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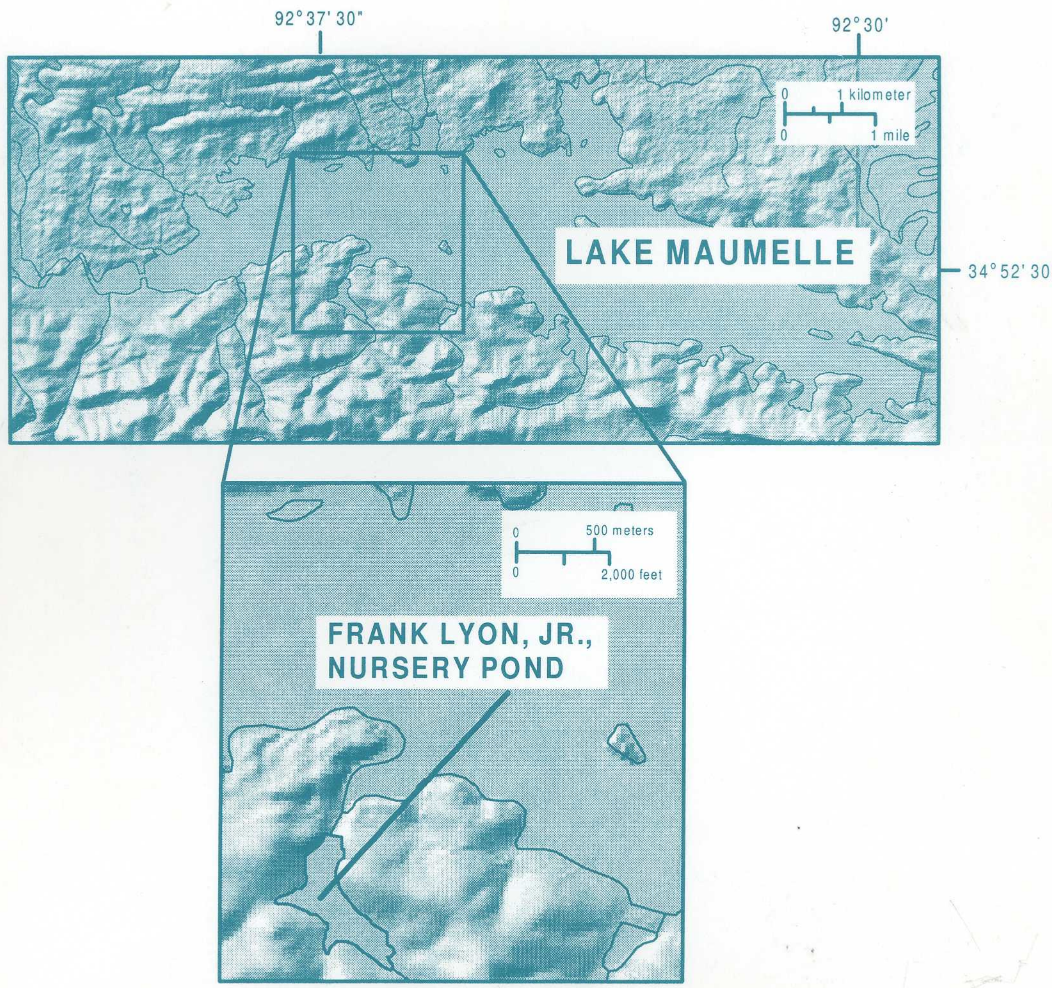
# WATER-QUALITY ASSESSMENT OF THE FRANK LYON, JR., NURSERY POND RELEASES INTO LAKE MAUMELLE, ARKANSAS, 1991-1996

## Water-Resources Investigations Report 98-4194




**U.S. Department of the Interior**
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U.S. GEOLOGICAL SURVEY
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Little Rock, Arkansas
1998

U.S. DEPARTMENT OF THE INTERIOR
**BRUCE BABBITT**, ***Secretary***

U.S. GEOLOGICAL SURVEY
**Thomas J. Casadevall**, ***Acting Director***

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For additional information write to:

District Chief
U.S. Geological Survey, WRD
401 Hardin Road
Little Rock, Arkansas 72211

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## CONVERSION FACTORS

| Multiply | By | To obtain |
|---|---|---|
| centimeter (cm) | 2.54 | inch |
| meter (m) | 3.281 | foot |
| kilometer (km) | 0.6214 | mile |
| square kilometer ($km^2$) | 0.3861 | square mile |
| cubic meter ($m^3$) | 35.31 | cubic foot |

# WATER-QUALITY ASSESSMENT OF THE FRANK LYON, JR., NURSERY POND RELEASES INTO LAKE MAUMELLE, ARKANSAS, 1991-1996

By W. Reed Green


## ABSTRACT

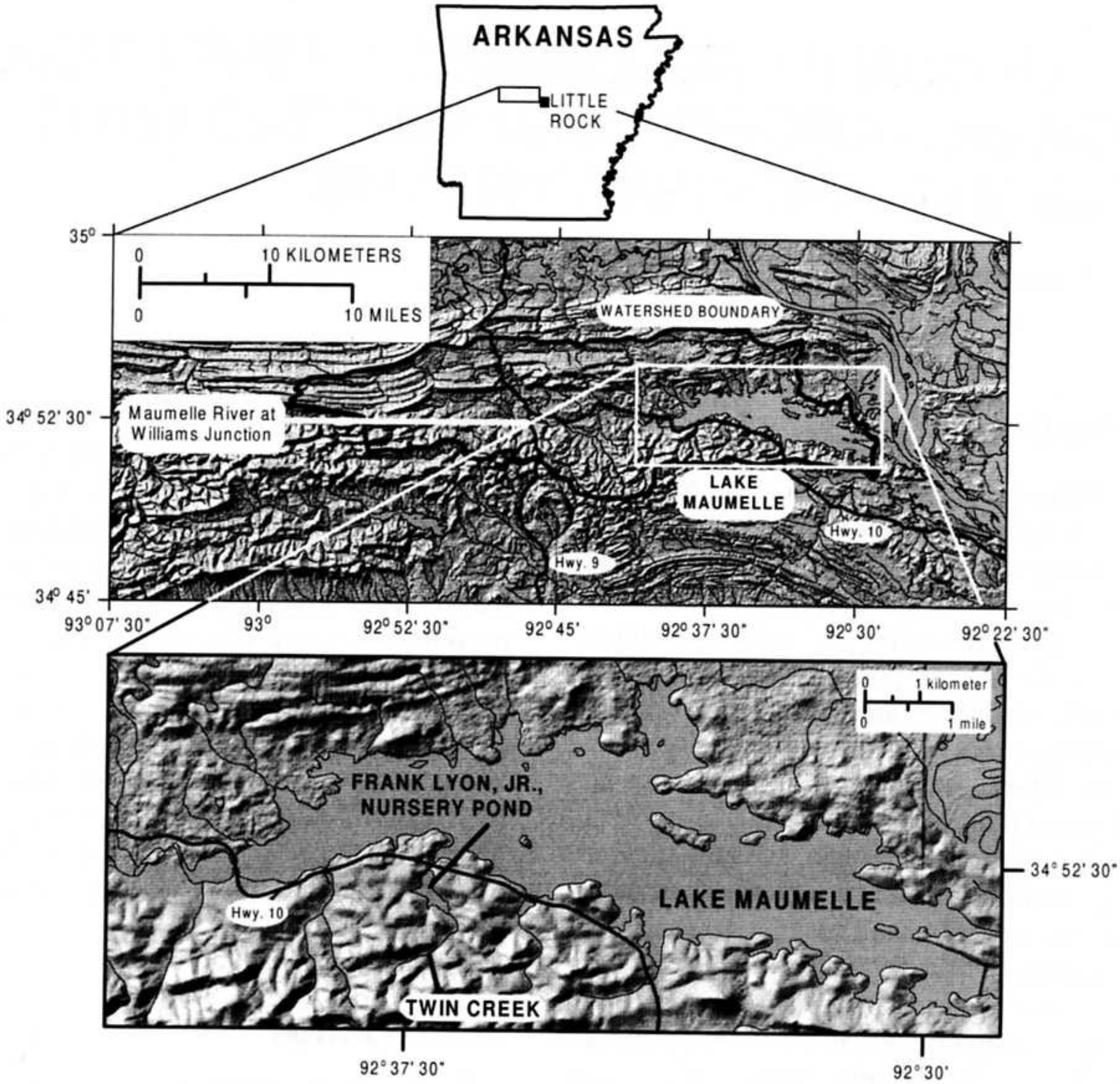
Releases of the Frank Lyon, Jr., Nursery Pond into Lake Maumelle were monitored during 1991 through 1996 to assess the impact that the releases have on the water quality of Lake Maumelle. Results indicated that the water-quality impact of the nursery pond release into Lake Maumelle is variable, and appears to be related to the volume of the nursery pond at release and the amount of fertilizer applied within the nursery pond earlier in the year. In 1991 through 1994 and in 1996, nursery pond release loads for nutrients (except for dissolved nitrite plus nitrate nitrogen), total and dissolved organic carbon, iron, and manganese were greater than what would be expected in the annual areal load from that basin. In 1995, only ammonium nitrate was applied to the nursery pond. As a result, the 1995 phosphorus load was lower than in other years, and was less than what would be expected in the annual areal load. Nutrient enrichment, on average, in Lake Maumelle from the nursery pond release resulted in what would be equivalent to an 8 percent increase in concentration of total phosphorus, 50 percent increase in dissolved orthophosphorus, 0.1 percent increase in dissolved nitrite plus nitrate nitrogen, 2.5 percent increase in total ammonia plus organic nitrogen, and 5.7 percent increase in dissolved ammonia nitrogen, assuming that the nutrient load was conservative and evenly distributed throughout the water body.

Evidence of elevated turbidity, nutrient, and chlorophyll *a* concentrations in the epilimnetic water outside the receiving embayment were apparent for as long as 3 weeks after the 1995 and 1996 releases. In general, highest values were found at the site located where the receiving embayment meets the open water of Lake Maumelle. Much of the released material in the nursery pond originated in the cooler, anoxic hypolimnetic water. The initial release water was seen to plunge beneath the warmer water existing in the receiving embayment and was transported into the open water of Lake Maumelle, under the thermocline. The quantity of water and mass of constituents transported into the open water under the thermocline is unknown and probably remained isolated from the surface water until fall turnover.


## INTRODUCTION

The quantity and quality of Lake Maumelle, a drinking-water supply reservoir in central Arkansas, have been monitored by the U.S. Geological Survey (USGS) and Little Rock Municipal Water Works (LRMWW) since 1989 (Green and Louthian, 1993; Green, 1993). As part of this cooperative effort, the annual release of the Frank Lyon, Jr., Nursery Pond into Lake Maumelle has been monitored (since 1991) to assess the impact that the releases have on the water quality of Lake Maumelle.

The Frank Lyon, Jr., Nursery Pond (hereinafter referred to as "nursery pond") was constructed by the Arkansas Game and Fish Commission in 1989 on Twin Creek, a lateral tributary flowing into Lake Maumelle (fig. 1), and went into production in 1990. The purpose of the nursery pond is to raise bait and game fish to supplement the fisheries in Lake Maumelle. Management practices include application of inorganic fertilizer to




Base from U.S. Geological Survey Digital Line Graphs
Universal Transverse Mercator
1:100,000 scale

Shaded relief from U.S. Geological Survey Digital Elevation Models
Universal Transverse Mercator
1:24,000 scale

**Figure 1.** Location of Lake Maumelle, detailing the location of Frank Lyon, Jr., Nursery Pond.

enhance food-web dynamics. Once the appropriate standing crop of fish is reached, usually in July or August, the nursery pond is drained, discharging the entire contents of the pond into Lake Maumelle. The drain usually remains open through the winter and is closed in the spring to trap the spring runoff. Once an appropriate volume of water is reached, the pond is restocked with target fish for release later in the summer.

## Purpose and Scope

The purpose of this report is to assess the impact of the releases on the water quality of Lake Maumelle. Releases of the nursery pond into Lake Maumelle were monitored during 1991 through 1996. Water-quality monitoring efforts varied in intensity during this time. In 1991 through 1994, water quality was monitored in the release water immediately after release began and daily through the release event. Water quality also was monitored daily through the release event at a site where the receiving embayment interfaces with the open water of the lake and then periodically during the following 3 weeks. In 1995 and 1996, monitoring was intensified to better resolve release loading and movement into the lake. Multiple water-quality samples were collected in the release water during the release event. Daily samples were collected at the embayment-open lake site and at seven sites in the lake during the release event and then periodically during the following 3 weeks. Water clarity, water temperature, dissolved oxygen, pH, and specific conductance were measured on site at the time of sampling. Water-quality samples were analyzed for turbidity, nutrients, selected metals, total and dissolved carbon, and chlorophyll *a*.

## Study Area

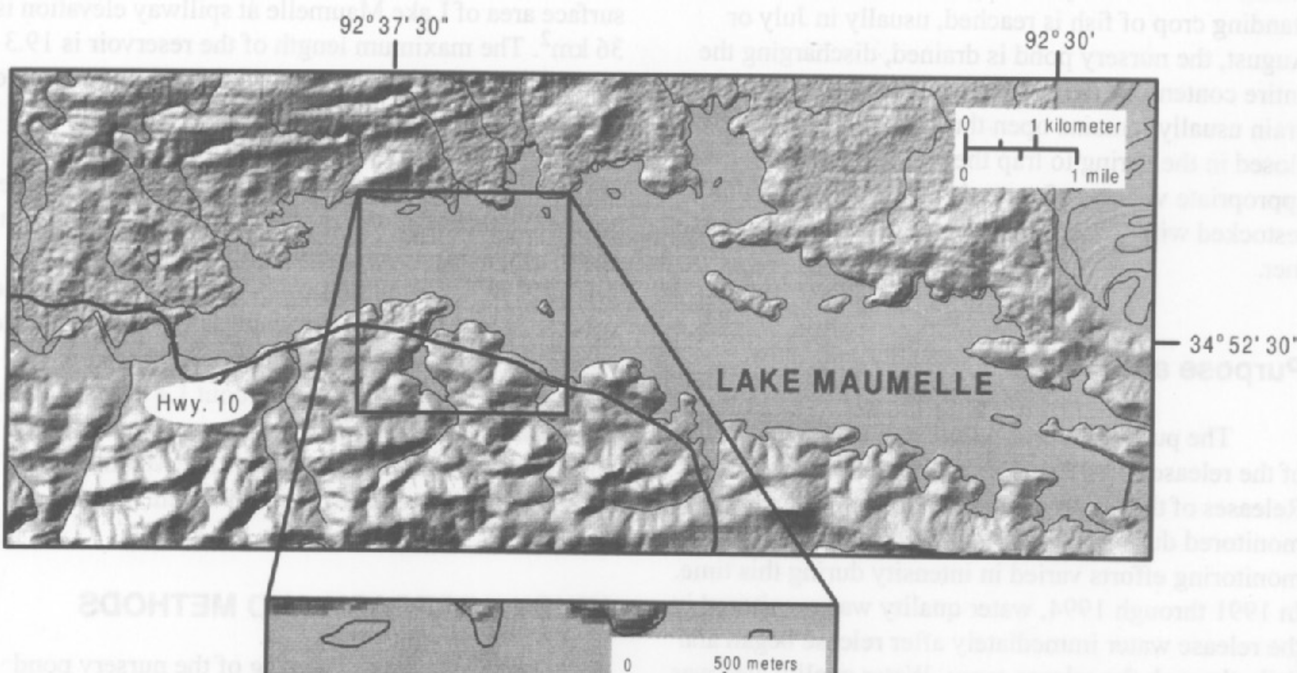
Lake Maumelle is a surface-water supply reservoir constructed on the Maumelle River, west of the city of Little Rock (fig. 1). Construction of Lake Maumelle was completed in 1956. The Maumelle River Basin has a drainage area of 355 $km^2$ at the Lake Maumelle dam, and is part of the Arkansas River drainage basin. About 62 percent of the water entering the reservoir enters through the Maumelle River. The normal annual rainfall within the Maumelle River Basin is about 137 cm (Freiwald, 1984). Lake Maumelle contains $2.70 \times 10^8$ $m^3$ of water at spillway elevation (88.39 m) and has $2.31 \times 10^8$ $m^3$ of usable water. The surface area of Lake Maumelle at spillway elevation is 36 $km^2$. The maximum length of the reservoir is 19.3 km, with a maximum depth of 13.7 m, and an average depth of 7.5 m (Green, 1993).

The nursery pond is located on Twin Creek, a small lateral tributary entering Lake Maumelle on the southern shore (fig. 1). At spillway elevation (108.2 m above sea level), the nursery pond contains about $1.38 \times 10^6$ $m^3$ of water and covers about 0.28 $km^2$. The volume of the nursery pond is about 0.5 percent of the volume of Lake Maumelle. The drainage area of the nursery pond is about 5.1 $km^2$, about 1.4 percent of the Lake Maumelle Basin. The maximum depth of the nursery pond is about the same as Lake Maumelle (13.7 m) and the average depth is about 5.0 m.

# STUDY APPROACH AND METHODS

Water-quality monitoring of the nursery pond releases varied in intensity from 1991 through 1996. Sampling sites were established in the nursery pond (NP), tailwater (TW), at the point where the Twin Creek embayment meets the open water of Lake Maumelle (L1), and at seven sites in the open water of Lake Maumelle (L2-L8) (fig. 2, table 1). Data collected included physicochemical field parameters (water temperature, dissolved oxygen concentration, pH, and specific conductance) and Secchi disk transparency. Water-quality samples were collected and analyzed for turbidity values, and concentrations of nutrients (total phosphorus, dissolved orthophosphorus, dissolved nitrite plus nitrate, dissolved ammonia, and total ammonia plus organic nitrogen), total iron, total manganese, total organic carbon, dissolved organic carbon, and chlorophyll *a*. The USGS collected and analyzed all field and water-quality samples.

Low intensity monitoring of the nursery pond tailwater and Lake Maumelle occurred during the 1991 through 1994 releases, followed by high intensity sampling during the 1995 and 1996 releases. During the low-intensity phase of monitoring, samples were collected at TW during the release period and at the embayment site (L1) before, during, and following the release. Physicochemical parameters (water temperature, dissolved oxygen, pH, and specific conductance) were measured at both sites using a multiparameter water-quality meter. Tailwater grab samples were collected for chemical analyses. Grab samples were collected by dipping a bucket (churn splitter) into the




Base from U.S. Geological Survey Digital Line Graphs
Universal Transverse Mercator
1:100,000 scale

Shaded relief from U.S. Geological Survey Digital Elevation Models
Universal Transverse Mercator
1:24,000 scale

**Figure 2.** Location of the Frank Lyon, Jr., Nursery Pond and sampling sites for release assessment.

**Table 1.** Station numbers, identification, and description of sample sites

| USGS station number | Station identification | Site description |
|---|---|---|
| 07263295 | | Maumelle River at Williams Junction |
| 072632972 | L8 | Lake Maumelle downstream from Yount Creek near Wye |
| 072632977 | NP | Twin Creek at Nursery Pond near Crossroads |
| 072632978 | TW | Twin Creek near Wye |
| 07263298 | L1 - L7 | Lake Maumelle downstream from Twin Creek near Wye |

center of the tailwater and sub-samples were split from this sample into individual bottles for chemical analysis. In 1991 through 1993, water-quality samples were collected at about 24-hour intervals in the tailwater of the 3-day releases. In 1994, two water-quality samples were collected in the tailwater during the first day of the release and one sample each of the following two days. Depth profiles of physicochemical parameters were measured at L1. Depth-integrated vertical composite water samples were collected at L1 for chemical analyses. A bailer (1-m in length) was used to collect water over a defined depth range. Samples were collected at 1-m intervals (0 to 1 m, 1 to 2 m, and so on) and poured into a churn splitter. The composited water was mixed and split into individual bottles for chemical analysis.

Monitoring was intensified during the 1995 and 1996 nursery pond releases. Depth profiles of physicochemical parameters were measured at NP prior to release, and depth- integrated vertical composite samples were collected to characterize the pond-water quality. Three depth-integrated vertical composite water samples were collected within the water column representing the epilimnion (the highest, turbulent stratum of water), metalimnion (the middle stratum of water exhibiting marked thermal discontinuity), and hypolimnion (the lowest, undisturbed stratum of water).

Numerous grab samples were collected at TW during the 1995 and 1996 releases to better define temporal changes in constituent concentration and loading. In 1995, nine samples were collected during the first day of the release and two on the second day. In 1996, six samples were collected during the first day of release, two on the second day, and one sample on the third day. Water-column profiles of physicochemical parameters were measured during each sampling event.

Depth-integrated composite samples were collected in the epilimnion at eight sites in Lake Maumelle (L1-L8). Site L1 was used to monitor the movement of the release water out of the Twin Creek embayment to the open water. Sites L2 - L7 were used to monitor the movement of the release water into the open water of Lake Maumelle. Two sites were located along three vectors originating from site L1. Sites were located about 305 m from each other along each vector. Sites L2 and L5 were located along a vector directed north-northeast. Sites L3 and L6 were located along a vector directed northeast, and sites L4 and L7 were located along a vector directed east. The other open-water site (L8) was used as an upstream reference site. Samples were collected at L1 through L8 prior to release to establish pre-release conditions and periodically through the release period and afterwards for about 3 weeks. Water-column profiles of physicochemical parameters were measured at each open-water site during each sampling event.

Constituent loads from the nursery pond release event were estimated by integrating volume of water discharged and TW constituent concentrations and calculating a sum total for the release. Discharge from the nursery pond, over time, was estimated using the equation:

$$Q = A\sqrt{2g(Za - Zb)}$$

where $Q$ is discharge ($m^3\ sec^{-1}$) at outlet,
$A$ is area ($m^2$) of outlet drain
$g$ is acceleration of gravity ($m\ sec^{-2}$), and
$Za$ - $Zb$ is the difference in elevation (m) between water surface and outlet.

Annual constituent loads from the Twin Creek drainage basin, assuming that the nursery pond did not exist, were estimated by area-adjusting loads determined for the continuous flow and water-quality monitoring station on the Maumelle River upstream of Lake Maumelle (07263295; Maumelle River at Williams Junction; fig. 1). The Twin Creek drainage area at the nursery pond dam is 5.1 $km^2$ or 4.3 percent the size of the drainage area of the Maumelle River at Williams Junction (119 $km^2$). Annual areal loading from the Twin Creek drainage was approximated by multiplying the annual areal load for Maumelle River at Williams Junction by 0.043. Water quality was monitored throughout the year at the Maumelle River at Williams Junction station during the same period (1990 through 1996) that the nursery pond release was monitored. Constituent loads at the Williams Junction station were estimated using a statistical model that implements the minimum variance unbiased estimator (Cohn and others, 1989; Gilroy and others, 1990). The statistical model estimates monthly basin constituent loads as a function of sampled concentrations, time, discharge, and seasonal variation. The monthly loads were summed to estimate annual instream constituent load.

Turbidity values, nutrients, and chlorophyll *a* concentrations were monitored at L1 through L8 in Lake Maumelle to trace the nursery pond release into the open water. Daily values or concentrations were spatially represented within the L1 through L7 defined space using triangulation with linear interpolation to produce contour lines of equal concentration (Golden Software, Inc., 1995). The triangulation algorithm creates triangles by drawing lines between data points. The original data points are connected in such a way that no triangle edges are intersected by other triangles. The result is a patchwork of triangular faces over the extent of the sample site grid. Triangulation results were represented by shaded intervals of values or concentrations within the space encompassed by L1 through L7.

## NURSERY POND CONDITIONS

Water-quality data were collected in the nursery pond in 1994, 1995, and 1996 shortly before the date of release. In 1994, the volume of water in the nursery pond was near capacity with a maximum depth of 13.7 m. The volume of the pond was considerably lower in 1995, with a maximum depth of 8.5 m. The maximum depth in 1996 was 12.2 m.

Water-column profiles of temperature and dissolved oxygen were measured at NP during each sampling in 1994 through 1996, and specific conductance and pH were measured in 1995 and 1996 (fig. 3). Dissolved oxygen depletion within the hypolimnion occurred each summer season as a result of the well-developed thermocline (plane of maximum rate of decrease of temperature with respect to depth). At the time of each sample collection, only the upper 2 to 3 m of water, the epilimnion, remained oxygenated. Under chemical reducing conditions within the anoxic hypolimnion, dissolution resulted in an increase in specific conductance values. A decrease in pH at the thermocline within the metalimnion is presumably the result of decomposing organic matter increasing the amount of inorganic carbon.

Nutrient distribution in the nursery pond reflected conditions typical of a thermally stratified water body with an anoxic hypolimnion. Depth-integrated composite nutrient concentrations increased from the epilimnion, through the metalimnion, and into the hypolimnion (fig. 4). In 1994 through 1996, total phosphorus concentrations in the epilimnion ranged from 0.014 to 0.020 mg/L. In 1995, when only ammonium nitrate fertilizer was applied to the nursery pond, total phosphorus concentrations increased slightly from 0.014 mg/L in the epilimnion to 0.018 in the metalimnion, and 0.032 mg/L in the hypolimnion. In 1994, total phosphorus concentration in the metalimnion was 0.044 mg/L, and 0.223 mg/L in the hypolimnion. In 1996, total phosphorus concentrations in the metalimnion and hypolimnion were 0.10 mg/L. Dissolved orthophosphorus distributions were similar to the total phosphorus distributions, with the exception of 1995. In 1995, dissolved orthophosphorus concentrations were 0.002 mg/L as P in the epilimnion and metalimnion and 0.001 mg/L as P in the hypolimnion. In contrast, the dissolved orthophosphorus concentration in the 1994 was 0.010 mg/L as P in the metalimnion and 0.148 mg/L as P in the hypolimnion. In 1996, the dissolved orthophosphorus concentration was 0.040 mg/L as P in the metalimnion and 0.060 mg/L as P in the hypolimnion.

Nitrogen (dissolved nitrite plus nitrate and total ammonia plus organic) concentrations in the nursery pond prior to release was variable (fig. 4). In the epilimnion, dissolved nitrite plus nitrate concentrations were less than 0.005 mg/L as N in 1994, and 0.002 mg L as N in 1995 and 1996. Metalimnetic concentrations were less than 0.005 mg/L as N in 1994, 0.002 mg/L as

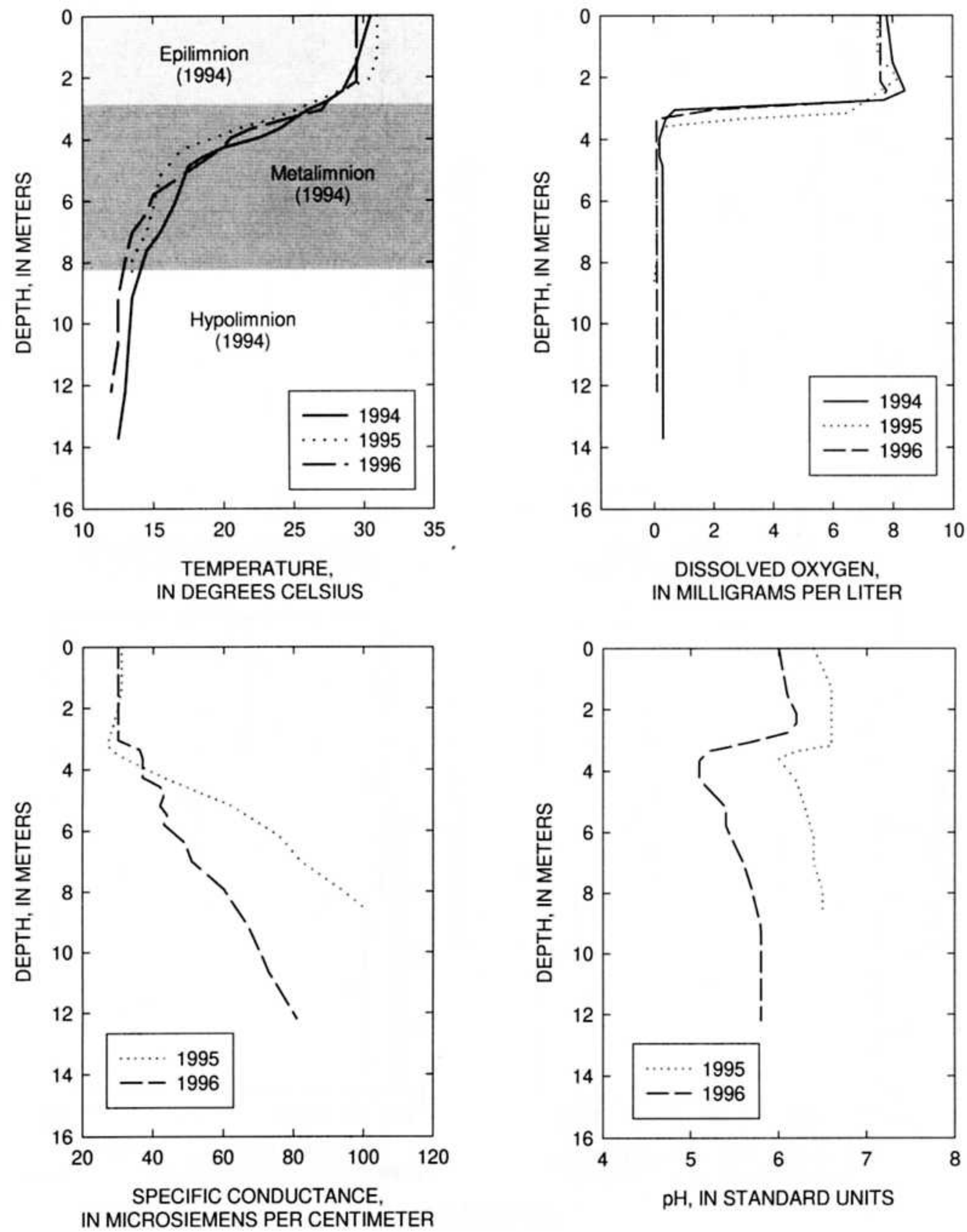



**Figure 3.** Water-column profiles of temperature, dissolved oxygen, specific conductance, and pH in the nursery pond (NP) prior to the 1994, 1995, and 1996 releases.

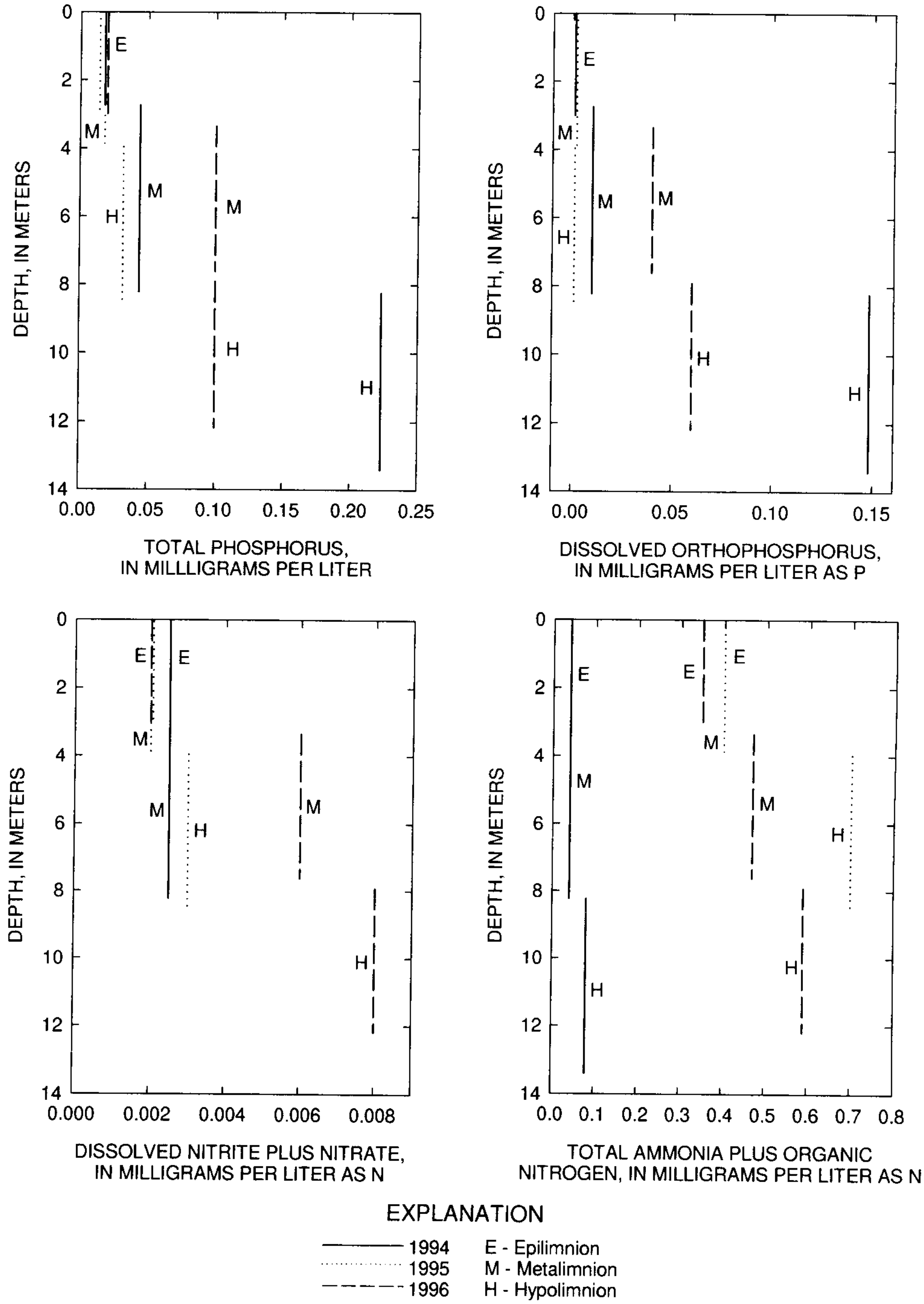



**Figure 4.** Phosphorus and nitrogen concentrations in the nursery pond from depth-integrated composite samples collected prior to releases in 1994, 1995, and 1996.

N in 1995, and 0.006 mg/L as N in 1996. Hypolimnetic concentrations in 1995 and 1996 were 0.003 and 0.008 mg/L as N, respectively. Total ammonia plus organic nitrogen (total Kjeldahl nitrogen) concentrations in the epilimnion were 0.04 mg/L as N in 1994, 0.40 mg/L as N in 1995, and 0.35 mg/L as N in 1996. Metalimnetic concentrations were 0.04 mg/L as N in 1994, 0.40 mg/L as N in 1995, and 0.47 mg/L as N in 1996. Hypolimnetic concentrations were 0.08 mg/L as N in 1994, 0.70 mg/L as N in 1995, and 0.59 mg/L as N in 1996.

Based on the nutrient results in the nursery pond prior to release, nitrogen appeared to be the nutrient limiting phytoplankton primary production in 1994, phosphorus in 1995, and both in 1996. Total nitrogen to total phosphorus concentration ratios were 2.4 in 1994, 29 in 1995, and 18 in 1996. These ratios (Redfield, 1958) indicate nitrogen limiting conditions in 1994 and phosphorus limiting conditions in 1995. In 1996, both nutrients may have had a limiting role in primary production.

Iron and manganese concentrations in the nursery pond also reflected conditions typical of a thermally stratified water body with an anoxic hypolimnion. Concentrations from depth-integrated composite samples increased from the epilimnion, through the metalimnion, and into the hypolimnion (fig. 5). Epilimnetic total iron concentrations in 1994 through 1996, ranged from 180 to 240 µg/L in samples collected prior to release. In 1994 and 1996, total iron concentrations in the metalimnion were 850 and 1,400 µg/L, and in the hypolimnion were 2,800 and 4,000 µg/L, respectively. In 1995, when nursery pond volume was low, total iron concentrations in the metalimnion and hypolimnion were 250 and 1,300 µg/L, respectively. Epilimnetic total manganese concentrations ranged from 16 to 30 µg/L in samples collected prior to release in 1994 through 1996. In 1994 and 1996, total manganese concentrations in the metalimnion were 210 and 250 µg/L, and in the hypolimnion were 480 and 620 µg/L, respectively. In 1995, total manganese

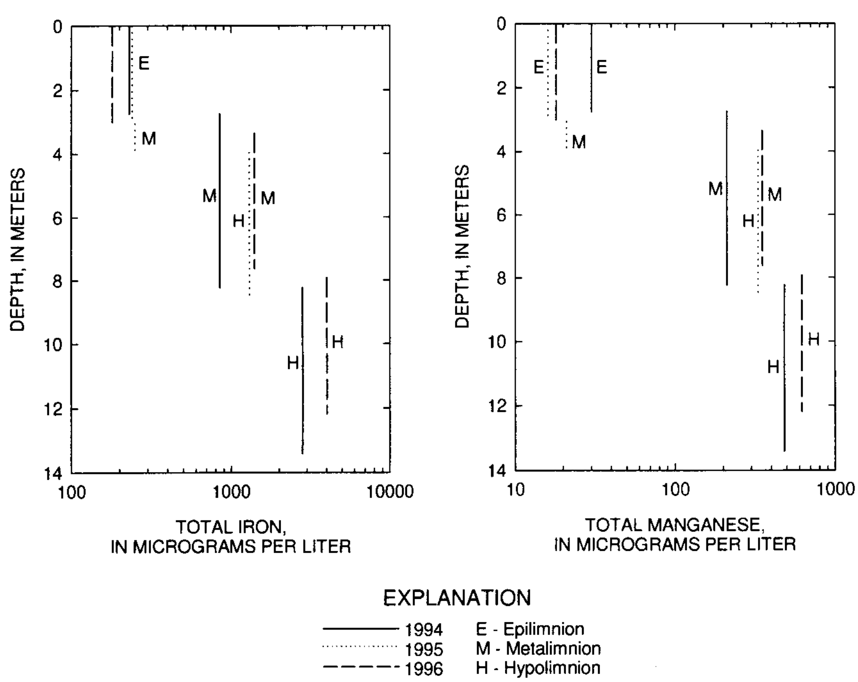



**Figure 5.** Total iron and manganese concentrations in the nursery pond from depth-integrated composite samples collected prior to releases in 1994, 1995, and 1996.

concentrations in the metalimnion and hypolimnion were 21 and 330 μg/L, respectively.

Total and dissolved organic carbon samples were collected at NP in 1996. Concentrations from depth-integrated samples increased from the epilimnion to the hypolimnion (fig. 6). Total organic carbon concentrations in the epilimnion, metalimnion, and hypolimnion were 6.7, 7.6, and 9.0 mg/L, respectively. Dissolved organic carbon concentrations in the epilimnion and metalimnion were slightly less than the total dissolved organic carbon concentrations, 6.5 and 7.4 mg/L, respectively. Dissolved organic carbon concentration in the hypolimnion (7.4 mg/L) was the same as in the metalimnion. Results indicate that most organic carbon at all depths exists in the dissolved phase. Proportionally less dissolved organic carbon exists in the hypolimnion than in the epilimnion or metalimnion.

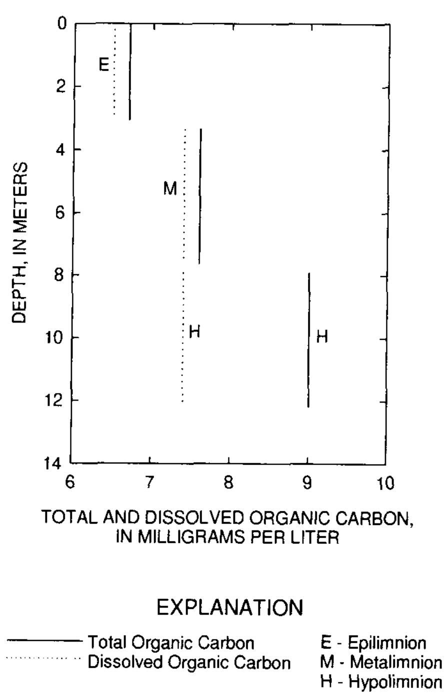



**Figure 6.** Total and dissolved organic carbon concentrations in the nursery pond from depth-integrated composite samples collected prior to the 1996 release.

## NURSERY POND RELEASE LOAD

The gate of the nursery pond is at the bottom near the dam, resulting in hypolimnetic water discharging first, followed by the metalimnetic and epilimnetic water. In general, higher values of turbidity and concentrations of nutrients (total phosphorus, dissolved orthophosphorus, dissolved nitrite plus nitrate nitrogen, total ammonia plus organic nitrogen, dissolved ammonia nitrogen), total iron, total manganese, total organic carbon, and dissolved organic carbon were measured during the initial hours of the tailwater release; values and concentrations decreased throughout the remainder of the release (figs. 7 and 8).

Constituent concentrations from TW were temporally integrated with estimated discharge values to estimate nursery pond release loads for each event. Constituent loads for each release are presented in table 2 and the mean concentration (load / volume) from each constituent load is presented in table 3.

Fertilizer application rates in the nursery pond (John Hogue, Arkansas Game and Fish Commission, oral commun., 1997) and loads in releases varied from 1991 through 1996. No information was available concerning fertilizer applications during 1991 through 1994 with the exception that applications in 1995 and 1996 were much different than in 1991 through 1994. In 1995, only ammonium nitrate was applied. In 1996, a small amount of 13-13-13 fertilizer was applied. Evidence of different application rates appears in the constituent load results. In 1995, when no phosphorus fertilizer was applied, only 31.5 kg of total phosphorus was estimated in the release load (table 2), whereas from 238 to 454 kg were estimated for 1991 through 1994. The mean total phosphorus load concentration (table 3) in 1995 was 2.4 to 4.6 times less than the 1991 through 1994 concentrations. The total phosphorus load in 1996 (53.7 kg) was lower than in 1991 through 1994, and somewhat (70 percent) higher than in 1995. Because the pond volume was less in 1995 than in 1996, the mean total phosphorus load concentration in 1995 was greater than in 1996, even though no phosphorus fertilizer was applied in 1995.

Only 1.55 kg of dissolved orthophosphorus (as P) was estimated in the 1995 release (table 2). The dissolved orthophosphorus load estimated in the 1991 through 1994 was 2 orders of magnitude greater, ranging from 136 to 217 kg as P. A load of 21.9 kg of dissolved orthophosphorus (as P) was estimated in the 1996 release. Dissolved orthophosphorus constituted 32 to 77 percent of the total phosphorus loads in the

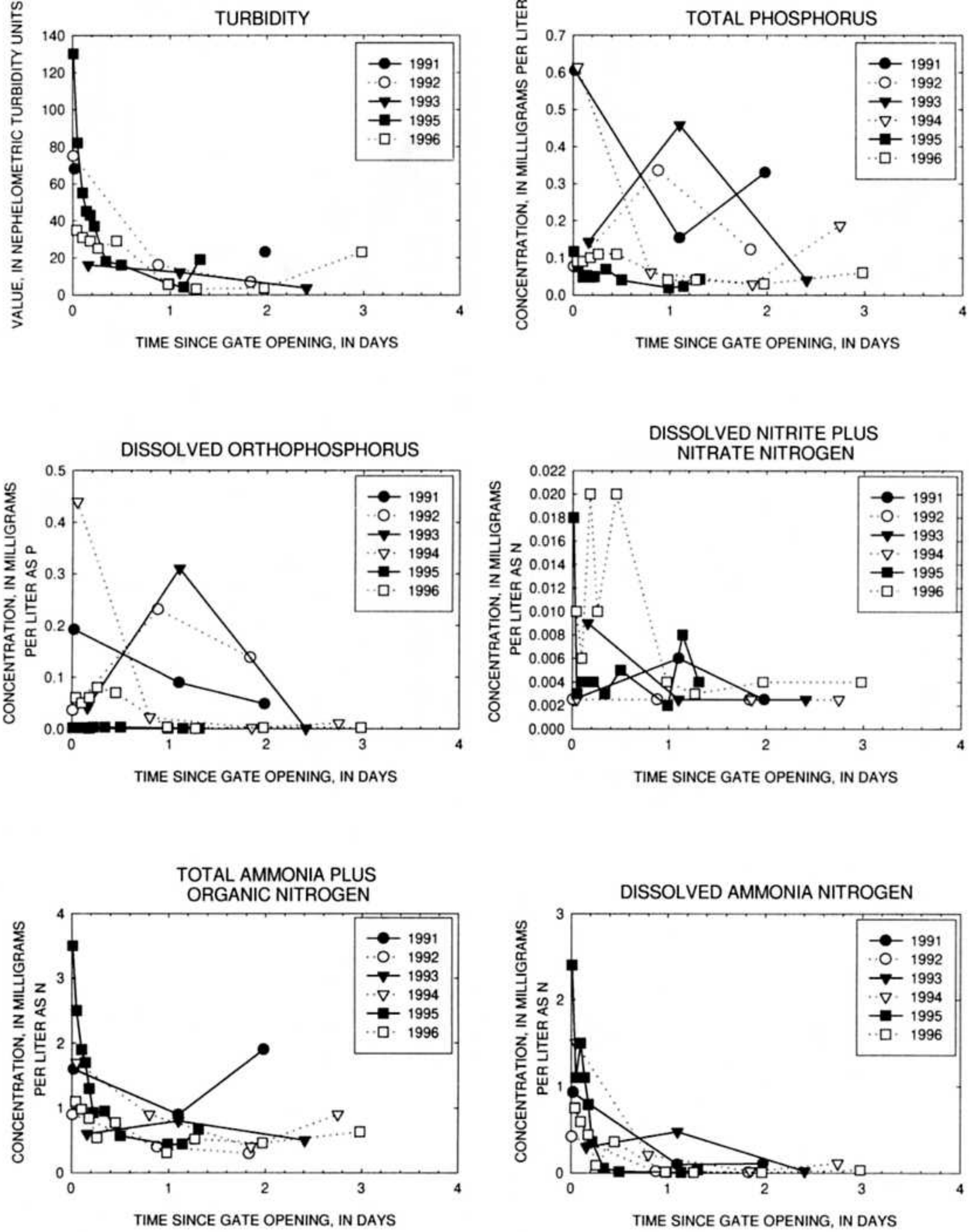



**Figure 7.** Turbidity values and concentrations of total phosphorus, dissolved orthophosphorus, dissolved nitrite plus nitra nitrogen, total ammonia plus organic nitrogen, and dissolved ammonia nitrogen in the tailwater following nursery pond releases in 1991 through 1996.

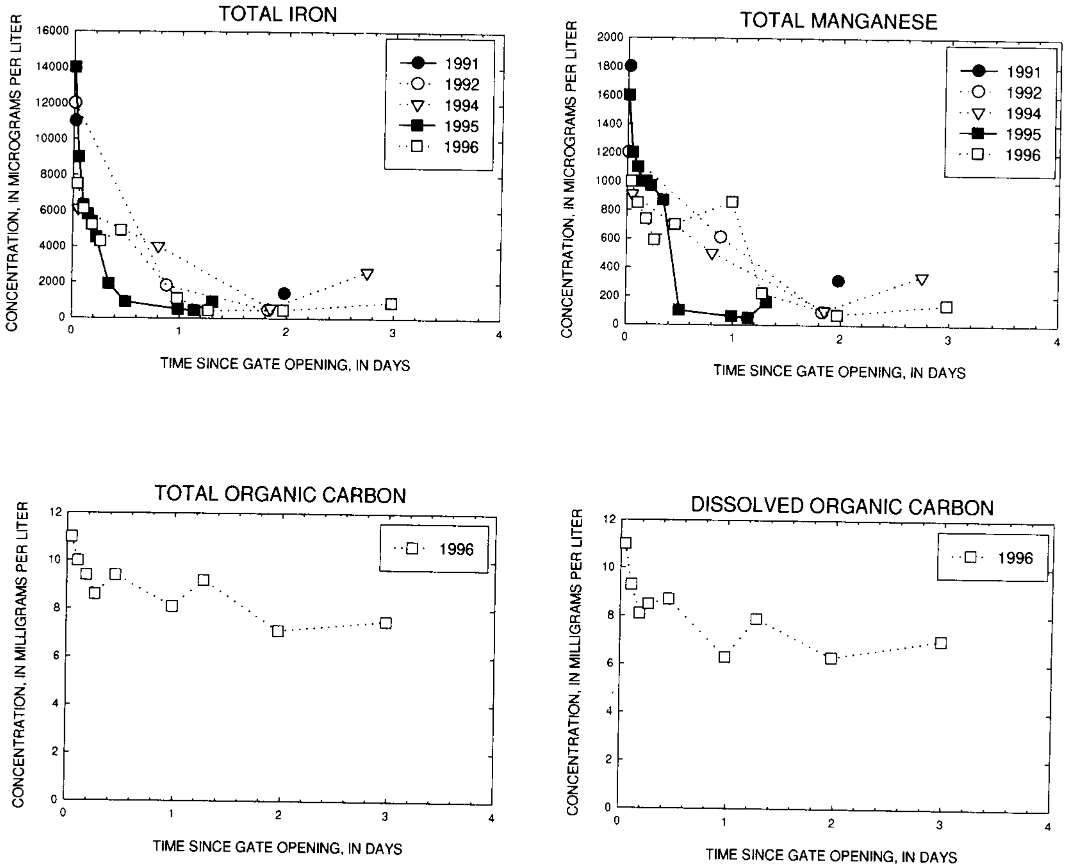



**Figure 8.** Concentrations of total iron, total manganese in the tailwater following nursery pond releases in 1991, 1992, and 1994 through 1996, and total organic carbon and dissolved organic carbon in 1996.

**Table 2.** Estimated constituent loads from the nursery pond releases, 1991 through 1996
[$m^3$, cubic meters; kg, kilogram; --, no data]

| Constituent | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 |
|---|---|---|---|---|---|---|
| Water volume ($m^3$)[1] | $1.38x10^6$ | $1.38x10^6$ | $1.38x10^6$ | $1.38x10^6$ | $4.38x10^5$ | $1.06x10^6$ |
| Total phosphorus (kg) | 454 | 289 | 280 | 238 | 31.5 | 53.7 |
| Dissolved orthophosphorus as P (kg) | 143 | 213 | 217 | 136 | 1.55 | 21.9 |
| Dissolved nitrite plus nitrate nitrogen (kg) | 7.50 | 6.91 | 8.56 | 6.91 | 3.22 | 7.56 |
| Total ammonia plus organic nitrogen (kg) | 1,900 | 650 | 930 | 1,300 | 650 | 590 |
| Dissolved ammonia nitrogen (kg) | 460 | 180 | 439 | 555 | 202 | 124 |
| Total iron (kg) | -- | 4,770 | -- | 4,450 | 1,740 | 2,060 |
| Total manganese (kg) | -- | 778 | -- | 612 | 326 | 438 |
| Total organic carbon (kg) | -- | -- | -- | -- | -- | 8,800 |
| Dissolved organic carbon (kg) | -- | -- | -- | -- | -- | 6,200 |

[1]Estimated volumes. Volumes for 1991-1993 were assumed to be full pool volume. Pool depths were available for 1994 through 1996 and volumes estimated from a capacity curve.

**Table 3.** Estimated mean constituent load concentrations (load / volume) from the nursery pond releases, 1991 through 1996
[mg/L, milligrams per liter; --, no data]

| Constituent | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 |
|---|---|---|---|---|---|---|
| Total phosphorus (mg/L) | 0.329 | 0.209 | 0.203 | 0.172 | 0.072 | 0.051 |
| Dissolved orthophosphorus as P (mg/L) | 0.104 | 0.154 | 0.157 | 0.099 | 0.004 | 0.021 |
| Dissolved nitrite plus nitrate nitrogen (mg/L) | 0.005 | 0.005 | 0.006 | 0.005 | 0.007 | 0.007 |
| Total ammonia plus organic nitrogen (mg/L) | 1.40 | 0.47 | 0.67 | 0.91 | 1.48 | 0.56 |
| Dissolved ammonia nitrogen (mg/L) | 0.333 | 0.130 | 0.318 | 0.402 | 0.461 | 0.117 |
| Total iron (mg/L) | -- | 3.45 | -- | 3.22 | 3.98 | 1.95 |
| Total manganese (mg/L) | -- | 0.563 | -- | 0.443 | 0.744 | 0.413 |
| Total organic carbon (mg/L) | -- | -- | -- | -- | -- | 8.3 |
| Dissolved organic carbon (mg/L) | -- | -- | -- | -- | -- | 5.8 |

1991 through 1994 releases. In 1995, when only ammonium nitrate was applied, dissolved orthophosphorus constituted only 5 percent of the total phosphorus load. In 1996, dissolved orthophosphorus was 41 percent of the total phosphorus load.

## Comparison of Nursery Pond Release Load to Expected Annual Areal Load

To better understand the magnitude of the nursery pond release load, expected annual areal loads were estimated for the Twin Creek drainage area based on annual loads estimated at Maumelle River at Williams Junction. Annual loads for total phosphorus, dissolved orthophosphorus, dissolved nitrite plus nitrate nitrogen, total ammonia plus organic nitrogen, dissolved ammonia nitrogen, total iron, total manganese, total organic carbon, and dissolved organic carbon, were estimated at Maumelle River at Williams Junction for water years (October-September) 1991 through 1996. Annual constituent loads at Maumelle River at Williams Junction varied over the 6-year period, in part because of variability in annual flow (table 4). Estimated mean constituent load concentrations are presented in table 5.

Constituent loading into Lake Maumelle fron the release of the nursery pond was often greater tha what would be expected annually from the nursery pond drainage (table 6). In 1991 through 1994, the to phosphorus load from the nursery pond release was 3 to 7.0 times greater than what would be expected ann ally from the nursery pond drainage. In 1995, when only ammonium nitrate was applied to the nursery pond, the total phosphorus load from the nursery po release was only 0.62 times the expected annual loa from the nursery pond drainage. In 1996, the nurser pond release load was 1.5 times as great. Over the 6 year period, the total phosphorus load resulting fron the nursery pond release averaged 3.9 times the expected annual load from the nursery pond drainag

Dissolved orthophosphorus load resulting fro the nursery pond release in relation to the expected annual load was proportionally greater than the total phosphorus load except in 1991 and 1995. In 1992 through 1994 and in 1996, the dissolved orthophosph rus load from the nursery pond release ranged from 1 to 21 times as great as the expected annual load fron

**Table 4.** Estimated annual constituent loads at Maumelle River at Williams Junction, water years 1991 through 1996
[m$^3$, cubic meter; kg, kilogram]

| Constituent | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 6-year average |
|---|---|---|---|---|---|---|---|
| Water volume (m$^3$) | 7.17x10$^7$ | 5.20x10$^7$ | 5.51x10$^7$ | 6.70x10$^7$ | 5.16x10$^7$ | 2.28x10$^7$ | 5.34x10$^7$ |
| Total phosphorus (kg) | 1,500 | 1,290 | 1,110 | 1,590 | 1,190 | 493 | 1,200 |
| Dissolved orthophosphorus as P (kg) | 488 | 332 | 243 | 262 | 164 | 49.3 | 256 |
| Dissolved nitrite plus nitrate nitrogen (kg) | 1,860 | 1,370 | 1,100 | 1,340 | 896 | 318 | 1,150 |
| Total ammonia plus organic nitrogen (kg) | 24,000 | 18,000 | 15,000 | 19,000 | 13,000 | 4,700 | 16,000 |
| Dissolved ammonia nitrogen (kg) | 2,310 | 1,450 | 992 | 986 | 586 | 152 | 1,080 |
| Total iron (kg) | 54,100 | 41,200 | 33,100 | 42,300 | 28,800 | 11,000 | 35,100 |
| Total manganese (kg) | 2,380 | 2,260 | 1,620 | 2,620 | 1,860 | 826 | 1,930 |
| Total organic carbon (kg) | 340,000 | 260,000 | 270,000 | 340,000 | 260,000 | 110,000 | 260,000 |
| Dissolved organic carbon (kg) | 330,000 | 280,000 | 230,000 | 320,000 | 230,000 | 90,000 | 250,000 |

**Table 5.** Estimated mean constituent load concentration at Maumelle River at Williams Junction, water years 1991 through 1996

[mg/L, milligrams per liter]

| Constituent | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 6-year average |
|---|---|---|---|---|---|---|---|
| Total phosphorus (mg/L) | 0.021 | 0.025 | 0.020 | 0.024 | 0.023 | 0.022 | 0.023 |
| Dissolved orthophosphorus as P (mg/L) | 0.007 | 0.006 | 0.004 | 0.004 | 0.003 | 0.002 | 0.004 |
| Dissolved nitrite plus nitrate nitrogen (mg/L) | 0.026 | 0.026 | 0.020 | 0.020 | 0.017 | 0.014 | 0.021 |
| Total ammonia plus organic nitrogen (mg/L) | 0.33 | 0.34 | 0.28 | 0.28 | 0.26 | 0.21 | 0.28 |
| Dissolved ammonia nitrogen (mg/L) | 0.032 | 0.028 | 0.018 | 0.015 | 0.011 | 0.002 | 0.018 |
| Total iron (mg/L) | 0.574 | 0.793 | 0.601 | 0.631 | 0.559 | 0.482 | 0.607 |
| Total manganese (mg/L) | 0.033 | 0.043 | 0.029 | 0.039 | 0.036 | 0.036 | 0.036 |
| Total organic carbon (mg/L) | 4.7 | 5.0 | 4.8 | 5.1 | 5.0 | 5.0 | 4.9 |
| Dissolved organic carbon (mg/L) | 4.6 | 5.4 | 4.1 | 4.8 | 4.5 | 4.0 | 4.6 |

**Table 6.** Ratio of the estimated nursery pond release load to the expected annual areal load of the nursery pond (Twin Creek) drainage area, 1991 through 1996

[Annual loads for the Twin Creek drainage basin were based on area-adjusted annual loading data from Maumelle River at Williams Junction; --, no data]

| Constituent | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 6- year average |
|---|---|---|---|---|---|---|---|
| Total phosphorus | 7.0 | 5.2 | 5.8 | 3.5 | 0.62 | 1.5 | 3.9 |
| Dissolved orthophosphorus | 6.8 | 15 | 21 | 12 | 0.22 | 10 | 11 |
| Dissolved nitrite plus nitrate nitrogen | 0.32 | 0.12 | 0.18 | 0.12 | 0.08 | 0.55 | 0.23 |
| Total ammonia plus organic nitrogen | 1.8 | 0.84 | 1.4 | 1.6 | 1.2 | 2.9 | 1.6 |
| Dissolved ammonia nitrogen | 4.6 | 2.9 | 10 | 13 | 8.0 | 19 | 9.6 |
| Total iron | -- | 2.7 | -- | 2.4 | 1.4 | 4.4 | -- |
| Total manganese | -- | 8.0 | -- | 5.4 | 4.1 | 12 | -- |
| Total organic carbon | -- | -- | -- | -- | -- | 1.9 | -- |
| Dissolved organic carbon | -- | -- | -- | -- | -- | 1.6 | -- |

the nursery pond drainage (table 6). In 1995, the dissolved orthophosphorus load from the nursery pond release was only 0.22 times the expected annual load for the nursery pond drainage. Over the 6-year period, the dissolved orthophosphorus load resulting from the nursery pond release averaged 11 times the expected annual load from the nursery pond drainage.

Of the three nitrogen constituents monitored in the nursery pond releases, only the dissolved nitrite plus nitrate load was consistently lower than the expected annual load for the nursery pond drainage (table 6). The nursery pond release load for dissolved nitrite plus nitrate nitrogen ranged from 0.08 to 0.55 times the annual load expected from the nursery pond drainage. Over the 6-year period, the dissolved nitrite plus nitrate load resulting from the nursery pond release averaged 0.23 times the expected annual load from the nursery pond drainage. The total ammonia plus organic nitrogen load resulting from the nursery pond release was higher than the expected annual load for the nursery pond drainage every year except 1992. Over the 6-year period, the total ammonia plus organic nitrogen load resulting from the nursery pond release averaged 1.6 times the expected annual load from the nursery pond drainage. The dissolved ammonia nitrogen load resulting from the nursery pond release was greater than the expected annual load for the nursery pond drainage for all years. The nursery pond release load for dissolved ammonia nitrogen ranged from 2.9 to 19 times the annual load expected from the nursery pond drainage. Over the 6-year period, the dissolved ammonia nitrogen load resulting from the nursery pond release averaged 9.6 times the expected annual load from the nursery pond drainage.

Total iron and total manganese loads from the nursery pond release were estimated in 1992, 1994, 1995, and 1996. The total iron load resulting from the nursery pond release was greater than the expected annual load for the nursery pond drainage, ranging from 1.4 to 4.4 times the expected annual load (table 6). The total manganese load resulting from the nursery pond release was greater than the expected annual load for the nursery pond drainage, ranging from 4.1 to 12 times the annual load expected from the nursery pond drainage.

Total and dissolved organic carbon loads from the nursery pond release were estimated in 1996. Both total and dissolved organic carbon loads resulting from the nursery pond release were greater than the expected annual load for the nursery pond drainage. The nursery pond release load for total organic carbon was 1.9 times the annual load expected from the nursery pond drainage and the dissolved organic carbon load was 1.6 times greater (table 6).

## Movement of the Nursery Pond Release Load Into Lake Maumelle

The release gate in the nursery pond is located at the bottom of the dam, the deepest point in the pond. As a result, water from the bottom (hypolimnion) of the nursery pond is released first followed by middle (metalimnion) and upper (epilimnion) layers. The temperature of the bottom water was generally less than 15 degrees Celsius (fig. 3), and when entering Lake Maumelle, this cooler water plunged beneath the warmer water of the receiving embayment. A mud plume was seen plunging into the depths of the embayment along the western side during the first day of each release (author's observation). As the nursery pond emptied into Lake Maumelle, the temperature of the released water became warmer and eventually reached ambient temperature and density of the receiving embayment (fig. 9). Dissolved oxygen concentrations in the hypolimnion of the nursery pond prior to release were near zero (fig. 3). However, because of turbulence in flow from the end of the release pipe to the sampling site (TW; about 150 m), dissolved oxygen concentrations increased to about 6 to 7 mg/L or greater than 50 percent saturation. Specific conductance values were relatively high at the beginning of the release, because of the higher values in the hypolimnion of the nursery pond, and decreased to ambient embayment values as the hypolimnetic water of the nursery pond was displaced and the metalimnetic and epilimnetic waters were discharged.

Evidence of the cooler water from the hypolimnion of the nursery pond plunging under the warmer surface water in Lake Maumelle can be seen in the depth profiles of temperature and dissolved oxygen at site L1 (fig. 10). Water temperatures at L1 prior to nursery pond release decreased slightly from about the 4-meter depth to the bottom. In the deeper, open water of Lake Maumelle, the thermocline usually develops within the 4- to 7-meter depth interval. Below about 7-meters, the hypolimnion in the deeper, open water of Lake Maumelle becomes anoxic. Dissolved oxygen concentrations at L1 prior to nursery pond release approached zero near the bottom. As the cold water was released from the nursery pond, temperature and

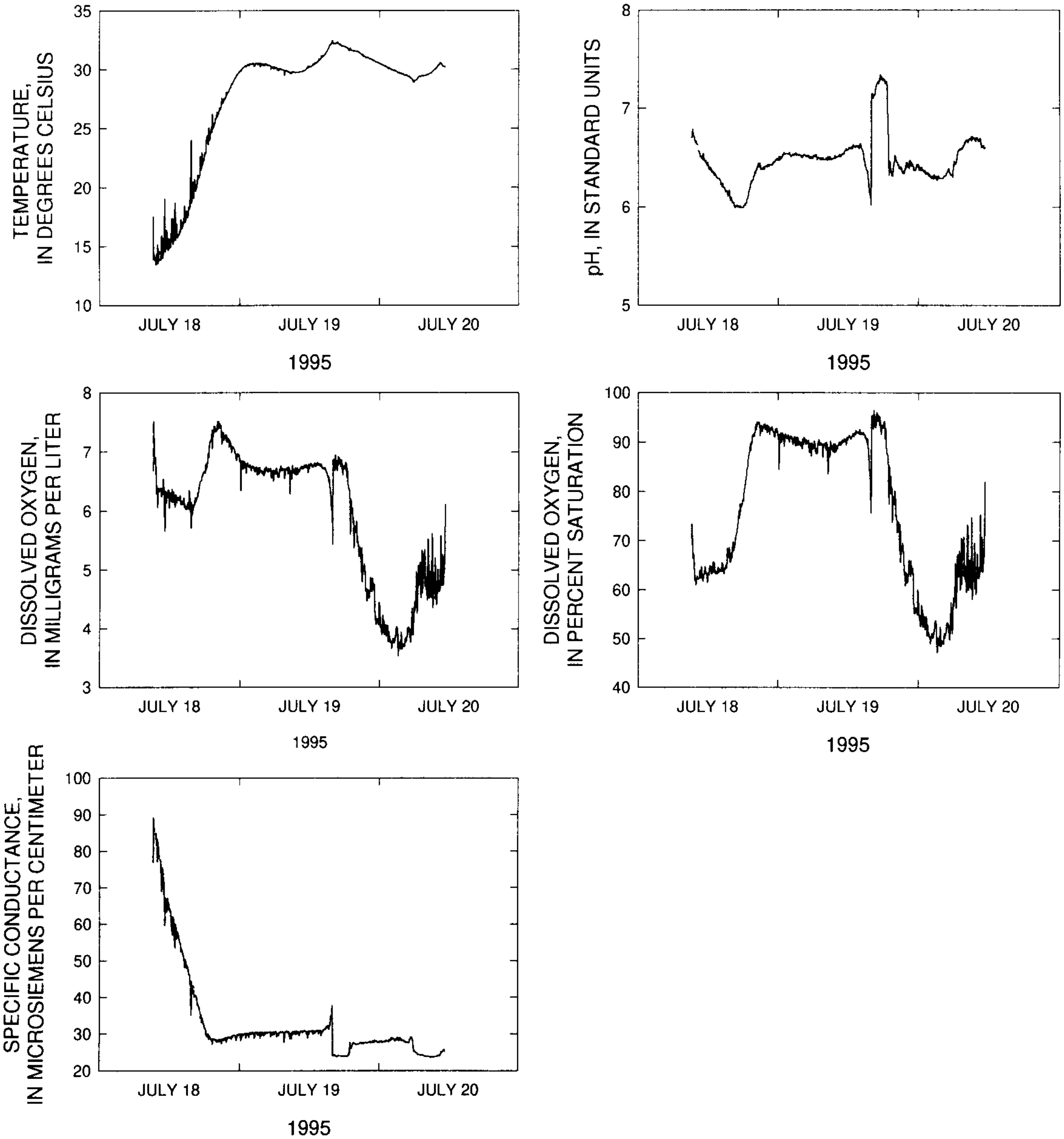



**Figure 9.** Temperature, pH, dissolved oxygen, and specific conductance values of the release water during the 1995 nur pond release at the tailwater (TW) sampling site.

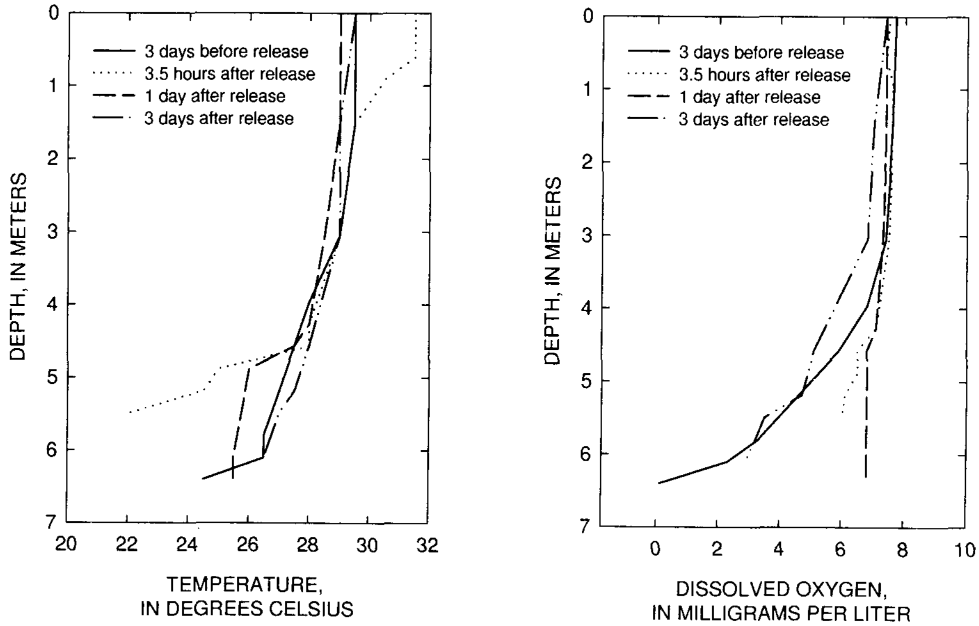



**Figure 10.** Temperature and dissolved oxygen profiles at L1 prior to and after the 1996 nursery pond release.

dissolved oxygen profiles at L1 changed near the bottom. Temperature decreased about 4 degrees Celsius and dissolved oxygen concentrations increased from about zero to about 7.0 mg/L. By 3 days after release, water temperature and dissolved oxygen concentrations returned to pre-release conditions.

During the 1995 and 1996 nursery pond releases, water-quality samples were collected at various time intervals at sites L1 through L7 (fig. 2) to follow constituent transport within the epilimnetic water and assess the effects of nutrient loading on phytoplankton biomass. Depth-integrated composite samples were collected from the water surface to the thermocline (the epilimnion). Within this part of the water column light is available for primary production by the phytoplankton. Samples collected before release represent pre-release conditions and samples collected at site L8 throughout the sampling period represent the reference, assumed to be non-impacted, condition.

## Turbidity

The 1995 pre-release mean turbidity value fo sites L1-L7 was 1.3 nephelometric turbidity units (NTU). A turbidity plume was measured outside the receiving embayment 1 day after release (fig. 11). E vated turbidity values remained at L1 through day 6 but remained near pre-release and reference (site L8 values at L2 through L7. On day 9, turbidity values all sites were near pre-release and reference values. ( day 15, higher turbidity values were recorded at L1 a turbidity dissipated farther out into the open water. ( day 23, turbidity values at all sites were near pre-release and reference values.

The 1996 pre-release mean turbidity value for sites L1 through L7 was 1.2 NTU. A plume of turbid expanded outside the embayment by day 2 and cont ued to be present through day 14 (fig. 12). By day 2 only turbidity values at L1 were greater than pre-release or reference conditions.

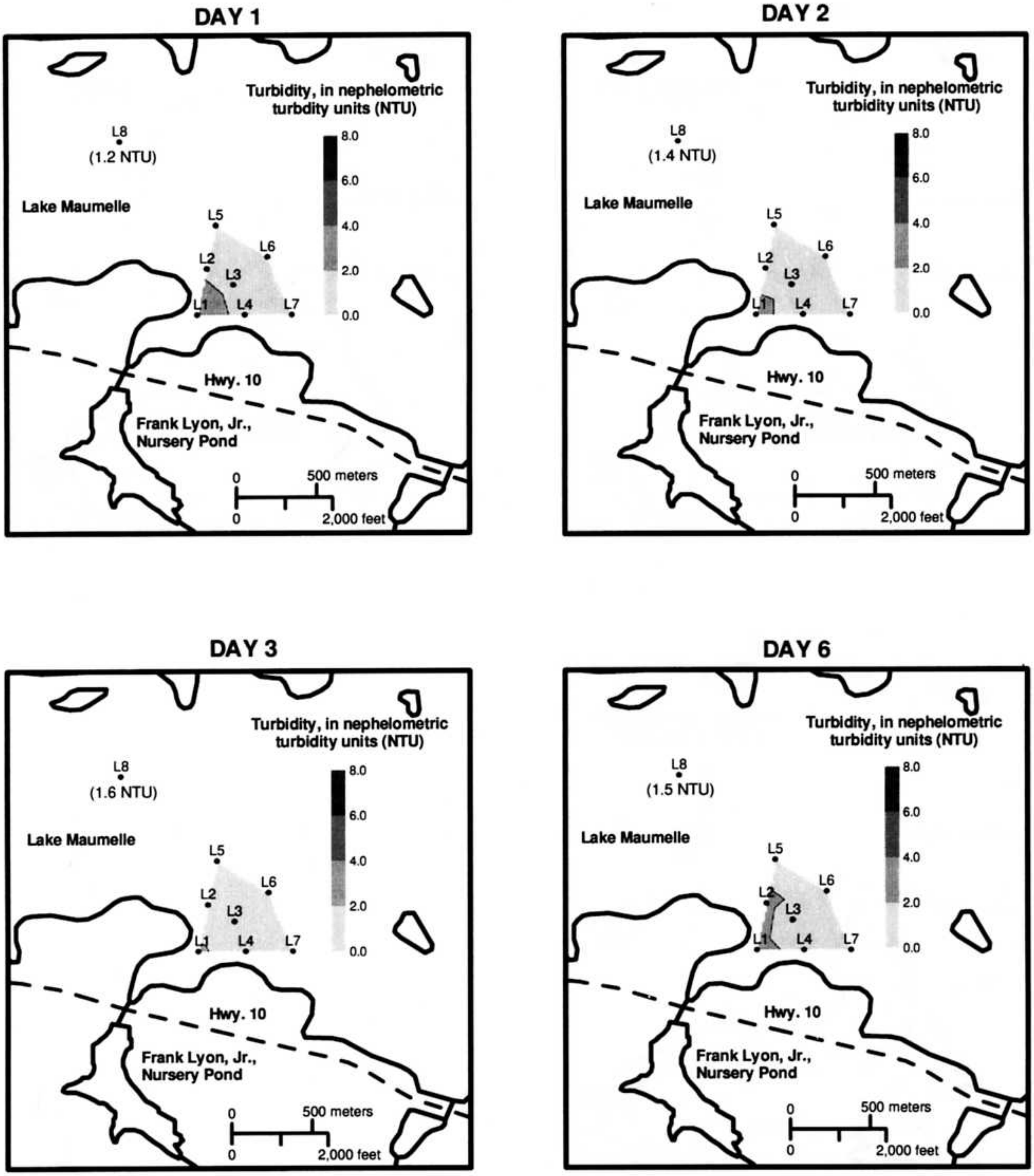



**Figure 11.** Turbidity values at sites L1 through L8 following the 1995 release.

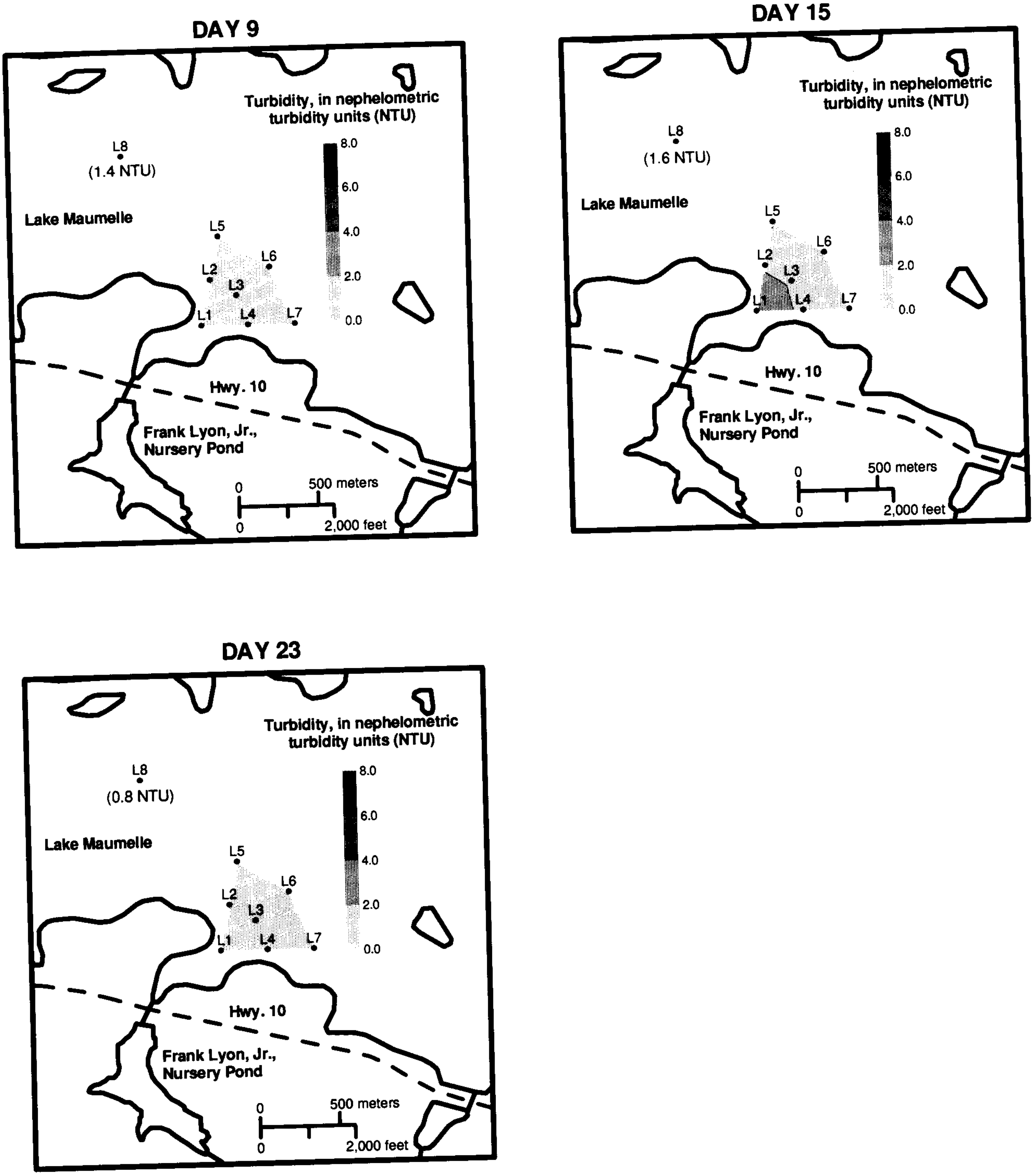



**Figure 11.** Turbidity values at sites L1 through L8 following the 1995 release--Continued.

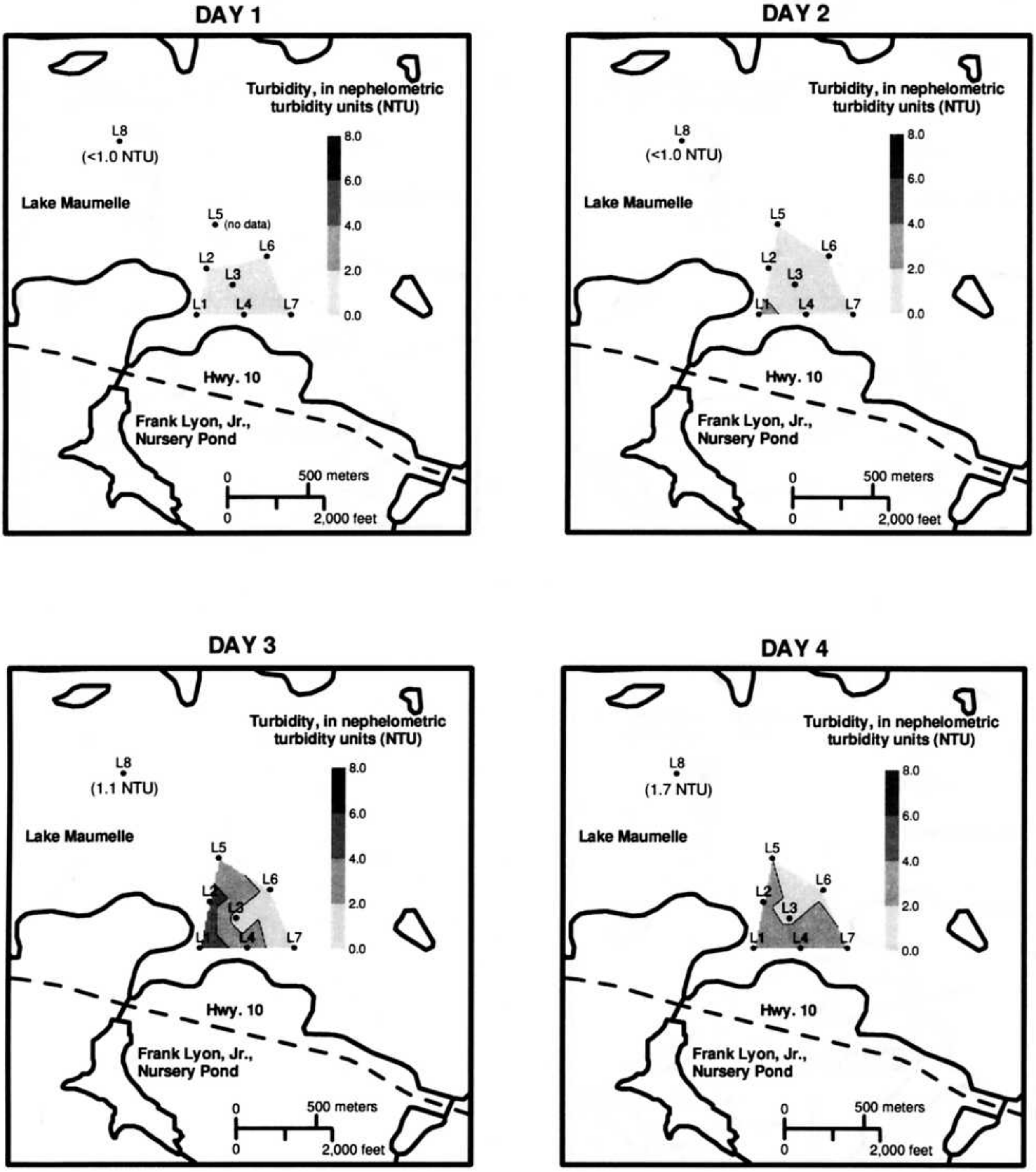



**Figure 12.** Turbidity values at sites L1 through L8 following the 1996 release.

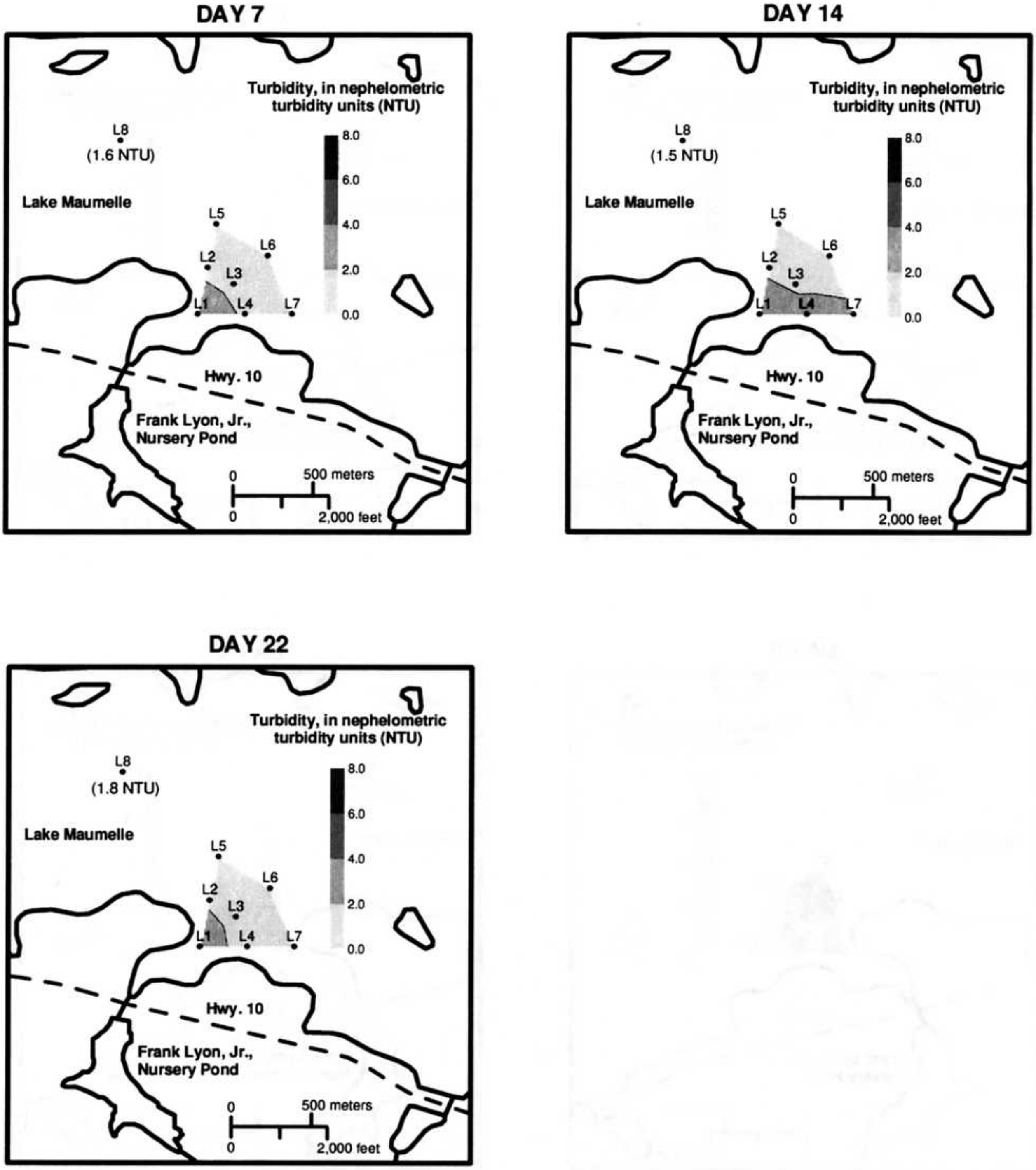



**Figure 12.** Turbidity values at sites L1 through L8 following the 1996 release--Continued.

### Total Phosphorus

The 1995 pre-release mean total phosphorus concentration for sites L1 through L7 was 0.009 mg/L. A plume of total phosphorus extended outside the embayment 1 day after release with the greatest concentration occurring at L1(fig. 13). The phosphorus plume remained through day 2 with the greatest concentrations occurring at the southern end of the L1 through L7 grid. The phosphorus plume had dissipated by day 3 but intensified by day 6, with higher concentrations than the pre-release condition and reference concentration occurring at all sites except L7. On day 9, the greatest phosphorus concentration was found at L7 and the concentration at L1 was greater than the pre-release or reference condition. On day 15, the reference phosphorus concentration (L8) was 0.020 mg/L and the phosphorus concentrations at L1 through L7 were equal to or below 0.020 mg/L, although these concentrations still were greater than the pre-release mean concentration. On day 23, phosphorus concentrations at L1 and L4 were greater than the pre-release or reference condition.

The 1996 pre-release mean total phosphorus concentration for sites L1 through L7 again was 0.009 mg/L. A plume of total phosphorus expanded outside the embayment by day 2 with the greatest concentration occurring at L1 (fig. 14). The plume continued to radiate from L1 through day 4. By day 7 and through day 22, phosphorus concentrations at L1 through L7 were near pre-release and reference concentrations.

### Dissolved Ammonia Nitrogen

The 1995 pre-release mean dissolved ammonia concentration for sites L1 through L7 was 0.004 mg/L as N. A plume of dissolved ammonia extended outside the embayment on day 2 and continued through day 15 (fig. 15). By day 23, dissolved ammonia concentrations at L1 through L7 were at or near pre-release and reference concentrations.

The 1996 pre-release mean dissolved ammonia concentration for sites L1 through L7 was 0.007 mg/L as N. A plume of dissolved ammonia extended outside the embayment on day 2 and continued through day 14 (fig. 16). However, ammonia concentrations at L1 through L7 on day 3 and day 7 were not greater than the respective daily reference concentrations (L8). On day 22, ammonia concentrations at L1 through L7 were greater than pre-release conditions but not the reference concentration.

### Chlorophyll *a*

Chlorophyll *a* concentrations at L1 through L8 following release in 1995 were variable and patterns of movement out of the embayment were not as evident as with the constituents discussed previously. The 1995 pre-release mean chlorophyll *a* concentration for sites L1 through L7 was 2.3 μg/L. Chlorophyll *a* concentrations outside the embayment on day 1 were greater than the pre-release and reference concentrations at L1 and L2, the western side of the L1 through L7 grid (fig. 17). On days 2, 3, and 6, chlorophyll *a* concentrations at the reference site (L8) increased from 3.7 to 6.2 μg/L. Chlorophyll *a* concentrations at L1 through L8 also increased during this time. On day 9, concentrations at L1 through L4 were greater than the reference condition. On day 15, only L3 had a concentration greater than the reference site (L8).

The 1996 pre-release mean chlorophyll *a* concentration for sites L1 through L7 was 1.2 μg/L. By day 2, a slight plume of higher chlorophyll *a* concentrations extended outside the embayment (fig. 18). Concentrations at L1, L3, and L4 were greater than the pre-release or reference concentrations. On day 3, concentrations higher than the pre-release or reference (L8) concentrations remained at L1 and L2, the western edge of the L1 through L7 sample grid. Chlorophyll *a* concentrations differed little outside the embayment from the pre-release or reference concentrations on days 4, 7, 14, and 22.

## WATER-QUALITY ASSESSMENT OF NURSERY POND RELEASES INTO LAKE MAUMELLE

Results from this study indicate that the water-quality impact of the Frank Lyon, Jr., Nursery Pond releases into Lake Maumelle is variable, and appears to be related to the volume of the nursery pond at release and the amount of nitrogen and phosphorus fertilizer applied within the nursery pond earlier in the year. Except for the 1995 nursery pond release, loads of all constituents entering Lake Maumelle from the nursery pond (except for nitrite plus nitrate nitrogen) were greater than what would be expected in the annual areal load from that basin. Total phosphorus load was lower in 1995 than the other years because only ammonium nitrate was applied to the nursery pond earlier in the spring. The volume of the nursery pond in 1995 also

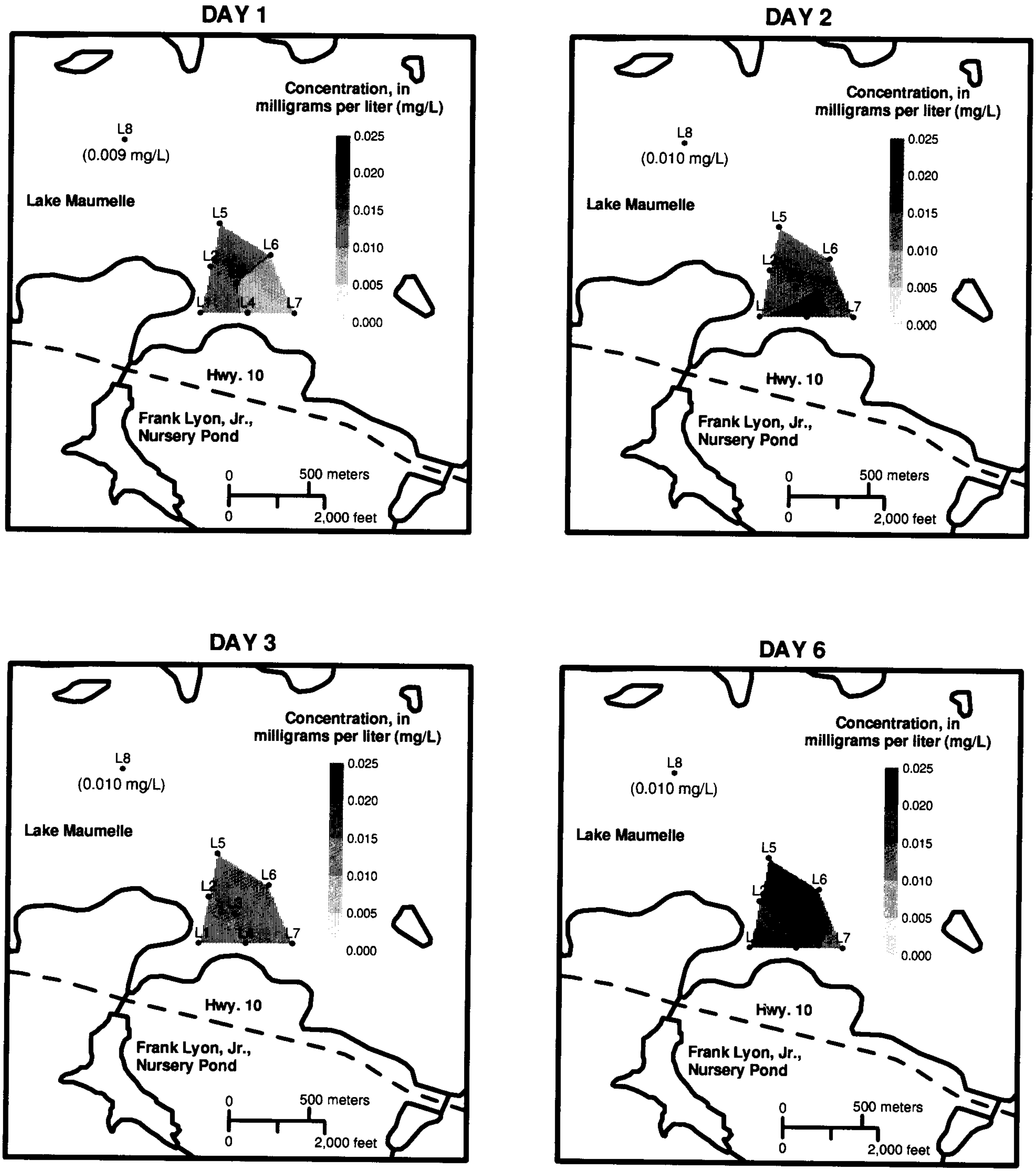



**Figure 13.** Total phosphorus concentrations at sites L1 through L8 following the 1995 release.

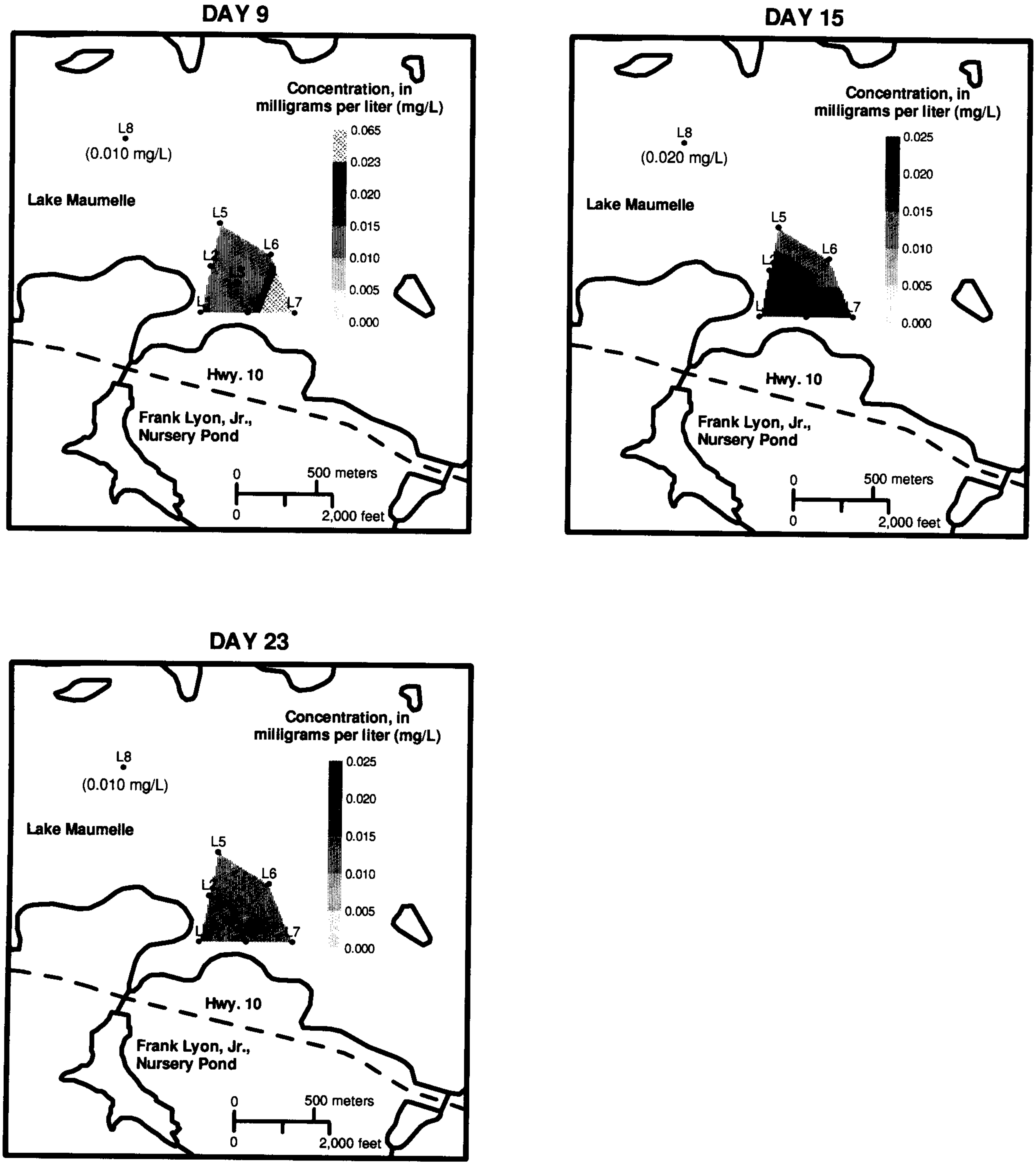



**Figure 13.** Total phosphorus concentrations at sites L1 through L8 following the 1995 release--Continued.

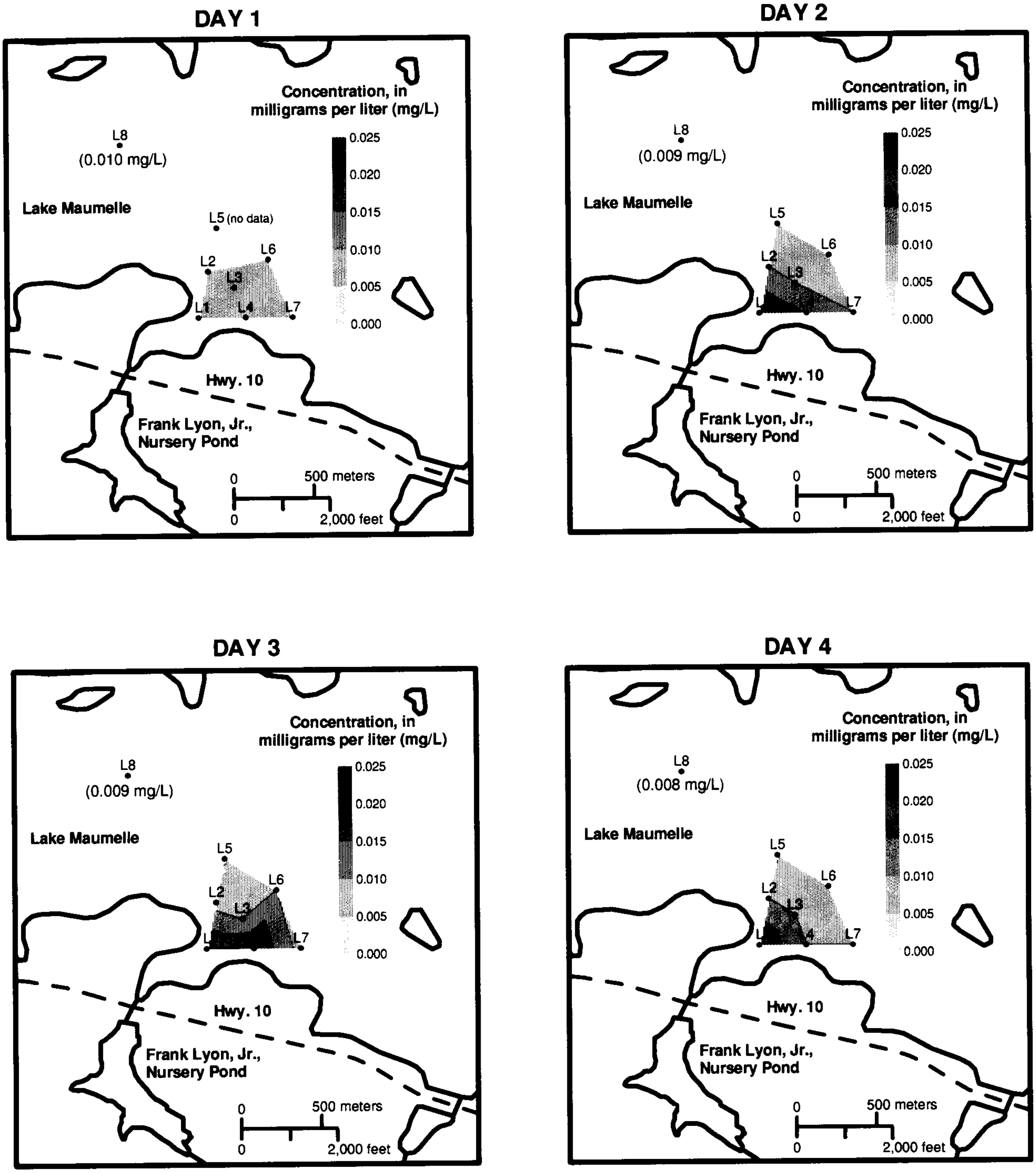



**Figure 14.** Total phosphorus concentrations at sites L1 through L8 following the 1996 release.

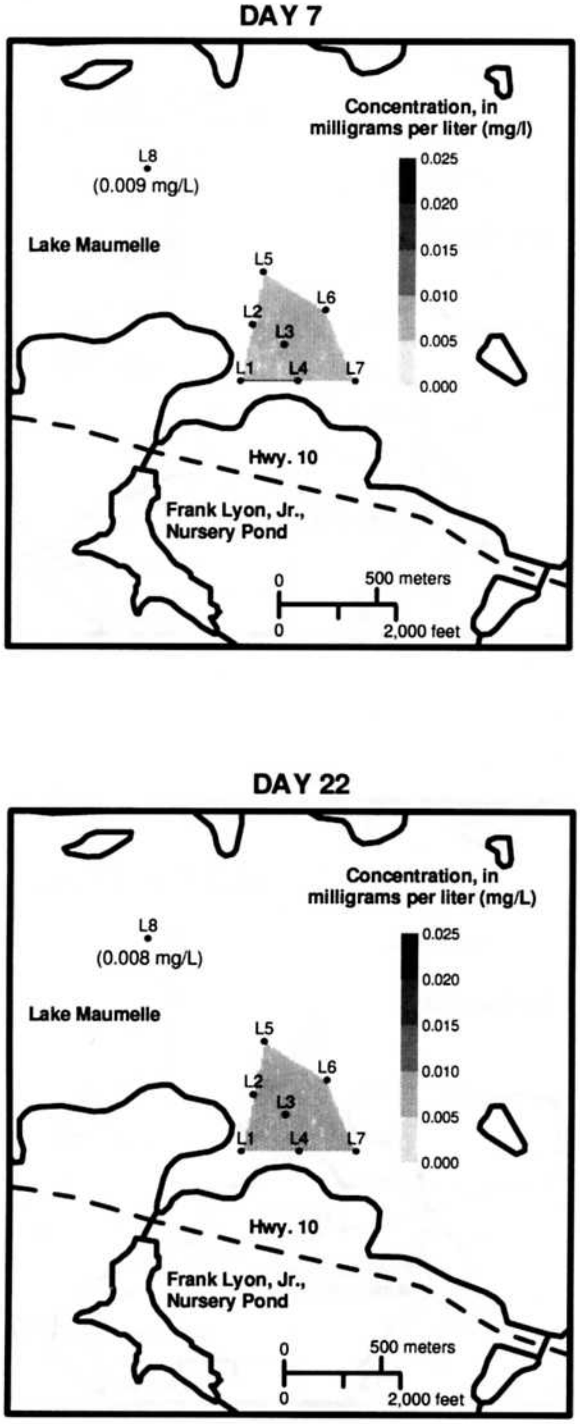



**Figure 14.** Total phosphorus concentrations at sites L1 through L8 following the 1996 release--Continued.

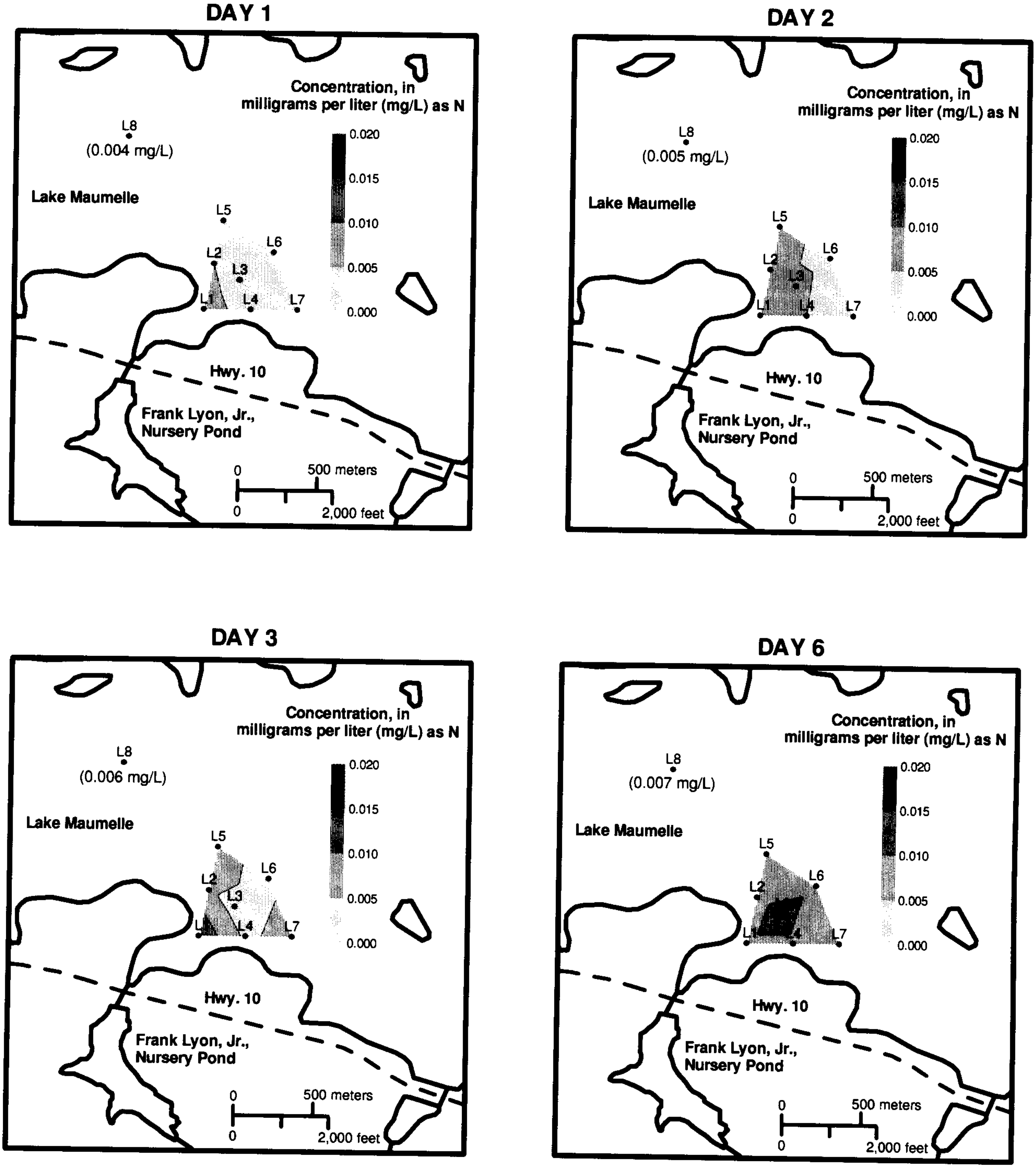



**Figure 15.** Dissolved ammonia as nitrogen concentrations at sites L1 through L8 following the 1995 release.

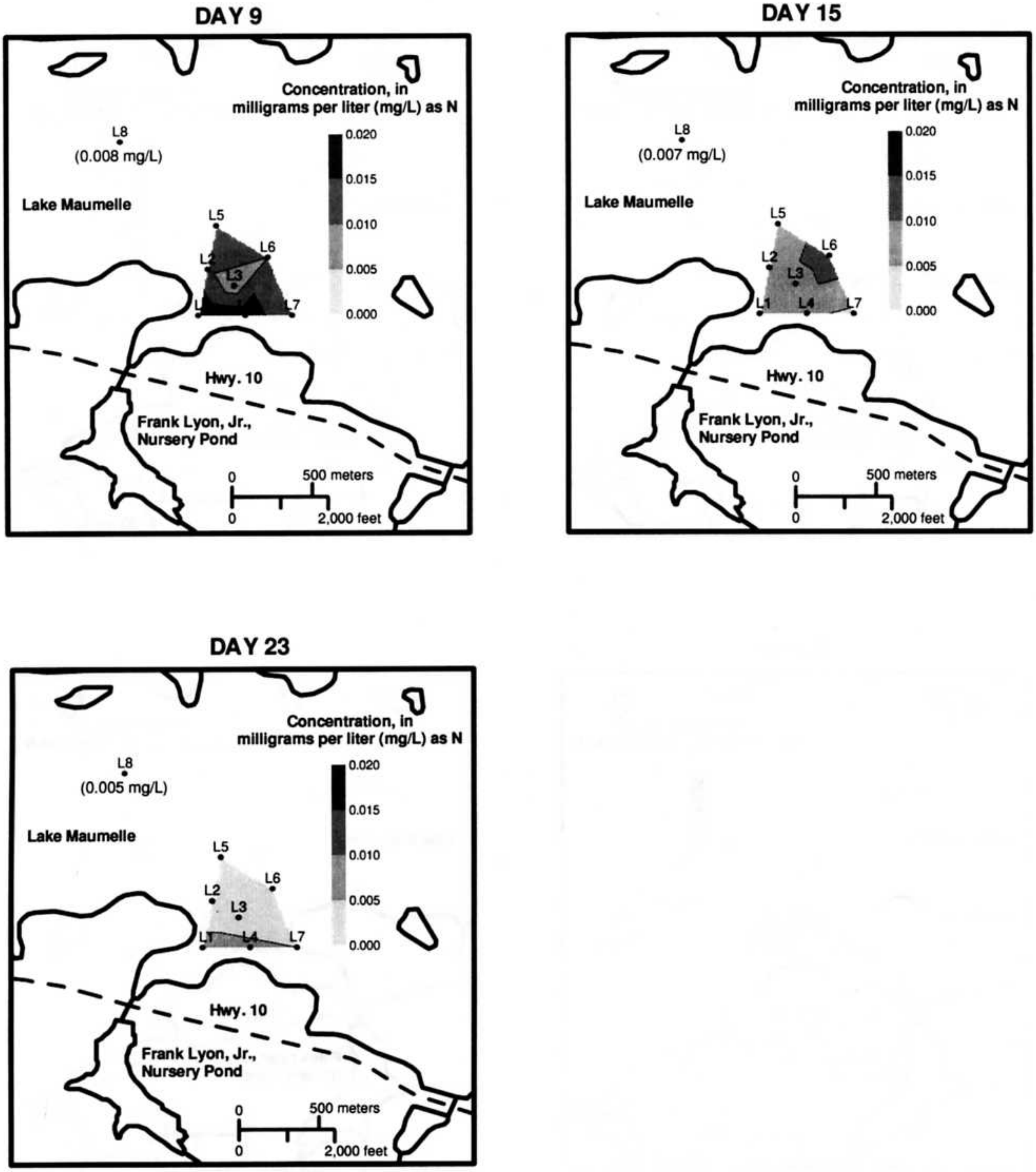



**Figure 15.** Dissolved ammonia as nitrogen concentrations at sites L1 through L8 following the 1995 release--Continued.

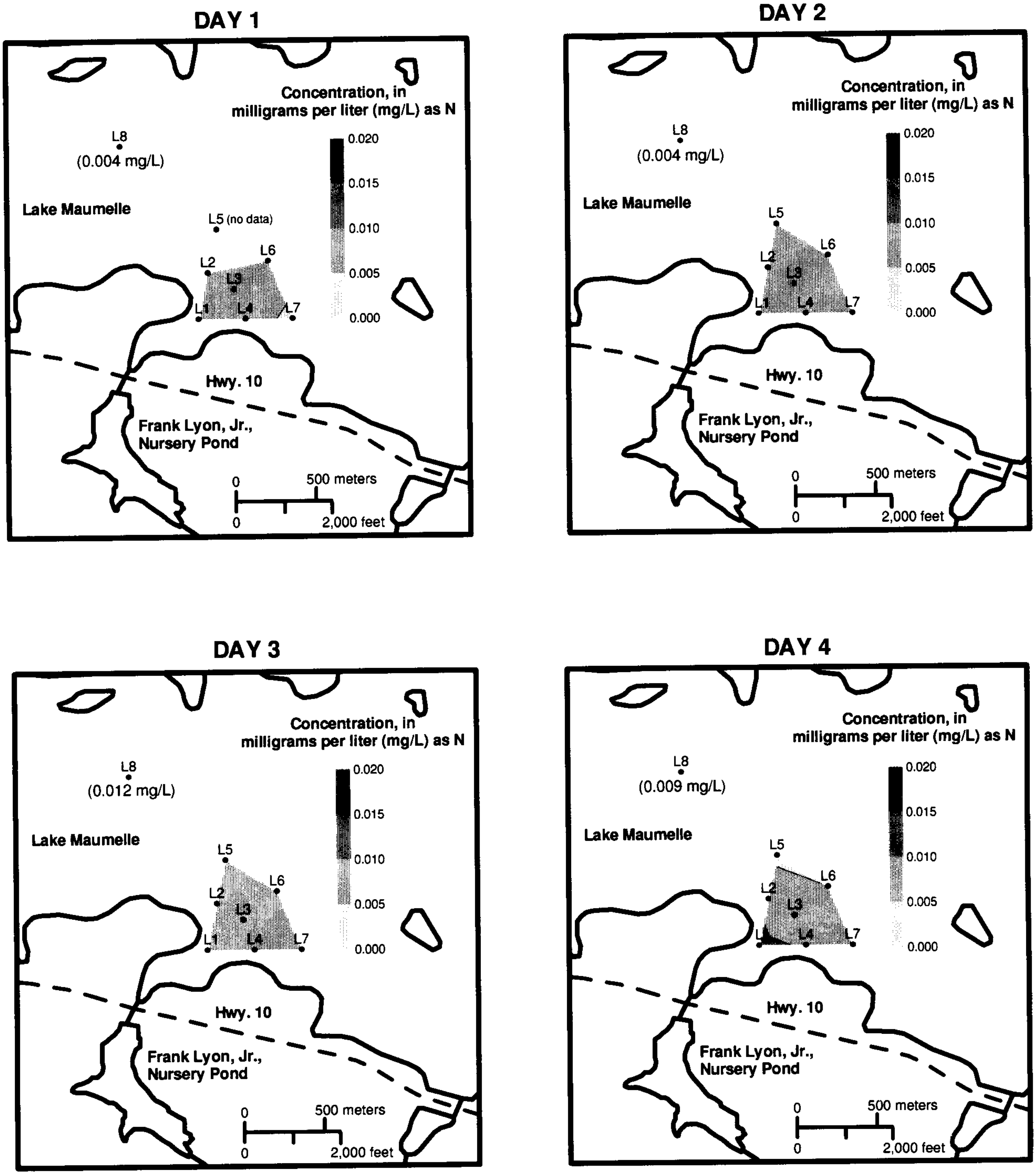



**Figure 16.** Dissolved ammonia as nitrogen concentrations at sites L1 through L8 following the 1996 release.

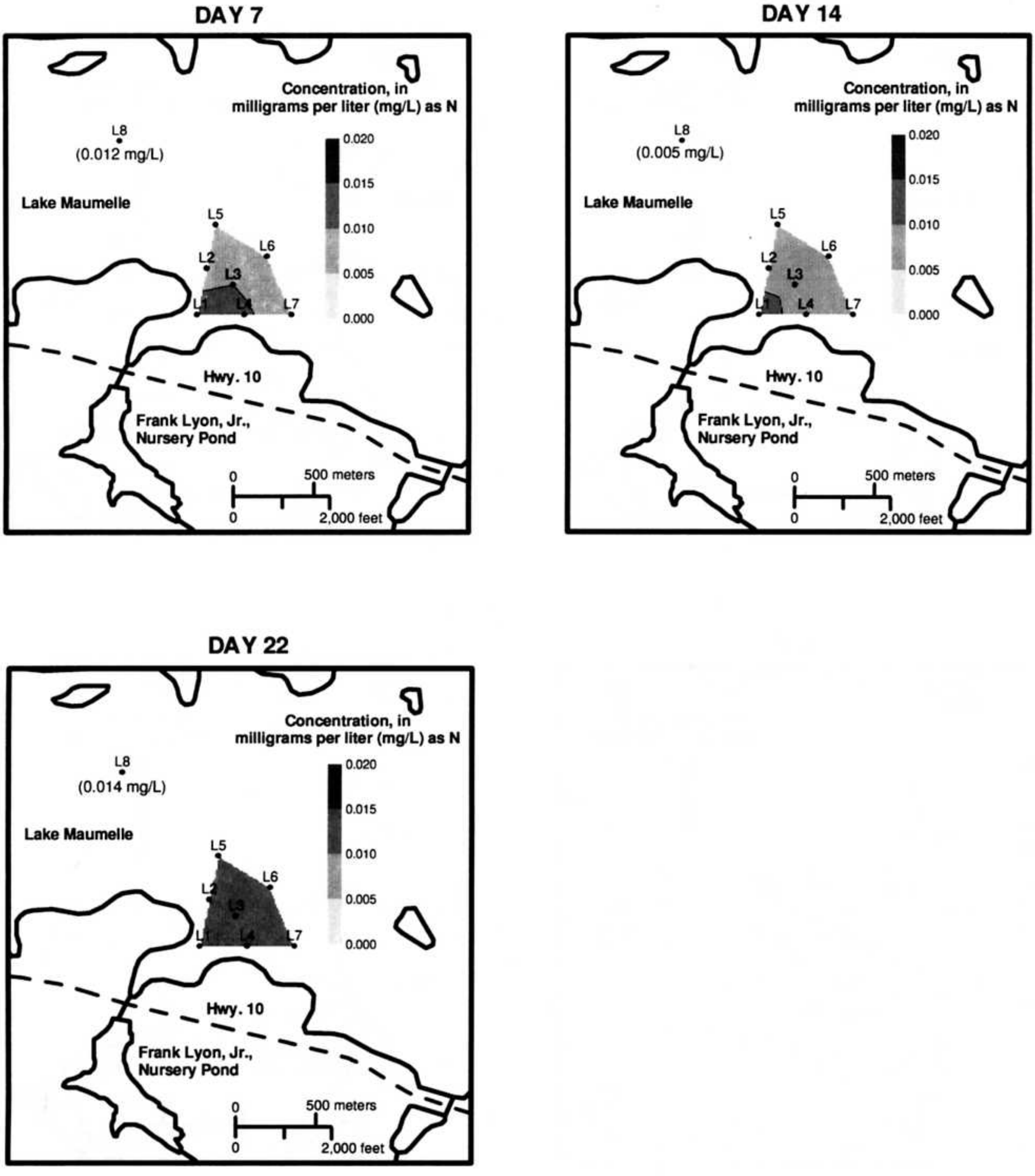



**Figure 16.** Dissolved ammonia as nitrogen concentrations at sites L1 through L8 following the 1996 release--Continued.

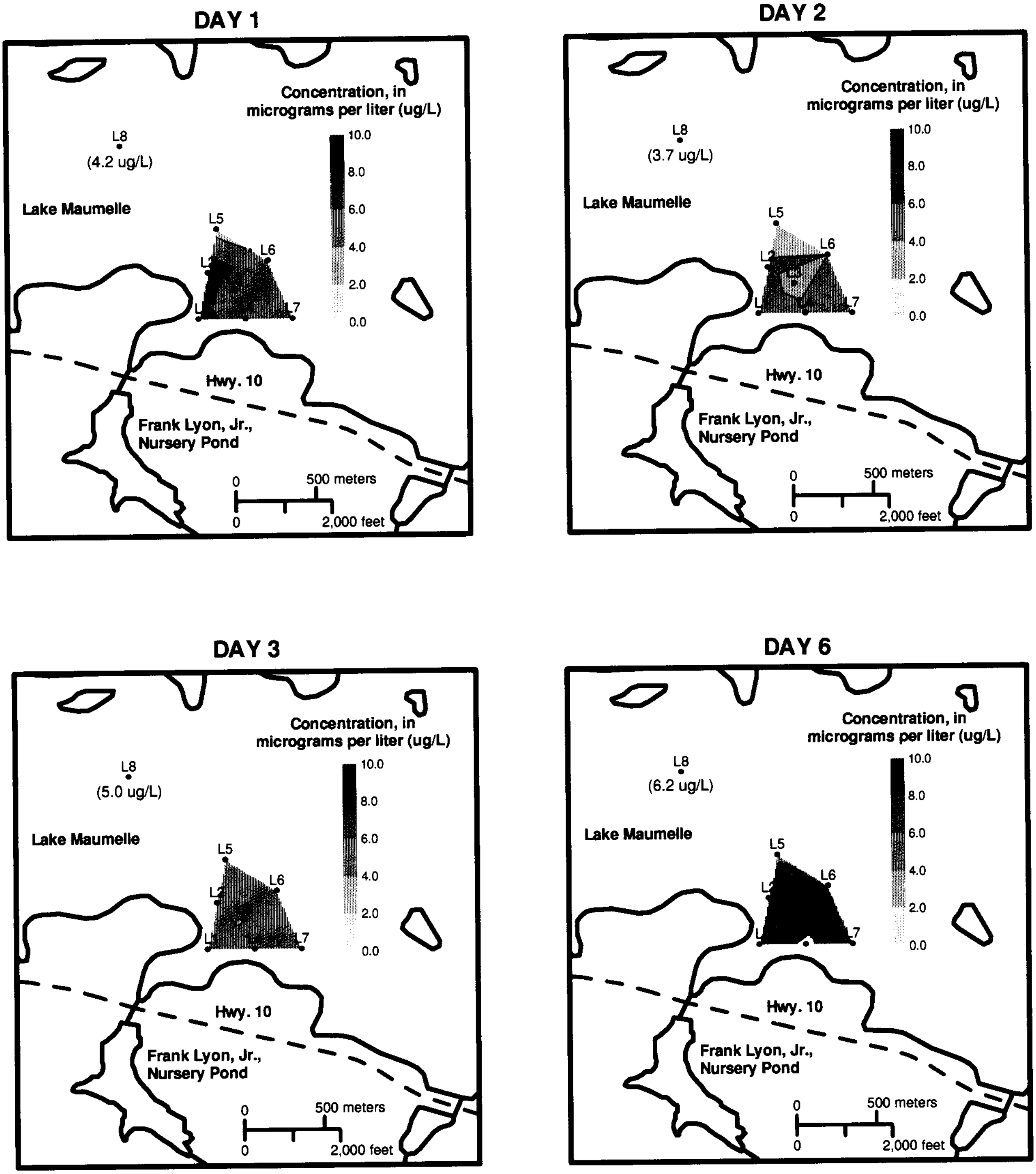
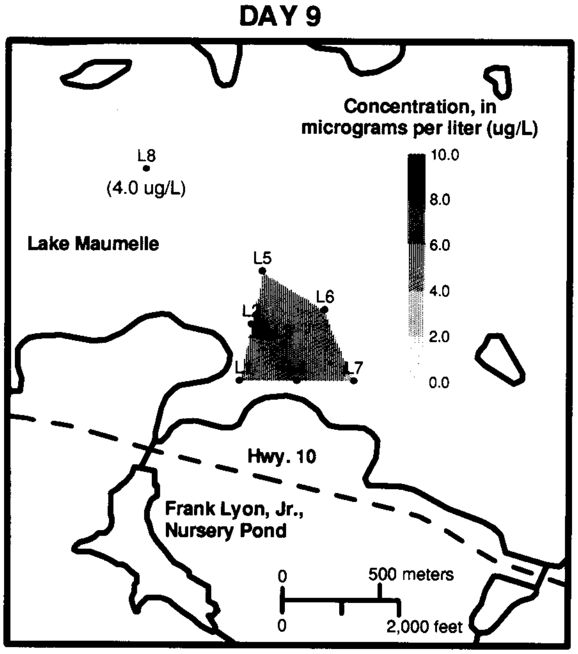



**Figure 17.** Chlorophyll *a* concentrations at sites L1 through L8 following the 1995 release.



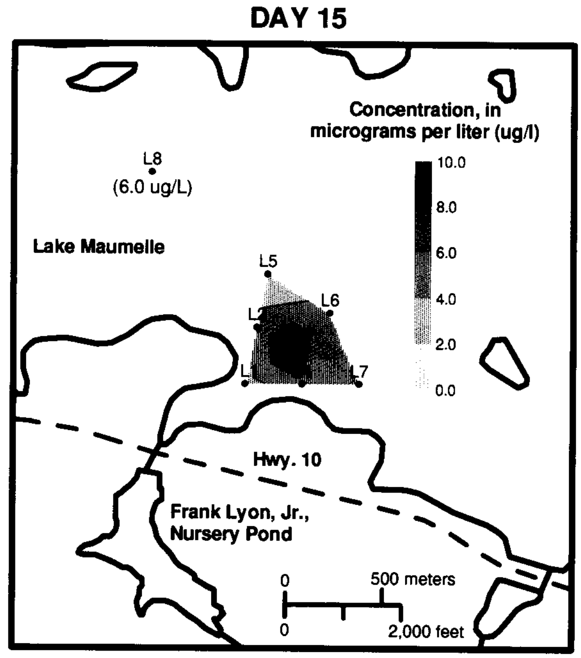




**Figure 17.** Chlorophyll *a* concentrations at sites L1 through L8 following the 1995 release--Continued.

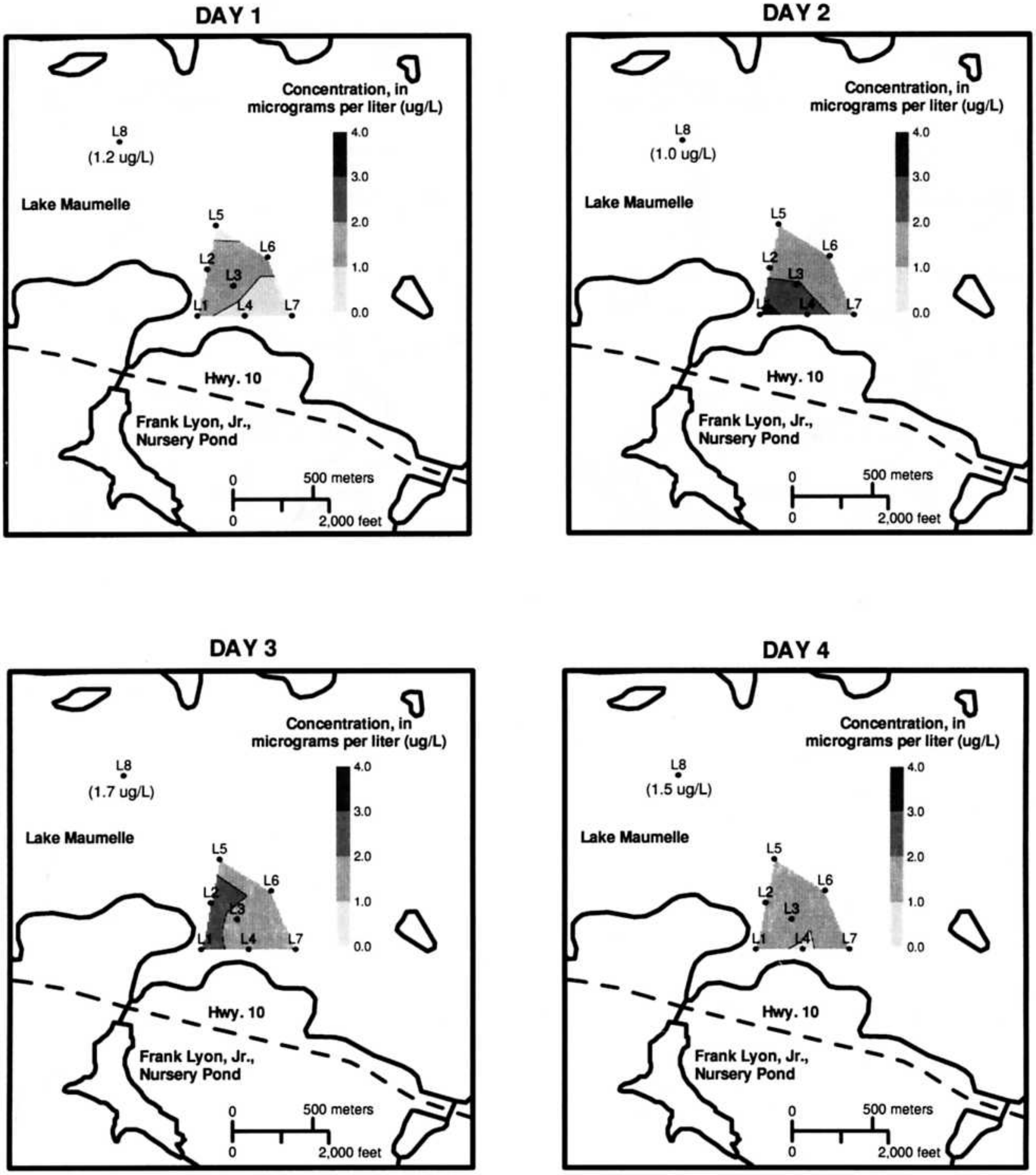



**Figure 18.** Chlorophyll *a* concentrations at sites L1 thorough L8 following the 1996 release.

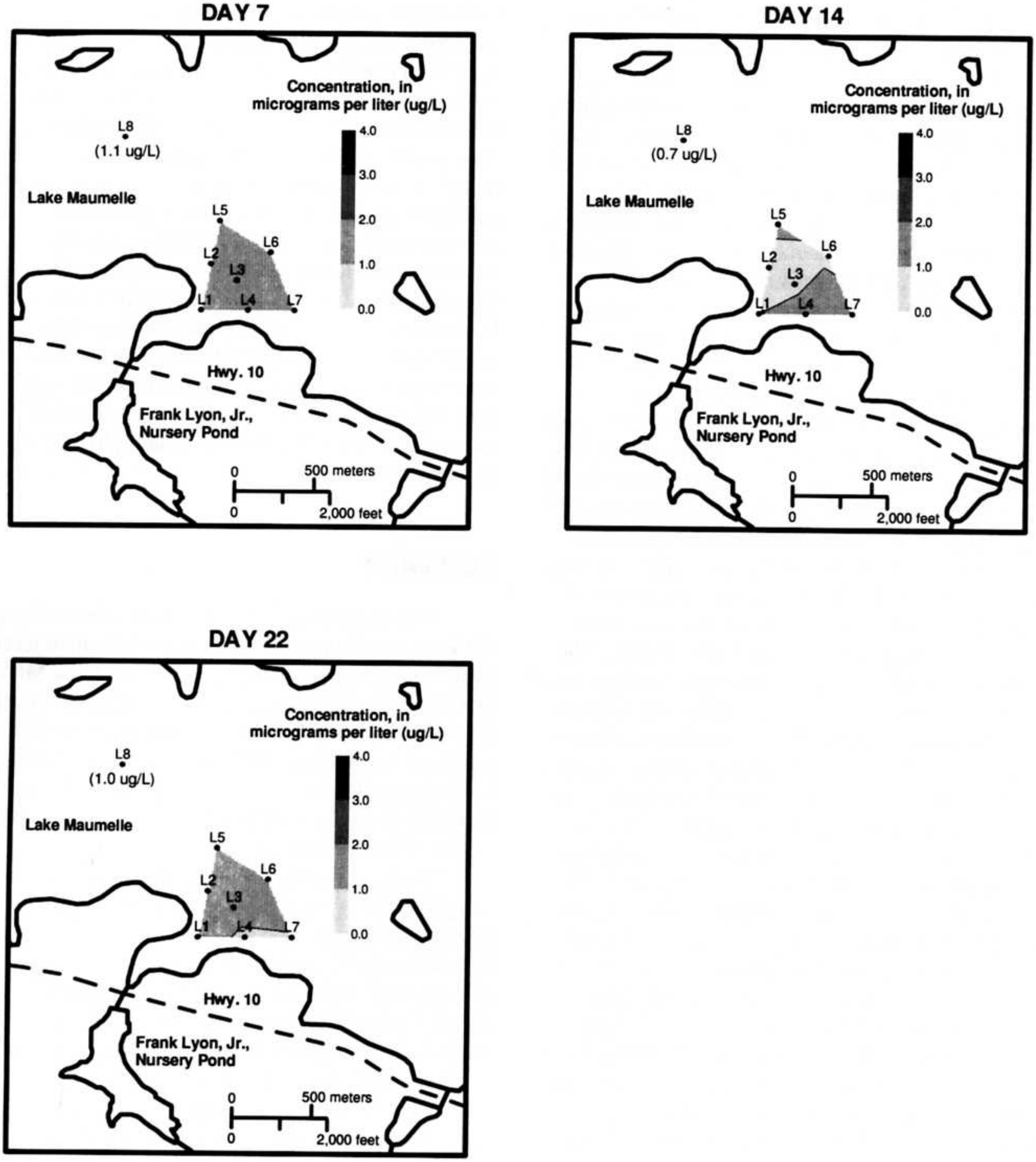



**Figure 18.** Chlorophyll *a* concentrations at sites L1 through L8 following the 1996 release--Continued.

was lower than other years, reducing the amount of water entering Lake Maumelle. Reduced nutrient loads appear to be related to reduced nursery pond volume and fertilizer applications in the nursery pond.

Potential enrichment of Lake Maumelle by nutrients from the nursery pond, over the 6-year period, can be estimated based on nursery pond nutrient loads and mean lake concentrations. The nursery pond total phosphorus mean load from 1991 through 1996 was 224 kg per release (table 2). The mean total phosphorus concentration in Lake Maumelle during this period of time (including contributions from previous Nursery Pond releases), using data from samples collected during well mixed, isothermal conditions (winter samples), was 10 μg/L. Thus, the total phosphorus load from the nursery pond would theoretically raise the concentration in Lake Maumelle by 8 percent (0.8 μg/L) to 10.8 μg/L, assuming that the load was conservative and evenly distributed throughout the water body. The mean load of dissolved orthophosphorus was 122 kg per release. The mean dissolved orthophosphorus concentration in Lake Maumelle was 1 μg/L. The dissolved orthophosphorus load from the nursery pond would theoretically raise the concentration in Lake Maumelle by 50 percent (0.5 μg/L) to 1.5 μg/L. The mean load of dissolved nitrite plus nitrate nitrogen was 6.8 kg as N per release. The mean dissolved nitrite plus nitrate nitrogen concentration in Lake Maumelle was 20 μg/L as N. The dissolved nitrite plus nitrate nitrogen load from the nursery pond would theoretically raise the concentration in Lake Maumelle by 0.1 percent (0.025 μg/L). The mean load of total ammonia plus organic nitrogen was 1,003 kg as N per release. The mean total ammonia plus organic nitrogen concentration in Lake Maumelle was 158 μg/L as N. The total ammonia plus organic nitrogen load from the nursery pond would theoretically raise the concentration in Lake Maumelle by 2.5 percent (4 μg/L) to 162 μg/L as N. The mean load of dissolved ammonia nitrogen was 327 kilograms as N per release. The mean dissolved ammonia nitrogen concentration in Lake Maumelle was 21 μg/L as N. The dissolved ammonia nitrogen load from the nursery pond would theoretically raise the concentration in Lake Maumelle by 5.7 percent (1.2 μg/L) to 22.2 μg/L as N.

Much of the nutrient load in the nursery pond was in the cooler, anoxic hypolimnetic water. This water, when released, plunged beneath the warmer water existing in the receiving embayment and moved into the open water of Lake Maumelle under the thermocline. The quantity of water and mass of constituents transported into the open water under the thermocline are unknown and probably remained isolated from the epilimnion and trophogenic zone (the superficial stratum in which photosynthetic production predominates) until fall turnover. Therefore, the impact from this load may not be evident until after turnover or later. Evidence of elevated turbidity, nutrient, and chlorophyll *a* concentrations in the epilimnetic water outside the receiving embayment was apparent for as long as 3 weeks after the 1995 and 1996 releases. However, the measured concentrations were considerably lower than what would be expected if the entire nursery pond load was evenly distributed in the water column. If the entire load had been evenly distributed in the water column in the receiving embayment and immediately outside in the open water of Lake Maumelle, much higher levels of phytoplankton biomass (chlorophyll *a*) would be expected.

## SUMMARY

The quantity and quality of Lake Maumelle, a drinking-water supply reservoir have been monitored by the U.S. Geological Survey and Little Rock Municipal Water Works since 1989. As part of this effort, the annual release of the Arkansas Game and Fish Commissions' Frank Lyon, Jr., fisheries Nursery Pond into Lake Maumelle has been monitored since 1991 to assess the impact that the release load has on the water quality of Lake Maumelle.

The purpose of the nursery pond is to raise bait and game fish to supplement the fisheries in Lake Maumelle. Management practices in the nursery pond include the application of inorganic fertilizer to enhance food-web dynamics. Once the appropriate standing crop of fish is reached, usually in July or August, the nursery pond is drained, discharging the entire contents of the pond into Lake Maumelle.

Low intensity monitoring of the nursery pond release occurred in 1991 through 1994, followed by more intense monitoring in 1995 and 1996. During 1991 through 1994, data were collected daily in the tailwater during the release and at a site located at the interface between the receiving embayment and the open water of Lake Maumelle. During 1995 and 1996, data were collected in the nursery pond prior to release and more frequently in the tailwater during the release. Data were collected at the embayment-open water interface and at seven sites in the open water of Lake Maumelle during and after the release.

Nutrient concentrations in the nursery pond, prior to release, reflected conditions typical of a thermally stratified water body with an anoxic hypolimnion. In the hypolimnetic water, nutrients, total organic carbon, iron, and manganese concentrations were greater than in the metalimnion or epilimnion. When the gate is opened to release the nursery pond into Lake Maumelle, the hypolimnetic water is discharged first. The higher concentrations of these constituents were measured in the tailwater early within each release. Concentrations generally decreased as the hypolimnetic waters were removed and the metalimnetic and epilimnetic waters were discharged.

Results indicated that the water-quality impact of the nursery pond release into Lake Maumelle is variable, and appears to be related to the volume of the nursery pond at release and the amount of fertilizer applied within the nursery pond earlier in the year. Constituent loads from the nursery pond were estimated by integrating volume discharged and constituent concentration and calculating the sum total for the release. Fertilizer application rates in the nursery pond varied over the years and evidence of this variability was apparent in the nutrient load results. Except for the 1995 nursery pond release, all constituents (except for nitrite plus nitrate nitrogen) entering Lake Maumelle from the nursery pond were greater in quantity than what would be expected in the annual areal load from that basin. In 1995, when only ammonium nitrate (no phosphorus) fertilizer was applied to the nursery pond, only 31.5 kg of total phosphorus was estimated in the release load. However, from 238 to 454 kilograms of total phosphorus were estimated in the load from 1991 through 1994. Relative to the estimated annual areal load of the nursery pond basin, the total phosphorus load from the nursery pond release was 3.5 to 7.0 times greater in 1991 through 1994, and only 0.62 times as great in 1995. Over the 6-year period, the total phosphorus load resulting from the nursery pond release averaged 3.9 times the expected annual areal load from the nursery pond basin. Dissolved orthophosphorus load from the nursery pond averaged 11 times the expected annual load from the nursery pond basin. Dissolved nitrite plus nitrate nitrogen loads were 0.08 to 0.55 times as great during the 6-year period as what would be expected in the annual areal load from the nursery pond basin. Over the 6-year period, total ammonia plus organic nitrogen loads averaged 1.6 times greater than what would be expected in the annual areal load, and dissolved ammonia nitrogen loads averaged 9.6 times greater. In 1996, total and dissolved organic carbon data were collected in the tailwater release. Total and dissolved organic carbon loads were 1.9 and 1.6 times greater, respectively, in the nursery pond release than what would be expected in the annual areal load.

Potential nutrient enrichment in Lake Maumelle from the nursery pond release would theoretically be equivalent to an 8 percent increase in concentration of total phosphorus, 50 percent increase in dissolved orthophosphorus, 0.1 percent increase in dissolved nitrite plus nitrate, 2.5 percent increase in total ammonia plus organic nitrogen, and 5.7 percent increase in dissolved ammonia nitrogen, assuming that the nutrient load was conservative and evenly distributed throughout the water body.

Much of the loaded material in the nursery pond was in the cooler, anoxic hypolimnetic water. This water, when released, plunged beneath the warmer water existing in the receiving embayment and moved into the open water of Lake Maumelle under the thermocline. The quantity of water and mass of constituents transported into the open water under the thermocline are unknown and probably remained isolated from the epilimnion until fall turnover or later. Therefore, the impact from this load may not be evident for some time following each release. Evidence of elevated turbidity, nutrient, and chlorophyll *a* concentrations (plumes) in the epilimnetic water outside the receiving embayment in the open water of Lake Maumelle was apparent for as long as 3 weeks after the 1995 and 1996 releases. However, the concentrations exhibited were considerably lower than what would be expected if the entire nursery pond load was evenly distributed in the water column outside the receiving embayment. If the entire load had been evenly distributed in the water column in the receiving embayment and immediately outside in the open water of Lake Maumelle, much higher levels of nutrients and phytoplankton biomass (chlorophyll *a*) would be expected.

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