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**Everglades Nutrient Removal Project Dye Tracer Study
- October 1994**

By

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Introduction

The Everglades Division of the South Florida Water Management District performed a pilot dye tracer study in the Everglades Nutrient Removal Project (ENRP) in October 1994, shortly after this treatment wetland began flow-through operation. The objectives of this study were to (1) gain experience in conducting large-scale tracer studies in wetlands, (2) identify any hydraulic short circuits in the upper reaches of the ENRP, (3) determine water time-of-travel and distribution of flow through culverts in the G252 Levee and (4) determine water time-of-travel at downstream locations in Treatment Cell 1.

Methods

Field and laboratory methods were followed Wilson (1968), Kilpatrick (1970) and Hubbard et al. (1981). A quantity of Rhodamine WT (47.3 L of a 20% solution), a fluorescent dye, was released into the Discharge Canal immediately downstream of the G250/G250s Inflow Pumps (Fig. 1) on the morning of October 3, 1994. The stock dye solution first was diluted with ambient water (approximately 4:1) in a holding tank (see Fig. 2). A small battery-powered bilge pump was used to pump the diluted dye solution from the holding tank into a diffuser pipe (6.1 m long x 2.54 cm i.d. PVC pipe) that was positioned across the width of the Distribution Canal. Small ports along the length of the diffuser pipe released dye to the water column. Sufficient dye was used so that the furthest downstream monitoring stations would have peak dye concentrations well above background fluorescence readings. Grab water samples were collected at each of the 10 culverts (A to J) along the G252 Levee that separated the Buffer Cell from Treatment Cell 1 (Fig. 1) at 0.5 to 1 hr intervals during the first 12 hrs after dye release and at approximately 1 to 2 hr intervals thereafter. Water samples also were collected at eight open-water stations in Treatment Cell 1 (C1, C2, C3, C4, C5, C6, ENR101, ENR102; Fig. 1) using autosamplers at 0.5, 1 or 2 hr intervals during the first 2 days of the study and at longer intervals thereafter. Stations C1, C2, C3 and C4 were situated on a large north-south oriented agricultural canal, whereas all other stations in Treatment Cell 1 were located within cattail stands adjacent to canals. Sample collection generally continued until dye concentrations decreased to less then 10% of the peak concentration at each station; sampling was concluded on October 10, 1994. A total of 821 samples were collected and analyzed. Flow monitoring equipment in the interior of the ENRP was not operational during this study. Consequently, I was unable to estimate the mass of dye that passed by these stations.

The concentration of dye in each water sample was determined from the intensity of dye fluorescence. Fluorescence was measured with a Turner Designs Model 10-AU-005 Field Fluorometer and corrected to a standard temperature following Turner Designs (1995):

$$F_r = F_s e^{[n(T_s - T_r)]}$$

(1)

where F_r is the temperature corrected fluorescence reading (f.u.), F_s is the fluorescence reading at the sample temperature (f.u.), T_s is the sample temperature (°C), T_r is the standard temperature (25 °C) and n is a dimensionless coefficient for Rhodamine WT (= 0.026). Dye concentration then was calculated as:

$$C = b + aF_r \qquad (2)$$

where C is the dye concentration (μg L^{-1}) and b and a are the intercept and slope, respectively, from linear regressions of dye standard curve data. Travel time for water to reach each station was determined based on detection of the peak dye concentration.

Results and Discussion

The bilge pump-diffuser pipe apparatus dispersed dye evenly across the width of the Distribution Canal and the dye plume was clearly visible for some distance downstream of the release point (Fig. 3). However, the dye became diluted with the darkly-stained water in the ENRP and was not always visible at the G252 culverts or at the sampling stations in Treatment Cell 1. Visual tracking of the dye plume indicated that water first traveled down the Distribution Canal and then descended into small north-south oriented agricultural canals leading to the interior of the Buffer Cell and the G252 Levee (Fig. 1). Average flow into the Buffer Cell during the study was 512,551 m^3 d^{-1} (209 cfs); daily flow ranged from 329,583 to 591,763 m^3 d^{-1} (135 to 242 cfs) (Table 1). Inflow water volumes were similar during the first five days and the last day of the study, but decreased by approximately 40% on days six and seven.

Travel times for water to reach the culverts along the G252 Levee varied considerably. Peak dye concentrations first were observed at the opposite ends of the levee (Culverts A and J) and then appeared in the other culverts after progressively longer time intervals (Fig. 4). Dye response surface (Fig. 5) and time-of-travel (Fig. 6) plots clearly illustrate that the Buffer Cell was severely short-circuited. Based on travel times, it took water almost three times as long to reach Culvert E in the center of the levee (29 hr) as it did to reach Culverts A and J (~10 hr). Note that for unknown reasons, the dye response curves at Culverts C and H did not exhibit a dye concentration peak comparable to the other culverts. Culvert flow data from a period when inflow to the Buffer Cell was comparable to inflow during this study (March 1995; Table 1) indicated that Culvert A passed at least twice the volume of water than the other culverts (Table 2).

The dye response curves at Stations C1 to C4 in Treatment Cell 1 were distinctly bimodal as opposed to the unimodal curves observed at the G252 Levee culverts (Fig. 4). Note the temporal progression of the first and second dye concentration peaks from Station C1 to C4 (indicated by dashed red lines in Fig. 4). There was a downstream decrease in the amplitude of the first dye concentration peak such that it almost disappeared by the time water reached Station C4. Station C5 also exhibited a bimodal dye response curve. The arrival of the second dye concentration peak at this station coincided with the timing of the second peak at Station C2. Water travel time at these two stations seemed to be more a function of downstream distance from the G252 Levee (C2 and C5 were approximately equidistant from the levee) rather than habitat differences that may have influenced local hydraulics (i.e., Station C5 was within a cattail stand located between two small agricultural canals while Station C2 was directly on a large canal). Markedly lower dye concentrations at the remaining stations in Treatment Cell 1 (C6, ENR101 and ENR102)

were attributed to dispersion of the dye as it moved down through the cell. Water travel times to Stations C6 and ENR101 appeared to be much longer than at the abovementioned stations. Missing data at Station ENR102 due to equipment malfunction made it difficult to interpret its dye response curve.

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Joanne Chamberlain, Mariano Guardo, Steve Kelly, Chad Kennedy, Tom Kosier and Jayantha Obeysekera of the Everglades Division, SFWMD were instrumental in carrying out the field and laboratory portions of this study.

References

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Kilpatrick, F.A. 1970. Dosage requirements for slug injections of rhodamine BA and WT dyes, in Geological Survey research, 1970. U.S. Geological Survey Professional Paper 700-B, p. 250-252.

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Table 1. Daily flow into the Buffer Cell during the dye tracer study (October 1994) and a period of comparable flow in March 1995.

	G250 ($m^3 d^{-1}$)	G250s ($m^3 d^{-1}$)	Total ($m^3 d^{-1}$)
3-Oct-94	252,291	327,956	580,247
4-Oct-94	253,906	337,857	591,763
5-Oct-94	253,221	336,556	586,776
6-Oct-94	254,615	335,059	589,674
7-Oct-94	254,052	287,179	541,231
8-Oct-94	254,640	74,944	329,583
9-Oct-94	255,569	88,138	343,707
10-Oct-94	453,815	80,612	534,428
MEAN	279,014	233,538	512,551
24-Mar-95	420,028	55,811	475,839
25-Mar-95	531,005	102,086	633,091
26-Mar-95	528,558	58,796	587,354
27-Mar-95	522,931	78,582	601,513
28-Mar-95	512,778	61,353	574,131
29-Mar-95	381,519	113,291	494,810
MEAN	482,803	78,320	561,123

Table 2. Daily flow discharged from the Buffer Cell through culverts in the G252 Levee and the proportion of the total flow in each culvert, March 24-29, 1995. See Fig. 1 for location of culverts.

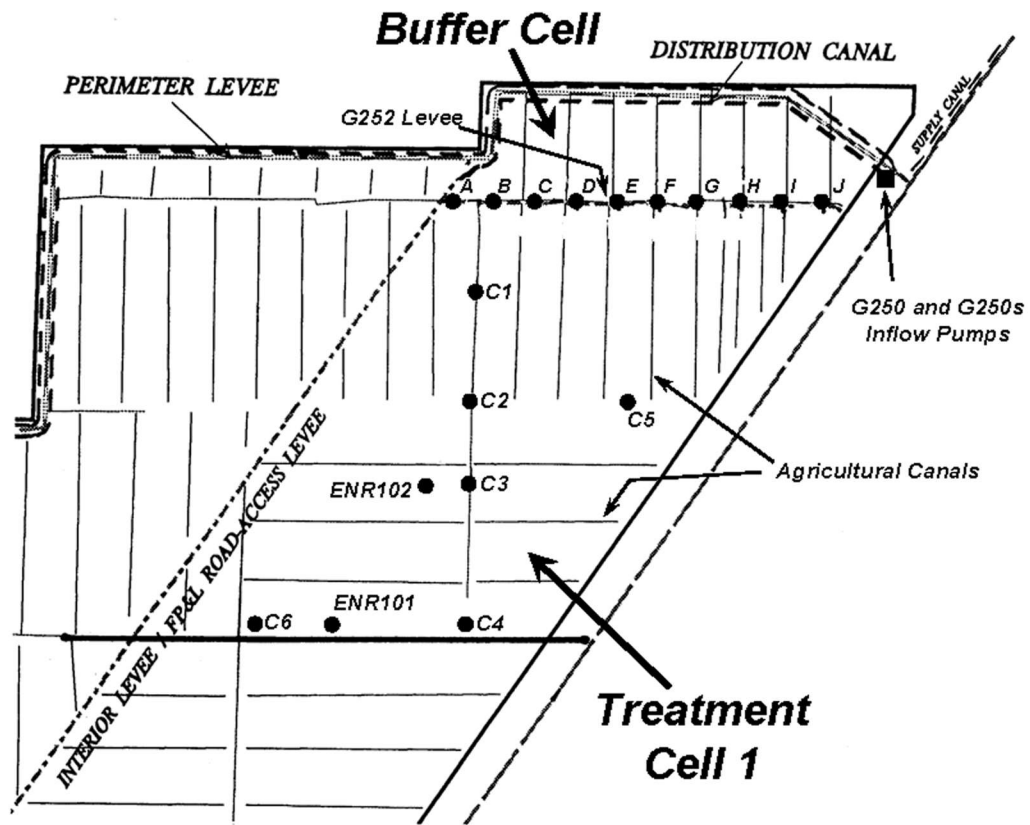|	A ($m^3 d^{-1}$)	B ($m^3 d^{-1}$)	C ($m^3 d^{-1}$)	D ($m^3 d^{-1}$)	E ($m^3 d^{-1}$)	F ($m^3 d^{-1}$)	G ($m^3 d^{-1}$)	H ($m^3 d^{-1}$)	I ($m^3 d^{-1}$)	J ($m^3 d^{-1}$)	TOTAL ($m^3 d^{-1}$)
24-Mar-95	64,785	21,662	21,178	18,278	35,253	28,013	32,028	32,028	22,017	22,012	297,254
25-Mar-95	85,552	35,727	32,561	28,030	48,087	38,162	45,242	45,242	31,681	31,681	421,966
26-Mar-95	81,207	37,707	32,855	27,588	40,731	35,563	43,666	43,666	31,695	31,695	406,374
27-Mar-95	77,955	38,379	32,826	28,018	41,279	35,889	44,026	44,026	31,989	31,989	406,376
28-Mar-95	75,372	36,065	33,941	30,171	41,054	36,535	43,348	43,348	30,817	30,817	401,468
29-Mar-95	69,099	35,867	30,585	26,132	35,517	32,451	38,766	38,766	28,390	28,388	363,960
MEAN	75,662	34,235	30,658	26,370	40,320	34,436	41,180	41,180	29,431	29,430	382,900
% TOTAL	19.8%	8.9%	8.0%	6.9%	10.5%	9.0%	10.8%	10.8%	7.7%	7.7%	

Figure 1. Map of the Everglades Nutrient Removal Project showing sampling stations along the G252 Levee and in Treatment Cell 1 used during the dye tracer study.

Figure 2. Preparations for releasing dye tracer into the Everglades Nutrient Removal Project, October 1994. Panel A: diluting the stock Rhodaine WT dye solution in the holding tank; Panel B: attaching diffuser pipe apparatus to the holding tank; Panel C: positioning diffuser pipe across the distribution canal downstream of the Inflow Pump Station; Panel D: close-up of a port in the diffuser pipe.
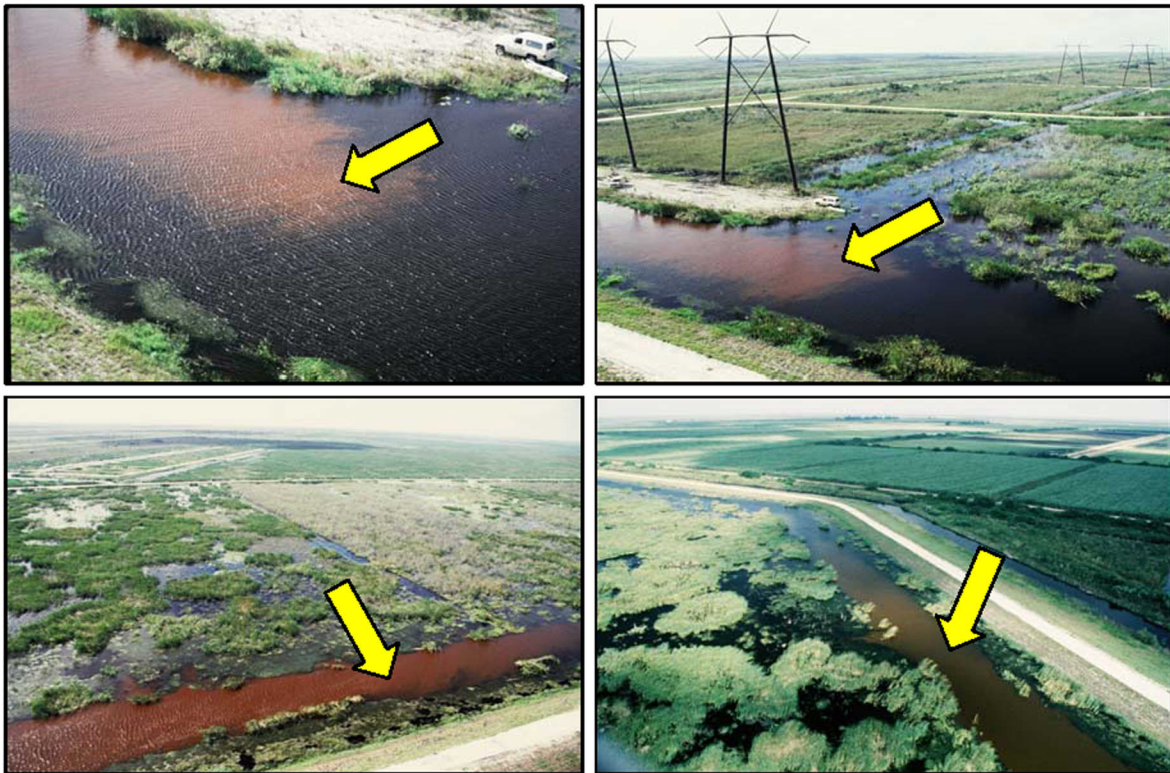
Figure 3. Aerial photographs of dye moving through the Buffer Cell shortly after the start of the dye tracer study, October 1994. Arrows indicate the dye; note the difference in color of the dye plume from adjacent water in the wetland.
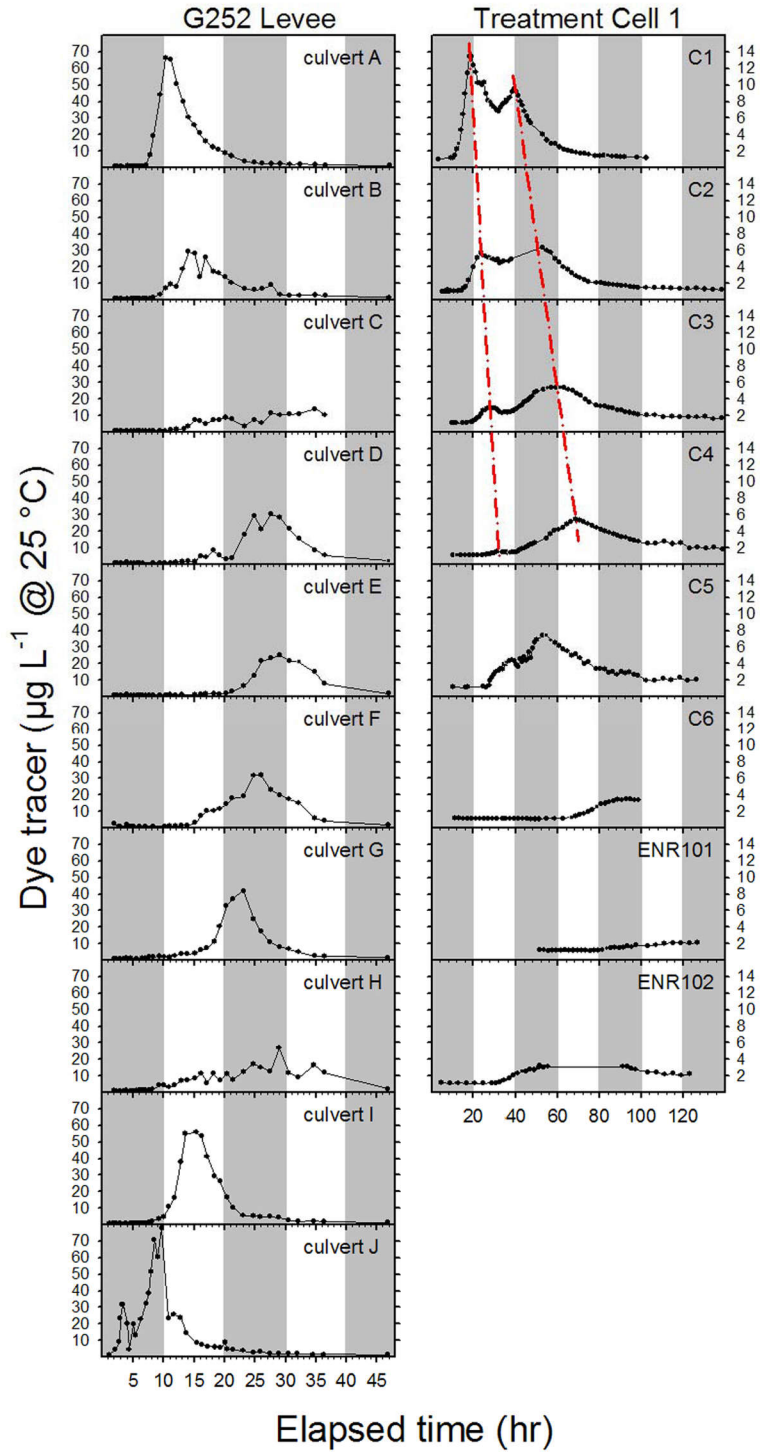
Figure 4. Dye response curves at sampling stations in the Everglades Nutrient Removal Project, October 1994. See Fig. 1 for location of stations. Dashed red lines denote the temporal progression of dye concentration peaks from Stations C1 to C4.
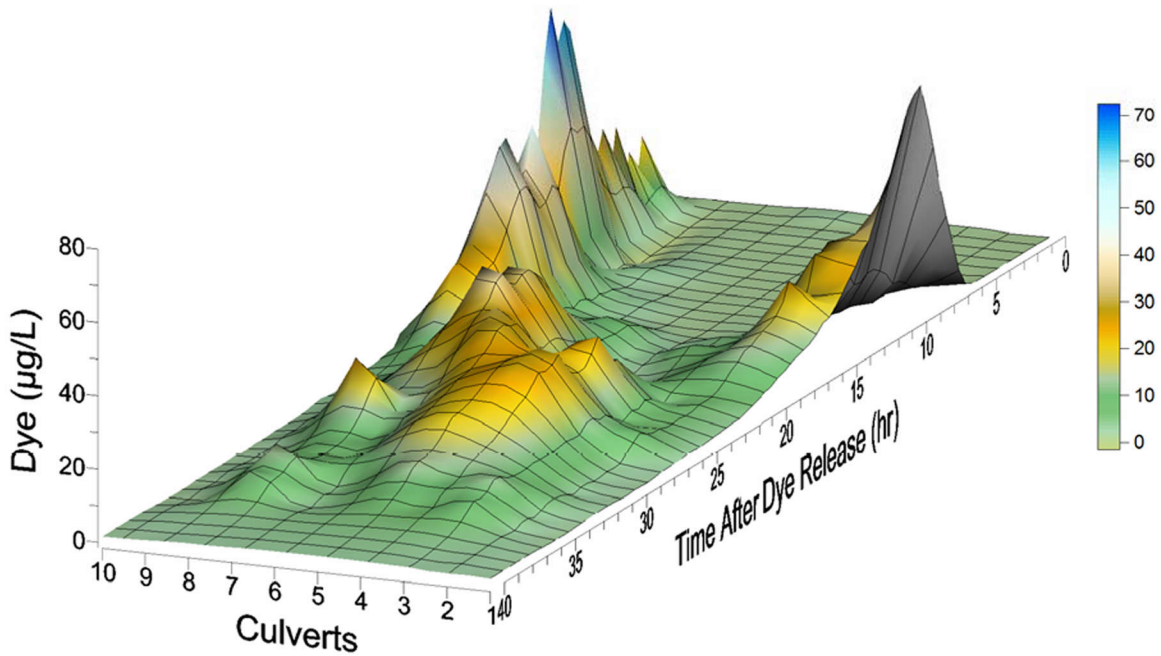
Figure 5. Response surface showing change in dye concentration in culverts along the G252 Levee, October 1994. Culvert 1 corresponds to Culvert A in Fig. 1; correspondingly, Culvert 10 corresponds to Culvert J.
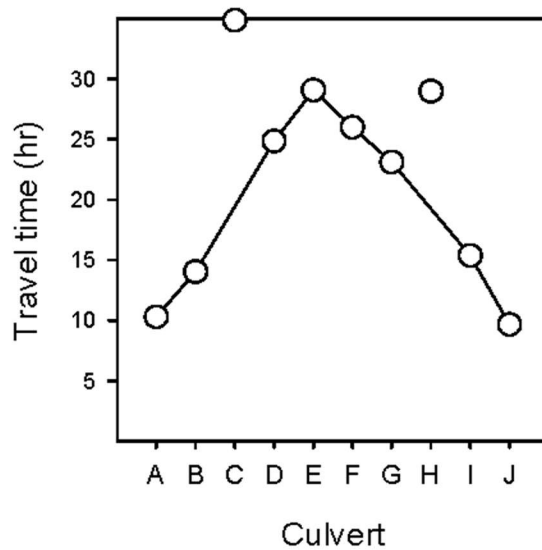
Figure 6. Travel time for water to reach individual culverts along the G252 Levee based on appearance of peak dye concentration, October 1994. Note that the line connecting the points ignores travel times for Culverts C and H.