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Technical Appendix

A Commitment Renewed

Restoration Progress and the Course Ahead Under the 1987 Bay Agreement

Chesapeake Bay Program

The Chesapeake Bay Program: A Commitment Renewed

Technical Appendices

A Report of the
Chesapeake Implementation Committee

June 1988

TECHNICAL APPENDICES

to

A COMMITMENT RENEWED: Restoration Progress and the Course Ahead Under the 1987 Bay Agreement

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TECHNICAL APPENDIX 1

ASSUMPTIONS AND METHODS USED IN THE ANALYSIS OF CURRENT AND FUTURE PROGRESS IN REDUCING AGRICULTURAL NPS NITROGEN AND PHOSPHORUS

Nonpoint sources of pollution in the Bay and its tributaries, the state and federal programs addressing these problems, and the effectiveness of Best Management Practices (BMPs) in reducing pollutant loads to the Bay are described in detail in "Chesapeake Bay Nonpoint Source Programs" (EPA, 1987).

In preparing this report, the Chesapeake Bay Liaison Office conducted an analysis to quantify the effect of BMPs in reducing sediment and nutrient pollutant loads. Data for the analysis were compiled in part from the Chesapeake Bay Program Implementation Grant BMP tracking system. EPA grant recipients report quarterly the number and types of BMPs installed (and certified) by watershed and county, the number of acres served, tons of erosion saved, animal units served or tons of manure stored, nutrients saved (if possible), and cost-share information. Similar information was supplied by the U.S. Department of Agriculture (USDA) from the Agricultural Conservation Program BMP tracking system.

The number of erodible acres needing treatment was derived from USDA's National Resource Inventory (NRI). The most recent data in NRI were for 1982; these figures were adjusted to 1985 by subtracting from the 1982 totals the acreage to which BMPs were applied in 1983 and 1984 and the amount of soil saved thereby. The nutrient contribution from animal waste was determined by multiplying the number of animal units per county (Agricultural Census Report, U.S. Department of Commerce, 1982) by the number of tons of manure produced per animal ("Animal Waste Utilization on Cropland and Pastureland," USDA/EPA, 1979).

EPA implementation grant funds were provided to the states initially at the beginning of FY 1985. For that reason, 1985 was used as the base year in measuring progress through 1986 and in making projections to future years. Quantitative data for erosion loss and animal waste were compiled to establish conditions in the base year.

Soil conservation measures were converted to nutrient pollutant load reductions through the use of average nutrient concentrations in soil: 1.1 pounds of phosphorus per ton of soil (Virginia data) and 5.4 pounds of nitrogen per ton of soil (Pennsylvania data). On the basis of USDA/EPA study cited above, one ton of animal waste stored, and subsequently spread properly at the appropriate time, was estimated to equal reductions of 1.3 pounds of phosphorus and 7.0 pounds of nitrogen.

Table TA-1 shows BMP nutrient reductions (including both soil saved and manure stored) achieved through 1986, broken down by state and tributary sub-basin. These data, extrapolated Baywide through the year 2000, show a 34.9 percent reduction in phosphorus and nitrogen originating from improperly stored animal waste and eroding cropland needing BMP treatment. This equals a 30.6 percent reduction from all agricultural sources.

These projections assume that USDA expenditures for BMP cost-sharing will be maintained at FY 1987 levels to the year 2000 and that CBP implementation grants will continue to be funded through FY 1998 at the $10 million level currently authorized under section 117 of the Clean Water Act. It also was assumed that BMPs will be maintained beyond the expiration dates in cost-share contracts.

Progress in nutrient reduction has been measured using only erosion control and animal waste storage BMPs implemented through cost-share programs. Many other kinds of BMPs are applied to agricultural lands in the Chesapeake Bay watershed (see NPS report, EPA, 1987), and efforts are under way to quantify reductions from these measures. Nutrient management, such as fertilizer plans, usually results in significant reductions in the amount of fertilizer used by the farmer. This decreased use brings greater reductions in nitrogen than phosphorus. Until the effectiveness of such plans can be determined, however, they cannot realistically be used as a basis for reduction goals and funding increases. Phosphorus reductions through soil management practices are measurable, however. In addition, phosphorus from erodible cropland represents 30.6 percent of the total agricultural phosphorus load. For these reasons, it is recommended that reduction goals and funding increases for cropland controls be based on phosphorus.

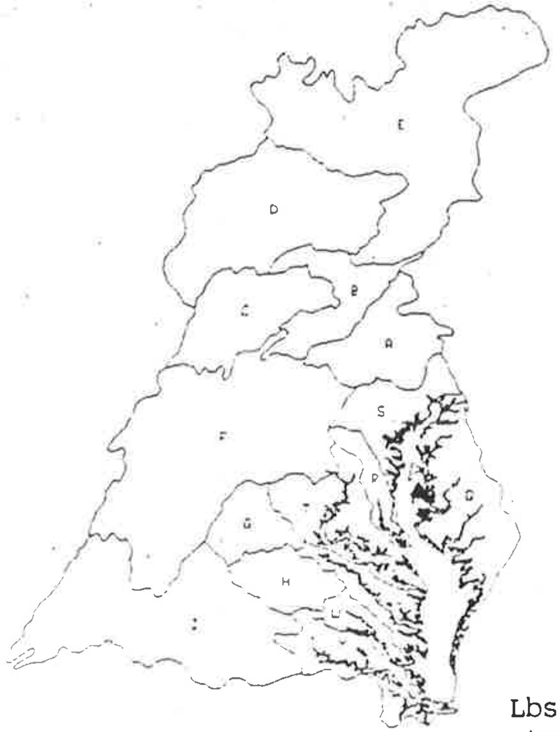
The reductions achieved in 1985 and 1986 reflect the expenditure of $27.03 million for agricultural cost-share programs in those two years: $11.4 million by USDA-ACP, $8.4 million by the three agreement states, and $7.23 by CBP. Budgeted and obligated agricultural cost-share funds for 1986 and 1987 total $34.95 million: $11.75 by USDA-ACP, $12.6 by the three agreement states, and $10.6 by CBP.

Assuming continued funding at FY 1987 levels, the USDA-ACP will spend an additional $72.33 million through FY 1999. CBP is authorized at $21 million through FY 1990, and the states are expected to match this with an additional $24 million. If these levels were extended through FY 1998, spending would increase to $88 million and $77 million, respectively. These additional funds for agricultural BMPs from the beginning of 1987 to the end of year 2000 would total $272.28 million, or 10 times the amount spent in 1985 and 1986. This additional funding would result in a 35 percent reduction in the phosphorus load to the Bay from eroding cropland and improperly stored animal waste.

To achieve a 40 percent reduction in all agricultural sources of phosphorus by the year 2000 would require an increase in state and CBP funds for agricultural BMPs of approximately $92 million. An increase of this magnitude would require legislative action at both the state and federal level, thus these funds likely could not be available until FY 1991. One approach would be to recommend reauthorization with an increase in funding under 117(b) in FY 1991 through FY 1998 to $16 million per year adjusted to 1987 dollars, with the increased funds to be used solely for expanding the ongoing state/CBP agricultural cost-share NPS control program.

There are several unknowns in these progress and cost projections. First, it is uncertain whether other federal sources of cost-share funding will remain constant through year 2000. Second, it is uncertain whether the private sector can support its portion of the cost-share projected through year 2000. The private share is small compared to the government contribution, but if the agricultural economy declines, the capability of achieving agricultural nutrient reduction goals could be seriously endangered.

TABLE TA-1



AGRICULTURAL NPS NUTRIENT
REDUCTION IN TERMS OF
SOIL SAVED AND MANURE STORED

	Nitrogen		Phosphorus	
State/Basin Code	Lbs needing treatment in 1985 (in 1000s)	Percent reduced 1985-86	Lbs needing treatment in 1985 (in 1000s)	Percent reduced 1985-86
PA/Susquehanna A	67809.31	3.33	13153.14	3.96
PA/Susquehanna B	27759.18	4.37	5429.88	2.37
PA/Susquehanna C	22563.99	0.71	4368.71	0.75
PA/Susquehanna D	25213.37	1.21	4937.33	1.26
PA/Susquehanna E	25153.11	1.52	4884.74	1.60
PA/Potomac F	13912.34	1.13	2684.86	1.19
PA/WChesapeake S	815.58	1.13	161.79	1.16
MD/Susquehanna A	2437.07	6.40	475.51	6.18
MD/Eastern Shore Q	19938.83	8.89	3821.60	8.91
MD/WChesapeake S	12957.67	3.32	2543.18	3.23
MD/Patuxent R	7359.25	2.10	1473.05	2.02
MD/Potomac F	21921.51	6.67	4232.96	6.61
MD/Potomac T	7546.21	1.23	1512.77	1.22
VA/Eastern Shore Q	718.21	26.18	139.22	27.51
VA/Potomac F	50574.38	2.55	9645.49	2.62
VA/Potomac T	4852.65	4.25	934.82	4.48
VA/Rappahannock G	17508.24	3.80	3387.75	3.98
VA/Rappahannock U	4280.78	13.73	848.94	14.09
VA/York H	8684.47	3.41	1688.92	3.51
VA/York W	3339.16	4.84	658.30	5.00
VA/James I	35185.73	4.76	6729.94	5.06
VA/James X	4441.81	6.66	877.42	6.85
BASIN TOTAL	384972.84	2.96	74590.32	3.03

TECHNICAL APPENDIX 2

THE 1985 CHESAPEAKE BAY WATERSHED BENCHMARK NUTRIENT BUDGET

Table TA-2 was derived from Watershed Model computer calculations of NPS fall line phosphorus and nitrogen loads in the lower Susquehanna River for each land use category in the watershed. Loads were further broken down into phosphorus and nitrogen originating from runoff or base flow (personal communication from John Friedman, NVPDC, to Virginia Tippie, EPA, July 12, 1982). The breakdown between point and nonpoint sources was drawn from the publication, Chesapeake Bay: A Framework for Action, Appendix B, Section 10, September 1983. These 1980 values were updated to 1985 by adjusting point/nonpoint source totals for each sub-basin to reflect changes in land use that occurred during that five-year period.

The NPS distribution and baseflow/runoff breakdown for the lower Susquehanna were projected to the balance of the basin and combined with 1985 point source loads to construct Table TA-2. Base flow loads in the table were further subdivided into natural and man-made components. This breakdown was derived from a Chesapeake Bay Steady-State Model run simulating pristine conditions. In this scenario, tributary loads at and below the fall line were calculated on the basis of 100 percent forest coverage with no nutrient contributions stemming from human activities. Fall line concentrations of 0.85 mg/l for total nitrogen and 0.014 mg/l for total phosphorus were determined for the Susquehanna River. It was estimated on the basis of the model run that 55.8 percent of the total phosphorus and 92.5 percent of the total nitrogen from forested land is transported in base flow. These percentages were applied to nutrient loads from the pristine scenario to calculate the proportion of phosphorus and nitrogen in base flow from natural sources; i.e., not controllable. The remainder of the base flow nutrient load presumably results from human activities and could be reduced by control programs.

The BFL source loads in Table TA-2 were derived from the above information, which was used to determine the nutrient source breakdowns presented in Figure 3-1 in the report, "A Commitment Renewed." Point source load information was the known value; source distributions as shown in Figure 3-1, with one exception, were used to determine overall phosphorus and nitrogen loads for each source. The exception was atmospheric deposition; this value was based on actual data compiled and used in the steady-state model.

Phosphorus and nitrogen loads originating above the fall line (AFL) are based on 1985 fall line monitoring data. The AFL data was subdivided only into natural and human-related sources because a more detailed breakdown would require separate calculations for each sub-basin and consideration of the different delivery factors involved.

When current work to revise and update the Watershed Model is completed, one of the first applications will be to define distribution loads for each sub-basin in order to refine the data presented in Table TA-2.

BFL nutrient budget loads were broken down for individual tributary streams on the basis of factors applicable to each area that govern contributions from various nonpoint sources and natural or other sources (see tables for individual tributaries). Animal waste nitrogen and phosphorus contributions for each State and tributary were based on animal population counts. Similarly, cropland contributions were calculated on the basis of acreage needing treatment (and vice versa) in each State and tributary basin. Nitrogen and phosphorus from forest and urban areas also were based on acreage totals. Nutrient loads from air and base flow were based on the total acreage in each State and tributary.

The 1987 Bay Agreement load reduction goals for each jurisdiction are presented on line "j" for each of the Bay tributaries. The year 2000 anthropogenic loads are shown on line "k." Line "p" represents the total year 2000 load contribution to each tributary by each jurisdiction in an average rainfall year if they achieve the 1987 Agreement reduction goals (line "j") for both point and nonpoint sources.

TABLE TA-2
CHESAPEAKE BAY BASIN BENCHMARK NUTRIENT BUDGET

SOURCE CATEGORY	MILLION LBS - NITROGEN IN 1985			MILLION LBS - PHOSPHORUS IN 1985		
	Total	BFL	AFL	Total	BFL	AFL
POINT SOURCES						
a. Municipal		55.4			5.71	
b. Industrial		5.83			0.098	
c. CSO		unknown			unknown	
Subtotal (a + b)		61.23			5.81	
NONPOINT SOURCES						
d. Animal Waste		22.00			2.29	
e. Cropland Needing Treat		13.67			1.43	
f. Urban		6.62			0.85	
g. Industrial		unknown			unknown	
h. Anthropogenic Base Flow		4.27			0.27	
i. Subtotal (a thru h)	217.55	107.79	110.93	22.79	10.65	12.17
j. 1987 Agreement Reduction Goal:	-87.02	-43.12	-44.37	-9.12	-4.26	-4.87
YEAR 2000 LOAD						
k. Subtotal (i - j)	130.53	64.67	66.56	13.67	6.39	7.30
NATURAL SOURCES						
l. Base Flow		91.81			0.95	
m. Air		49.3			2.5	
n. Forest		3.63			0.46	
OTHER SOURCES						
o. Cropland Not Needing Treatment		4.91			0.48	
p. Subtotal (l thru o)	239.32	149.65	89.67	5.80	4.39	1.41
TOTAL (i plus p)	456.87	257.44	200.60	28.59	15.04	13.56

Notes: At the fall line (AFL) loads (lines i,p and total) are based on State and USGS 1985 monitoring data at the fall lines for the tributary rivers. Anthropogenic base loads were determined based on steady state model projections of pristine conditions. Industrial loads are based on 250 operating work days per year.

BENCHMARK NUTRIENT BUDGET --- SUSQUEHANNA RIVER/PENNSYLVANIA

SOURCE CATEGORY	MILLION LBS - NITROGEN IN 1985			MILLION LBS - PHOSPHORUS IN 1985		
	Total	BFL	AFL	Total	BFL	AFL
POINT SOURCES						
a. Municipal			19.68*			5.48*
b. Industrial			0.24*			0.45*
c. CSO						
Subtotal (a + b)			19.92*			5.93*
NONPOINT SOURCES						
e. Animal Waste						
e. Cropland Needing Treat						
f. Urban						
g. Industrial						
h. Anthropogenic Base Flow						
i. Subtotal (a thru h)			66.8			2.6
j. 1987 Agreement Reduction Goal:			-26.72			-1.04
YEAR 2000 LOAD						
k. Subtotal (i - j)			40.08			1.56
NATURAL SOURCES						
l. Base Flow						
m. Air						
n Forest						
OTHER SOURCES						
o. Cropland Not Needing Treatment						
p. Subtotal (l thru o)			53.99			0.31
TOTAL (i plus p)			120.79			2.91

* Loads not delivered to Fall line.

BENCHMARK NUTRIENT BUDGET --- EASTERN SHORE/PENNSYLVANIA

SOURCE CATEGORY	MILLION LBS - NITROGEN IN 1985			MILLION LBS - PHOSPHORUS IN 1985		
	Total	BFL	AFL	Total	BFL	AFL
POINT SOURCES						
a. Municipal		unknown			unknown	
b. Industrial		unknown			unknown	
		unknown			unknown	
Subtotal (a + b)						
NONPOINT SOURCES						
c. Animal Waste		0.10			0.01	
d. Cropland Needing Treat		0.09			0.009	
e. Urban		0.025			0.003	
f. CSO		unknown			unknown	
g. Industrial		unknown			unknown	
h. Anthropogenic Base Flow		0.01			0.0008	
i. Subtotal (a thru h)		0.225			0.228	
j. Draft Agreement Reduction Goal:		-0.09			0.009	
YEAR 2000 LOAD						
k. Subtotal (i - j)		0.135			0.0137	
NATURAL SOURCES						
l. Base Flow		0.26			.002	
m. Air		0.14			.007	
n Forest		0.004			.0005	
OTHER SOURCES						
o. Cropland Not Needing Treatment		0.001			0.001	
p. Subtotal (l thru o)		0.405			9.6E-03	
TOTAL (i plus p)		.630			0.0324	

BENCHMARK NUTRIENT BUDGET --- W. CHESAPEAKE/PENNSYLVANIA

SOURCE CATEGORY	MILLION LBS - NITROGEN IN 1985			MILLION LBS - PHOSPHORUS IN 1985		
	Total	BFL	AFL	Total	BFL	AFL
POINT SOURCES						
a. Municipal		0			0	
b. Industrial		0			0	
c. CSO		unknown			unknown	
Subtotal (a + b)		0			0	
NONPOINT SOURCES						
d. Animal Waste		0.18			0.020	
e. Cropland Needing Treat		0.21			0.02	
f. Urban		0.012			0.0015	
g. Industrial		unknown			unknown	
h. Anthropogenic Base Flow		0.013			0.0008	
i. Subtotal (a thru h)		0.415			0.042	
j. 1987 Agreement Reduction Goal:		-0.166			0.017	
YEAR 2000 LOAD						
k. Subtotal (i - j)		0.249			0.025	
NATURAL SOURCES						
l. Base Flow		0.312			.003	
m. Air		0.148			.008	
n Forest		0.007			.0001	
OTHER SOURCES						
o. Cropland Not Needing Treatment		0.14			0.013	
p. Subtotal (l thru o)		0.61			0.0241	
TOTAL (i plus p)		1.02			0.066	

BENCHMARK NUTRIENT BUDGET --- POTOMAC RIVER/PENNSYLVANIA

SOURCE CATEGORY	MILLION LBS - NITROGEN IN 1985			MILLION LBS - PHOSPHORUS IN 1985		
	Total	BFL	AFL	Total	BFL	AFL
POINT SOURCES						
a. Municipal			0.61*			0.17*
b. Industrial			0.015			0.001
Subtotal (a + b)			0.6			0.188
NONPOINT SOURCES						
c. Animal Waste						
d. Cropland Needing Treat						
e. Urban						
f. CSO						
g. Industrial						
h. Anthropogenic Base Flow						
i. Subtotal (a thru h)			6.02			.90
j. Draft Agreement Reduction Goal:			-1.67			-0.36
YEAR 2000 LOAD						
k. Subtotal (i - j)			2.47			0.45
NATURAL SOURCES						
l. Base Flow						
m. Air						
n Forest						
OTHER SOURCES						
o. Cropland Not Needing Treatment						
p. Subtotal (l thru o)			3.38			0.11
TOTAL (i plus p)			7.55			1.00

* Loads not delivered to the Fall line.

BENCHMARK NUTRIENT BUDGET --- SUSQUEHANNA RIVER/MARYLAND

SOURCE CATEGORY	MILLION LBS - NITROGEN IN 1985			MILLION LBS - PHOSPHORUS IN 1985		
	Total	BFL	AFL	Total	BFL	AFL
POINT SOURCES						
a. Municipal			0.022*			0.007*
b. Industrial			---			---
c. CSO						
Subtotal (a + b)			.022*			.007*
NONPOINT SOURCES						
d. Animal Waste						
e. Cropland Needing Treat						
f. Urban						
g. Industrial						
h. Anthropogenic Base Flow						
i. Subtotal (a thru h)			0.78			0.085
j. 1987 Agreement Reduction Goal:			-0.31			-0.034
YEAR 2000 LOAD						
k. Subtotal (i - j)			0.47			0.051
NATURAL SOURCES						
l. Base Flow						
m. Air						
n Forest						
OTHER SOURCES						
o. Cropland Not Needing Treatment						
p. Subtotal (l thru o)			0.63			0.01
TOTAL (i plus p)			1.41			0.095

* Loads not delivered to the Fall line.

BENCHMARK NUTRIENT BUDGET --- W. CHESAPEAKE/MARYLAND

SOURCE CATEGORY	MILLION LBS - NITROGEN IN 1985			MILLION LBS - PHOSPHORUS IN 1985		
	Total	BFL	AFL	Total	BFL	AFL
POINT SOURCES						
a. Municipal		16.05			1.59	
b. Industrial		3.59			0.018	
c. CSO		unknown			unknown	
Subtotal (a + b)		19.64			1.604	
NONPOINT SOURCES						
d. Animal Waste		4.04			0.42	
e. Cropland Needing Treat		2.8			0.29	
f. Urban		1.06			0.135	
g. Industrial		unknown			unknown	
h. Anthropogenic Base Flow		0.5			0.03	
i. Subtotal (a thru h)		28.04			2.48	
j. 1987 Agreement Reduction Goal:		-11.22			-0.99	
YEAR 2000 LOAD						
k. Subtotal (i - j)		16.82			1.49	
NATURAL SOURCES						
l. Base Flow		11.5			0.11	
m. Air		6.8			0.29	
n Forest		0.36			0.045	
OTHER SOURCES						
o. Cropland Not Needing Treatment		0.22			0.02	
p. Subtotal (l thru o)		18.26			0.465	
TOTAL (i plus p)		46.20			2.95	

BENCHMARK NUTRIENT BUDGET --- PATUXENT RIVER/MARYLAND

SOURCE CATEGORY	MILLION LBS - NITROGEN IN 1985			MILLION LBS - PHOSPHORUS IN 1985		
	Total	BFL	AFL	Total	BFL	AFL
POINT SOURCES						
a. Municipal		0.47		0.38	0.11	
b. Industrial		0.034			0.003	
c. CSO		unknown			unknown	
Subtotal (a + b)		0.504			0.113	
NONPOINT SOURCES						
d. Animal Waste		1.09			0.11	
e. Cropland Needing Treat		2.18			0.23	
f. Urban		0.54			0.069	
g. Industrial		unknown			unknown	
h. Anthropogenic Base Flow		0.23			0.015	
i. Subtotal (a thru h)		4.54			0.54	
j. 1987 Agreement Reduction Goal:		-1.82			-0.22	
YEAR 2000 LOAD						
k. Subtotal (i - j)		2.72			0.32	
NATURAL SOURCES						
l. Base Flow		5.37			0.05	
m. Air		2.88			0.135	
n Forest		0.19			0.024	
OTHER SOURCES						
o. Cropland Not Needing Treatment		0.17			0.02	
p. Subtotal (l thru o)		8.61			0.23	
TOTAL (i plus p)		13.15			0.55	

BENCHMARK NUTRIENT BUDGET --- EASTERN SHORE/MARYLAND

SOURCE CATEGORY	MILLION LBS - NITROGEN IN 1985			MILLION LBS - PHOSPHORUS IN 1985		
	Total	BFL	AFL	Total	BFL	AFL
POINT SOURCES						
a. Municipal		1.02			0.38	
b. Industrial		0.34			0.009	
c. CSO		unknown			unknown	
Subtotal (a + b)		1.37			0.389	
NONPOINT SOURCES						
d. Animal Waste		10.07			1.05	
e. Cropland Needing Treat		2.43			0.25	
f. Urban		0.67			0.09	
g. Industrial		unknown			unknown	
h. Anthropogenic Base Flow		0.89			0.06	
i. Subtotal (a thru h)		15.43			1.84	
j. 1987 Agreement Reduction Goal:		-6.17			-0.74	
YEAR 2000 LOAD						
k. Subtotal (i - j)		9.26			1.10	
NATURAL SOURCES						
l. Base Flow		20.62			0.21	
m. Air		11.07			0.56	
n Forest		0.76			0.10	
OTHER SOURCES						
o. Cropland Not Needing Treatment		0.19			0.02	
p. Subtotal (l thru o)		32.64			0.89	
TOTAL (i plus p)		48.07			2.73	

BENCHMARK NUTRIENT BUDGET - POTOMAC RIVER/MARYLAND

SOURCE CATEGORY	MILLION LBS - NITROGEN IN 1985			MILLION LBS - PHOSPHORUS IN 1985		
	Total	BFL	AFL	Total	BFL	AFL
POINT SOURCES						
a. Municipal		6.07	2.01*		0.169	0.62*
b. Industrial		.03	.016*		.005	.016*
		unknown			unknown	
Subtotal (a + b)	8.333	6.37	2.023	0.806	0.174	0.633*
NONPOINT SOURCES						
c. Animal Waste		1.02			0.11	
d. Cropland Needing Treat		2.28			0.24	
e. Urban		0.64			0.082	
f. CSO		unknown			unknown	
g. Industrial		unknown			unknown	
h. Anthropogenic Base Flow		0.33			0.021	
i. Subtotal (a thru h)	16.42	10.64	5.78	1.87	0.63	1.24
j. 1987 Agreement Reduction Goal:	-3.67	-4.26	-2.31	-.75	-0.25	-0.50
YEAR 2000 LOAD						
k. Subtotal (i - j)	9.79	6.38	3.41	1.00	0.38	-.62
NATURAL SOURCES						
l. Base Flow		7.57			0.07	
m. Air		4.07			0.19	
n Forest		0.31			0.039	
OTHER SOURCES						
o. Cropland Not Needing Treatment		0.18			0.02	
p. Subtotal (l thru o)	16.81	12.13	4.68	0.47	0.32	0.15
TOTAL (i plus p)	33.23	17.33	10.46	2.34	0.91	1.39

BENCHMARK NUTRIENT BUDGET --- POTOMAC RIVER/D.C.

SOURCE CATEGORY	MILLION LBS - NITROGEN IN 1985			MILLION LBS - PHOSPHORUS IN 1985		
	Total	BFL	AFL	Total	BFL	AFL
POINT SOURCES						
a. Municipal		6.65			0.065	
b. Industrial		---			---	
c. CSO		unknown			unknown	
Subtotal (a + b)		6.65			0.065	
NONPOINT SOURCES						
d. Animal Waste		N/A			N/A	
e. Cropland Needing Treat		N/A			N/A	
f. Urban		0.115			0.015	
g. Industrial		unknown			unknown	
h. Anthropogenic Base Flow		0.017			0.017	
i. Subtotal (a thru h)		6.78			0.097	
j. 1987 Agreement Reduction Goal:		-2.71			-0.039	
YEAR 2000 LOAD						
k. Subtotal (i - j)		4.07			0.068	
NATURAL SOURCES						
l. Base Flow		0.41			0.004	
m. Air		0.22			0.01	
n Forest		0.003			0.0003	
OTHER SOURCES						
o. Cropland Not Needing Treatment		N/A			N/A	
p. Subtotal (l thru o)		0.633			0.0143	
TOTAL (i plus p)		7.42			0.111	

Note: Nutrient loads from Blue Plains are distributed to each jurisdiction based on flow contribution.

BENCHMARK NUTRIENT BUDGET --- POTOMAC RIVER/VIRGINIA

SOURCE CATEGORY	MILLION LBS - NITROGEN IN 1985			MILLION LBS - PHOSPHORUS IN 1985		
	Total	BFL	AFL	Total	BFL	AFL
POINT SOURCES						
a. Municipal		7.86	1.41*		0.1	0.47*
b. Industrial		--- unknown	---		--- unknown	---
Subtotal (a + b)	9.22	7.86	1.41*	0.57	0.1	0.47*
NONPOINT SOURCES						
c. Animal Waste		2.25			.23	
d. Cropland Needing Treat		0.69			.07	
e. Urban		1.35			.17	
f. CSO		unknown			unknown	
g. Industrial		unknown			unknown	
h. Anthropogenic Base Flow		0.5			0.03	
i. Subtotal (a thru h)	24.86	12.65	12.21	3.23	0.60	2.63
j. Draft Agreement Reduction Goal:	- 9.94	-5.06	-4.88	-1.29	-0.24	-1.05
YEAR 2000 LOAD						
k. Subtotal (i - j)	14.80	7.59	7.21	1.67	0.36	1.31
NATURAL SOURCES						
l. Base Flow		11.48			0.11	
m. Air		6.16			0.29	
n Forest		0.40			0.05	
OTHER SOURCES						
o. Cropland Not Needing Treatment		0.05			0.01	
p. Subtotal (l thru o)	27.86	18.09	9.87	.72	0.41	0.31
TOTAL (i plus p)	52.82	30.74	22.08	3.94	1.01	2.93

BENCHMARK NUTRIENT BUDGET --- RAPPAHANNOCK RIVER/VIRGINIA

SOURCE CATEGORY	MILLION LBS - NITROGEN IN 1985			MILLION LBS - PHOSPHORUS IN 1985		
	Total	BFL	AFL	Total	BFL	AFL
POINT SOURCES						
a. Municipal		0.30	0.18*		0.11	0.07*
b. Industrial		---	---		---	---
c. CSO		unknown			unknown	
Subtotal (a + b)		0.30	0.18*	0.18	0.11	0.07*
NONPOINT SOURCES						
d. Animal Waste		.93			0.1	
e. Cropland Needing Treat		1.1			0.12	
f. Urban		.43			0.055	
g. Industrial		unknown			unknown	
h. Anthropogenic Base Flow		0.47			0.03	
i. Subtotal (a thru h)	4.89	2.79	2.1	0.54	0.36	.18
j. 1987 Agreement Reduction Goal:	-1.96	-1.12	-0.84	-1.072	-0.14	0.072
YEAR 2000 LOAD						
k. Subtotal (i - j)	3.03	1.67	1.36	0.33	0.22	0.108
NATURAL SOURCES						
l. Base Flow		11.05			.11	
m. Air		5.94			.28	
n Forest		0.56			.07	
OTHER SOURCES						
o. Cropland Not Needing Treatment		0.09			.01	
p. Subtotal (l thru o)	19.12	17.64	1.48	.49	.47	0.02
TOTAL (i plus p)	24.01	20.43	3.58	1.03	0.83	0.2

* Loads not delivered to Fall line.

BENCHMARK NUTRIENT BUDGET --- EASTERN SHORE/VIRGINIA

SOURCE CATEGORY	MILLION LBS - NITROGEN IN 1985			MILLION LBS - PHOSPHORUS IN 1985		
	Total	BFL	AFL	Total	BFL	AFL
POINT SOURCES						
a. Municipal		0.006			.002	
b. Industrial		0.24			---	
c. CSO		unknown			unknown	
Subtotal (a + b)		0.25			.002	
NONPOINT SOURCES						
d. Animal Waste		0.3			0.03	
e. Cropland Needing Treat		0.12			.02	
f. Urban		0.05			0.007	
g. Industrial		unknown			unknown	
h. Anthropogenic Base Flow		0.44			.03	
i. Subtotal (a thru h)		1.16			0.089	
j. Draft Agreement Reduction Goal:		-0.46			-0.036	
YEAR 2000 LOAD						
k. Subtotal (i - j)		0.70			0.0531	
NATURAL SOURCES						
l. Base Flow		2.86			0.03	
m. Air		1.53			0.078	
n Forest		0.14			0.017	
OTHER SOURCES						
o. Cropland Not Needing Treatment		0.01			0.0	
p. Subtotal (l thru o)		4.54			0.125	
TOTAL (i plus p)		5.75			0.214	

BENCHMARK NUTRIENT BUDGET --- YORK RIVER/VIRGINIA

SOURCE CATEGORY	MILLION LBS - NITROGEN IN 1985			MILLION LBS - PHOSPHORUS IN 1985		
	Total	BFL	AFL	Total	BFL	AFL
POINT SOURCES						
a. Municipal		0.51	0.11*		0.16	0.03*
b. Industrial		0.075	---		0.063	---
c. CSO		unknown			unknown	
Subtotal (a + b)	0.68	0.59	0.11*	0.24	0.22	0.03*
NONPOINT SOURCES						
d. Animal Waste		.92			0.1	
e. Cropland Needing Treat		0.78			0.08	
f. Urban		0.48			0.06	
g. Industrial		unknown			unknown	
h. Anthropogenic Base Flow		0.32			0.02	
i. Subtotal (a thru h)	7.48	3.09	4.41	0.87	0.48	0.40
j. 1987 Agreement Reduction Goal:	-3.01	-1.24	-1.78	0.35	-0.19	-0.16
YEAR 2000 LOAD						
k. Subtotal (i - j)	4.50	1.85	2.66	0.52	0.29	0.24
NATURAL SOURCES						
l. Base Flow		7.46			0.07	
m. Air		4.01			0.19	
n Forest		0.37			0.047	
OTHER SOURCES						
o. Cropland Not Needing Treatment		0.06			0.047	
p. Subtotal (l thru o)	13.06	11.9	1.16	0.365	0.32	0.045
TOTAL (i plus p)	20.57	14.99	5.6	1.235	0.80	0.445

* Loads not delivered to Fall line.

BENCHMARK NUTRIENT BUDGET - JAMES RIVER/VIRGINIA

SOURCE CATEGORY	MILLION LBS - NITROGEN IN 1985			MILLION LBS - PHOSPHORUS IN 1985		
	Total	BFL	AFL	Total	BFL	AFL
POINT SOURCES						
a. Municipal		16.53	1.63*		3.03	0.58*
b. Industrial		1.50	0.005*		0.0001	0.001*
c. CSO		unknown			unknown	
Subtotal (a + b)	19.365	18.03	1.635*	3.6111	3.0301	0.581*
NONPOINT SOURCES						
d. Animal Waste		1.15			0.1	
e. Cropland Needing Treat		1.08			0.11	
f. Urban		1.27			0.16	
g. Industrial		unknown			unknown	
h. Anthropogenic Base Flow		0.56			0.036	
i. Subtotal (a thru h)	28.54	22.09	6.75	5.50	3.44	2.06
j. 1987 Agreement Reduction Goal:	-11.42	-8.84	-2.7	-2.21	-1.38	-0.83
YEAR 2000 LOAD						
k. Subtotal (i - j)	17.12	13.25	4.05	3.29	2.06	1.23
NATURAL SOURCES						
l. Base Flow		13.16			0.125	
m. Air		7.07			0.33	
n Forest		0.55			0.07	
OTHER SOURCES						
o. Cropland Not Needing Treatment		0.08			0.01	
p. Subtotal (l thru o)	26.06	20.86	5.2	.78	0.54	.24
TOTAL (i plus p)	54.60	42.95	11.95	6.28	3.98	2.3

* Loads not delivered to Fall line.

TECHNICAL APPENDIX 3

CHESAPEAKE BAY EUTROPHICATION MODEL: RESULTS OF MANAGEMENT SCENARIOS

Introduction

A steady-state eutrophication model of the Chesapeake Bay and major tidal tributaries was used to evaluate the effects of various control scenarios on water quality conditions. A detailed description of the steady state model is included in "Development of a Coupled Steady State Hydrodynamic/Water Quality Model of the Eutrophication and Anoxia Process in Chesapeake Bay" (HydroQual, Inc, August, 1987). It should be noted that modeling information and results in this report are largely dependent on the portion of the model which adjusts Bay bottom nutrient release rates and oxygen demand in relation to reductions in point and nonpoint source loadings. A complete discussion of this "sediment rate adjustment methodology" is contained in the HydroQual model documentation report.

Nutrient Limitation

To better understand and interpret the modeling results, it is useful to examine first how the model deals with nutrient limitation of phytoplankton growth and how well model projections of nutrient limitation compare with observed data. The model calculates the effect of nutrient concentrations on the phytoplankton growth rate by the Michaelis-Menton formulation. Growth rate reductions resulting from dissolved inorganic phosphorous (DIP) and dissolved inorganic nitrogen (DIN) concentrations are calculated individually, with the minimum value controlling growth as the limiting nutrient. In the main Bay, the half saturation constants used in the Michaelis-Menton formulation are 15 ug N/l and 1.5 ug P/l. Therefore, for DIN/DIP ratios of less than 10, the model calculates nitrogen limitation. For DIN/DIP ratios greater than 10, phosphorous limited conditions are calculated.

The degree to which the steady state model reproduces the observed DIN/DIP data must be assessed in order to determine the model's ability to accurately portray phytoplankton growth. Figure 1 (adopted from HydroQual, 1987), shows the final model calibration for DIN/DIP in transect 2 (main channel) of the Bay for the summer of 1984. It can be seen that the model slightly underpredicts the observed DIN/DIP data in layer 1, where most phytoplankton growth occurs. Both the data and model indicate a strongly nitrogen limited condition from the mouth of the Bay to KM 100. From KM 100 to KM 160, the model projects nitrogen limitation while data shows a borderline condition between nitrogen and phosphorus limitation. This area will be nitrogen limited at some times, and phosphorus limited at others. Above KM 160, both the data and the model indicate a strongly phosphorus limited condition, although the model underpredicts this somewhat. The comparison of observed DIN/DIP data with the model projection shows that for 1984 calibration conditions the model will somewhat overstate to a degree the effectiveness of nitrogen control strategies due to the underprediction of DIN/DIP, primarily in the area between KM 100 and KM 160.

The final model calibration for 1985 shown in Figure 2 (adopted from HydroQual, 1987) indicates that the model is over-predicting DIN/DIP in the area between KM 100 and KM 220. In this area, the data indicates a moderate degree of nitrogen limitation while the model predicts a borderline condition. As a consequence, effects of nitrogen control strategies will be significantly understated when 1985 conditions are simulated.

Scenarios Evaluated

Point source scenarios ranging from currently planned upgrades to the limit of technology for both existing (1985) point source flows and flows projected for the year 2000 were evaluated using the model. Since the relative ranking of scenarios does not change between 1985 and year 2000 conditions however, information presented here is limited primarily to year 2000 conditions. The use of year 2000 projections also makes sense in view of the time necessary to implement control strategies. Tables 1 and 2 show the loadings associated with each point source scenario. Only point sources discharging below the fall line were included in control scenarios except for the Patuxent River, where discharges above the fall line were included. For the Patuxent, the fall line concentration was adjusted to reflect the effect of the scenario being considered. This fall line adjustment considers in-stream losses, which are somewhat different for 1984 and 1985 stream flows. All other point sources above the fall line were assumed to remain at their current loading, reflected in fall line concentration.

In addition to point source control scenarios, a NPS scenario was evaluated separately and in combination with point source strategies. The NPS control strategy (NPS 2000) considered was based on projecting the current rate of BMP implementation on agricultural lands through the year 2000. At that implementation rate, it has been estimated that the "controllable loading" at the fall line and NPS loadings below the fall line can be reduced 23% for P, with a 20% reduction of N. The controllable load at the fall line is that fraction in excess of natural background or pristine conditions.

Summaries of model results for the main Bay for the year 2000 scenarios are shown in Table 3. A discussion of scenario results follows.

Pristine Conditions

An estimate of pristine conditions in the main Bay was made by running the calibrated model with no point sources, reduced fall line and NPS loads to levels representative of forested conditions and reduced SOD and sediment nutrient flux rates. The following values were used:

Fall Line Concentration

TP = .014 mg/l
DOP = .001 mg/l
POP = .009 mg/l

DIP = .004 mg/l
TN = .85 mg/l
DON = .05 mg/l
PON = .15 mg/l
NH3 = .01 mg/l
NO3 = .64 mg/l
$CBOD_5$ = 1.0 mg/l
Chlor = 5 ug/l
DO = 8 mg/l

Sediment Rates

SOD reduced 50% from calibration rates (range from .15 gm/m2 - d to .50 gm/m2 - d in transect 2)

PO4 1.0 mg/m2 - d for everything > 1.0

NH3 10 mg/m2 - d for everything > 10

NO3 -10 mg/m2 - d for everything more neg. than -10

NPS Loads

P - 30% of existing load
N - 60% of existing load
BOD5 - 50% of existing load

Plots of the model projection for pristine conditions for 1984 and 1985 circulation re contained in Figures A1-8 and B1-8.

Minimum DO levels are projected to be 3.1 mg/l and 3.5 mg/l for 1984 and 1985 circulation respectively. Maximum chlorophyll levels in the area between km 150 and km 200 were 10.6 ug/l and 8.5 ug/l for 1984 and 1985. This represented about a 9 ug/l and 5 ug/l decrease, respectively from 1984 and 1985 calibration conditions.

Comparison of Dual Biological Nutrient Removal (BNR) with Only P-Removal (TP=1)

The control of both N and P at point sources has been advocated by various members of the Bay community and most recently by the Scientific and Technical Advisory Committee (STAC) in recommending that BNR be implemented at point sources Baywide. The BNR process can achieve effluent concentrations of TP=1, TN=6 according to Dr. Clifford Randall of VPI. For year 2000 point source flows, model projections of the main Bay water quality response to BNR are compared to projections of P removal (TP=1) alone for 1984 and 1985 calibrations in figures C1-2 (1984) and D1-2 (1985). As seen from the plots for 1984 circulation, the removal of N in addition to P results in a decrease of about 1.25-1.8 ug/l in chlorophyll (km 100 - 150) compared to P only. The reason is that N was limiting algal growth rather strongly from the mouth of the Bay up to km 167 in the 1984 calibration. Even when P is controlled to 1 mg/l at all point sources, this area remains N limited. Thus, the addition of N controls produces benefits in this N limited area of the Bay. DO levels improve

.10 - .20 mg/l from km 75 - 220 over DO values with P only. It appears that the high degree of vertical stratification during 1984 minimizes the response of DO.

With 1985 circulation conditions, however, the effect of BNR is minimal except in the lower 80 km of the Bay. This is because the model, under the 1985 calibration, calculates a borderline condition for nutrient limitation between KM 108 and KM 220, and a strong phosphorus limitation above KM 220. When phosphorus is controlled to 1 mg/l, most of the borderline zone is pushed to a phosphorus limited condition, even when nitrogen is also controlled. Only in the lower 80 KM of the Bay, where the model shows strong nitrogen limitation, is the control of nitrogen calculated to be effective. It should be noted that control of P alone results in the transport of additional N to this area of the lower Bay, stimulating algal growth to levels which equal calibration levels.

In considering these scenario results, remember that projections for 1985 circulation significantly underestimate the effect of nitrogen control while projections for 1984 circulation somewhat overestimate those effects.

In addition to estimating water quality effects of a BNR process achieving TP=1 and TN=6, the impact of a somewhat less efficient BNR process (TP=2, TN=8) also was estimated, based on conclusions in a report prepared for EPA by Hazen and Sawyer and J.M. Smith Associates ("Assessment of Cost and Effectiveness of Biological Dual Nutrient Removal Technologies in the Chesapeake Bay Drainage Basin"). Not surprisingly, a less effective BNR process has less impact upon water quality. The differences in nutrient limitation in 1984 and 1985 still apply, however, Table 3 summarizes model results and can be used to compare alternatives.

NPS Control

The effect of reducing agricultural runoff of N, P, and C at the field by 27 percent, 30 percent, and 30 percent, respectively, is shown in Figures E1-2 (1984) and F1-2 (1985). Note that this scenario represents a reduction in the "controllable loading" at the fall line of 23 percent for P and C, and 20 percent for N. This scenario, referred to as NPS2000, reflect the current rate of BMP implementation from 1985 through year 2000.

As can be seen in the figures, control of NPS has a significant impact on water quality in both 1984 and 1985, since both N and P are being controlled. Even though significant improvements occur, however, the minimum DO is still only .32 mg/l for 1984 circulation due to the high degree of stratification.

Under 1985 conditions, DO improvements are significantly greater, with the minimum about 1.1 mg/l. As a result of DO greater than 1.0 mg/l, aerobic sediment nutrient flux rates become effective, producing a significant decrease in chlorophyll.

Effects of Growth

The effects of population growth on point source flows and Bay water quality are shown in figures G1-2 (1984) and H1-2 (1985). Currently planned upgrades (essentially phosphorus removal except for several plants on the Patuxent that remove nitrogen as well), produce a decrease in chlorophyll and an increase in DO under both 1984 and 1985 conditions, compared to the calibration. At year 2000 projected population levels there is some loss in water quality improvements gained from currently planned upgrades. The year 2000 projection is based on a point source flow increase of 6 percent.

This was based on point source flows increasing in direct proportion to population. In view of the uncertainty associated with projecting point source flows, an alternative estimate called 2000X was developed. This estimate, based on the design capacity of existing facilities, results in a 42 percent increase in point source flow. With this scenario, water quality degrades to point erasing all gains from full implementation of planned upgrades under both 1984 and 1985 circulation conditions.

Combined Point Source/NPS Controls

The effect of combining the NPS 2000 alternative with the 3-stage BNR (TP=2, TN=8) alternative for 1984 circulation is shown in figure I1-2. As expected, this combination shows some improvement of water quality, primarily below KM 200, as a result of the increased removal of nitrogen. For 1985 circulation, similar increment of improvement occurs, although the control of phosphorus is responsible upstream of KM 100 in this case. Table 3 summarizes these results.

1987 Bay Agreement

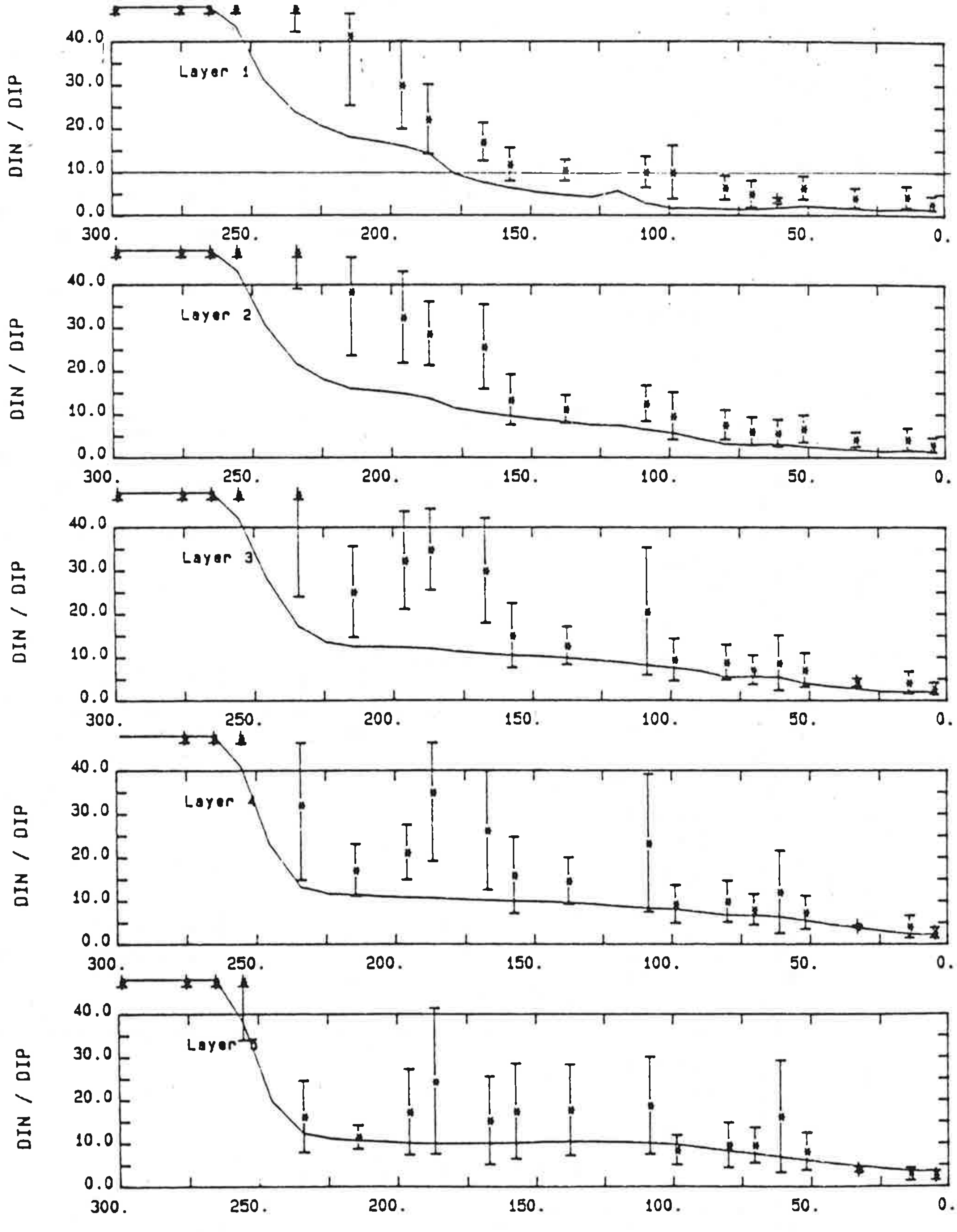
The 1987 Chesapeake Bay Agreement calls for a 40 percent reduction in nutrient loadings by the year 2000. Projected water quality improvements these reductions are shown as figures J2-2 (1984) and K2-2 (1985). For comparative purposes, a 40 percent reduction in phosphorus alone also is shown. In this model projection, point source loads below the fall line were reduced 40 percent. The controllable fraction of NPS loads below the fall line and controllable fall line loads also were reduced 40 percent.

For 1984 circulation, there is significant water quality improvement from the 40 percent reduction of N and P as compared to P alone. In addition to improving the minimum DO from 0.12 mg/l (calibration) to 0.62 mg/l and reducing the maximum chlorophyll from 18.3 mg/l (calibration) to 15.1 ug/l, the volume of water with DO<2.0 mg/l (considered acutely toxic to fish and shellfish) and the mass of chlorophyll is significantly reduced. Table 4 contains these comparisons. As can be seen, a 40 percent reduction of phosphorus results in an 8.6 percent decrease in chlorophyll in the Bay and tributaries. Control of both N and P decreases chlorophyll 16.4%, about twice the reduction achieved with phosphorus control alone. Similar effects can be seen in the projected decrease in volume of main Bay water with DO less than 2.0 mg/l. A 40% reduction in

P decreased this volume 30 percent while a 40 percent reduction in both N and P results in a 65 percent decrease in the volume with DO less than 2.0 mg/l.

For 1985 circulation, a 40 percent reduction of both N and P is projected to be effective in only the lower 100 KM of the Bay, compared to a 40 percent duction of phosphorus. However, as discussed earlier, the model significantly underestimates the effect of nitrogen control for 1985 circulation conditions. It is estimated that the effect of nitrogen control under 1985 circulation should approximate the results from the model simulations of 1984 circulation. While the absolute improvements in DO and chlorophyll probably will be about the same as those projected by the model, the incremental improvement due to nitrogen will be greater than projected, while the increment due to phosphorus reductions will be smaller.

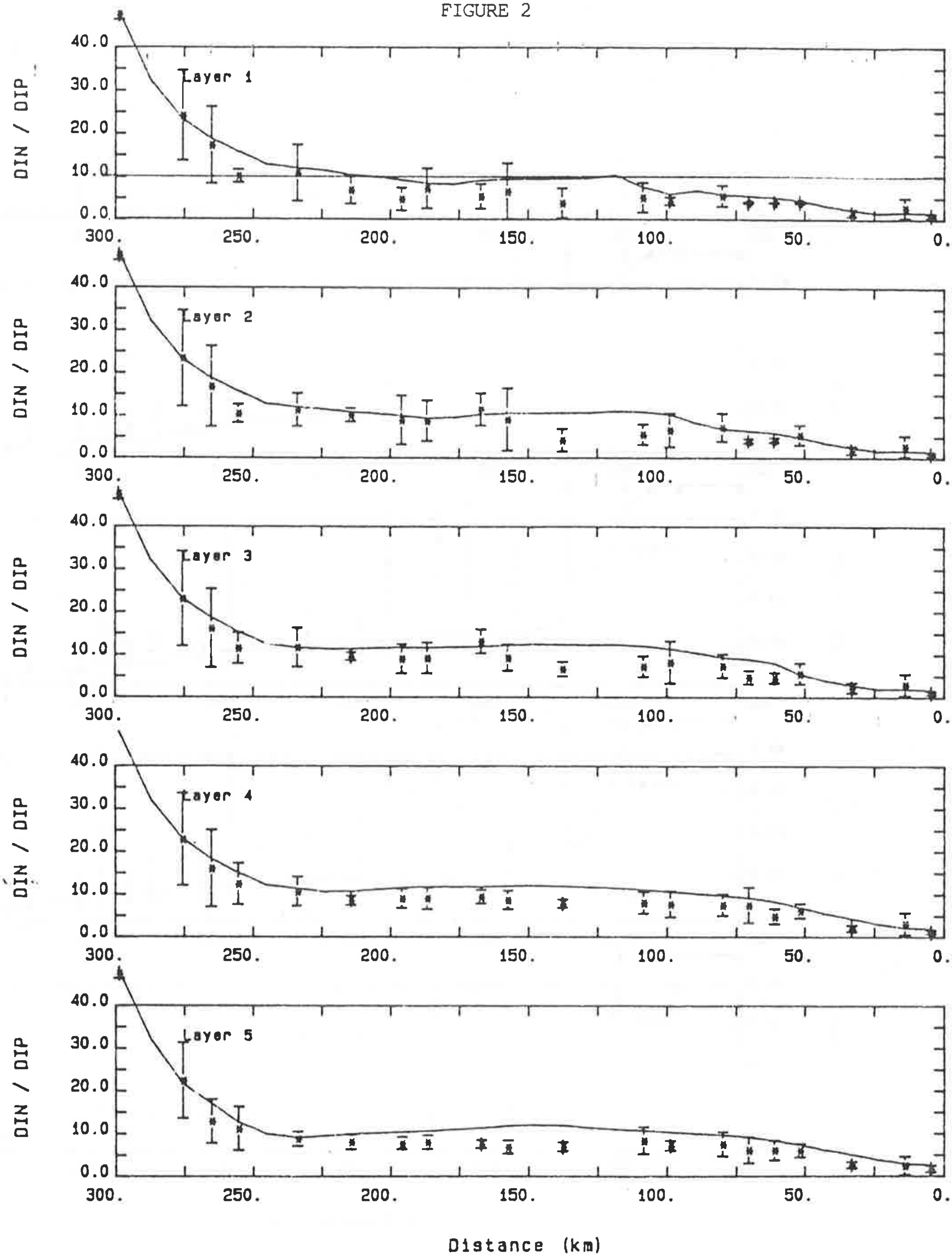
FIGURE 1



Spatial Profile of Dissolved Inorganic Nitrogen to Dissolved Inorganic Phosphorus Ratio - Transect 2 (1984)

HYDROQUAL

FIGURE 2



Spatial Profile of Dissolved Inorganic Nitrogen to Dissolved Inorganic Phosphorus Ratio - Transect 2 (1985)

HYDROQUAL

TABLE 1
LOADINGS FOR EXISTING (1985) POINT SOURCE FLOW SCENARIOS

	Below Fall Line							Patuxent P.S. Load at F. L.		
	TP (#/d)	% change 1/	TN (#/d)	% change	BOD_5 (#/d)	% change	Total Flow(mgd)	TP (#/d)	TN (#/d)	(1984 CIRC.) (1985 CIRC.)
Existing (1985)	15894	-	150618	-	143488	-	1150	292 492	2039 2250	
Planned Upgrades	10470	-35	137831	-8	75125	-48	1150	107 170	1609 1822	
Planned Upgrades + TP = 1	3879	-76	137831	-8	75125	-48	1150	107 170	1609 1822	
Planned Upgrades + TP = 1, TN = 6 (Dual BNR)	3879	-76	72710	-52	75125	-48	1150	107 170	584 661	
Limit of Tech. (TP = .10, TN= 3)	1020	-94	34589	-77	75125	-48	1150	11 17	322 365	

1/ % change relative to 1985 Existing

TABLE 2

LOADINGS FOR YEAR 2000 POINT SOURCE FLOW SCENARIOS

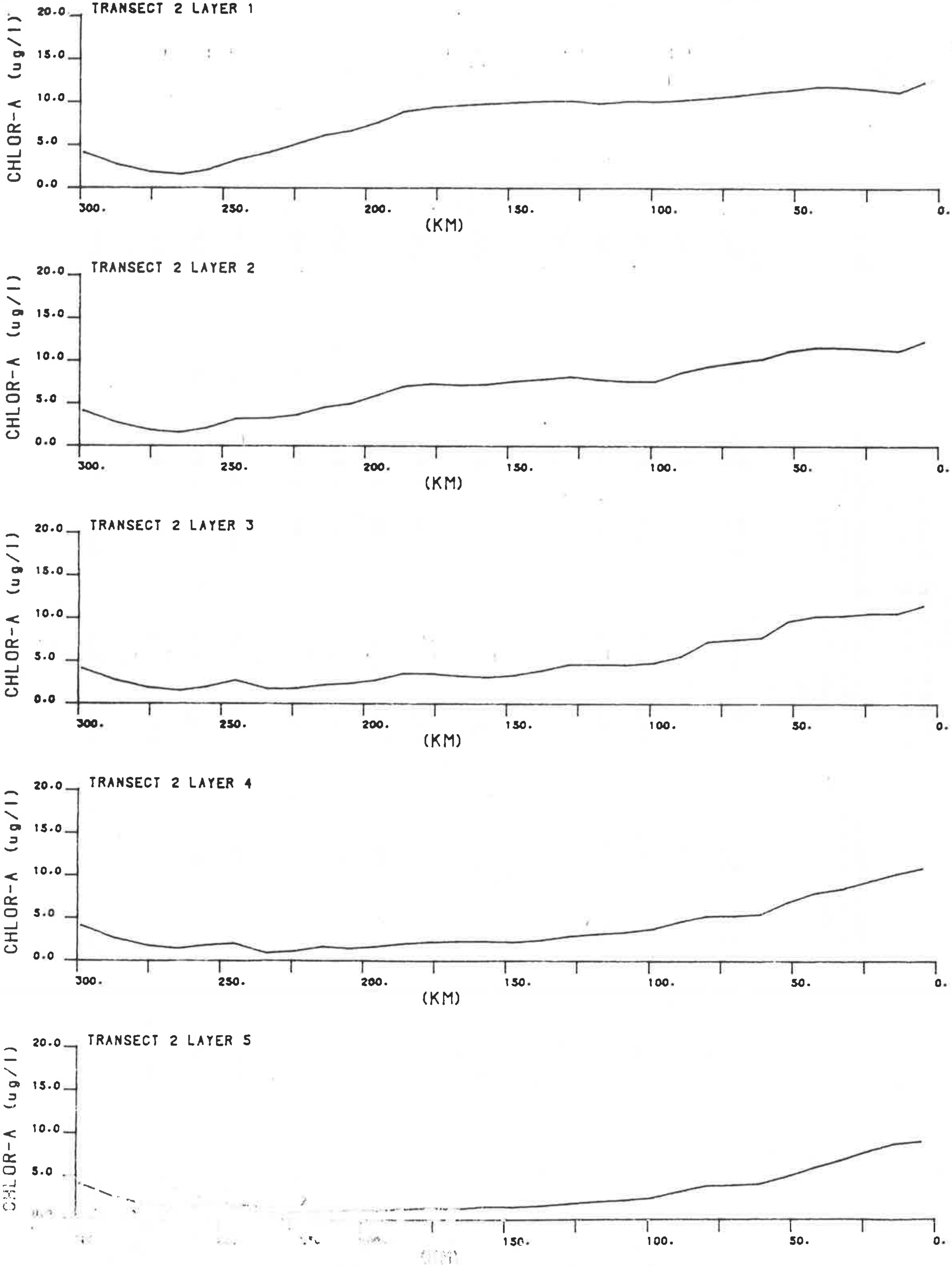
	Below Fall Line							Patuxent P.S. Load at F.L.		
	TP (#/d)	% change 1/	TN (#/d)	% Change	BOD_5 (#/d)	% Change	Total Flow(MGD)	TP (#/d)	TN (#/d)	(1984 CIRC.) (1985 CIRC.)
Existing Calibration	17784	+12	160898	+7	150257	+5	1226	334 558	2556 2835	
Planned Municipal Upgrades	11790	-26	147207	-2	79578	-45	1226	139 220	2112 2390	
Planned Municipal Upgrades at design flow in year 2000X	17999	+13	202773	+26	108319	-24	1226	175 278	2603 2947	
Planned Municipal Upgrades + TP = 1	4217	-73	147207	-2	79578	-45	1226	139 220	2112 2390	
Planned Municipal Upgrades + TP = 1, TN = 6 (BNR-Randall est)	4217	-73	76689	-49	79578	-45	1226	139 220	763 921	
Planned Municipal Upgrades + TP = 2, TN = 8 (BNR-EPA est.)	6953	-56	77760	-48	79578	-45	1226	139 220	1224 1386	
Limit of Technology (TP = .18, TN = 3)	1070	-93	36833	-76	79578	-45	1226	14 22	416 471	

1/ % change relative to 1985 Existing

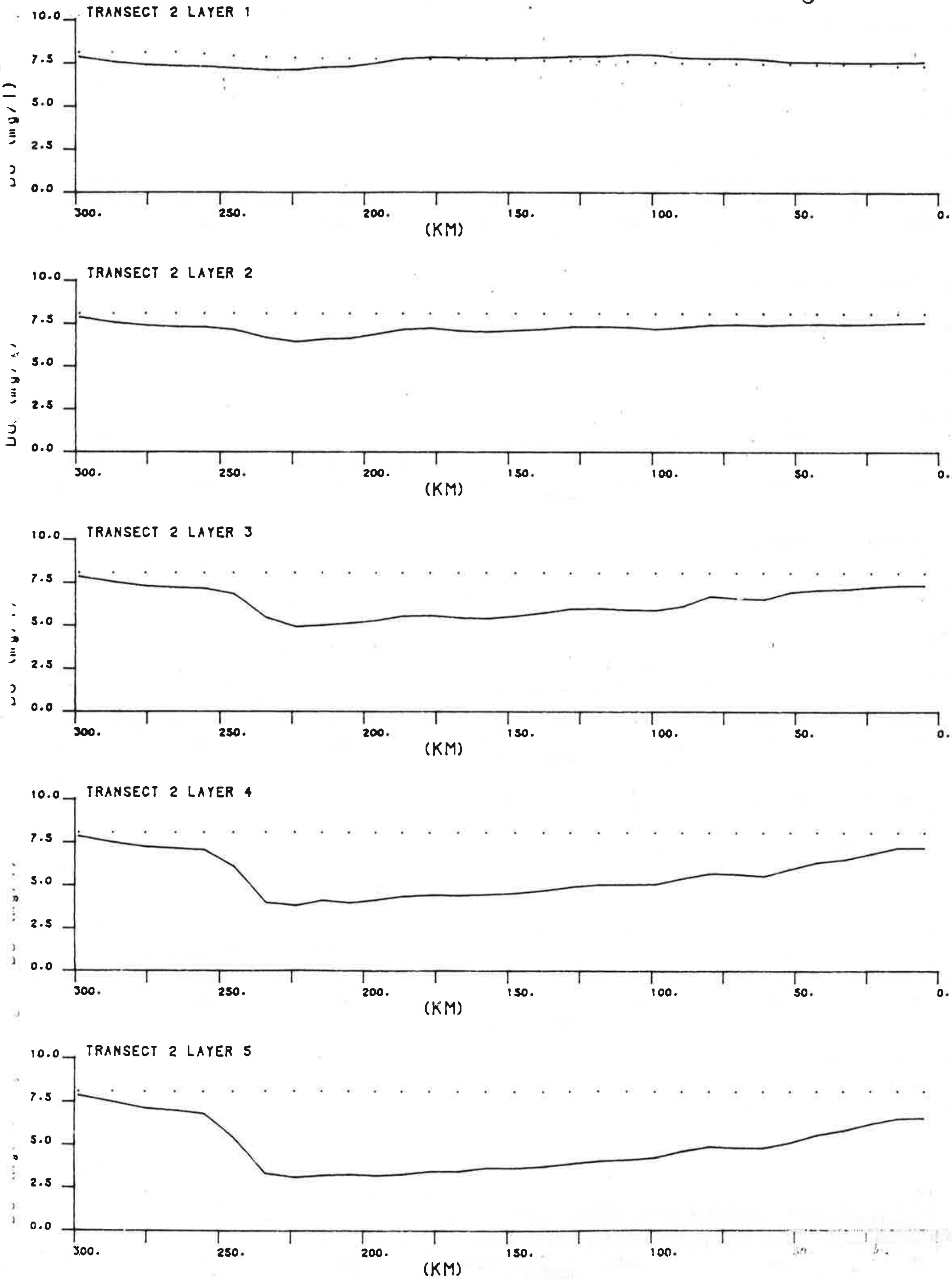
Table 3
Summary of Model Results
Year 2000 Projections

	Bay + Tribs. Chlorophyll Mass (10^6kg)		Bay Main Channel Peak Chlorophyll (KM 148-187) (ug/l)		Bay Main Channel Summer Ave. Min. DO (mg/l)		Bay Water Vol. (10^{10} M3) 1984			Bay Water Vol. (10^{10} M3) 1985		
	1984	1985	1984	1985	1984	1985	DO<1	DO<2	DO<3.3	DO<1	DO<2	DO<3.3
Calibration	.806	.717	18.3	13.6	.12	.43	.226	.370	.770	.135	.276	.549
Planned Upgrades	.745	.619	16.6	10.4	.22	1.1	.135	.311	.621	0	.155	.454
2000X Planned Upgrades	.786	.663	17.5	11.2	.17	.87	.177	.332	.707	.031	.195	.464
Planned Upgrades + TP=1	.732	.581	16.3	9.8	.24	1.28	.135	.295	.621	0	.155	.417
Planned Upgrades + TP=1, TN=6 (Dual BNR-Randall Estimate)	.700	.575	15.8	9.8	.31	1.33	.135	.259	.519	0	.135	.417
Planned Upgrades + TP=2, TN=8 (Dual BNR - EPA Estimate)	.705	.591	16.1	10.0	.29	1.23	.135	.275	.550	0	.135	.417
Limit of Technology	.672	.552	15.1	9.5	.39	1.46	.093	.206	.505	0	.135	.379
Planned Upgrades + 2000 NPS	.716	.604	15.6	10.0	.38	1.40	.093	.259	.536	0	.135	.417
TP=2,TN=8+2000 NPS	.676	.577	15.1	9.7	.51	1.53	.093	.226	.475	0	.135	.357
Limit of Technology + 2000 NPS	.647	.540	14.3	9.1	.64	1.75	.063	.208	.432	0	.061	.295
40% Reduction of TP	.723	.596	15.7	9.7	.42	1.54	.093	.240	.536	0	.135	.357
40% Reduction of TP+TN	.661	.584	14.8	9.9	.72	1.65	.047	.208	.432	0	.098	.337
Limit of Technology +40% NPS Reduction	.627	.533	13.7	9.0	.93	1.96	.016	.135	.412	0	.031	.260
Pristine	.560	.500	12.6	8.6	2.0	2.7	0	.016	.259	0	0	.155

Figure H 1

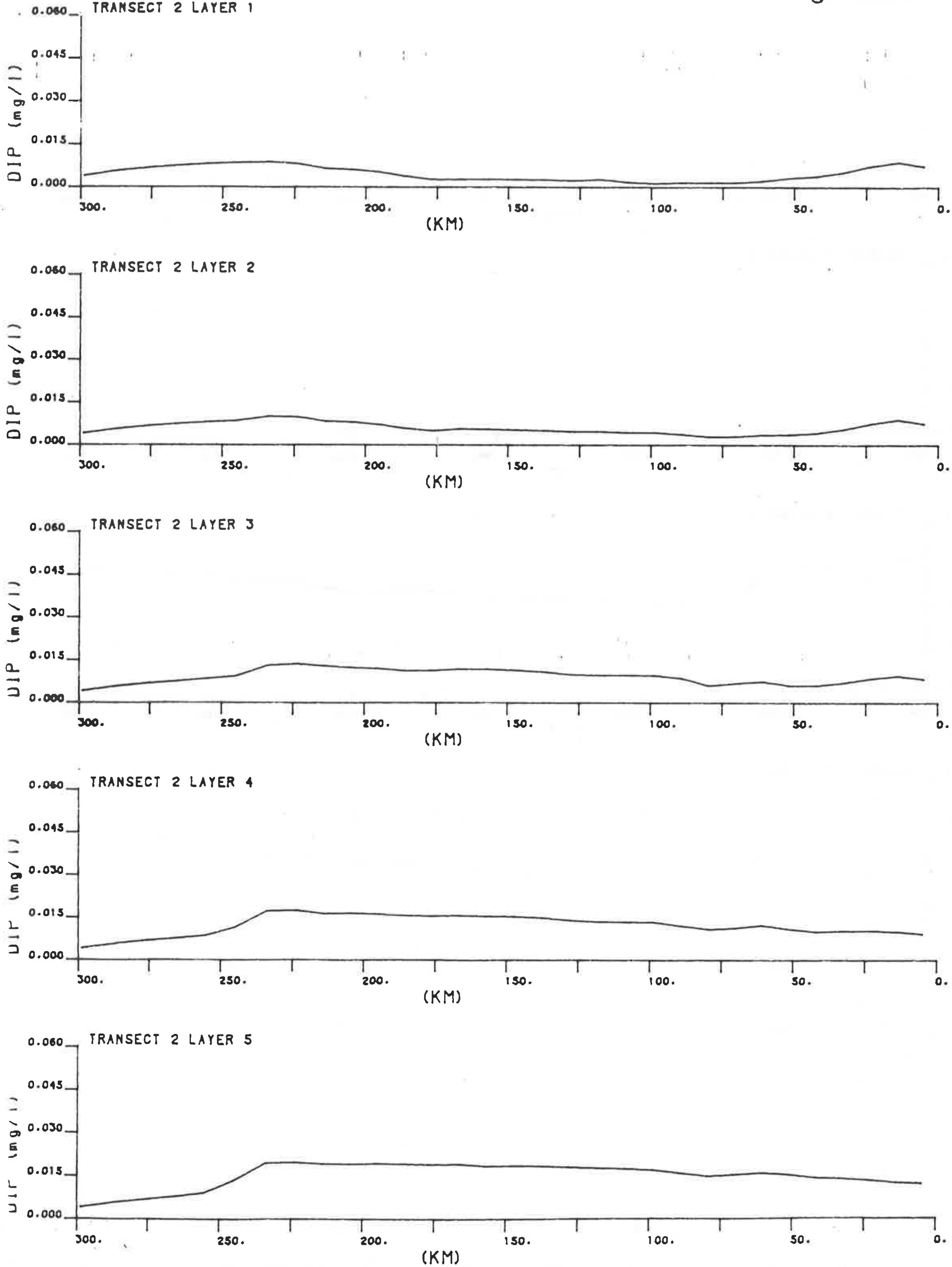


DITIONS - PRISTINE



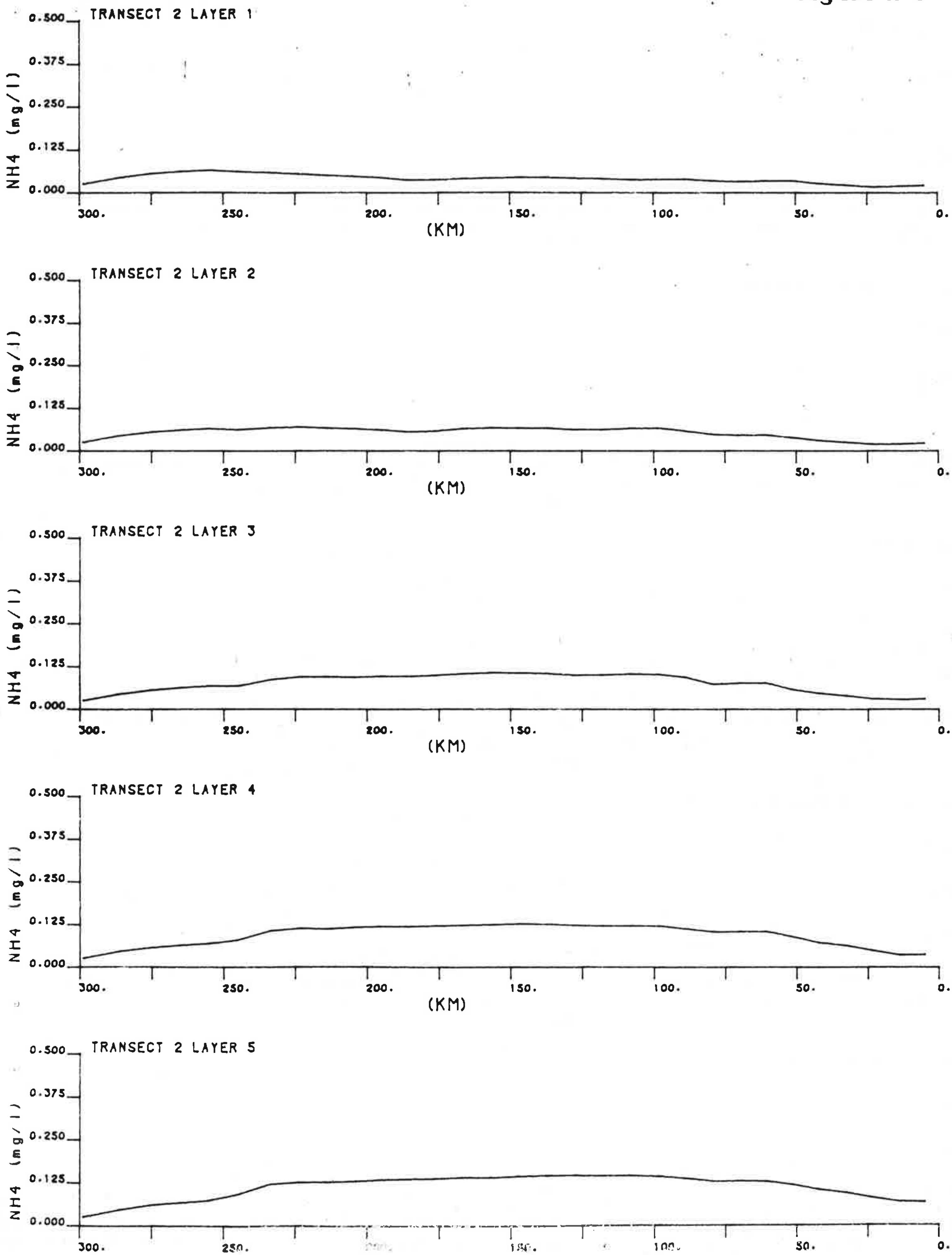
1984 CONDITIONS - PRISTIN

Figure A 3



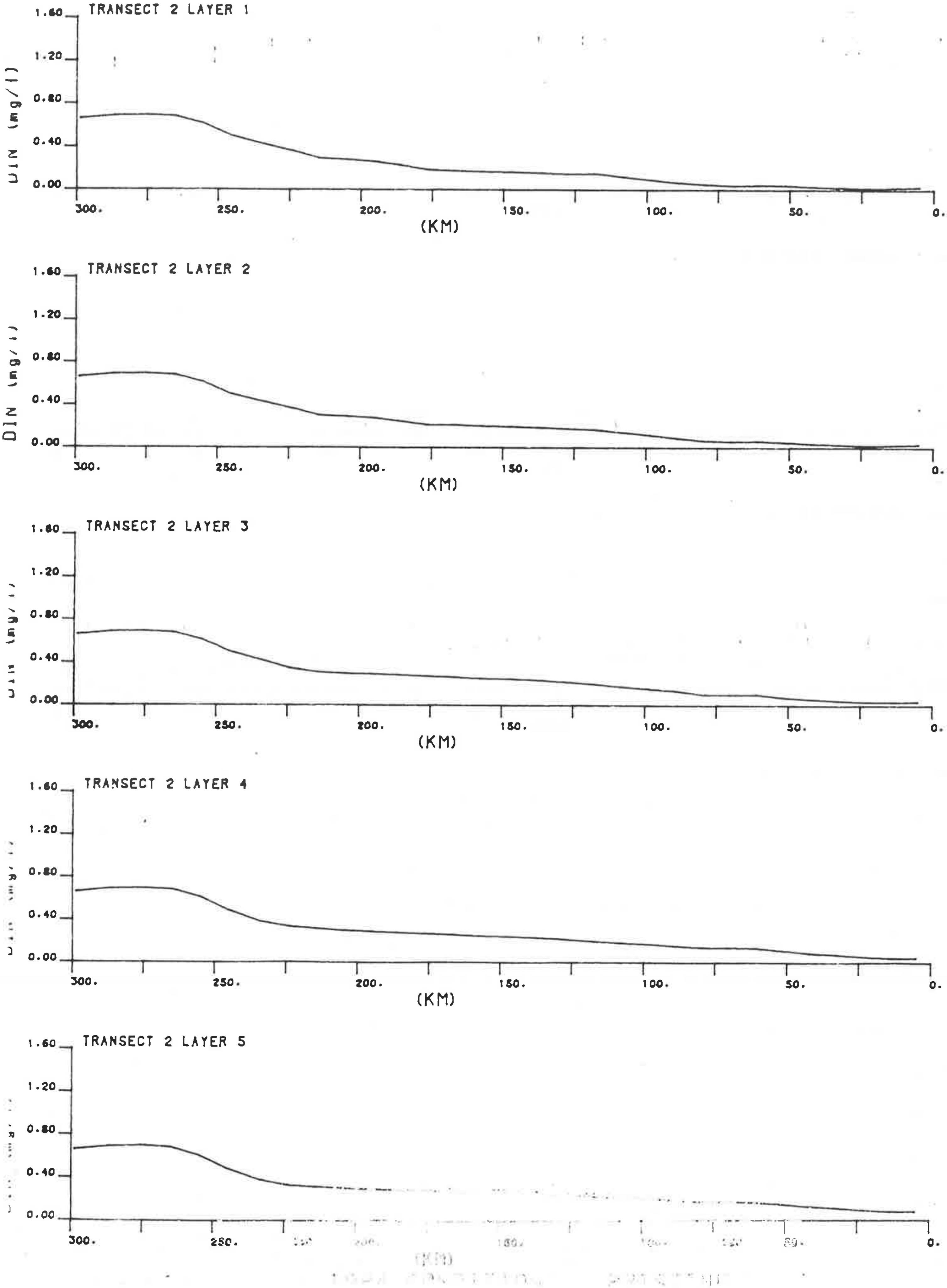
1984 CONDITIONS - PRISTINE

Figure II 4



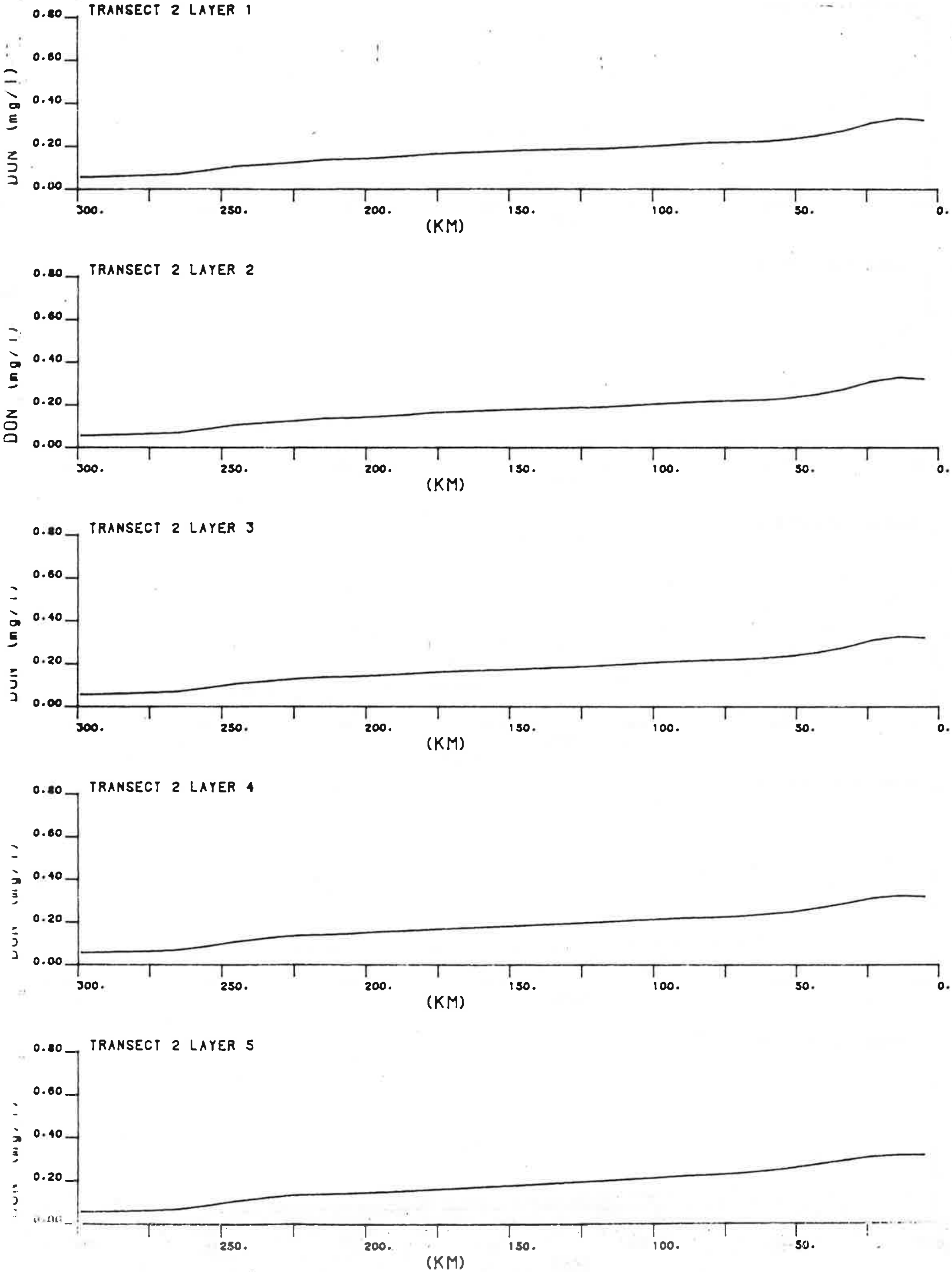
1984 CONDITIONS - PRISTINE

Figure A 5



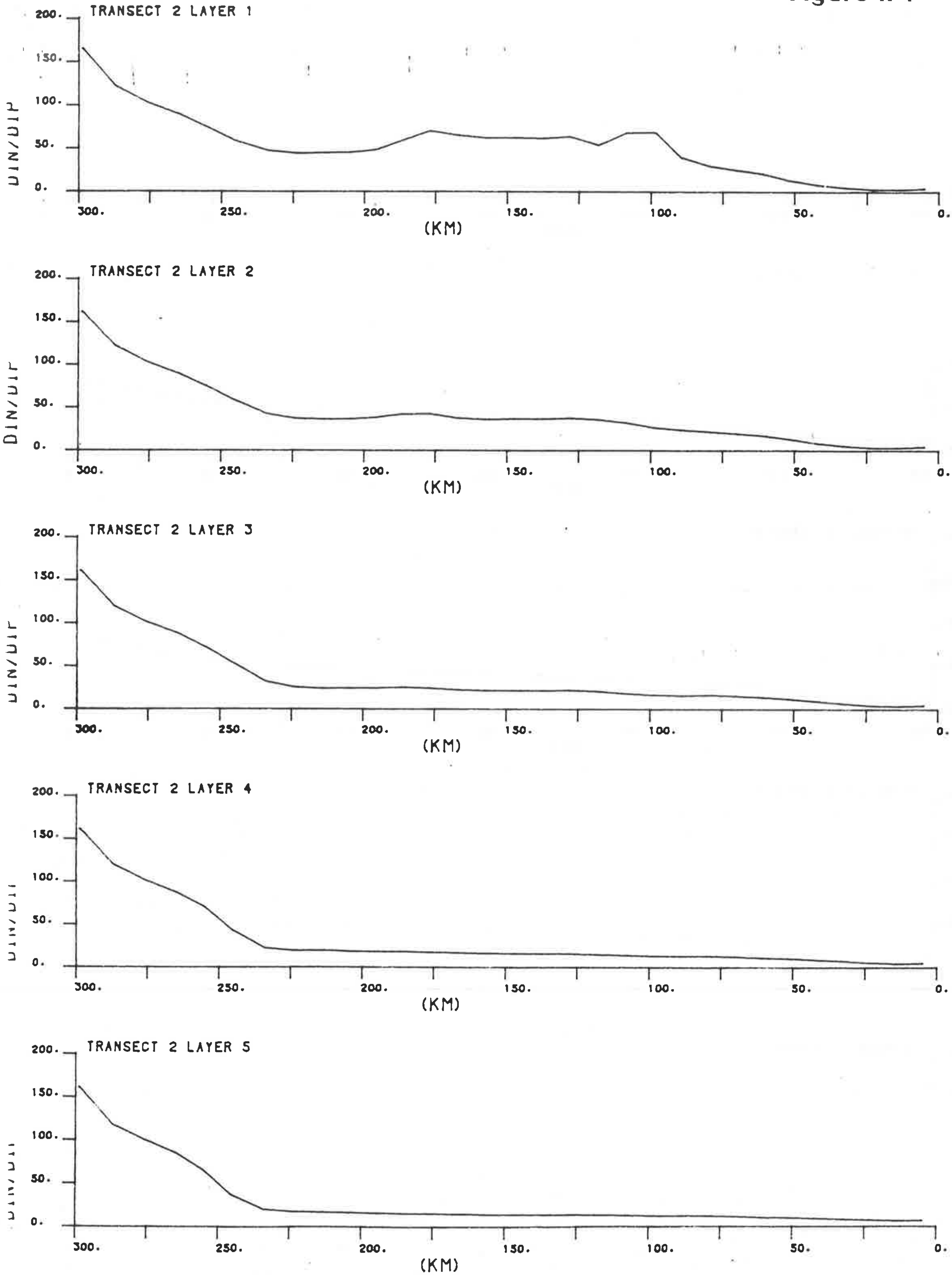
TRANSECT 2 LAYER 1
DIN (mg/l)
1.60
1.20
0.80
0.40
0.00
300.
250.
200.
150.
100.
50.
0.
(KM)
TRANSECT 2 LAYER 2
DIN (mg/l)
1.60
1.20
0.80
0.40
0.00
300.
250.
200.
150.
100.
50.
0.
(KM)
TRANSECT 2 LAYER 3
1.60
1.20
0.80
0.40
0.00
300.
250.
200.
150.
100.
50.
0.
(KM)
TRANSECT 2 LAYER 4
1.60
1.20
0.80
0.40
0.00
300.
250.
200.
150.
100.
50.
0.
(KM)
TRANSECT 2 LAYER 5
1.60
1.20
0.80
0.40
0.00
300.
250.
0.

Figure A 6



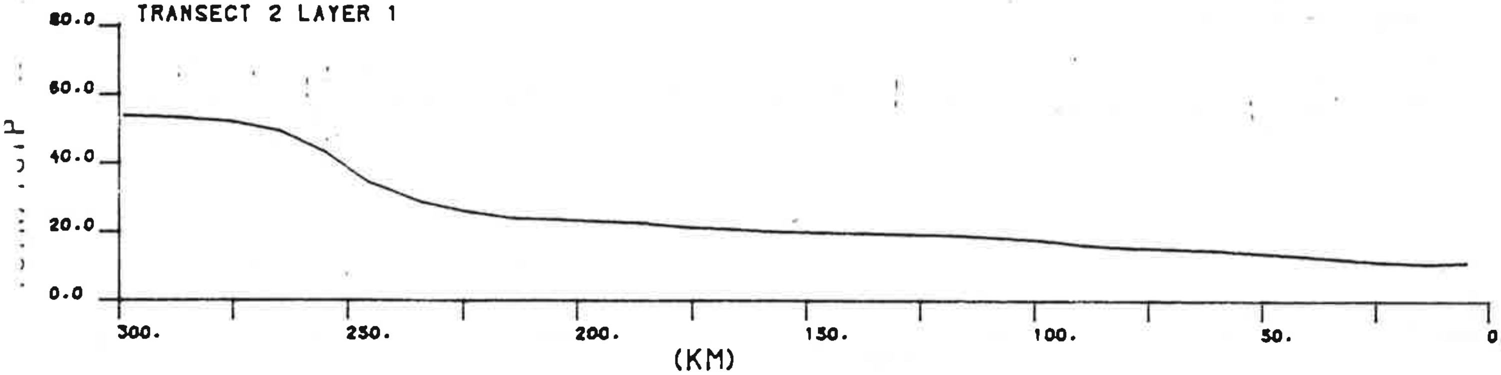
[illegible] CONDITIONS - PRISTINE

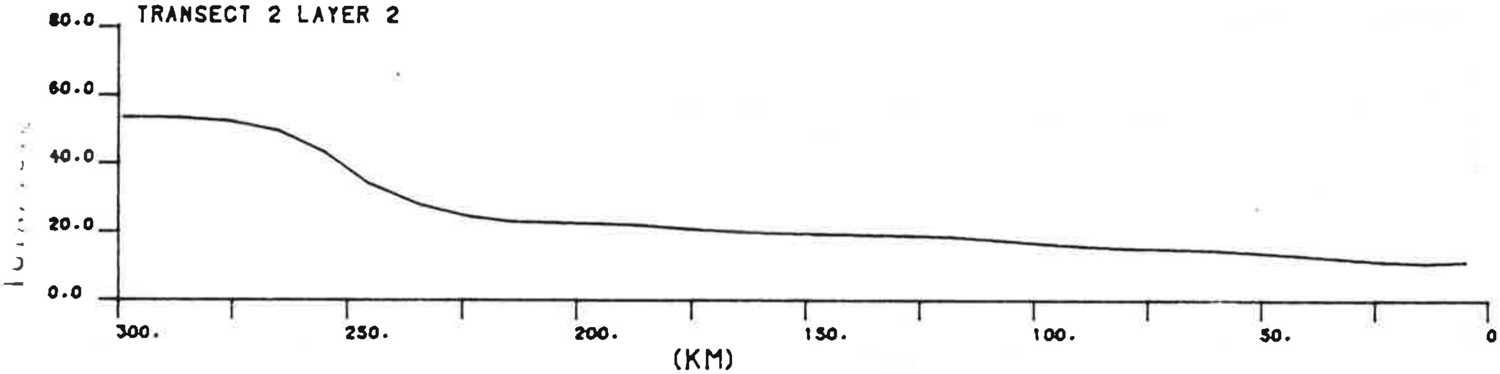
Figure A 7

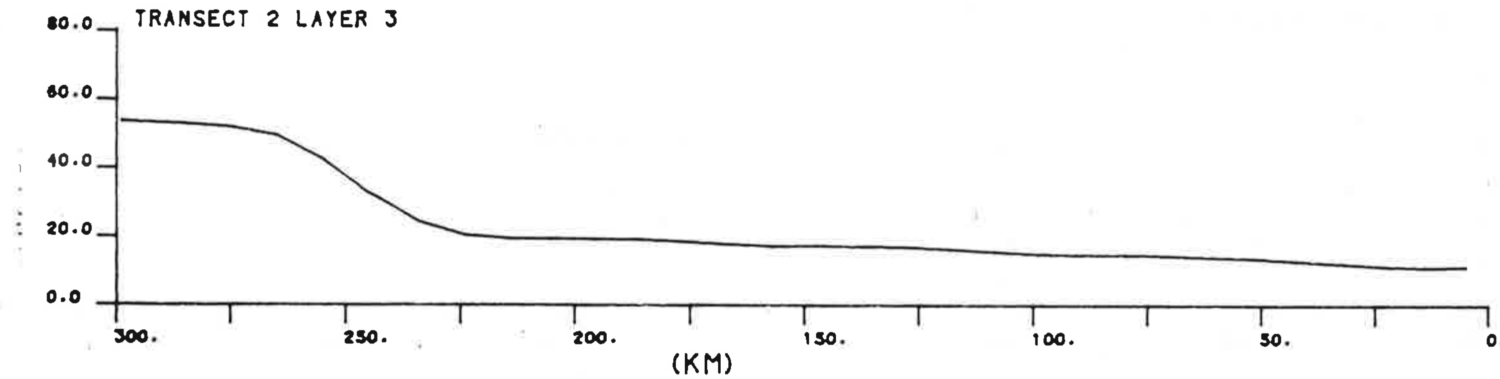


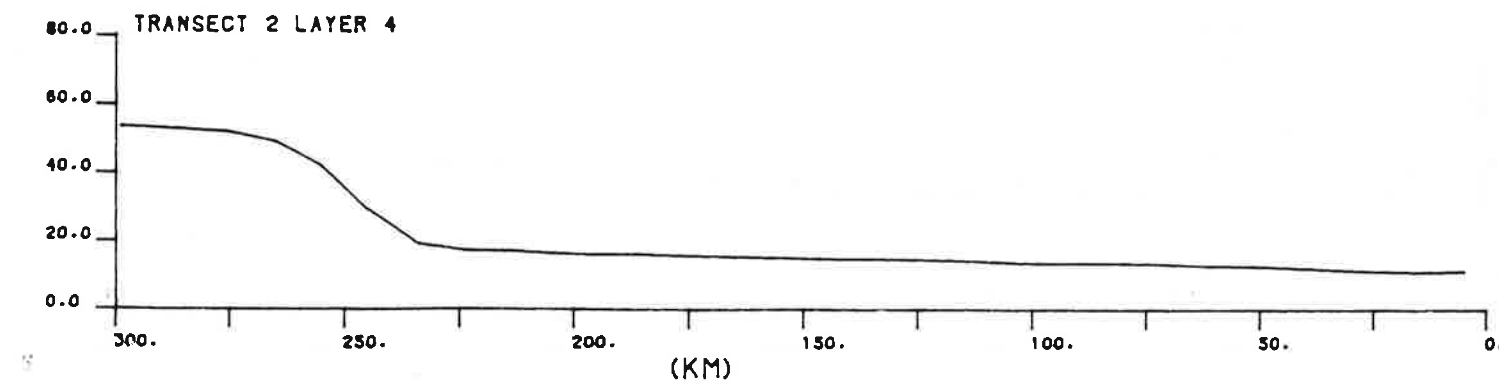
1984 CONDITIONS - PRISTINE

Figure H 8


TRANSECT 2 LAYER 1
80.0
60.0
40.0
20.0
0.0
300.
250.
200.
150.
100.
50.
0.
(KM)


TRANSECT 2 LAYER 2
80.0
60.0
40.0
20.0
0.0
300.
250.
200.
150.
100.
50.
0.
(KM)


TRANSECT 2 LAYER 3
80.0
60.0
40.0
20.0
0.0
300.
250.
200.
150.
100.
50.
0.
(KM)


TRANSECT 2 LAYER 4
80.0
60.0
40.0
20.0
0.0
300.
250.
200.
150.
100.
50.
0.
(KM)

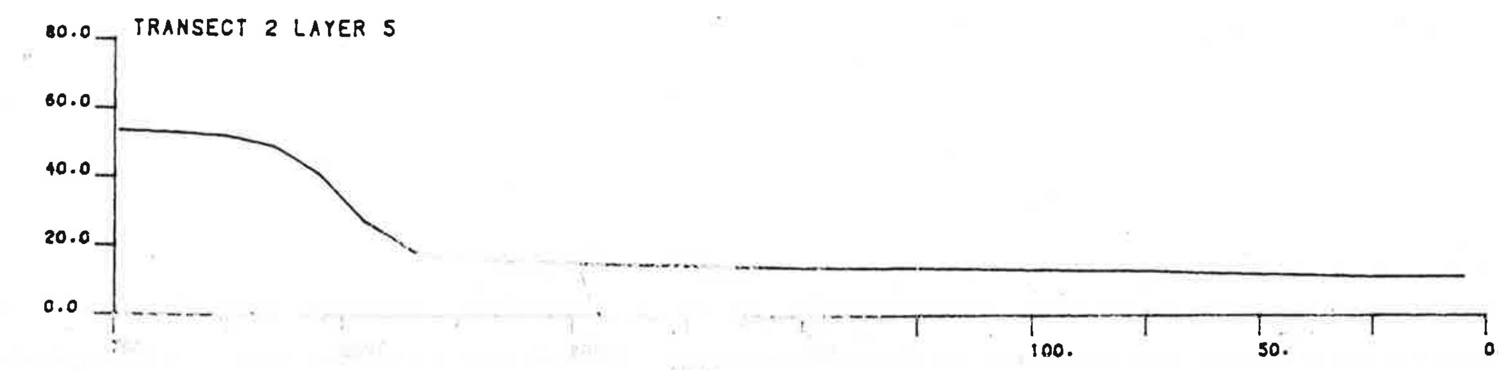
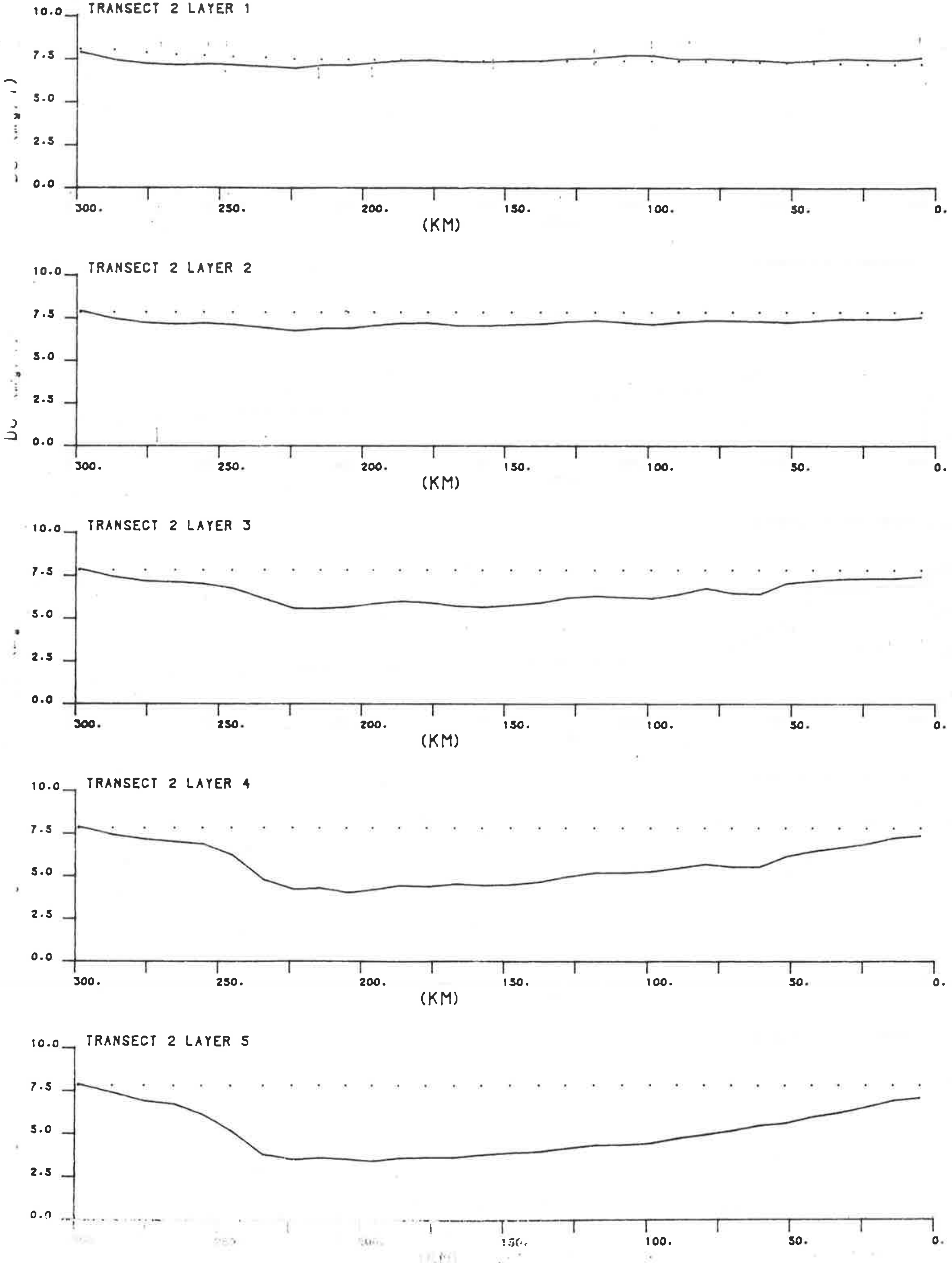
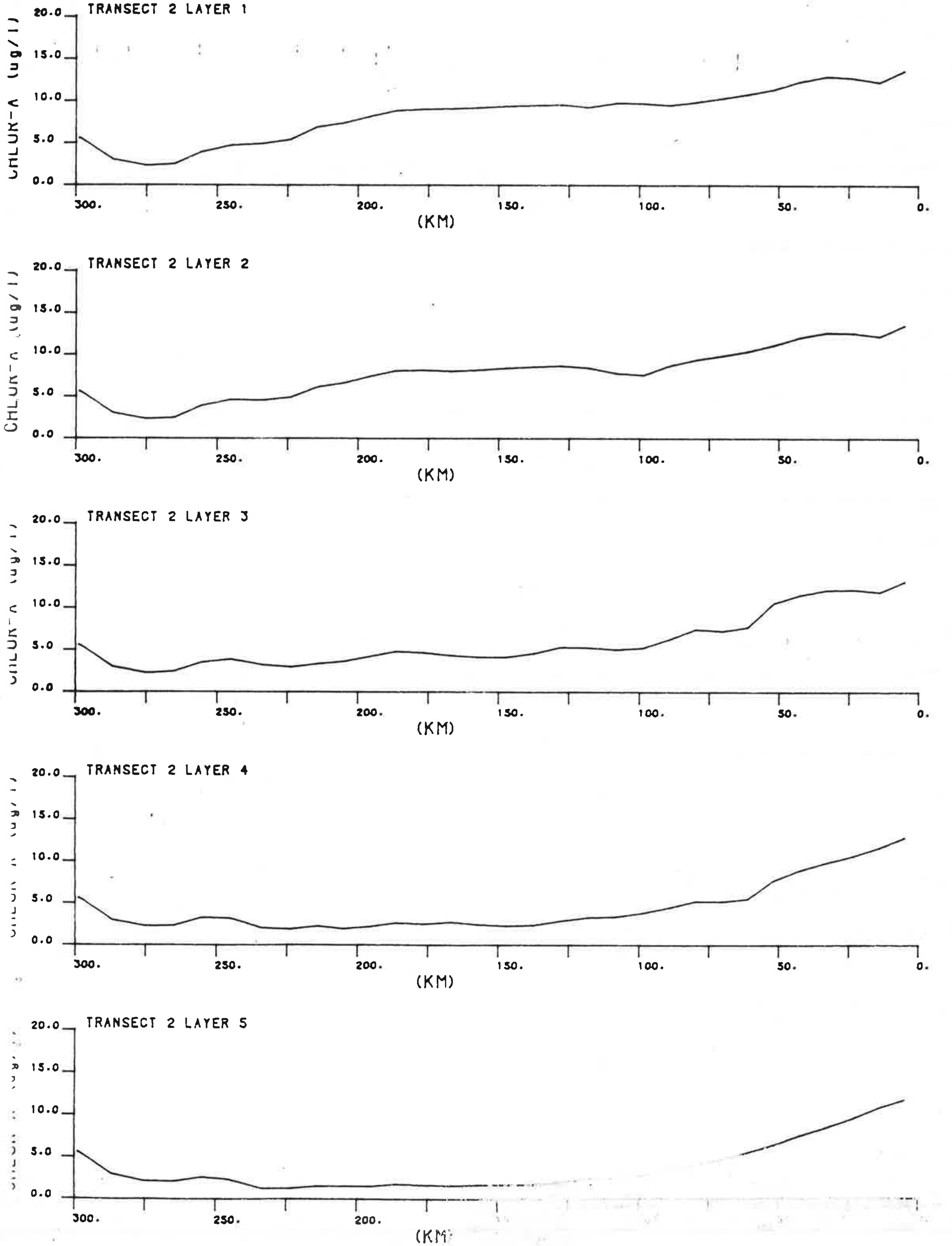

TRANSECT 2 LAYER 5
80.0
60.0
40.0
20.0
0.0
100.
50.
0.

Figure B 1



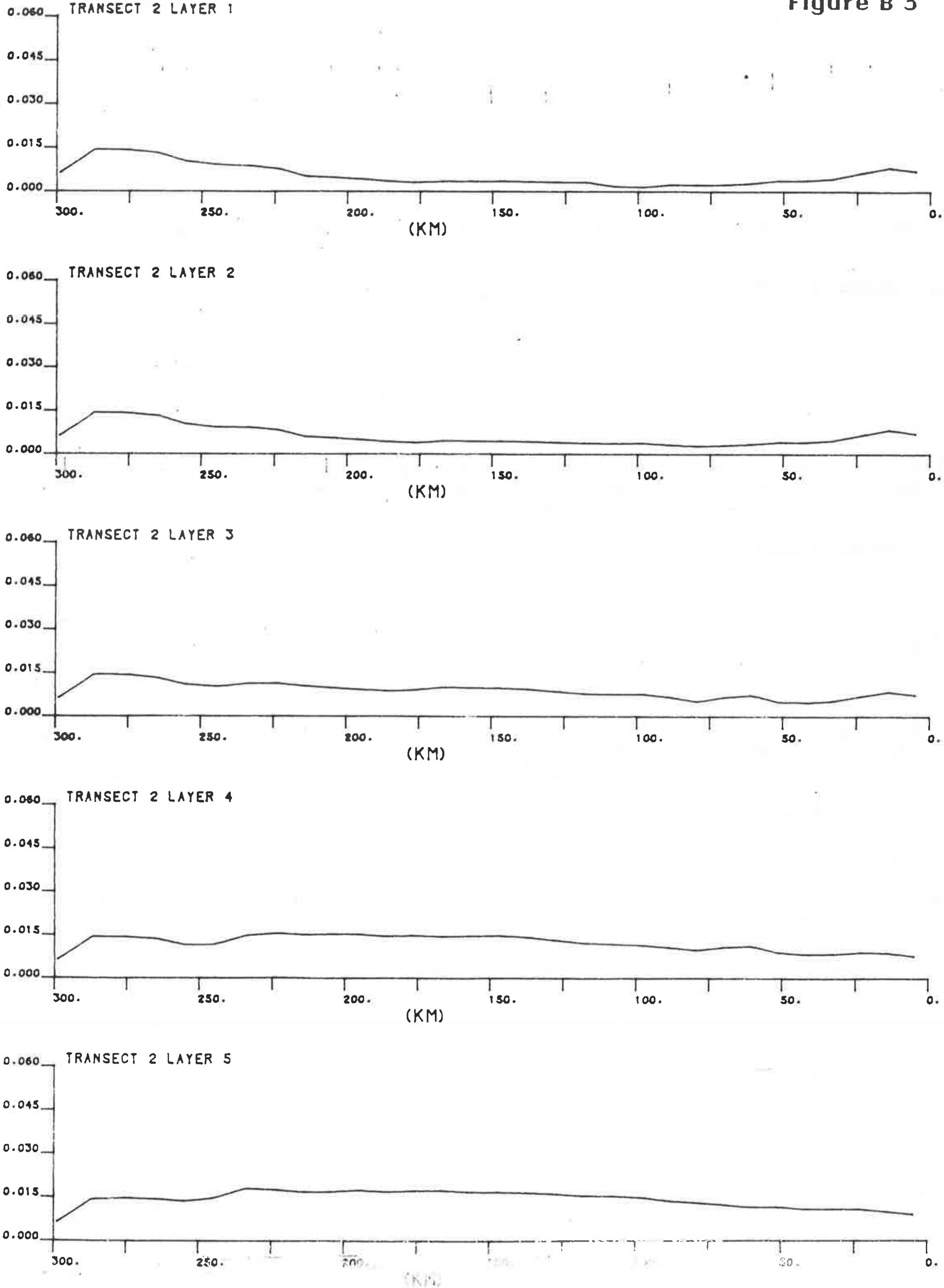
1989 CONDITIONS - PRISTINE

Figure B 2



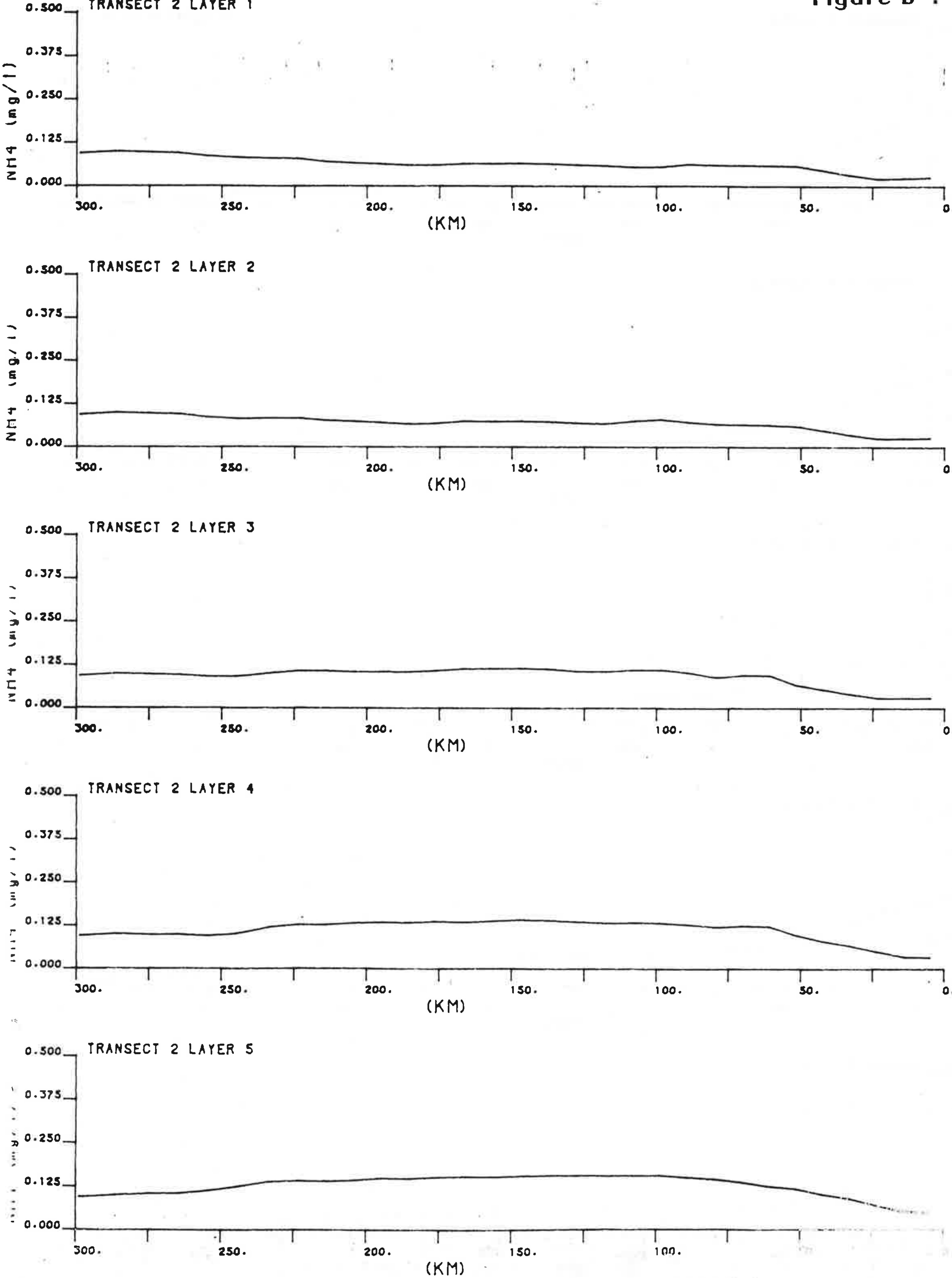
1985 CONDITIONS - PRISTINE

Figure B 5



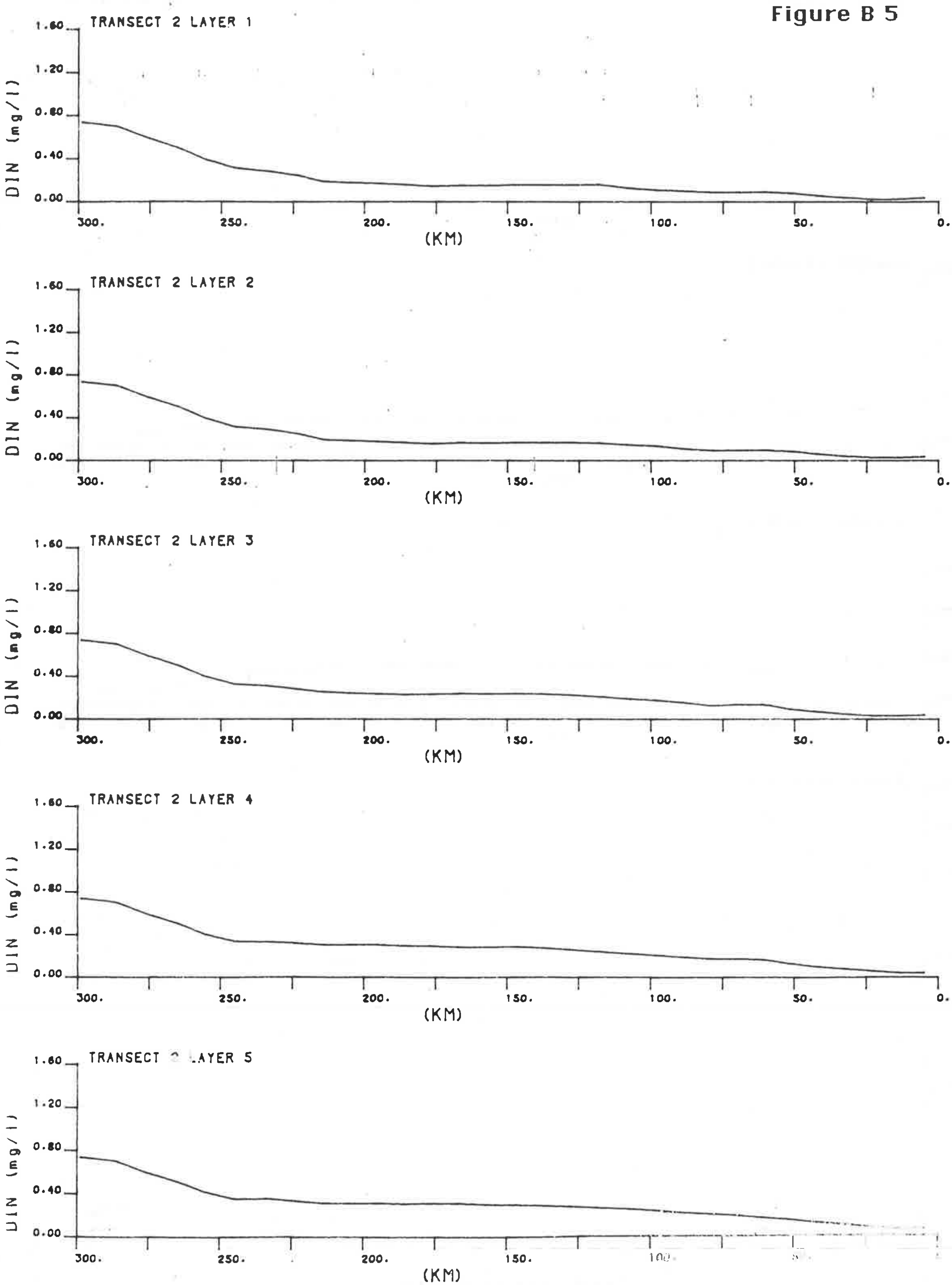
CONDITIONS = PRISTINE

Figure B



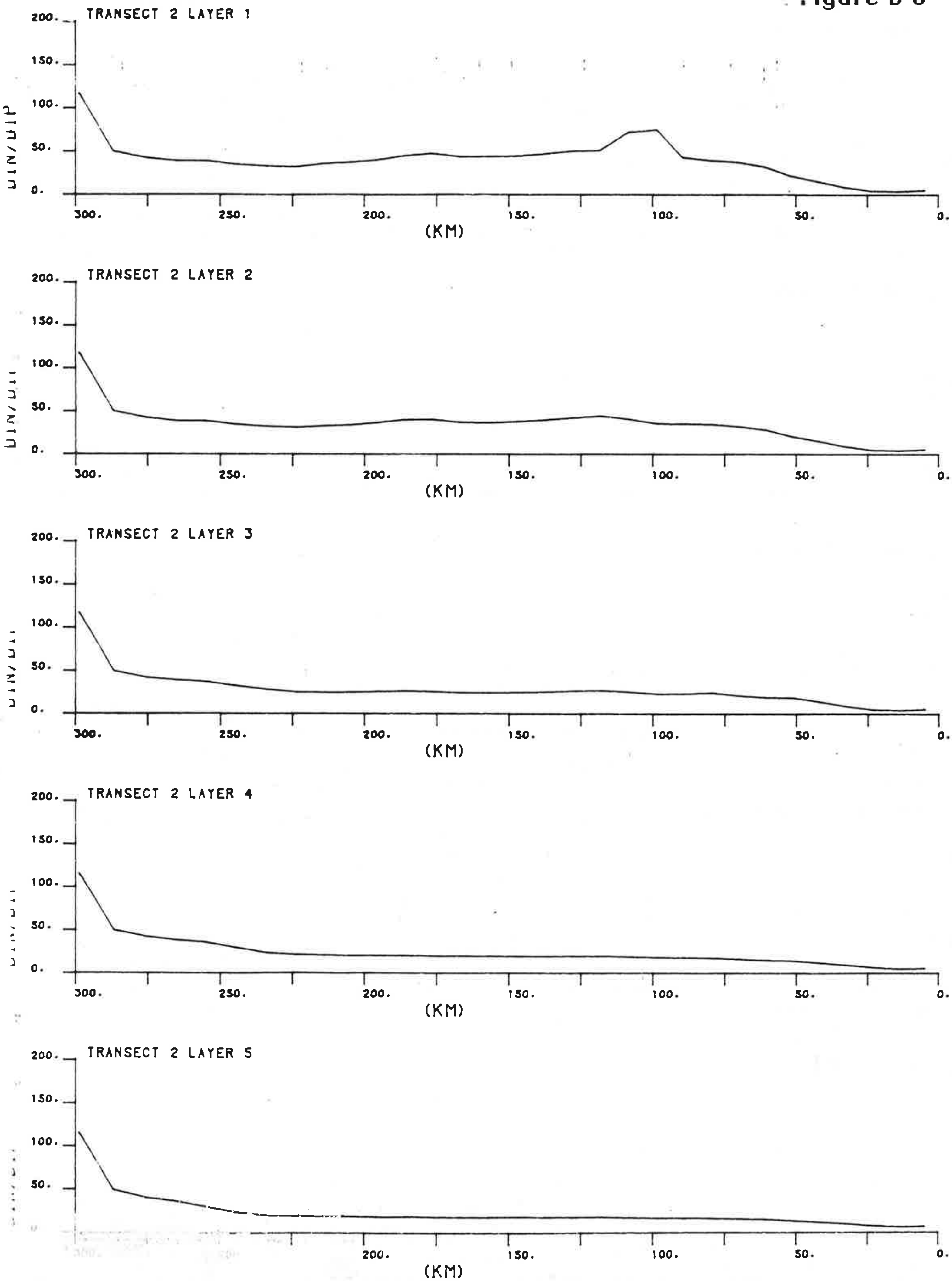
1985 CONDITIONS - PRIST

Figure B 5



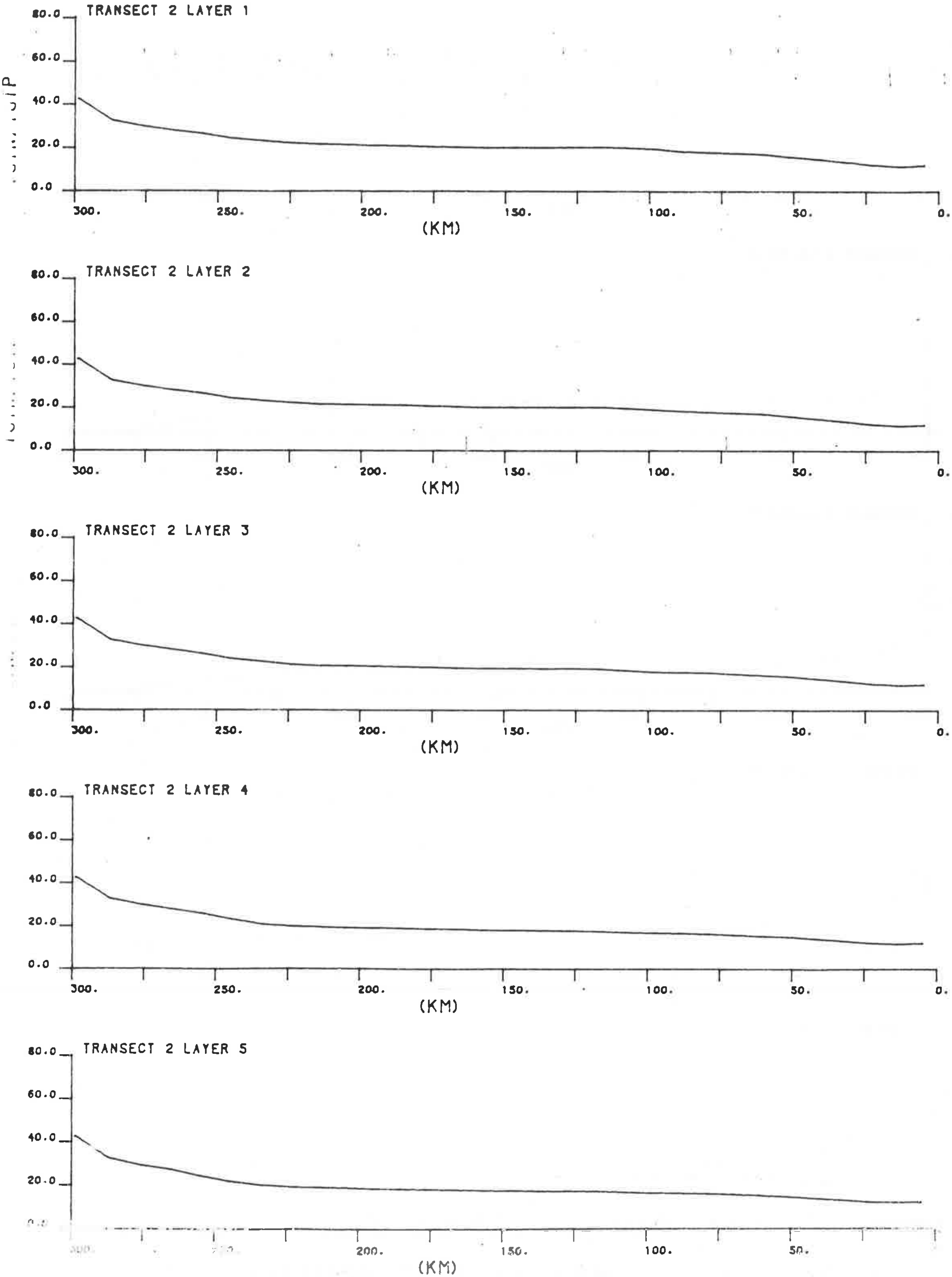
1985 CONDITIONS

Figure B-8

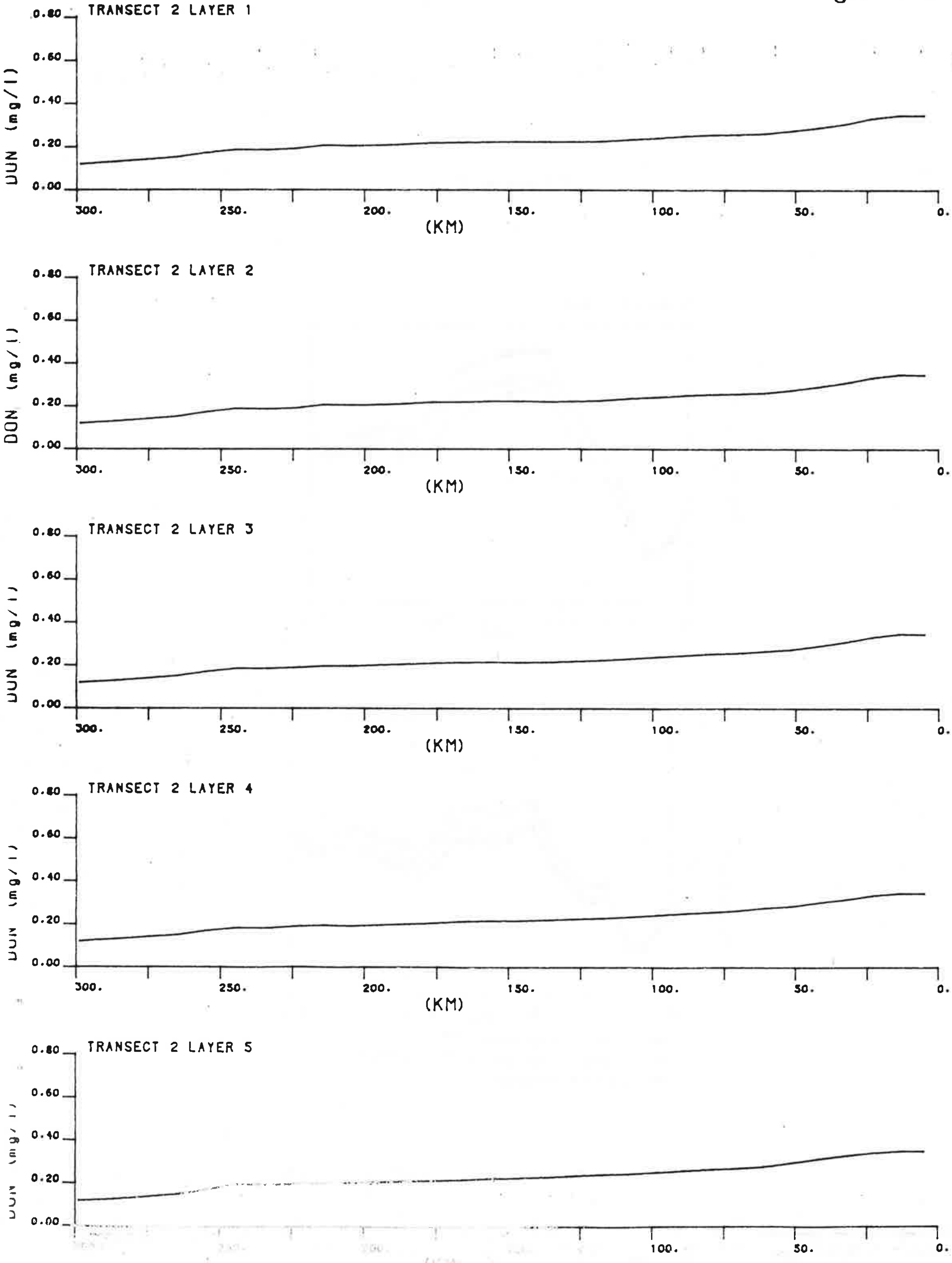


1985 CONDITIONS - PRISTINE

Figure B 7

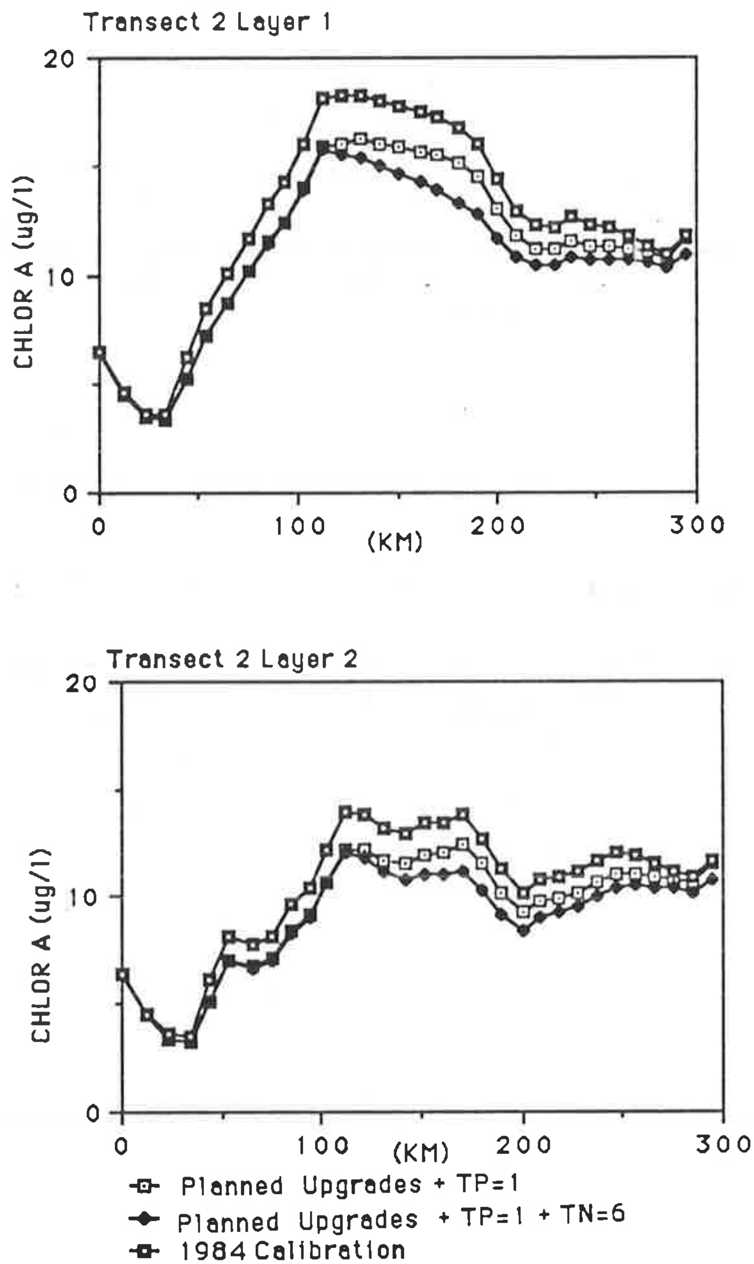


1985 CONDITIONS - PRISTINE



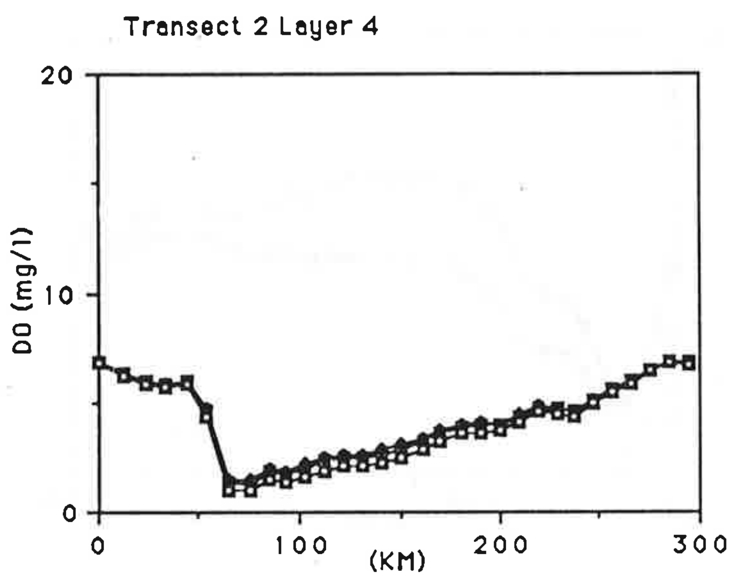
1985 CONDITIONS - PRISTINE

Figure C 1



Transect 2 Layer 1
CHLOR A (ug/l)
20
10
0
0
100
200
300
(KM)
Transect 2 Layer 2
CHLOR A (ug/l)
20
10
0
0
100
200
300
(KM)
Planned Upgrades + TP=1
Planned Upgrades + TP=1 + TN=6
1984 Calibration

Figure C 2


Transect 2 Layer 4
20
10
0
DO (mg/l)
0
100
(KM)
200
300

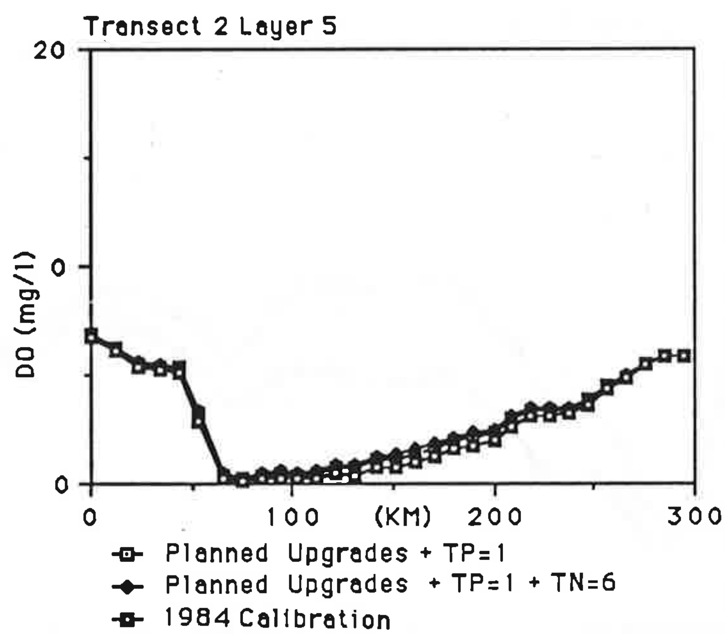
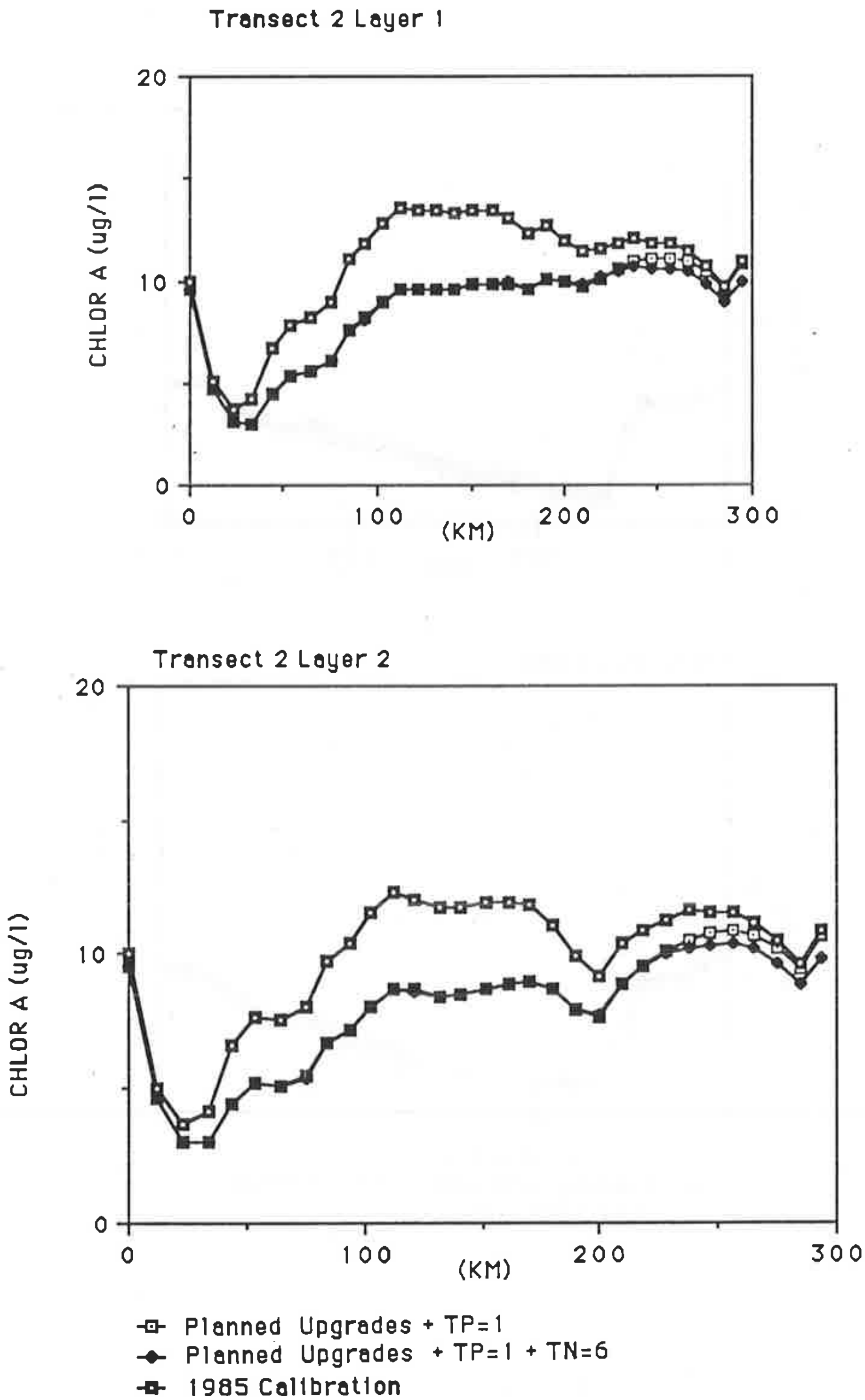
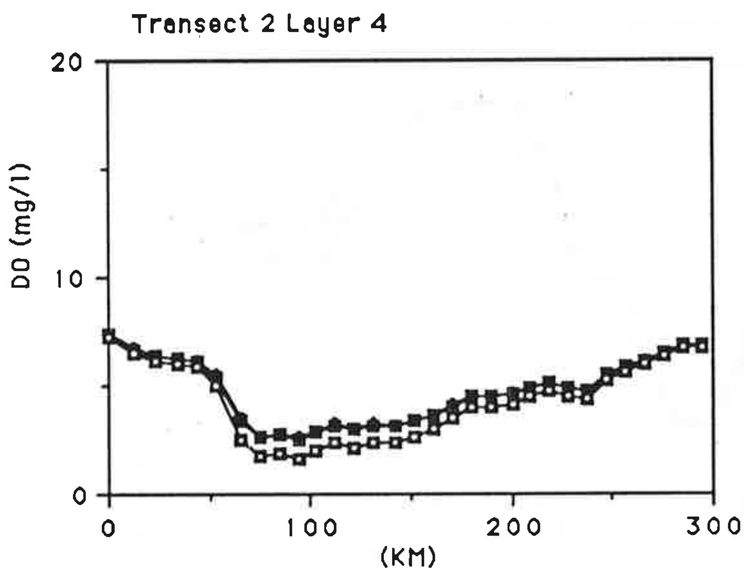

Transect 2 Layer 5
20
0
0
DO (mg/l)
0
100
(KM)
200
300
Planned Upgrades + TP=1
Planned Upgrades + TP=1 + TN=6
1984 Calibration

Figure D 1



Transect 2 Layer 1
CHLOR A (ug/l)
20
10
0
0
100
200
300
(KM)
Transect 2 Layer 2
CHLOR A (ug/l)
20
10
0
0
100
200
300
(KM)
Planned Upgrades + TP=1
Planned Upgrades + TP=1 + TN=6
1985 Calibration

Figure D 2


Transect 2 Layer 4
20
10
0
DO (mg/l)
0
100
200
300
(KM)

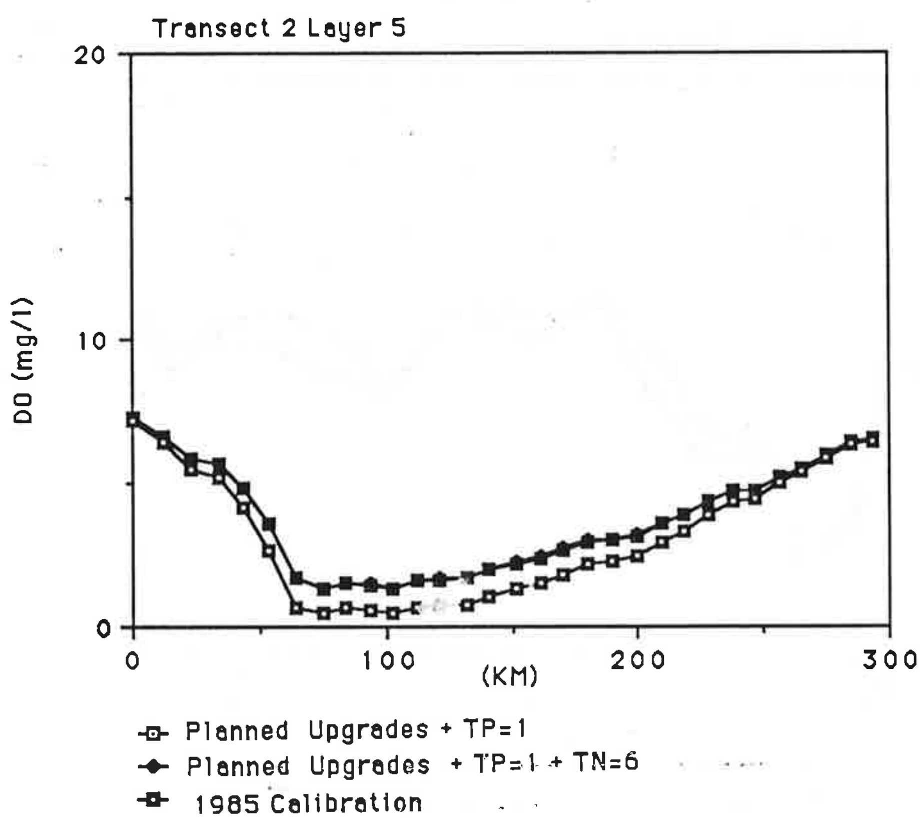
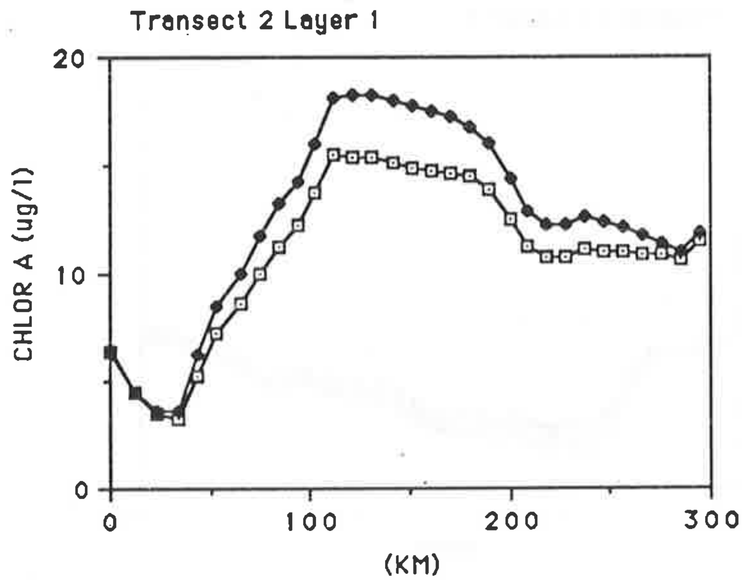
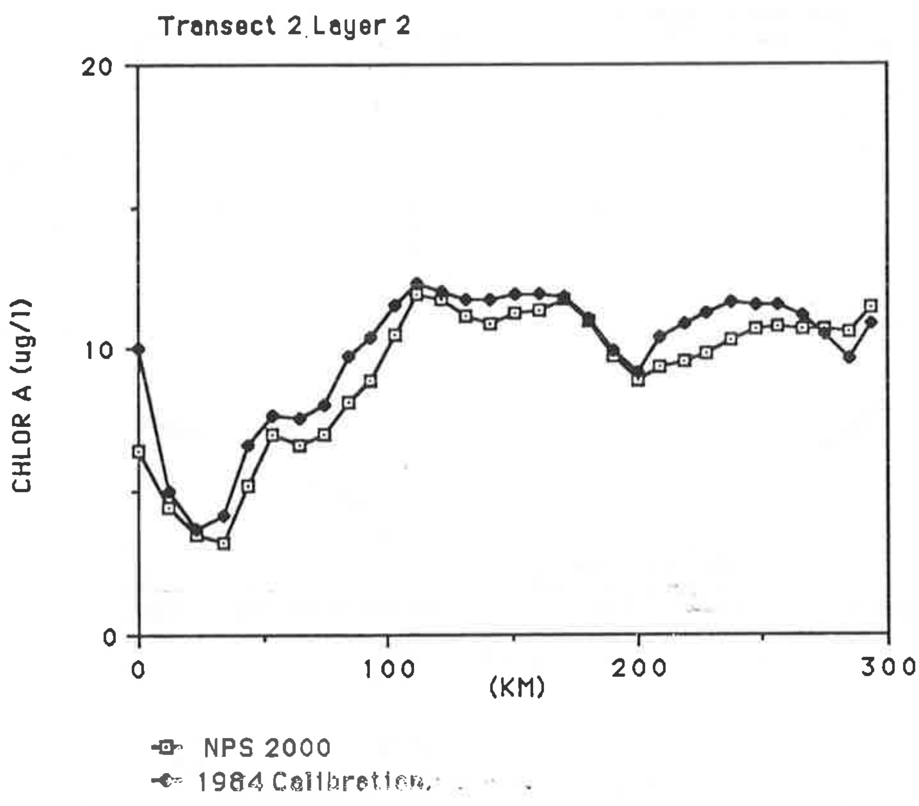

Transect 2 Layer 5
20
10
0
DO (mg/l)
0
100
200
300
(KM)
Planned Upgrades + TP=1
Planned Upgrades + TP=1 + TN=6
1985 Calibration

Figure E 1

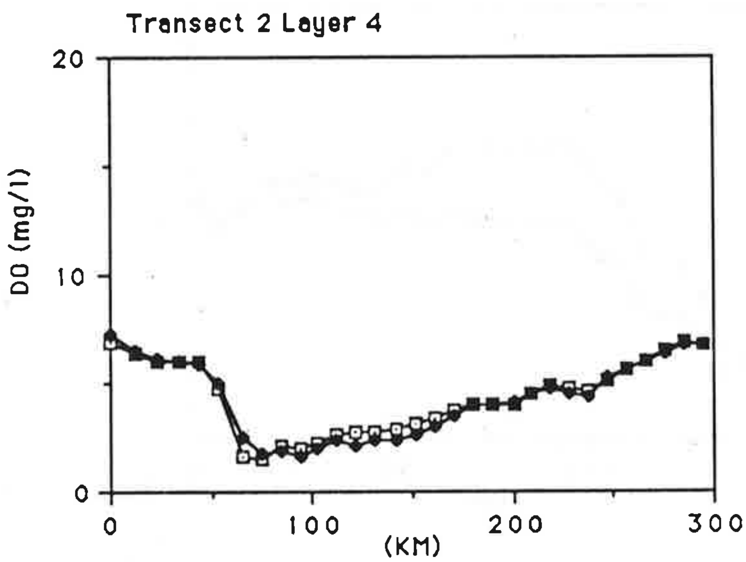


Transect 2 Layer 1
CHLOR A (ug/l)
20
10
0
0
100
200
300
(KM)

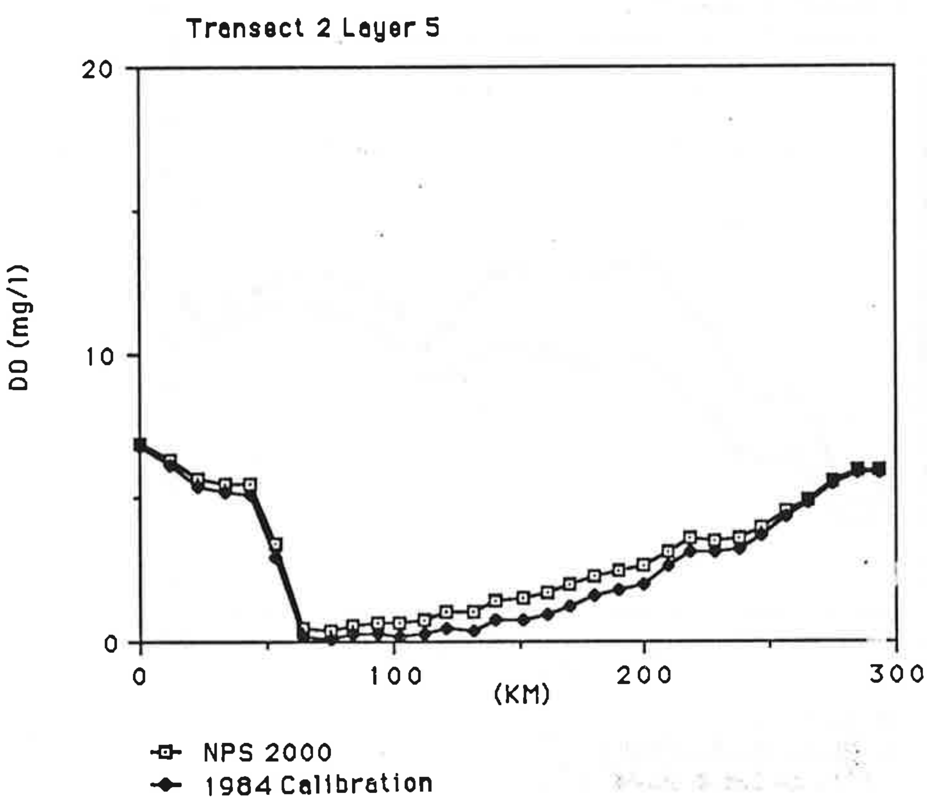


Transect 2 Layer 2
CHLOR A (ug/l)
20
10
0
0
100
200
300
(KM)
NPS 2000
1984 Calibration

Figure E 2



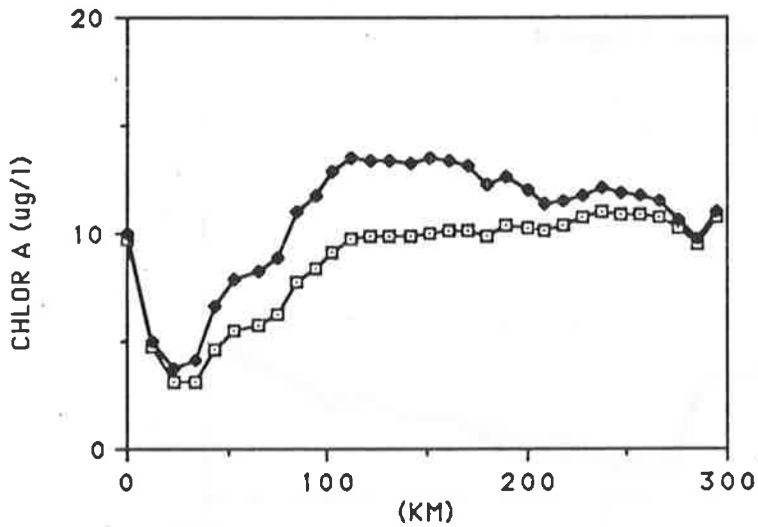
Transect 2 Layer 4
20
10
0
DO (mg/l)
0
100
200
300
(KM)



Transect 2 Layer 5
20
10
0
DO (mg/l)
0
100
200
300
(KM)
NPS 2000
1984 Calibration

Figure F 1

Transect 2 Layer 1



Transect 2 Layer 2

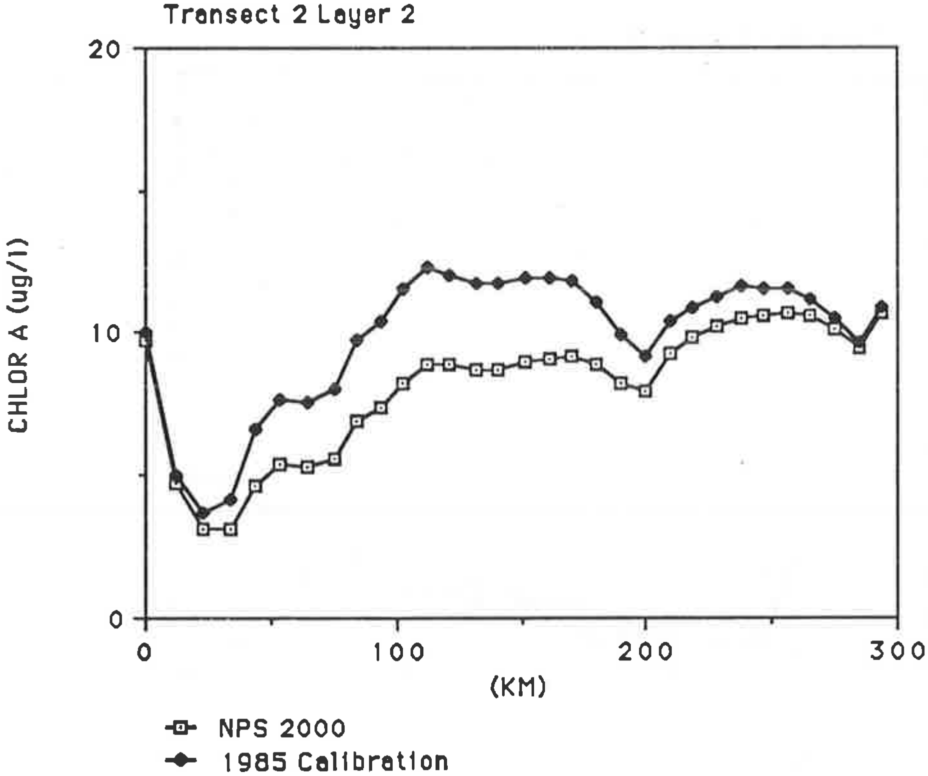
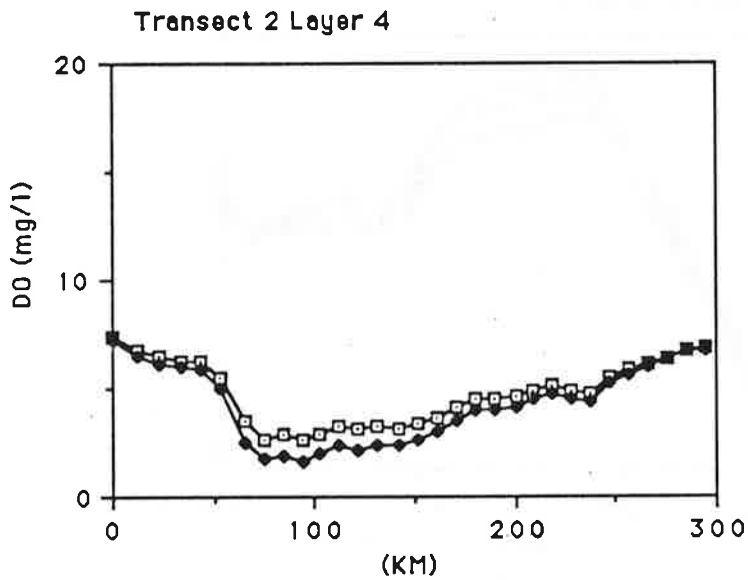
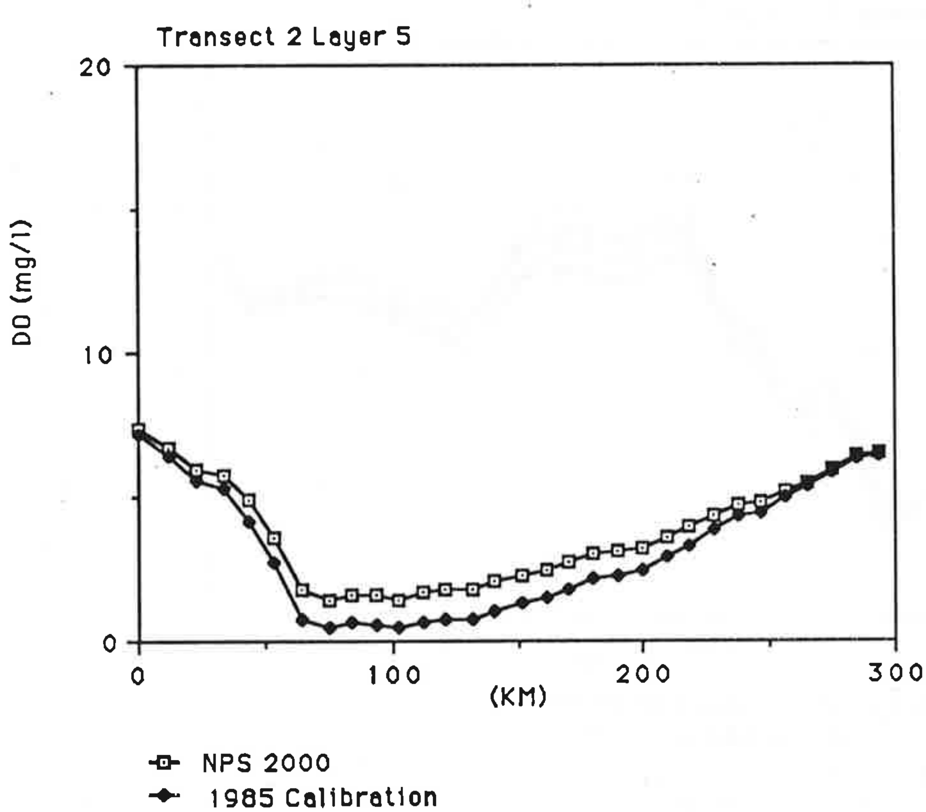


Figure F 2

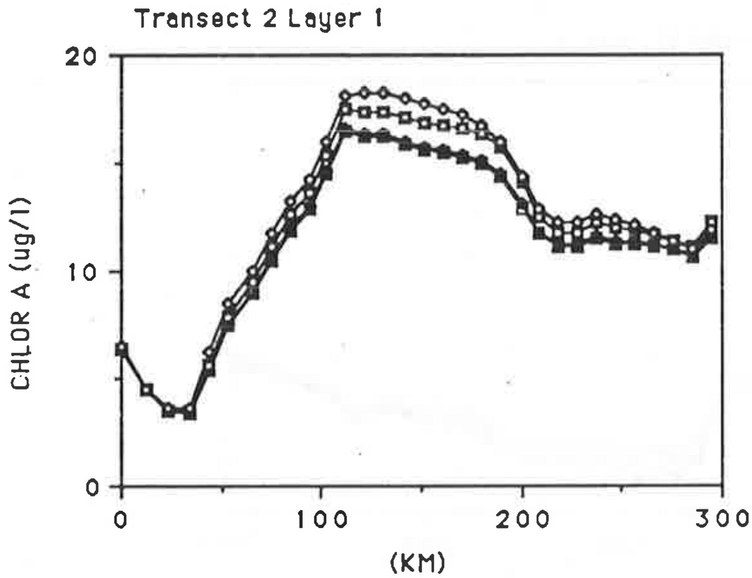


Transect 2 Layer 4
20
10
0
DO (mg/l)
0
100
200
300
(KM)

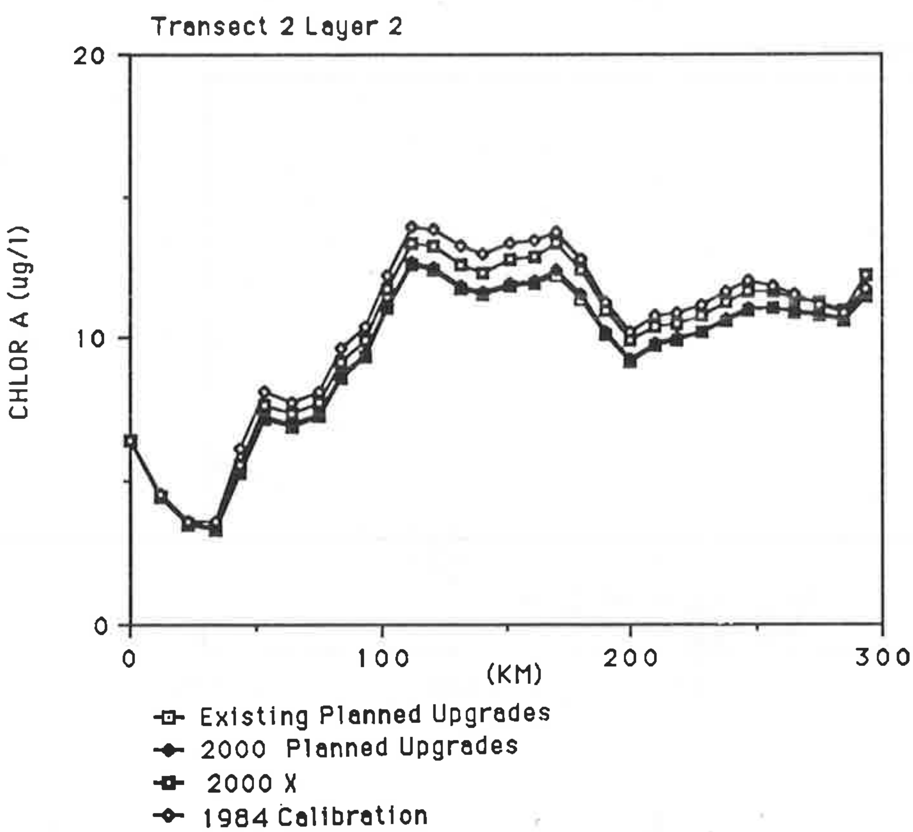


Transect 2 Layer 5
20
10
0
DO (mg/l)
0
100
200
300
(KM)
NPS 2000
1985 Calibration

Figure G 1

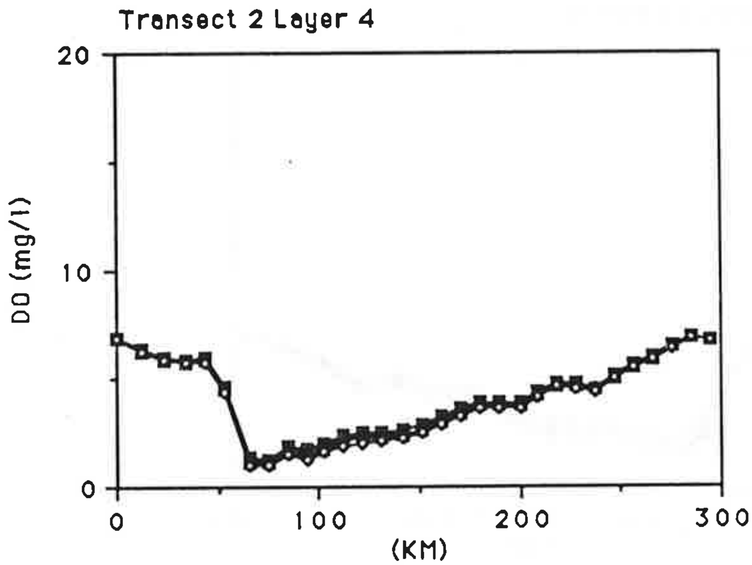


Transect 2 Layer 1
20
10
0
CHLOR A (ug/l)
0
100
200
300
(KM)

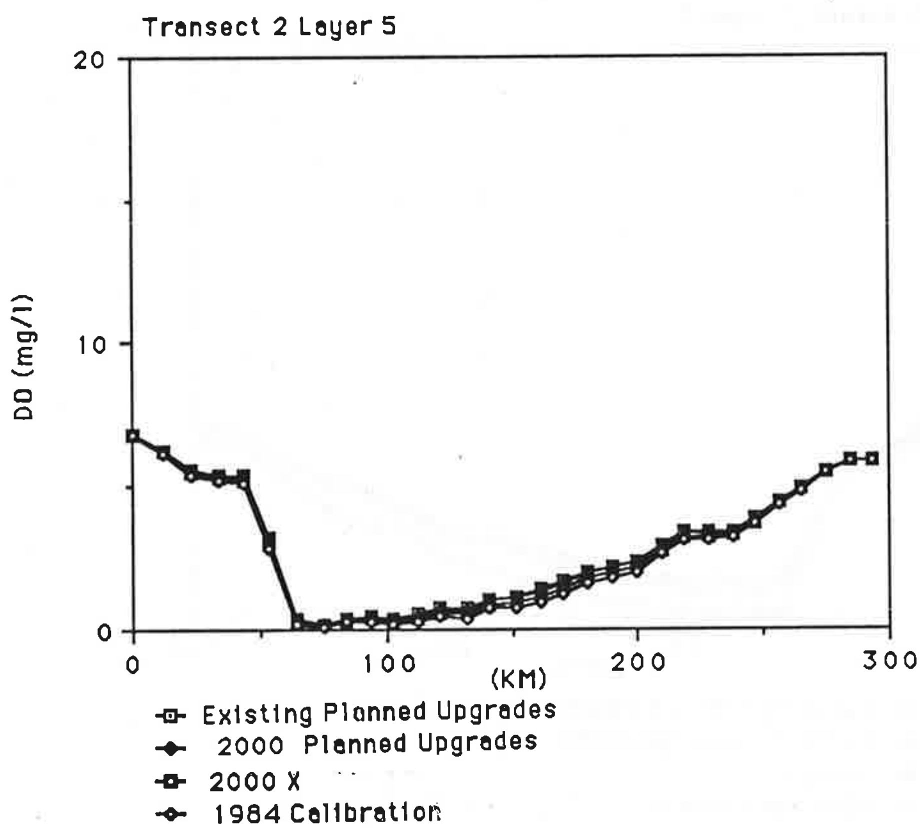


Transect 2 Layer 2
20
10
0
CHLOR A (ug/l)
0
100
200
300
(KM)
Existing Planned Upgrades
2000 Planned Upgrades
2000 X
1984 Calibration

Figure G 2



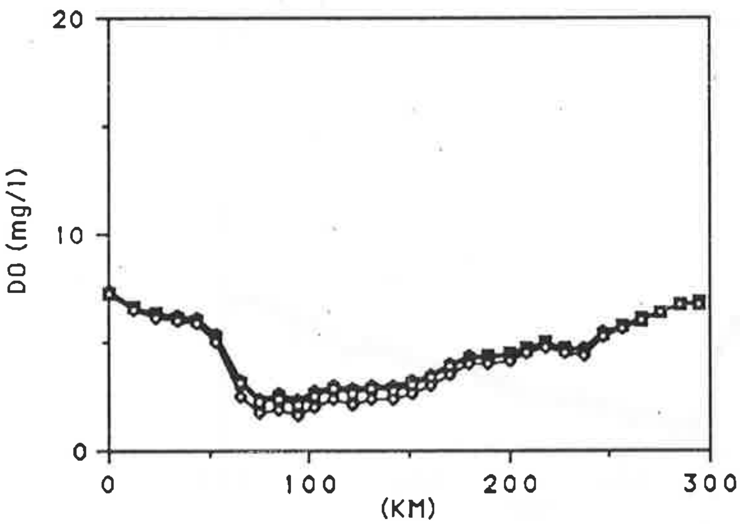
Transect 2 Layer 4
20
10
0
DO (mg/l)
0
100
200
300
(KM)



Transect 2 Layer 5
20
10
0
DO (mg/l)
0
100
200
300
(KM)
Existing Planned Upgrades
2000 Planned Upgrades
2000 X
1984 Calibration

Figure H 1

Transect 2 Layer 4



Transect 2 Layer 5

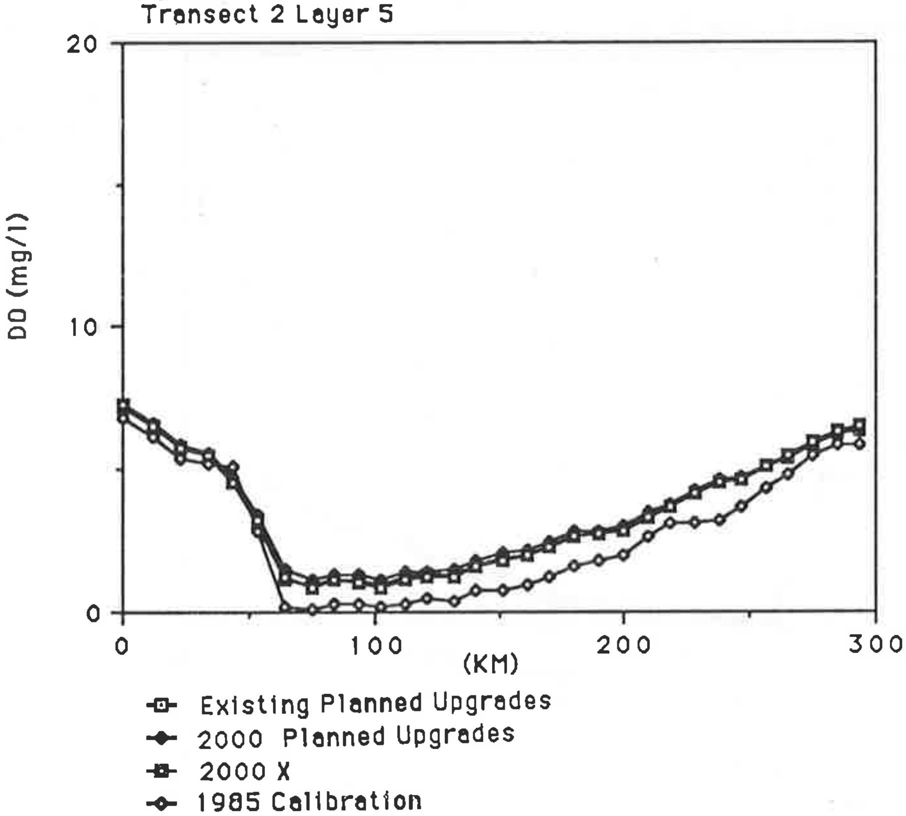
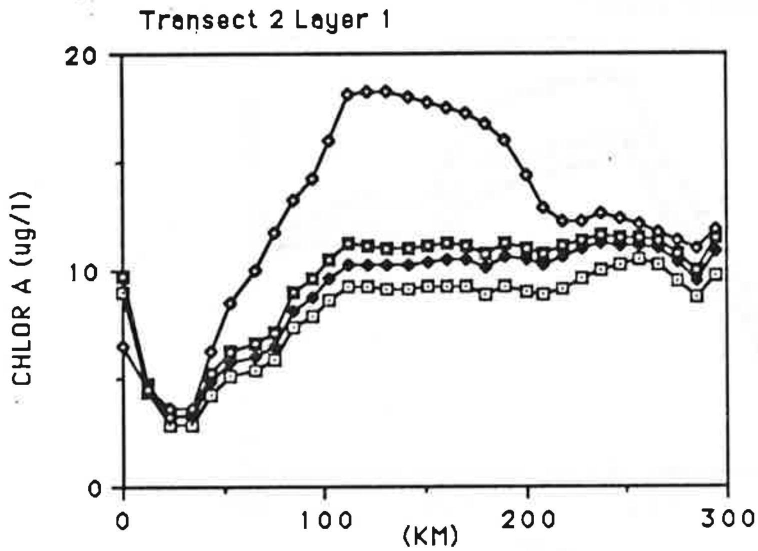
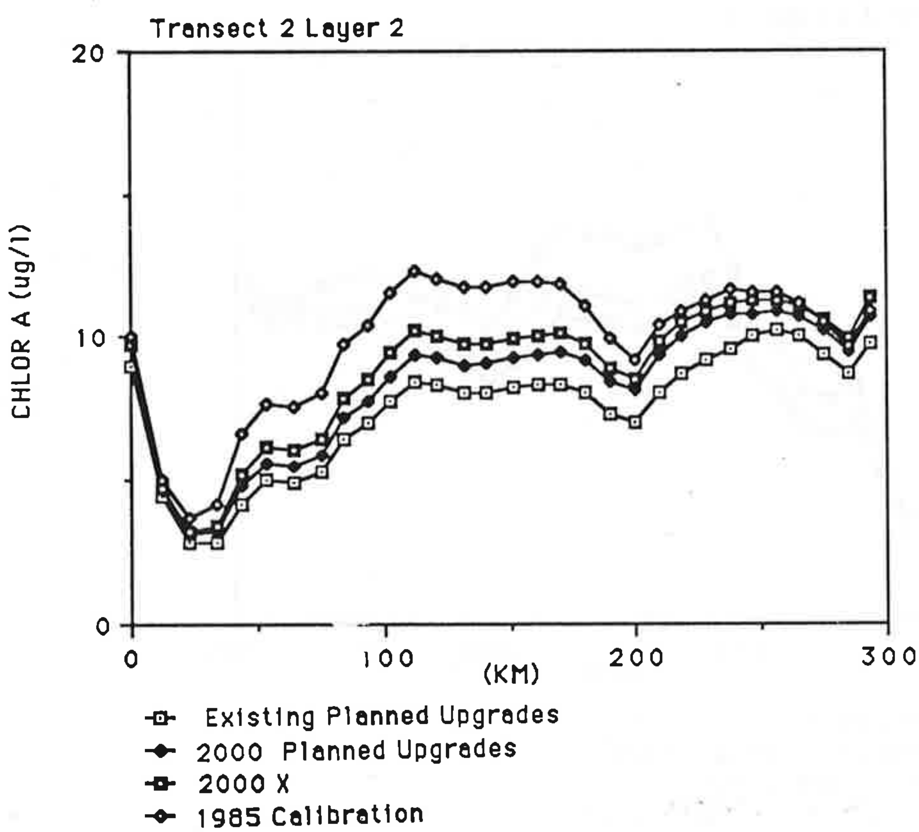


Figure H 2

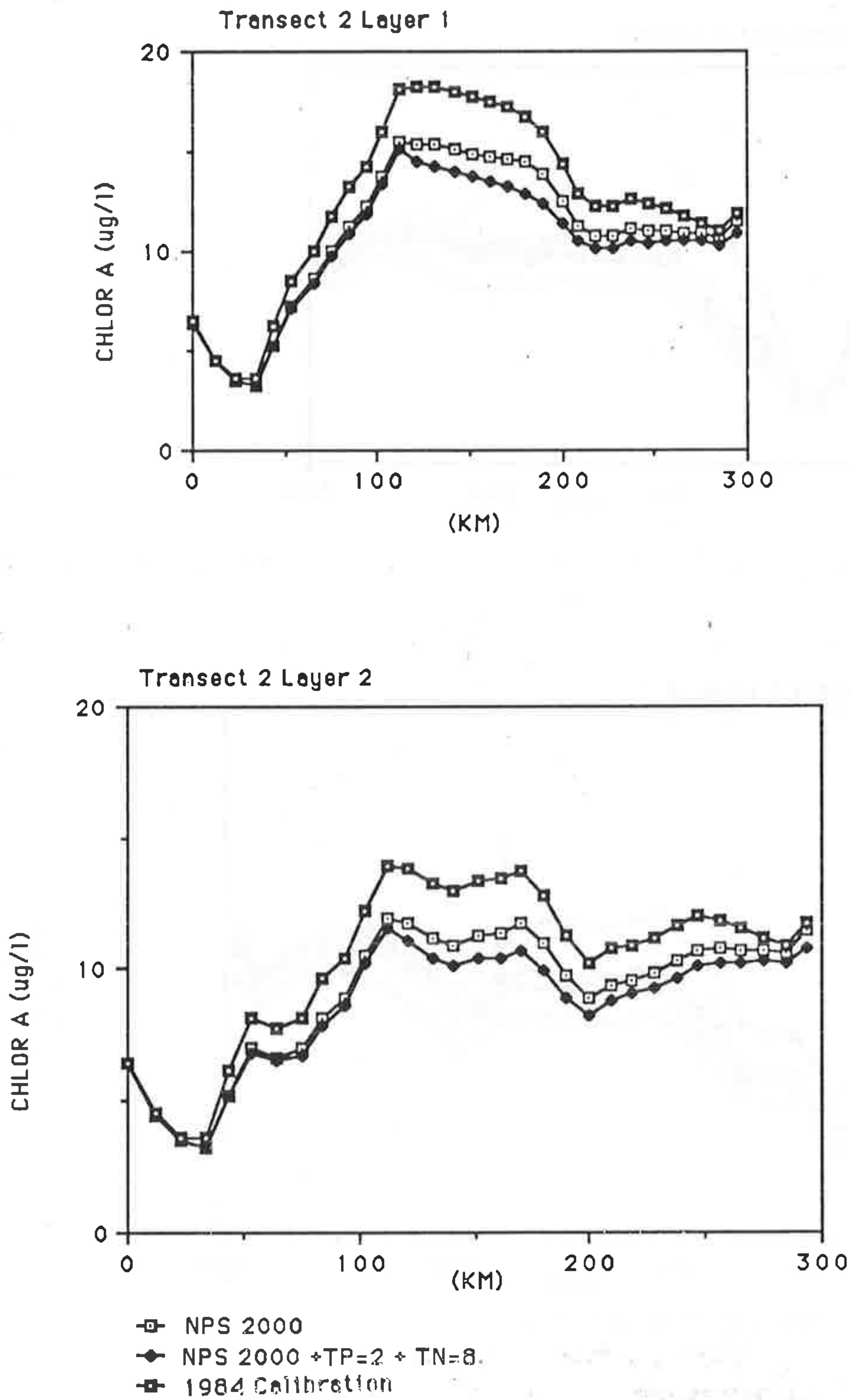


Transect 2 Layer 1
CHLOR A (ug/l)
20
10
0
0
100
200
300
(KM)



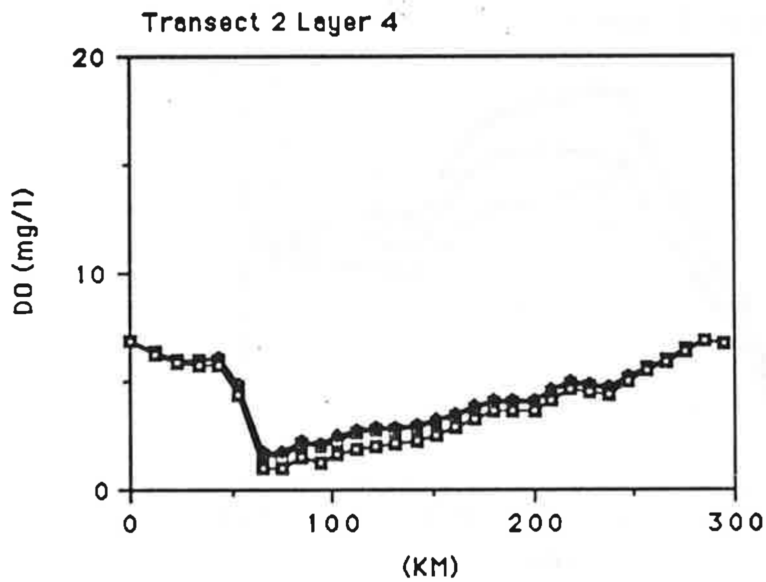
Transect 2 Layer 2
CHLOR A (ug/l)
20
10
0
0
100
200
300
(KM)
Existing Planned Upgrades
2000 Planned Upgrades
2000 X
1985 Calibration

Figure I 1



Transect 2 Layer 1
20
10
0
CHLOR A (ug/l)
0
100
200
300
(KM)
Transect 2 Layer 2
20
10
0
CHLOR A (ug/l)
0
100
200
300
(KM)
NPS 2000
NPS 2000 +TP=2 + TN=8
1984 Calibration

Figure I 2


Transect 2 Layer 4
20
10
0
DO (mg/l)
0
100
200
300
(KM)

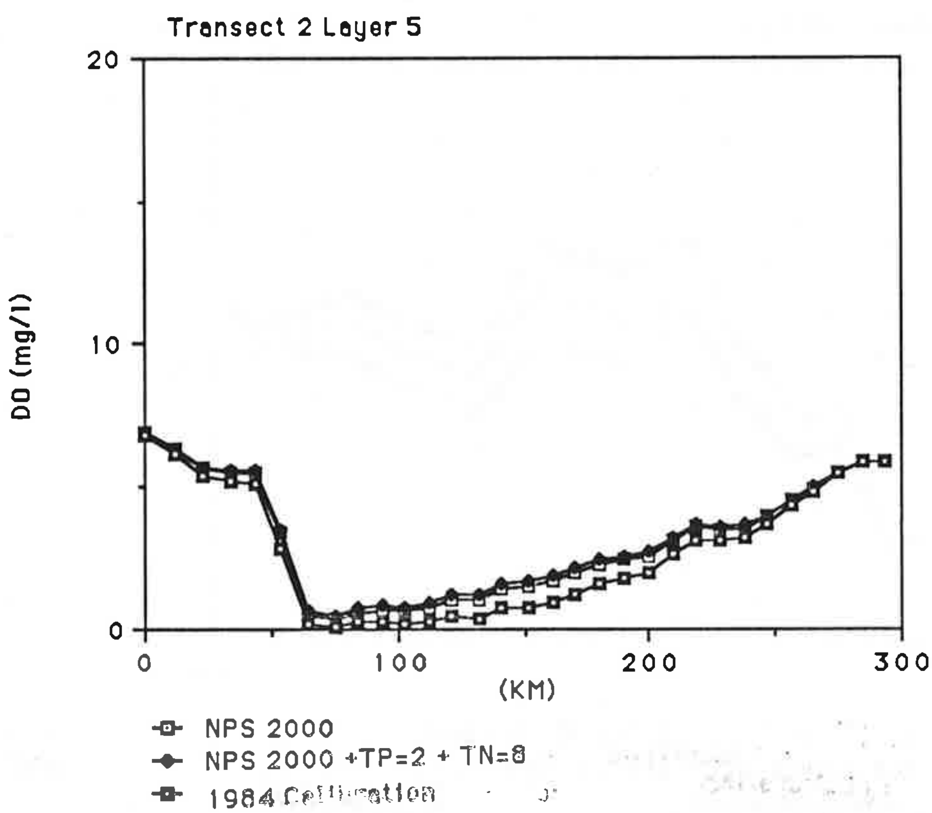

Transect 2 Layer 5
20
10
0
DO (mg/l)
0
100
200
300
(KM)
NPS 2000
NPS 2000 +TP=2 + TN=8
1984

Figure J 1

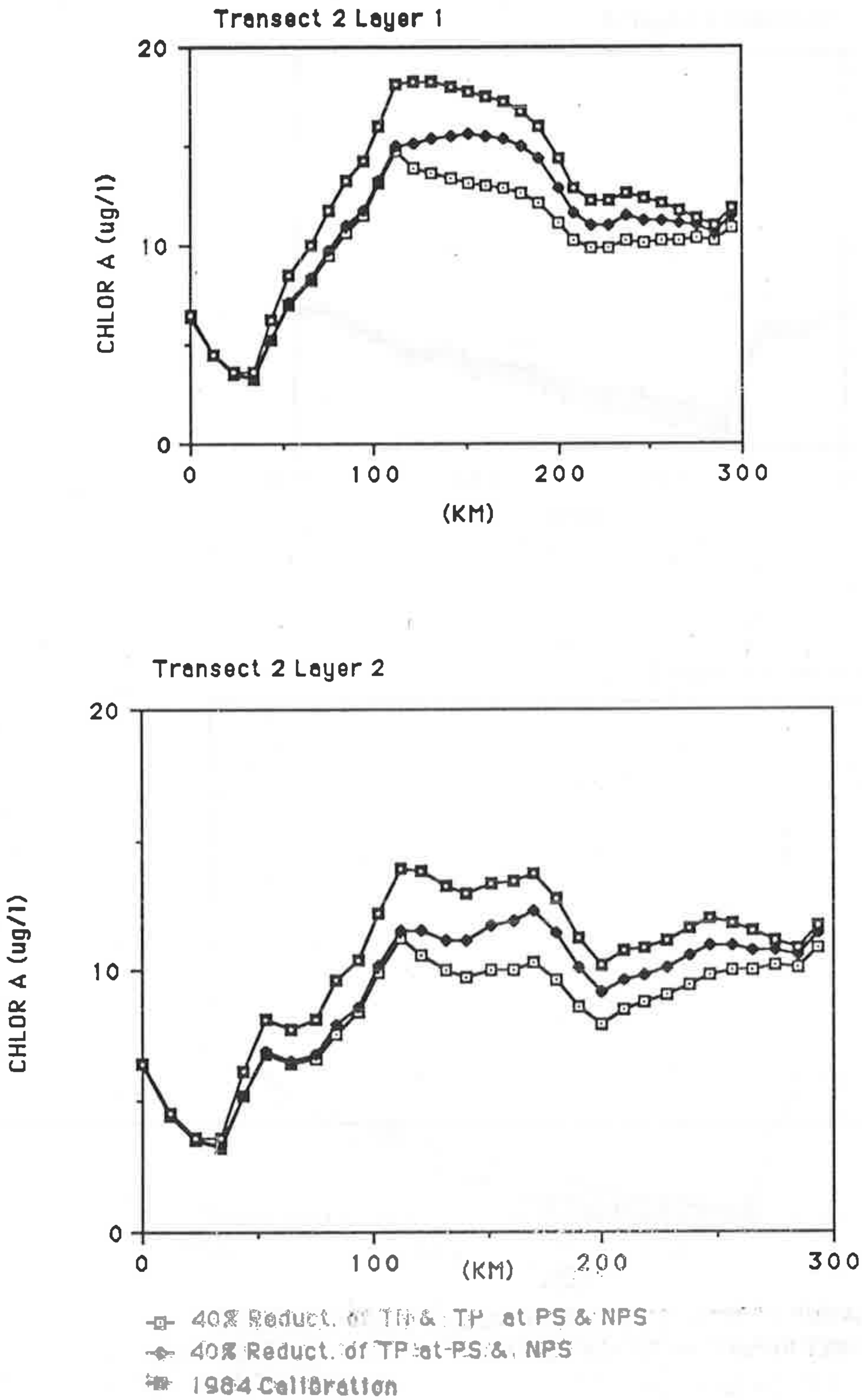
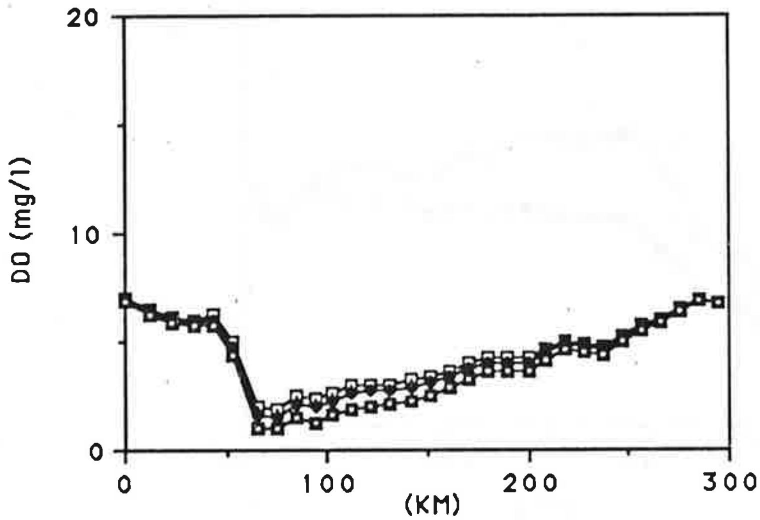

Transect 2 Layer 1
CHLOR A (ug/l)
20
10
0
0
100
200
300
(KM)
Transect 2 Layer 2
CHLOR A (ug/l)
20
10
0
0
100
200
300
(KM)
40% Reduct. of TN & TP at PS & NPS
40% Reduct. of TP at PS & NPS
1984 Calibration

Figure J 2

Transect 2 Layer 4



Transect 2 Layer 5

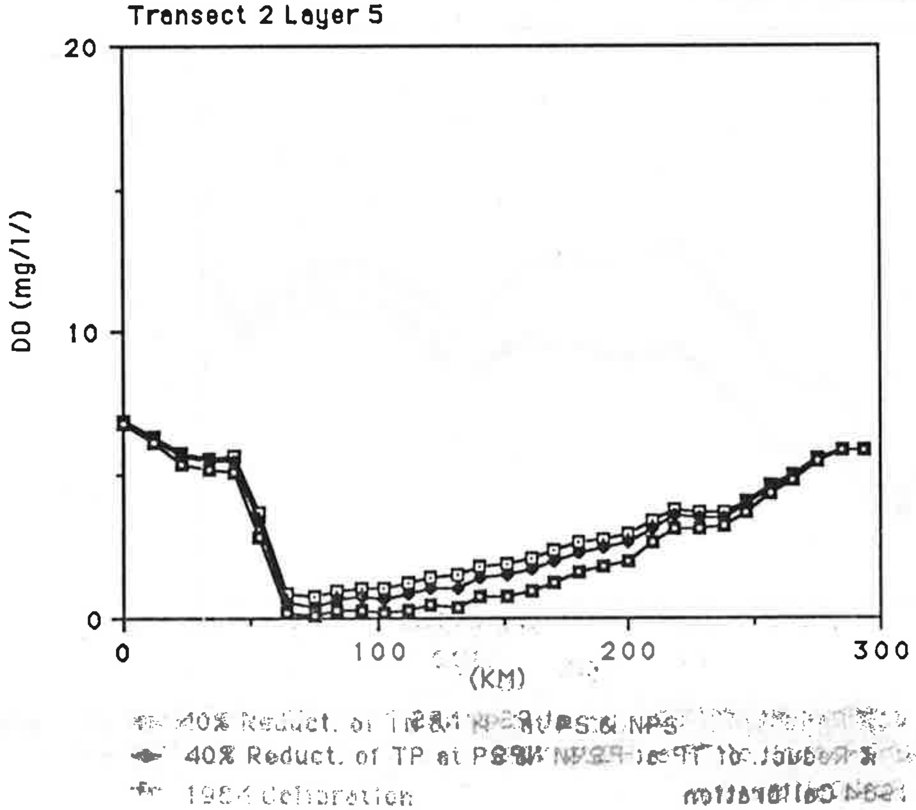
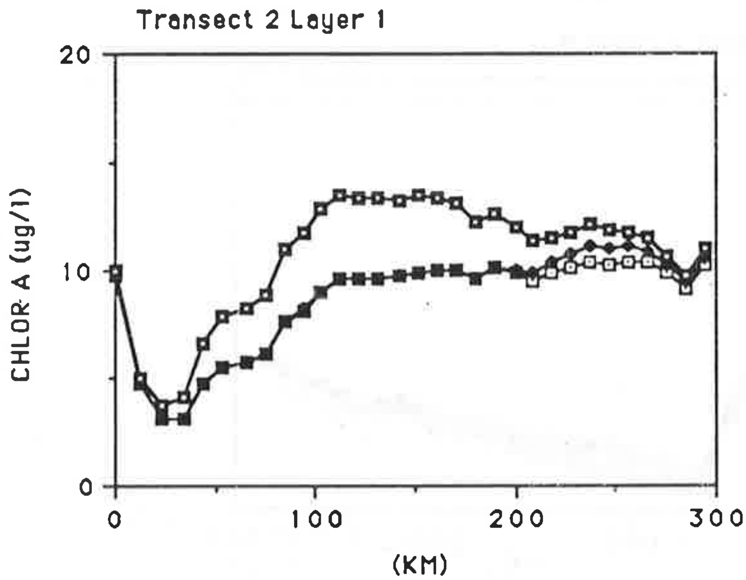
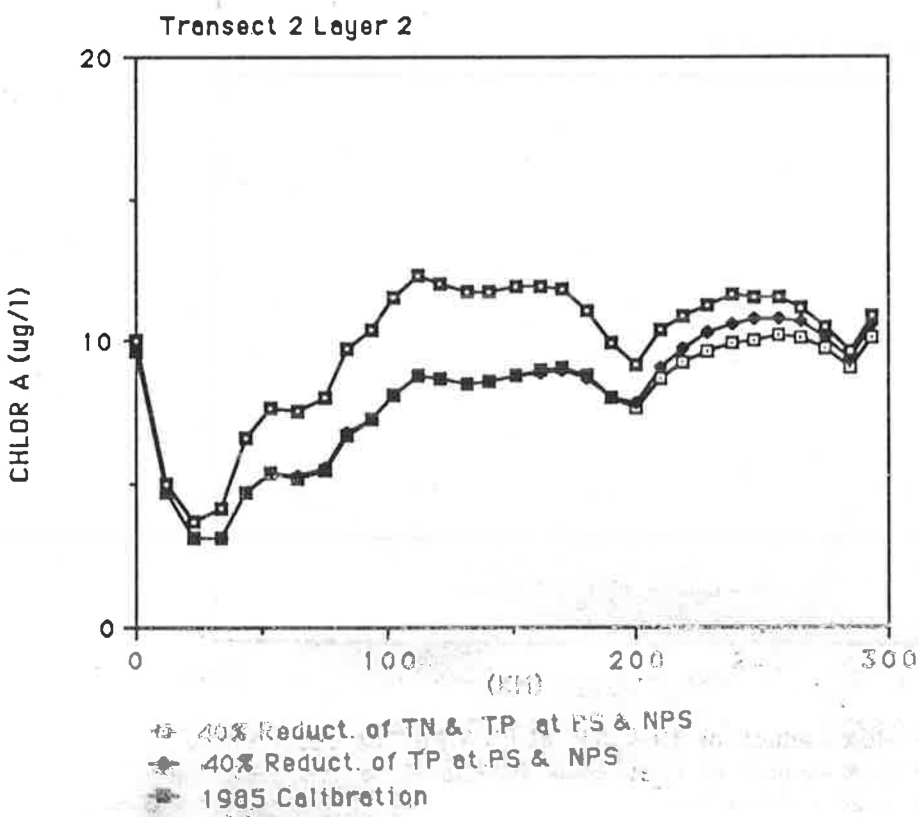


Figure K 1

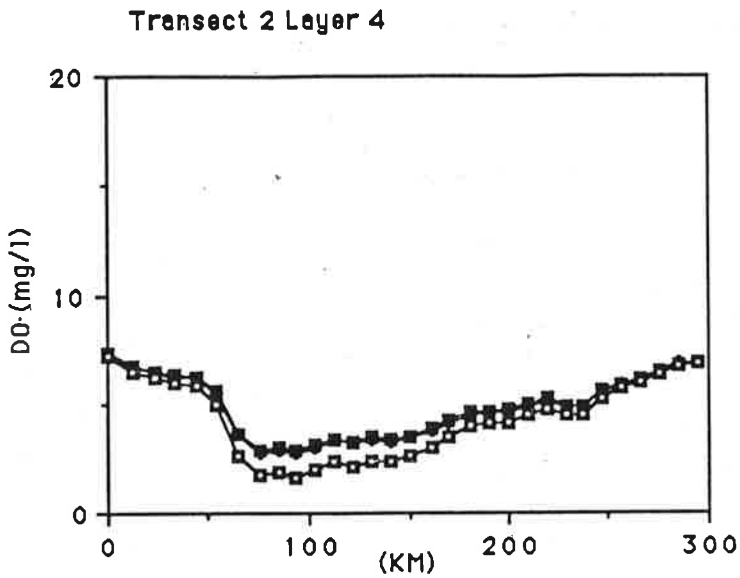


Transect 2 Layer 1
CHLOR A (ug/l)
20
10
0
0
100
200
300
(KM)

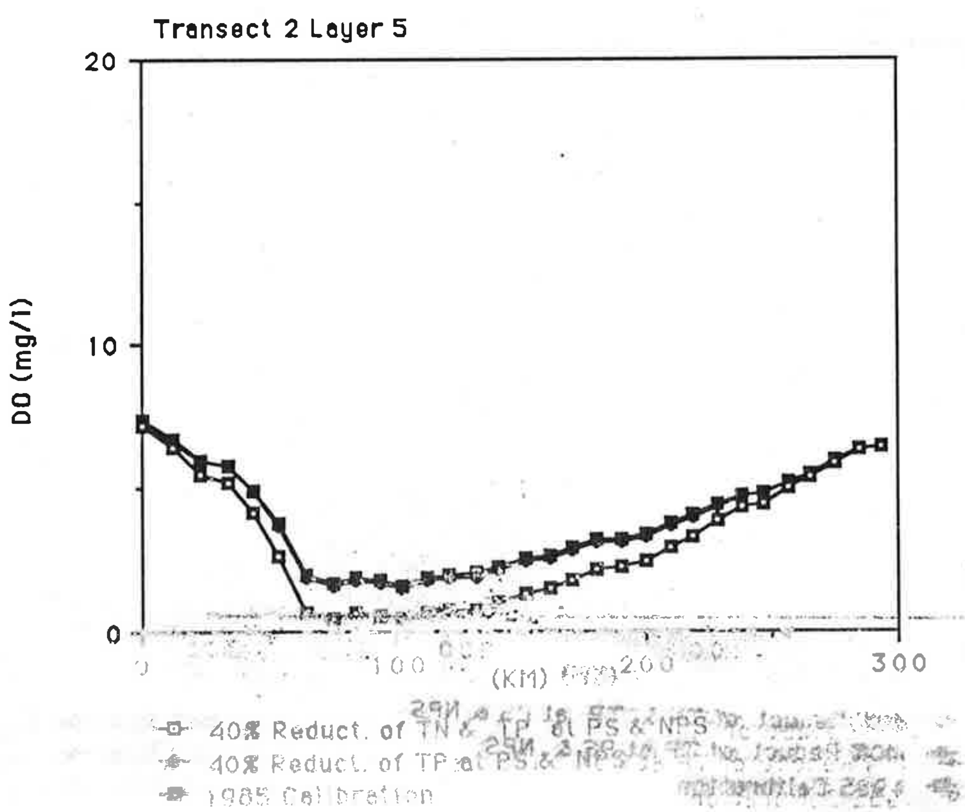


Transect 2 Layer 2
CHLOR A (ug/l)
20
10
0
0
100
200
300
40% Reduct. of TN & TP at PS & NPS
40% Reduct. of TP at PS & NPS
1985 Calibration

Figure K 2



Transect 2 Layer 4
DO (mg/l)
20
10
0
0
100
200
300
(KM)



Transect 2 Layer 5
DO (mg/l)
20
10
0
100
200
300
(KM)
40% Reduct. of TN & TP at PS & NPS
40% Reduct. of TP at PS & NPS
1985 Calibration

TECHNICAL APPENDIX 4

ESTIMATED BNR CAPITAL COSTS TO ACHIEVE 40 PERCENT NITROGEN LOAD REDUCTION AT MUNICIPAL POINT SOURCES BFL

Plants that could be upgraded to reduce municipal nitrogen loads by 40 percent from 1985 levels in order to achieve the Bay Agreement goals are listed in Table TA-4. Total capital construction costs at 14 plants to meet the goal BFL are estimated at $129.5 million.

Capital construction costs were developed from equations and site specific estimates provided in the reports, "Assessment of Cost and Effectiveness of Biological Dual Nutrient Removal Technologies in the Chesapeake Bay Drainage Basin, Volume I and Volume II." Annual incremental operation and maintenance costs associated with BNR would range from 9 to 15 percent of total construction costs, but are not included.

Loads for 1985 were based on Chesapeake Bay Liaison Office flow and effluent data updated with state estimates provided in December 1985. Loads for the year 2000 were determined by adjusting 1985 loads on the basis of population changes (1985-2000) expected in counties where the facilities are located. Service area boundaries were not considered. Year 2000 reduction goals for each State and the District were determined by combining the 40 percent reduction in 1985 loads and increases or decreases in loads associated with population changes. Alternate year 2000 loads were calculated based on projected flows and implementation of high level BNR technology (total nitrogen effluent concentration of 8.0 mg/l). Western Branch was upgraded to a total nitrogen effluent concentration of 3.0 mg/l. Potential reductions were determined for each plant by comparing alternate year 2000 load projections based on existing treatment with those that would be achieved with BNR.

Reductions were added plant by plant until the Agreement reduction goal was reached. Plants with the largest reductions in nitrogen loads were considered first. Loads from the Blue Plains plant were attributed to Maryland, Virginia and the District, based on flow contributions. The Blue Plains upgrade was factored into the loads and costs for each jurisdiction.

If greater population growth, increased municipal flows, or different population distributions occur, additional sewage treatment plants may need to be upgraded. This may significantly affect costs. The 14 plants identified in Table TA-4 for BNR retrofit account for 83 percent of the municipal effluent flow below the fall line. Upgrading smaller plants to achieve additional nitrogen reductions would mean losing economies of sale realized at the larger plants. Removal costs per pound of nitrogen therefore would increase.

TABLE TA4. NUTRIENT LOADS FOR 1985 AND TOTAL CAPITAL CONSTRUCTION COST FOR HIGH LEVEL BNR TREATMENT FOR YEAR 2000 FLOWS AT SELECTED PLANTS TO ACHIEVE BAY AGREEMENT GOAL OF 40 PERCENT MUNICIPAL NITROGEN LOAD REDUCTION

STATE/GOAL/FACILITY NAME	1985 FLOW	1985 DESIGN FLOW	1985 PHOSPHORUS	1985 NITROGEN	20000 PHOSPHORUS	20000 NITROGEN	REDUCTION PHOSPHORUS	REDUCTION NITROGEN	COST
DISTRICT OF COLUMBIA									
DC TOTAL REDUCTION GOAL								2770343	
DC BLUE PLAINS (54 % FLOW)	162.500	309.000	59396	6632502	60446	4029758	0	2602744	9.6898
DC TOTAL REDUCTION AND COST								2602744	9.6898
MARYLAND									
MD TOTAL REDUCTION GOAL								10222560	
BETH STEEL (FROM BACKR STP)	100.500	.	355094	7316160	525922	2337433	0	4978726	.
BACKRIVER	63.000	209.000	312786	4029759	298546	1465257	14240	2564502	38.3960
PATAPSCO	43.000	70.000	458412	2619496	250024	1000096	208388	1619400	6.9760
BLUE PLAINS (42 % flow)	126.400	.	46201	5159066	53359	3557240	0	1601826	7.5365
WESTERN BRANCH	10.800	30.000	108557	473702	35970	107909	72587	365793	14.0000
MD TOTAL REDUCTION AND COST								11130247	66.9084
VIRGINIA									
VIRGINIA TOTAL REDUCTION GOAL								12493614	
HOPEWELL STP CITY OF	30.82	50.0	178363	6101902	190254	801070	0	5300831	6.10900
ALEXANDRIA CITY SANITARY AUTHO	36.52	54.0	16685	2046764	52804	938738	0	1108026	7.21000
ARLINGTON	26.56	30.0	45304	1642265	46051	657875	0	984390	1.36600
LOWER POTOMAC	32.98	36.0	14064	1908638	16562	946417	0	962220	3.70600
RICHMOND CITY OF	66.10	55.0	845610	2456295	394329	1577315	451281	878980	10.07600
HRSD - LAMBERTS POINT	20.10	33.0	202036	1346908	121191	484764	80845	862144	9.94697
HRSD - BOAT HARBOR	15.50	25.0	254944	1052824	93456	373823	161488	679001	4.08747
HRSD - CHESAPEAKE/ELIZ.	14.40	30.0	285099	1000038	86823	347294	198275	652745	4.58746
HRSD - ARMY BASE	12.96	14.0	177638	773714	78141	312564	99497	461149	2.83171
HRSD - WILLIAMSBURG	9.86	9.6	114125	642702	59450	237800	54675	404903	2.23018
BLUE PLAINS (4 % FLOW)	12.04	.	4401	491417	4626	308429	0	182989	0.71760
VA TOTAL REDUCTION AND COST								12477377	52.86833
DC MD AND VA TOTAL REDUCTION AND COST								26210369	129.46657
DC MD AND VA TOTAL REDUCTION GOAL								25427046	

Flow in millions of gallons per day
Loads in pounds per year based on CBLO data base updated to correspond to state data, 22 December, 1987
Reduction goal in pounds per year based on all size plants
Cost=total capital construction cost in millions of 1987 dollars
Cost source="Assessment of Cost and effectiveness of BNR technologies in Chesapeake Bay Drainage basin" (BNR report),VOL I, II
High Level BNR=Biological nutrient removal , total nitrogen=8.0 mg per liter; Western Branch at total nitrogen=3.0 mg per liter
Design is existing design used in BNR report
Design= " . " indicates partial flow from upgrade elsewhere
2000 loads based on flow changes tied to increases or decreases in county population