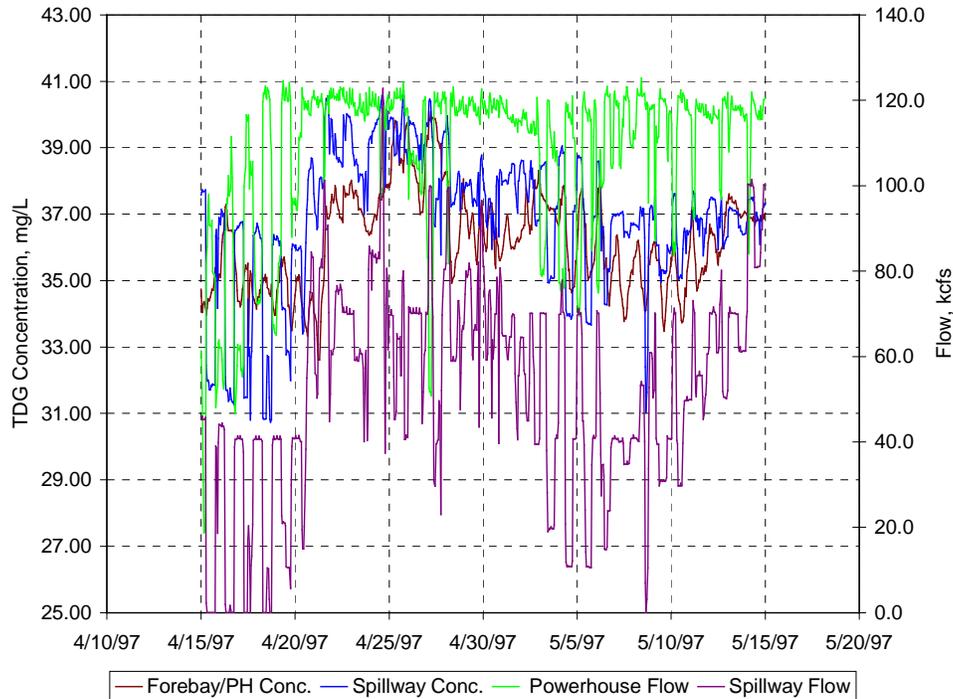


Figure 158. Computed TDG concentration in the Lower Monumental forebay during the Spring 1997 study.

Model boundary temperature and dissolved gas concentrations were also established at the Lower Monumental dam boundary using the temporary pool study monitors. Three temporary monitors were located in the Lower Monumental tailrace during Summer 1997 study period, as shown in Figure 159. The temperatures and TDG pressures recorded by these monitors are shown in Figure 160 and Figure 161, respectively. TDG concentrations computed from the measured TDG pressures and temperatures are shown in Figure 162. The transport simulation boundary was established at grid row 36 of block 1 (shown in red in Figure 159). Temporary monitor TDG concentrations and temperatures as follows along the model grid:

- IHR04075P: columns 1 to 8;
- IHR04073P: columns 9 to 22; and
- IHR04071P: columns 23 to 34.

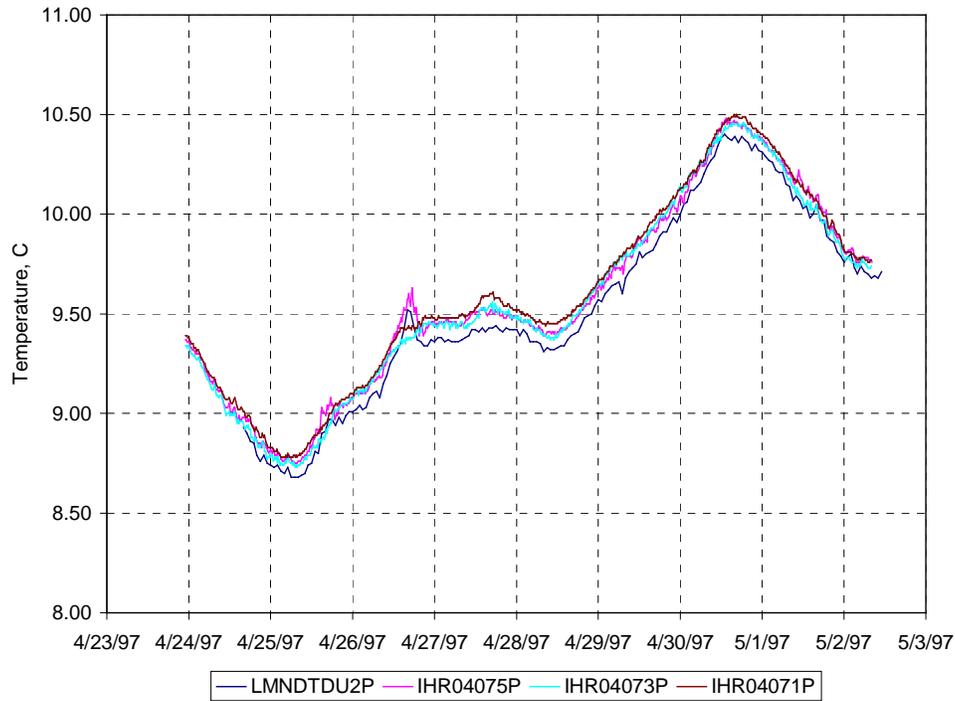


Figure 160. Temperatures measured by temporary monitors near Lower Monumental dam during the Spring 1997 study period.

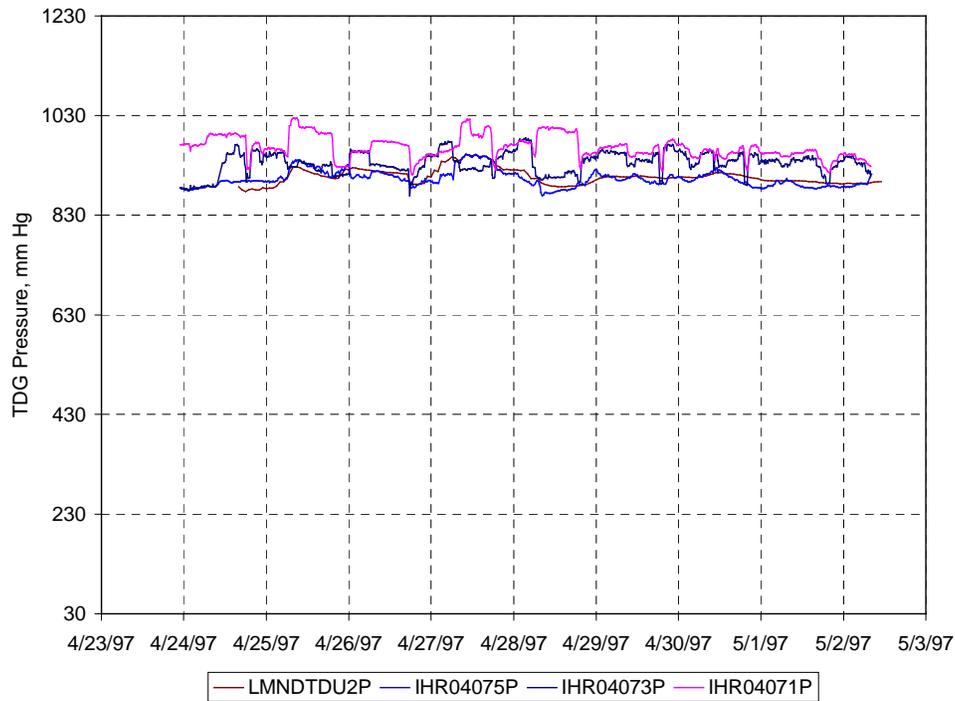


Figure 161. TDG pressures measured by temporary monitors near Lower Monumental dam during the Spring 1997 study period.

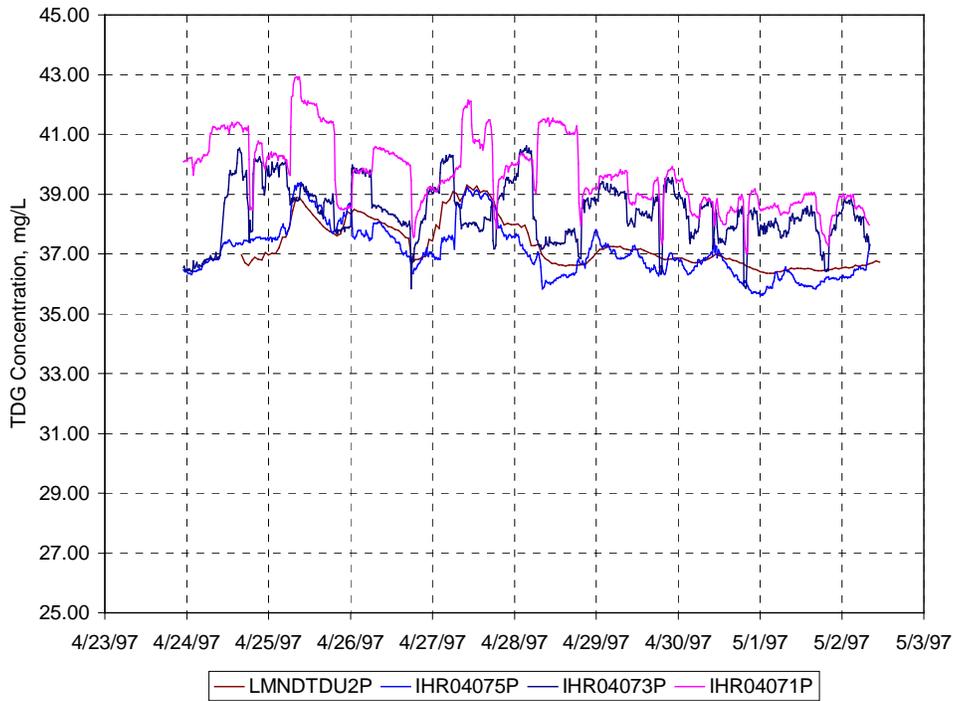


Figure 162. TDG concentrations computed from temporary monitor data near Lower Monumental dam during the Spring 1997 study period.

C.4 Ice Harbor Dam Boundary Operations

Forebay stage for Ice Harbor dam was obtained from hourly CHROMS operations data and is shown in Figure 163.

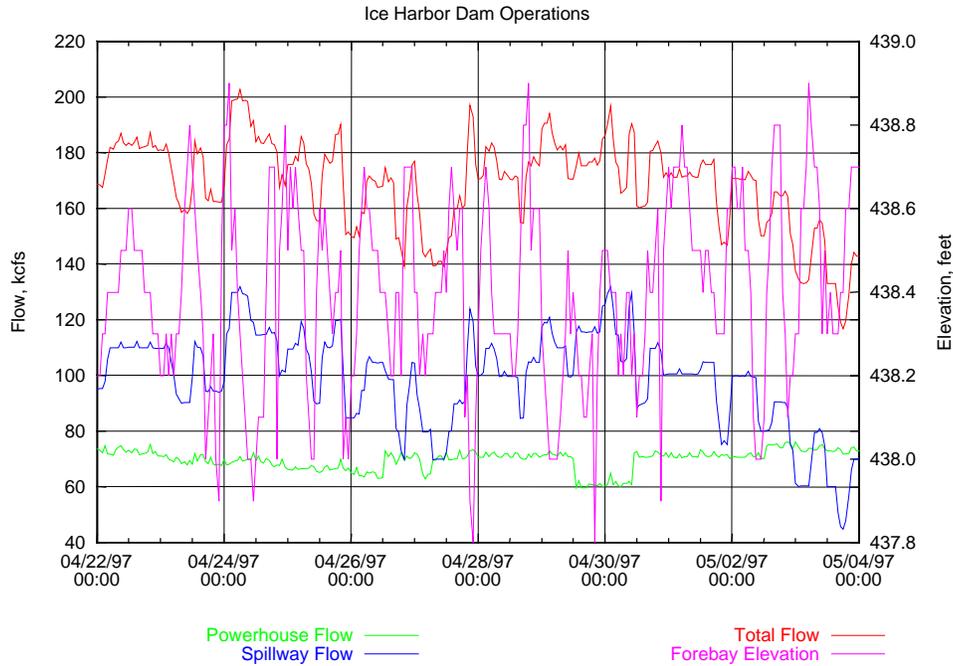


Figure 163. Ice Harbor dam operations during the Spring 1997 study.

C.5 Weather

Atmospheric conditions were considered constant over the entire pool. Pasco, Washington, air and dew point temperature (Figure 164) and wind speed (Figure 165) were used from the NWS weather database. Barometric pressure measured by the IHR FMS (also shown in Figure 164) was considered to apply over the entire modeled area. Measured short-wave radiation was available from the WeatherPak database for the Spring 1997 study. The available radiation data was extended using NWS Pasco dew point and cloud cover data. Net incoming solar radiation based both on the measured and estimated total solar radiation is shown in Figure 166.

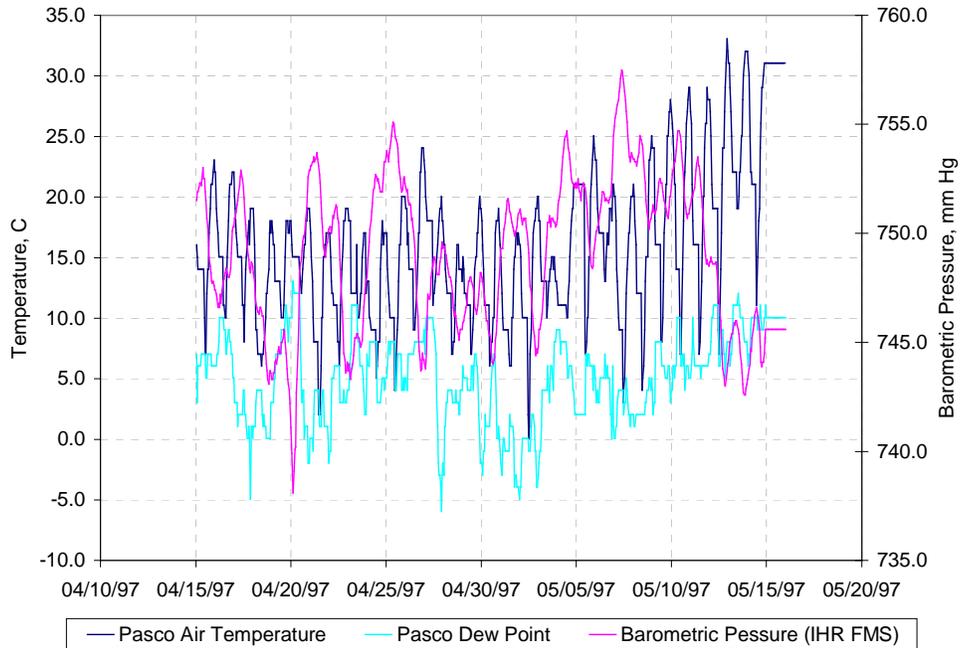


Figure 164. Air temperature, dew point, and barometric pressure used during the Spring 1997 study period.

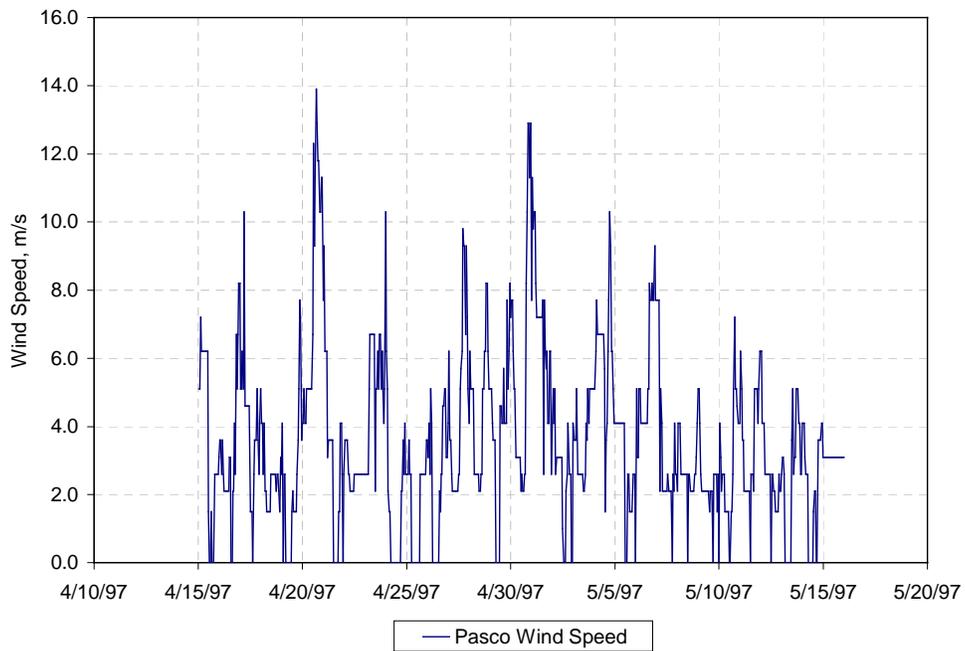


Figure 165. Wind speed used during the Spring 1997 study period.

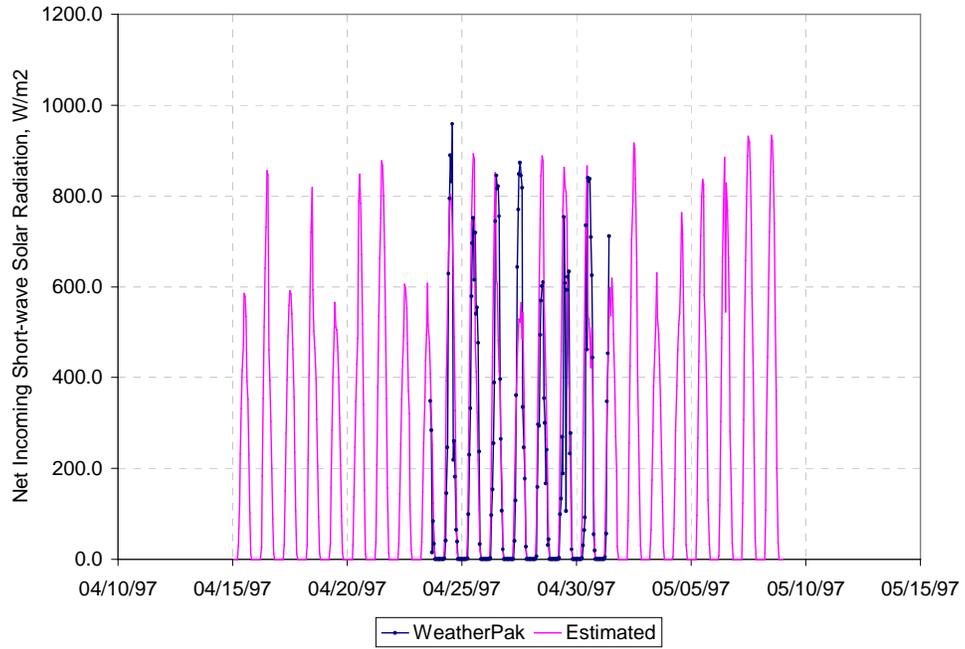


Figure 166. Net incoming short-wave solar radiation based on observed and estimated total radiation during the Spring 1997 study period.