Multi-year change in water quality from small, single use pasture watersheds

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North Appalachian Experimental Watershed
Coshocton, Ohio

Objectives:

- To quantitatively compare base flow with storm flow in perennially flowing streams

- To assess the temporal and quantitative impacts of single-use-watershed pasture management practices on groundwater quality


OHIO STATE
USDA
USDA AGRICULTURAL RESEARCH SERVICE
NORTH APPALACHIAN
EXPERIMENTAL WATERSHED
IN COOPERATION WITH
OHIO AGRICULTURAL
RESEARCH & DEVELOPMENT CENTER
THE OHIO STATE UNIVERSITY

Wooded Watershed (Wo)

- 17.7 ha
- All wooded
- No chemical treatment

Unimproved Pasture Watershed (UImpr)

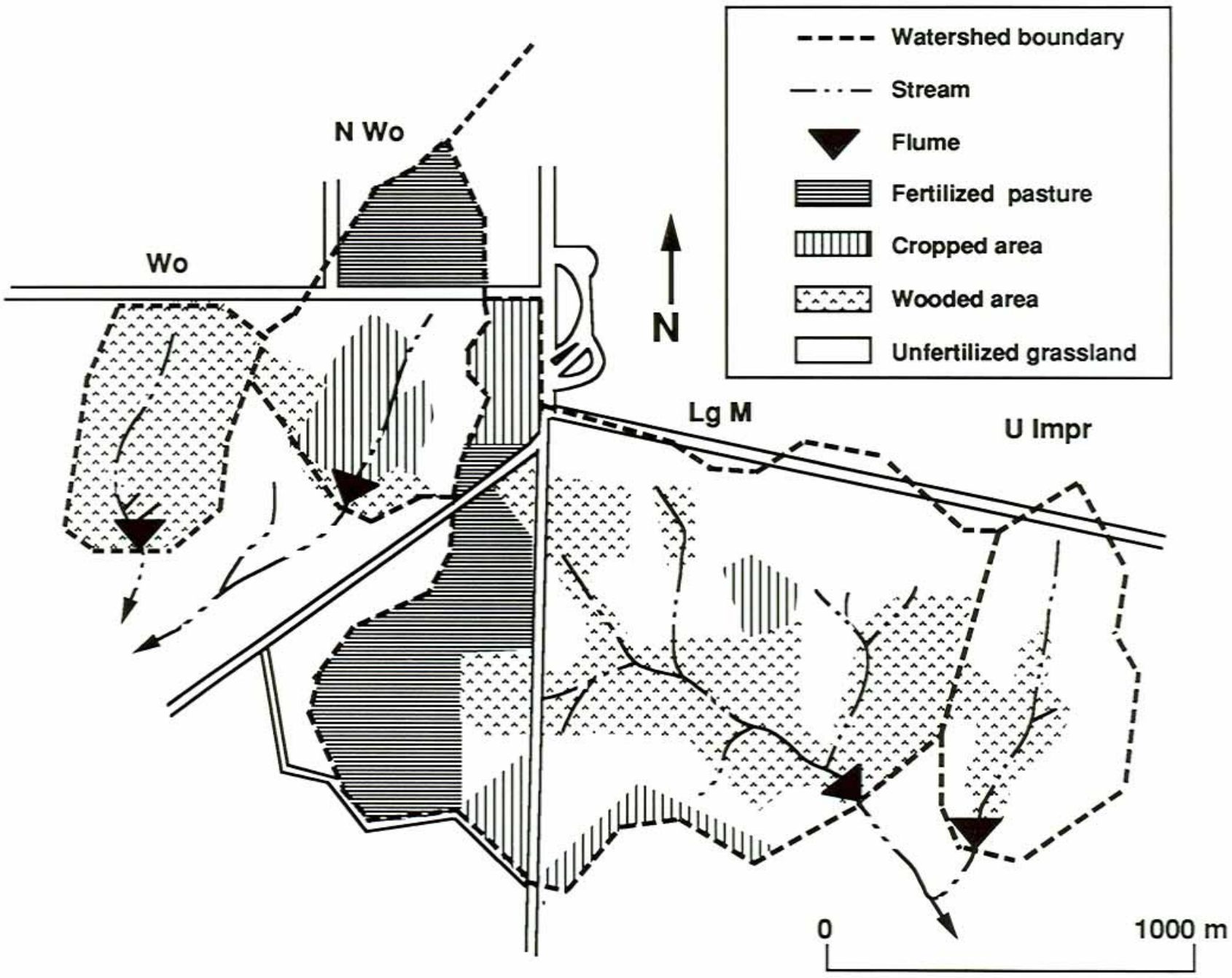
- 28.8 ha
- 82% Unimproved pasture
- 18% wooded
- No chemical treatment

Non-Wooded Watershed (N Wo)

- 32.1 ha
- 34% meadow – no chemical treatment
- 23% medium-high fertility pasture
  - 13% summer pasture
  - 10% year round pasture/feeding
- 32% fertilized cropland
- 11% wooded

Large Mixed Management Watershed (Lg M)

- 122.7 ha
- 43% meadow – no chemical treatment
- 34% wooded
- 14% high fertility pasture
- 9% fertilized cropland


Watershed boundary
Stream
Flume
Fertilized pasture
Cropped area
Wooded area
Unfertilized grassland
N Wo
Wo
N
Lg M
U Impr
0
1000 m

Sample Collection

"Large Watersheds"

-- Storm flow samples collected by an automated, flow proportional tear-drop sampler on an event basis

-- Base flow samples – weekly grab samples during not storm flow periods

Small, single-use watersheds

-- Subsurface flow – weekly grab samples from developed springs

Calculations of Annual Data

Transport (event or weekly sample) = Flow (event) x Conc (event)

Transport (annual) = sum of all Transport (events) during that year

Flow (annual) = sum of all Flow (events) during that year

Concentration (annual) is a flow-weighted conc

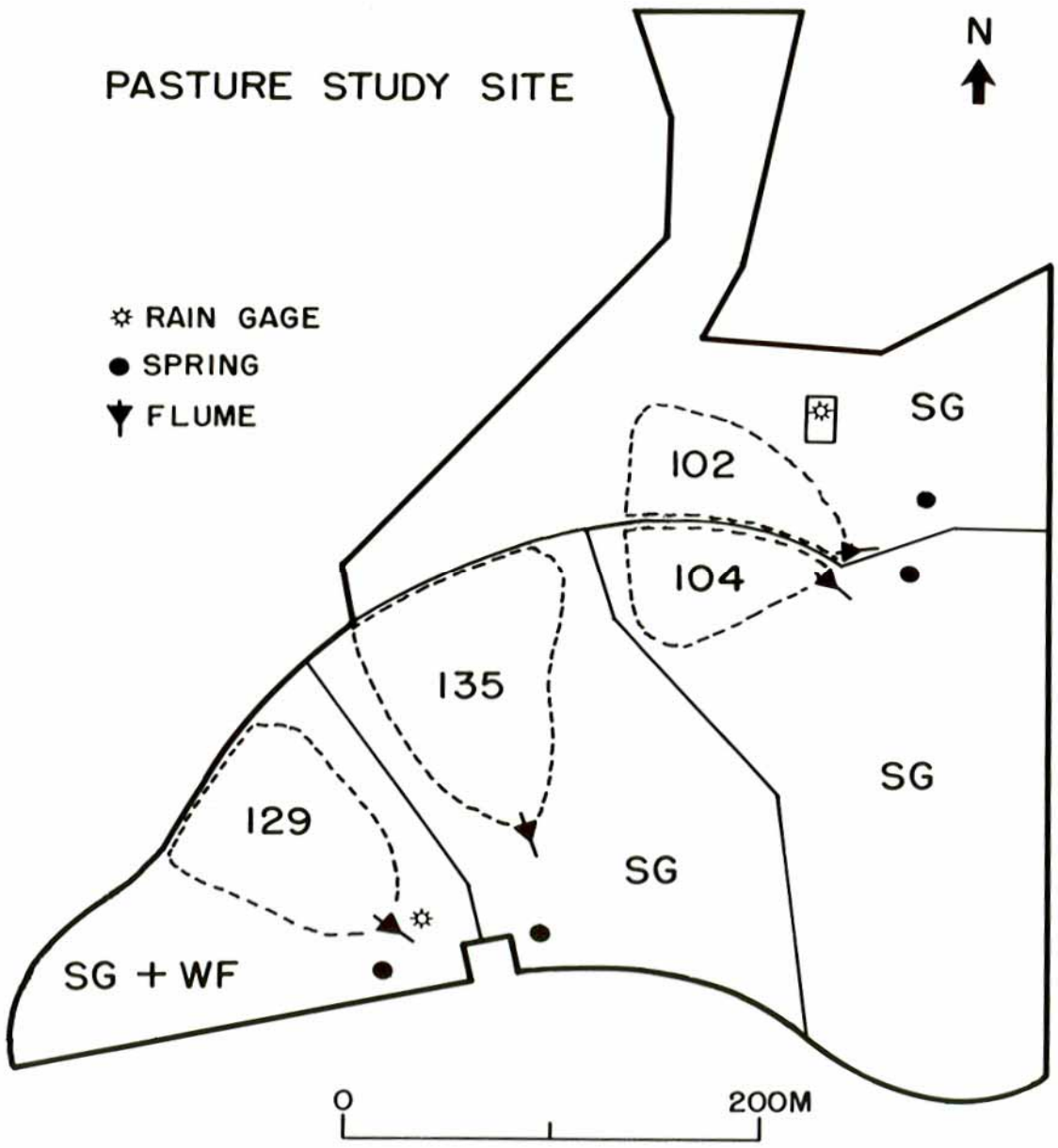
Watershed hydrologic data – 25 yr averages

(January 1976 – December 2000)

	Wo 17.7 ha	UImpr 28.8 ha	N Wo 32.1 ha	Lg M 122.7 ha	Avg of 4 WS
Precipitation-mm	911	998	979	1005	973
Total flow-mm	327	334	317	460	360
% of Precip	35.9%	33.5%	32.4%	45.8%	37.0%
Storm flow-mm	126	155	120	234	159
% of Tot flow	38.5%	46.5%	37.8%	50.7%	44.1%
Base flow-mm	201	179	197	227	201
% of Tot flow	61.5%	53.5%	62.2%	49.3%	55.9%

25-yr average annual N and P transport (1976-2000)

	Wo 17.7 ha	UImpr 28.8 ha	N Wo 32.1 ha	Lg M 122.7 ha	Avg of 4 WS
NO_3-N Flux (kg/ha)					
Storm flow	1.73	1.54	2.54	3.59	2.35
% of total	57.7%	45.6%	41.2%	60.0%	50.7%
Base flow	1.28	1.84	3.62	2.39	2.28
% of total	42.5%	54.5%	58.8%	40.0%	49.3%
PO_4-P Flux (kg/ha)					
Storm flow	0.022	0.091	0.193	0.128	0.109
% of total	40.0%	67.4%	76.0%	71.5%	69.7%
Base flow	0.033	0.044	0.061	0.051	0.047
% of total	60.0%	32.6%	24.0%	28.5%	30.3%

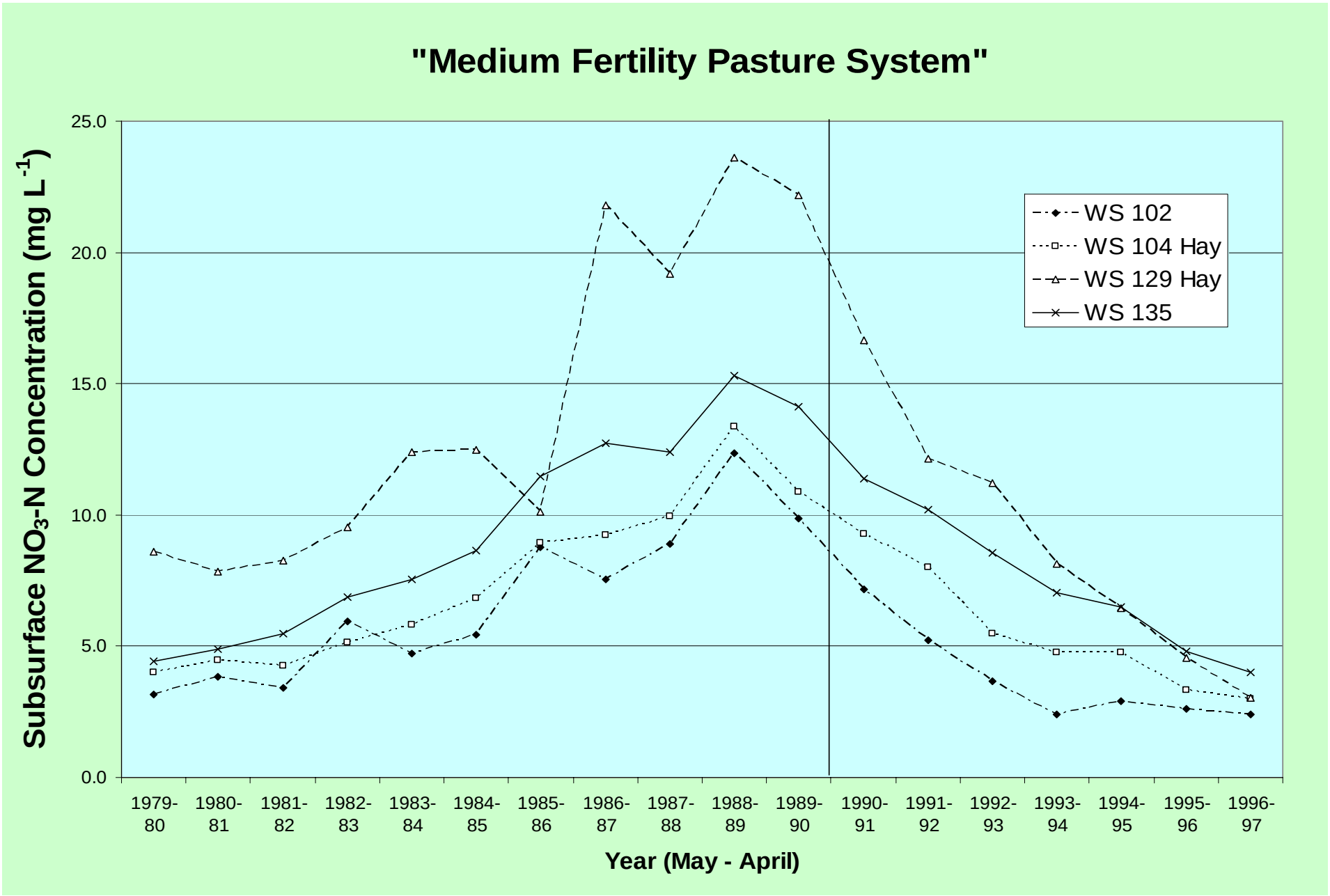

PASTURE STUDY SITE
N
RAIN GAGE
SPRING
FLUME
SG
102
104
135
SG
129
SG
SG + WF
0
200M

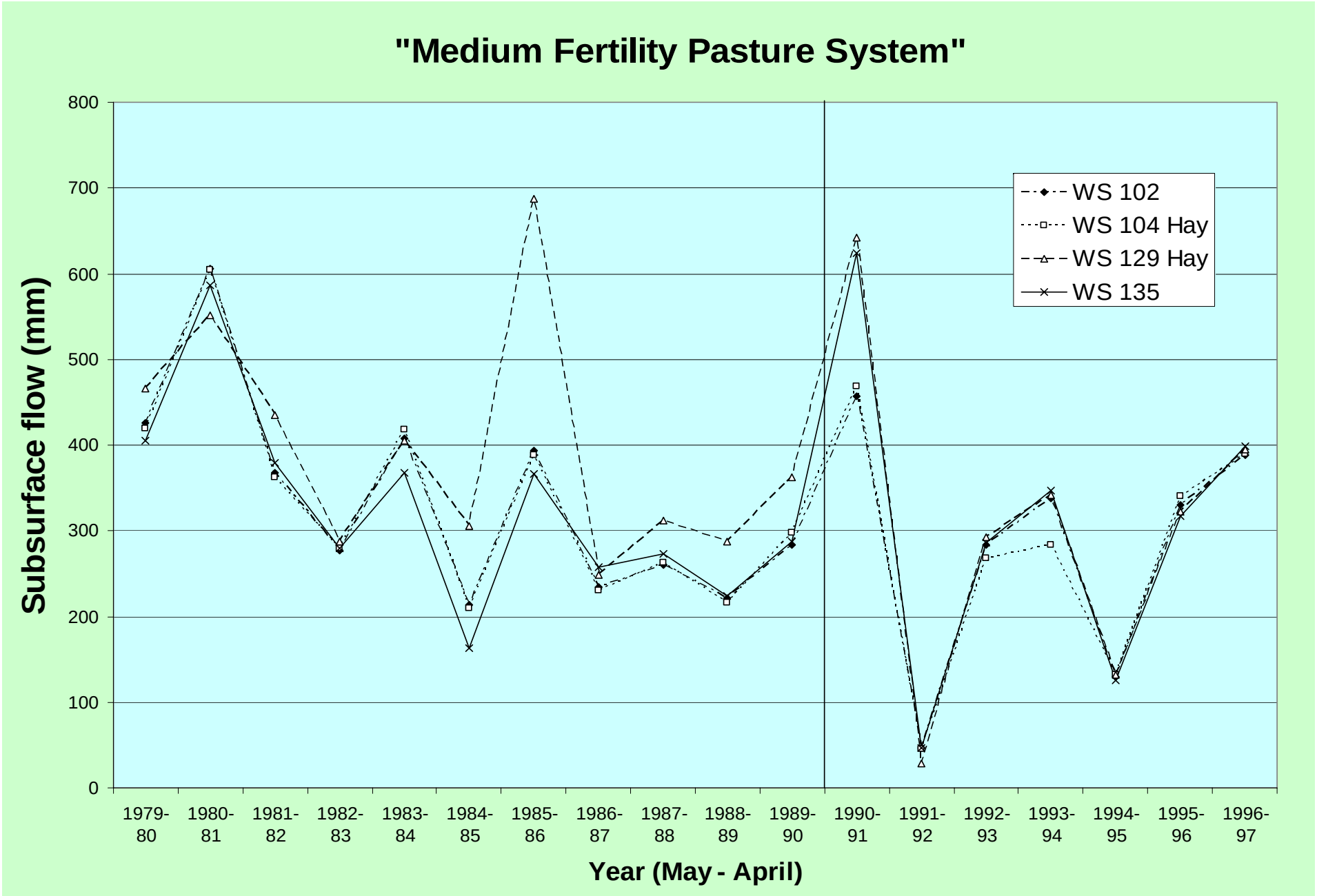
Pasture Management Practices – Medium-high Fertility Pastures

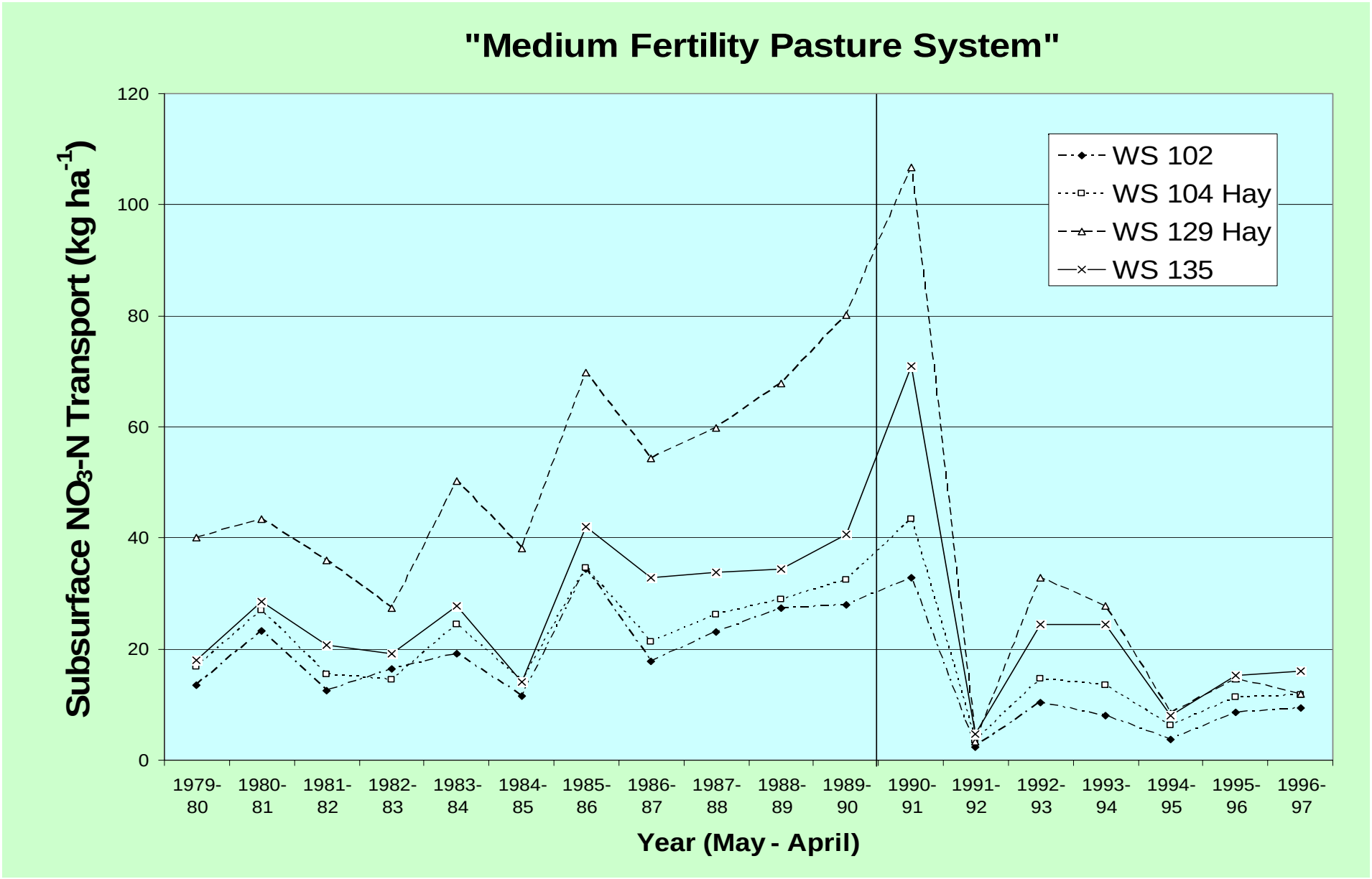
1974-79 56 kg/ha N as NH_4NO_3 annually
3 pastures summer grazed only-WS 102, 104, 135
1 pasture summer grazed/winter fed-WS 129
(also received 297 kg N annually in hay)

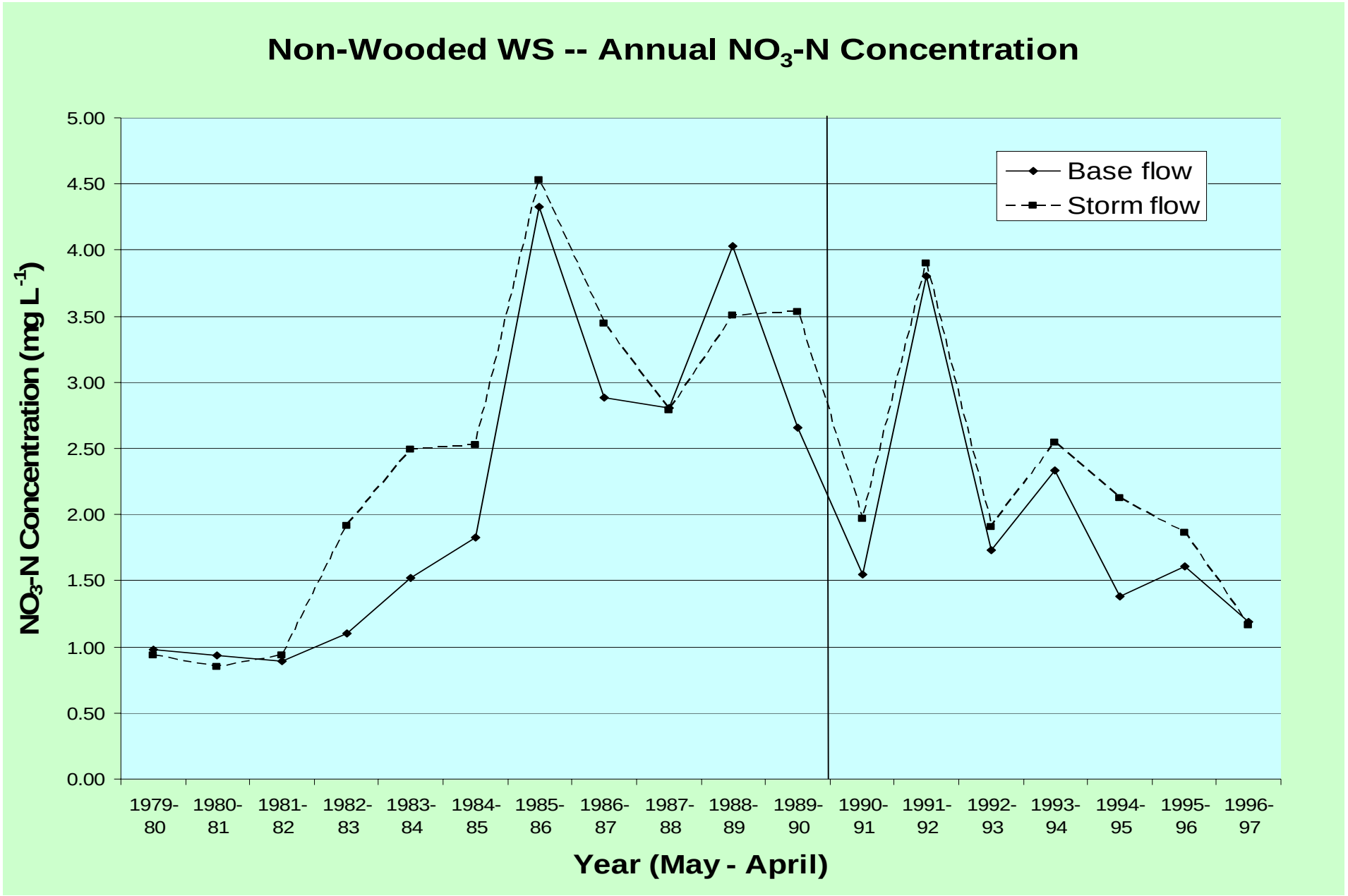
1979-90 Same rotational management; SG areas received 168 kg N/ha annually
WF/SG area received no fertilizer (no wintering after 1986)

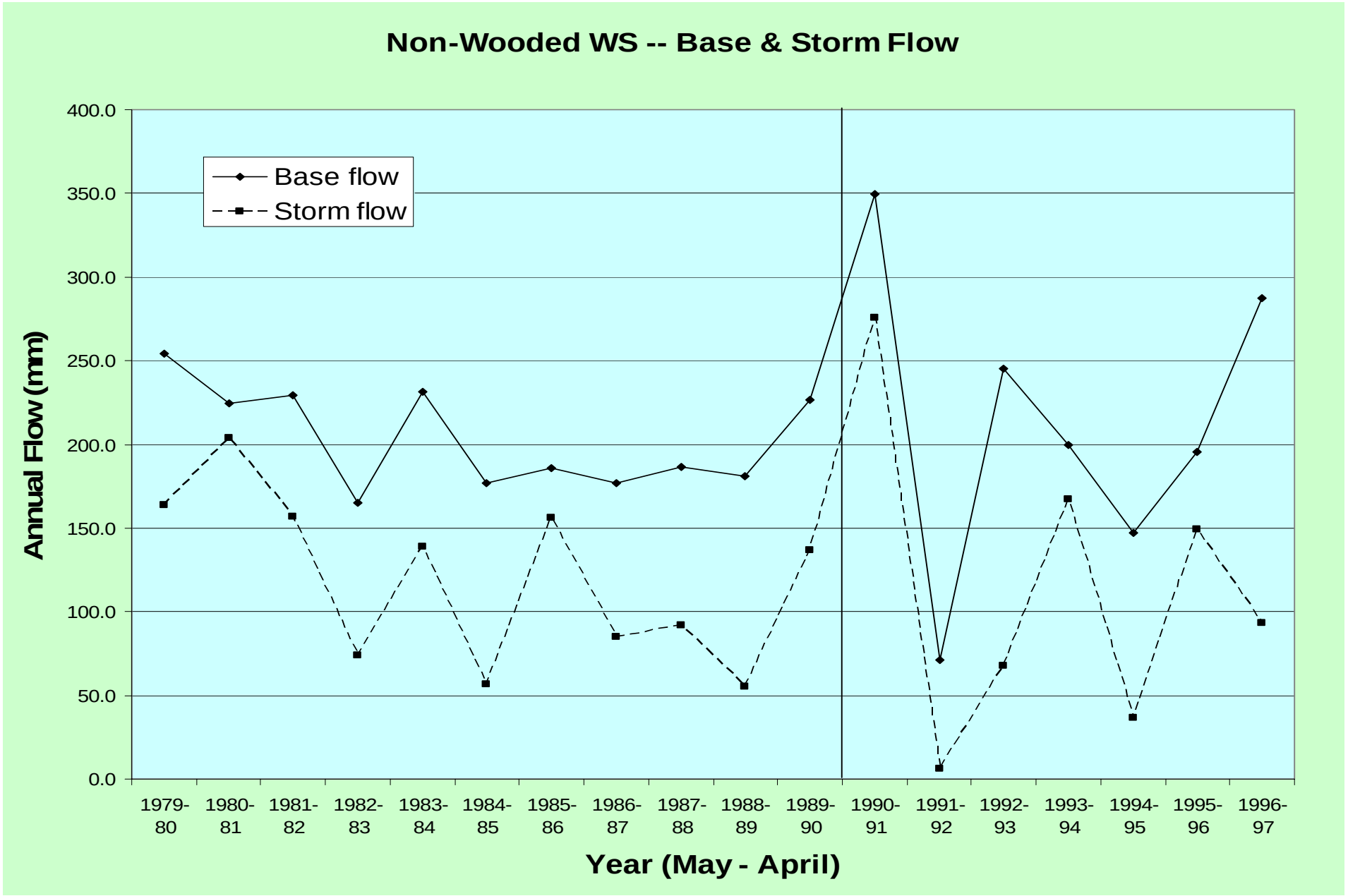
1990-97 No fertilizer applied
WS 102 & 135 were rotationally grazed
WS 104 & 129 were hayed (hay was removed)

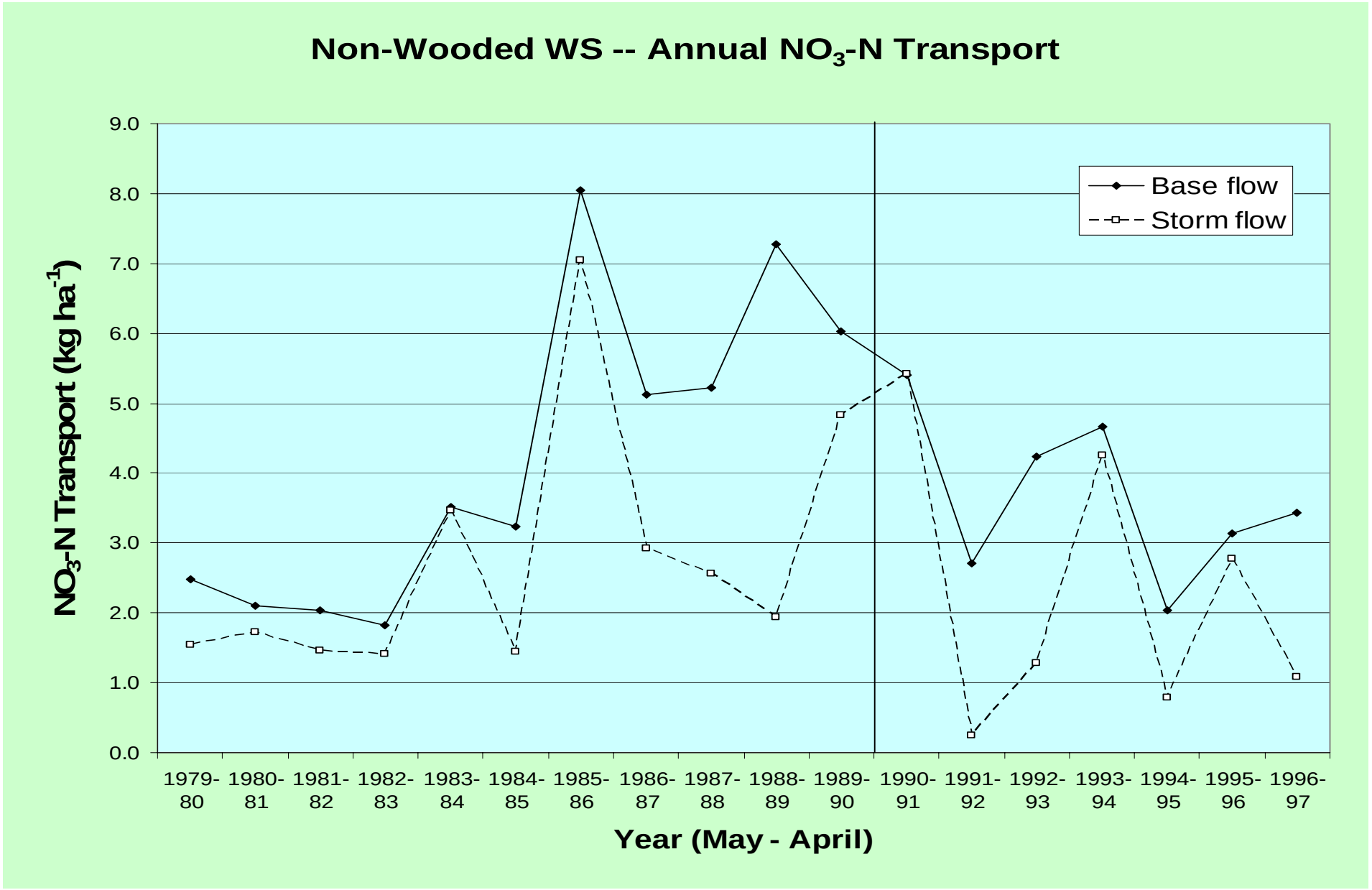

"Medium Fertility Pasture System"
Subsurface NO3-N Concentration (mg L-1)
25.0
20.0
15.0
10.0
5.0
0.0
WS 102
WS 104 Hay
WS 129 Hay
WS 135
1979-80
1980-81
1981-82
1982-83
1983-84
1984-85
1985-86
1986-87
1987-88
1988-89
1989-90
1990-91
1991-92
1992-93
1993-94
1994-95
1995-96
1996-97
Year (May - April)

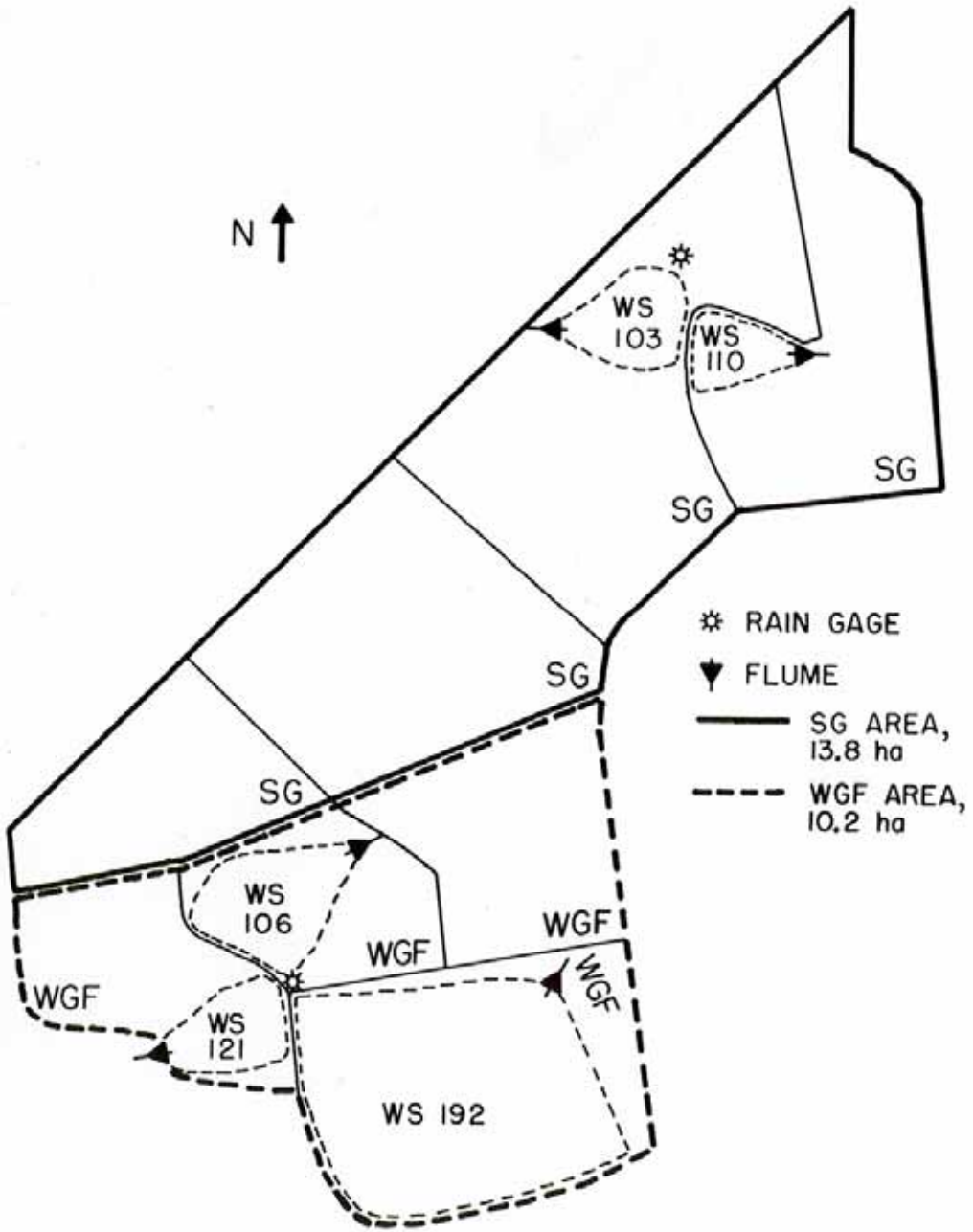

"Medium Fertility Pasture System"
Subsurface flow (mm)
800
700
600
500
400
300
200
100
0
WS 102
WS 104 Hay
WS 129 Hay
WS 135
1979-80
1980-81
1981-82
1982-83
1983-84
1984-85
1985-86
1986-87
1987-88
1988-89
1989-90
1990-91
1991-92
1992-93
1993-94
1994-95
1995-96
1996-97
Year (May - April)


"Medium Fertility Pasture System"
Subsurface NO3-N Transport (kg ha-1)
120
100
80
60
40
20
0
WS 102
WS 104 Hay
WS 129 Hay
WS 135
1979-80
1980-81
1981-82
1982-83
1983-84
1984-85
1985-86
1986-87
1987-88
1988-89
1989-90
1990-91
1991-92
1992-93
1993-94
1994-95
1995-96
1996-97
Year (May - April)


Non-Wooded WS -- Annual NO3-N Concentration
NO3-N Concentration (mg L-1)
5.00
4.50
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
Base flow
Storm flow
1979-80
1980-81
1981-82
1982-83
1983-84
1984-85
1985-86
1986-87
1987-88
1988-89
1989-90
1990-91
1991-92
1992-93
1993-94
1994-95
1995-96
1996-97
Year (May - April)


Non-Wooded WS -- Base & Storm Flow
Base flow
Storm flow
Annual Flow (mm)
400.0
350.0
300.0
250.0
200.0
150.0
100.0
50.0
0.0
1979-80
1980-81
1981-82
1982-83
1983-84
1984-85
1985-86
1986-87
1987-88
1988-89
1989-90
1990-91
1991-92
1992-93
1993-94
1994-95
1995-96
1996-97
Year (May - April)


Non-Wooded WS -- Annual NO3-N Transport
NO3-N Transport (kg ha-1)
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
Base flow
Storm flow
1979-80
1980-81
1981-82
1982-83
1983-84
1984-85
1985-86
1986-87
1987-88
1988-89
1989-90
1990-91
1991-92
1992-93
1993-94
1994-95
1995-96
1996-97
Year (May - April)


N
WS 103
WS 110
SG
SG
SG
SG
WS 106
WGF
WGF
WGF
WGF
WS 121
WS 192
RAIN GAGE
FLUME
SG AREA, 13.8 ha
WGF AREA, 10.2 ha

Pasture Management Practices – High Fertility Pastures

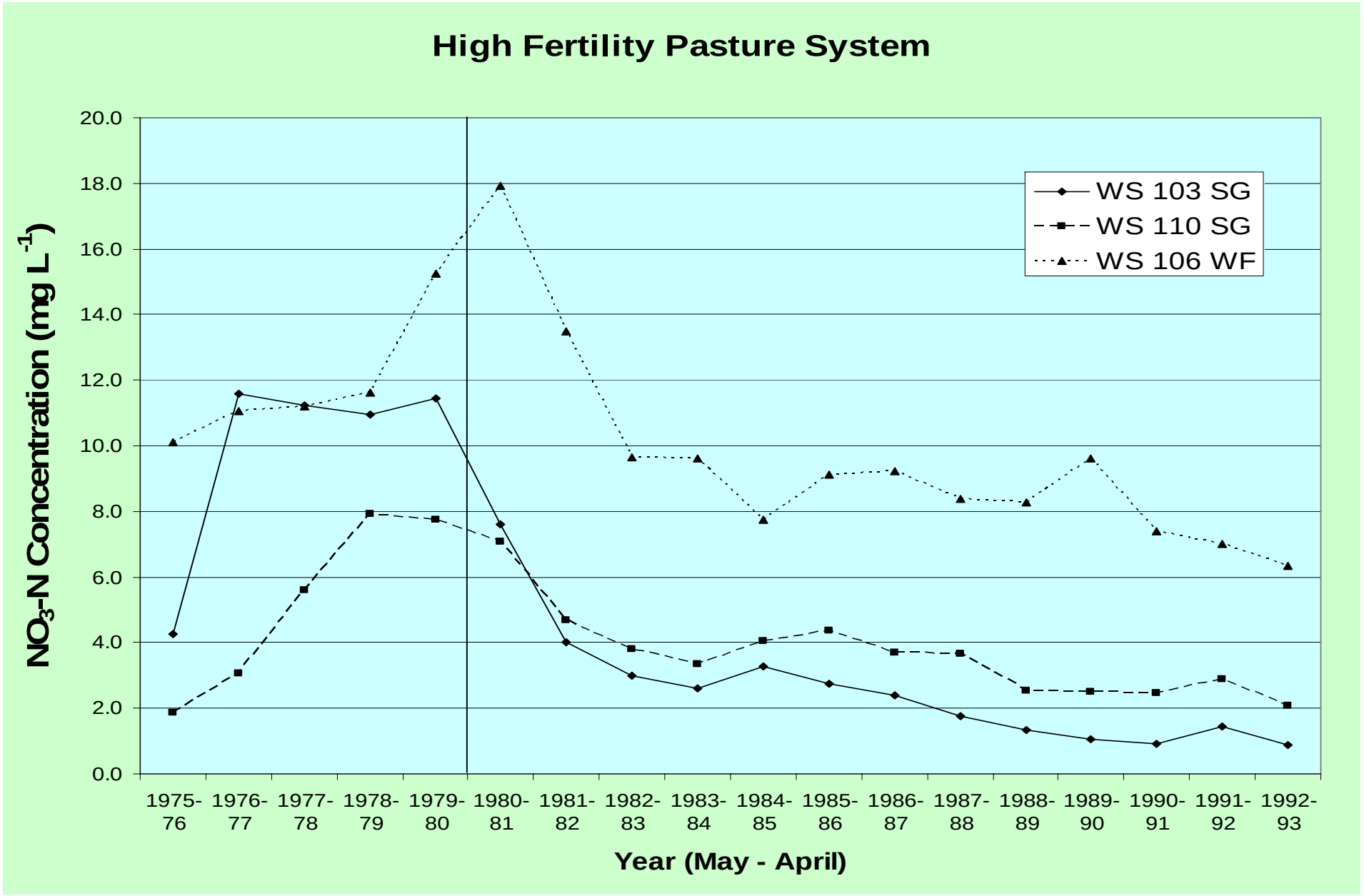
1975-80 224 kg/ha N as NH_4NO_3 annually

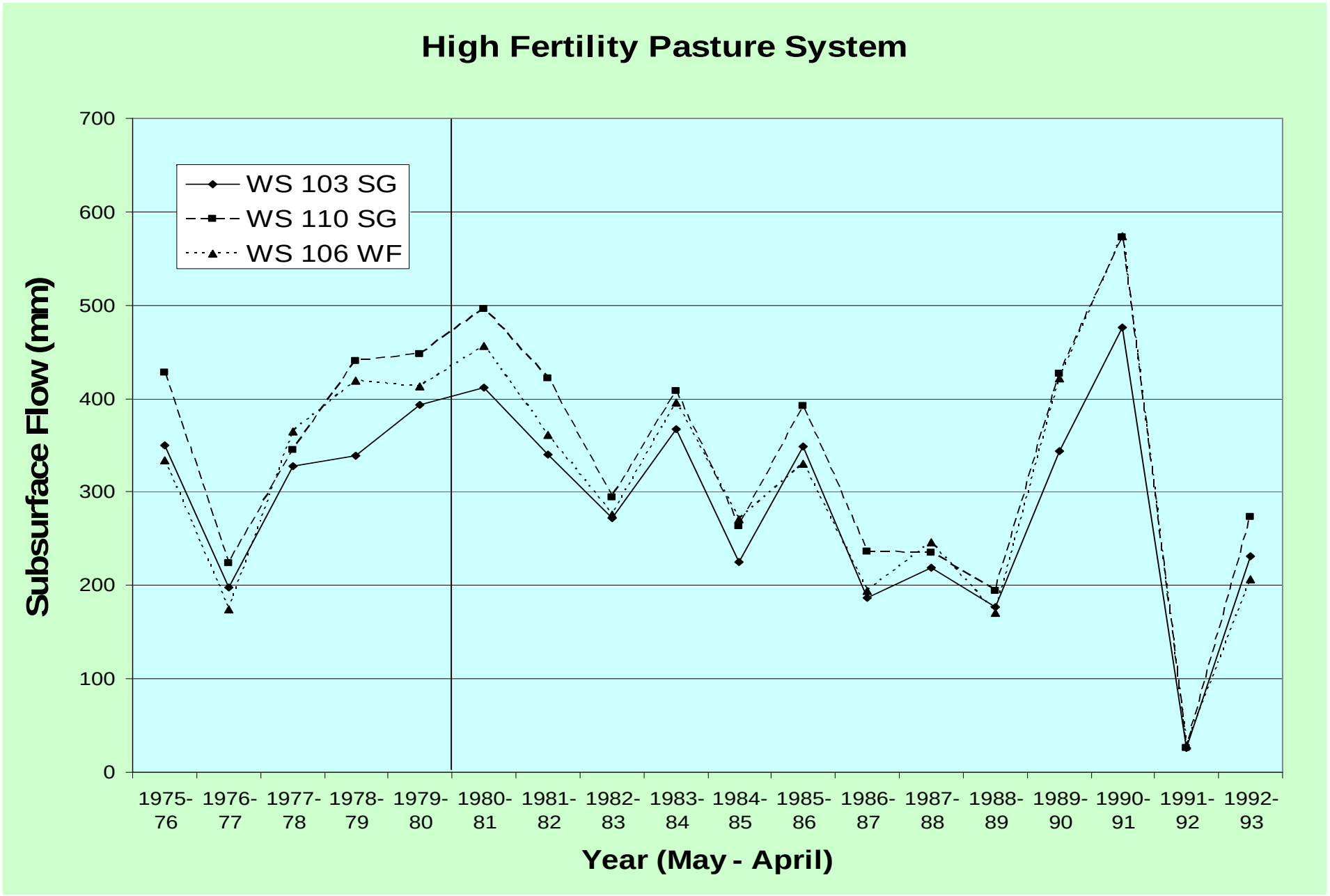
4 pastures (2 with WS) were summer grazed [orchard grass]

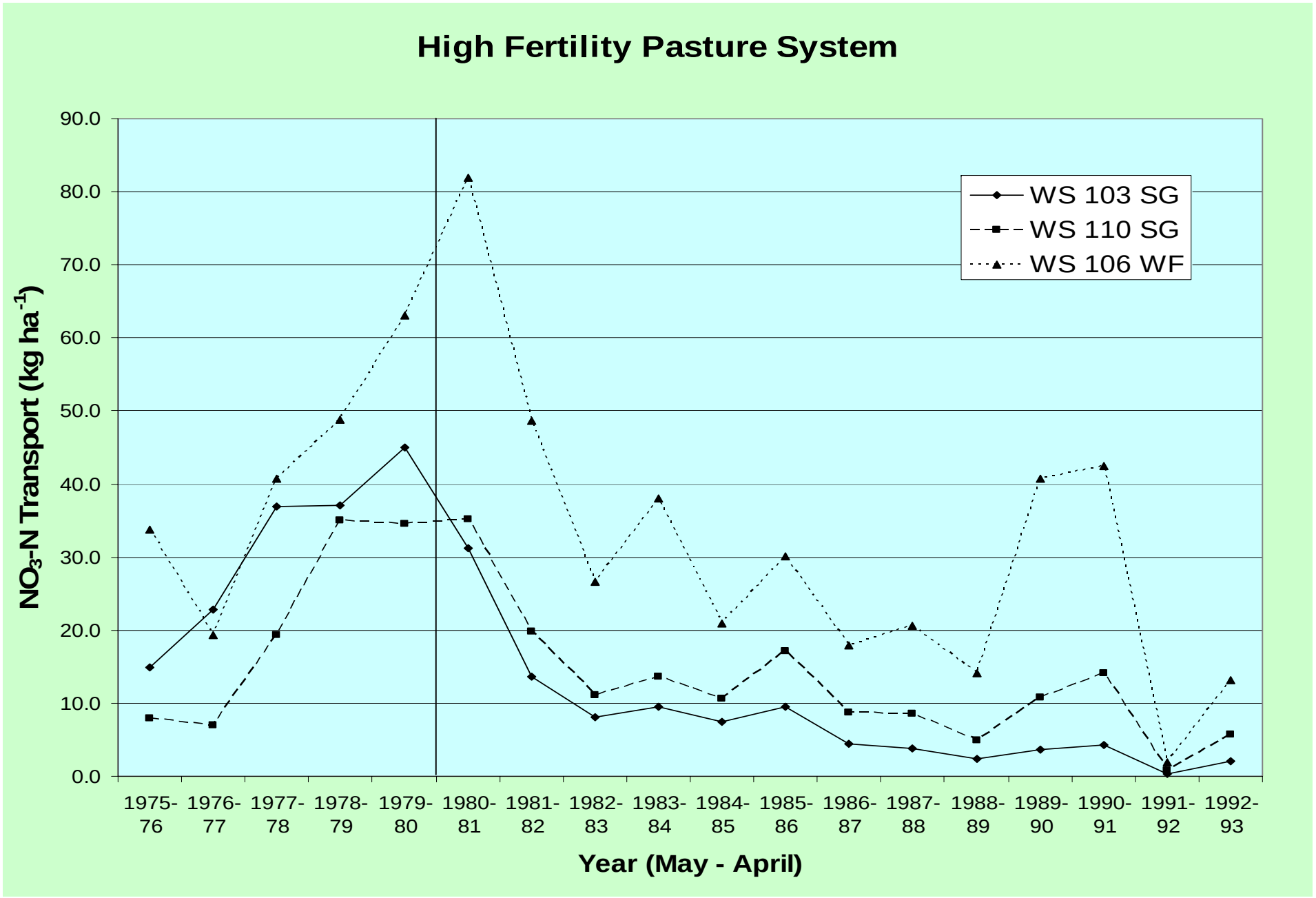
4 pastures (2 with WS) were winter grazed/fed hay [tall fescue]

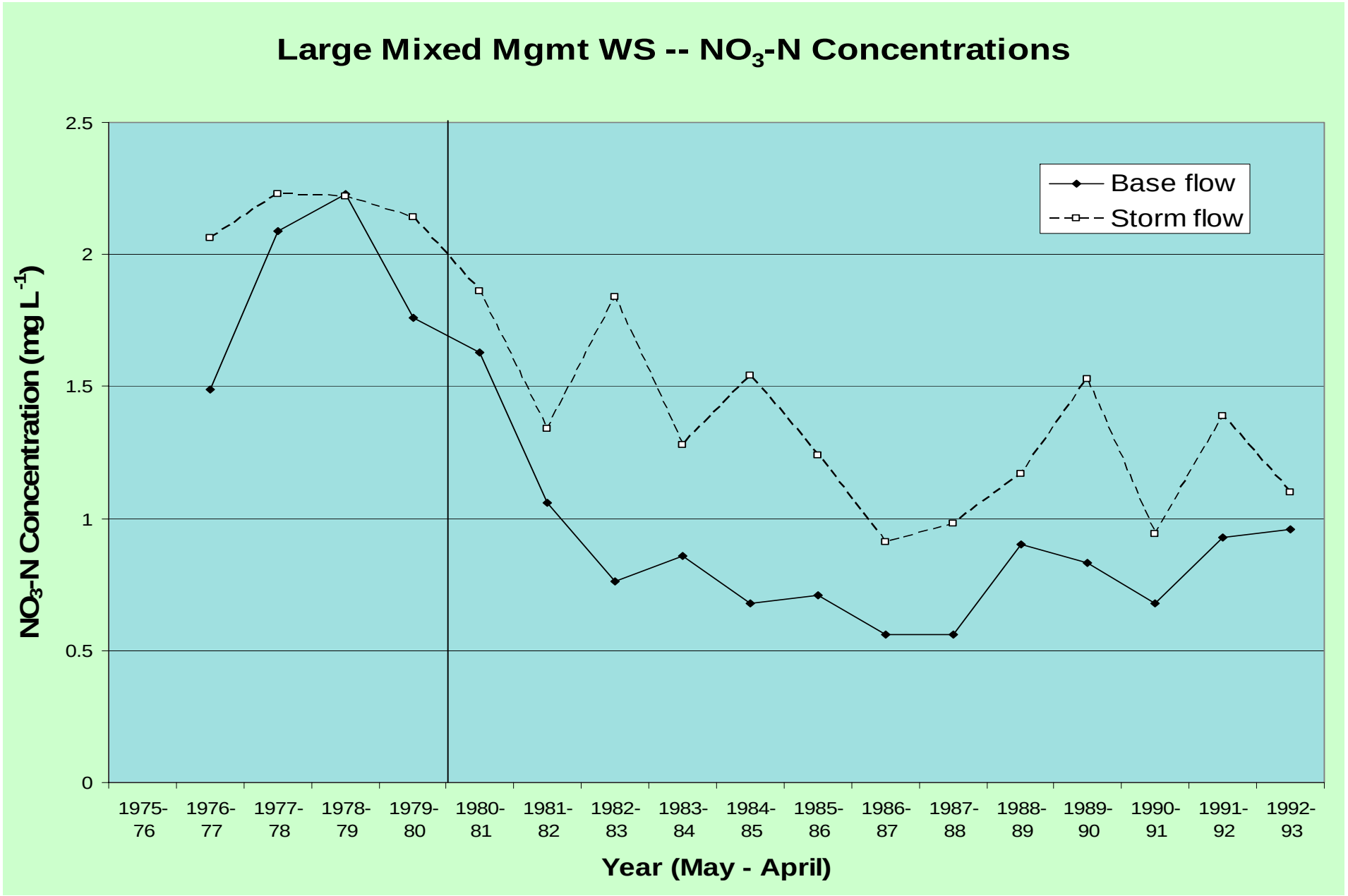
1980-93 grass pastures interseeded with alfalfa – no N fertilizer was added

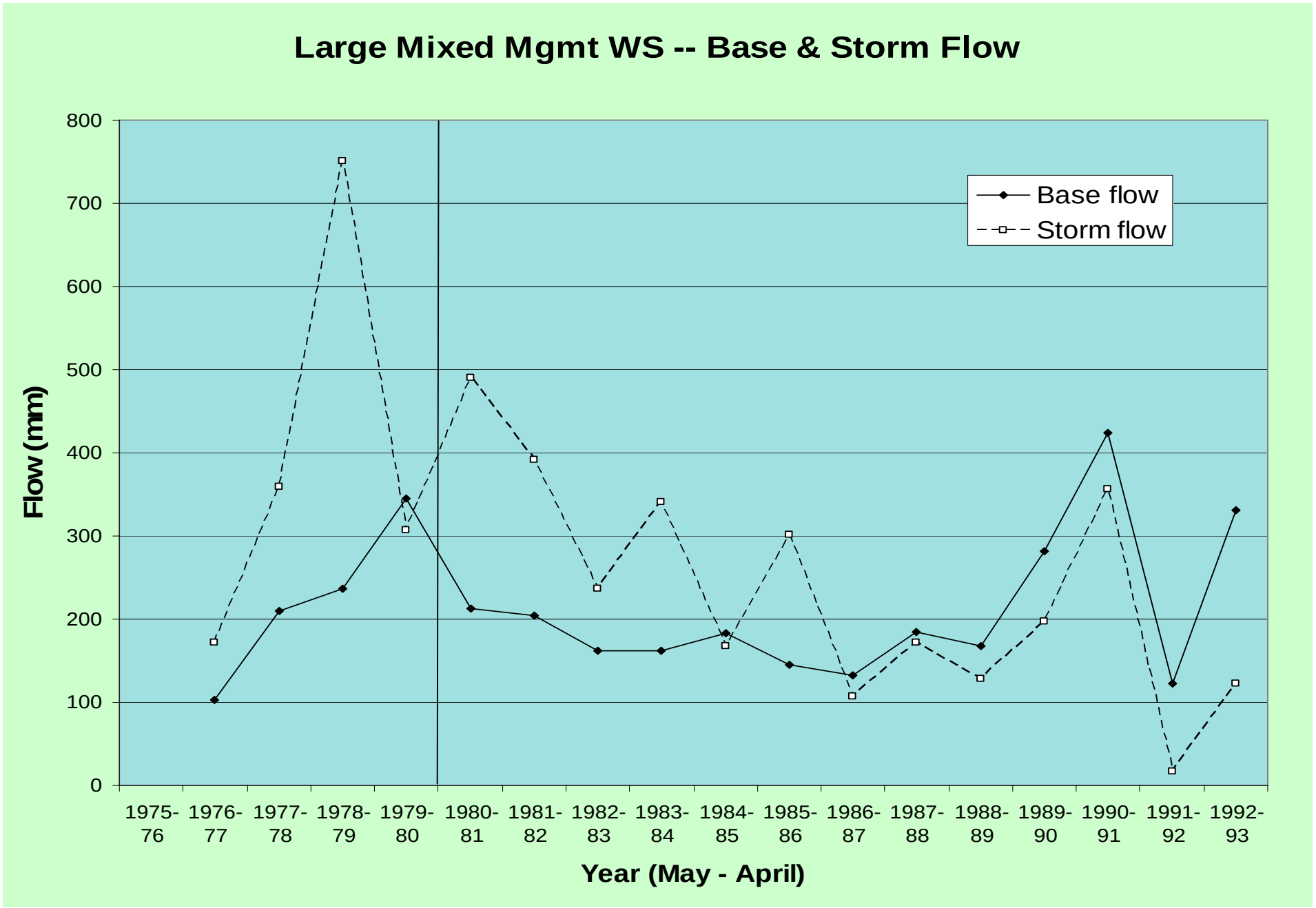
Same rotational grazing pattern was continued

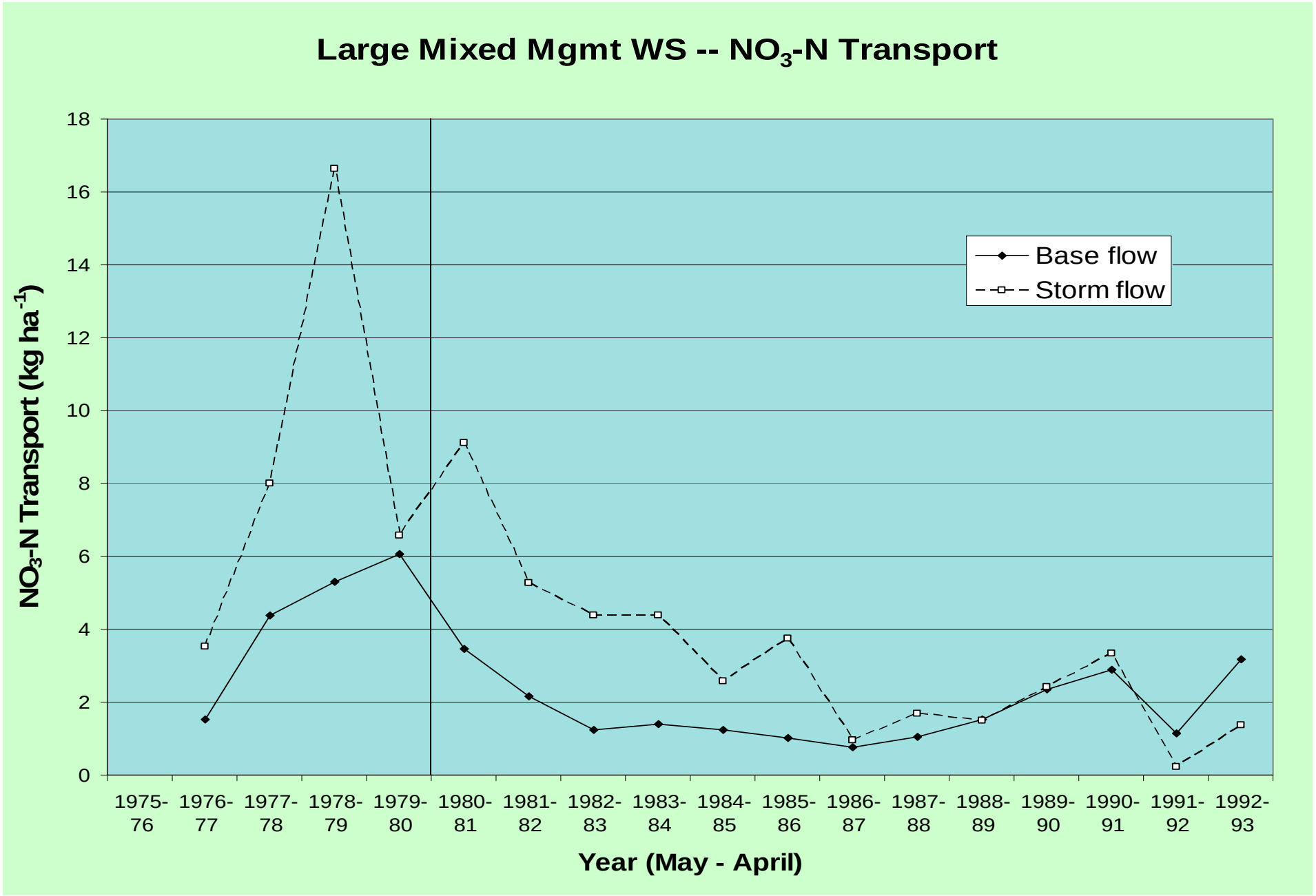

High Fertility Pasture System
20.0
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
NO3-N Concentration (mg L-1)
WS 103 SG
WS 110 SG
WS 106 WF
1975-76
1976-77
1977-78
1978-79
1979-80
1980-81
1981-82
1982-83
1983-84
1984-85
1985-86
1986-87
1987-88
1988-89
1989-90
1990-91
1991-92
1992-93
Year (May - April)


High Fertility Pasture System
WS 103 SG
WS 110 SG
WS 106 WF
Subsurface Flow (mm)
700
600
500
400
300
200
100
0
1975-76
1976-77
1977-78
1978-79
1979-80
1980-81
1981-82
1982-83
1983-84
1984-85
1985-86
1986-87
1987-88
1988-89
1989-90
1990-91
1991-92
1992-93
Year (May - April)


High Fertility Pasture System
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
NO3-N Transport (kg ha-1)
WS 103 SG
WS 110 SG
WS 106 WF
1975-76
1976-77
1977-78
1978-79
1979-80
1980-81
1981-82
1982-83
1983-84
1984-85
1985-86
1986-87
1987-88
1988-89
1989-90
1990-91
1991-92
1992-93
Year (May - April)


Large Mixed Mgmt WS -- NO3-N Concentrations
NO3-N Concentration (mg L-1)
2.5
2
1.5
1
0.5
0
Base flow
Storm flow
1975-76
1976-77
1977-78
1978-79
1979-80
1980-81
1981-82
1982-83
1983-84
1984-85
1985-86
1986-87
1987-88
1988-89
1989-90
1990-91
1991-92
1992-93
Year (May - April)


Large Mixed Mgmt WS -- Base & Storm Flow
Flow (mm)
800
700
600
500
400
300
200
100
0
Base flow
Storm flow
1975-76
1976-77
1977-78
1978-79
1979-80
1980-81
1981-82
1982-83
1983-84
1984-85
1985-86
1986-87
1987-88
1988-89
1989-90
1990-91
1991-92
1992-93
Year (May - April)


Large Mixed Mgmt WS -- NO3-N Transport
NO3-N Transport (kg ha-1)
18
16
14
12
10
8
6
4
2
0
Base flow
Storm flow
1975-76
1976-77
1977-78
1978-79
1979-80
1980-81
1981-82
1982-83
1983-84
1984-85
1985-86
1986-87
1987-88
1988-89
1989-90
1990-91
1991-92
1992-93
Year (May - April)

Summary:

In watersheds with perennially flowing streams, approx 50% of NO_3-N is transported via baseflow

Changes in subsurface water quality resulting from changes in fertility management occur over several years (e.g. 5-10 yr on small pasture watersheds)

Multi-year changes occur for both increasing and decreasing NO_3-N concentrations

Similar trends are observed in streamflow that are fed by these smaller streams

Conclusions:

Subsurface water flow has a major impact on stream flow and water quality.

Therefore, water quality changes resulting from changes in management practices will take several years to be adequately observed, even on small (<2 ha), single use watersheds.