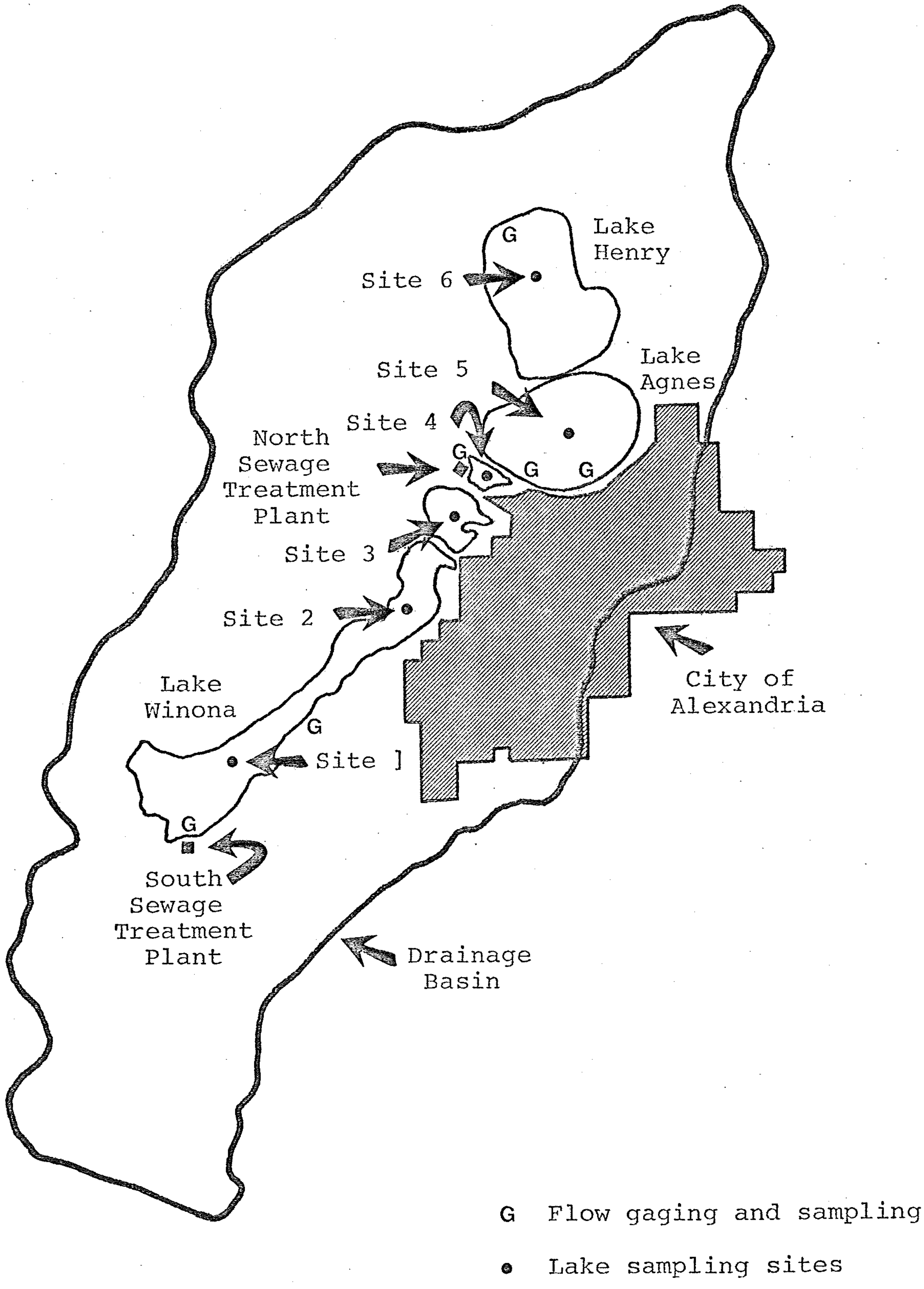
Figure A

Upper Chain Sampling Locations



Analytical data from the laboratory analysis of water samples is found in Appendix A.

Table 8, Phosphorus and Hydrologic Budget, shows the hydrologic and phosphorus inputs and outputs of all lakes in the Winona-Agnes-Henry Chain. The numbers in Table 8 are based on both actual and assumed phosphorus concentrations and upon the surface and groundwater hydrologic calculations presented in Sections II-B and II-C of this report.

The nitrogen contribution of the six discharges monitored are shown in Table 9. Table 10 shows the relationship between flow and phosphorus and nitrogen loading, as well as the ratio of nitrogen to phosphorus. The supply of N to P in the Winona-Agnes-Henry Watershed is found to be 9:1, 11:1 and 17:1 for the three urban storm sewers monitored. Considerably lower N to P ratios were noted in the wastewater treatment plant discharges (3:1 and 6:1). Assuming that an N to P ratio of 12"1 (average N:P ratio for the three storm sewers monitored), the content of nitrogen in the unmonitored portion of the hydrologic and nutrient budget is 7,776 lbs. of N to 648 lbs. of P, or 12:1.

In a phosphorus-limited aquatic ecosystem, nitrogen is found in greater amounts than phosphorus by a ratio of 12:1.* The estimated nutrient load for the Winona-Agnes-Henry chain shows an N:P ratio of 4:1 indicating that phosphorus may be present in greater quantities than required by plants for photosynthesis, on the basis of external loading, that nitrogen may be the factor limiting the amount of productivity.

*Dillon and Rigler, 1974.

Table 11

Physical Parameters
Lakes Winona, Agnes and Henry

	Winona	South Pond (Site 3)	North Pond (Site 4)	Agnes	Henry
Drainage Area	2,710 acres $1.12\times10^7 m^2$	80 acres $3.30\times10^5 m^2$	40 acres $1.65\times10^5 m^2$	630 acre $2.60\times10^6 m^2$	740 acre $3.05\times10^6 m^2$
Lake Area	170 acres $7.01\times10^5 m^2$	30 acres $1.24\times10^5 m^2$	12 acres $4.95\times10^4 m^2$	137 acre $5.65\times10^5 m^2$	159 acre $6.56\times10^5 m^2$
Drainage Area to Lake Area	16:1	3:1	3:1	5:1	5:1
Lake Volume	510 acre-feet $6.47\times10^5 m^3$	30 acre-feet $3.81\times10^4 m^3$	12 acre-feet $1.52\times10^4 m^3$	2329 acre-feet $3.00\times10^6 m^3$	3021 acre-feet $3.83\times10^6 m^3$
Mean Depth	3 feet .9m	1 ft. .3m	1 ft. .3m	17 feet 5.2m	19 feet 5.8m
Vertical zonation	mixed	mixed	mixed	stratified	stratified
Total Discharge	800 acre-feet $1.02\times10^6 m^3$	280 acre-feet $3.56\times10^5 m^3$	975 acre-feet $1.24\times10^6 m^3$	1111 acre-feet $1.41\times10^6 m^3$	464 acre-feet $4.89\times10^5 m^3$
Flushing Rate (yr^{-1})	1.57	9.3	81	.48	.15
Hydrologic Retention time (yrs.)	.64	.11	.01	2.10	6.5
Phosphorus Retention	.84	-1.49	.50	.49	.62
Aerial Loading	3,088 lb/170 ac. 1.96 gm/m2/yr	204 lb/30 ac. .75 $gm/m^2/yr$	19,317 lb/12 ac. 177 $gm/m^2/yr$	1518lb/137 ac. 7.6 $gm/m^2/yr$	2793 lb/159 ac. 1.9$gm/m^2/yr$
Mean Secchi Disc (range)	1.1 ft. (.5" to 2.5')	.9	.9	5.2' (2.5' to 13.0')	4.4' (1.0' to 13.0')

loading may reverse this trend and make a phosphorus limited condition in time. Further discussion of this will be presented in a later section.

C. BIOLOGICAL CHARACTERISTICS

1. Macrophytes

All three lakes have very limited diversity of plant species. Lakes Agnes and Henry have no floating leaf plants at all and almost a monoculture of *Potamogeton pectinatus* (submerged). Lake Winona has only about 10 different plant species, most natural lakes have 30 to 50 plant species.

If these lakes are classified according to Rickett's "vegetation zones" Lake Winona would have approximately 80% of its vegetation in zone I (shore to 1 m deep) and 20% in zone II (1 to 3 m deep). Lake Agnes would have approximately 60% in zone I and 40% in zone II. Lake Henry would have approximately 70% in zone I and 30% in zone II. (Note: that percent based on mass.) None of the lakes would have any vegetation in zone III. This according to Lie (1976) indicates a eutrophic condition with the aquatic plant distribution limited by light (transparency) unless limited by sediment.

Rooted vegetation in Lake Winona generally did not extend to a depth of 2 feet, although in some areas, aquatic plants did extend to 3 to 4 feet. Secchi disc transparency was generally 1 foot but ranged from as much as 2 feet to as little as .5 feet. A qualitative survey of aquatic vegetation was made at the 20 sites shown in Figure J. The following enumerates the species found.

this report where:

$$[P] = L(1 - R)/ZF$$

By use of this relationship, the [P] value for Lake Winona will be calculated and will include the nutrient and hydrologic changes associated with the new tertiary WWTP discharge. The [P] value calculated for Lake Winona will then be assumed to be the average phosphorus concentration of the Lake Winona discharge to the South Pond. A similar calculation will yield the projected [P] value for each of the lakes and subsequently, their discharge. External loading and flushing rates (L and f) will then be calculated based upon the hydrologic (input and output) data and the [P] value calculated for the upstream lake and its subsequent discharge into the downstream lake. The assumptions and rationale behind predicting the fraction of phosphorus retention (R) will be presented in the following paragraphs.

The phosphorus retention coefficient (R) is that fraction of the incoming phosphorus which remains in the lake as opposed to being carried out by a discharge (surface flow or groundwater exfiltration). The phosphorus retention coefficient (R) is therefore an indicator of whether the lake's sediments act as a phosphorus source or sink. If the R values are between 0 and 1.0, there is a net loss of phosphorus from the water to the sediment, and the sediments act as a phosphorus sink. As the R value increases, the rate at which phosphorus is lost to the sediment will increase. R values of less than zero indicate that more phosphorus is leaving the lake than is entering and that there is a net contribution of phosphorus from the sediment to the water. In such a case, the lake sediment would act as a phosphorus source.

Based upon the 1976-77 study year data, Lake Winona appeared to exhibit the greatest net retention of phosphorus (R = .84) with 84% of the incoming phosphorus load being

2. Projected Conditions

With the expansion of the ALASD service area and the completion of the new tertiary WWTP, the total external phosphorus loading to the Upper Chain will be reduced by 62 percent, and the total hydrologic input to the system will be increased by 43 percent. This decreased phosphorus loading and increased flushing rate (decreased retention time) will combine to improve the trophic status of the lakes based upon the Vollenweider external phosphorus loading model. However, detectable changes in the water quality of the lake, as measured by both nutrient and productivity levels, are not expected to occur at a perceivable rate because of the increased role of lake sediments in the phosphorus budget. Sediments contain a substantial reservoir of phosphorus, the result of a yearly contribution of 15-25,000 pounds of phosphorus for the past several decades. Because of the shallow, well-mixed nature of Lake Winona, the North Pond, and the South Pond in particular, the internal component of sediment phosphorus loading may replace the existing external component as the primary nutrient contributor.

B. WATER QUALITY

1. Existing Conditions

Because of the excessive nutrient loading to the lakes in the Winona-Agnes-Henry Chain, and particularly the load contributed by Alexandria Wastewater Treatment Plant discharges, water qulaity conditions are very poor and can be classified as highly eutrophic. This is indicated by the high level of essential plant nutrient and the abundance of primary productivity found in all of the lakes. Lake water quality data, as well as nutrient budget data, suggest that the lakes in the Upper Chain are presently moving toward a condition of nitrogen limitation, a symptom typically found in highly eutrophied lakes.