THE EFFECTS OF LIVESTOCK MANURE APPLICATION METHODS ON WATER QUALITY, FOCUSING ON NITROGEN AND BACTERIA TRANSPORT IN SOIL

Final Report

Upper Thames River Conservation Authority, London Ontario.

March 29, 1996

BACKGROUND

The trends toward liquid manure handling systems and conservation tillage systems in Ontario have raised questions regarding the best manure management methods to achieve maximum economic yield while preventing nitrogen and bacterial contamination of tile drains and groundwater. Liquid manure application methods, application rates for different soils and crops, and the timing of application are among questions being asked by producers.

Beauchamp and Kachanoski (1990) have suggested that conservation tillage practices should work well with manure injection systems by conserving nitrogen and reducing nutrient runoff losses. In addition, chisel plowing after manure application should result in sufficient crop residues left on the soil surface to prevent significant runoff of nutrients, however, incorporation of manure into no-till cropping systems remains a problem. The authors cite a Quebec study that found when manure was used as a source of nitrogen in a no-till corn crop, poorer corn seedling emergence, weed control and an increased risk of frost damage occurred. In addition, the formation of macropores including earthworms channels, which is enhanced by a reduction in tillage, can increase the likelihood of manure contaminants reaching the tile drains. Research has indicated that while conventional injection methods may be effective in reducing odours and losses of ammonia to the air they may result in levels of tile water contamination equal to or greater than surface broadcasting methods (Fleming and Bradshaw, 1992).

While it is frequently assumed that bacteria are not transported great distances through the soil matrix, recent studies have suggested that bacterial transport through soil macropores may be a significant process in contamination of tile drainage waters. Patni *et al.* (1984) reported an increase of fecal bacteria populations in tile drain water minutes to hours after irrigation with liquid manure. In tile drains with an average depth of 75 cm Culley and Phillips (1982) observed high fecal bacteria counts for several days following fall or winter application of liquid manure. Recent studies by

Dean and Foran (1991) in southwestern Ontario have further increased concerns with respect to direct transport of bacteria to tile drains from liquid manure applications. In their field studies they observed that tile drains became contaminated with fecal coliform shortly after liquid manure application for 9 of 12 events monitored. In these studies, tillage of the soils prior to manure application appeared to disrupt macrospore continuity and prevent bacteria transport to the tile drains.

The role of macropores in the transport of surface applied nutrients is not yet well understood and is of particular concern for no-till fields where agricultural amendments are usually applied to the soil surface and macrospore systems are not subjected to periodic disruption by tillage (Shipitalo *et al.* 1990). The lack of disturbance or disruption by tillage, which is associated with no-till systems, has also been shown to result in increased earthworm activity that can significantly contribute to macrospore formation (Beven and Germann 1982; Edwards *et al.* 1988). The phenomenon of preferential flow by macropores acts to conduct water and solutes quickly to significant soil depths without the soil matrix being saturated (Beven and Germann, 1982; Thomas and Phillips, 1979). Measurement has been limited of the magnitude of nutrient losses by preferential flow in unsaturated soil and accompanying solute transport variability from a field scale under no-till management.

Objectives:

In a joint effort between Agriculture and Agri-Food Canada, the Upper Thames River Conservation Authority and the Ontario Ministry of Agriculture Food and Rural Affairs, this study was conducted with the following objectives:

1) To evaluate several manure management application techniques used in conservation management systems to determine the best method to minimize downward movement of nutrient and bacteria to tile drains under three different soil types;

2) To compare fuel consumption requirements of manure management application techniques and recommend practices with field scale testing;

3) Conduct detailed crop monitoring to determine the effects of the manure application methods on crop growth and yield.

METHODOLOGY

Two field sites with contrasting soils, medium and light textured, containing 12 parallel tiles under a no-till corn crop management system were studied. A third site (heavy textured soil) was located and instrumented for use in the 1996 field season. Several detailed soil pits were completed for each site to determine the soil characteristics for the sites. Soil data including texture, horizonation, bulk density, hydraulic conductivity, organic matter and pH were collected. Soil series and drainage classification were assigned to each pit area. Detailed soil data is given in table 1 for the medium texture soil (Kintore) and the light textured soil (Putnam).

Tile drains were intercepted in a perpendicular transect spanning the field and 22 L buckets inserted into the tile lines (Figure 1). Small water pumps were placed in the buckets and monitored using a datalogger. Flow rates in the tiles were determined from the frequency and duration of the pump operation. Tile drainage flow and quality (NO_3-N, NH_4-N and bacteria) were monitored for the growing season (April-October).

From the soil and manure analysis, the application rate of the manure required to supply the total nitrogen to the crop was determined for each site. A detailed crop monitoring program was setup in the spring prior to planting. Monitoring included weed pressure, plant population, crop disease, time to silking, lodging and yield. Yield was conducted using a weigh wagon and moisture meter.

Manure was applied using three application methods; (1) surface spreading, (2) conventional injection, and (3) modified injection (loosening the soil ahead of the injectors). In addition to the application treatments, control plots were established. Treatments were replicated 3 times. Manure was applied over each tile line in two passes covering a width of 8 m for 60 m of tile length. The manure applied had a bacterial and chemical tracer (strontium chloride for year 1 and bromide for year 2) added prior to application. Following manure application the tiles were monitored every 15 minutes and sampled for flow rate, nutrients, bacteria and tracer content for a period of three hours. Nutrient analysis included total nitrogen, ammonium and nitrate and total and soluble phosphorous.

Bacterial analysis included fecal coliform and the tracer bacteria. An ISCO automated water sampler was used at each of the tile lines to collect samples every 3 hours the subsequent night. On the day following manure application, the field was irrigated (1 inch of water) using a travelling gun. Sampling was conducted at 15 minute intervals for the first 3 hours, then at 3 hour intervals for the following 24 hours. Sampling continued on a weekly bases for the remainder of the growing season.

Comparisons of draft and fuel consumption between methods of manure application were carried out in cooperation with Dr. N. McLaughlin of the Research Branch, Agriculture and Agri-Food Canada, Ottawa. Each application method was monitored for fuel consumption, time to apply the manure and draft.

Table 1: Detailed Soil Information for Medium Textured Soil (Kintore) Manure Application Site

Soil Series: *Crombie*

Drainage: *Poor*

Site: *Pit # 1*

Horizon	Depth cm	Texture	Sand %	Silt %	Clay %	pH $CaCl_2$	$CaCO_3$ %	OM %	Pb gm/cc	Ksat cm/hr
Apk	0-25	SIL	35	50	15	7.2	1.4	3.1	1.31	13.2
Ckgj	25-42	FSL	70	24	6	7.5	14.3	0.5	1.51	0.2
Ckgl	42-52	L	51	41	9	7.6	28.4	0.4	1.72	0.6
Ckg2	52-85	L	52	37	11	7.6	24.9	0.3	1.89	1.5

Soil Series: *Embro*

Drainage: *Imperfect*

Site: *Pit # 2*

Horizon	Depth cm	Texture	Sand %	Silt %	Clay %	pH $CaCl_2$	$CaCO_3$ %	OM %	Pb gm/cc	Ksat cm/hr
Ap	0-25	SIL	24	57	19	6.8	1.0	5.6	1.16	1.9
Bmgj	25-50	L	51	37	12	7.2	1.7	0.4	1.55	0.04
Ckg	50+	SIL	37	53	10	7.6	24.6	0.4	1.56	0.1

Table 1: (cont'd.) Detailed Soil Information for the Light Texture Soil (Putnam) Manure Application Site

Series: Brisbase

Drainage: Imperfect

Site: *Pit # 1*

Horizon	Depth cm	Texture	Sand %	Silt	Clay %	pH $CaCl_2$	CaO_3 %	OM %	Pb gm/cc
Ap	0-30	L	45	45	10	6.9	1.7	3.9	1.29
Bm	30-44	L	48	42	10	6.9	0.2	1.7	1.46
Bmgj	44-75	FSL	61	30	9	7.2	3.8	0.5	1.46
Ckgj	75-87	GFSL	69	26	5	7.3	24.2	0.1	1.43
Ckg	87+	FSL	52	43	5	7.7	28.4	0.4	

Site: *Pit # 2*

Series: Brisbane

Drainage: Imperfect

Horizon	Depth cm	Texture	Sand %	Silt %	Clay %	pH $CaCl_2$	$CaCO_3$ %	OM	Pb gm/cc
Apt	0-17	L	45	42	13	7.0	1.2	4.3	1.27
Ap2	17-26	L	43	45	12	7.2	0.8	3.4	1.21
Bm	26-42	L	45	41	14	7.3	1.6	1.8	1.49
BC	42-53	GL	48	39	13	7.4	4.9	1.0	
Ck	53-69	GSL	74	20	6	7.5	12.8	0.7	
Ckg	69-90	L	44	45	11	7.8	30.6	0.3	1.82

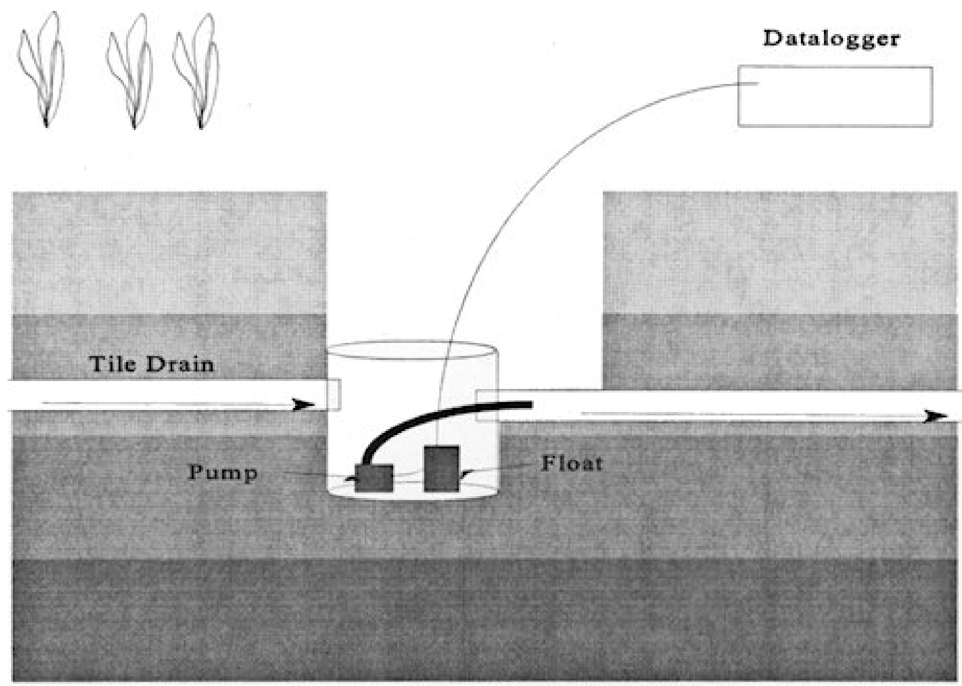

Figure 1: Tile drain monitoring installation for field scale study.

PRELIMINARY FINDINGS

Water Quality

Medium textured soil (Kintore)

The preliminary results indicate that some form of soil disturbance in the surface soil can decrease the amount of nutrients and bacteria entering the tile drains if manure is applied when the tiles are flowing. The application of manure to the plots, which were randomly established over existing field tile lines, resulted in increased flow rates for all treatments. The surface applied method resulted in the greatest increases in flow rates immediately following manure application (day 1).

The results suggest that the application of manure to a tile drain field when tiles are flowing, using any of the methods tested, will cause levels of nitrogen, phosphorus and bacteria to increase within 3 hours of application. Manure contamination was visually evident within as little as 7 minutes with the surface applied application method. It took 10 to 20 minutes to appear in the tiles under the conventional and the modified injection methods. All treatments exceeded water quality standards for phosphorus and bacteria concentrations. Within approximately 12 hours bacteria, ammonia and phosphorus levels had dropped off, but were still above water quality standards.

Irrigation resulted in an increase flow for all tiles. Bacteria, ammonia and phosphorous levels increased for all treatments as well, but were still higher from the surface applied method. Within 48 hours following irrigation bacteria, ammonia and phosphorus levels had dropped off to below water quality standards.

Strontium and Chloride were also observed in the tile flow water from all treatments, within 10 minutes of application, suggesting that the macropore flow was probably the main source of tiles contamination within the first few minutes following application. With strontium being a reactive tracer it would be expected to react with the soil quickly and not move to the tile water. Soil tests conducted two weeks following the manure application showed that most of the strontium remained in the upper 30 cm for the modified injection method, but conventional injection and surface applied had a significant amount move to the 30 - 60 cm depth or can not be accounted for (figure 2).

Figure 3 shows the effect of rainfall on tile flow. There is a relatively quick response of the tiles from rainfall in early spring when the ground is at a higher moisture, but as the soil dries tile response time diminishes rapidly.

The loadings of nitrate to the tiles was not significantly affected by the application of manure the first day following manure application, however, there was a slight increase in nitrate concentrations several days after manure application. The nitrate levels dropped back to background levels within two weeks following application (figure 4). The average nitrate levels ranged form a high of 10.6 ppm from surface applied to a low of 8.4 ppm for conventional injection. The total seasonal loadings of nitrate to the tile drains ranged from a low of 27 kg/ha to a high of 50 kg/ha. It should be noted that a large portion of the nitrogen loss was observed in the early spring before planting and for several weeks following manure application when tile flow was highest.

Light textured soil (Putnam site)

The preliminary results indicate that if there is no tile flow, and the soil is relatively dry, manure application alone does not seem to cause tile contamination on a light textured soil. The application of manure to the plots resulted in no flow for all treatments.

The results suggest that the application of manure to a tile drain field when tiles are not flowing, using any of the methods tested, will not cause tile contamination, if however, irrigation (simulated rainfall) occurs within 24 hours of manure application, tile contamination is evident under surface applied, controls and to a lesser extent modified injection. Conventional injection had no tile flow, but this is probably due more to the soil characteristics under these tiles, rather then the actual treatment, because only one modified injection tile flowed. All surface and control tiles flowed following irrigation. Bacteria and bromide were detected in the tile flow as well as increased levels of ammonia and phosphorus. This indicates that the manure was moving with the irrigation water to the tile drains. The tests will be repeated in 1996 with different tiles being used for the treatments. This should eliminated and problems with the different soil characteristics across the field.

On a seasonal bases, figure 5 shows the effect of rainfall on tile flow. There is a relatively quick response of the tiles from rainfall in early spring when the ground is at a higher moisture content, but as the soil dries tile response time diminishes rapidly.

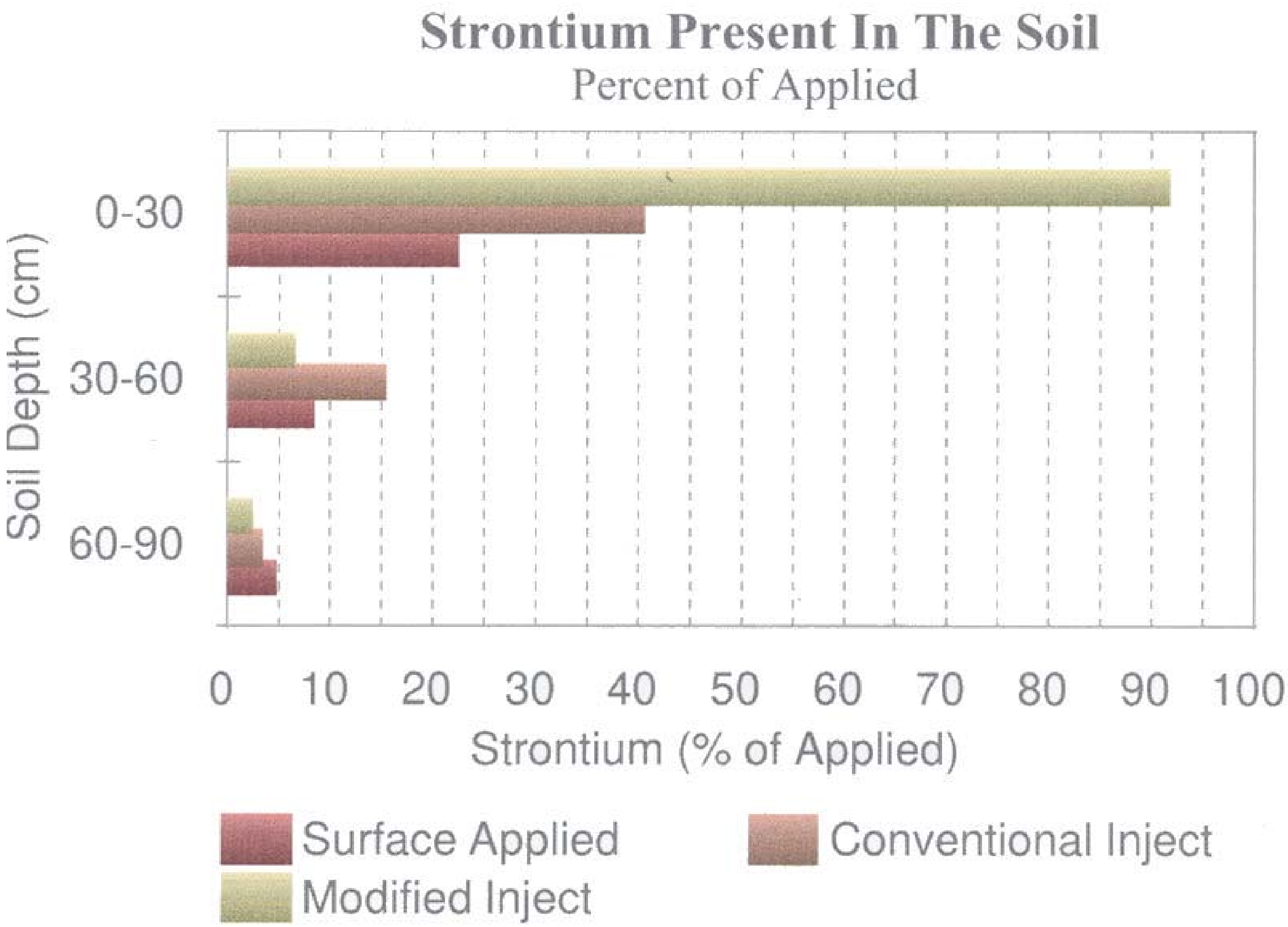

Figure 2: Strontium Present In The $oil

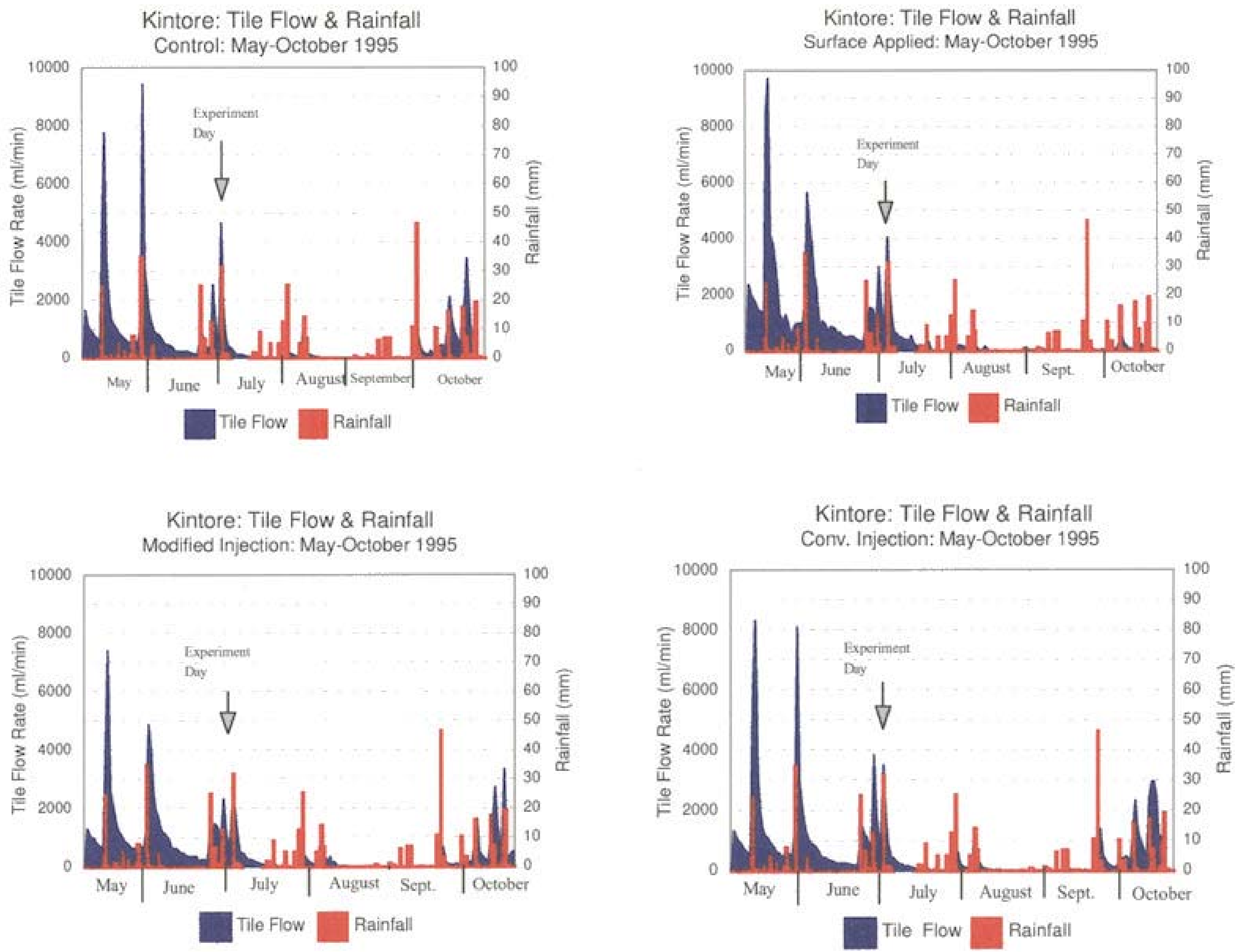

Figure 3: Tile Flow vs. rainfall - Medium textured soil

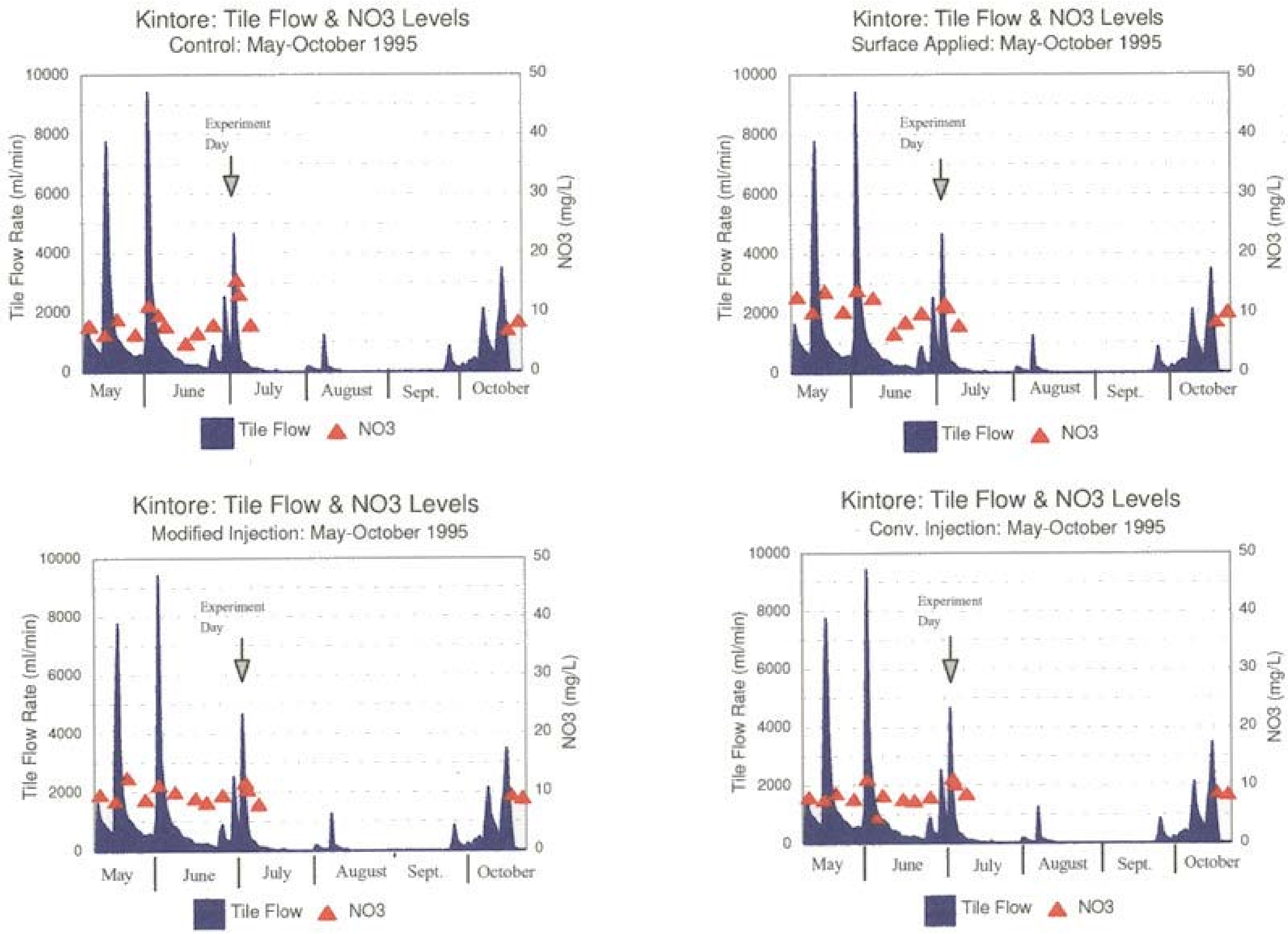

Figure 4: Tile Flow vs. Nitrate Levels - Medium textured soil

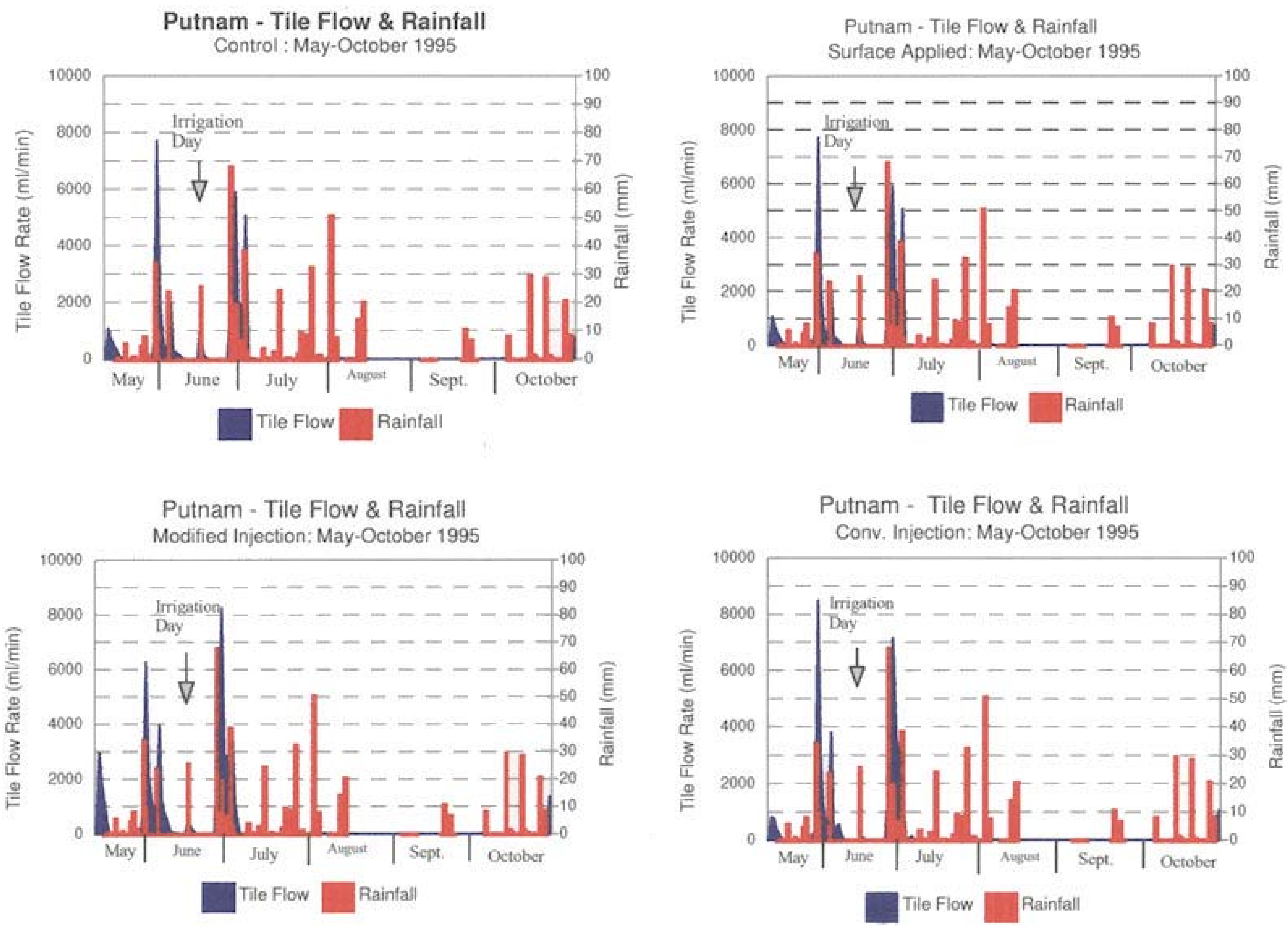

Figure 5: Tile flow vs. Rainfall - Light Textured soil

The loadings of nitrate to the tiles was not significantly affected by the application of manure the first day following manure application, however, there was a slight increase in nitrate concentrations several days after manure application. The nitrate levels dropped back to background levels within two weeks following manure application (figure 6). The average nitrate levels ranged form a high of 29 ppm from the control tiles to a low of 20 ppm for conventional injection and modified injection. The total seasonal loadings of nitrate to the tile drains ranged from a low of 43 kg/ha to a high of 62 kg/ha.

Crop Monitoring

Soil fertility and manure analysis indicated that manure had to be applied at a rate of 5,400 and 6,400 gal/acre for the medium textured and the light textured soils respectively. From a crop standpoint, the amount of nutrients lost through the tile drains within the first 48 hours following manure application, would be insignificant, only 1 to 3 percent for the injection methods and the surface applied respectively for both sites. The effect of the manure application methods on crop productivity was indiscernible from the control treatment under minimal fertilizer management. No additional agronomic impact of the application treatments was observed (table 2).

Table 2: Crop Yield

Treatment	Yield (bu/ac) - Kintore	Yield (bu/ac) - Putnam
Surface Applied	104	135
Modified Inject	112	135
Conventional Inject	121	138
Control	114	138

Draft and Fuel Consumption Comparisons

The negligible differences in fuel consumption between the injection methods indicate that the modified injection method is an economically viable alternative for farmers. The increase in power requirements with the modified injection method is a practical consideration, because the increase in fuel consumption was less than 2L/ha over surface applied.

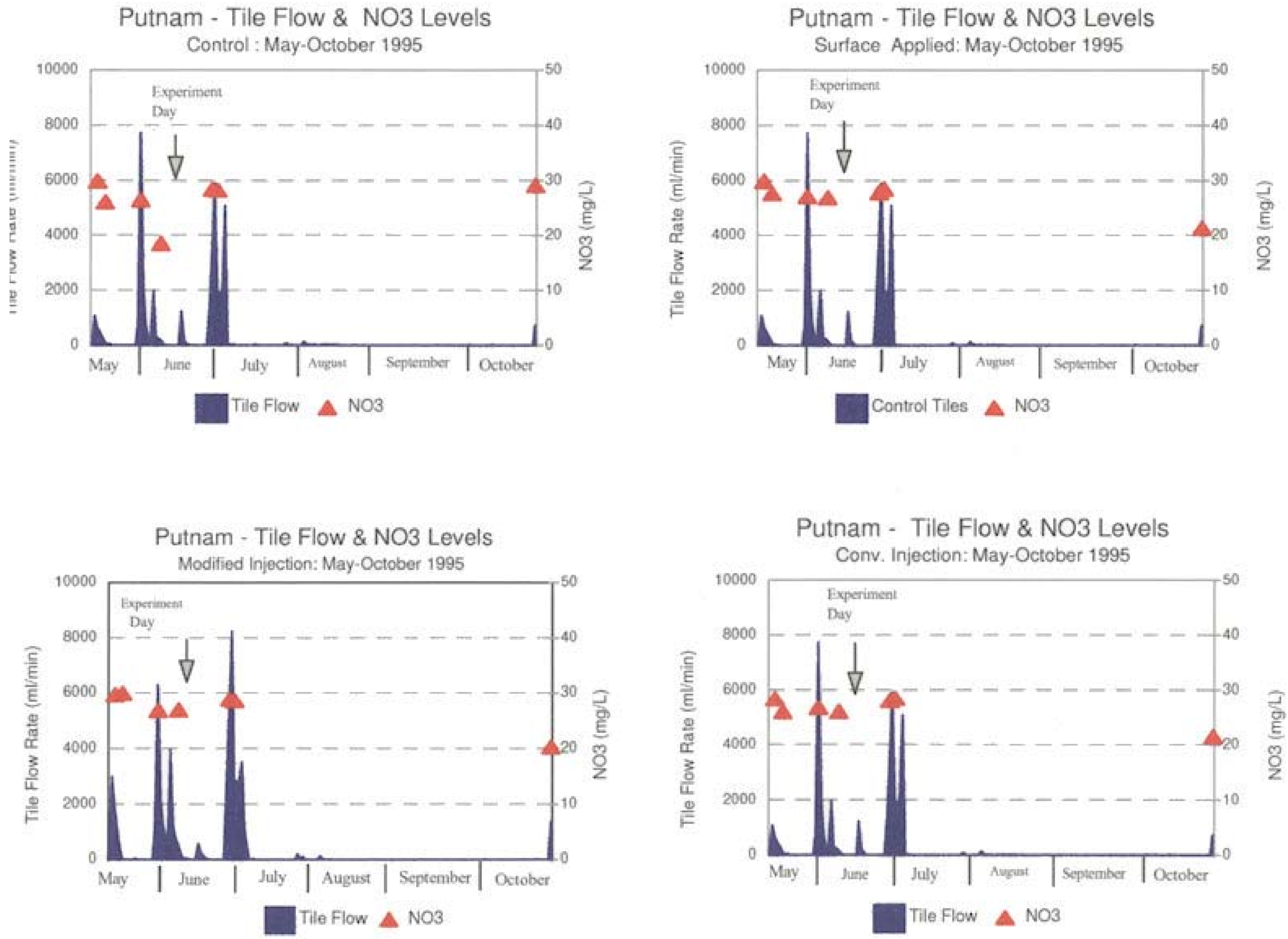

Figure 6: Tile Flow vs. Nitrate levels - Medium Textured Soil

REFERENCES

Beauchamp, E.G. and R.G. Kachanoski. 1990. Compatibility of conservation tillage and manure spreading. Pub 1490, Agdex 570. Ontario Ministry of Agriculture and Food, Toronto, ON.

Beven, K. and P. Germann. 1982. Macropores and water flow in soils. Water Resour. Res. 18:1311- 1325.

Culley J.L.B. and P.A. Phillips. 1982. Bacteriological quality of surface and subsurface runoff from manured sandy clay loam soil. J. Env. Qual. 11:155-8.

Dean, D.M. and M.E. Foran. 1991. The effect of farm liquid waste application on receiving water quality. Final report RAC projects 430G and 512G. Ausable-Bayfield Conservation Authority, Exeter, ON.

Edwards, W.M., L.D. Norton and C.E. Redmond. 1988. Characterizing macropores that affect infiltration into non-tilled soil. Soil Sci. Soc. Am. J. 52:483-487.

Fleming, R.J. and S.H. Bradshaw. 1992. Contamination of subsurface drainage systems during manure spreading. Paper at ASAE Int. Winter Mtg. December 15-18, 1992.

Kachanoski, R.G., and E. Beauchamp. 1991. Nitrogen soil test for corn. Department of Land Resource Science, University of Guelph, Guelph Ontario. Canada.

McKeauge, J.A., (ed). 1978. Manual on soil sampling and methods of analysis. Canada Soil Survey Committee, Can. Soc. Of Soil Science.

Patni, N.K., R. Toxopeus, A.D. Tennant and F.R. Hore. 1984. Bacterial quality of tile drainage water from manured and fertilized cropland. Water Res. 18:127-32.

Shipitalo, M.J., W.M. Edwards, W.A. Dick and L.B. Owens. 1990. Initial Storm Effects on Macrospore Transport of Surface-Applied Chemical in No-Till Soil. Soil Sci. Soc. Am. J. 54:1530-1536.

Thomas, G. W. And R.E. Philips. 1979. Consequences of water qmovement in macropores. J. Environ. Qunal. 8:149-152.