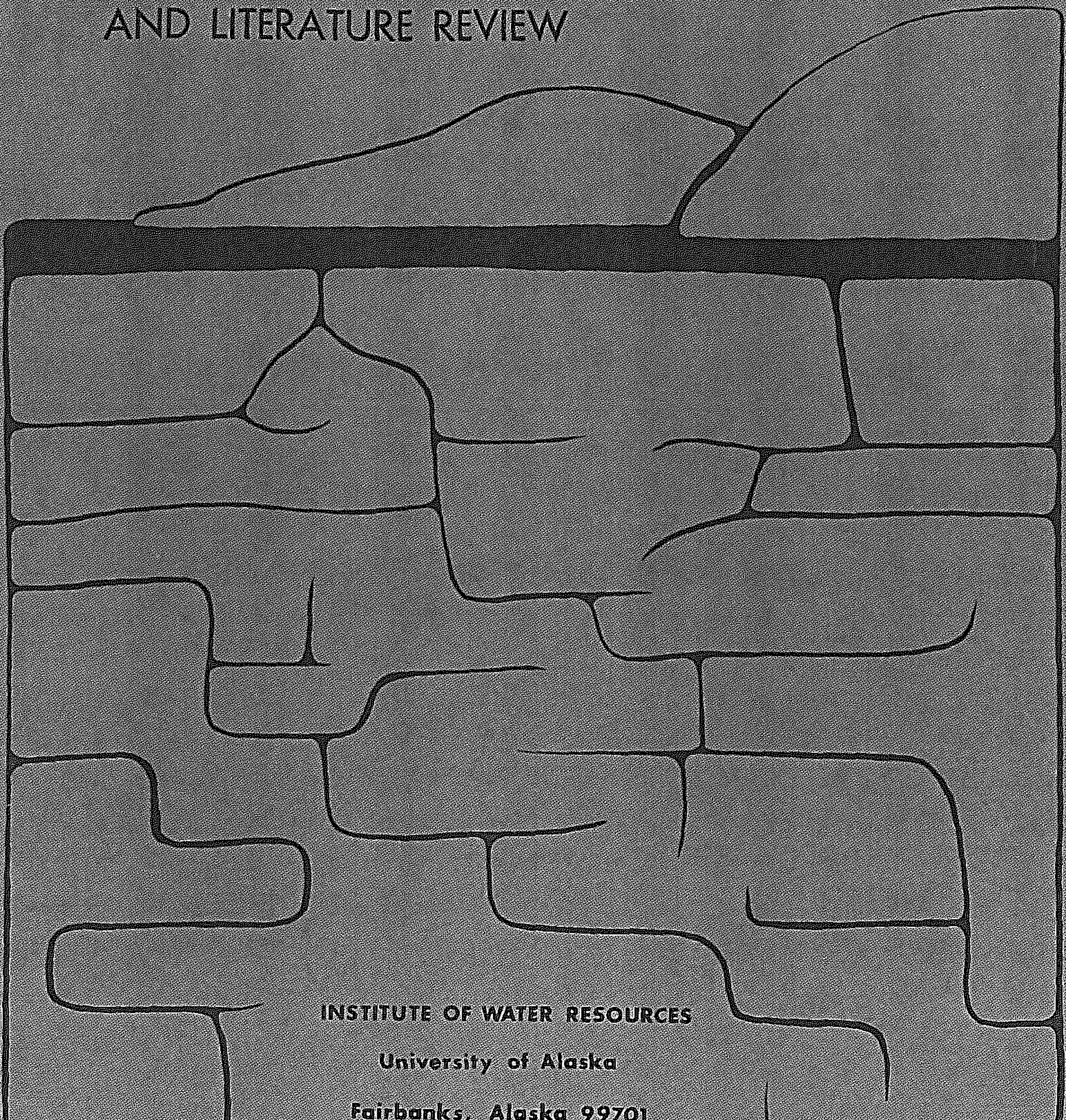
CLEARING ALASKAN WATER SUPPLY IMPOUNDMENTS – MANAGEMENT, LABORATORY STUDY, AND LITERATURE REVIEW



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CLEARING ALASKAN WATER SUPPLY IMPOUNDMENTS: MANAGEMENT, LABORATORY STUDY, AND LITERATURE REVIEW

Clearing Alaskan water supply impoundments: Management, laboratory study and literature review
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PREFACE

The literature review prepared in conjunction with this study is contained in IWR-67-A, published separately as "Clearing Alaskan Water Supply Impoundments: Literature Review" by the Institute of Water Resources, University of Alaska, Fairbanks, Alaska.

The data developed in the laboratory portion of the study are contained in IWR-67-B. Contact the Institute of Water Resources for access to this material. IWR-67-A and IWR-67-B are available on microfiche.

PART I

IMPOUNDMENT MANAGEMENT IN NORTHERN REGIONS

INTRODUCTION

Water supply impoundments in northern regions have seen only limited application. Reasons for the lack of use of such impoundments include the following:

1) little demand for water due to the low population densities and rustic life styles
2) a lack of conventional distribution systems in many communities
3) poorly developed technology for construction of dams on permafrost
4) adequacy of existing river, lake, ice, and lagoon water supplies
5) shortage of capital to finance the high cost of construction in remote regions.

In many villages the need for water retention and storage facilities is quite acute. The traditional means by which native communities have obtained water in the winter include melting blocks of ice harvested from nearby streams, lakes or sea ice pressure ridges, and hauling water from nearby springs or through holes chopped in the ice on bodies of fresh water. Hand transportation of water from nearby streams and ponds has sufficed during the summer. The problem with this system is the inconvenience involved and the lack of adequate control over contamination. The spread of disease has been found to be significantly reduced when running water is provided in the individual household.

With the partial acceptance of values from technological societies, the native people are no longer satisfied with traditional methods of supplying water. Hence, the need and demand for good running water systems has increased.

To meet water demands, some areas will require the construction of water retention and treatment facilities which have sufficient capacity to provide a continuous water supply. The design, construction, and operation of such facilities will require a great deal of information and study. Among important aspects of this challenge are the changes in water quality which will occur with time due to the leaching process. Leaching studies of the type which follow provide valuable information as to the types of quality changes which may occur.

The technique of constructing dams on permafrost is still being developed, although several dams have been constructed and operated successfully in permafrost regions. Articles have been published by Borisov (1959), Tsvetkova (1966), Kitze and Simoni (1972), Fulwider (1973), and George (1973) on various techniques of constructing dams on permafrost. The key to m4st of the construction methods is to maintain the core of the dam in a frozen state by some combination of insulating in the summer and cooling in the winter.

The discovery and exploitation of vast resources in northern regions will stimulate the trend of urban center development with the subsequent demand for dependable water supplies at reasonable costs. In regions with limited supplies of continually available water, dams and impoundments may be necessary to provide the needed storage.

Another force which will lead to the construction of more dams is the economic and social incentive to control floods. Events such as the flood of 1967 which inundated nearly all of the city of Fairbanks make control impoundments economically advantageous. In the transportation deficient north country, cities are usually located on the flood plain of a river. As these towns increase in importance and size, more emphasis will be placed on control flood.

Construction of hydroelectric power plants is receiving renewed interest as fossil fuels become more scarce and expensive. The northern regions have tremendous untapped potential for power dams. In recent years this potential power source is being developed by a dam near Juneau and other dams have been proposed for the Susitna and Yukon Rivers. The possibility of severe damage to ecosystems, fisheries, and water supplies will necessitate careful evaluation of any proposed impoundment site. Leaching studies of the type outlined in this paper should be a part of any reservoir planning project.

SITE PREPARATION

At present, site preparation procedures for reservoirs in the arctic and subarctic are based on practices followed in the warmer states or on economic constraints. The procedures selected may not be the best or most economical for northern regions. A basis for making design decisions must be developed for Alaska's climate and topography.

Clearing alternatives should be examined at each reservoir site in order that the best balance between construction and operating costs is chosen for each unique area. Considerable savings in water treatment cost might be realized if site preparation alternatives were carefully examined. Environmental damage due to the release of low quality water may be predicted before it happens and the clearing procedure could be designed so as to avoid potential problems.

WINTER PROBLEMS

Reservoir sites in the arctic and subarctic are frequently flat boggy areas surrounded by rolling terrain. Little is known about the effect the bog soils will have on water quality during long, cold periods.

Winter oxygen depletion in cold region lakes is often equal to or greater than summer depletion. This condition has also been shown to occur in laboratory leaching columns using soils from Alaskan reservoir sites as well as in many more southerly impoundments. The problem results from chemical and biological oxygen demand continuing to be exerted, while surface reaeration is restricted by ice cover. The water influent to reservoirs is often low in volume and oxygen. Under more serious conditions, anoxic conditions develop in the lower regions of the reservoir. Anoxic conditions allow the degradation of water quality by setting up a reducing state in the bottom mud and allowing some chemicals to go into solution.

Furthermore, winter water quality decreases as a result of the removal of relatively pure water from the available water supply by the freezing process. This results in the remaining water's having an even higher concentration of dissolved constituents. This problem is especially acute in shallow reservoirs where half or more of the total available volume may be in the frozen state. (See the section on ice cover in Part II for more information on this subject).

LIMITATIONS OF COLUMN LEACHING STUDIES

Leaching studies are a valuable tool in predicting water quality changes resulting from impoundment. Studies by Mortimer (1941, 1942), Nielson (1967), and Keup *et al.* (1970) demonstrate the feasibility of water quality prediction. (For more discussion of these articles see the section on leaching in Part II).

Laboratory leaching studies suffer from several limitations, one of which is the sealed nature of the column bottoms, eliminating mass water movement into and out of the soil. The influences of groundwater entering the soil, and reservoir water percolating away through the soil, are not accounted for in such column studies. This problem would be especially significant in reservoirs with fluctuating water levels which would cause bank areas to be periodically inundated and drained.

Lee (1970) discusses the effect of mixing on the accuracy of water quality prediction from laboratory studies. He reports that quiescent leaching column conditions do not represent the situation as it occurs in reservoirs. (For more discussion on Lee's work, see the section on leaching in Part II).

The dilution of leachate must be considered in reservoir water quality studies. In deep reservoirs, the leachate may be diluted considerably more than in shallow reservoirs, hence reservoirs with greater surface area to volume ratios may have more serious leaching problems. If stratification is present, leaching will only affect the deepest layers, making it important to consider the flow patterns of the reservoir. Substantial reduction of surface area can be realized at some reservoir sites by placing dikes to keep water out of areas which will be shallow. This will also help prevent the growth of bottom-attached plants.

Leachate dilution can also be caused by reservoir inflow. The calculation of inflow dilution is complicated by thermal and chemical stratification, wind effects, depth of outlets, and reservoir morphology. (For more on this subject, see the section on stratification and selective withdrawal in Part II).

LABORATORY STUDIES

The evaluation of the effect on water quality of proposed impoundment sites has followed several different procedures. The work described herein made use of relatively standard laboratory procedures designed to evaluate water quality changes over long periods of time. The objectives of the work were to examine the effect of new reservoirs on the quality of the water that would be released and to determine what improvement could be expected by stripping away surface material.

Undisturbed soil samples were collected from five reservoir sites around the State of Alaska as shown in Figure 1. Samples were collected from the surface and various depths below the surface. The soil was classified by the U.S. Soil Conservation Service and was analyzed for moisture content, volatile solids, and particle sizes. Leaching was conducted in sealed quiescent columns and determinations of temperature, electrical conductivity (E.C.), alkalinity, tannin/lignin, dissolved oxygen, color, nitrate plus nitrite, ammonia, total organic carbon (TOC), iron, and manganese were made on the leachate.

The leaching rate was intensified by maintaining the column temperature above expected reservoir temperature. This resulted in the six-week leaching period approximately equivalent to the period of ice cover.

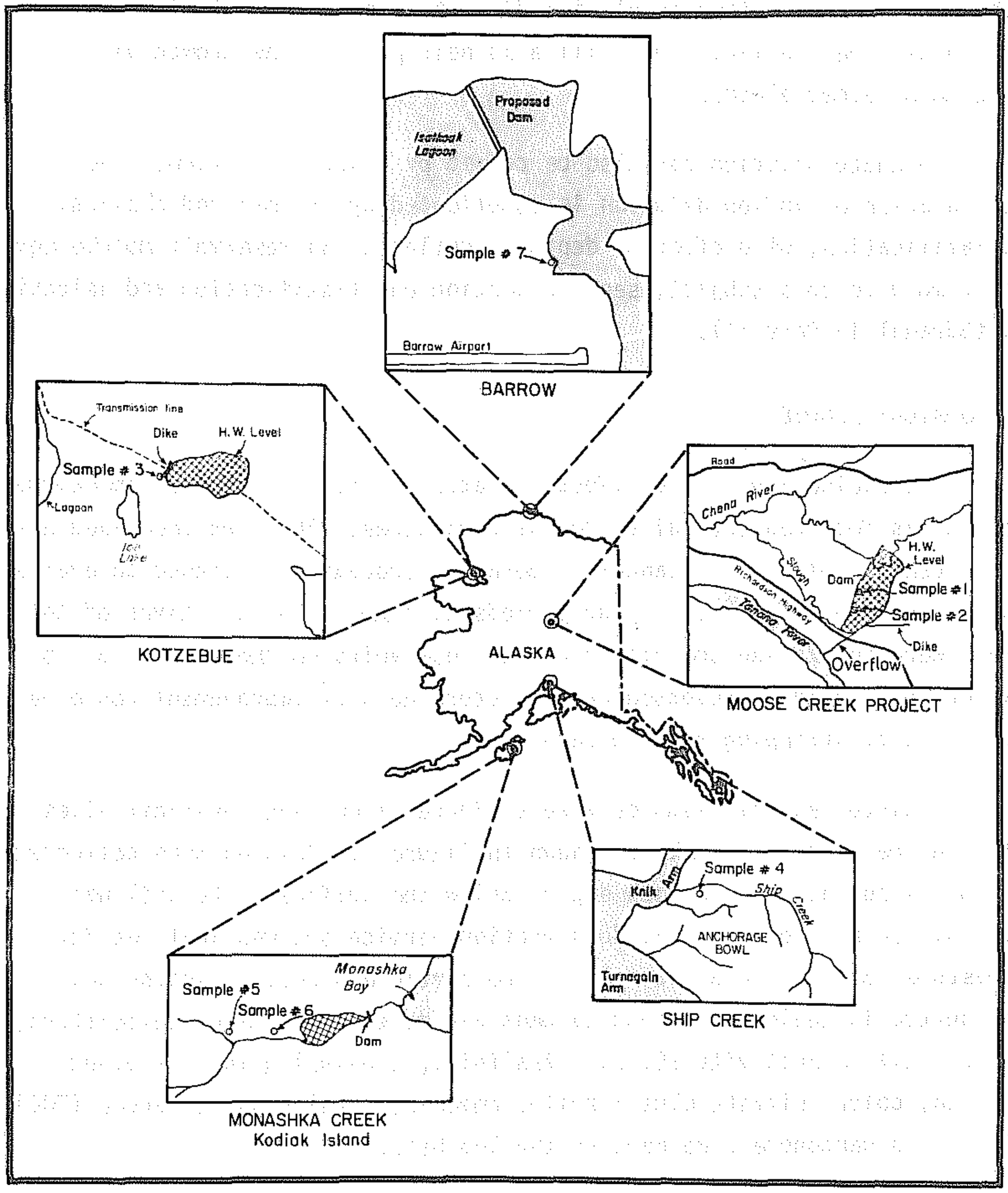


FIGURE 1: Location of Sample Sites

A method for examining the economics of various depths of reservoir clearing was developed and applied to a hypothetical case. It compares the cost of clearing with the capital and operating cost of the water treatment plant needed to bring the water to acceptable standards.

The following recommendations were derived by analyzing the water quality data. These recommendations are subject to change where the economic variables of each case are considered. Other items such as slope stability and erosion control also warrant careful consideration.

Moose Creek Reservoir

The marsh-grass areas should be stripped to a depth of 25 cm. This stripping will result in significant improvement of water quality characteristics. On the higher and dryer areas, the upper 15 cm of material should be removed. Much less leaching occurs from the material below this depth.

Kotzebue Reservoir

Relative to the surface layer, little improvement of water quality was obtained when subsurface layers were leached; thus, stripping is not recommended for this site as only slight improvement of water quality would result. The possibility exists that our sample was obtained from a disturbed site.

Ship Creek

A 7.6 cm depth of cut is recommended for stripping operations at this site. Remarkable improvement of water quality resulted from leaching subsurface material relative to surface layers. Good water quality will result from the impoundment on this site if the top 7.6 cm are removed.

Monashka Creek, Kodiak Is.

Surface material at this site will degrade water quality severely. The deeper ash material had almost no effect on the quality constituents we observed; thus, removal of all organic material above the ash is recommended. The effect of reservoir currents in scouring ash is unknown. Examination of ash scour is recommended before final clearing decisions are made.

Barrow Reservoir

Primarily because oxygen resources remained good when deeper layers were leached, removal of 10 cm of surface material is recommended. Moderate water quality degradation will still occur but aerobic conditions will remain, thus avoiding problems due to anaerobic conditions.

ANALYSIS OF TREATMENT AND CLEARING COSTS

One of the primary objectives of this study was to present a simple and reliable method of examining the economics of various degrees of reservoir site clearing. The following assumptions are made in the analysis scheme:

1) The cost of water treatment after 10 years of reservoir operation will be the same for all degrees of clearing. This assumption is based on a number of studies which have shown that initial differences in site treatment have an effect on water quality for 10 years or less. (Fair, Geyer, and Okun, 1966).

2) The costs of constructing dams, roads, transmission lines, etc., are independent of whether the reservoir is cleared or not and are therefore not considered.

The factors which are considered in the economic method are:

1) The cost of reservoir clearing is calculated for various depth alternatives. Obviously, not clearing at all is the cheapest and costs increase as depth of cut increases.

2) The initial capital cost of the water treatment plant as a function of how much clearing is done is considered. This cost is usually highest for uncleared reservoirs and decreases if organic material is removed by clearing.

3) The annual water treatment plant operating cost as a function of how much clearing is done is considered. Initially this cost will be high and will decrease for approximately 10 years after which it will remain constant (Fair, Geyer, and Okun, 1966).

Clearing costs can best be obtained from local contractors familiar with the terrain, but these estimates can vary greatly. Other sources of such data are the Building Cost File and the Engineering News Record. Adjustments have to be made to account for Alaska's remoteness and escalated prices. At the site, the area of land to be cleared must be determined and, if the terrain varies, different clearing costs may have to be applied to compensate for the variations. It would be advisable to apply different clearing criteria to different soil zones if the leaching studies show that some zones will be more likely to contaminate the water. LeSchack and Brown (1969) suggest the use of aerial photography for easy determination of different vegetation types of a given area so that clearing costs can be calculated.

The capital cost of water treatment plants is best obtained by a comparison of completed plants of similar size, process, and location with those being considered. Leaching studies will provide a fair approximation of the water quality which can be expected from the new reservoir. A comparison with the applicable water quality standards will show the degree of treatment necessary to reach the standards. With this data, educated adjustments can be made as to the cost of the necessary treatment plant.

The operation cost of treatment plants can also be obtained from existing treatment plant managers. A treatment cost has to be determined for each of the predicted water qualities resulting from the clearing alternatives. Treatment costs decrease with time depending on the nature of the material flowing into the reservoir. For example, if water with a high organic content flows into the reservoir, the water quality may degrade as this material decomposes. In this study, the quality of influent water was not determined at any of the sites.

For comparing alternatives, it is only necessary to use the added operating and capital cost of an alternative over the cheapest alternative because many of the basic units, such as the chlorination system and the building, will cost the same no matter what degree of clearing is done. The cheapest treatment alternative is that which would be required after the 10-year break-in period.

Annual operating costs must be converted to present worth to facilitate cost comparisons.

The equation used to compute the significant cost of each alternative is given by the formula:

$$\Delta Cost = CC + \Delta WTOC + \Delta WTCC \qquad (1)$$

where

ΔCost = significant cost of a clearing alternative

CC = clearing cost

ΔWTCC = cost of additional water treatment equipment over that which will be needed after the 10-year break-in period.

ΔWTOC = additional water treatment operating costs over that which will be needed after the 10-year break-in period (converted to present worth).

To convert the annual water treatment operating cost to present worth the standard formula was written as follows:

$$\Delta WTOC = \sum_{1}^{n} \Delta AOC_j \cdot \left(\frac{1}{(1+i)^n}\right) \qquad (2)$$

where

$\frac{1}{(1+i)^n}$ = sppwf = single payment present worth factor

ΔAOC_j = additional annual operating cost for year j

i = interest rate

n = number of years until the operating cost is the same for all alternatives. Ten years was used in this example.

Example

The following example is supplied only to demonstrate the analysis method with a hypothetical situtation. To utilize the method, cost data would have to be carefully gathered on the unique situation involved.

Given:

Population	= 1,000
Design water flow	= 50,000 gal/day
Cost of clearing	= \$1 per m^3
Area to be cleared	= 10,000 m^2
Interest rate	= 9%

Water Quality as a Function of Clearing

No clearing:

Assume that leaching studies show that water quality will be seriously degraded, requiring intensive treatment if no clearing is done.

15 cm clearing:

Much improvement of water quality but some constituents still must be removed.

30 cm clearing:

Good water results from this clearing alternative. Leaching studies show that little water treatment will be required if this alternative is chosen.

45 cm clearing:

No additional improvement of water quality is expected to be obtained beyond that which will result from 30 cm clearing.

Additional Water Treatment Operating Costs (WTOC)

no clearing - \$2,500 for the first year decreasing by \$250 per year.

15 cm clearing - \$1,500 for the first year decreasing by \$150 per year.

30 cm clearing - no additional costs

45 cm clearing - no additional costs

TABLE 1

CONVERSION OF WATER TREATMENT OPERATING COSTS TO PRESENT WORTH

Year	WTOC		sppwf	Present Worth WTOC	
	no clearing	15 cm clearing		no clearing	15 cm clearing
1	2500	1500	.91743	2294	1376
2	2250	1350	.84168	1894	1136
3	2000	1200	.77218	1544	927
4	1750	1050	.70843	1240	744
5	1500	900	.64993	975	585
6	1250	750	.59627	745	447
7	1000	600	.54703	547	328
8	750	450	.50187	376	226
9	500	300	.46043	230	138
10	250	150	.42241	106	63
			Σ*	9951	5970

*Interest rate: 9%

Clearing Costs:

no clearing:

zero

15 cm clearing:

$\$1/m^3\ (10{,}000\ m^2)\ (.15\ m) = \$1{,}500$

30 cm clearing:

$\$1/m^3\ (10{,}000\ m^2)\ (.30\ m) = \$3{,}000$

45 cm clearing:

$\$1/m^3\ (10{,}000\ m^2)\ (.45\ m) = \$4{,}500$

Total Significant Costs:

$\Delta WTCC + \Delta WTOC + CC = Cost$

no clearing:

15,000 + 9,951 + 0 = 24,951

15 cm clearing:

2,000 + 5,970 + 1,500 = 9,470

30 cm clearing:

0 + 0 + 3,000 = 3,000

45 cm clearing:

0 + 0 + 4,500 = 4,500

For this hypothetical example, the data was adjusted to produce results indicating that removal of 30 cm of material is the most economical alternative. In some situations, the alternative of "no clearing" may be the most economical. At other impoundment sites, it may prove valuable to integrate the analysis procedure over the entire area to arrive at the best water quality at the least cost.

PART II

LABORATORY STUDY OF THE EFFECTS OF CLEARING ALASKAN WATER SUPPLY IMPOUNDMENT SITES

INTRODUCTION

As noted earlier, many factors are involved in the limited use of water impoundments in the Arctic and subarctic. With the increasing demand for running water supply, flood control, and hydropower generation, the number of such facilities will increase. Such installations will result in a variety of changes in the quality of downstream waters. These changes are examined in detail in this report.

One of the major causes of changes in the downstream water quality is the process of leaching of various metals and organics from continuously or intermittently inundated soil, vegetation, and organic litter. This part of the report deals with the leaching process as it can be studied in the laboratory. Soil samples were collected from prospective impoundment sites and a column leaching study conducted. The results of the test as well as preliminary recommendations as to the degree of site clearing required for minimum water quality changes and costs are included.

OBJECTIVES

The primary objective of this study was to evaluate site preparation alternatives and the effect of each on the quality of water in Arctic and subarctic reservoirs. This objective was approached by a series of steps which were designed to develop a general understanding of the effects of leaching on water quality. These steps were:

1) a review of the literature on effects of reservoirs on water quality
2) the collection of soil samples from selected reservoir sites in Alaska
3) the characterization of the soil samples
4) the leaching of various layers of the samples under simulated, but accelerated, reservoir conditions
5) the determination of the changes in water quality due to leaching as a function of the soil sample depth and soil characteristics.

A secondary objective was to develop a method of evaluating the economics of several clearing alternatives. This was done by comparing clearing costs with related water treatment costs to reach the same quality water.

EXPERIMENTAL METHODS

In selection of experimental methods, emphasis was placed on using simple, standard techniques to maximize the usefulness of the data and facilitate comparison with the work of other investigators. A method which could be easily repeated in future leaching studies was also considered of value.

Soil Sampling

Selection of sampling site was done carefully to ensure that it represented the entire area to be inundated. If more than one distinctly different type of terrain was present, either multiple samples were taken or the sample site was located in the transition zone between areas. For more accurate water quality predictions, more samples should be tested.

Two techniques were used for collection of undisturbed soil samples. At the first three sites, a block of soil 2 feet high and 10 inches square was cut out by digging a trench around it. A plastic-lined wooden box was slipped tightly over the sample, then the sample and box were removed from the hole. After being sealed, the samples were shipped to the Institute of Water Resources in Fairbanks, Alaska. None of the samples were successfully collected undisturbed by this method. Inevitably a layer was encountered that was not stable and the soil column would have to be removed in sections and placed in the box.

Samples 4 through 7 were proficiently collected in the 6-inch diameter by 4-inch high, cylindrical shape required by the leaching apparatus. Samples were removed from the soil profile at the surface and at all points of obvious change in soil type. Figure 2 shows a sample after it has been trimmed in place. Figure 3 shows a sample as placed in the leaching cap. The samples were transported to Fairbanks either in the caps or in 48-oz. coffee cans.

FIGURE 2 : Sample after being trimmed in place.

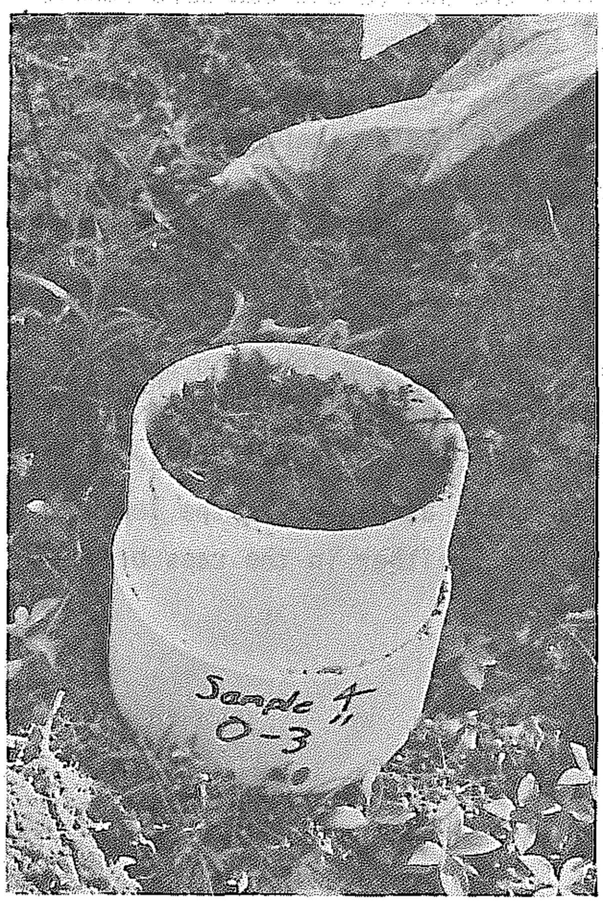


FIGURE 3 : Sample placed in leaching cap.

Two sets of grab samples were also taken from all soil layers. One set was used for determination of particle sizes, moisture content, and volatile solids. The second set was sent to the U.S. Soil Conservation Service in Palmer, Alaska, for classification by soil scientist Dr. Samual Reiger. Descriptions of the soil profile were recorded and photographs were taken of the site and the soil profile. The hole was then refilled.

Soil Characterization: All the soil analysis methods were done according to Lambe (1951). The procedures are the standard ones used by most soil test laboratories.

The first tests to be run in the lab were for moisture content and volatile solids. Problems with water draining during transportation of the wetter soils may have influenced the data adversely.

Particle sizes were determined by standard sieve analysis techniques using sieve numbers 4, 10, 16, 30, 40, 50, 80, and 200. The material retained on the 200 gauge sieve was washed because static charges interfered with free passage of particles.

The results of the sieve analysis on the high organic content samples was questionable because, with enough shaking, all the particles could have been broken down to a very fine size.

Hydrometer analysis was used on the first three soil samples to determine particle sizes smaller than the 200 sieve but it was too time consuming so was not done on samples 4 thru 7. The method used was according to Lambe (1951).

Leaching

Figures 4 and 5 show the apparatus used to simulate reservoir conditions. The stands are constructed of 1/2-inch plywood and 2-inch by 4-inch lumber. The columns are made of 6-inch diameter, 5-foot long, polyvinal chloride (PVC) pipe and fastened to the stands with plumbers strap and bolts.

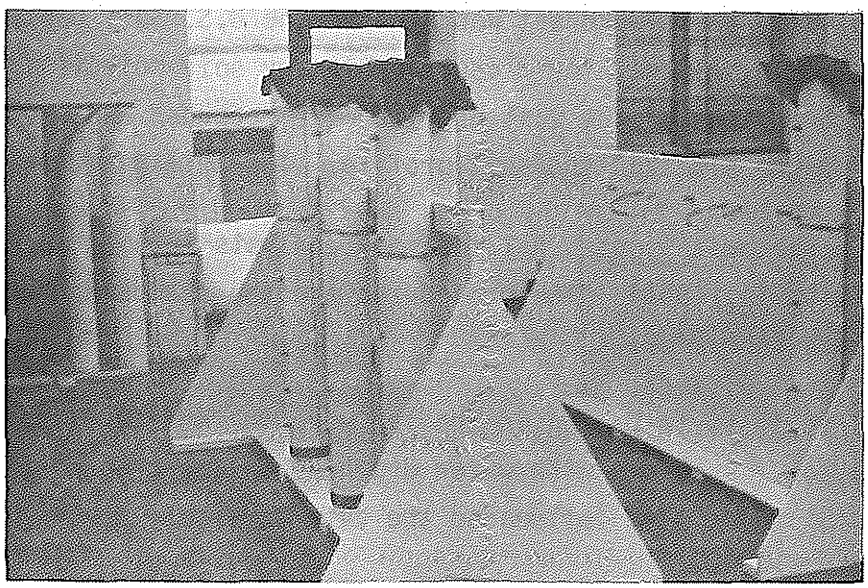


FIGURE 4 : Leaching apparatus.

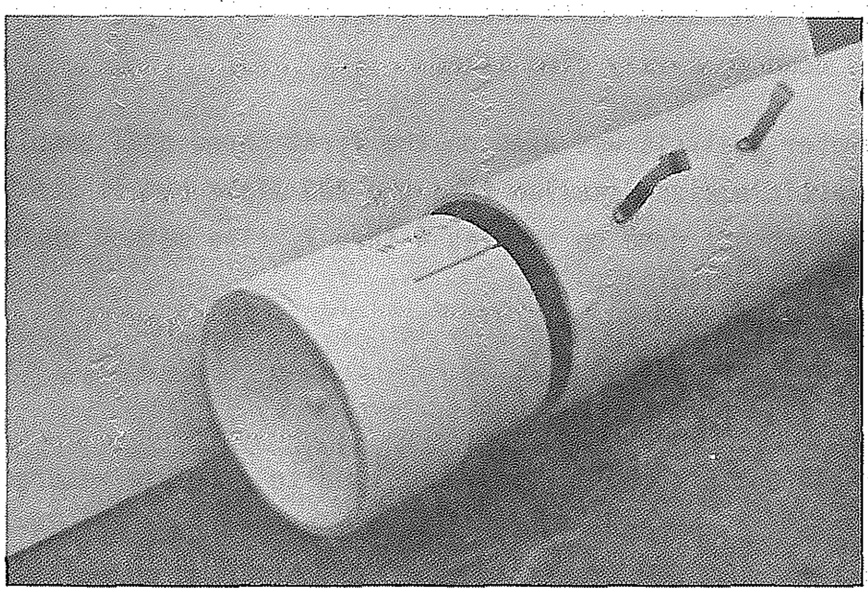


FIGURE 5 : Leaching column and cap before assembly.

The sampling ports consist of 1/4-inch rigid plastic pipe, glued in place, and fitted with a length of flexible rubber tubing, sealed at the end. Samples were drawn from the ports by gravity flow using a large diameter hypodermic needle connected to a length of flexible tubing as shown in Figure 6.

The soil samples were placed in PVC caps and sealed to the columns with a flexible silicon-rubber caulking compound, teflon tape, nylon-reinforced packaging tape, large rubber bands cut from car inner tubes, and tensioning devices made of nylon cord. Several other sealing techniques were tried with little success. Figure 7 details the connection between the soil-containing caps and leaching apparatus.

Once the columns were in place on the stands, they were filled with distilled water. The first of the two runs went smoothly, but after the columns had been filled for the second run, the water from the distillation unit was observed to have a pH of 3. Apparently after the ion exchange column in the distiller had been regenerated with acid, not enough water was wasted, thus a small amount of mineral acid contaminated the unbuffered pure water. Chemically, the low pH should intensify leaching because the reducing condition will convert constituents from insoluble to soluble forms. On the other hand, biological activity could be slowed by the extreme pH conditions, thus decreasing leaching rates. The overall effect is unknown, but leaching rates were slower in the second run than in the first. Whether this was due to the different soil or the acid condition was undiscernable.

The leaching rate in the laboratory columns was greater than that which may be expected in the reservoirs due to the higher temperatures maintained in the columns. As a rough approximation, many reaction rates are considered to double for every 10°C temperature increase (Hem, 1970). The column temperatures averaged around 24°C; whereas, during the period of ice cover, the reservoir water should be near 4°C. This 20°C difference means the reaction rates will be quadrupled. Thus the 1.75-month sample run time is

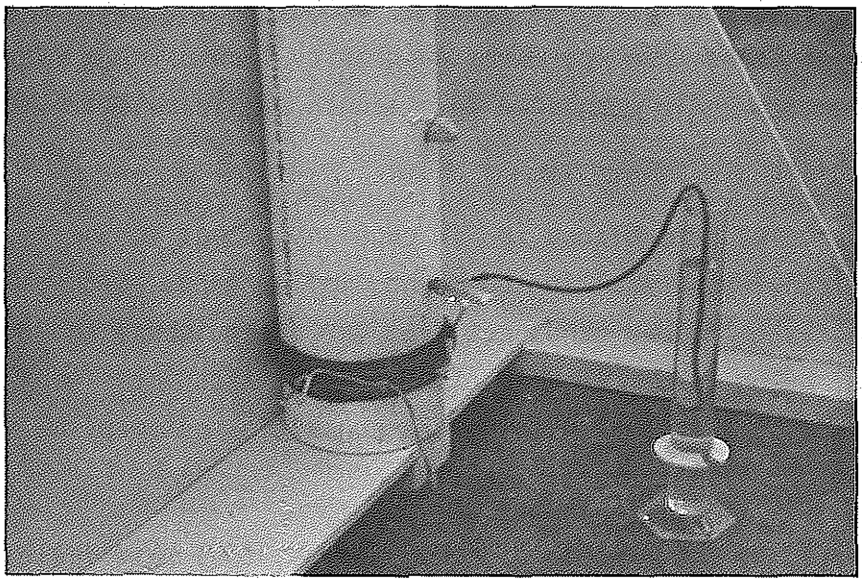


FIGURE 6 : Water sampling method using a hypodermic needle attached to tubing.

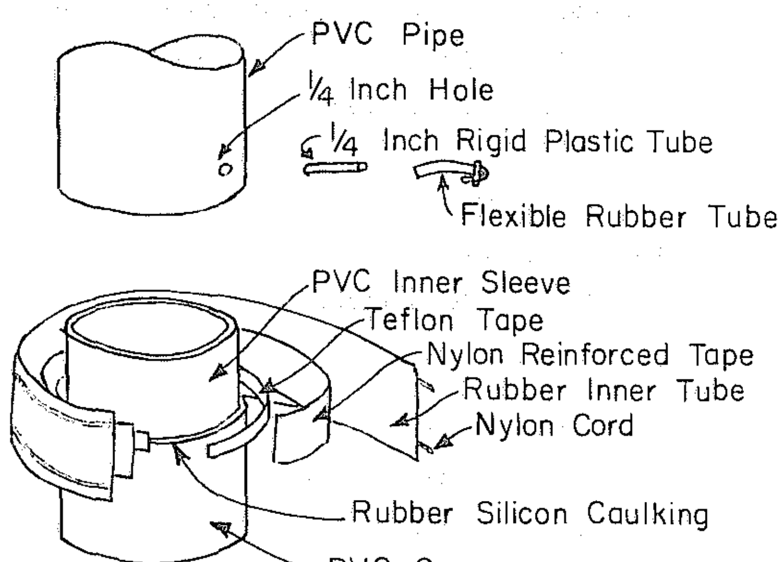


FIGURE 7 : Leaching apparatus - detail working drawing.

equal to approximately 7 months in the reservoir, the normal period of ice cover. If all other reservoir and column conditions are equal, then the water quality at the end of the sampling run approximates that which will be found in the reservoir at the end of the period of ice cover.

Water samples of 220 ml were drawn from the columns at weekly intervals. In the first of the two sampling runs, three ports, 0.5, 2.5, and 4.5 feet above the soil, were sampled for the first 4 weeks; only the bottom port was sampled thereafter. Samples from the second run were obtained from three ports on the first and third week; the remaining samples came from the lowest port only. Immediately after sampling, the leachate was analyzed for temperature, electrical conductivity (E.C.), alkalinity, tannin/lignin, dissolved oxygen, and color. A drop of nitric acid was added to 10 mls of the sample to preserve it for subsequent total organic carbon (TOC), iron, and manganese determinations. A 100 ml portion of the sample was frozen in plastic bottles for the determination of ammonia and nitrate plus nitrite.

Chemical Analyses

The methods of chemical analysis and the problems encountered are discussed in this section. For more information on the constituents see the respective sections in the literature review on the effect of reservoirs on the water quality paramters.

Initially dissolved oxygen measurements were attempted with a Beckman D.O. probe which was set in an apparatus where the sample could be delivered to the probe without contacting the atmosphere. Stable readings could not be obtained, so a Hach kit was used along with the azide modification of the Winkler Method to check for accuracy.

A Beckman Electromate pH meter was used for pH determination and alkalinity titrations.

Electrical Conductivity was measured with an industrial instrument, an RC16B2 electrical conductivity meter. The reading for the first week of the first run were unusually high. An instrumental or operational malfunction was suspected to be the cause of the high readings. As we have mentioned, the high readings at the start of the second run are thought to be due to contamination of the distilled water supply.

Color was determined using nessler tubes with potassium chloroplatinate standards as described in *Standard Methods* (APHA, 1971). Turbidity was not removed from the samples so apparent color is reported.

Total organic carbon (TOC) was determined using a Beckman, model 915, TOC analyzer. The samples for this analysis were acidified with nitric acid at the time of collection to prevent growth of microorganisms. At the time of TOC analysis, several months later, growths were noticed in some of the samples which may invalidate some data.

Manganese and iron were determined with a Perkin Elmer Atomic Absorption spectrophotometer, model 303. The samples were reacidified with nitric acid, then were shaken to ensure that the growths reported earlier were destroyed and the iron and manganese returned to solution.

Tannin/lignin was determined colorimetrically using *Standard Methods* (APHA, 1971) procedure and a Bausch and Lomb spec 20 spectrophotometer. A couple of times the wave length setting was inadvertently left on the wrong setting after the instrument had been borrowed by other analysts. Some readings were missed entirely because the light in the spectrophotometer burned out.

The nitrogen forms, ammonia and nitrate plus nitrite, were determined on a Technicon Auto Analyzer by the U.S. Environmental Protection Agency (1971) methods.

RESULTS

The five sample sites were located in greatly different regions of Alaska. The sites were selected to show the differences as well as the similarity of the problems encountered with reservoir site preparation.

This section contains discussions of the proposed project work at the sampling sites, characterization of the soils, results of the leaching experiments, and recommendations as to the preferred clearing alternative. See Tables 2 through 8 for the position of the leaching samples in the profile, comments on the profile, results of particle size, moisture content, and organic content analysis. The data for the water quality is presented in the appendix.

Moose Creek Project

General Comments: In the summer of 1967, a summer rain storm over the Chena River drainage caused the river to flood, inundating 30 per cent of the town of Fairbanks and causing extensive damage. In order to prevent further flooding, a dam is being built on the Chena River with a high-water spillway discharging into the Tanana River. A dike is being built to prevent the Tanana River from flooding Fairbanks.

The major water quality concern is the Fairbanks water supply which is drawn from the gravels below the Chena River. Other resources which will be effected by water quality changes are the fish: salmon, grayling, white fish, pike, burbot and some aquatic mammals, including beaver and muskrat.

The area to be inundated is a combination of white spruce forest on the dryer sites, black spruce and larch on the permafrost and wetter sites, and several large areas of deep grass and bogs.

TABLE 2

Soil Information for Indicated Sample Site

Sample Site No. 1 - Location: Moose Creek Reservoir

Soil Profile	Depth cm	Comments on Soil Profile	% Sand and Fines <4.8 mm	% Fines <0.07 mm	% Moisture (wet wt.)	% Volatile Solids (dry wt)	Column Number	Soil Depth cm
	7.6	Frozen organic material			58.3	20.0	2	0-10.2
		Deep Brown organic root mat	100	84	73.1	31.5	3	15.2 - 25.4
	33.0							
							4	30.5 - 40.6
		Very plastic clay, grey brown	100	97	27.1	2.9	5	40.6 - 50.8
	66.0							
		Extremely plastic clay, grey						
	78.7							

The U.S. Soil Conservation Service classified this soil as follows:

Histic Pergelic Cryaquents, Goldstream series. Both samples and analyses indicate that the mineral soil is a silt loam with little plasticity rather than a plastic clay. See the Salcha-Big Delta Area soil survey report for a complete description of the Goldstream series.

TABLE 3

Soil Information for Indicated Sample Site

Sample Site No. 2 - Location: Moose Creek Reservoir

Soil Profile	Depth cm	Comments on Soil Profile	% Sand and Fines <4.8 mm	% Fines <0.07 mm	% Moisture (wet wt.)	% Volatile Solids (dry wt)	Column Number	Soil Depth cm
	2.5						6	0-10.2
	7.6	leaves & roots, organic material			52.7	46.4		
		rusty red and grey silt	98.5	34.0	3.3	1.3		
	15.2							
		reddish silt with clay lenses	66.4	41.7	5.5	1.6	7	15.2 - 25.4
	22.9							
	30.5							
		gravel with sand	34.4	8.3	2.4		8	30.5 - 40.6
	35.6							

The U.S. Soil Conservation Service classified this soil as follows:

> Typic Cryofluvents, Jarvis series, shallow phase. If the gravelly substream were just slightly closer to the surface, the soil would be classifed in the Chena series of the Typic Cryorthents subgroup. There are silt lenses in this soil, but no clay lenses. See the Salcha-Big Delta report.

TABLE 4

Soil Information for Indicated Sample Site

Sample Site No. 3 - Location: Kotzebue

Soil Profile	Depth cm	Comments on Soil Profile	% Sand and Fines <4.8 mm	% Fines <0.07 mm	% Moisture (wet wt.)	% Volatile Solids (dry wt)	Column Number	Soil Depth cm
		plants and roots			81.0	78.7	9	0-10.2
	10.2							
		frozen, dark brown organic soil	100	85.6	44.9	19.2	10	15.2 - 25.4
	35.6							
		thawed, dark brown organic soil, overlies permafrost	100	88.7	50.7	32.4	11	30.5 - 40.6
	61.0							

The U.S. Soil Conservation Service classified this soil as follows:

> This is a rather unusual soil which, from the appearance of the samples, is from a disturbed site. It is one of two subgroups--Histic Pergelic Cryaquepts if less than half of the soil column (the active layer plus 10 inches of permafrost) is organic, and Pergelic Cryosaprists if the soil is dominantly organic. Based on my examination of the samples, I would prefer the former. No existing series covers the soil.

TABLE 5

Soil Information for Indicated Sample Site

Sample Site No. 4 - Location: Ship Creek

Soil Profile	Depth cm	Comments on Soil Profile	% Sand and Fines <4.8 mm	% Fines <0.07 mm	% Moisture (wet wt.)	% Volatile Solids (dry wt)	Column Number	Soil Depth cm
	5.1	Dark red brown, roots and organic			45.6	53.3	12	0-7.6
	6.4	black, organics and roots	100	38.1			13	7.6 - 17.8
	7.6	grey variable layer	100	74.3				
							14	20.3 - 30.5
	20.3	red brown with grey spots			38.4	60.0		
							15	30.5 - 40.6
	30.5	brown	99.9	9.3	19.9	39.9		
	40.6	dark brown sand			7.3	24.8		

The U.S. Soil Conservation Service classified this soil as follows:

Trypic Cryorthods, Delyndia series (assuming the soil is well drained). The 3-8" sample seems to have less sand than the analysis indicated.

TABLE 6

Soil Information for Indicated Sample Site

Sample Site No. 5 - Location: Monashka Creek

Soil Profile	Depth cm	Comments on Soil Profile	% Sand and Fines <4.8 mm	% Fines <0.07 mm	% Moisture (wet wt.)	% Volatile Solids (dry wt)	Column Number	Soil Depth cm
	5.1	dark brown organic mat, roots			64.8	40.72		
							16	0-10.2
	10.2	brown, less organic, roots light red brown, sandy	100	64.5	33.13	1.3	17	10.2 - 22.9
	22.9	tan, fine uniform sand	100	48.8	32.0	1.3		
							18	22.9 - 33.0
	33.0	dark brown, silt to clay	99.9	67.5	50.9	4.7		
							19	33.0 - 43.2

The U.S. Soil Conservation Service classified this soil as follows:

Andic Cryaquepts, Salonie or Kalsin series depending on depth to underlying gravel. The material above the 13-17" layer is volcanic ash from the 1912 eruption near Mt. Katmai. See the Northeastern Kodiak Island Area soil survey report for description of the two series and the ash.

TABLE 7

Soil Information for Indicated Sample Site

Sample Site No. 6 - Location: Monashka Creek

Soil Profile	Depth cm	Comments on Soil Profile	% Sand and Fines <4.8 mm	% Fines <0.07 mm	% Moisture (wet wt.)	% Volatile Solids (dry wt)	Column Number	Soil Depth cm
							20	0 - 7.6
	7.6	dark brown, organic mat, roots			79.4	63.9		
							21	7.6 - 17.8
	20.3	tan, sandy			42.0	2.0		
	22.9	grey and white, sandy	99.9	39.0				
							22	20.3 - 33.0
	27.9	reddish brown, uniform sand			36.9	1.7		
	33.0	grey and white, sand	99.9	29.9				
		dark brown, silt, rich soil	73.1	12.1	82.2	42.8		

The U.S. Soil Conservation Service classified this soil as follows:

> Andic Cryaquepts, Ugak series. The material above 13 inches is ash. The analysis indicates more than 50% gravel (coarser than 2 mm), but the sample given me had no gravel.

TABLE 8

Soil Information for Indicated Sample Site

Sample Site No. 7 - Location: Barrow

Soil Profile	Depth cm	Comments on Soil Profile	% Sand and Fines <4.8 mm	% Fines <0.07 mm	% Moisture (wet wt.)	% Volatile Solids (dry wt)	Column Number	Soil Depth cm
	5.1	black root mat			35.8	12.4	23	0-10.2
		black and brown, silt with discontinuous dark layers, a few rocks	85.9	29.7	11.5	2.6	24	17.8 - 27.9
	33.0	dark tan, wet soft gravel, plastic	91.9	43.1	15.1	3.6	25	35.6 - 45.7
	50.8	frozen						

The U.S. Soil Conservation Service classified this soil as follows:

> Pergelic Cryaquepts, no existing series. Texture of the samples is gravelly loam, approaching gravelly sandy clay loam. This is the most plastic of the samples submitted.

Sample site number 1 is shown in Figure 8 and is in an area of transition between grass bog and spruce-larch areas. Sample site number 2 is from a dryer site in a white spruce forest. No photograph was taken of the second site.

Soil Characterization: Table 2 shows the data from classification of the soil from the first Moose Creek sample site. Figure 9 shows the soil profile of sample site number 1. The surface layer was all grass detritus with 20 per cent volatile solids.

The layer from 15.2 to 25.4 cm below the surface was an organic root mat with 31.5 per cent volatile solids. It was fairly fine material.

From 30.5 to 40.6 cm below the surface a very plastic grey brown silt was encounterd. Sieve analysis showed that 97 per cent was "fine" material.

The soil from 40.6 to 50.8 cm below the surface was similar to the soil directly above it except that the soil was even more plastic.

Table 3 shows the data from classification of the soil from the second Moose Creek sample site.

The surface material was organic detritus below a Spruce-Birch forest with 46.4 per cent organic matter.

The material 15.2 to 25.4 cm below the surface was rusty and grey silt with only 1.6 per cent organic matter. Sand amounted to 24 per cent of the soil and 42 per cent was fines. The water overlaying this soil was of good quality. Tannin/lignin and NO_3 rose initially but decreased by the end of the run.

From 30.5 to 40.6 below the surface, gravel and sand were encountered which contained very little organic matter. Sand constituted 26.1 per cent of the soil and only 8.3 per cent was fines. Excellent water quality resulted from inundating this soil.

FIGURE 8 : Sample Site Number 1, Moose Creek.

FIGURE 9 : Soil profile at Sample Site Number 1, Moose Creek.

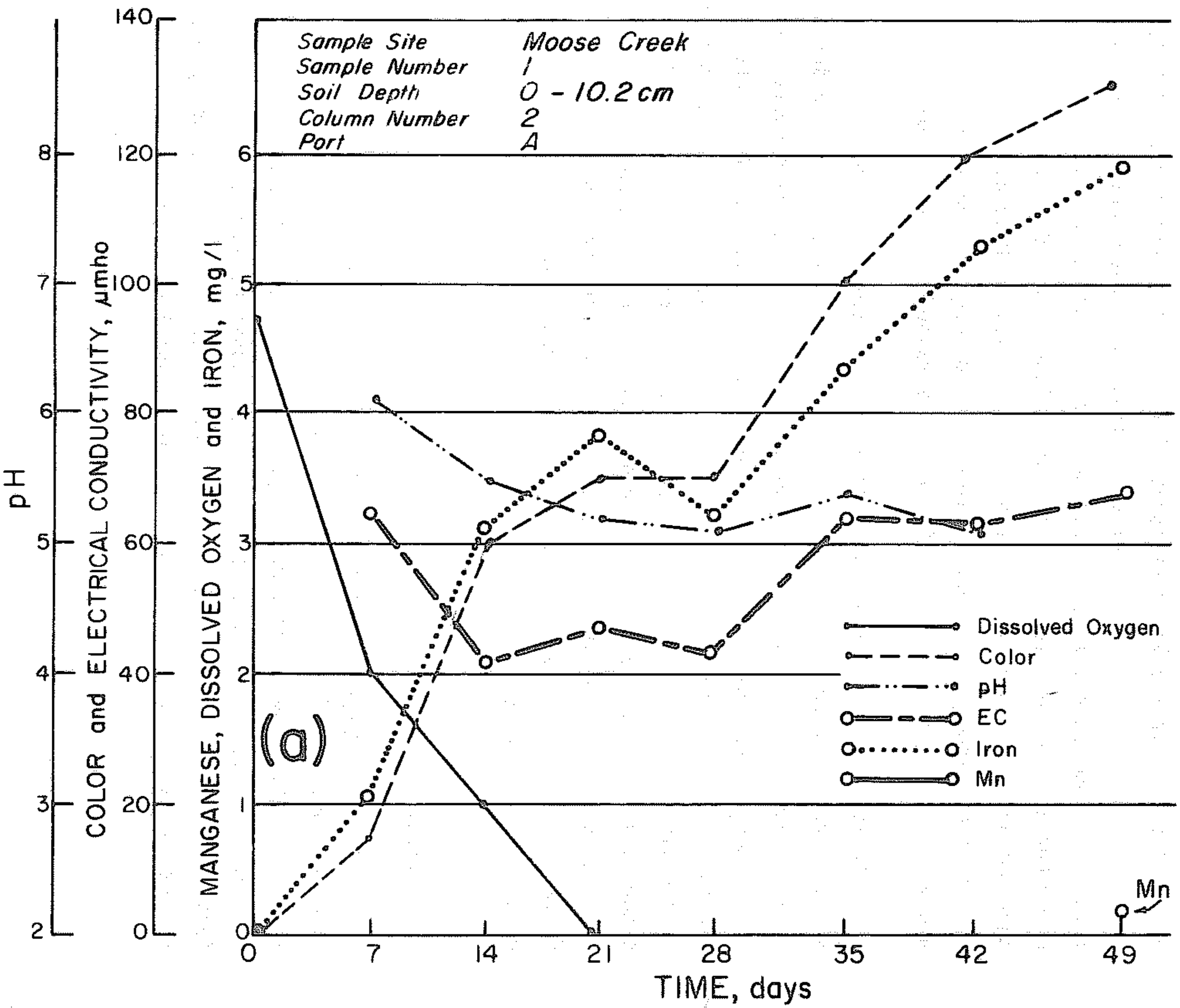
Conclusions and Recommendations: Figures 10 through 16 show the results of leaching different layers of soil from the two Moose Creek sampling sites. The upper two layers from the first sample site, Figures 10 and 11, developed severe water quality degradation. The top layer in particular released large quantities of undesirable constituents into the water which rapidly became anaerobic. The potential for pollution from this layer makes it imperative that it be removed prior to inundation. The second layer also degraded the water but not to the extent that the first layer did. Oxygen did not go to zero but iron and color rose to unacceptable levels. Removal of this layer is also recommended. The deeper layers did not degrade the water significantly and no improvement of water quality would be gained by their removal.

The results from the second sample site, Figures 14 through 16, demonstrated the advantages that can be gained from soil stripping. The surface layer caused severe water quality degradation, recording the highest values of TOC and EC observed. Anaerobic conditions developed rapidly. Water quality resulting from inundation of this soil could cause rapid depletion of dissolved oxygen resulting in destruction of aerobic organisms. The results established the superiority of clearing away the surface material since good to excellent water quality was found in the leachate from columns containing deeper soil layers. No advantage would be gained from removal of the material below 10 centimeters.

Kotzebue Reservoir

General Comments: The water supply for Kotzebue has historically been provided by melted ice in the winter and surface water from nearby lagoons in the summer. More recently, in order to provide continuously running water to the village, a dam has been constructed near the town, forming a small, shallow reservoir. Water is heated at the dam and pumped through an insulated pipe to the treatment plant located in the town.

FIGURE 10-a



Sample Site Moose Creek
Sample Number 1
Soil Depth 0 - 10.2 cm
Column Number 2
Port A
pH
COLOR and ELECTRICAL CONDUCTIVITY, μmho
MANGANESE, DISSOLVED OXYGEN and IRON, mg/l
TIME, days
Dissolved Oxygen
Color
pH
EC
Iron
Mn
(a)

FIGURE 10-b

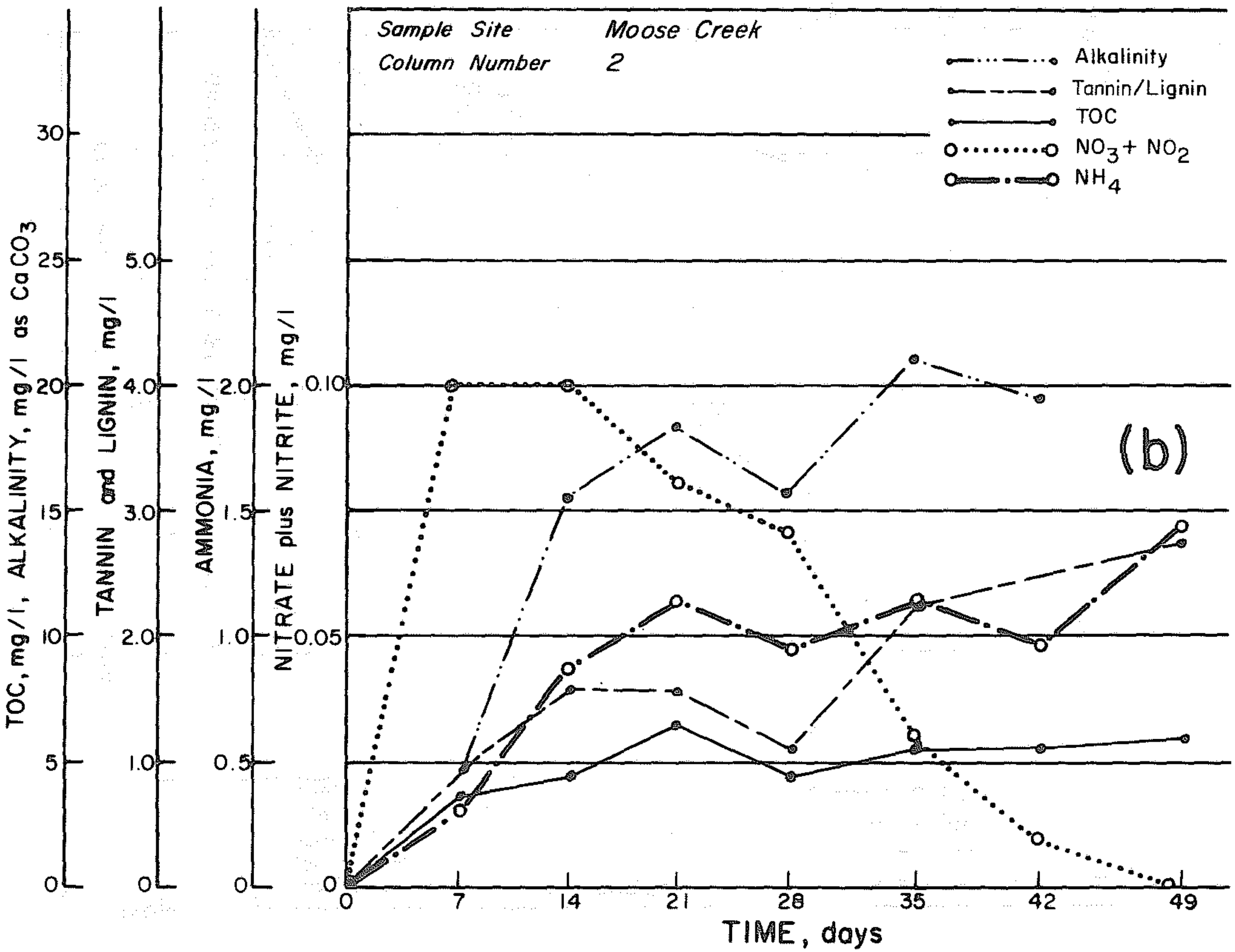
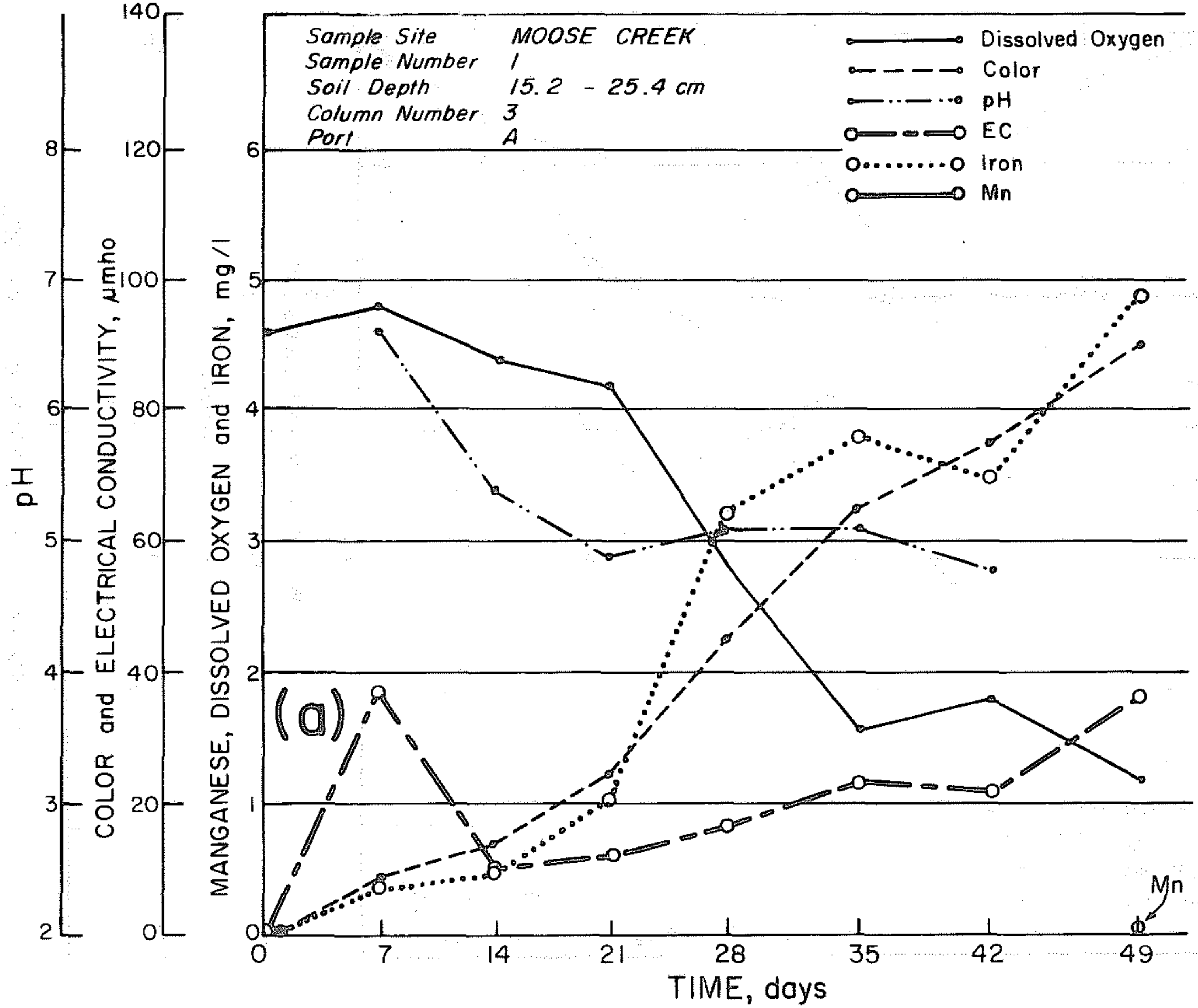
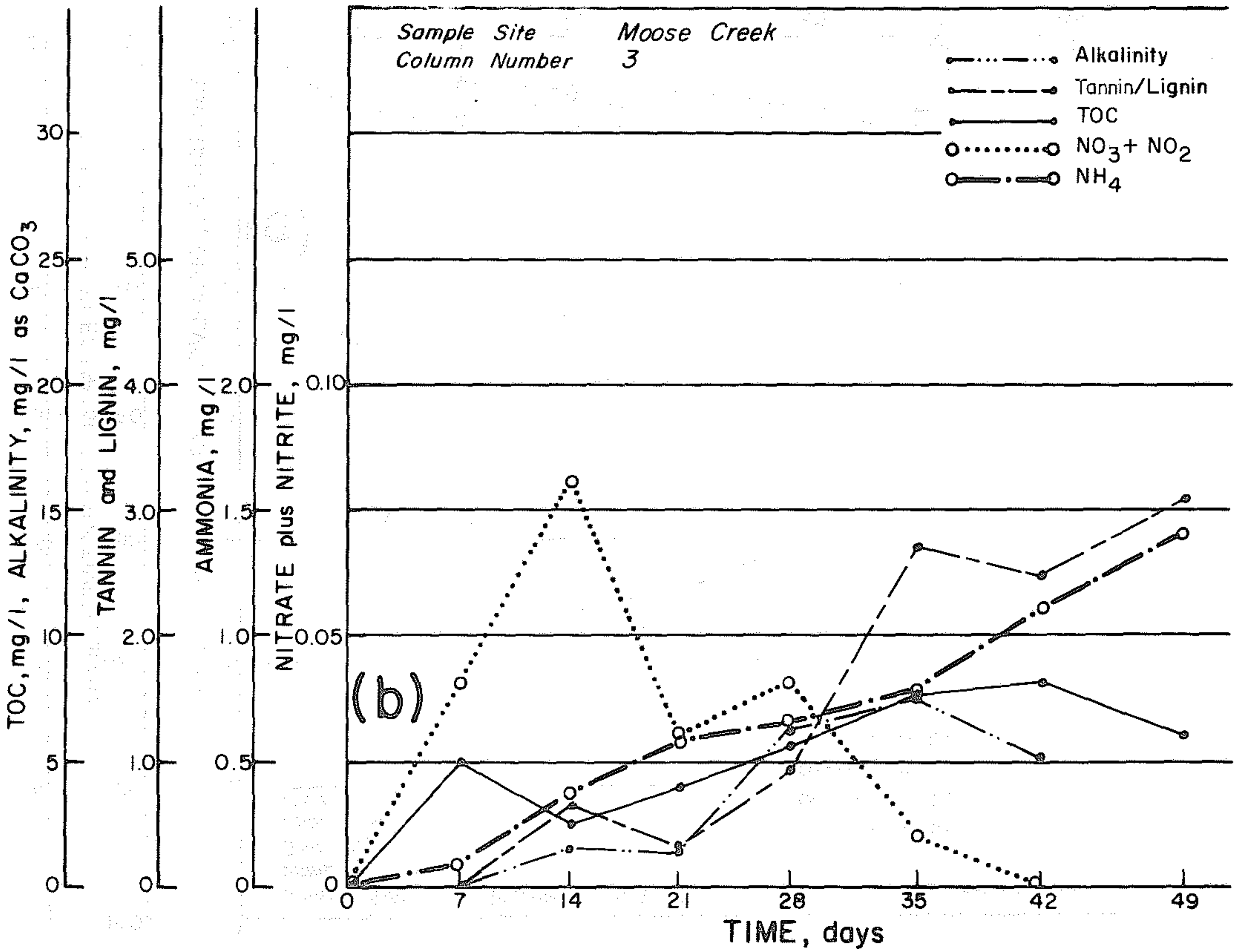

Sample Site Moose Creek
Column Number 2
Alkalinity
Tannin/Lignin
TOC
$NO_3 + NO_2$
NH_4
(b)
TOC, mg/l, ALKALINITY, mg/l as $CaCO_3$
TANNIN and LIGNIN, mg/l
AMMONIA, mg/l
NITRATE plus NITRITE, mg/l
TIME, days
0
7
14
21
28
35
42
49
30
25
20
15
10
5
0
5.0
4.0
3.0
2.0
1.0
2.0
1.5
1.0
0.5
0.10
0.05

FIGURE 11-a



Sample Site MOOSE CREEK
Sample Number 1
Soil Depth 15.2 - 25.4 cm
Column Number 3
Port A
Dissolved Oxygen
Color
pH
EC
Iron
Mn
(a)
Mn
pH
COLOR and ELECTRICAL CONDUCTIVITY, μmho
MANGANESE, DISSOLVED OXYGEN and IRON, mg/l
TIME, days

FIGURE 11-b


Sample Site Moose Creek
Column Number 3
Alkalinity
Tannin/Lignin
TOC
$NO_3 + NO_2$
NH_4
(b)
TOC, mg/l, ALKALINITY, mg/l as $CaCO_3$
TANNIN and LIGNIN, mg/l
AMMONIA, mg/l
NITRATE plus NITRITE, mg/l
0
5
10
15
20
25
30
1.0
2.0
3.0
4.0
5.0
0.5
1.5
0.05
0.10
7
14
21
28
35
42
49
TIME, days

FIGURE

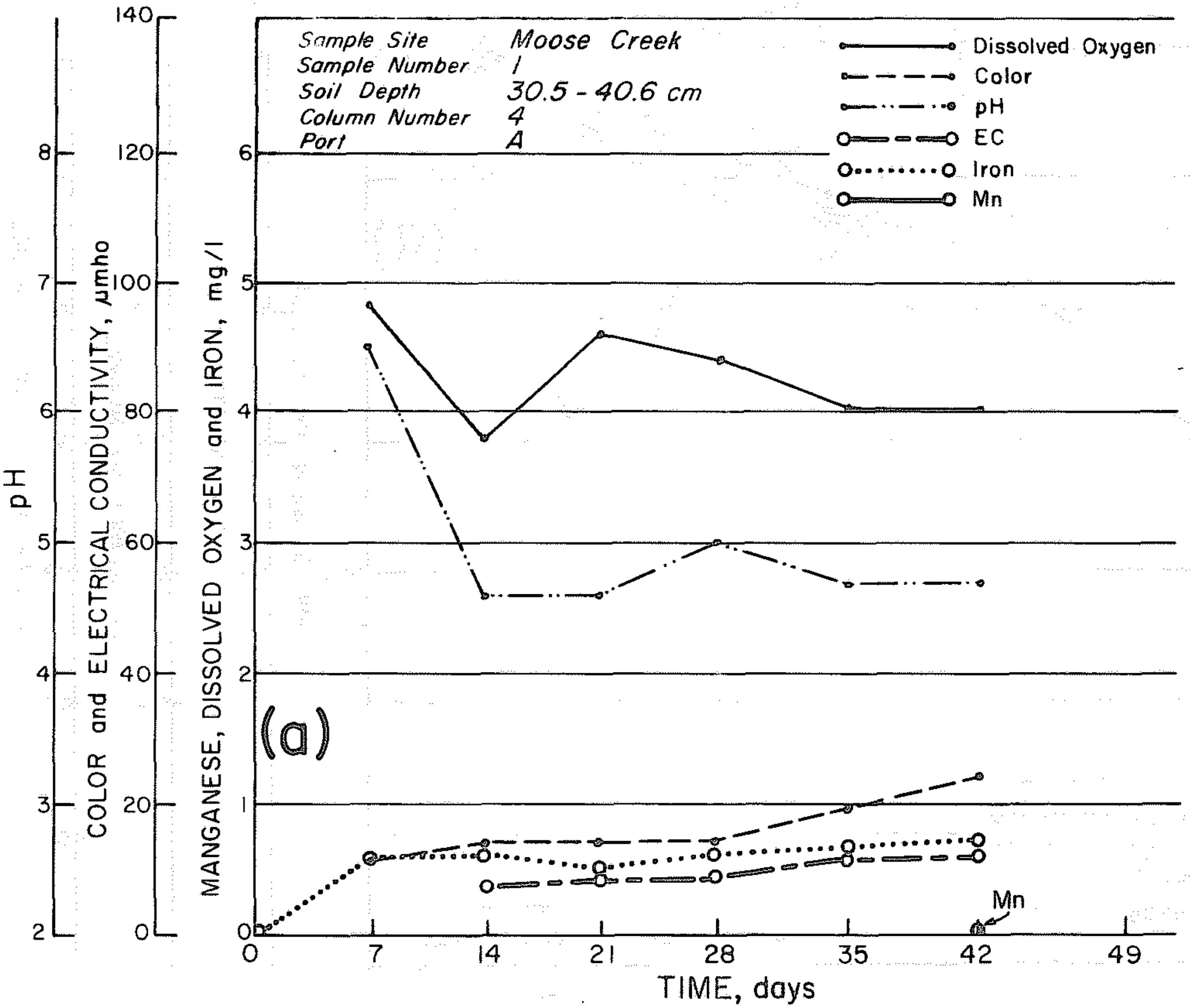

Sample Site Moose Creek
Sample Number 1
Soil Depth 30.5 - 40.6 cm
Column Number 4
Port A
Dissolved Oxygen
Color
pH
EC
Iron
Mn
(a)
Mn
pH
COLOR and ELECTRICAL CONDUCTIVITY, μmho
MANGANESE, DISSOLVED OXYGEN and IRON, mg/l
TIME, days

FIGURE 12-b

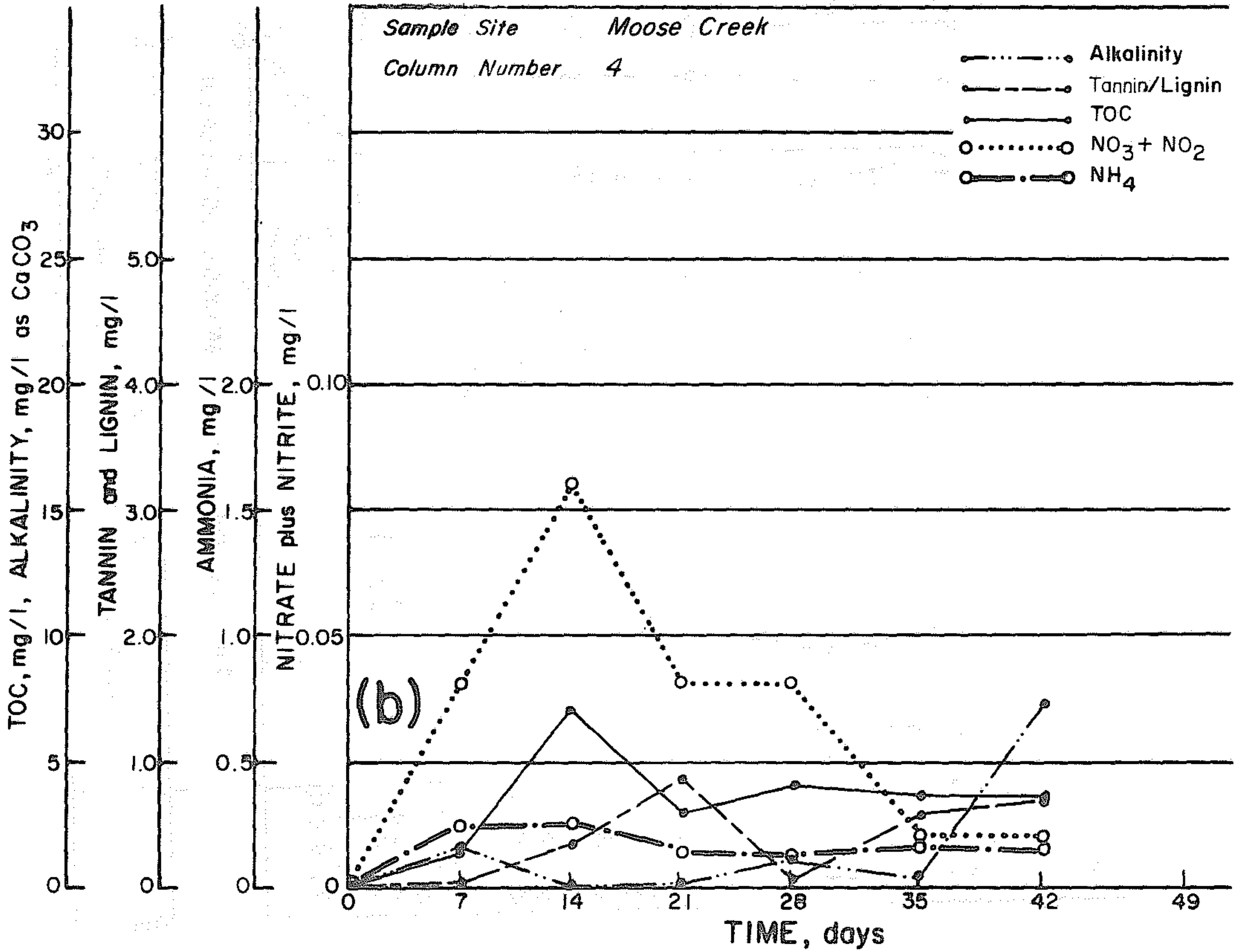

Sample Site Moose Creek
Column Number 4
Alkalinity
Tannin/Lignin
TOC
NO3 + NO2
NH4
(b)
TOC, mg/l, ALKALINITY, mg/l as CaCO3
TANNIN and LIGNIN, mg/l
AMMONIA, mg/l
NITRATE plus NITRITE, mg/l
0
5
10
15
20
25
30
0
1.0
2.0
3.0
4.0
5.0
0
0.5
1.0
1.5
2.0
0
0.05
0.10
0
7
14
21
28
35
42
49
TIME, days

FIGURE 13-a

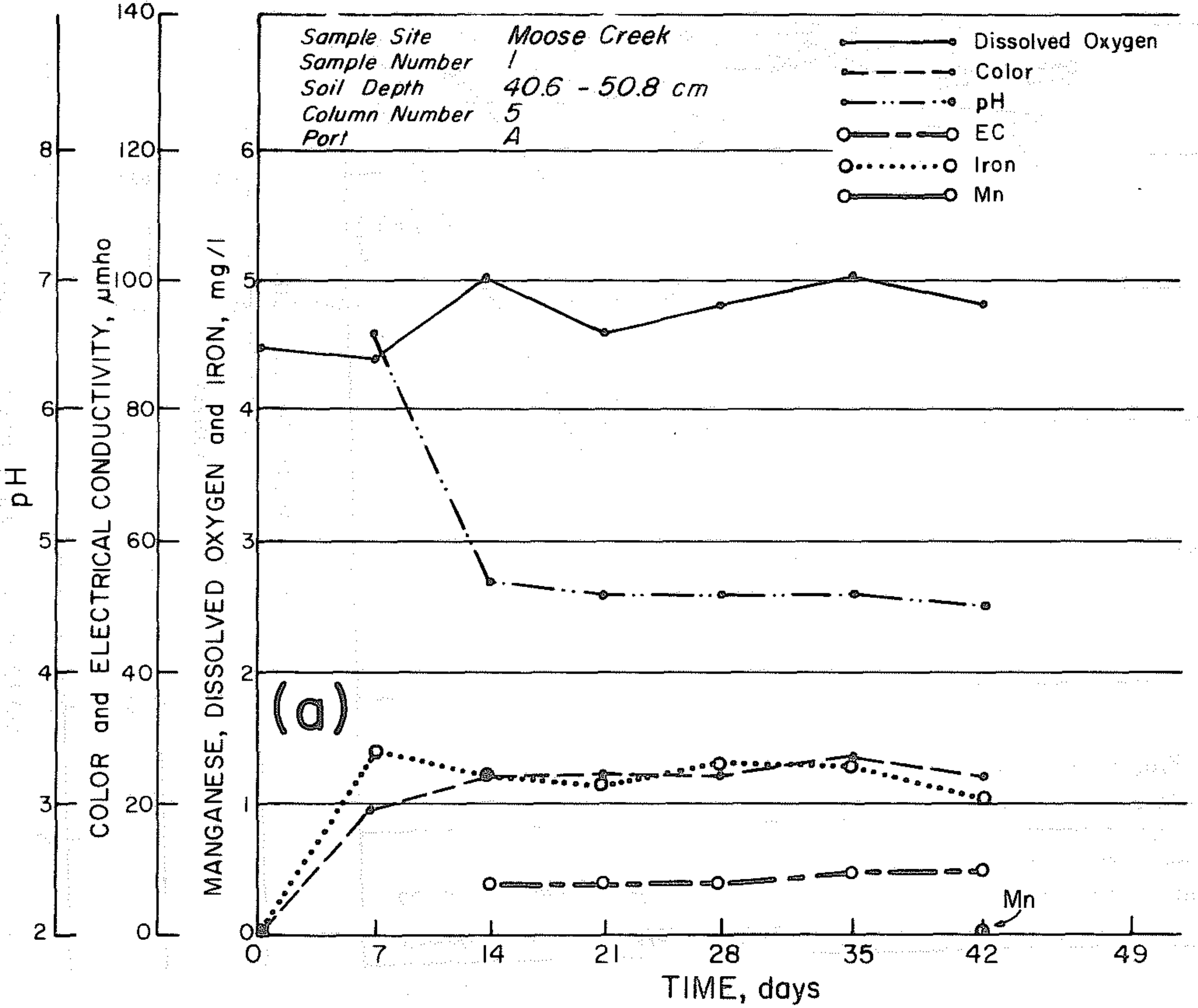
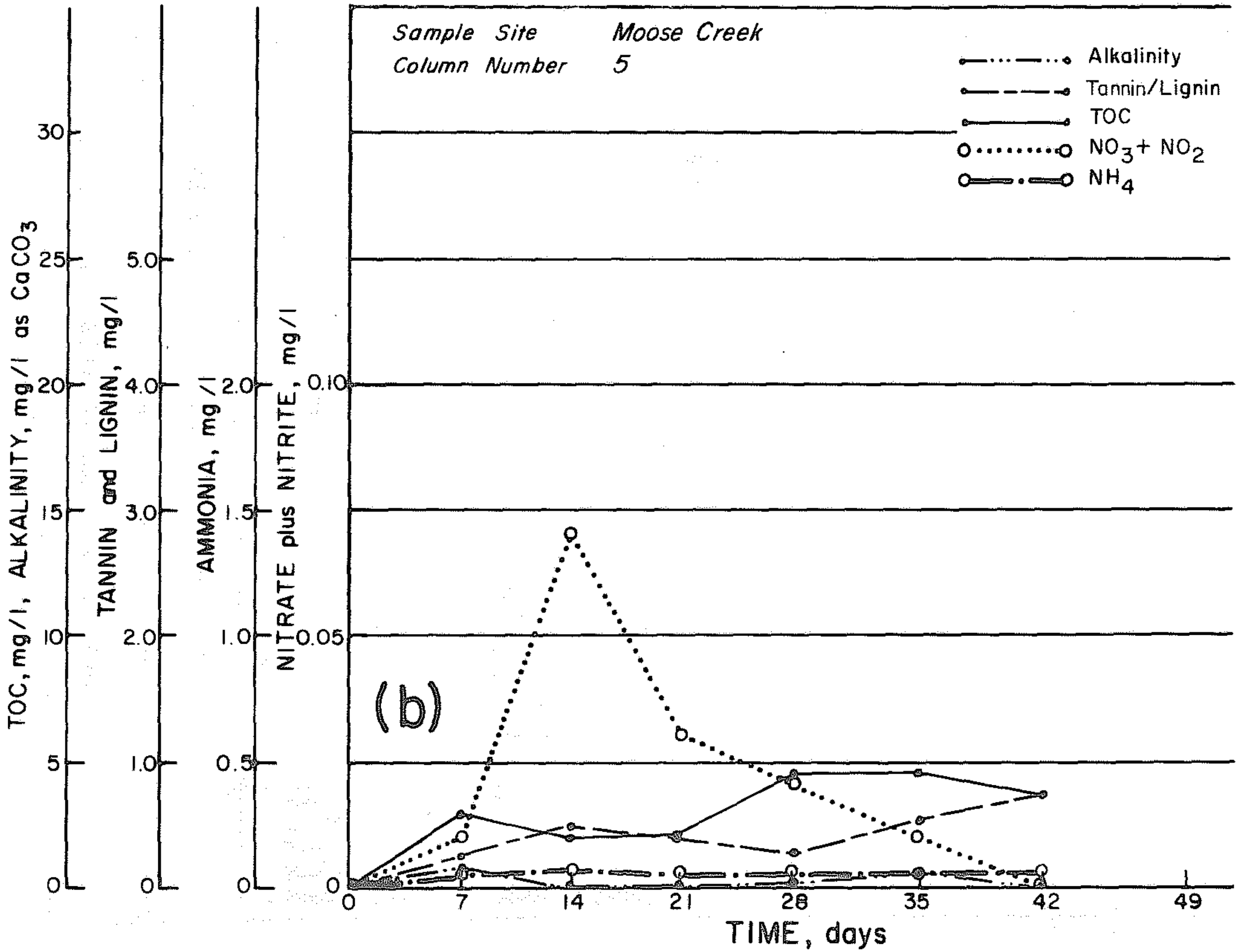

Sample Site Moose Creek
Sample Number 1
Soil Depth 40.6 - 50.8 cm
Column Number 5
Port A
Dissolved Oxygen
Color
pH
EC
Iron
Mn
(a)
Mn
pH
COLOR and ELECTRICAL CONDUCTIVITY, µmho
MANGANESE, DISSOLVED OXYGEN and IRON, mg/l
TIME, days
2
3
4
5
6
7
8
0
20
40
60
80
100
120
140
0
1
2
3
4
5
6
0
7
14
21
28
35
42
49

FIGURE 13-b



Sample Site Moose Creek
Column Number 5
Alkalinity
Tannin/Lignin
TOC
$NO_3 + NO_2$
NH_4
(b)
TOC, mg/l, ALKALINITY, mg/l as $CaCO_3$
TANNIN and LIGNIN, mg/l
AMMONIA, mg/l
NITRATE plus NITRITE, mg/l
TIME, days
0
7
14
21
28
35
42
49
0
5
10
15
20
25
30
1.0
2.0
3.0
4.0
5.0
0.5
1.5
2.0
0.05
0.10

FIGURE 14-a

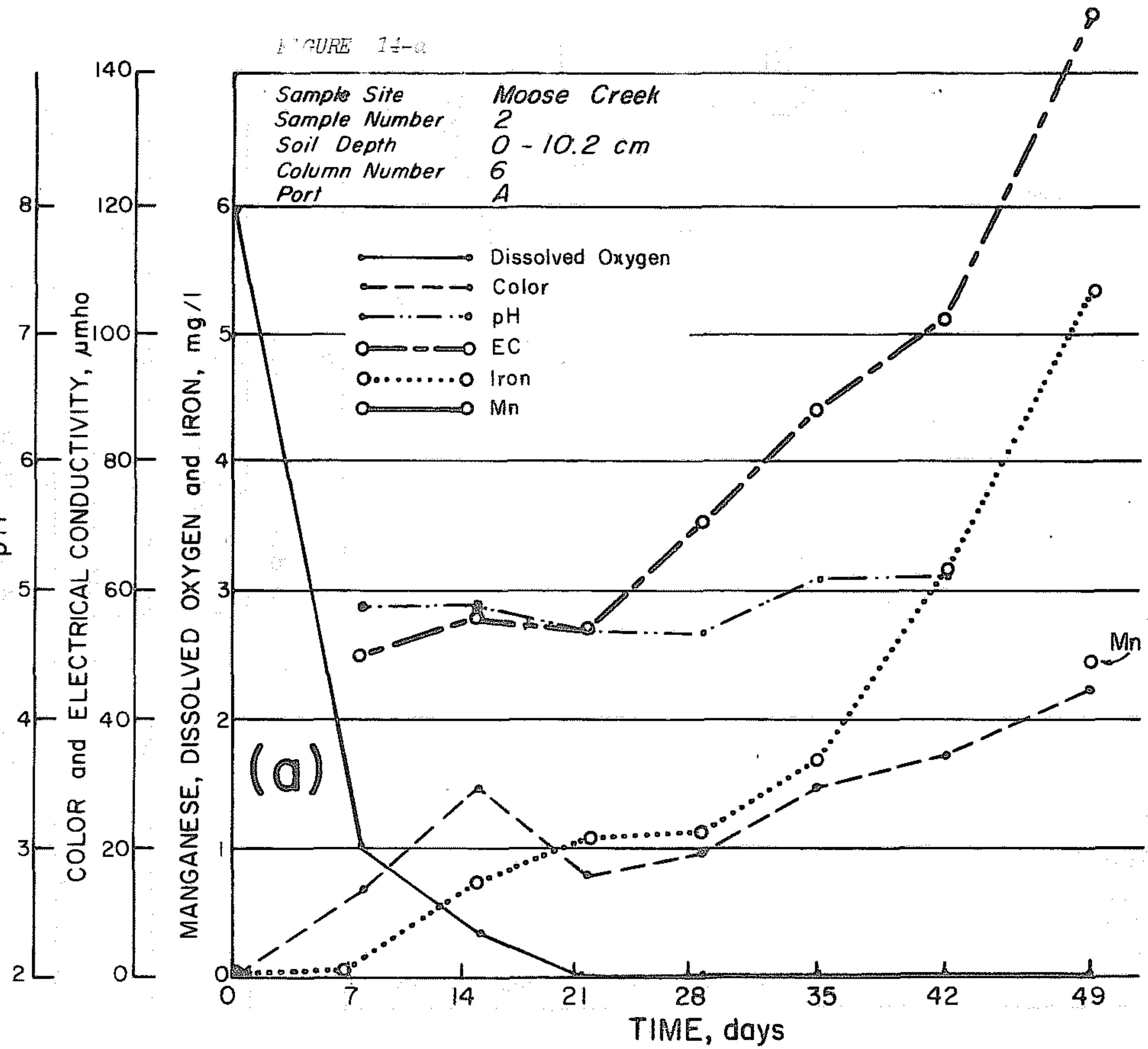

Sample Site Moose Creek
Sample Number 2
Soil Depth 0 - 10.2 cm
Column Number 6
Port A
Dissolved Oxygen
Color
pH
EC
Iron
Mn
(a)
Mn
pH
COLOR and ELECTRICAL CONDUCTIVITY, μmho
MANGANESE, DISSOLVED OXYGEN and IRON, mg/l
TIME, days

FIGURE 14-b

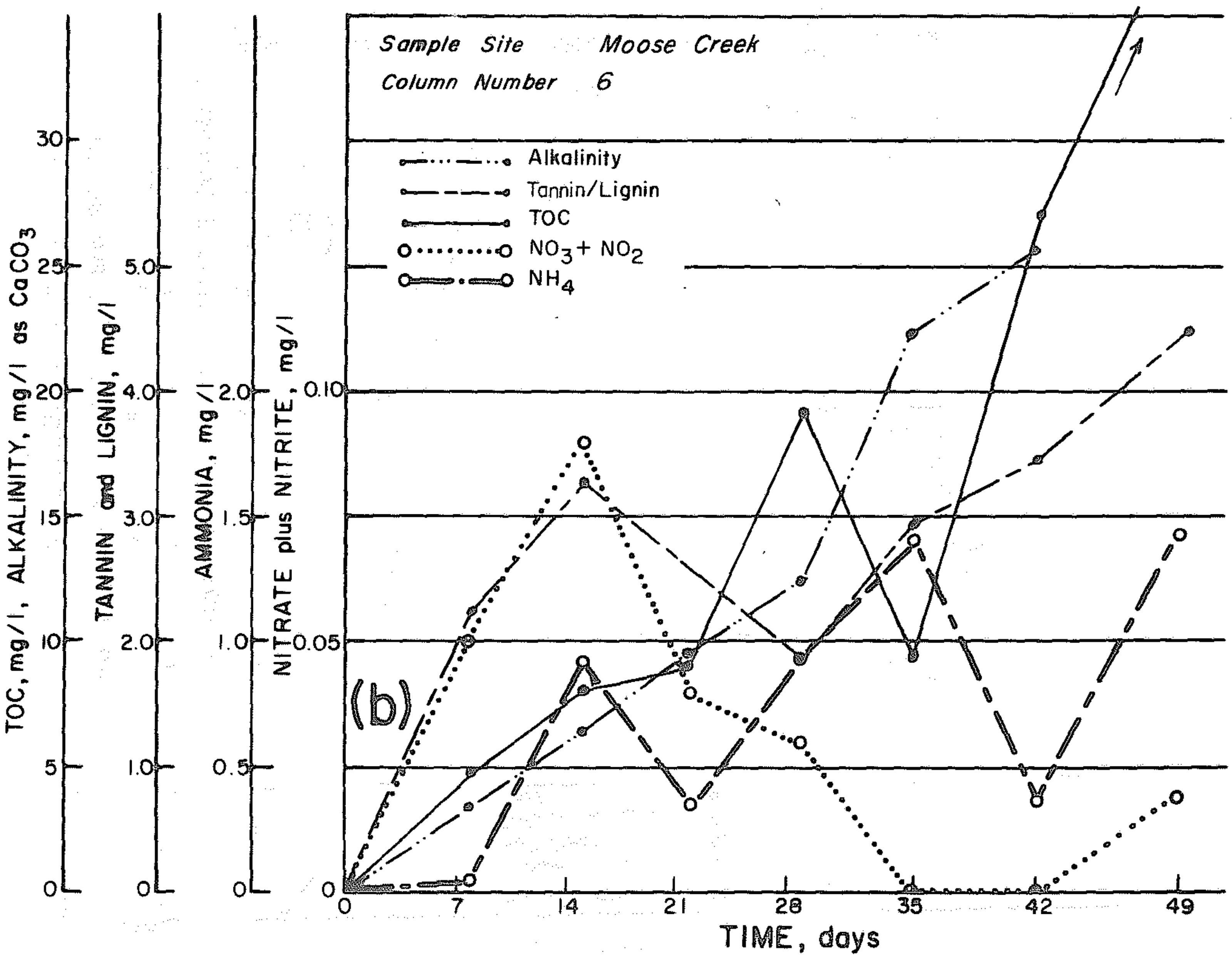

Sample Site Moose Creek
Column Number 6
Alkalinity
Tannin/Lignin
TOC
$NO_3 + NO_2$
NH_4
(b)
TOC, mg/l, ALKALINITY, mg/l as $CaCO_3$
TANNIN and LIGNIN, mg/l
AMMONIA, mg/l
NITRATE plus NITRITE, mg/l
TIME, days
0
7
14
21
28
35
42
49
0
5
10
15
20
25
30
1.0
2.0
3.0
4.0
5.0
0.5
1.5
0.05
0.10

FIGURE 15-a

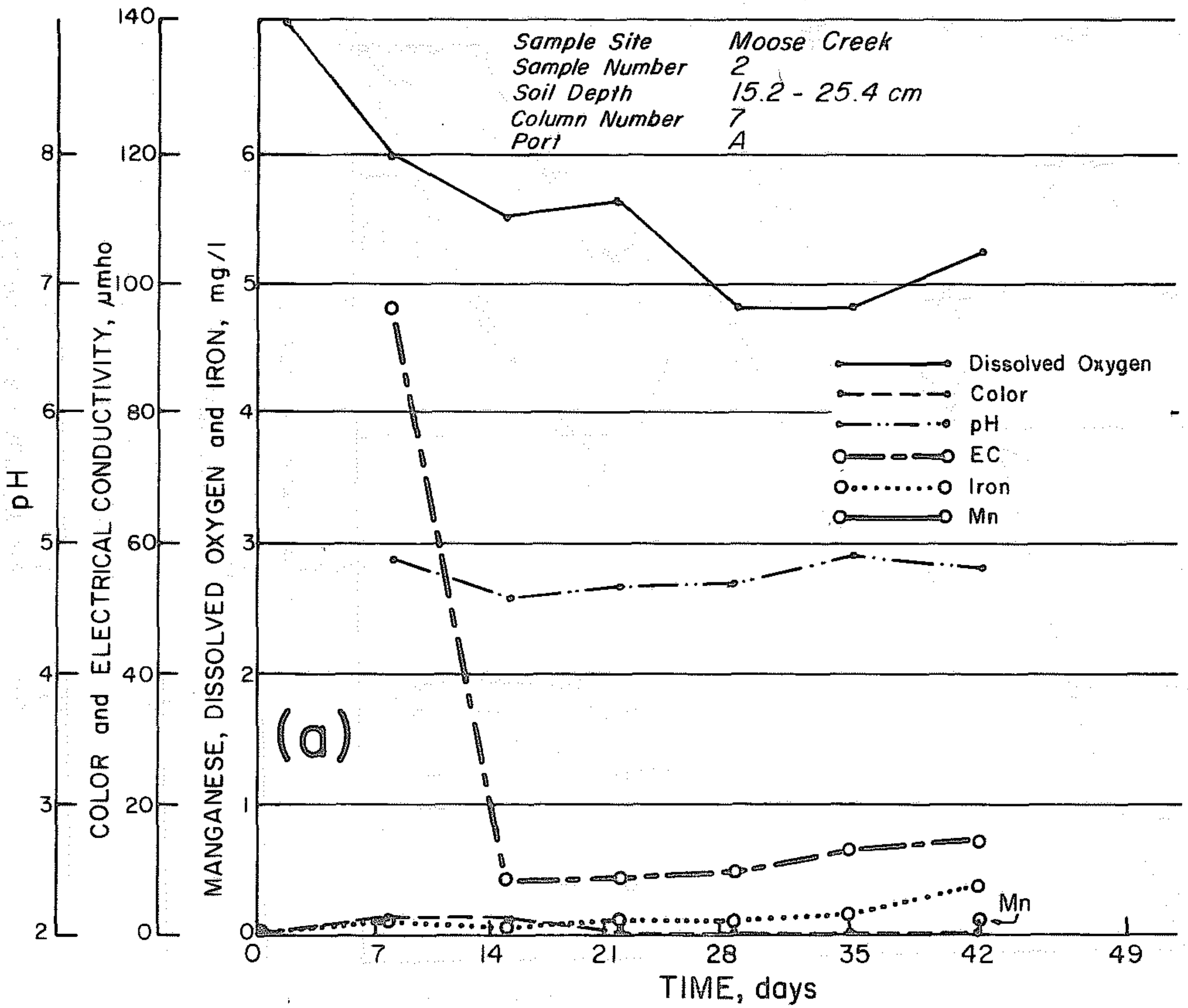

Sample Site Moose Creek
Sample Number 2
Soil Depth 15.2 - 25.4 cm
Column Number 7
Port A
Dissolved Oxygen
Color
pH
EC
Iron
Mn
(a)
Mn
pH
COLOR and ELECTRICAL CONDUCTIVITY, μmho
MANGANESE, DISSOLVED OXYGEN and IRON, mg/l
TIME, days
0
7
14
21
28
35
42
49

FIGURE 15-b

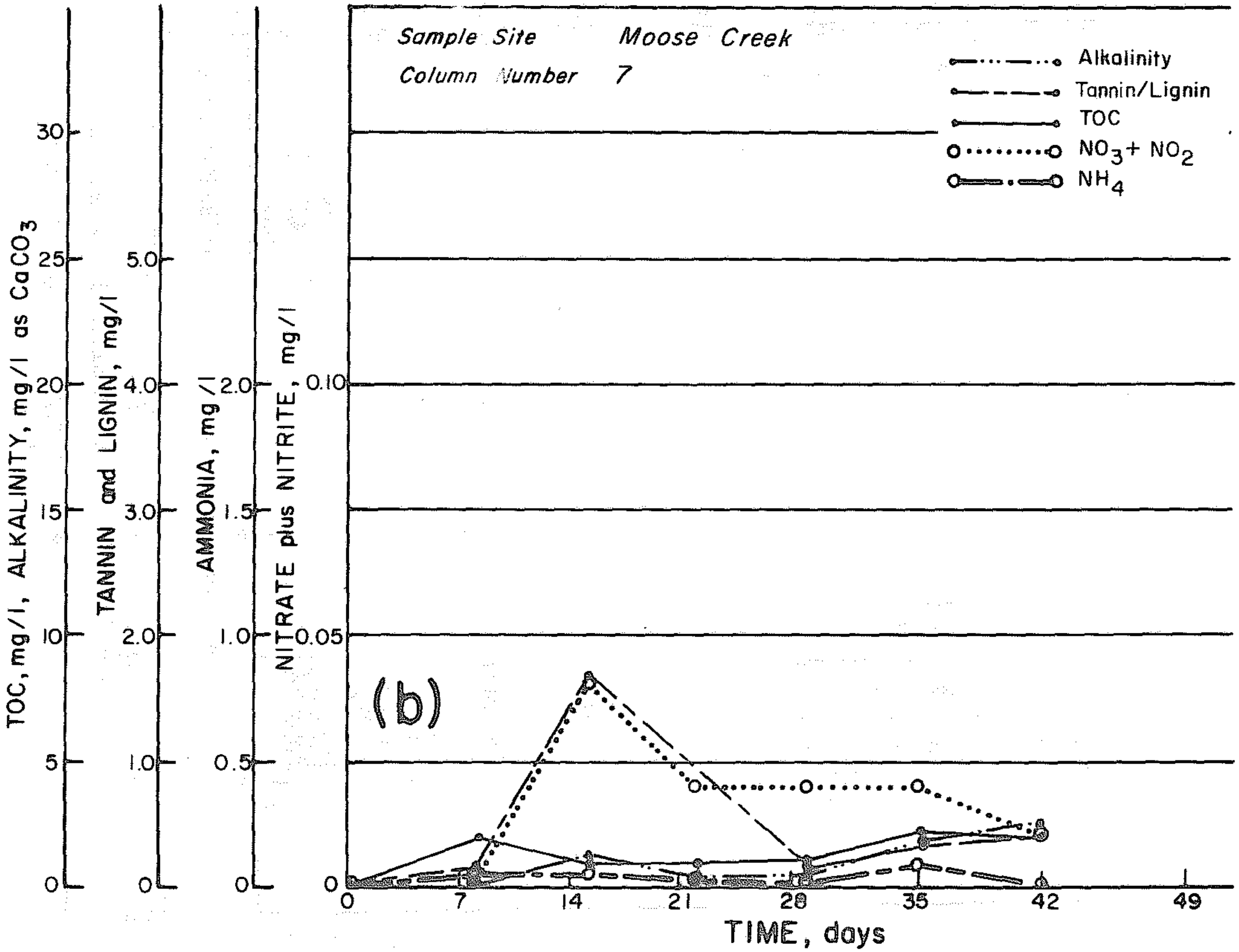

Sample Site Moose Creek
Column Number 7
Alkalinity
Tannin/Lignin
TOC
$NO_3 + NO_2$
NH_4
(b)
TOC, mg/l, ALKALINITY, mg/l as $CaCO_3$
TANNIN and LIGNIN, mg/l
AMMONIA, mg/l
NITRATE plus NITRITE, mg/l
0
5
10
15
20
25
30
0
1.0
2.0
3.0
4.0
5.0
0
0.5
1.0
1.5
2.0
0
0.05
0.10
0
7
14
21
28
35
42
49
TIME, days

FIGURE 16-a

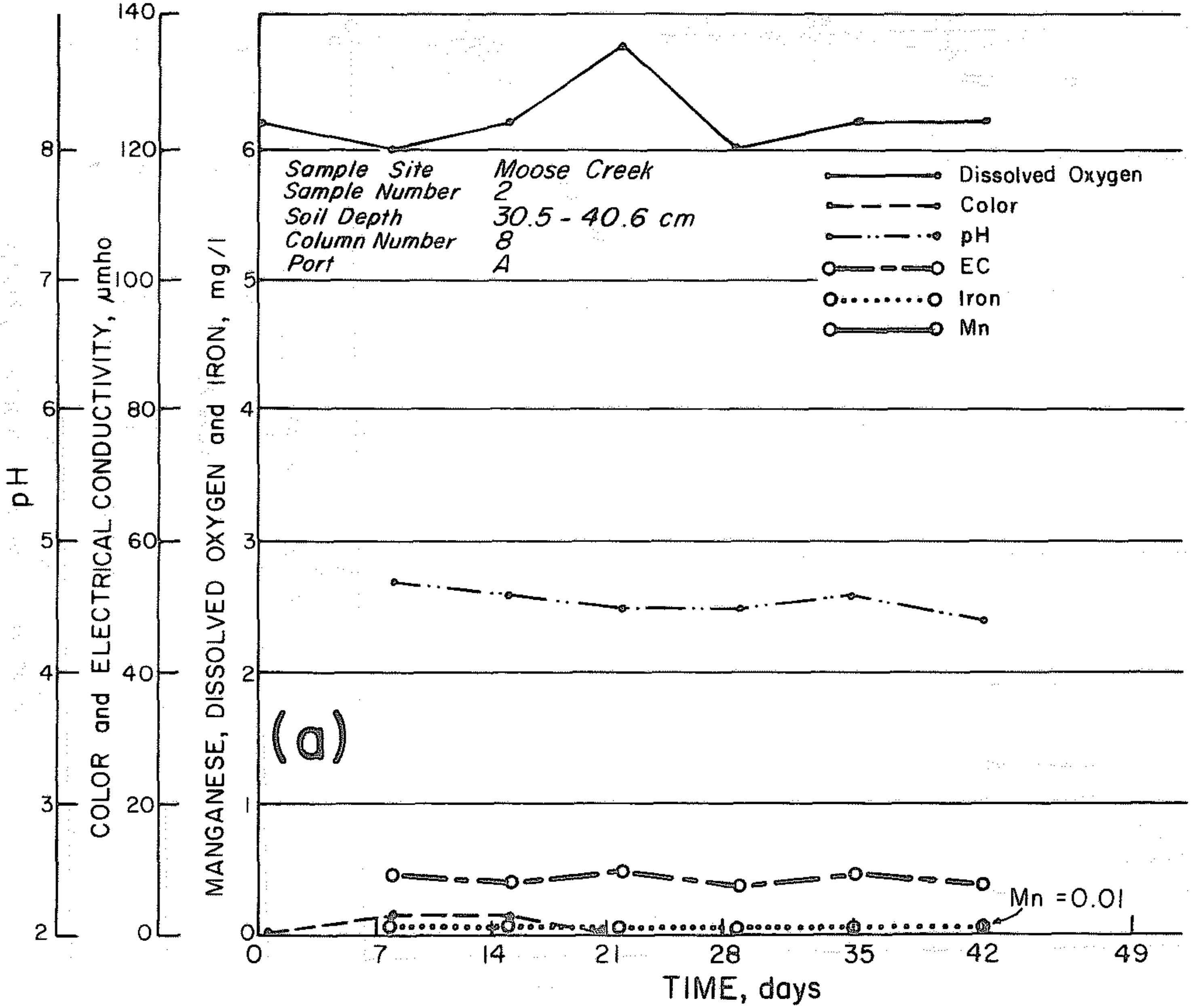
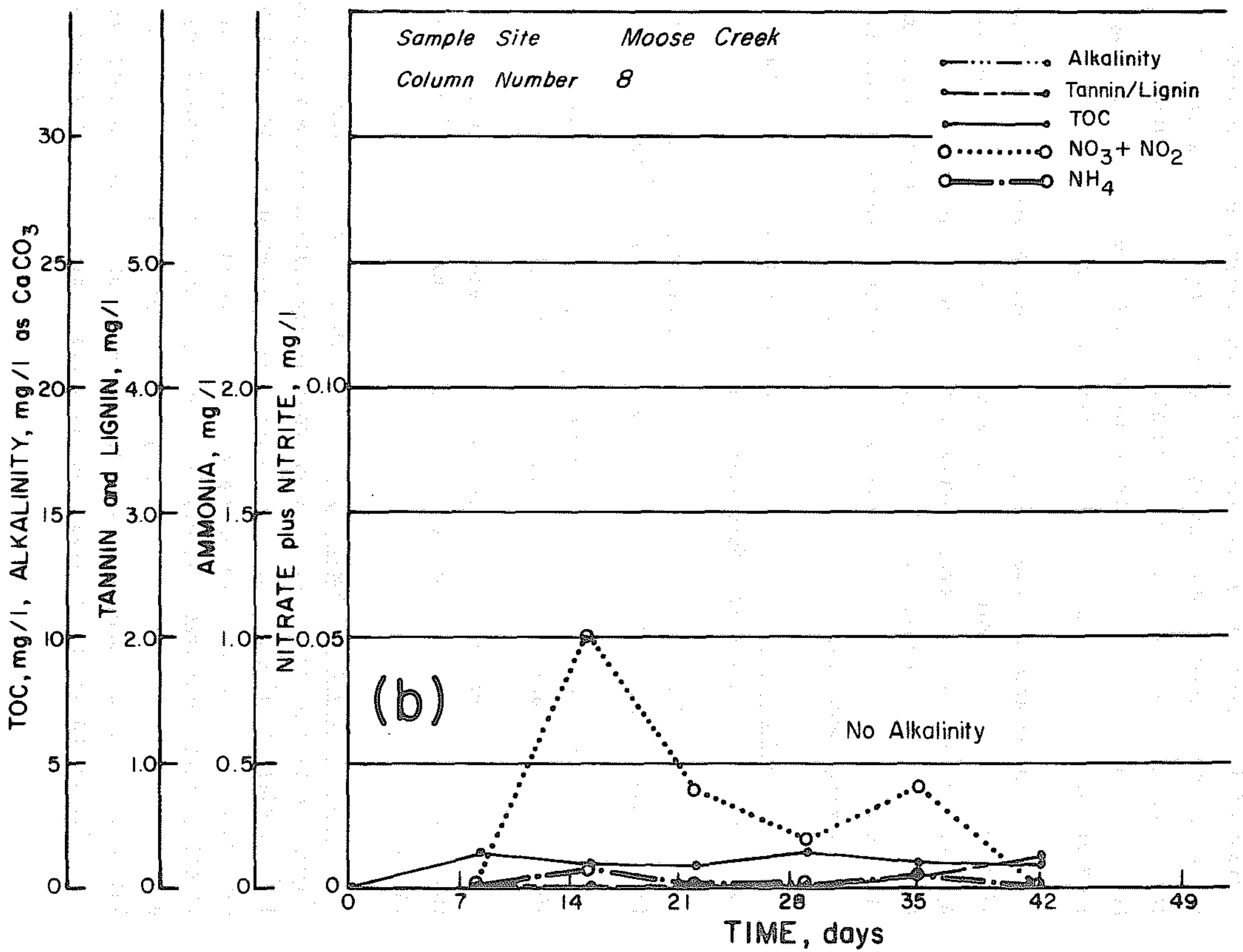

Sample Site Moose Creek
Sample Number 2
Soil Depth 30.5 - 40.6 cm
Column Number 8
Port A
Dissolved Oxygen
Color
pH
EC
Iron
Mn
(a)
Mn = 0.01
pH
COLOR and ELECTRICAL CONDUCTIVITY, μmho
MANGANESE, DISSOLVED OXYGEN and IRON, mg/l
TIME, days

FIGURE 16-b



Sample Site Moose Creek
Column Number 8
Alkalinity
Tannin/Lignin
TOC
$NO_3 + NO_2$
NH_4
(b)
No Alkalinity
TOC, mg/l, ALKALINITY, mg/l as $CaCO_3$
TANNIN and LIGNIN, mg/l
AMMONIA, mg/l
NITRATE plus NITRITE, mg/l
0
5
10
15
20
25
30
0
1.0
2.0
3.0
4.0
5.0
0
0.5
1.0
1.5
2.0
0
0.05
0.10
0
7
14
21
28
35
42
49
TIME, days

Severe water quality problems have been experienced during the long periods of ice cover. Material leached from the reservoir bottom causes color to rise to unacceptable levels. By conducting leaching studies on soil from this area, reservoir clearing alternatives can be examined as a potential solution to water quality problems associated with possible expansion of the Kotzebue reservoir or new reservoirs in similar areas.

The land around Kotzebue is rather consistent, rolling tundra with some flatter bog areas. Sample site number 3 was located below the dam in what appeared to be typical tundra. Figure 17 shows the sample site. Some evidence developed during soil classification that indicated the sample may have been from a disturbed site, but the possibility is remote in that mature, slow growing tundra plants existed on the surface.

Soil Characterization: Table 4 shows the characteristics of the soil taken from the Kotzebue Reservoir site.

The top 10.2 cm of this sample contained tundra plants and their roots in an organic mat. The organic content was found to be 78.7 per cent.

The layer from 15.2 to 25.4 cm below the surface was an organic soil with 19.2 per cent organic matter and 85.6 per cent fines.

The layer from 30.5 to 40.6 cm below the surface was also organic soil containing 32.4 per cent organic matter with fines making up 88.7 per cent of the sample.

Conclusions and Recommendations: The results from the Kotzebue area, Figures 18 through 20, do not show any obvious demarcation of the most profitable clearing alternative. The surface layer caused anaerobic conditions and increases in TOC and tannin/lignin. The deeper layers, although remaining aerobic, caused undesirable levels of color and iron. It is apparent that all the layers will cause water quality degradation in one form or another. The results indicate that the best alternative is not to clear at this site since little improvement of water quality would be gained, but further study is needed. Another site should be tested, including material from below 40 cm. An economic analysis should be made before selection of clearing alternative.

FIGURE 17: Sample Site Number 3, below dam at Kotzebue.

FIGURE 18-a

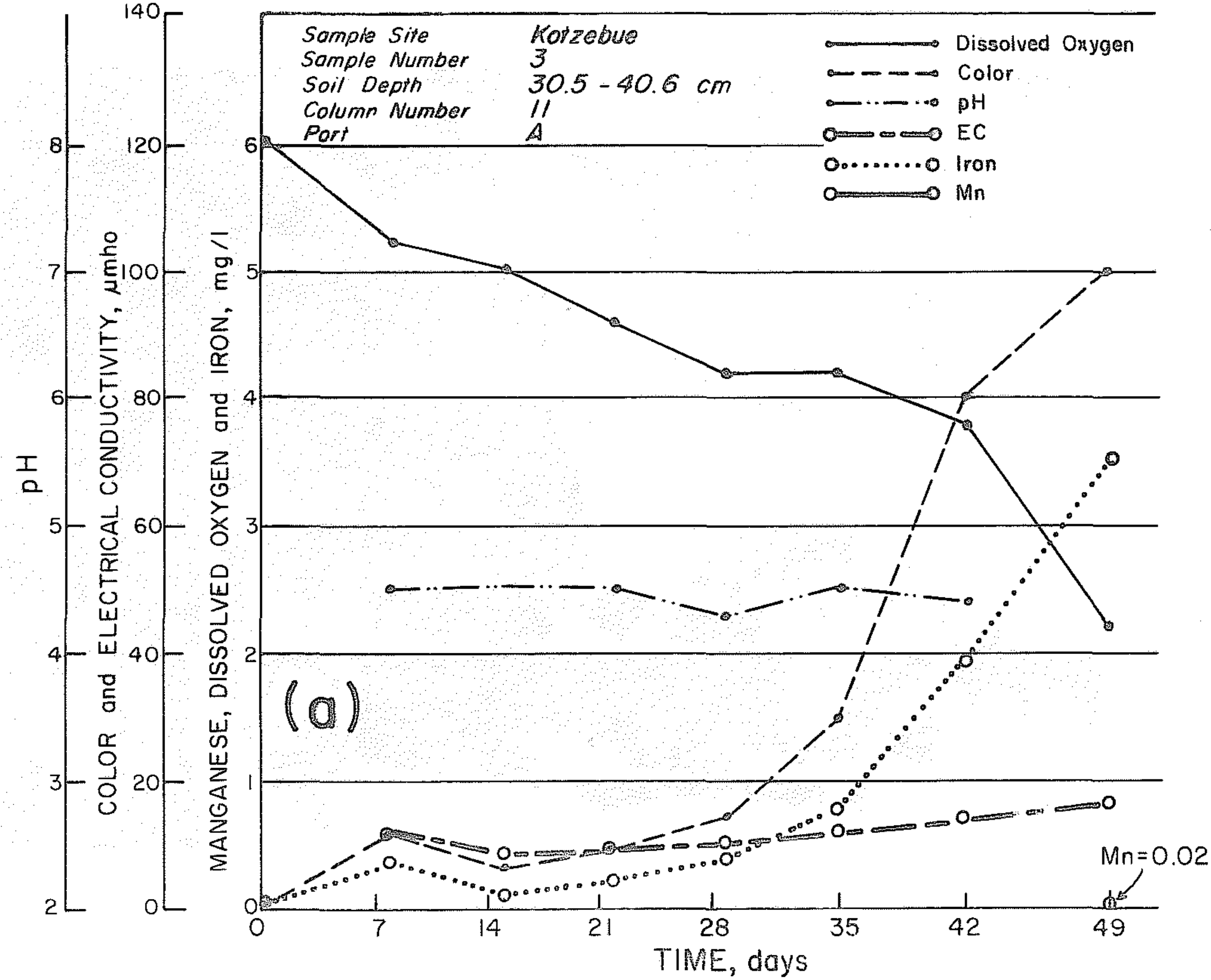

Sample Site
Kotzebue
Sample Number
3
Soil Depth
30.5 - 40.6 cm
Column Number
11
Port
A
Dissolved Oxygen
Color
pH
EC
Iron
Mn
(a)
Mn=0.02
pH
COLOR and ELECTRICAL CONDUCTIVITY, μmho
MANGANESE, DISSOLVED OXYGEN and IRON, mg/l
TIME, days
0
7
14
21
28
35
42
49
2
3
4
5
6
7
8
0
20
40
60
80
100
120
140
1
2
3
4
5
6

FIGURE 18-b

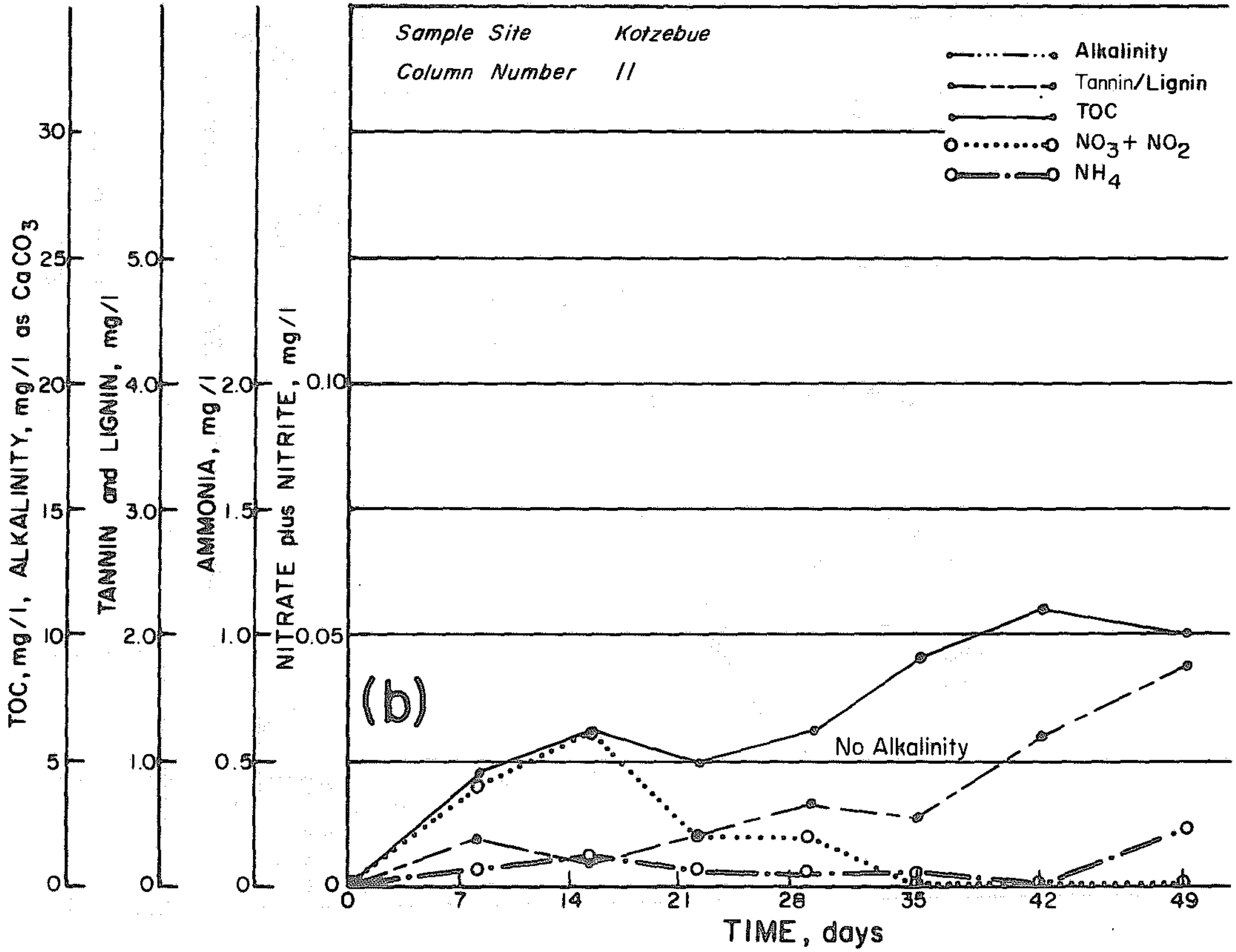
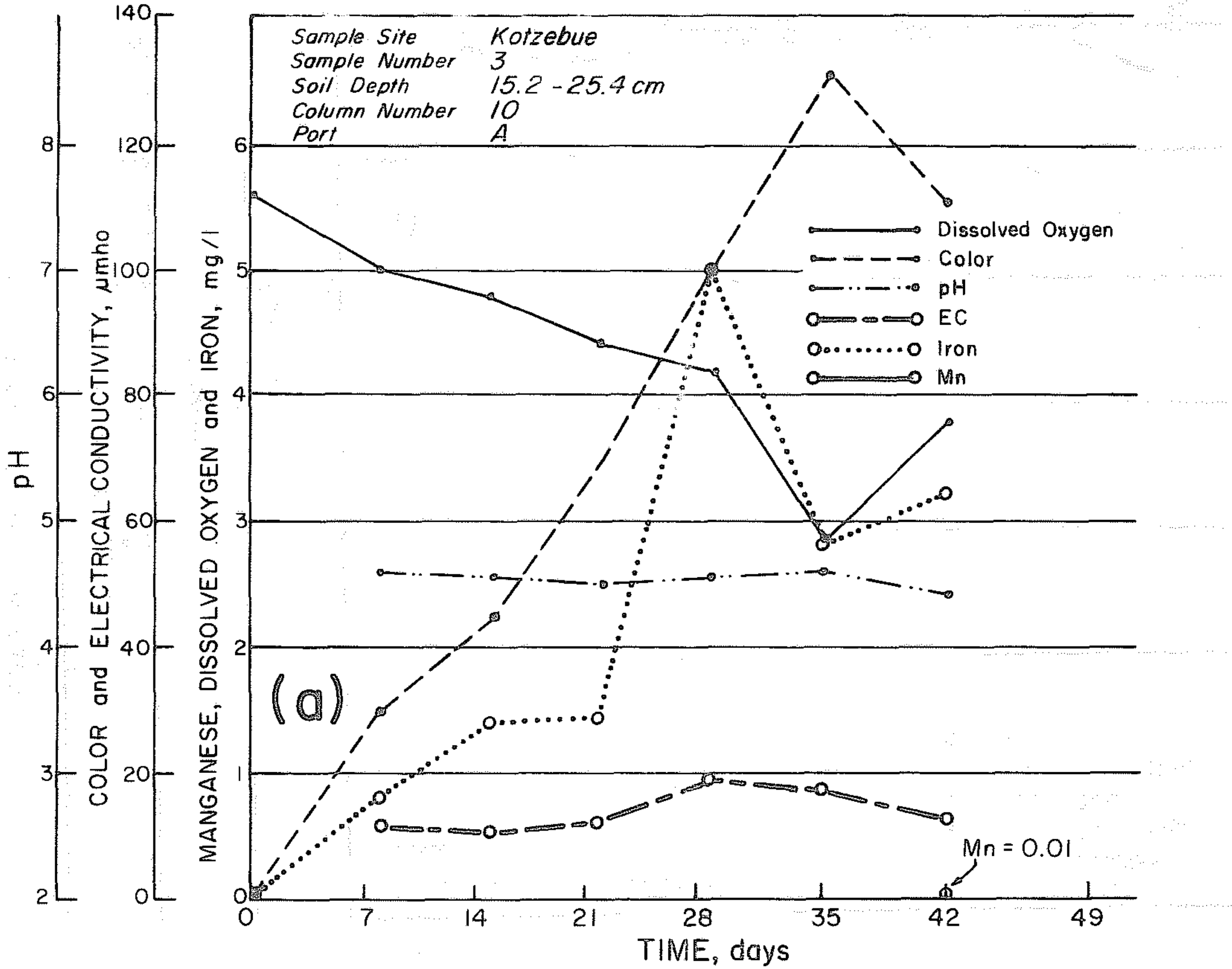

Sample Site Kotzebue
Column Number 11
Alkalinity
Tannin/Lignin
TOC
NO3 + NO2
NH4
(b)
No Alkalinity
TOC, mg/l, ALKALINITY, mg/l as CaCO3
TANNIN and LIGNIN, mg/l
AMMONIA, mg/l
NITRATE plus NITRITE, mg/l
TIME, days

FIGURE 19-a



Sample Site Kotzebue
Sample Number 3
Soil Depth 15.2 - 25.4 cm
Column Number 10
Port A
Dissolved Oxygen
Color
pH
EC
Iron
Mn
(a)
Mn = 0.01
pH
COLOR and ELECTRICAL CONDUCTIVITY, μmho
MANGANESE, DISSOLVED OXYGEN and IRON, mg/l
TIME, days

FIGURE 19-b

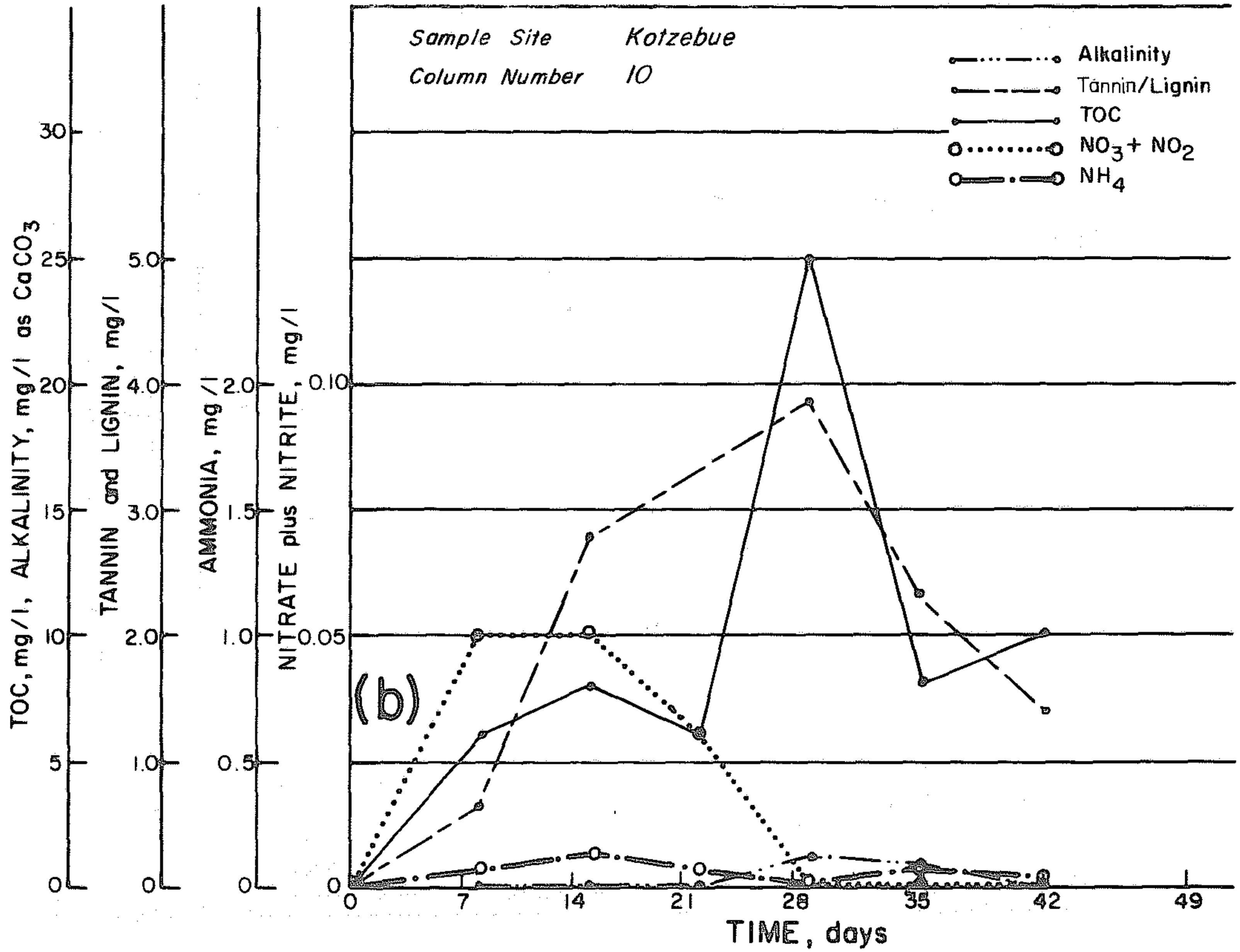
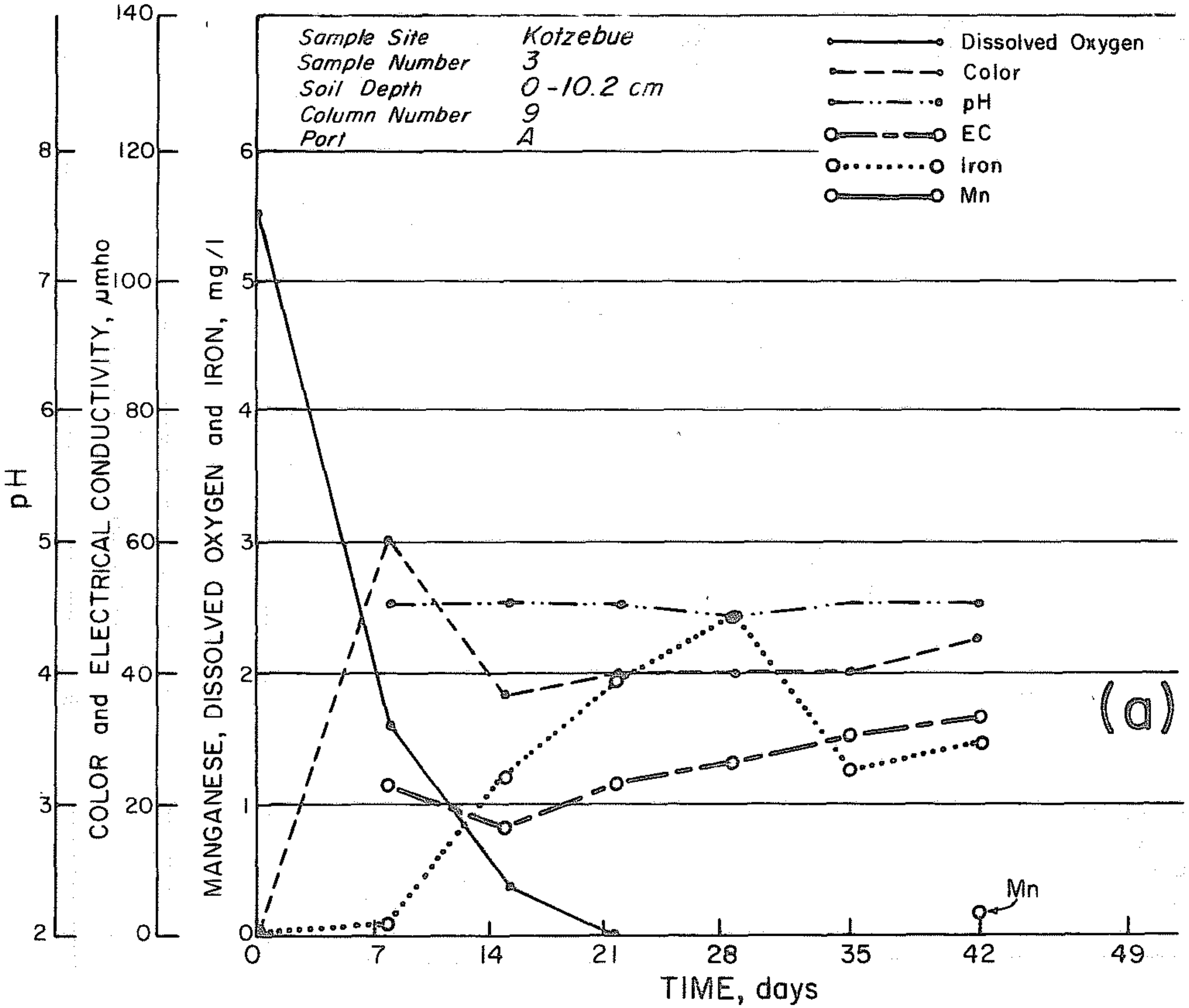
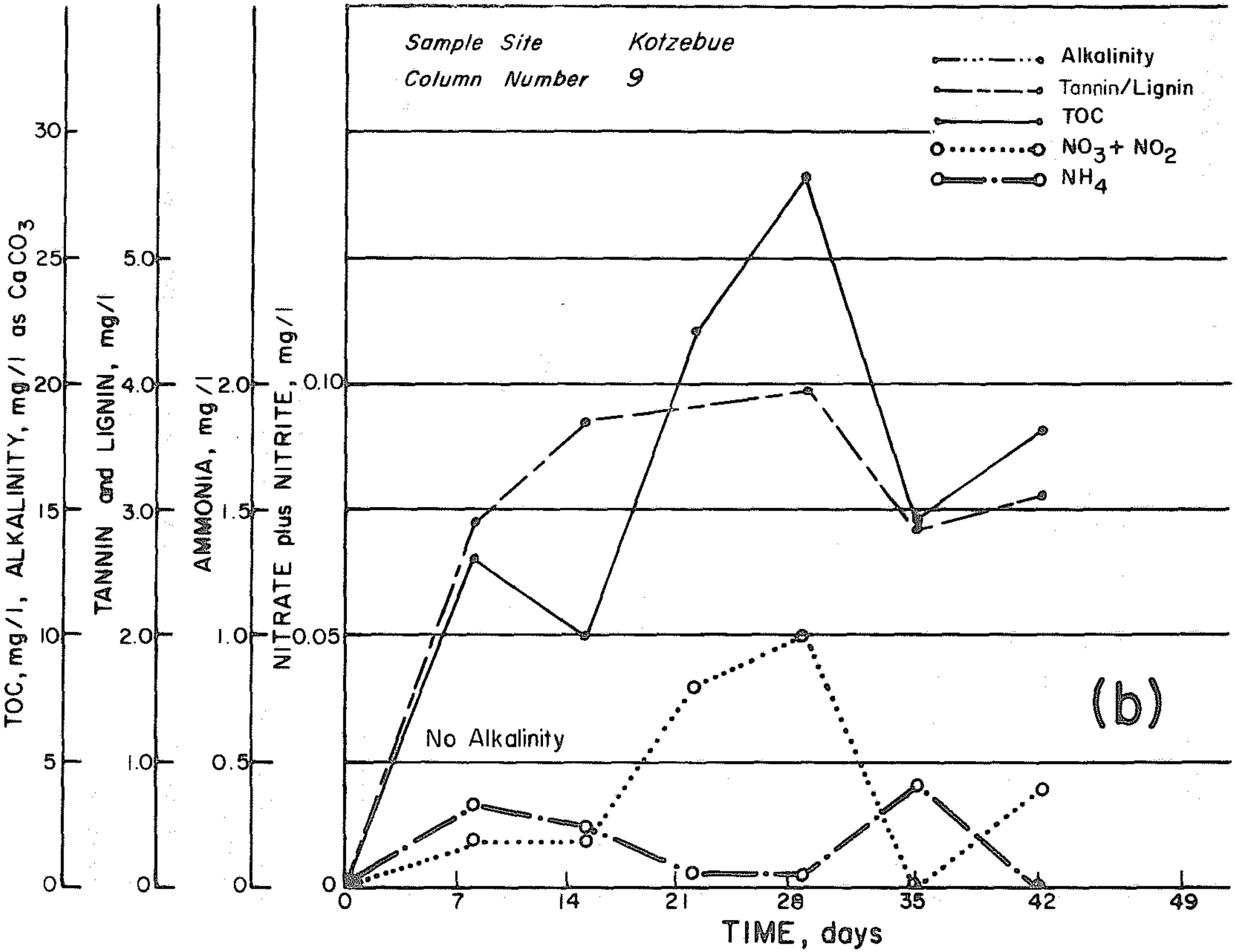

Sample Site Kotzebue
Column Number 10
Alkalinity
Tannin/Lignin
TOC
$NO_3 + NO_2$
NH_4
(b)
TOC, mg/l, ALKALINITY, mg/l as $CaCO_3$
TANNIN and LIGNIN, mg/l
AMMONIA, mg/l
NITRATE plus NITRITE, mg/l
TIME, days
0
7
14
21
28
35
42
49
5
10
15
20
25
30
1.0
2.0
3.0
4.0
5.0
0.5
1.5
0.05
0.10

FIGURE 20-a



Sample Site Kotzebue
Sample Number 3
Soil Depth 0-10.2 cm
Column Number 9
Port A
Dissolved Oxygen
Color
pH
EC
Iron
Mn
(a)
Mn
pH
COLOR and ELECTRICAL CONDUCTIVITY, μmho
MANGANESE, DISSOLVED OXYGEN and IRON, mg/l
TIME, days

FIGURE 20-b


Sample Site Kotzebue
Column Number 9
Alkalinity
Tannin/Lignin
TOC
$NO_3 + NO_2$
NH_4
TOC, mg/l, ALKALINITY, mg/l as $CaCO_3$
TANNIN and LIGNIN, mg/l
AMMONIA, mg/l
NITRATE plus NITRITE, mg/l
No Alkalinity
(b)
TIME, days
0
7
14
21
28
35
42
49
30
25
20
15
10
5
5.0
4.0
3.0
2.0
1.0
2.0
1.5
1.0
0.5
0.10
0.05

Ship Creek Project

General Description: Anchorage, the largest Alaskan population center is growing at a rapid rate and is actively attempting to increase its water retention capabilities. Many alternative plans have been suggested for storage of Ship Creek water. Off-stream storage, created by digging out 45- to 50-foot deep ponds in the alluvial material of Anchorage Bowl, is the alternative of choice. Since the surface soils will be removed, leaching studies at this site will not be of any use except as they show the water quality changes resulting from inundation of this type of soil for possible future dam sites in similar areas.

Figure 21 shows the dense birch, cottonwood, willow, fireweed, and small plants which characterize this area.

Soil Characterization: Figure 22 shows a sample soil profile at Ship Creek.

Table 5 shows the results of soil analysis on samples from the Ship Creek area.

The top 7.6 cm contained roots and organic material in dark red-brown soil of which 53.3 per cent was organic matter.

The layer 7.6 to 17.8 cm below the surface was red-brown silt with grey areas. It was found to have a high organic content of 60 per cent. Sand comprised 60 per cent of the soil; and the other 40 per cent was fines.

From 20.3 to 30.5 cm below the surface, a brown soil was encountered with 39.9 per cent organics. Sand comprised 26 per cent of the soil and the remainder was fines.

At the 30.5 to 40.6 cm level a dark brown sand was encountered with 24.8 per cent organic matter. Only 10 per cent was fines, the rest being sand sized.

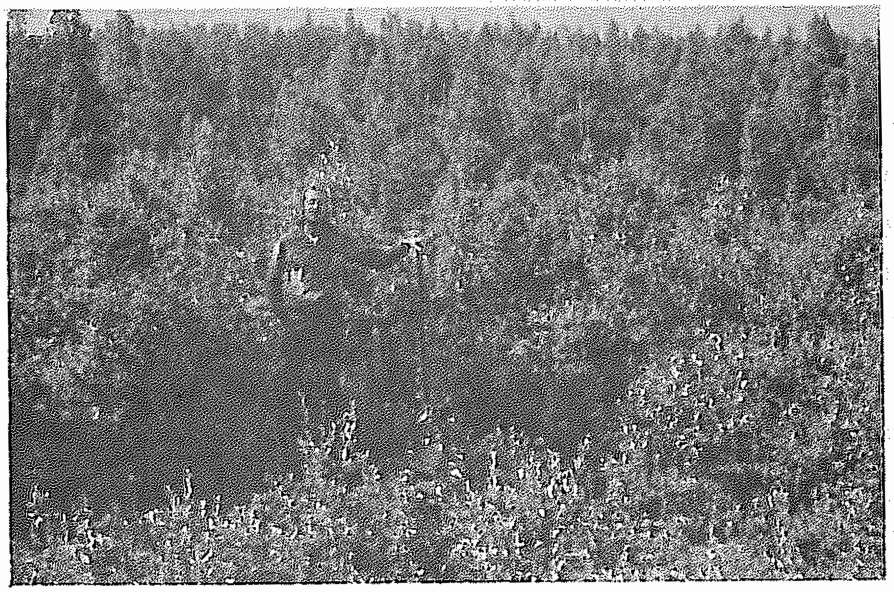


FIGURE 21: Sample Site Number 4, Ship Creek.

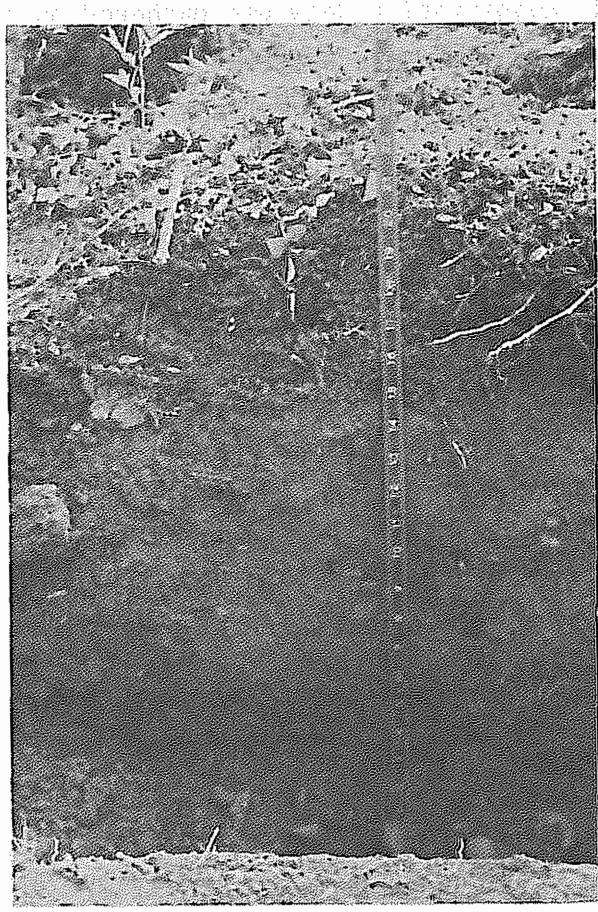


FIGURE 22 : Soil Sample at Ship Creek Sample Site.

Conclusions and Recommendations: Figures 25 through 29 show the results of leaching studies on soil from the Ship Creek area. The only water quality degradation occurred from leaching the top 7.6 centimeters of soil. Column 12, containing surface material, went anaerobic in three weeks and all of the constituents rose to undesirable levels. The much improved water quality shown in Figures 27 through 29 prompted the recommendation of stripping the surface material, as the deeper layers will not seriously degrade the quality of the overlaying water.

Monashka Creek, Kodiak Island

General Descriptions: The town of Kodiak needs large quantities of good quality water for operation of several large canning and seafood processing plants in addition to domestic water needs. The present Monashka Creek supply is a small reservoir created by a dam across the creek. This impoundment was not cleared, leaving many unsightly snags sticking above the water surface. No quantitative data was gathered on the water from the present reservoir but dead fish were observed on the bottom. A proposed expansion of this reservoir will be accomplished by raising the height of the dam.

The vegetation of the area is typical coastal Alaskan dense brush and forests. There is a mosaic of open areas with deep grass and other plants, dense regions of alder and cottonwood thickets, and various successional stages of Sitka spruce-hemlock forests. Sample site number 5, as shown in Figure 23, was located in the transition zone between a thicket of alders and cottonwood and an open meadow with fireweed, various grasses, moss, and other broad-leafed plants. Sample site 6, as shown in Figure 24, was in a wet grassy meadow, surrounded by hills covered with Sitka spruce and alder. Open standing water was in the lowest depression of the area.

Soil Characterization: Table 6 shows the characteristics of the first soil sample from the Monashka Creek area (See Figure 29).

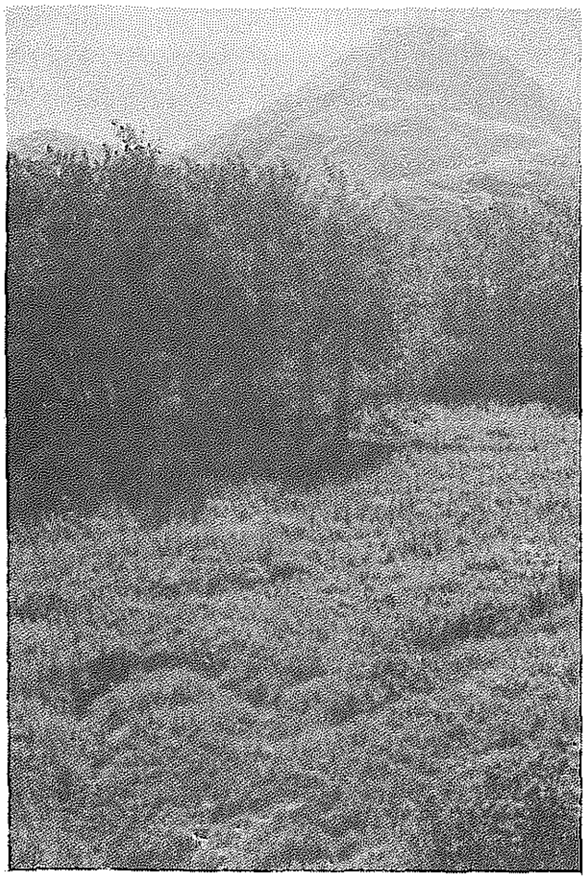


FIGURE 23 : Sample Site Number 5, Monashka Creek.

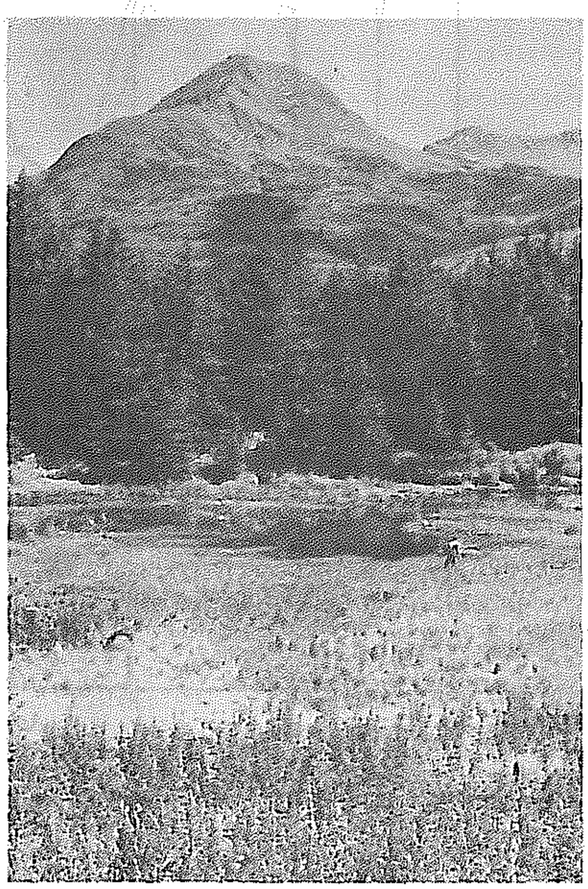
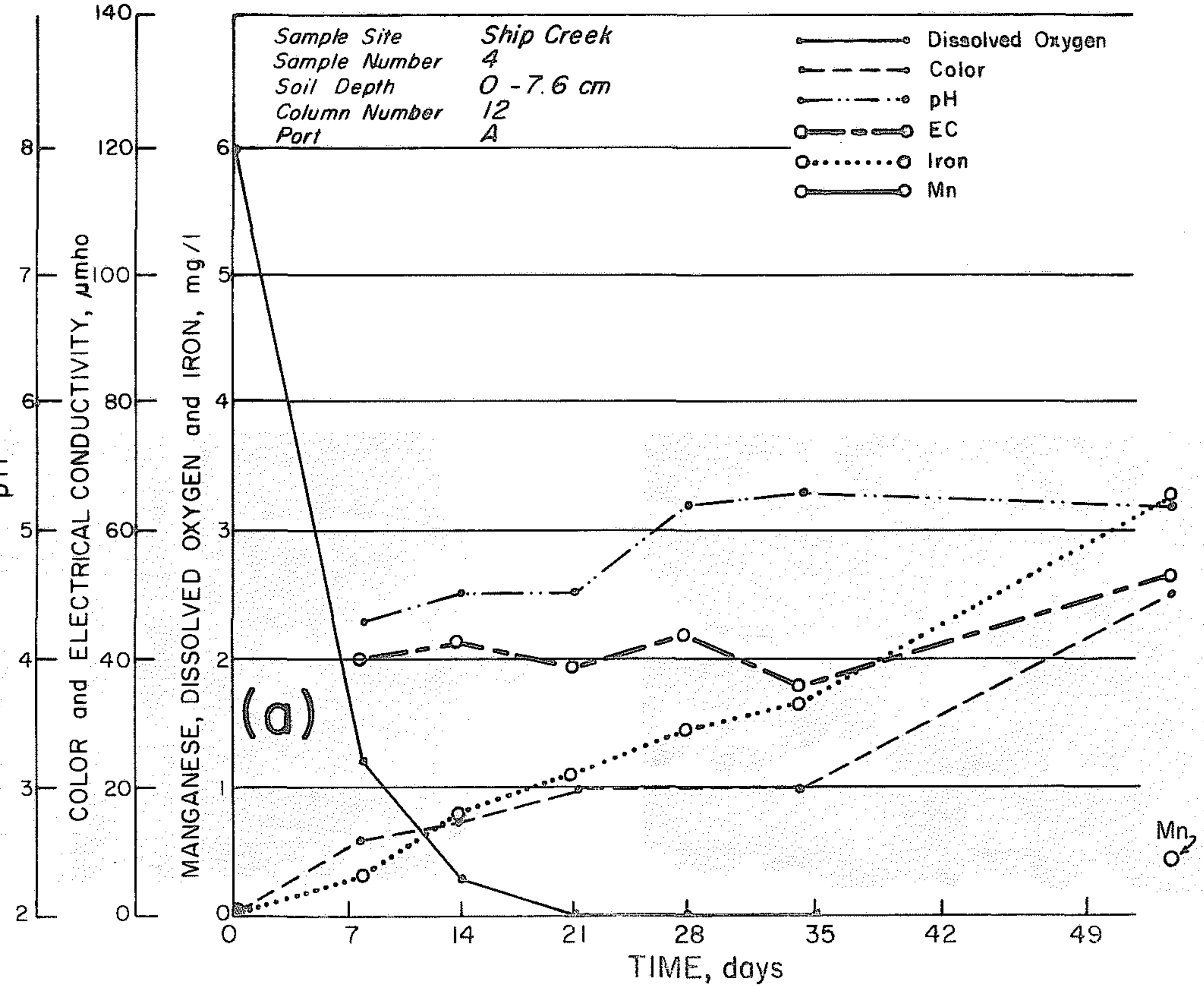


FIGURE 24 : Sample Site Number 6, Monashka Creek.

FIGURE 25-a



Sample Site Ship Creek
Sample Number 4
Soil Depth 0 - 7.6 cm
Column Number 12
Port A
Dissolved Oxygen
Color
pH
EC
Iron
Mn
(a)
Mn 2
pH
COLOR and ELECTRICAL CONDUCTIVITY, μmho
MANGANESE, DISSOLVED OXYGEN and IRON, mg/l
TIME, days
2 3 4 5 6 7 8
0 20 40 60 80 100 120 140
0 1 2 3 4 5 6
0 7 14 21 28 35 42 49

FIGURE 25-b

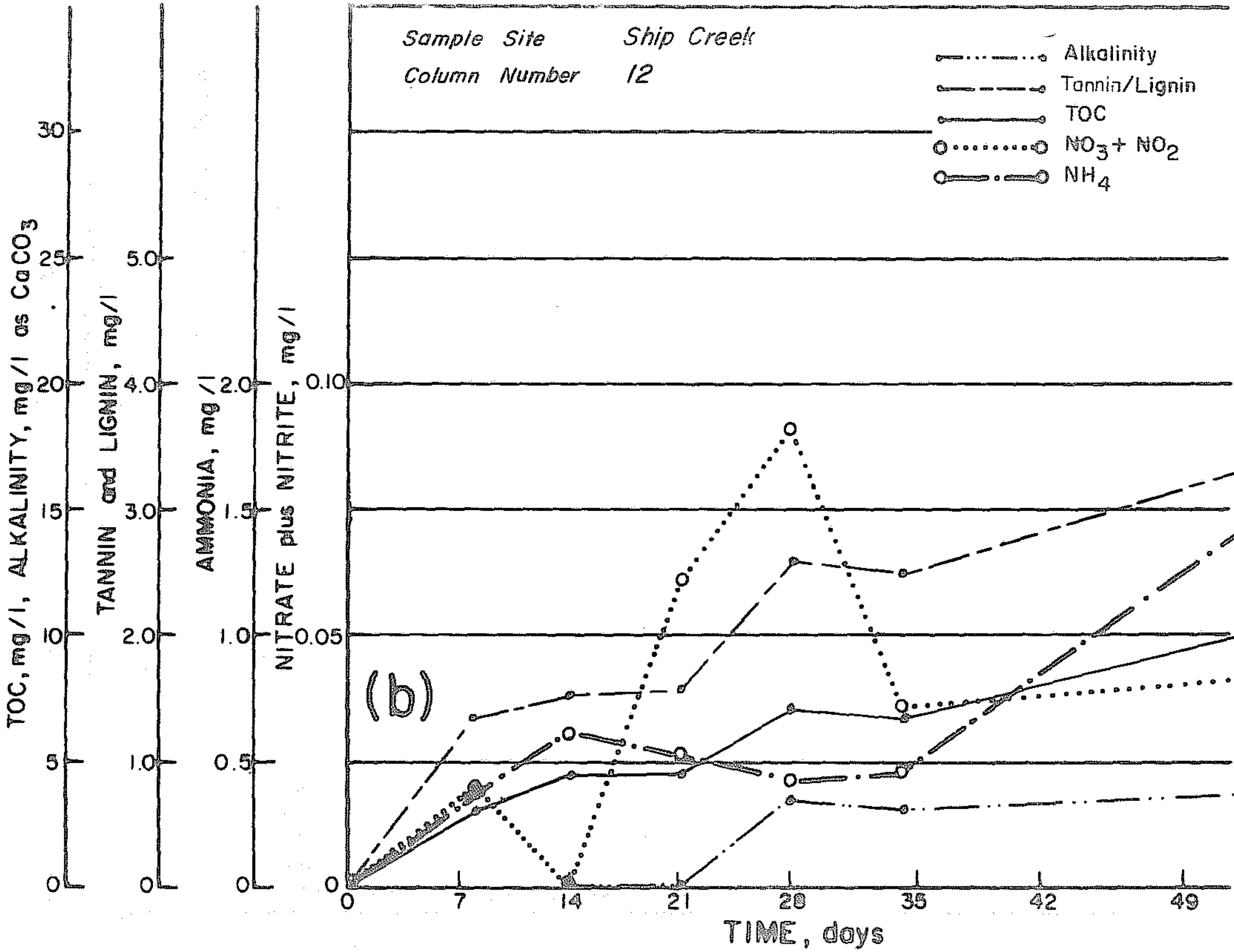

Sample Site Ship Creek
Column Number 12
Alkalinity
Tannin/Lignin
TOC
NO3 + NO2
NH4
(b)
TOC, mg/l, ALKALINITY, mg/l as CaCO3
TANNIN and LIGNIN, mg/l
AMMONIA, mg/l
NITRATE plus NITRITE, mg/l
30
25
20
15
10
5
0
5.0
4.0
3.0
2.0
1.0
0
2.0
1.5
1.0
0.5
0
0.10
0.05
0
0
7
14
21
28
35
42
49
TIME, days

FIGURE 26-a

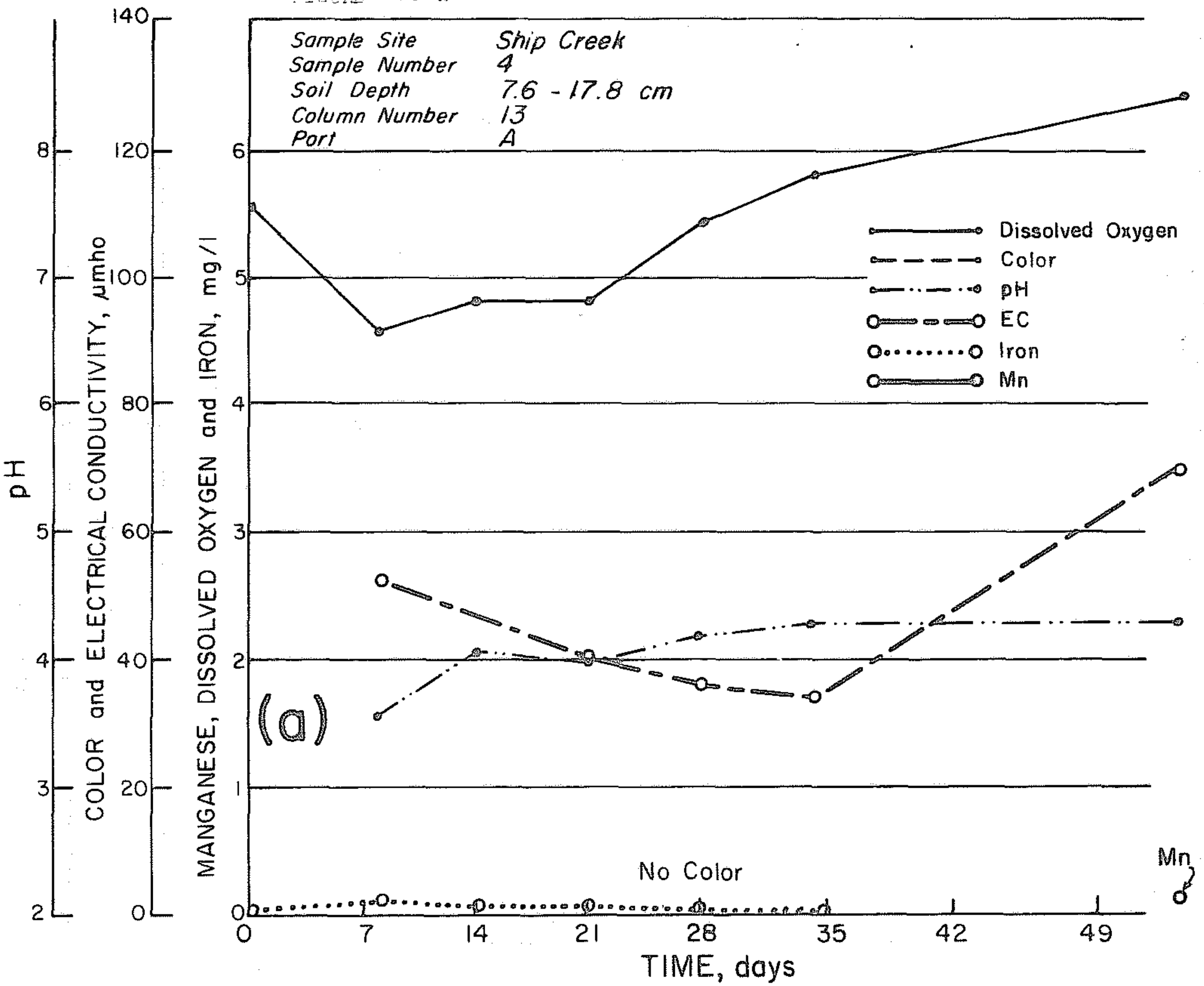
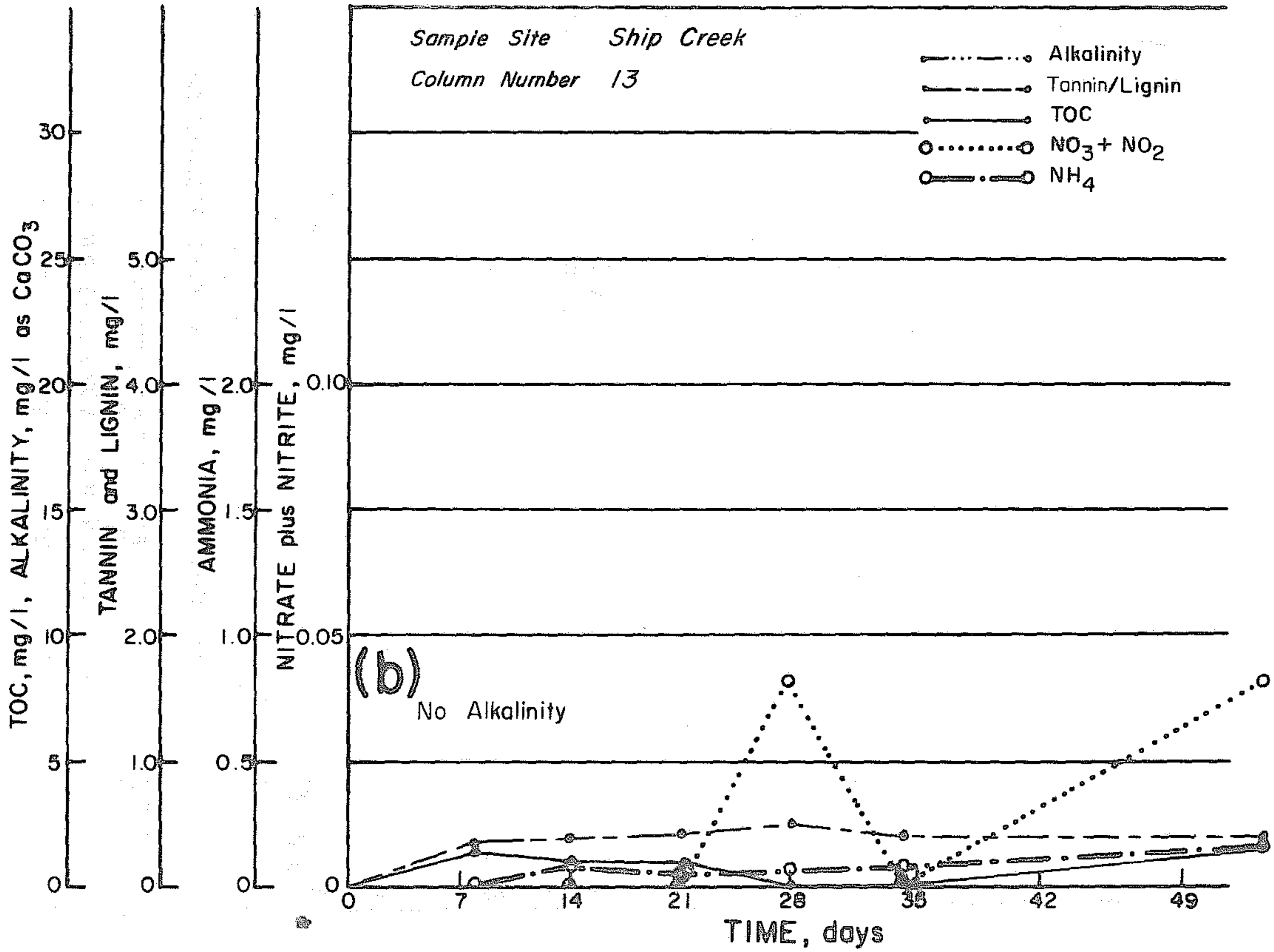
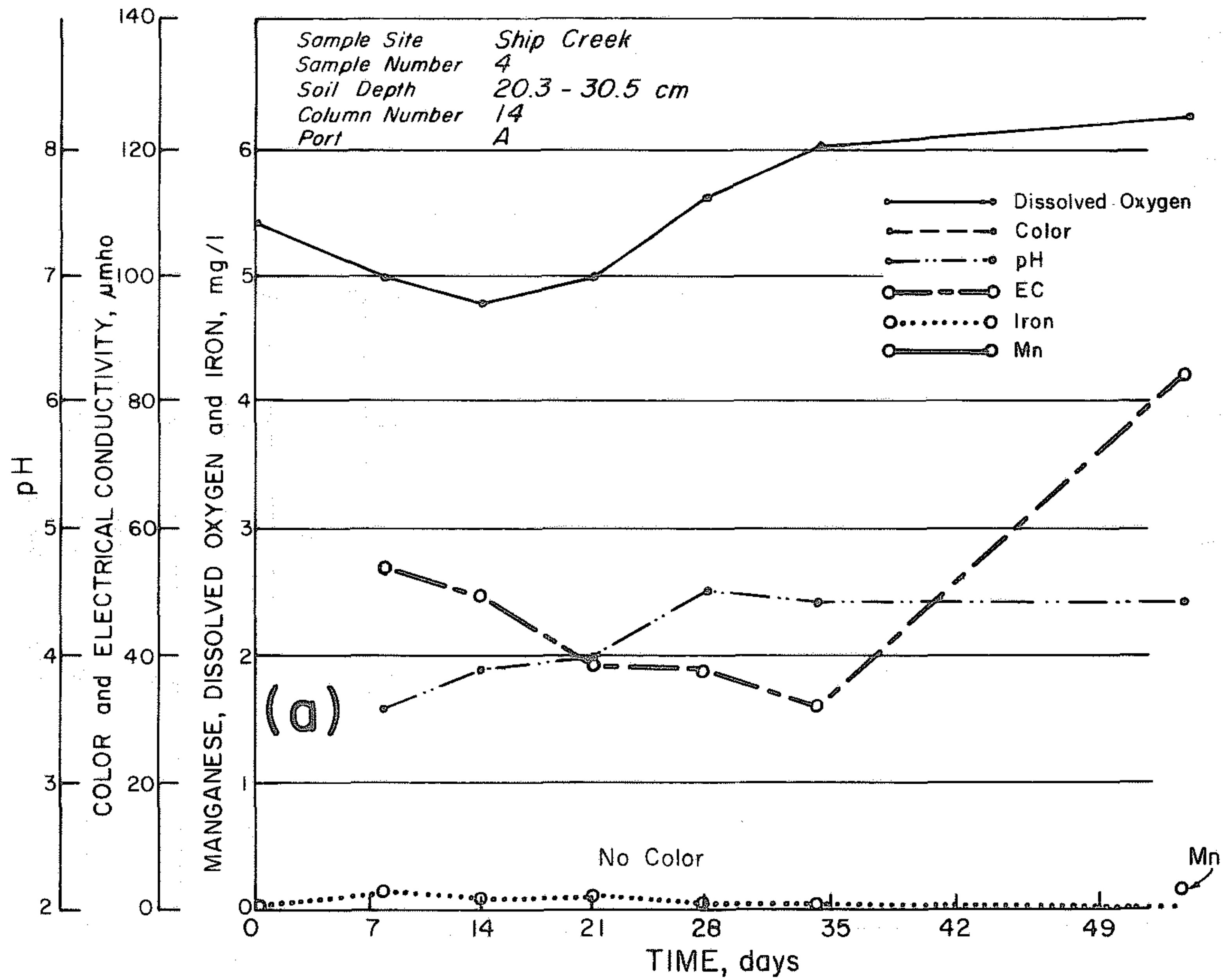

Sample Site Ship Creek
Sample Number 4
Soil Depth 7.6 - 17.8 cm
Column Number 13
Port A
Dissolved Oxygen
Color
pH
EC
Iron
Mn
(a)
No Color
Mn
pH
COLOR and ELECTRICAL CONDUCTIVITY, µmho
MANGANESE, DISSOLVED OXYGEN and IRON, mg/l
TIME, days
0
7
14
21
28
35
42
49
2
3
4
5
6
7
8
20
40
60
80
100
120
140
1
2
3
4
5
6

FIGURE 26-b



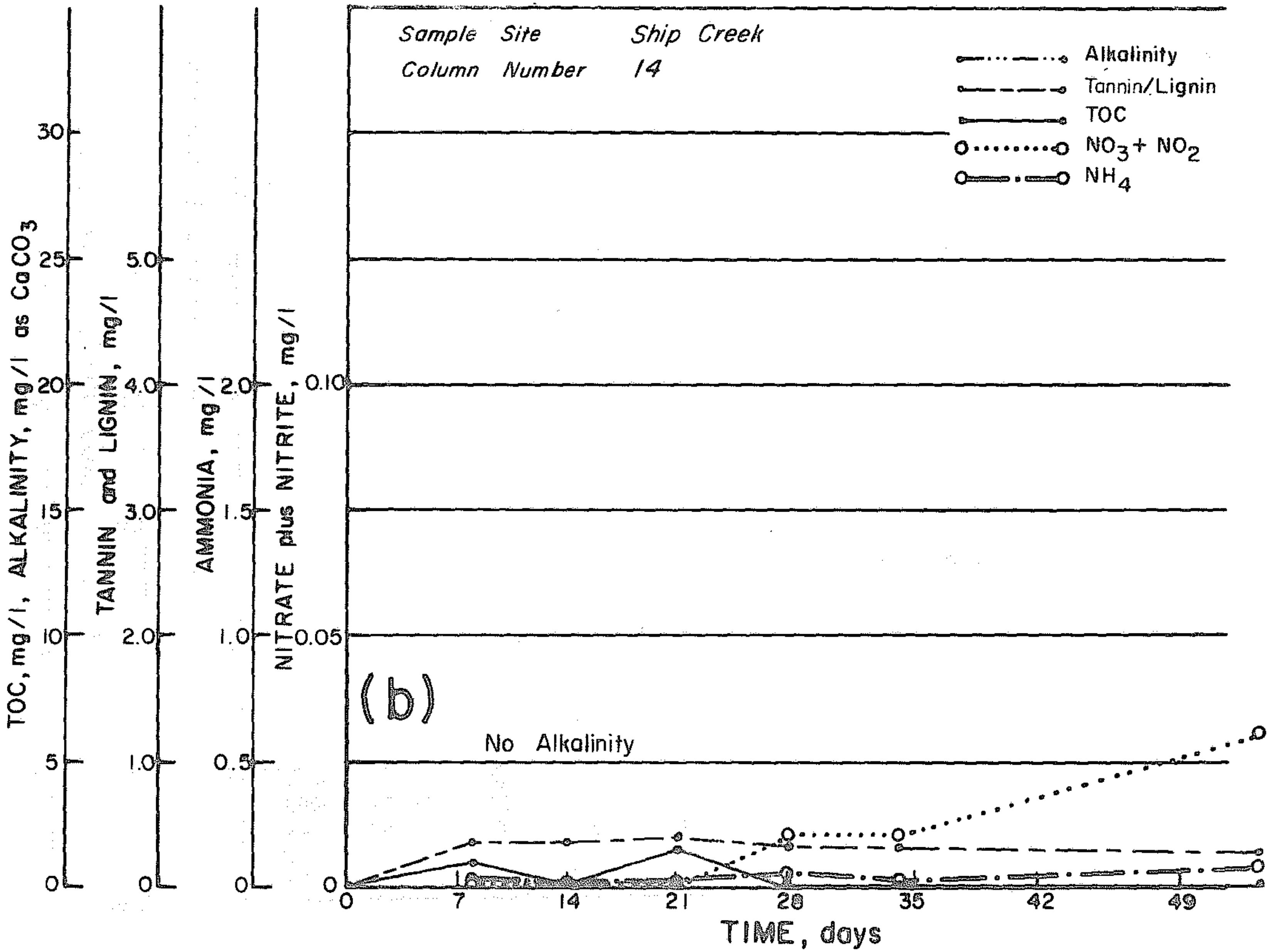
Sample Site Ship Creek
Column Number 13
Alkalinity
Tannin/Lignin
TOC
$NO_3 + NO_2$
NH_4
(b)
No Alkalinity
TOC, mg/l, ALKALINITY, mg/l as $CaCO_3$
TANNIN and LIGNIN, mg/l
AMMONIA, mg/l
NITRATE plus NITRITE, mg/l
TIME, days

FIGURE 37-a



Sample Site Ship Creek
Sample Number 4
Soil Depth 20.3 - 30.5 cm
Column Number 14
Port A
Dissolved Oxygen
Color
pH
EC
Iron
Mn
(a)
No Color
Mn
pH
COLOR and ELECTRICAL CONDUCTIVITY, µmho
MANGANESE, DISSOLVED OXYGEN and IRON, mg/l
TIME, days

FIGURE 27-b



Sample Site Ship Creek
Column Number 14
Alkalinity
Tannin/Lignin
TOC
$NO_3 + NO_2$
NH_4
(b)
No Alkalinity
TOC, mg/l, ALKALINITY, mg/l as $CaCO_3$
TANNIN and LIGNIN, mg/l
AMMONIA, mg/l
NITRATE plus NITRITE, mg/l
TIME, days

FIGURE 28-a

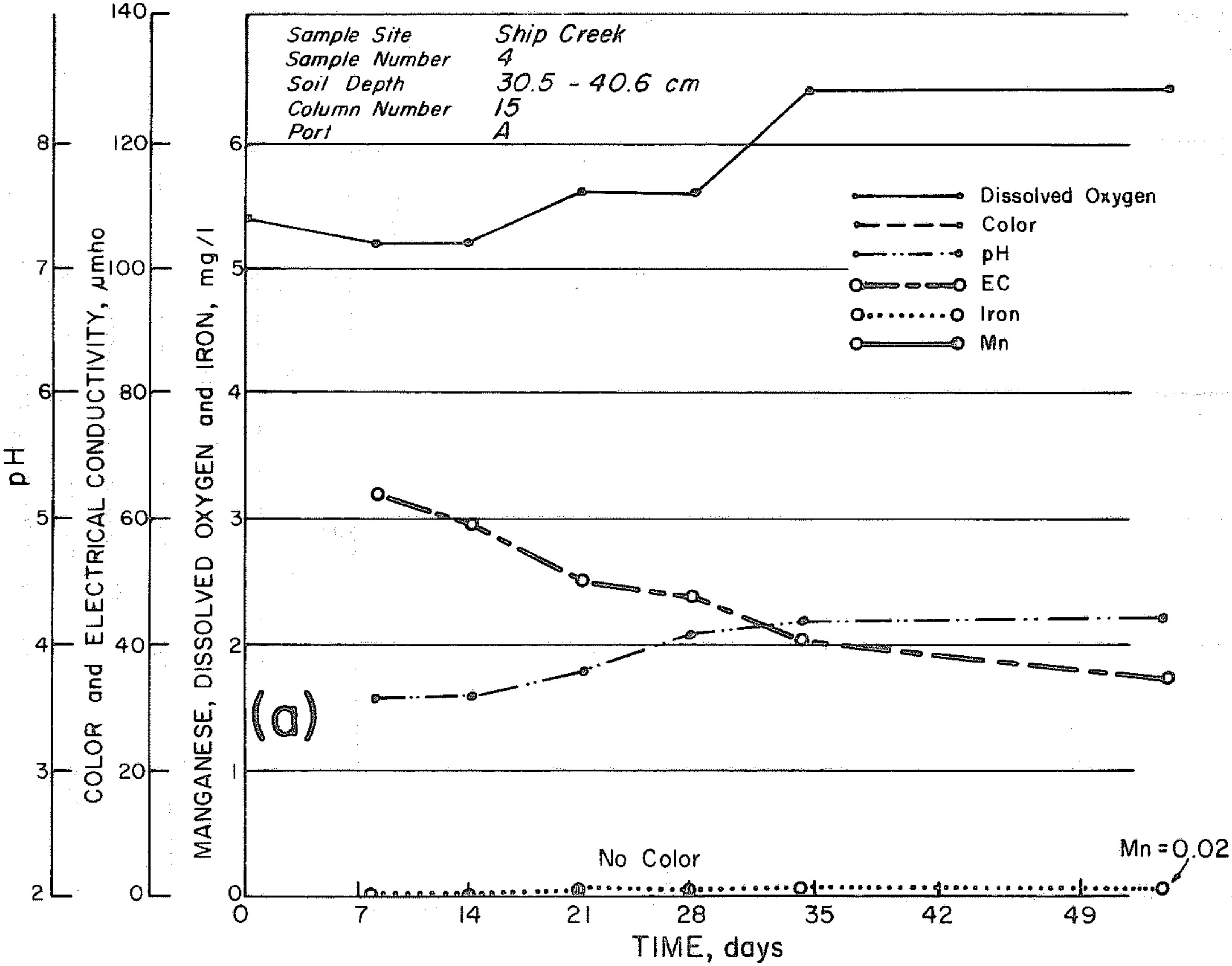
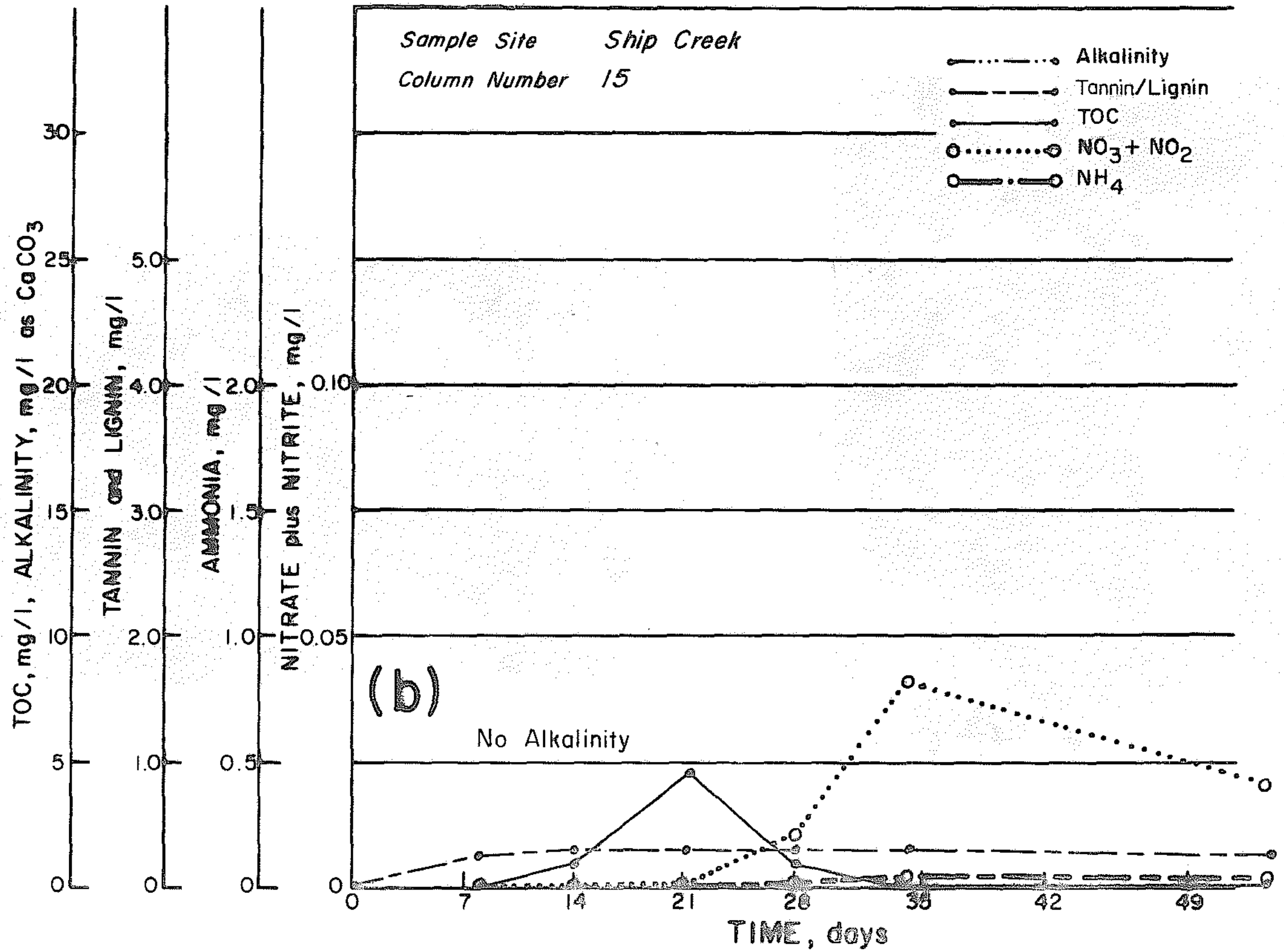

Sample Site Ship Creek
Sample Number 4
Soil Depth 30.5 - 40.6 cm
Column Number 15
Port A
Dissolved Oxygen
Color
pH
EC
Iron
Mn
(a)
No Color
Mn = 0.02
pH
COLOR and ELECTRICAL CONDUCTIVITY, µmho
MANGANESE, DISSOLVED OXYGEN and IRON, mg/l
TIME, days

FIGURE 28-b


Sample Site Ship Creek
Column Number 15
Alkalinity
Tannin/Lignin
TOC
NO3 + NO2
NH4
(b)
No Alkalinity
TOC, mg/l, ALKALINITY, mg/l as CaCO3
TANNIN and LIGNIN, mg/l
AMMONIA, mg/l
NITRATE plus NITRITE, mg/l
TIME, days

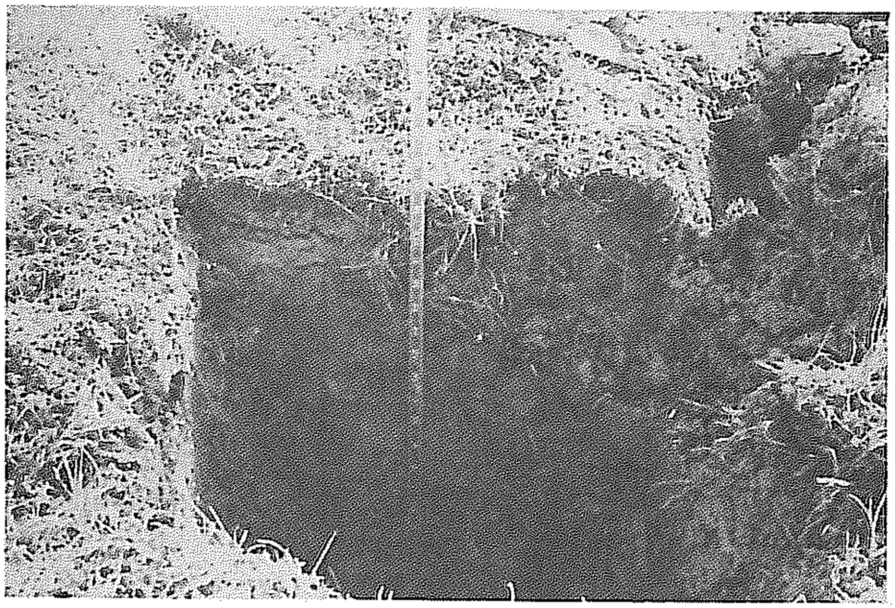


FIGURE 29 : Soil Profile, Monashka Creek Sample Site Number 1.

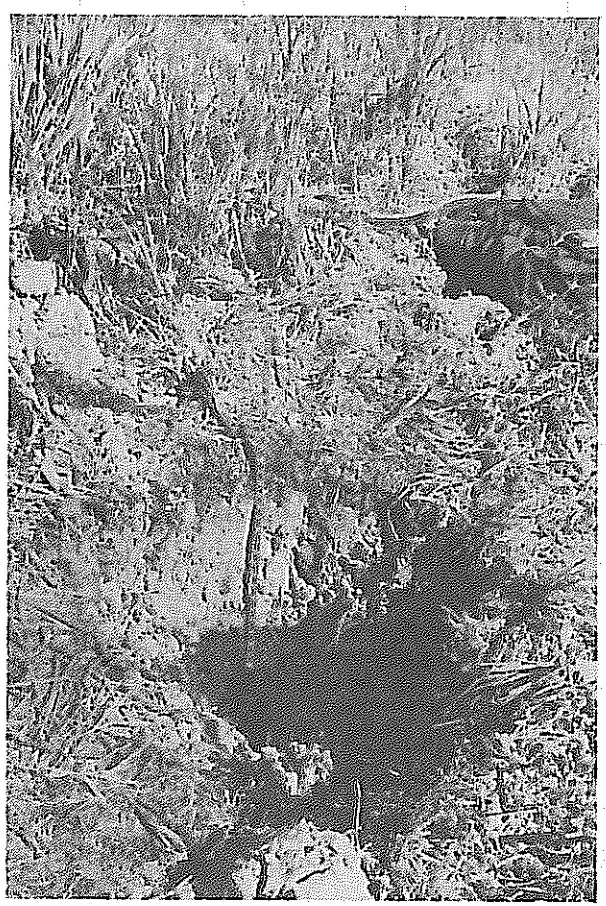


FIGURE 30 : Soil Profile, Monashka Creek Sample Site Number 2.

The surface layer at this site was a dark brown organic root mat with organic matter comprising 40.7 per cent.

From 10.2 to 22.9 cm below the surface, a volcanic ash layer from the 1912 eruption near Mt. Katmai was encountered. It is a light red-brown sandy material with roots running through it. By sieve analysis, it was found to contain 64 per cent fines and 36 per cent sand-sized material. Only 1.3 per cent organic matter was found.

The next layer down was 22.9 to 33.0 cm below the surface and was an ash material similar to the previous layer. More of this layer was sand-sized material than the former with only 51 per cent fines. The organic content was the same at 1.3 per cent.

Under the ash layer, we encountered an old organic soil from before the eruption. It was a dark brown silt, or clay material with 4.7 per cent organics. Sieve analysis showed it to contain 68 per cent fines.

Table 7 contains the soil characteristics from the second Monashka Creek sample site (See Figure 30).

Near the surface, a dark brown organic root mat was encountered containing 63.9 per cent organic matter.

At the 7.6 to 17.8 cm depth the ash layer noted at the previous sample site was found. The organic content was found to be 2.0 per cent. The fines comprised 39 per cent and sand 61 per cent of the sample.

The lowest level to be leached at this site was 20.3 to 33.0 cm beneath the surface and was ash material again. Less fines were found in this deeper layer, comprising only 30 per cent of the sample. Soil organic content was essentially the same as in the previous layer.

The old organic soil was found below 33.0 cm.

Conclusions and Recommendations: Leaching study results from the two Monashka Creek sites are shown in Figures 33 through 39. The surface material from sample site number 5 caused anaerobic conditions and high concentrations of ammonia and TOC. All the deeper layers resulted in good quality leachate, demonstrating that an advantage would be gained by removal of the top 10.2 centimeters of material. But the ash material of the deeper layers is of concern as there is a possibility that it could become suspended by reservoir currents, thereby causing undesirable turbidity. Further study is needed to determine if the ash material will be stable if it is exposed and used as a reservoir bottom.

The leachate from samples taken from the second Monashka Creek site, Figures 37 through 39, show very similar results and the same recommendations are made.

Barrow Reservoir

General Comments: For several years Barrow, has been using a nearby lagoon for its water supply. A tank truck pumps water from the lagoon and then delivers it to water tanks in the individual households. To modernize the system, a dam is planned on Isatkoak Lagoon to increase the volume in order to store sufficient water for the long winter. Water will be pumped directly from this reservoir to a water treatment plant and then into a piped distribution system. The leaching study of this area shows the extent of water quality degradation resulting from inundation of areas around Isatkoak Lagoon and what improvements could be obtained by removing soils to various depths.

The vegetation is typical north slope tundra consisting of grass, arctic poppies, and various alpine plants. Sample site 7 is located near the proposed raw water intake on the shore of Isatkoak Lagoon (See Figure 31).

Soil Characterization: Table 8 shows the results of soil analysis on samples from the Barrow Reservoir site (See Figure 32).

FIGURE 31 : Sample Site Number 7, Barrow - Isatkoak Lagoon in background.

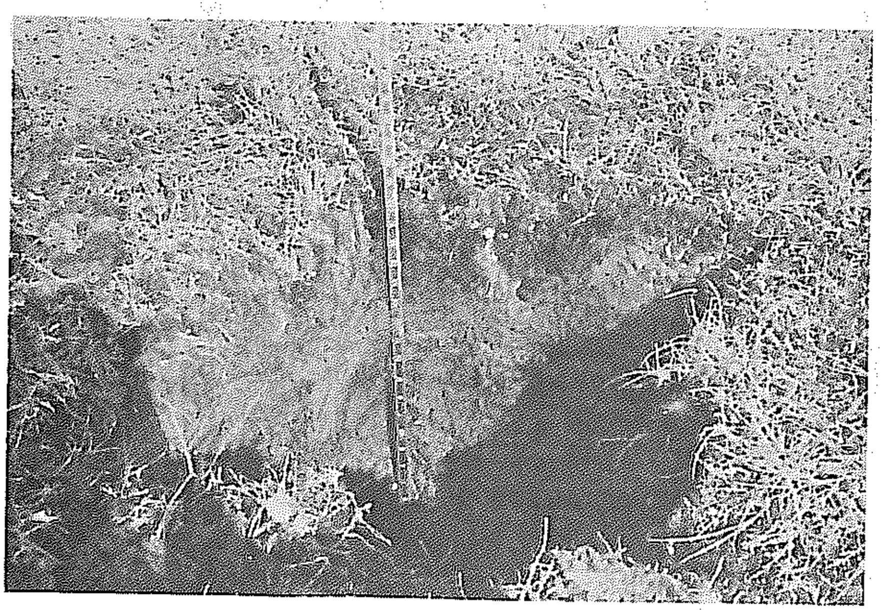


FIGURE 32 : Soil Profile at Barrow Sample Site.

FIGURE 33-a

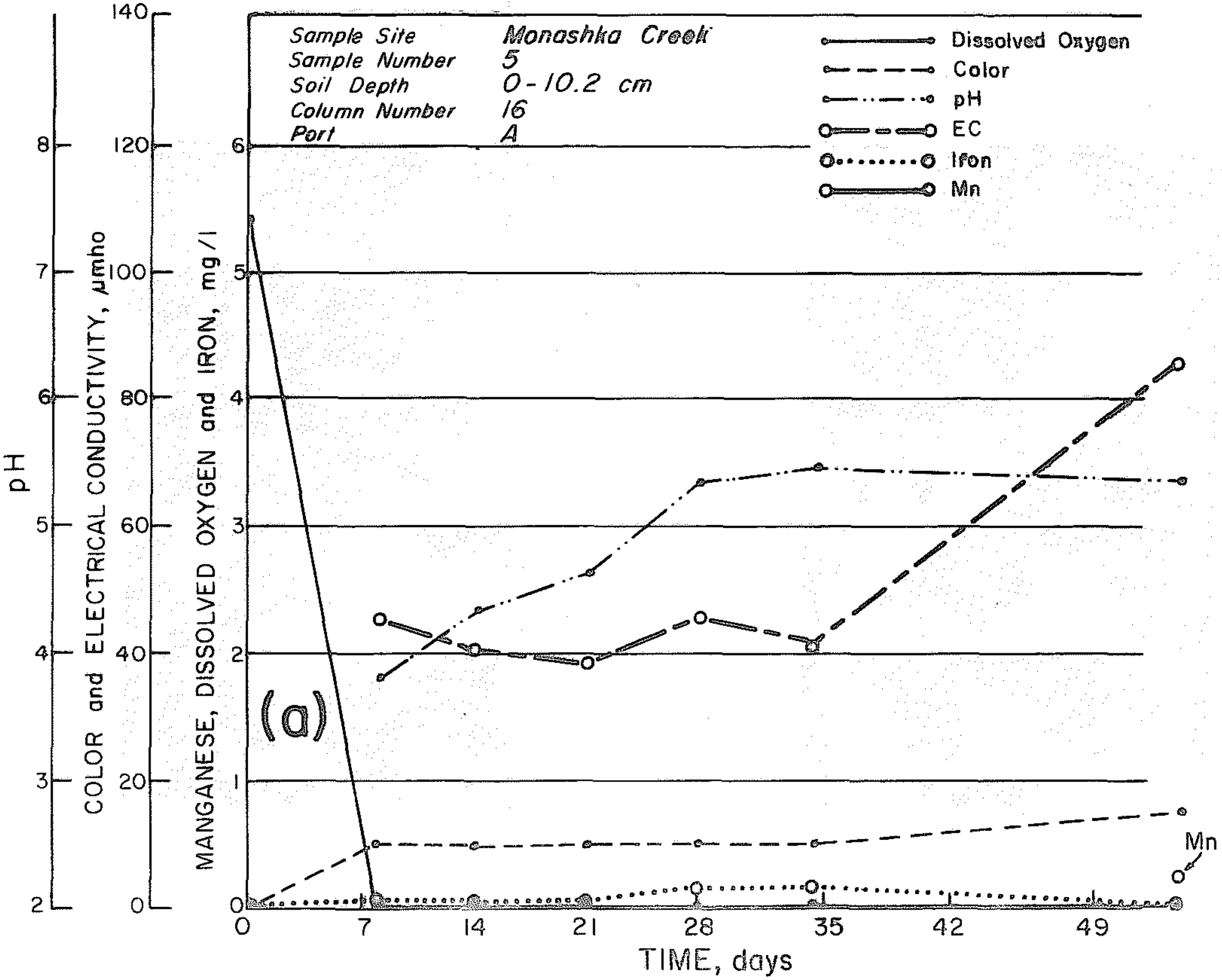

Sample Site Monashka Creek
Sample Number 5
Soil Depth 0-10.2 cm
Column Number 16
Port A
Dissolved Oxygen
Color
pH
EC
Iron
Mn
(a)
Mn
pH
COLOR and ELECTRICAL CONDUCTIVITY, µmho
MANGANESE, DISSOLVED OXYGEN and IRON, mg/l
TIME, days
0
7
14
21
28
35
42
49
2
3
4
5
6
7
8
0
20
40
60
80
100
120
140
1
2
3
4
5
6

FIGURE 33-b

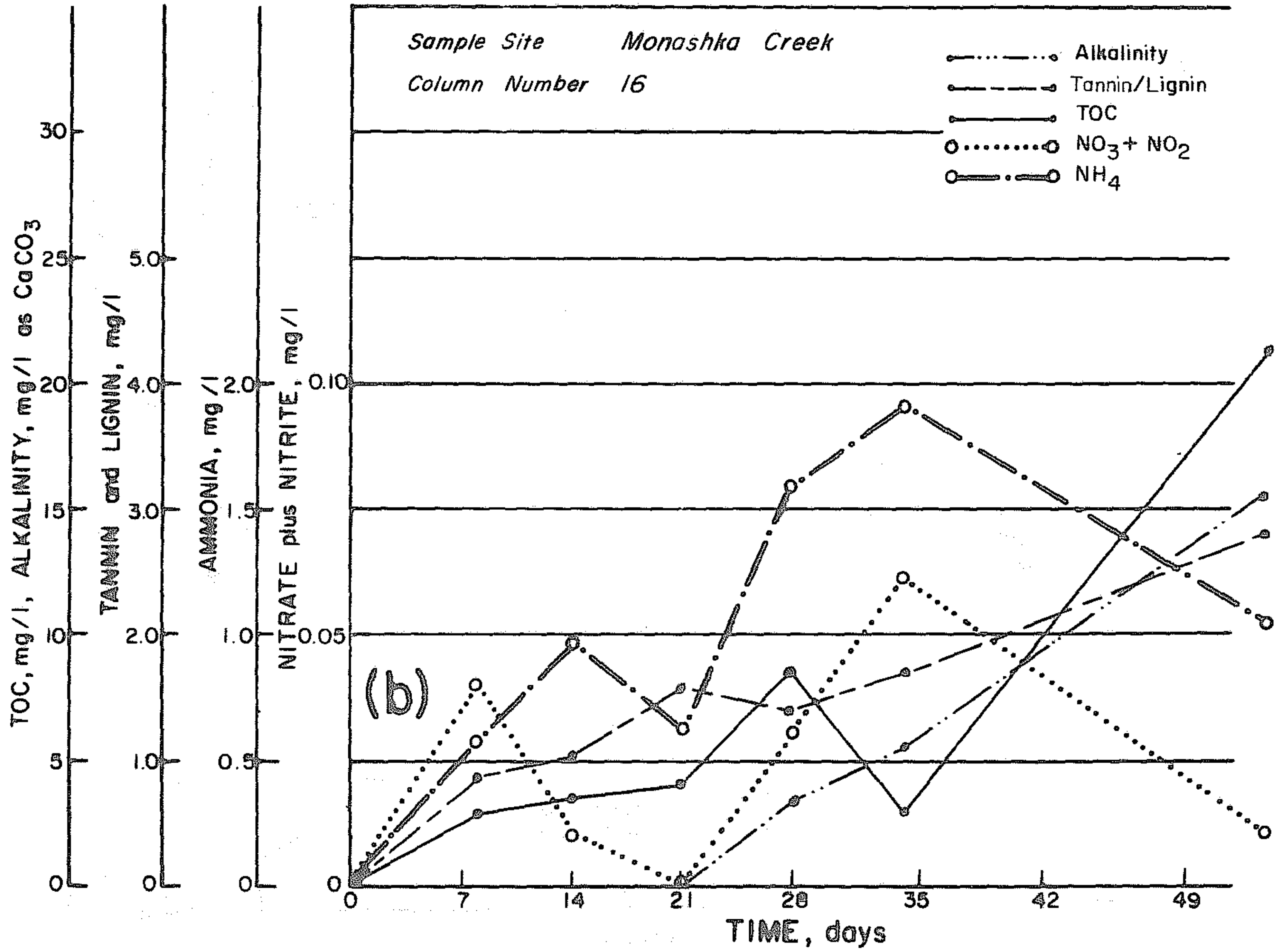

Sample Site Monashka Creek
Column Number 16
Alkalinity
Tannin/Lignin
TOC
$NO_3 + NO_2$
NH_4
(b)
TOC, mg/l, ALKALINITY, mg/l as $CaCO_3$
TANNIN and LIGNIN, mg/l
AMMONIA, mg/l
NITRATE plus NITRITE, mg/l
TIME, days

FIGURE 34-a

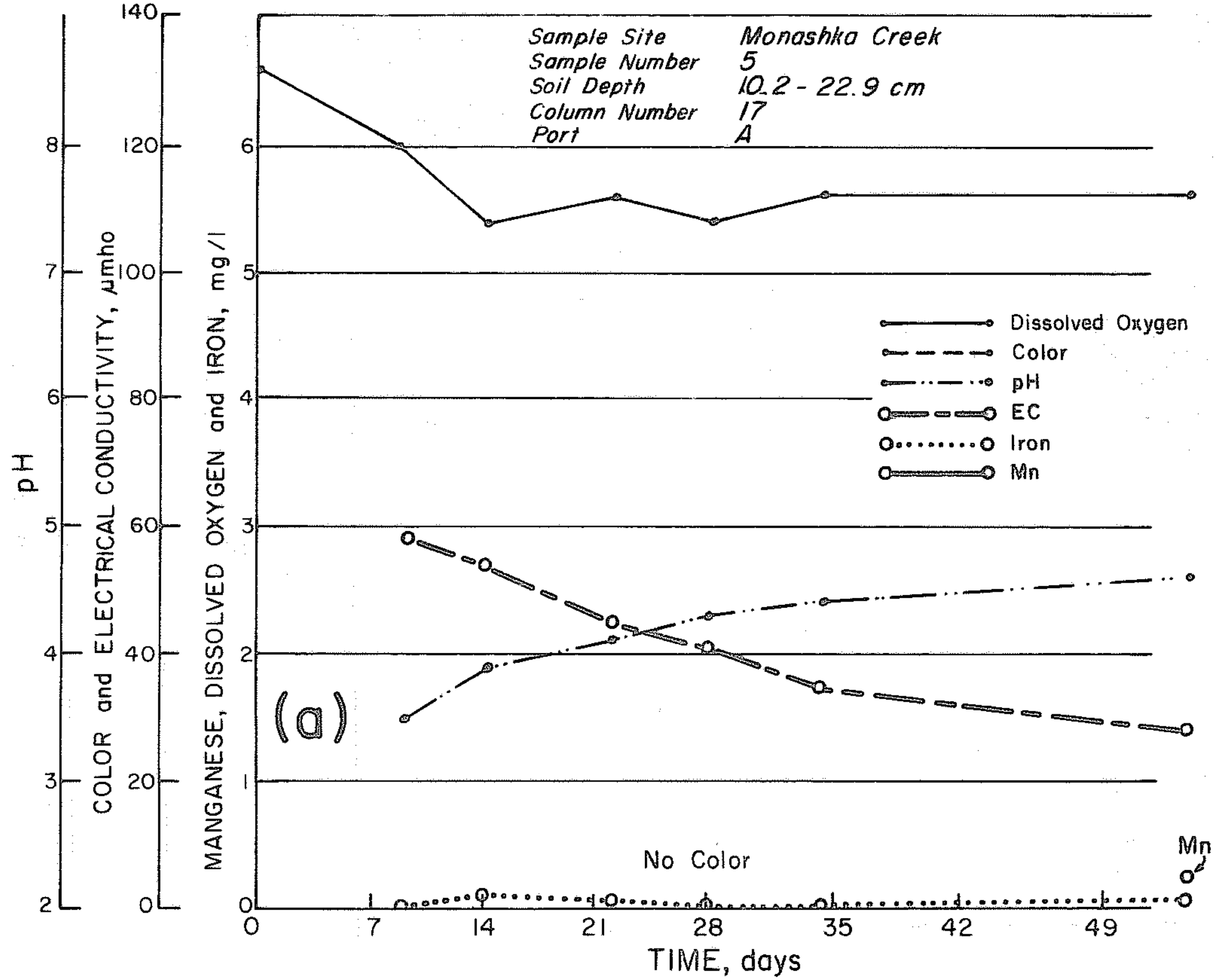
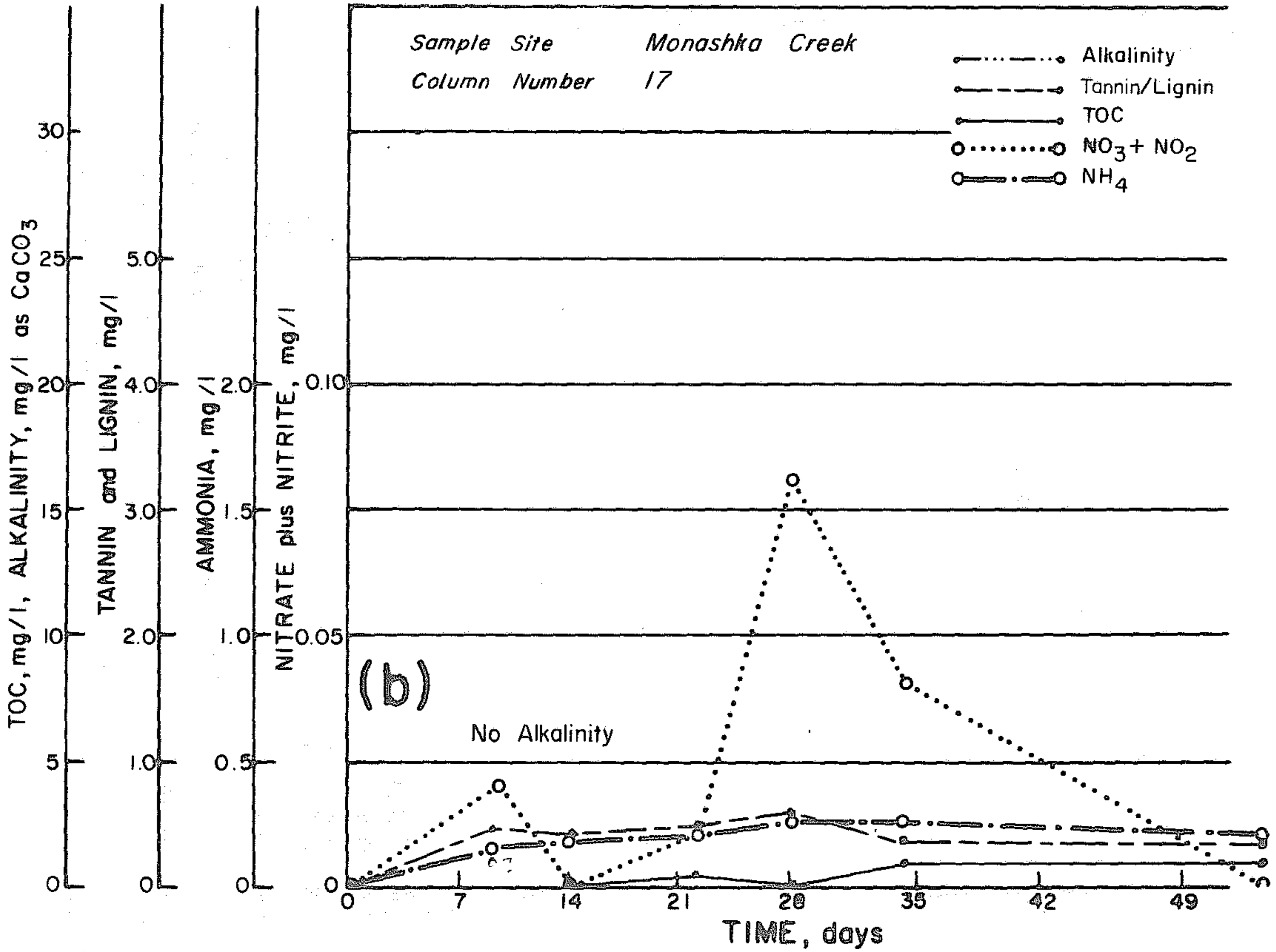

Sample Site Monashka Creek
Sample Number 5
Soil Depth 10.2 - 22.9 cm
Column Number 17
Port A
Dissolved Oxygen
Color
pH
EC
Iron
Mn
(a)
No Color
Mn
pH
COLOR and ELECTRICAL CONDUCTIVITY, μmho
MANGANESE, DISSOLVED OXYGEN and IRON, mg/l
TIME, days

FIGURE 34-b



Sample Site Monashka Creek
Column Number 17
Alkalinity
Tannin/Lignin
TOC
$NO_3 + NO_2$
NH_4
(b)
No Alkalinity
TOC, mg/l, ALKALINITY, mg/l as $CaCO_3$
TANNIN and LIGNIN, mg/l
AMMONIA, mg/l
NITRATE plus NITRITE, mg/l
TIME, days

FIGURE 35-a

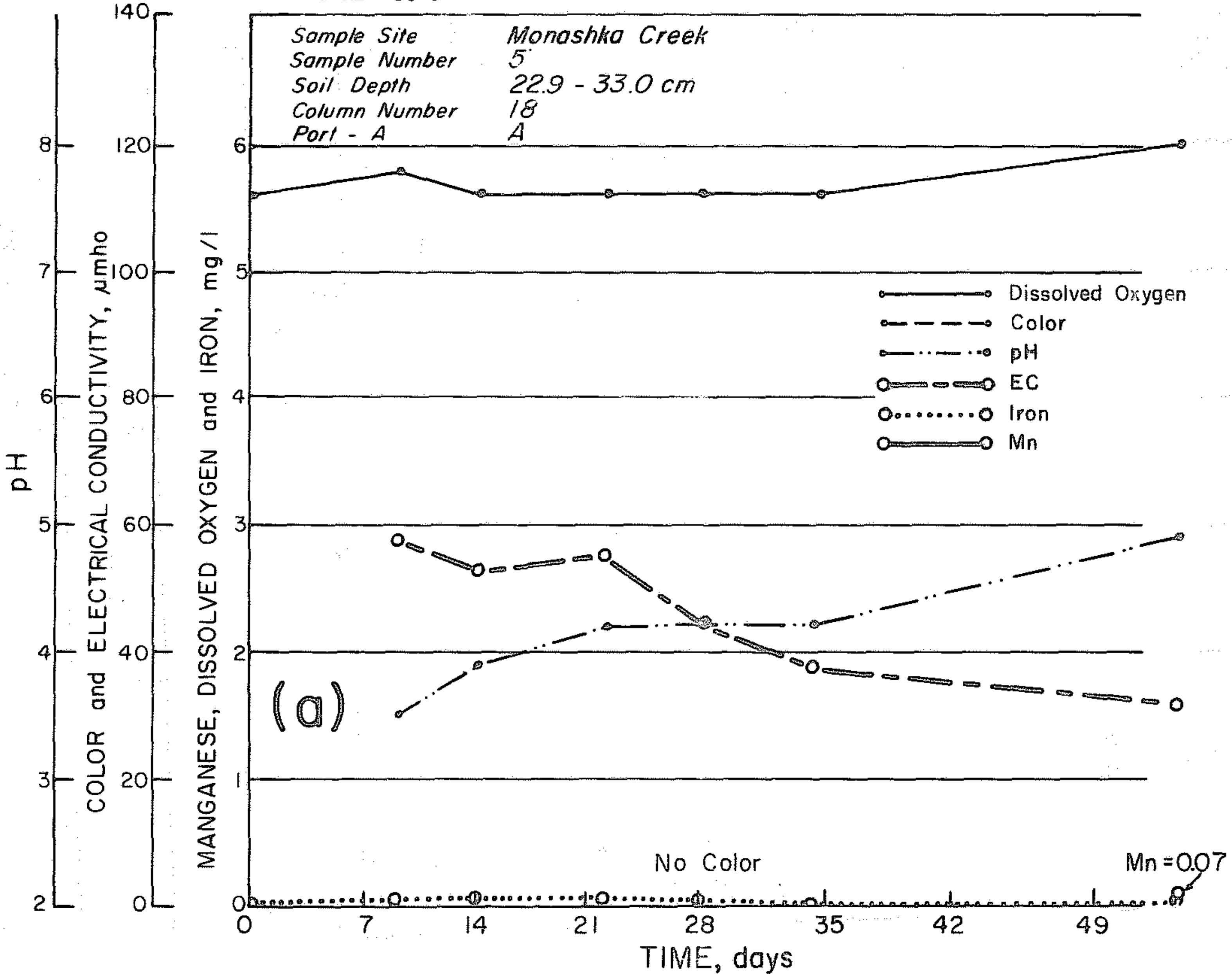

Sample Site Monashka Creek
Sample Number 5
Soil Depth 22.9 - 33.0 cm
Column Number 18
Port - A A
Dissolved Oxygen
Color
pH
EC
Iron
Mn
(a)
No Color
Mn = 0.07
pH
COLOR and ELECTRICAL CONDUCTIVITY, μmho
MANGANESE, DISSOLVED OXYGEN and IRON, mg/l
TIME, days
0
7
14
21
28
35
42
49
2
3
4
5
6
7
8
20
40
60
80
100
120
140
1

FIGURE 35-b

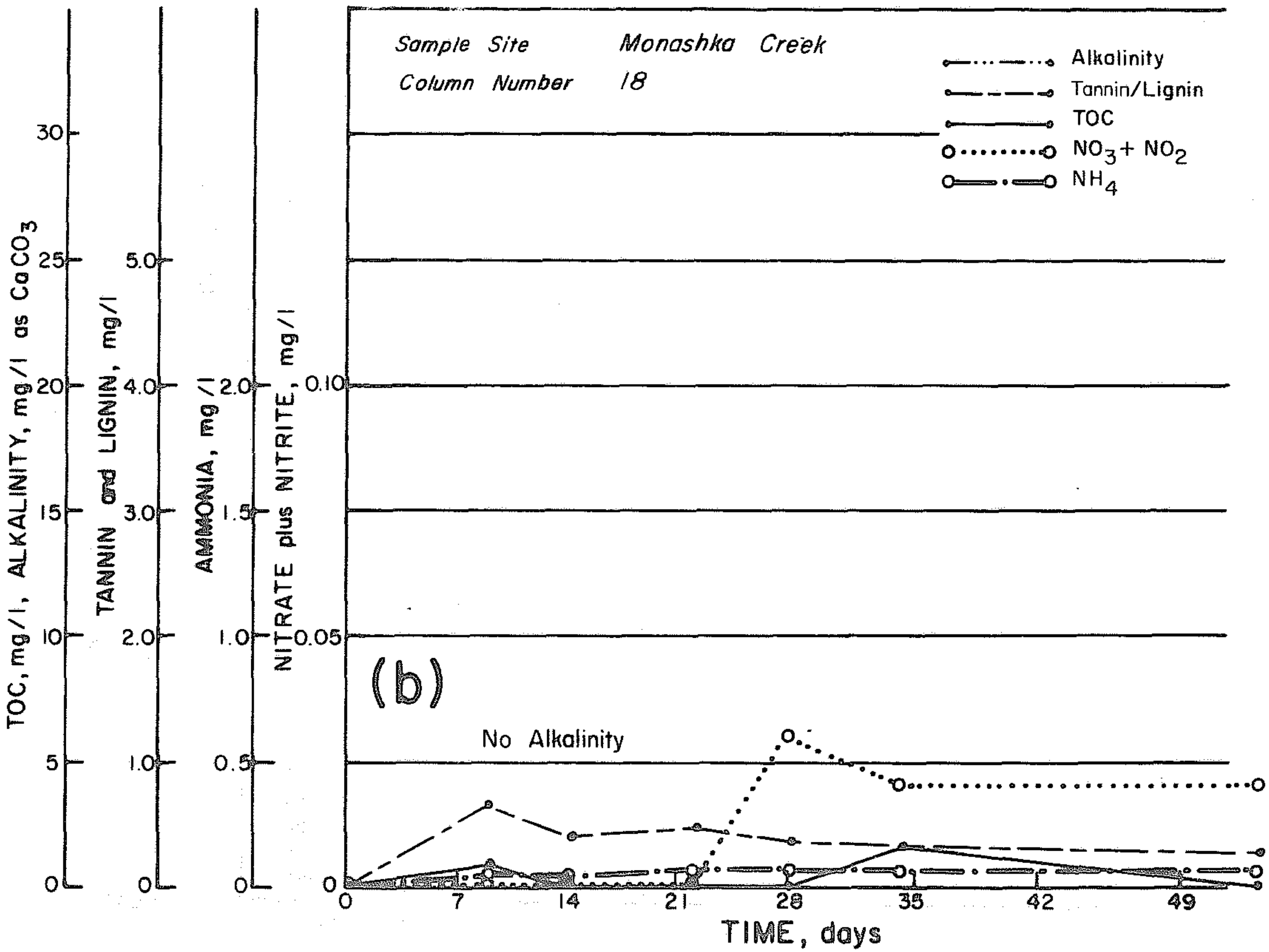
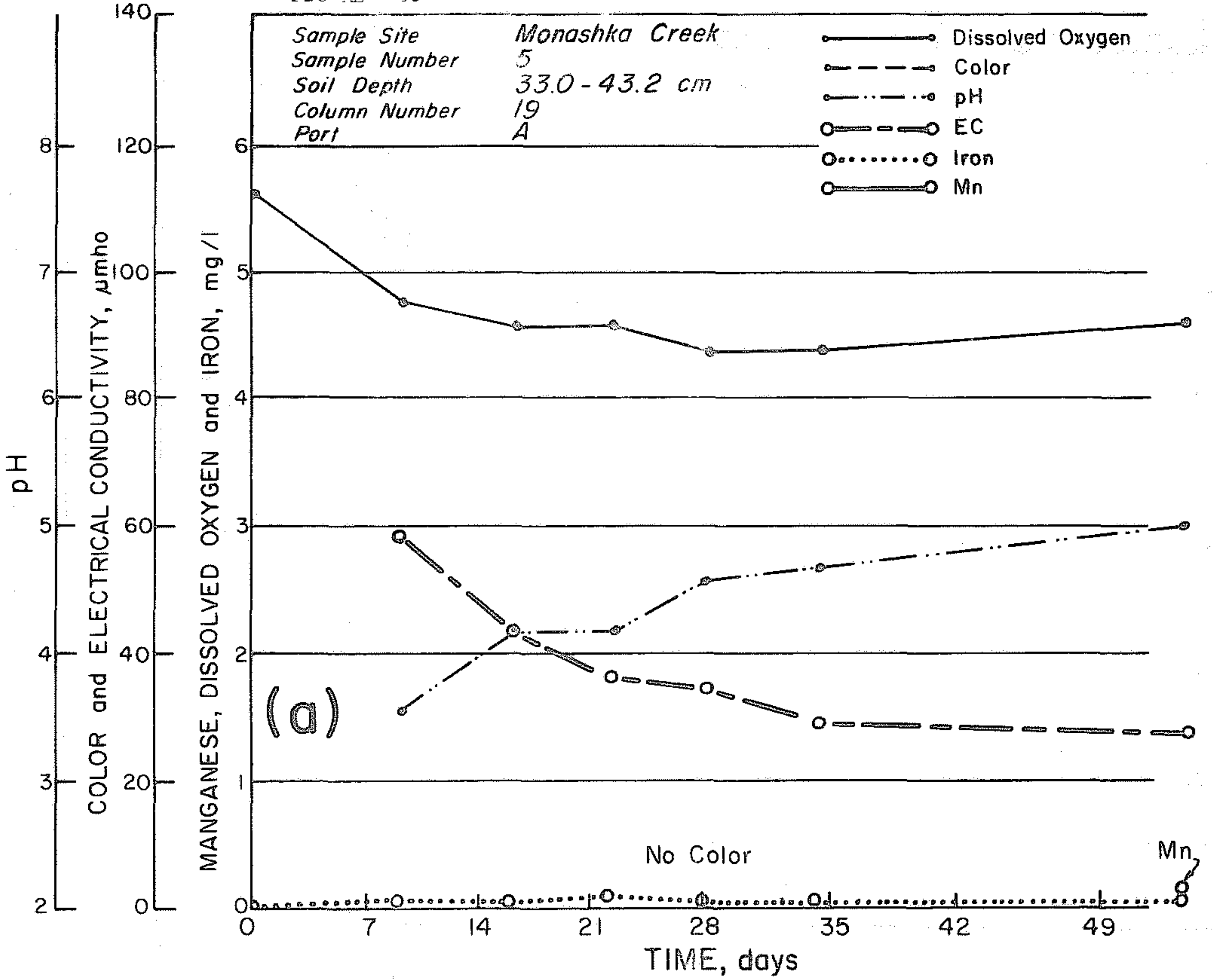
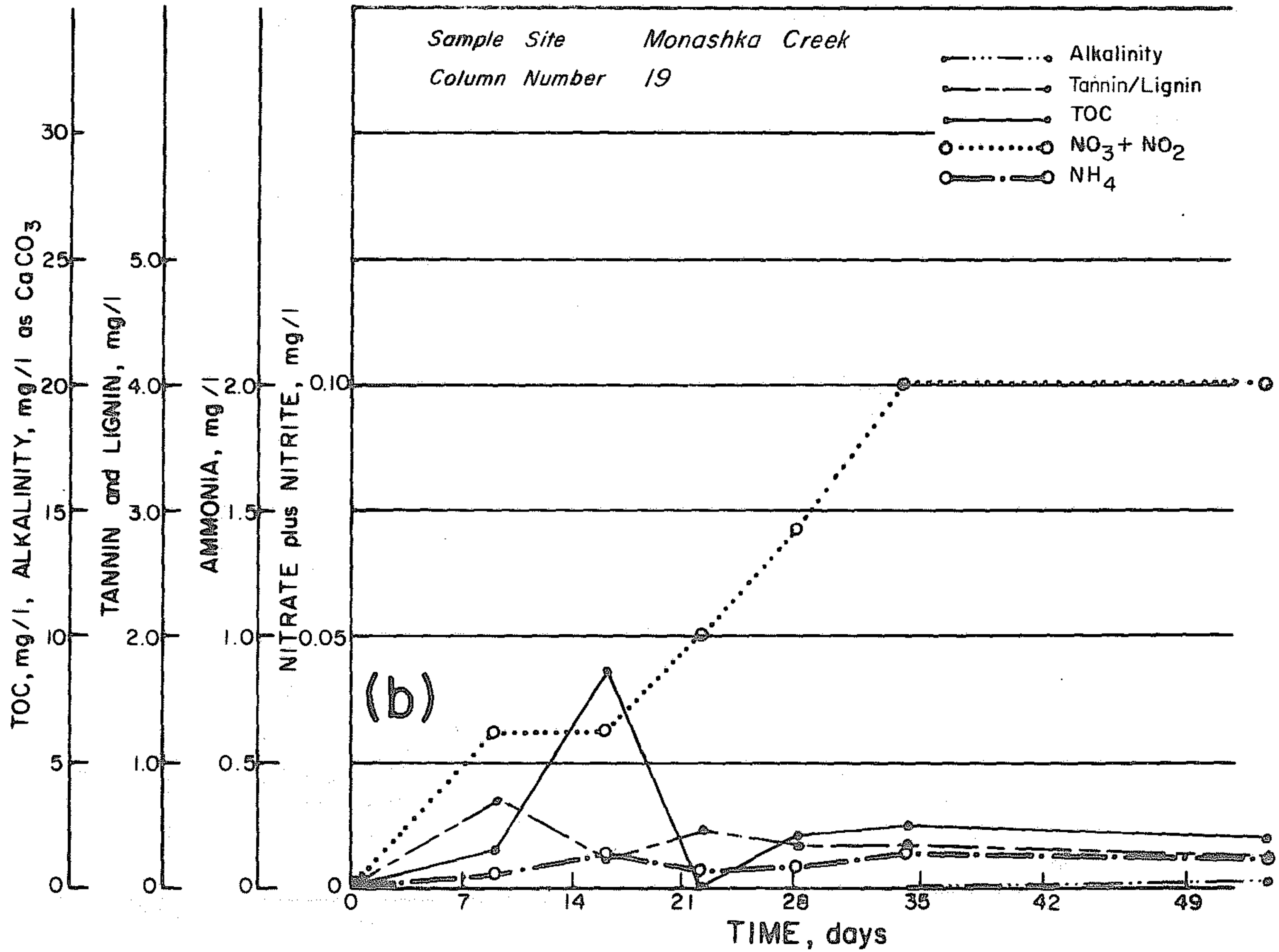

Sample Site Monashka Creek
Column Number 18
Alkalinity
Tannin/Lignin
TOC
$NO_3 + NO_2$
NH_4
(b)
No Alkalinity
TOC, mg/l, ALKALINITY, mg/l as $CaCO_3$
TANNIN and LIGNIN, mg/l
AMMONIA, mg/l
NITRATE plus NITRITE, mg/l
TIME, days

FIGURE 38-4


Sample Site Monashka Creek
Sample Number 5
Soil Depth 33.0 - 43.2 cm
Column Number 19
Port A
Dissolved Oxygen
Color
pH
EC
Iron
Mn
(a)
No Color
Mn
pH
COLOR and ELECTRICAL CONDUCTIVITY, µmho
MANGANESE, DISSOLVED OXYGEN and IRON, mg/l
TIME, days

IGURE 36-



Sample Site Monashka Creek
Column Number 19
Alkalinity
Tannin/Lignin
TOC
NO3 + NO2
NH4
(b)
TOC, mg/l, ALKALINITY, mg/l as CaCO3
TANNIN and LIGNIN, mg/l
AMMONIA, mg/l
NITRATE plus NITRITE, mg/l
TIME, days
0
7
14
21
28
35
42
49

FIGURE 37-

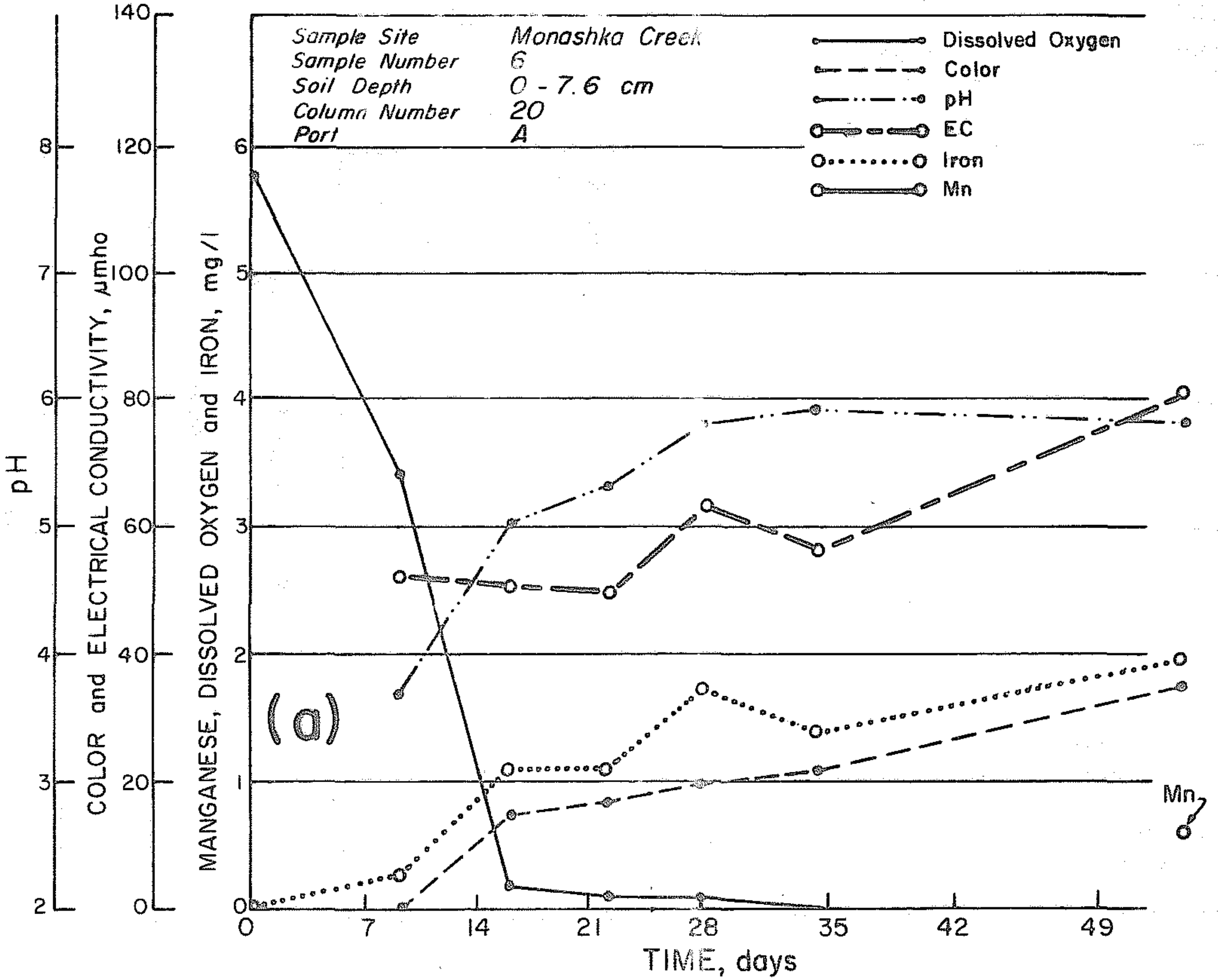

Sample Site Monashka Creek
Sample Number 6
Soil Depth 0 - 7.6 cm
Column Number 20
Port A
Dissolved Oxygen
Color
pH
EC
Iron
Mn
(a)
Mn
pH
COLOR and ELECTRICAL CONDUCTIVITY, µmho
MANGANESE, DISSOLVED OXYGEN and IRON, mg/l
TIME, days

FIGURE 37-b

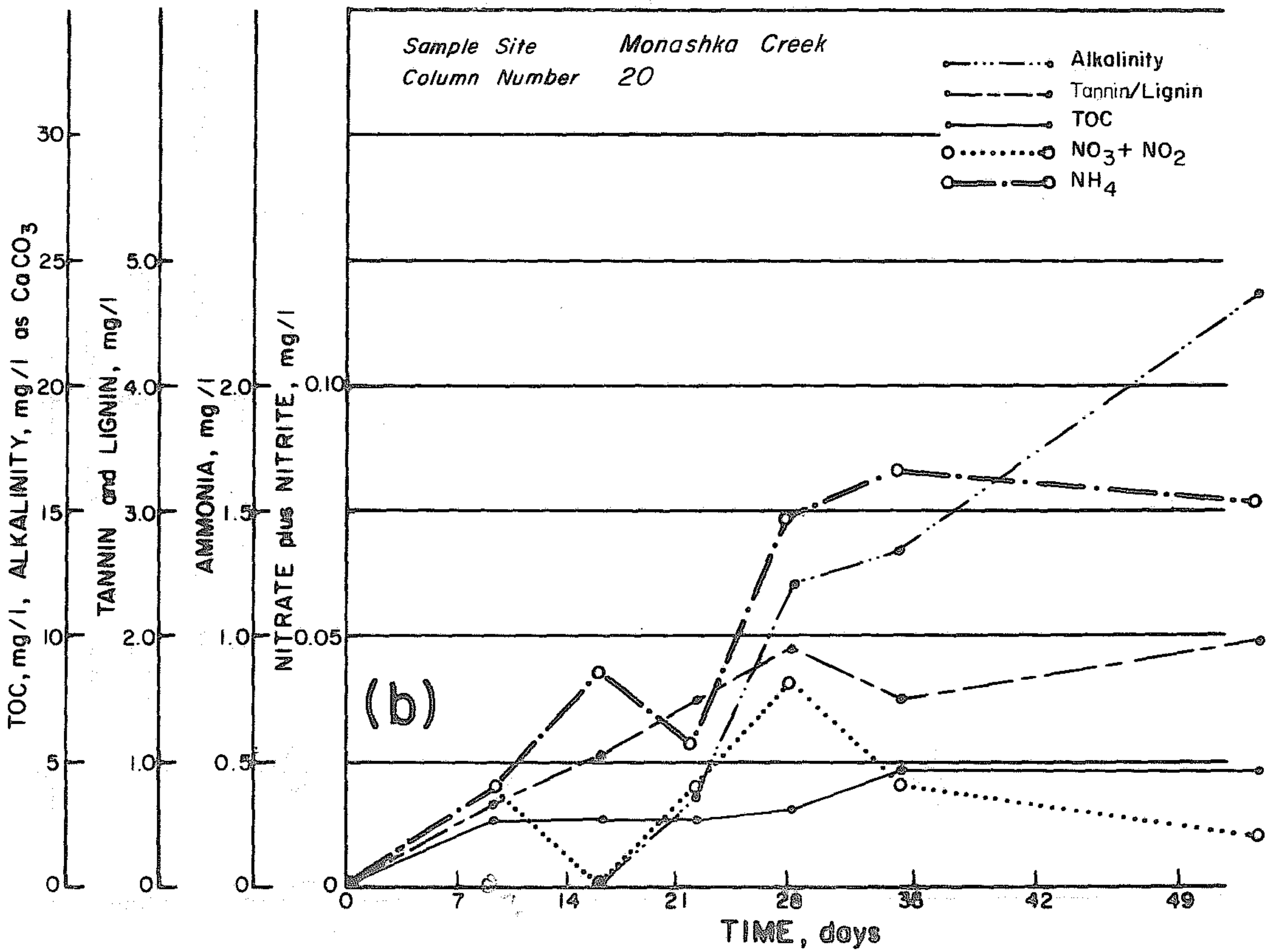
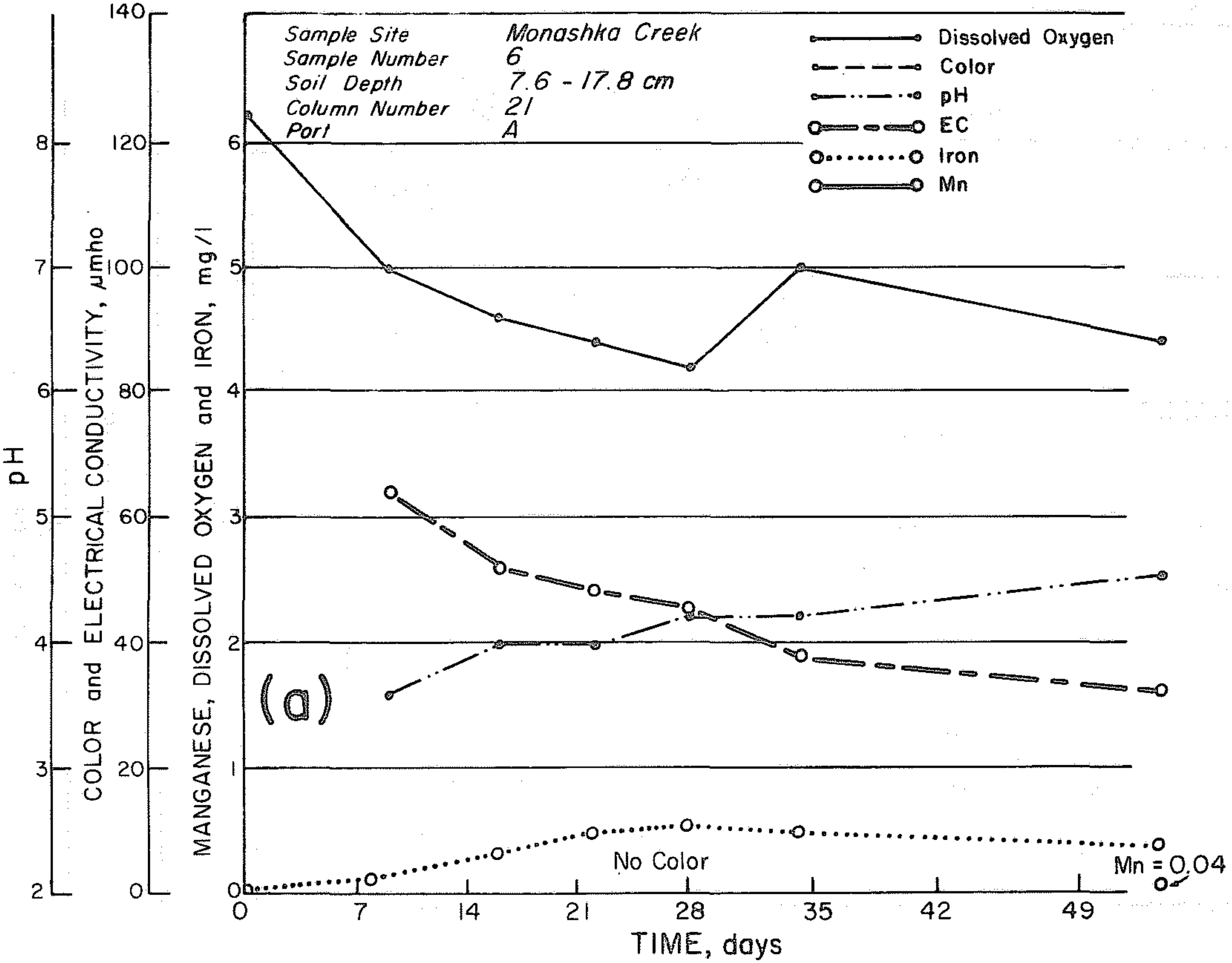
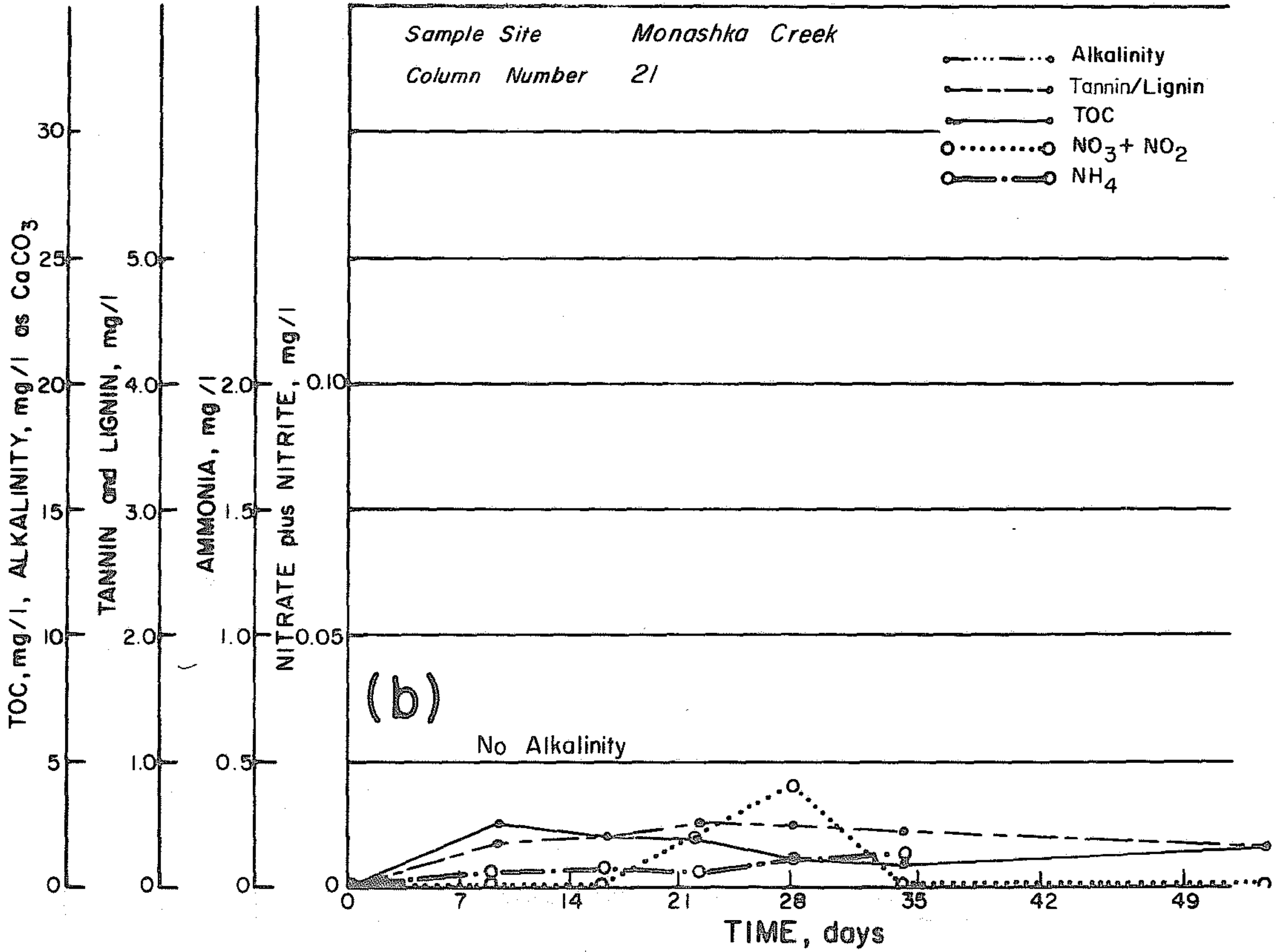

Sample Site Monashka Creek
Column Number 20
Alkalinity
Tannin/Lignin
TOC
$NO_3 + NO_2$
NH_4
(b)
TOC, mg/l, ALKALINITY, mg/l as $CaCO_3$
TANNIN and LIGNIN, mg/l
AMMONIA, mg/l
NITRATE plus NITRITE, mg/l
TIME, days
0
5
10
15
20
25
30
1.0
2.0
3.0
4.0
5.0
0.5
1.5
0.05
0.10
7
14
21
28
35
42
49

FIGURE 38-a



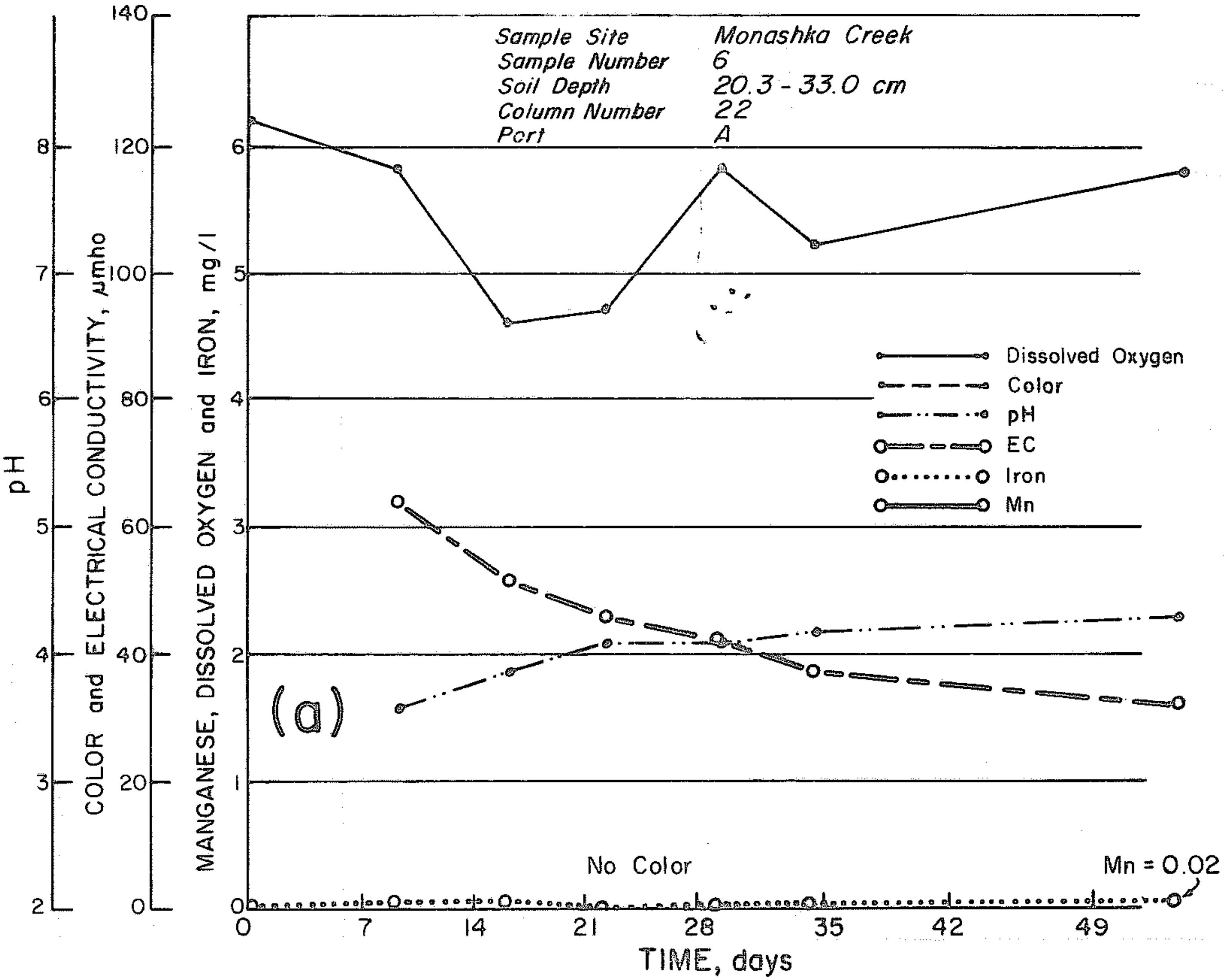
Sample Site Monashka Creek
Sample Number 6
Soil Depth 7.6 - 17.8 cm
Column Number 21
Port A
Dissolved Oxygen
Color
pH
EC
Iron
Mn
(a)
No Color
Mn = 0.04
pH
COLOR and ELECTRICAL CONDUCTIVITY, μmho
MANGANESE, DISSOLVED OXYGEN and IRON, mg/l
TIME, days

FIGURE 38-b



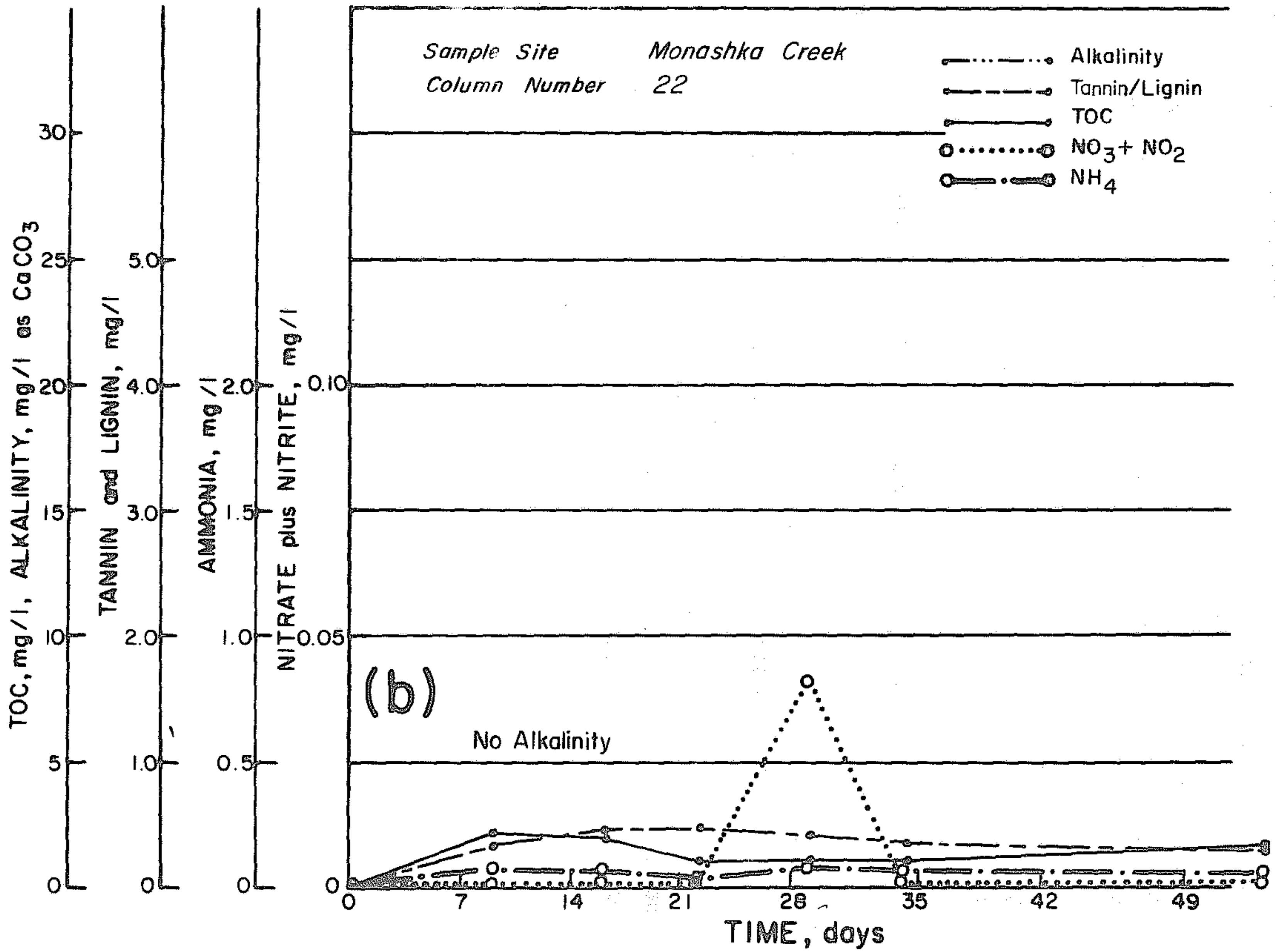
Sample Site Monashka Creek
Column Number 21
Alkalinity
Tannin/Lignin
TOC
$NO_3 + NO_2$
NH_4
(b)
No Alkalinity
TOC, mg/l, ALKALINITY, mg/l as $CaCO_3$
TANNIN and LIGNIN, mg/l
AMMONIA, mg/l
NITRATE plus NITRITE, mg/l
30
25
20
15
10
5
0
5.0
4.0
3.0
2.0
1.0
0
2.0
1.5
1.0
0.5
0
0.10
0.05
0
0
7
14
21
28
35
42
49
TIME, days

FIGURE 39-a



Sample Site Monashka Creek
Sample Number 6
Soil Depth 20.3 - 33.0 cm
Column Number 22
Port A
Dissolved Oxygen
Color
pH
EC
Iron
Mn
(a)
No Color
Mn = 0.02
pH
COLOR and ELECTRICAL CONDUCTIVITY, µmho
MANGANESE, DISSOLVED OXYGEN and IRON, mg/l
TIME, days

FIGURE 38-b


Sample Site Monashka Creek
Column Number 22
Alkalinity
Tannin/Lignin
TOC
$NO_3 + NO_2$
NH_4
(b)
No Alkalinity
TOC, mg/l, ALKALINITY, mg/l as $CaCO_3$
TANNIN and LIGNIN, mg/l
AMMONIA, mg/l
NITRATE plus NITRITE, mg/l
0 5 10 15 20 25 30
0 1.0 2.0 3.0 4.0 5.0
0 0.5 1.0 1.5 2.0
0 0.05 0.10
0 7 14 21 28 35 42 49
TIME, days

The surface layer of this tundra soil was a black root mat with 12.4 per cent organic matter.

Below the root mat was a brown silt layer containing a few rocks and having an organic content of 2.6 per cent; 29 per cent was fine material; 57 per cent was sand; and 14 per cent was gravel.

The last sample leached was a dark tan gravel mixed with fines from 35.6 to 45.7 cm below the surface. The organic content was 3.6 per cent. The fines comprised 43 per cent, the sand 49 per cent and gravel 8 per cent.

<u>Conclusions and Recommendations</u>: Figures 40 through 42 show the results of leaching different layers of soil from the Barrow reservoir site. Leaching of the surface layer showed depletion of oxygen resources and undesirable increases in alkalinity and other constituents. The second layer down produced the best quality leachate and the deepest layer released much color and iron. The permafrost directly below the deepest layer prevents drainage, thus trapping soluble constituents. Stripping the top 10 centimeters of material is recommended; however, this would be of marginal value which may be changed upon economic analysis.

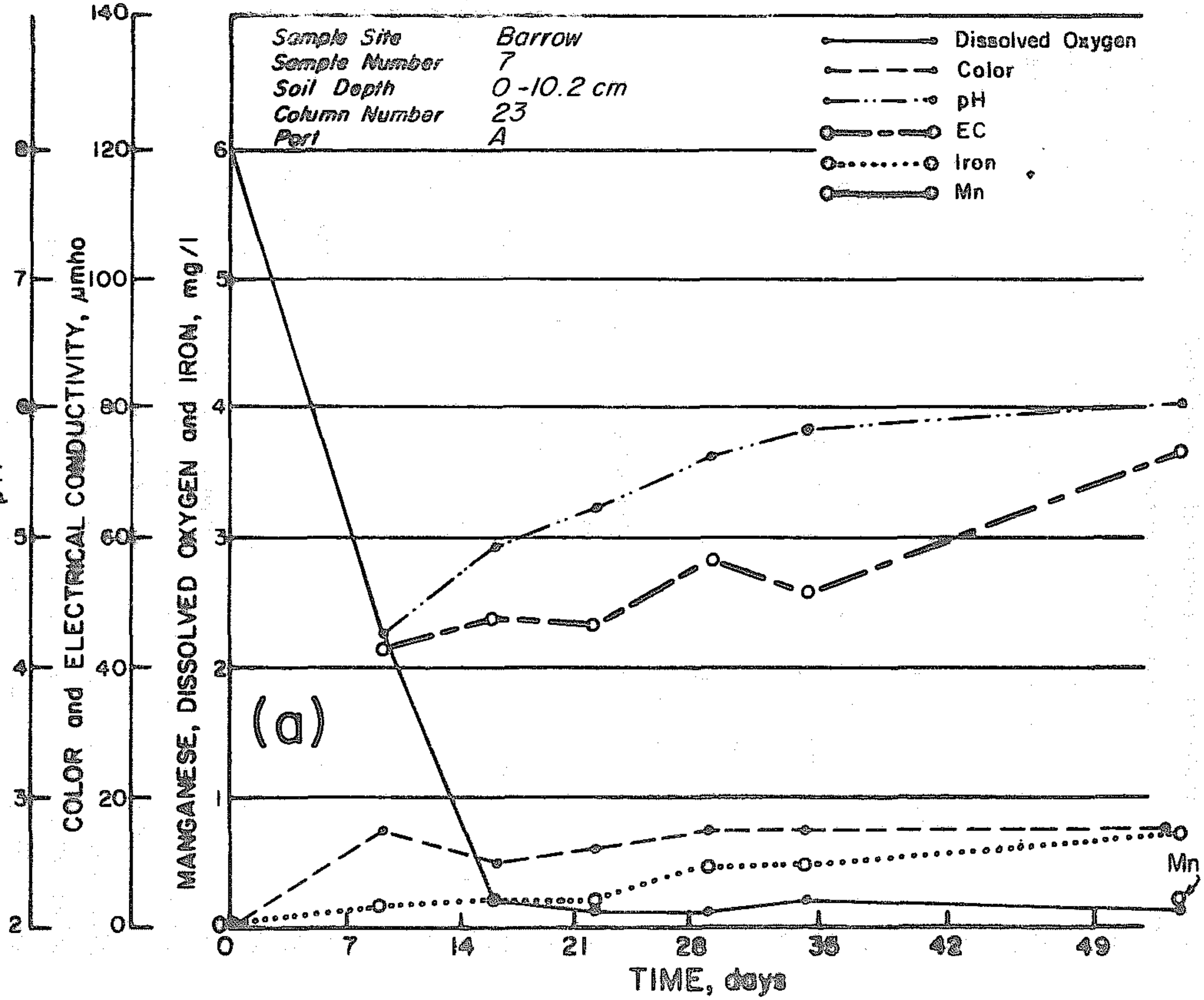
WATER QUALITY RELATIONSHIPS

The relationship between a reservoir site and the resultant water quality is dependent on a number of interrelated processes such as stratification, eutrophication, evaporation, sedimentation, ice cover, etc. These are discussed in the Literature Review (published separately as noted in the Preface). One of the most useful relationships reported in the literature, also seen in the data reported here, was that between the organic content of the inundated soil and water quality. This section details that relationship in terms of apparent color, iron, tannin-lignin, TOC and some of the nitrogen forms.

Soil Organic Content vs. Leachate: Graphical study of all data collected indicated that a general trend exists between various leachate constituents and the amount of organic material present in the soil. As could be expected, dissolved oxygen remained high in columns with low organic content and fell in columns containing appreciable organics. This fact is supported in the work of Ingols (1959) and Sylvester and Carlson (1961). Three soil samples had high organic contents but the water columns remained high in oxygen. All three samples were from deep within the soil profile so, it appears that deeper, covered, and older organic material does not degrade the overlaying water as much as fresh, recently submerged organic material. The same columns also remained low in concentration of other constituents. Sylvester and Carlson (1961) report similar findings.

A positive relationship was observed to exist between organic content in the soil and the concentration of total organic carbon, tannin/lignin, electrical conductivity, manganese, and the nitrogen forms (ammonia and nitrate plus nitrite). At the 95 per cent level it was not possible to establish a reliable correlation equation between organic content and the other parameters noted above. The results do, however, indicate that the removal of organic material is one of the most important considerations in site preparation. The work of Ingols (1959), Sylvester and Carlson (1961), Sylvester and Seabloom (1965), and Keup *et al.* (1970) substantiate the advantages to be gained by removal of organic material. Other investigators,

FIGURE 40-a


Sample Site Barrow
Sample Number 7
Soil Depth 0-10.2 cm
Column Number 23
Port A
Dissolved Oxygen
Color
pH
EC
Iron
Mn
(a)
Mn
pH
COLOR and ELECTRICAL CONDUCTIVITY, μmho
MANGANESE, DISSOLVED OXYGEN and IRON, mg/l
TIME, days
0
7
14
21
28
35
42
49
2
3
4
5
6
7
8
0
20
40
60
80
100
120
140
0
1
2
3
4
5
6

F·GURE 40-b

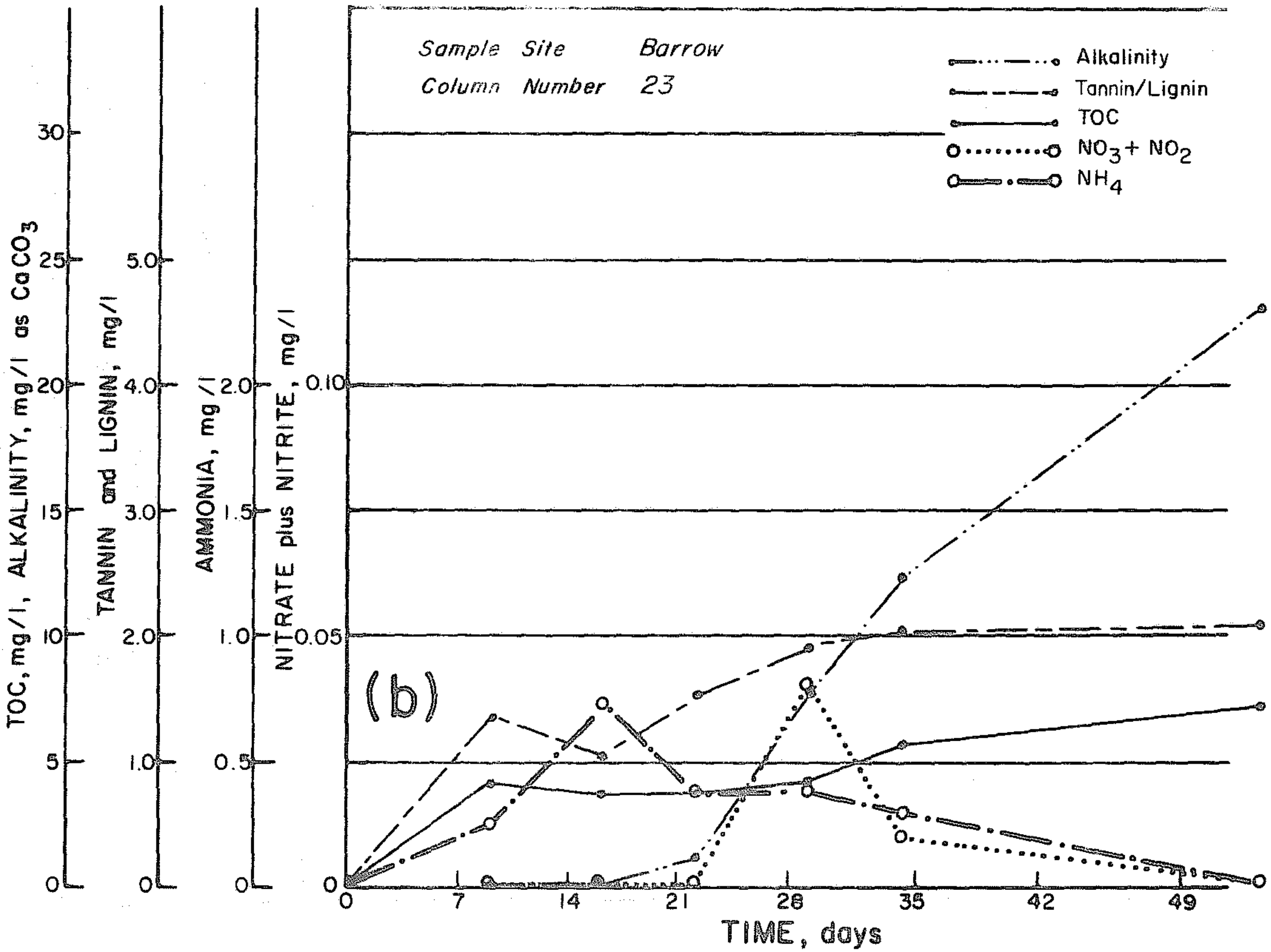

Sample Site Barrow
Column Number 23
Alkalinity
Tannin/Lignin
TOC
$NO_3 + NO_2$
NH_4
(b)
TOC, mg/l, ALKALINITY, mg/l as $CaCO_3$
TANNIN and LIGNIN, mg/l
AMMONIA, mg/l
NITRATE plus NITRITE, mg/l
TIME, days
0
5
10
15
20
25
30
1.0
2.0
3.0
4.0
5.0
0.5
1.5
0.05
0.10
7
14
21
28
35
42
49

FIGURE 41-a

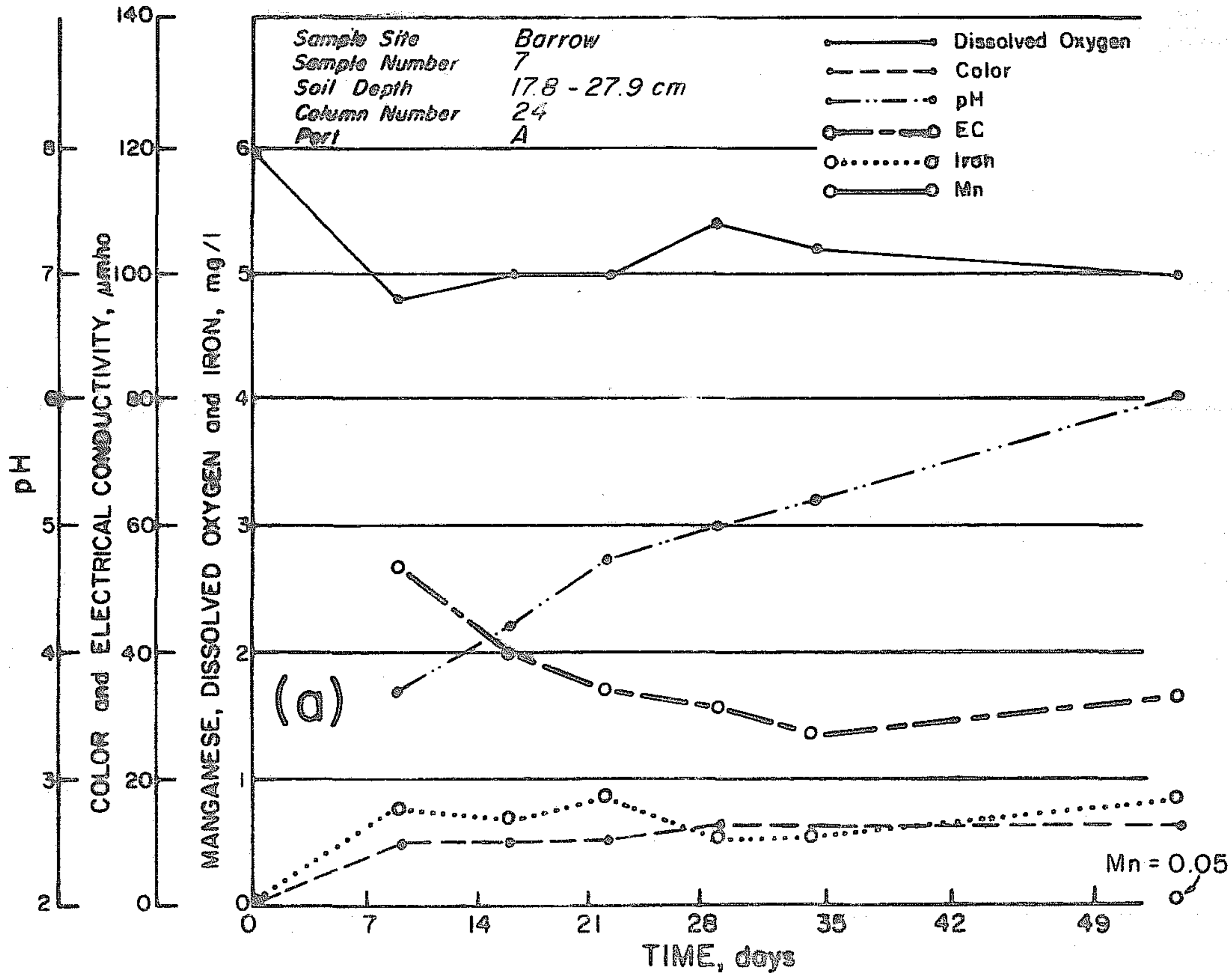
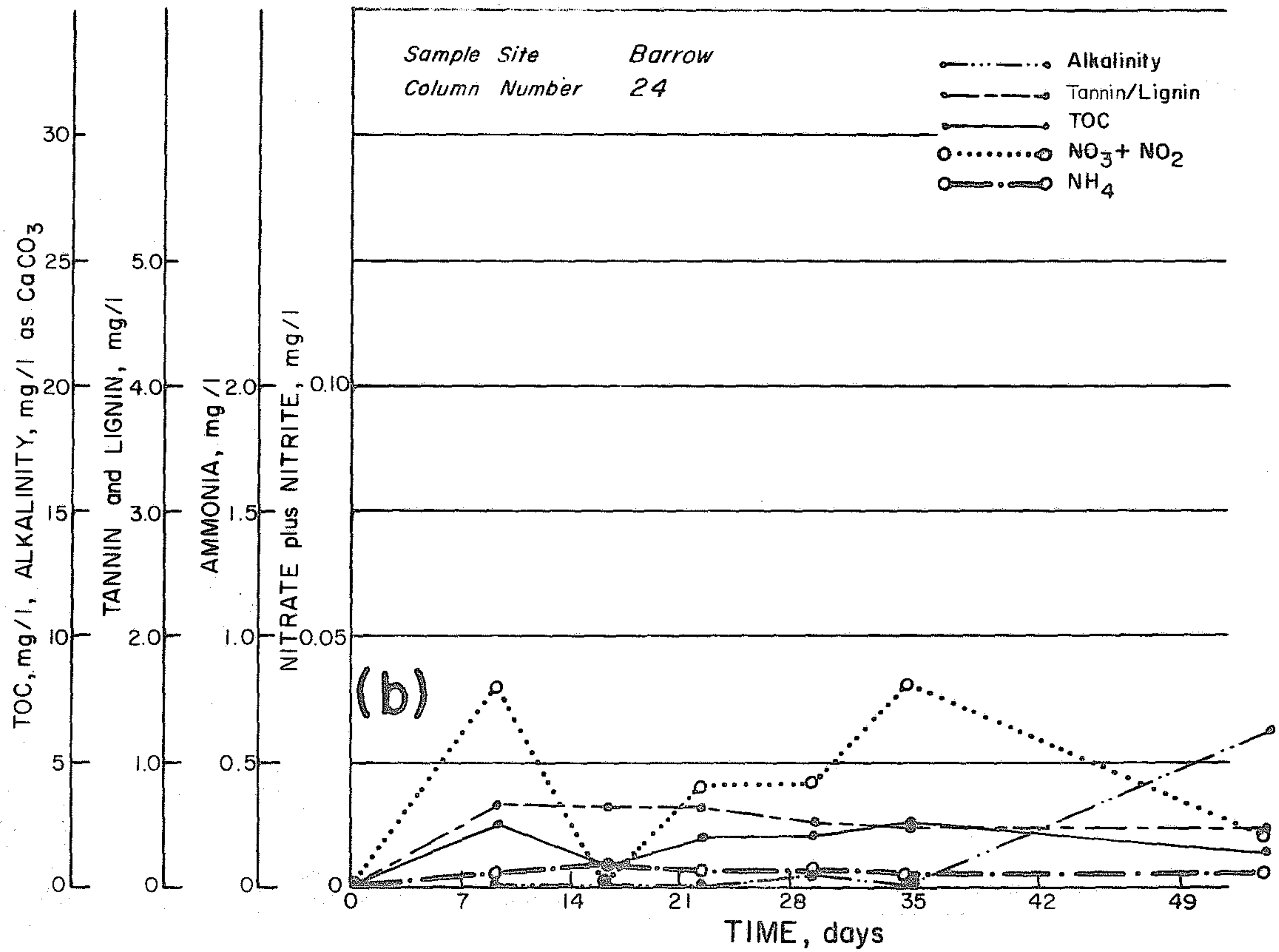

Sample Site Barrow
Sample Number 7
Soil Depth 17.8 - 27.9 cm
Column Number 24
Part A
Dissolved Oxygen
Color
pH
EC
Iron
Mn
(a)
Mn = 0.05
pH
COLOR and ELECTRICAL CONDUCTIVITY, µmho
MANGANESE, DISSOLVED OXYGEN and IRON, mg/l
TIME, days

FIGURE 41-b



Sample Site Barrow
Column Number 24
Alkalinity
Tannin/Lignin
TOC
$NO_3 + NO_2$
NH_4
(b)
TOC, mg/l, ALKALINITY, mg/l as $CaCO_3$
TANNIN and LIGNIN, mg/l
AMMONIA, mg/l
NITRATE plus NITRITE, mg/l
TIME, days
0
5
10
15
20
25
30
1.0
2.0
3.0
4.0
5.0
0.5
1.5
0.05
0.10
7
14
21
28
35
42
49

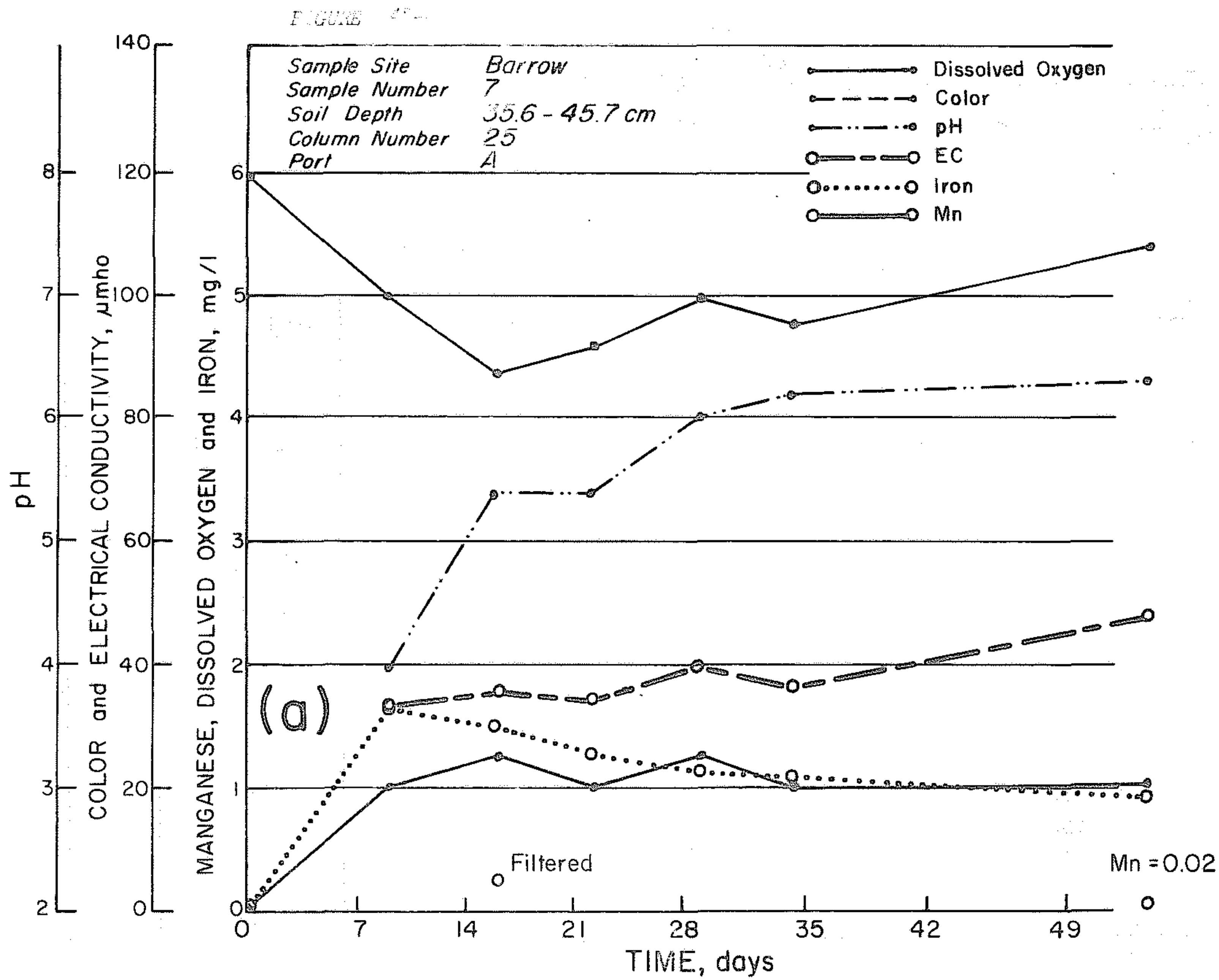
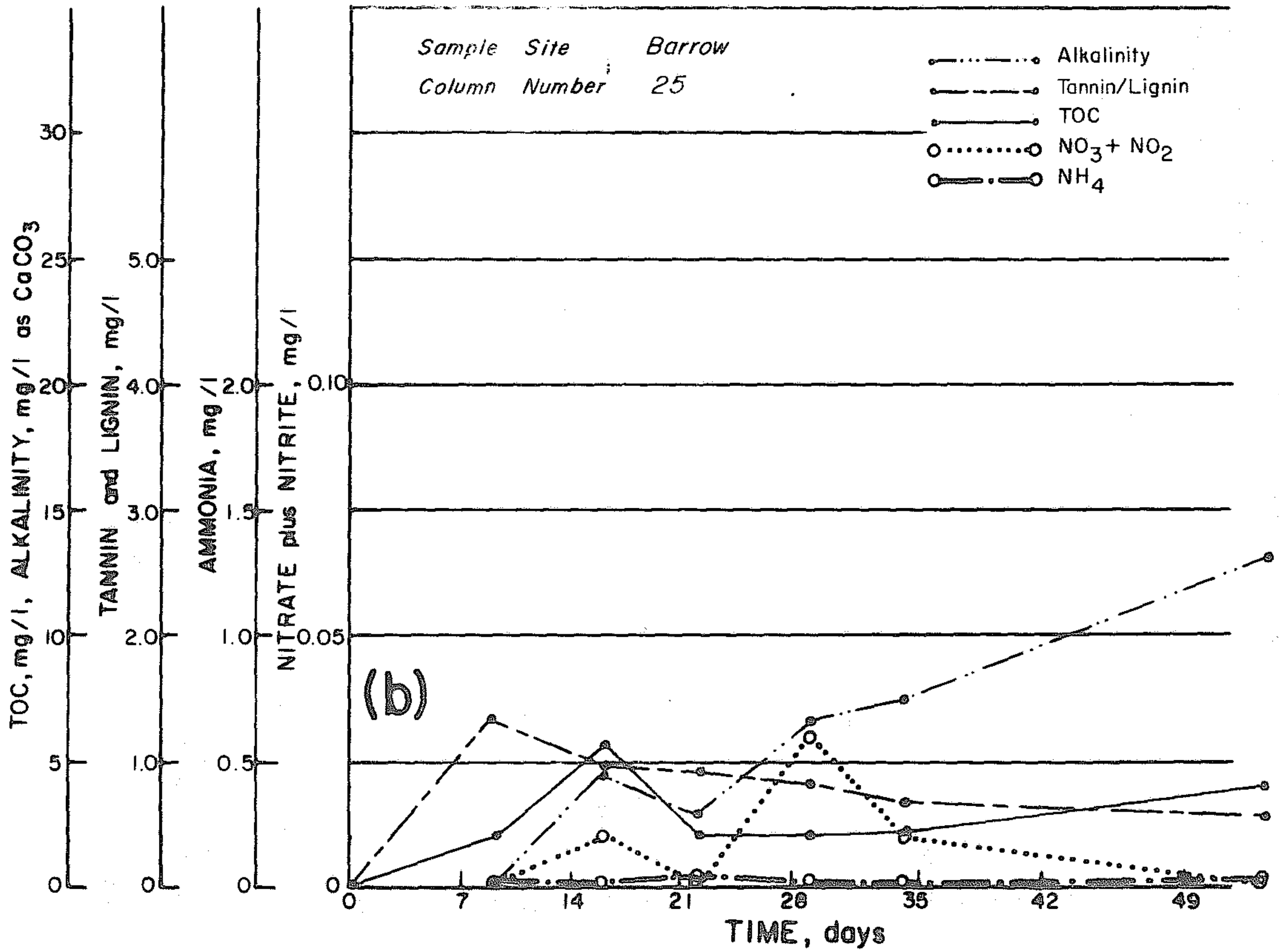


FIGURE
Sample Site Barrow
Sample Number 7
Soil Depth 35.6 - 45.7 cm
Column Number 25
Port A
Dissolved Oxygen
Color
pH
EC
Iron
Mn
(a)
Filtered
Mn = 0.02
pH
COLOR and ELECTRICAL CONDUCTIVITY, μmho
MANGANESE, DISSOLVED OXYGEN and IRON, mg/l
TIME, days
0
7
14
21
28
35
42
49
2
3
4
5
6
7
8
20
40
60
80
100
120
140
1


Sample Site Barrow
Column Number 25
Alkalinity
Tannin/Lignin
TOC
NO3 + NO2
NH4
(b)
TOC, mg/l, ALKALINITY, mg/l as CaCO3
TANNIN and LIGNIN, mg/l
AMMONIA, mg/l
NITRATE plus NITRITE, mg/l
TIME, days

Sylvester and Seabloom (1965) and Lawrence *et al.* (1971) suggest that burning of the organic material reduces the leaching potential (See the sections on carbon and leaching in the Literature Review for more information on this subject).

Color vs. TOC: A direct relationship was found between apparent color and the observed total organic carbon concentration change using only the surface soil samples. Figure 43 presents the data in a reduced form which will allow easy interpretation of the relative changes which can be expected. The 50 per cent confidence limits plotted show the reliability of the estimates.

Color vs. Tannin/lignin: From graphs and statistical analysis of color vs. tannin/lignin, it was apparent that some positive correlation exists, although the points are widely scattered. The points for columns 2, 6, 11, and 12 fall along fairly straight lines but the slope of the lines are quite different. Figure 44 presents the data in a statistically reduced fashion for easier handling. The data leads to the conclusion that a positive correlation exists between color and tannin/lignin for most sites, but the relationship at one location will not necessarily apply at another site or even at a different depth at the same site. Keup *et al.* (1970) found good correlation between color and tannin/lignin. More on their work is presented in the section on leaching.

Color vs. Iron: As shown in Figure 45 apparent color correlates well with iron, more so than with TOC or tannin/lignin. The graphs show a fair amount of scatter but there is a definite trend for color to increase with iron concentration. This result was expected. Some samples, such as 6 and 10, fall in a fairly straight line but not with the bulk of the data.

Nitrogen Relationships: The analysis of nitrogen forms showed nitrate plus nitrite to reach a maximum in the second to fourth week and then fall to low values as reducing conditions developed. Ammonia values either remained low, presumably because microorganisms were consuming the oxidized

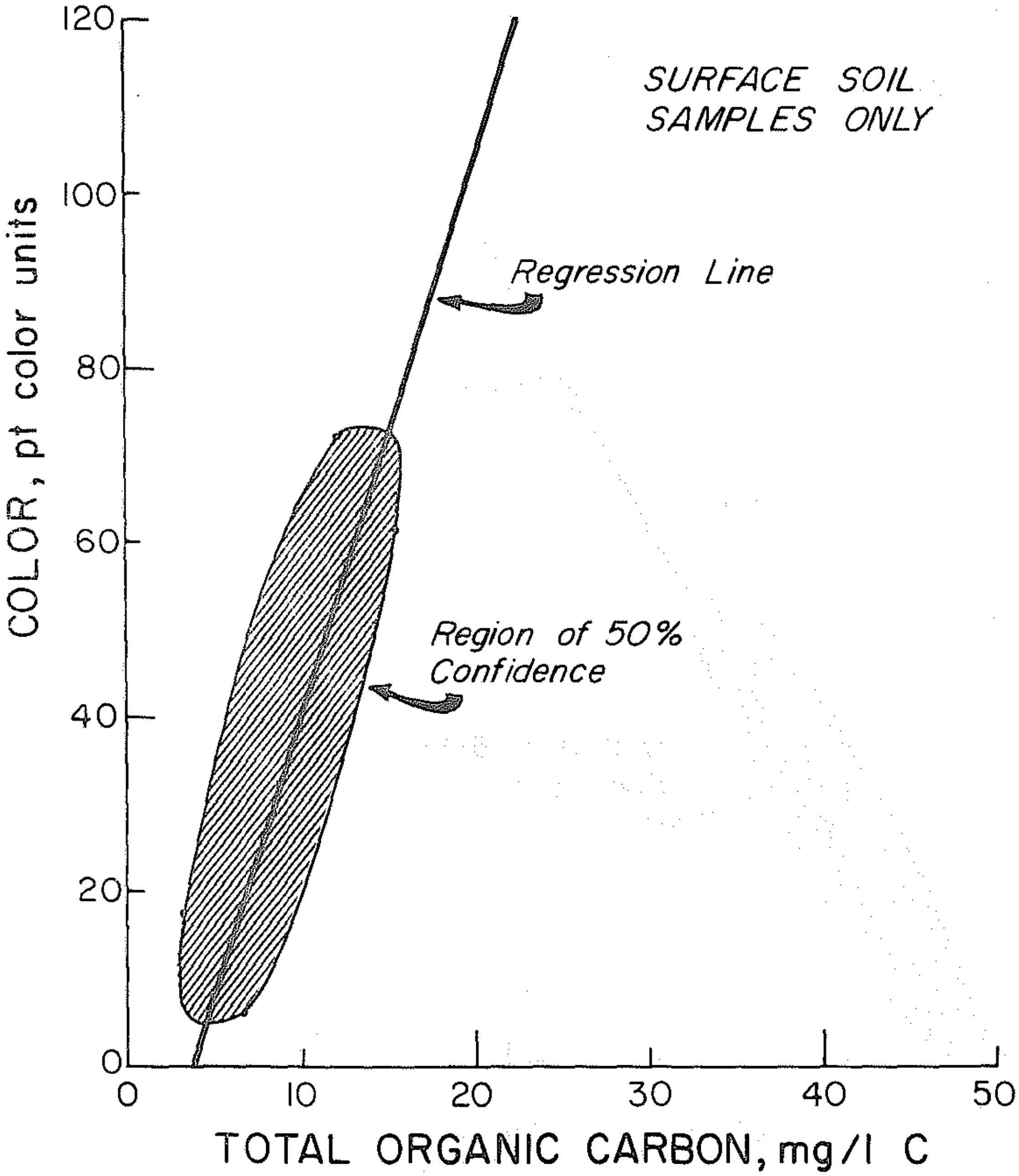


FIGURE 43: Color vs. Total Organic Carbon.

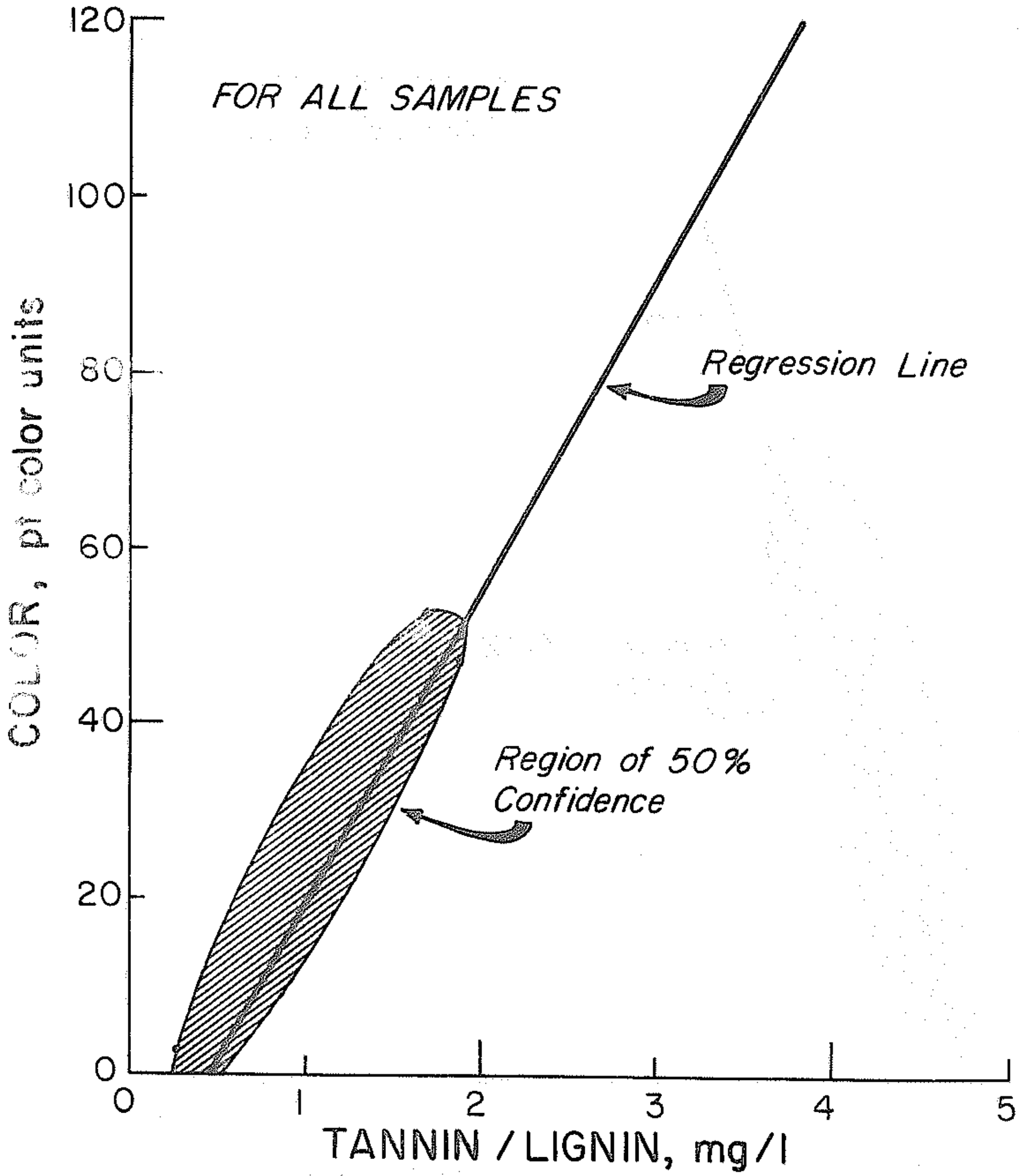


FIGURE 44: Color vs. Tannin/Lignin.

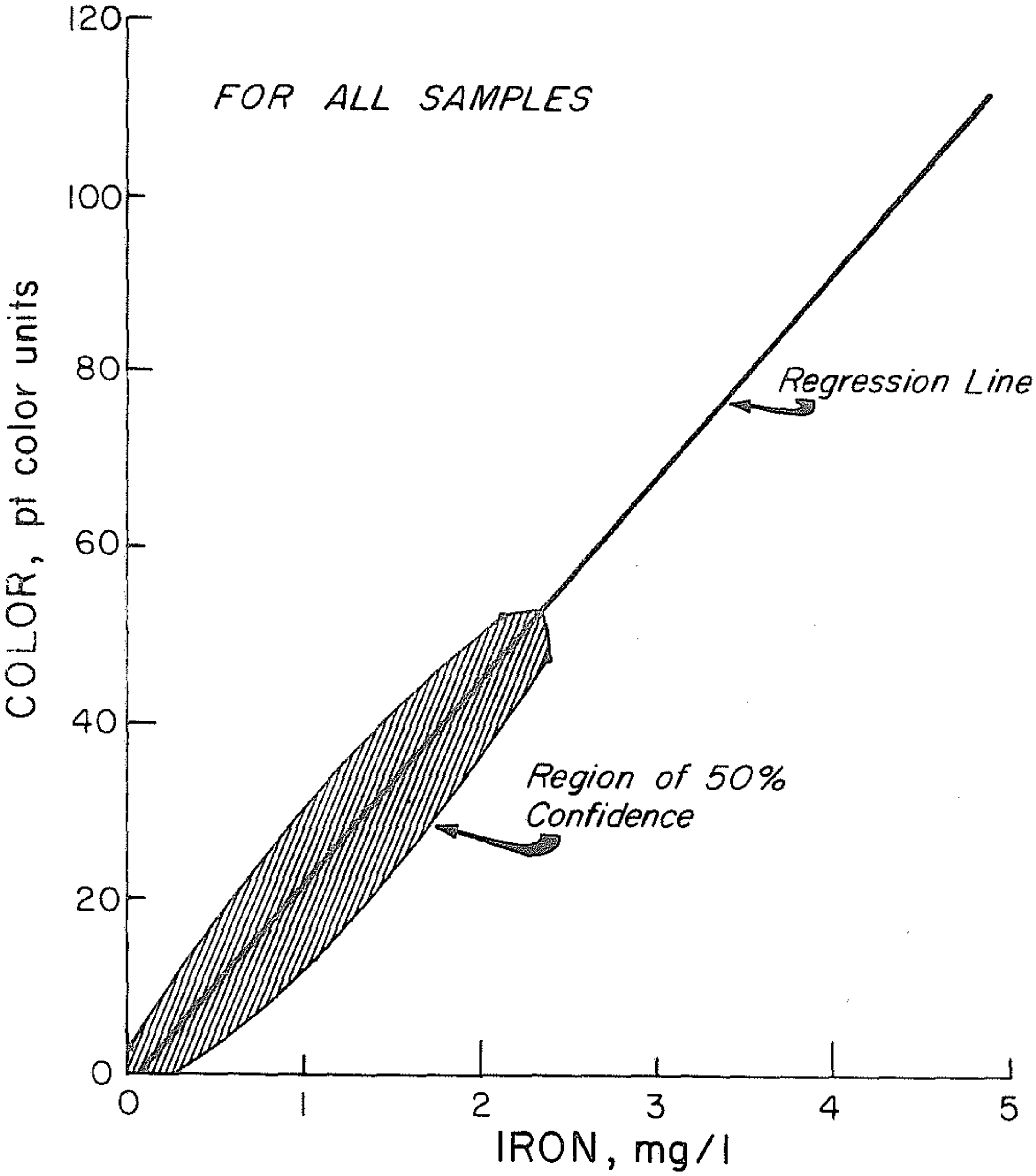


FIGURE 45: Color vs. Iron.

forms of nitrogen, or rose steadily as nitrate and nitrite were reduced. Figure 10 (column 2, Port A) is a typical example of nitrogen being reduced to NH_4^+ and Figure 13 (column 5, Port A) shows the behavior when microorganisms consume the nitrogen forms. Similar reactions were reported by Mortimer (1941, 1942) and Hutchinson (1957). See the section on nitrogen in the Literature Review for more detailed information.

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