WATER QUALITY STATUS REPORT NO. 91

MUNICIPAL WASTEWATER SLUDGE STOCKPILING AND THE EFFECT ON SOIL AND SOIL WATER
Latah County, Idaho
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Idaho Department of Health and Welfare
Division of Environmental Quality
Water Quality Bureau
1410 N. Hilton
Boise, Idaho 83706

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ABSTRACT

With the increased interest in the land application of municipal wastewater sludge, it is necessary to better understand the potential impacts of the sludge on the underlying soils and soil waters. In this study a sludge stockpile was instrumented using neutron probe access ports, suction lysimeters, and shallow monitoring wells. In addition to the above instrumentation, soil samples were collected under and adjacent to the sludge stockpile before and after its placement.

The results of this study indicated that the presence of the sludge stockpile did not cause measureable heavy metal or fecal coliform bacteria contamination in the underlying soil and soil water, but it did cause a nutrient enrichment in the soil water in the immediate vicinity of the stockpile. The nutrient enrichment in the soil and soil water was more pronounced in the soil and soil water adjacent to the stockpile than under the stockpile itself. This distribution of nutrient enrichment indicates that runoff from the stockpile contributes more to their potential for nutrient enrichment than does the passage of leachate through the stockpile.

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I. INTRODUCTION

A. GENERAL

On February 4, 1986, the United States Environmental Protection Agency (E.P.A.) proposed rule 51 FR 4458 which required states to develop sludge management programs that complied with Federal sludge utilization and disposal standards. The E.P.A. regulatory program was structured to assure that environmentally safe procedures are utilized in sludge management plans and that the Federal standards promulgated under 405(d) for the use and disposal of sludge were met.

On February 4, 1987, Congress passed the Water Quality Act of 1987, which amended the current Clean Water Act. This amendment included significant changes to the sludge management provisions as outlined in Section 405(d) of the Federal standards.

On March 9, 1988, the E.P.A. amended the state sludge management program requirements to include those additional requirements and directions established in the amendments to the Water Quality Act of 1987. As part of this revision the existing National Pollutant Discharge Elimination System (N.P.D.E.S.) permit requirements and procedures were changed to incorporate sludge permitting and state sludge management program requirements.

In addition to the above listed regulation changes, the E.P.A. once more revised the existing rules and regulations for the management and disposal of sludge and sludge products. The emphasis of this revision will actively promote those municipal sludge management practices that provide for the beneficial use of sludge while maintaining or improving environmental quality and protecting public health. The roles and responsibilities of the agencies involved in the implementation of the E.P.A. sludge management policies are as outlined below:

1. E.P.A. is responsible for establishing the basic program regulatory requirements for sludge management and providing an oversight role.

2. The State of Idaho is responsible for ensuring that an effective sludge program is implemented by the governing municipality.

3. Each municipality is reponsible for the operation and maintenance of an appropriate Federal and State approved sludge management program.

The ever increasing emphasis by the E.P.A. and the State of Idaho Division of Environmental Quality (D.E.Q.) on the proper management and disposal of municipal wastewater sludge, has caused a major problem for the City of Lewiston, Idaho.

Prior to January 1988, the City of Lewiston disposed of their sludge at the Asotin County landfill site in neighboring Washington. When they were prohibited from taking their sludge to the Asotin county landfill, the City of Lewiston selected to stockpile their sludge east of the existing wastewater treatment plant site while they explored other handling and disposal alternatives. The City solicited public bids from contractors who were interested in contracting with the City for the removal and ultimate disposal of the stabilized wastewater sludge. The selected low bidder was Agrow Technologies of Lewiston. Agrow Technologies proposed to land-apply the stabilized wastewater sludge on agricultural ground owned and operated by William Haxton and located northeast of Genesee. The intent was to land-apply the stabilized sludge during the months of August and September just prior to planting a crop of winter wheat.

The City of Lewiston was required to develop an approvable sludge management plan that could meet all of the E.P.A. and D.E.Q. rules and regulations for the disposal of the wastewater plant sludge. The City elected to require Agrow Technologies, as a condition of their contract, to develop an E.P.A. approvable sludge management plan. The different aspects of this plan had to address the potential risks to the environment and the public health, as well as the physical obstacles of handling, storage, and application.

Because the City of Lewiston's sludge has been anaerobically digested, it dewaters well to about 20 percent solids. It has an inoffensive odor, and the pathogens have been significantly reduced. Chemical coagulants are added to the digested sludge prior to the sludge being filter belt pressed and loaded for hauling to the land application site. Dewatering converts the digested sludge from a flowing mixture of liquids and solids to a cake-like substance, which can be handled as a solid. The wastewater sludge generated at the City of Lewiston's plant contains nutrients and organic matter that can be of value to the farmer as a fertilizer and a soil conditioner. Unfortunately the sludge also contains nutrients, heavy metals, and pathogens that, if not properly handled, could pose a risk to the environment and the public health.

B. THE PROBLEM

The sludge management plan for the City of Lewiston had to address nutrient loading, heavy metal loading, and pathogen reduction strategies in sufficient detail to satisfy the E.P.A. and D.E.Q. rules and regulations. The pathogen reduction rules and regulations for the sludge were primarily satisfied by the anaerobic digestion process that the City of Lewiston currently uses to process the sludge prior to dewatering. The nutrient loading to the agricultural ground is governed by the nitrogen as nitrate uptake of the winter wheat crop, which is estimated to be approximately 110 pounds per crop rotation. The nitrogen as nitrate loading limits the application rate of the wastewater sludge to appoximately three dry tons per acre per year. The heavy metal loading is currently limited to an accumulative loading over the life of the project site. Copper is the limiting metal with a total application life of approximately 20 annual applications to the same ground.

To increase the potential life of the disposal site and to reduce the environmental risks due to heavy metal contamination, the City of Lewiston has implemented a pretreatment program to reduce the heavy metal loadings in the sludge. Agrow Technologies and the City of Lewiston are also committed to an extensive monitoring program of the land application site soils, soil waters, and plant tissue as outlined in their sludge management plan.

For the City of Lewiston's proposed sludge management program to benefit the farmer, it is necessary for the City to stockpile the dewatered sludge from October of one year to August of the next year. The impact on the underlying soil and soil water due to leachate from the stockpile was an unknown. Because the land required to dispose of one year's sludge production is less than 200 acres and the contractor has a limited amount of time to apply all of the sludge generated in one year, it would be advantageous to be able to relocate the stockpiling site if necessary. Many different methods can be used to control runoff from sludge land application sites without major capital expenditures. The only method normally accepted for containing leachate from stockpiled sludge is an impermeable liner. This liner could be damaged easily by the loading and unloading of sludge, be fairly expensive to install and maintain, and would limit the flexibility of the land application process.

Because the quality and quantity of the leachate from the stockpiled sludge were unknown parameters, potential impacts to the underlying soil and soil water were completely unknown. During the first year of operation the State of Idaho Division of Environmental Quality agreed to assist the City of Lewiston and Agrow Technologies in instrumenting a portion of the stockpiled sludge. The intent of this instrumentation was to identify the quantity and quality of the leachate that would enter the underlying soil and soil water due to leaching of precipitation through the stockpiled sludge.

C. THE OBJECTIVE

The objective of this research was to instrument a portion of the stockpiled sludge and to identify the quantity and the characteristics of the leachate that entered the soil and soil water beneath the 12 to 18 inch thick sludge blanket as a result of seasonal precipitation and snow melt. Baseline heavy metal and nutrient data for the underlying soils was collected prior to the placement of the sludge blanket during the first part of October. After the sludge had been exposed to precipitation from October to May the following year, the soil was again sampled for heavy metals and nutrients. The results of the follow-up sampling of the soils indicated if the leachate transported heavy metals and/or excessive nutrients into the underlying soils.

To monitor the flow rate of leachate into the underlying soil two inch aluminum access ports for a neutron moisture measuring device were installed. The moisture contents were measured in the sludge blanket and the underlying soil at six inch depths on a monthly basis from September 1988 to May 1989 with the exception of January and February of 1989 when the neutron probe was out of service for repair. The varying moisture contents in the sludge blanket and underlying soils were used to identify the movement of leachate under the sludge blanket.

Tensiometers and suction lysimeters were used to identify both quantity and quality of soil water both immediately under the sludge blanket and adjacent to the sludge blanket. The extracted soil water was tested for nutrients and heavy metals. Because suction lysimeters can only be used when the moisture content in the soil is high enough to reduce the capillary tension to 70 centibars or less, soil water samples were only collected during the late spring. See appendix for figure depicting moisture content/capillary tension relationships.

During the soil profile investigation it was noted that a saturated zone had historically formed over the heavy clay soils at the four to five foot depth. Shallow monitoring wells were installed at the four corners of the instrumented site in an effort to sample this saturated zone when it developed. Soil water from this zone was tested for excess nutrient and heavy metals using the same procedures as were used for the other soil waters.

From the data collected above it was the intent of this research to identify the importance of placing an impermeable liner under the stockpiled wastewater sludge.

II. RELATED RESEARCH

The objective of this literature review is to provide a brief synopsis of the current level of knowledge concerning the effects of short-term stockpiling of municipal wastewater sludge on the underlying soil and soil water. There has not been a lot of work on the short term effects of stockpiling of municipal wastewater sludge, however, there has been a lot of work in the area of handling, treating, and land application of these sludges. Because confined animal feedlots are often times simply stockpiles of animal wastes, this review also includes those animal feedlot studies that are pertinent to the stockpiling of municipal wastewater sludge

A. Municipal Wastewater Sludge

The Federal Register (Vol. 53, No.46, Wednesday, March 9, 1988) Proposed Rules, defines sewage sludge as "any solid, semi-solid, or liquid residue which contains materials removed from municipal or domestic wastewater during treatment, including primary and secondary solids, septage, and portable toilet pumpings." In reality, the physical and chemical properties of municipal wastewater sludge are functions of numerous factors, including composition of the influent wastewater, extent of industrial pretreatment, extent of nonpoint pollution sources, and type of wastewater treatment. Because of these factors, sludge quantity and composition are highly variable among treatment plants. Furthermore, the daily fluctuations in sludge properties within a treatment plant are often greater than those differences seen between different wastewater plants (U.S.E.P.A. 1989). There are approximately 7.6 million dry tons of sludge generated by publicly owned treatment works in the United States each year as a consequence of treating municipal wastewater (U.S.E.P.A. 1989).

The City of Lewiston's wastewater treatment plant generates approximately 600 dry tons of anaerobically digested sludge each year. Anaerobically digested sludge is described by the U.S.E.P.A. document "POTW Sludge Sampling and Analysis Guidance Document" as "a thick slurry of dark-colored particles and entrained gases" (U.S.E.P.A. 1988). Lewiston's sludge is a well digested sludge which is dewatered in a filter

belt press to an average moisture content of approximately 20 percent dry solids by weight (City of Lewiston Sludge Management Plan 1988). The dewatering and chemical treatment process used converts the sludge from a flowing mixture of liquids and solids to a cake-like substance that can be easily handled as a solid by a truck and trailer.

The nutrient content of the sludge is within the normal range of expected values but due to the munitions and plating industries in the City of Lewiston some of the heavy metal levels are higher than the average of other communities in the United States. Table II-1.0 shows the characteristics of the City of Lewiston's wastewater sludge and compares it to the expected levels of heavy metals in an average domestic sludge.

TABLE II-1.0

SLUDGE CHARACTERISTICS

Parameters	City of Lewiston Average Level (1) ppm	Normal Sludge Average Level (2) ppm
Ammonia Nitrogen	9300	6540
Nitrate Nitrogen	0	490
TKN Nitrogen	50000	40000
Phosphate Phosphorous	14220	25000
Potassium	2073	-
Arsenic	11	11
Cadmium	11	16
Copper	3288	850
Lead	2124	500
Mercury	-	-
Nickel	514	82
Silver	53	-
Zinc	1608	1740

1. (City of Lewiston Sludge Management Plan, 1988)
2. (Reed and Matsumoto, 1988)

In addition to nutrients and heavy metals, the City of Lewiston's sludge most likely also contains pathogens. Studies to define the risk of infection by primary pathogens to people working with sewage wastes are not as extensive as might be expected, but available data indicate that the risk is probably low. The predominant route of infection from the waste material is through the mouth and therefore, prevention of infection involves such precautions as thorough washing of the hands before eating to prevent ingestion of pathogens (U.S.E.P.A., 1980). Some examples of pathogens that can be found in Lewiston's sludge are coliform and salmonella bacteria, protozoa, helminths, and hepatitus virus.

The anaerobic digestion system utilized at the City of Lewiston wastewater treatment plant is recognized by the U. S. Environmental Protection Agency as a process that significantly reduces pathogens. Once destroyed, viruses, helminths, protozoans, and most bacteria will not repopulate within the digested sludge because they cannot grow outside of their host organism. Salmonella, one of the most common organisms causing food poisoning, is an exception because it can regrow to a limited extent in the digested sludge (U.S.E.P.A., 1980).

B. Stockpiling and Storage of Sludge

There is limited data available on stockpile storage of municipal wastewater sludge which has been dewatered to 20-25% dry solids by weight. In the U.S.E.P.A. "Process Design Manual for Sludge Treatment and Disposal" (U.S.E.P.A., 1974), it is stated that "if wastewater solids are to be stored for any extended period of time, they must be stable. It is impractical to store unstabilized dewatered or partially dried sludge (sludge containing more than 10 percent and less than 30 percent solids) for much longer than three to four days because septic conditions and problems associated with septicity (odors, poor solids transport properties) can develop." This reference further states that "wastewater solids are usually stored in concentrated form. If these solids are biodegradable, indigenous oxygen supplies can readily be depleted and anaerobic decomposition begins. Anaerobic decomposition is often times accompanied by the production of undesirable odors."

The fact that anaerobic sludge storage facilities have been known to operate without the presence of nuisance odors certainly demonstrates that it is possible to stockpile sludge in an anaerobic state (U.S.E.P.A., 1979). If methane bacteria are present in an anaerobic sludge storage facility nuisance odors will not develop. Serious odor problems will develop, however, if for some reason the methane bacteria are destroyed. The top layer of stockpiled sewage sludge is dewatered and dried during periods of dry weather and as a result the methane bacteria die off, while inside the sludge pile the methane bacteria are healthy. With the presence of aerobic conditions on the surface and the presence of anaerobic conditions and methane bacteria in the pile, nuisance odor levels are very low. During precipitation periods or when the outer dried layer gets wet, anaerobic activity resumes and the nuisance odor level increases. Nuisance odor problems experienced with approximately 580 acres of sludge drying lagoons at San Jose, California, immediately following a rainstorm is an example of this type of problem (U.S.E.P.A 1979).

Despite the potential nuisance odor problems associated with the stockpiling of municipal wastewater sludges under anaerobic conditions, there are still some significant advantages to this mode of operation. First, storage areas can provide for additional disinfection due to pathogen die off with time (U.S.E.P.A., 1979). With long storage times a sludge's organics content and its content of pathogenic bacteria, viruses, and parasites will be greatly reduced (U.S.E.P.A. 1979). Secondly, the risk of nitrate transport to the underlying soil and soil water through leaching is greatly reduced because nitrates formed by the mineralized organic nitrogen can go through a denitrification process that volatilizes them and reduces the formation of oxyanions (Mielke, Swanson and McCalla, 1974).

In the U.S.E.P.A. "Process Design Manual for Sludge Treatment and Disposal," it is stated that mechanically dewatered stabilized sludge which has less than 25 percent dry solids by weight looses all semblance of stability when exposed to extensive rainfall. This did not appear to be the case with the City of Lewiston's sludge that was stockpiled throughout the winter without any major change in structural character.

C. Cattle Feedlot

Because animal feedlots are similar in nature to stockpiles of dewatered municipal sludge, studies conducted on feedlots are included in this

literature review. Manure, like wastewater sludge, serves as a food source for microorganisms. The microbial decomposition produces various by-products, such as organic gels and polysaccharides that reduce water infiltration by plugging the soil pores. In addition, infiltration of water is controlled by the most limiting layer which in feedlots is the combined effects of the surface and the interface layer (Mielke, Swanson and McCalla, 1974).

It was noted by Mielke, Swanson and McCalla that the hydrophilic substances in the manure swell and slow down water movement down through the feedlot accumulation. Because of this mechanism and the anaerobic conditions that exist under the surface of the feedlot floor, the chances of groundwater pollution by nitrates is greatly reduced. As stated earlier, under the anaerobic conditions which exist in the manure pile, the natural nitrogen cycle precludes the formation of the nitrate oxyanions and denitrifies any nitrate oxyanions that may leach down from the surface (I.D.H.W/D.O.E., 1987b). In the State of Idaho "Guidelines for Concentrated Animal Feeding Operations" it states that "data indicates that even for nonsurfaced feedlots, manure, moisture, and animal traffic form a nearly impermeable seal that impedes water movement into the soil."

According to McCalla and Elliott (1984), further study of the survival of pathogens in animal wastes is necessary to better understand the potential health risks. McCalla and Elliott also state that in laboratory tests salmonella added to beef cattle manure survived under anaerobic conditions but quickly died under aerobic conditions. Geldriech et al (1962) stated that if the feedlot is maintained under wet, anaerobic conditions pathogen survival is a possibility. Because sludge piles are normally wet and anaerobic in nature, the risk for salmonella to be present in the sludge should be considered. McCalla and Elliott (1984) summarized their paper by stating that feedlots with an aerobic surface will produce minimal odors and if an organic layer is maintained over a soil surface, the risk for downward movement of pollutants would be slight.

The sludge stockpile, like the accumulation of organic matter in a feedlot, forms an impervious layer which, with the organic matter in the soil profile, could provide an environment that is suitable for denitrification (McCalla, Elliott, Swanson , and Viets , 1970). McCalla et al (1984)

conducted an intensive study for approximately three and a half years on groundwater quality under a feedlot near Central City, Nebraska. The soils were sandy and permeable with a shallow groundwater table at approximately 2 1/2 to 10 feet, depending on the time of the year and the level of irrigation. In three years of monitoring the fifteen wells used in the study, the nitrate-nitrogen level in the groundwater exceeded ten parts per million only two times. The times that the ten parts per million of nitrate-nitrogen was exceeded, McCalla et al suspect that the source of the nitrate-nitrogen was from fertilized fields near the feedlot and not from the feedlot.

D. Land Application

Because of the abundance of data available on the land application of municupal wastewater sludge, this review will not attempt to be all encompassing and will instead concentrate on only those items that can be related directly to stockpiled sludge. The general areas of concern with respect to land application and stockpiling of wastewater sludge seem to be nutrients, heavy metals , and pathogen transport to groundwater.

Stamm and Walsh (1988) conducted a pilot study which compared the quality of leachate from anaerobically digested sludge to leachate from lime treated sludge. They determined that the leachate produced from anaerobically digested sludge was more benign than the leachate from lime treated sludge and thus posed a lower threat to groundwater. They were able to conclude from their work that rapid transfer of complex organic pollutants to the leachate and eventually to the groundwater does not occur.

Hermanson, Cogger, Engle and Smith (1987) noted in their work that certain persistent organic compounds such as PCB's are only a health threat if they are directly consumed. This is because organic compounds are held tightly by soils and are not taken up by plants. They also noted in their work that heavy metals pose little threat to the groundwater when they are applied at E.P.A. recommended rates because they are so tightly held on the cationic exchange sites in the soil matrix.

Unless soils have an extremely low cationic exchange capacity (CEC), the first limiting factor in the application of wastewater sludge to land sites is the nutrient level in the form of nitrogen as nitrate. According to Campbell (1987) nitrogen as nitrate moves with the water front and unlike the positively charged cations, it is not attracted and held by the soil matrix. Data suggest that fifteen to twenty percent of the organic nitrogen in wastewater sludge is mineralized to plant available forms the first year, with decreasing amounts converted each following year. In stockpiled sludges it can be assumed that twenty to seventy percent of the nitrogen as ammonia will be lost to the atmosphere in the form of ammonia gas. The exact proportion lost depends on the climatic conditions, sludge type and soil conditions (U.S.E.P.A, 1978).

Nitrogen is lost or removed from sludge and soil systems through the mechanisms of denitrification, crop uptake and harvest, ammonia volatilization and leaching. On a sludge stockpile site there is no loss due to crop uptake and harvest and little or no exchange between the soil and the sludge to facilitate the formation of nitrate oxyanions that could be leached to the groundwater. Because the stockpiled sludge is normally anaerobic a major vehicle for transport of nitrogen is through ammonia volatilization and denitrification (Campbell, 1987).

The majority of the data available on heavy metals in soils used for land application of municipal sludge, is related to the uptake of heavy metals by plants (U.S.E.P.A., 1977). Because many heavy metals are more soluble to plants in soils with pH less than 6.5, a great deal of research work is directed towards soil pH, metal solubility, maximum application rates, and plant variety uptake. When heavy metals are placed on soils there are two natural mechanisms by which they can be removed. One is uptake and harvest by plants and the other is leaching through the soil to the groundwater. Because the stockpiled sludge precludes the presence of a crop, only the leaching mechanism will be addressed in this review, however, loss in the form of sediment removal by runoff appears to play an important role.

According to Crites (1984) heavy metal and other trace element removal normally involves the mechanisms of adsorption, precipitation, ion exchange and complexation. The surface of clay minerals, metal oxides, and organic matter are the sites for the adsorption of most of the heavy

metals and trace elements found in sludge. Because of the above, fine textured soils, which normally have high cationic exchange capacities (CEC), have greater heavy metal and trace element attenuation capabilities than do sandy soils. The valence or charge of the cation (heavy metals can be cations) and the degree of hydration are the most important factors determining the stability of the cation/soil bond. Arsenic, cadmium, copper, chromium, lead, nickel, mercury, and zinc pose little threat to groundwater contamination because they have either low solubility in slightly acid or neutral soils or their presence in the sludge is at very low concentrations (U.S.E.P.A. 1976). According to I.D.H.W/D.O.E. (1987a) heavy metals are less mobile in soils that retain pH's in the range of 5.7 to 7.9 and soils containing carbonates and oxides. Certain sequioxides also will tend to attenuate the transport of heavy metals. The following is a brief description of the heavy metals that might be found in municipal sludge and their stability in the soil matrix underlying a sludge stockpile (U.S.E. P.A. 1976).

Arsenic - When arsenic is incorporated in the soil matrix it reverts to the chemical form of arsenate, which is strongly held by the clay fraction of most soils.

Cadmium - The chemistry of cadmium/soil mixtures are not well understood, but cadmium appears to be influenced by the soil organic matter, type and amount of clay, amount of hydrous oxide, the soil pH, and the soil's redox potential.

Chromium - Soluble chromium is rarely found in soils. Hexavalent chromium is reduced to the trivalent form during the wastewater treatment phase and in the trivalent form it is quickly complexed into a form that is not soluble under weak acid conditions.

Copper - Copper often occurs in association with hydrous oxides of manganese and iron, and also as soluble and insoluble complexes with some organic matter. Other studies indicate that with time copper complexes form that are no longer easily extractable. The normal soil concentration range is 10 to 80 ppm.

Lead - The solubility of lead in a soil/lead mixture is greatly reduced by the reaction of soluble lead with clays, phosphates, carbonates, hydroxides, oxides, sesquioxides, and organic matter. Lead is retained as hydroxide or hydroxyphosphate in acid soils and as the carbonate in calcareous soils.

Mercury - Mercury reacts with the exchange complex of the clay and organic fractions of soils to form both ionic and covalent bonds. Because of these high affinity bonds between the mercury and the soil, mercury persists in the upper layers of the soil and poses little threat to groundwater. The normal range in soils is .01 to .5 ppm.

Nickel - The level of extractable nickel in most soils is usually governed by the surfaces of iron and manganese hydrous oxides, which act as "sinks" for nickel. Organic chelates also complex with nickel. The normal range in soils is 10 to 100 ppm.

Zinc - Zinc can occur in solution in the Zn^{++} form if acid conditions exist in the soil/zinc mixture. Zinc is retained in soils by sorption on clay and hydrous iron oxide surfaces and chelation by organic matter.

In addition to the potential of groundwater contamination by nutrients and heavy metals, there is also a risk of contamination caused by pathogens. According to Hermanson, Cogger, and Engle (1987) testing for the presence of pathogenic microoganisms are normally not included in sludge analyses, because pathogens do not present serious long term problems. According to Jerold and York (1974), as of 1974, no incidence of disease transmission had been traced back to the use of digested sludge. In addition, they identify long term storage as a reasonable method to assure disinfection of digested municipal wastewater sludge. They also state that "the anaerobic digestion process either destroys or greatly reduces most pathogenic bacteria. The fate of viruses is not as certain, but the fourteen day heated anaerobic digestion cycle should provide a considerable margin of safety for the public health."

Extensive field observations indicate that microorganisms are removed by filtration, adsorption, desiccation, radiation, predation, and exposure to other adverse conditions (I.D.H.W/D.O.E, 1987a). Unless fissures or dissolution channels exist, soils should adequately remove most pathogens within a few feet. Fecal coliforms normally require a distance of at least five feet. Baxter, Johnson, Burge, Kienholz, and Cramer (1983) described a major reduction in the number of fecal coliforms, total coliforms, salmonella, bacteriophage, and ascario ova due to drying of the sludge over a period of a few months.

In their work, Goldstein, Yanko, Walker, and Jakubowski (1988) found very few pathogenic viruses and viable parasitic ova in digested sludge products. They did, however, find salmonella in some of the products, which should be expected, because the virus occurs commonly in the environment. In order to qualify as a process that significantly reduces pathogens per the U.S.E.P.A. definition, the anaerobic digestion process must be carried out in an absence of air with residence times ranging from sixty days at twenty degrees centrigrade to fifteen days at 35 to 55 degrees centigrade. The volatile solids reduction should be at least thirty-eight percent (State of Washington Department of Ecology, 1982). A State of Idaho Division of Environmental Quality accepted method for further reduction of pathogens is retention in an impermeable lagoon for sixty days at 20 degrees centigrade or one hundred and twenty days at 4 degrees centrigrade (I.D.H.W/D.O.E., 1986).

E. Sampling Procedures

The method of collection of soil and soil water samples varies greatly depending on the material and the selected analysis. It is very important that the sampling equipment used be properly cleaned between samples and that the materials of construction in the equipment not contaminate the sample (Albert 1987). Brown (1987) stated in his work that soil pore water samplers, such as suction lysimeters, are most often used to sample fast moving contaminants such as nitrates. Soil-core samples are most often selected to sample the slower moving contaminants, such as heavy metals. Brown's work showed statistically that there was no significant difference between the two sampling schemes although the wide variability of his data made any measurement of correlation between the two methods impossible. Alberts, Burwell and Schuman (1977) examined the differences in nitrate-nitrogen reading in samples collected by both pore water samplers and soil cores. For most cases once the cups had been flushed with several volumes of soil water the results from both analyses correlated very closely. Ceramic cup suction lysimeters are the most practical method for collecting in-situ soil water samples at a particular elevation and location.

Hornby, Zabcik and Crawley (1986) describe the various soil-pore liquid monitoring devices available and the advantages and disadvantages of each. According to their work the choice of sampler used should be selected based on the following:

1. The differences in character of the soil-pore liquid produced by different soil-pore liquid samples.

2. The soil-pore liquid fraction to be monitored (macropore or micropore).

3. The nature and properties of the soil being monitored (i.e., well structured or massive structured).

4. The accepted level of site disturbance that can take place during the installation and operation of the instruments.

5. The compatibility between the contaminants being sampled and the materials of construction in the sampler.

The work by Everett and McMillion (1985) outlined the important procedures and considerations that must be considered when developing a soil-pore liquid monitoring program. These considerations were as follows:

1. All lysimeters should be pressure tested prior to field installation.

2. Low flow ceramic cups, high flow ceramic cups, and PTFE cups have approximate bubbling pressures of 35 psi, 18 psi and 1 psi, respectively.

3. A vacuum can be held in a low flow ceramic cup for several months.

4. Polytetraflouroethylene (PTFE) cups must be installed in silica flour to be effective.

5. Prior to placing the lysimeters in service the presence and amount of dead space in each lysimeter must be determined.

6. In most types of soils suction lysimeters will experience a rapid decrease in intake rate, but this will level off after approximately fifteen liters of soil water has been pulled through the cup.

7. In order to negate the plugging of the porous cup by fine soil particles, silica flour can be placed around the lysimeter cup.

8. The effective range of operation for ceramic cup suction lysimeters is 0 to 60 centibars, even with the use of silica flour.

9. The expected operating range of PTFE lysimeters is very narrow even with the use of silica flour.

Robbins and Gemmell (1985) described in their work the steps that are critical to an effective vadose monitoring program. They advised the installation of similar equipment outside the monitored area to assess background conditions and to evaluate instrument performance. The other steps that they recommend to develop an effective vadose monitoring plan are as follows:

1. Conduct a thorough site review.

2. Conduct a detailed evaluation of available monitoring equipment and sampling procedures.

F. Research Objective

Despite the abundance of literature on the subject of land application of municipal wastewater sludge, the overall scope of an efficient sludge management plan must take into account the logistics and time frame constraints of handling the sludge. The sludge is produced daily as a continuous process stream, but it can only be applied in a winter wheat crop rotation during a short period in the fall just before crop planting. The only logical solution for this logistical dilemma is a sludge stockpile which is accumulated throughout the year and applied in the crop rotation at the most efficient time of the year.

Due to the lack of understanding of the effects of leachate from the stockpiled sludge on the underlying soils and groundwater, sludge storage facilities are normally located over impermeable liners (I.D.H.W/D.O.E, 1986). Since the sludge is used as a fertilizer on agricultural ground it is necessary to maintain a great deal of operational flexibility and mobility to most efficiently use the sludge. It would be a tremendous advantage to the sludge management plan if the sludge storage stockpiles could be placed directly on the ground without the construction of a liner. This can be accomplished only if there is a better understanding of the effect the mucicipal sludge leachate has on the underlying soils and soil water. The goal of this study is to provide some of the understanding of the extent to which sludge leachate is transported through the vadose zone and what effects it has on the soil and soil water it encounters.

III. FACILITIES AND EQUIPMENT

A. Site Layout

The instrumented site was designed and equipped to monitor and analyze the effects of municipal sludge leachate on the underlying soil and soil water. The required instrumentation was selected and installed prior to the placement of the sludge blanket. The municipal sludge blanket was placed in a single lift 12 to 18 inches thick approximately one month after the installation of the last of the site monitoring instruments and prior to the beginning of fall precipitation. The intent was to have the sludge blanket exposed to the elements during the wet seasons of the year and to monitor any changes in the underlying soil and soil water as a result of sludge blanket leachate.

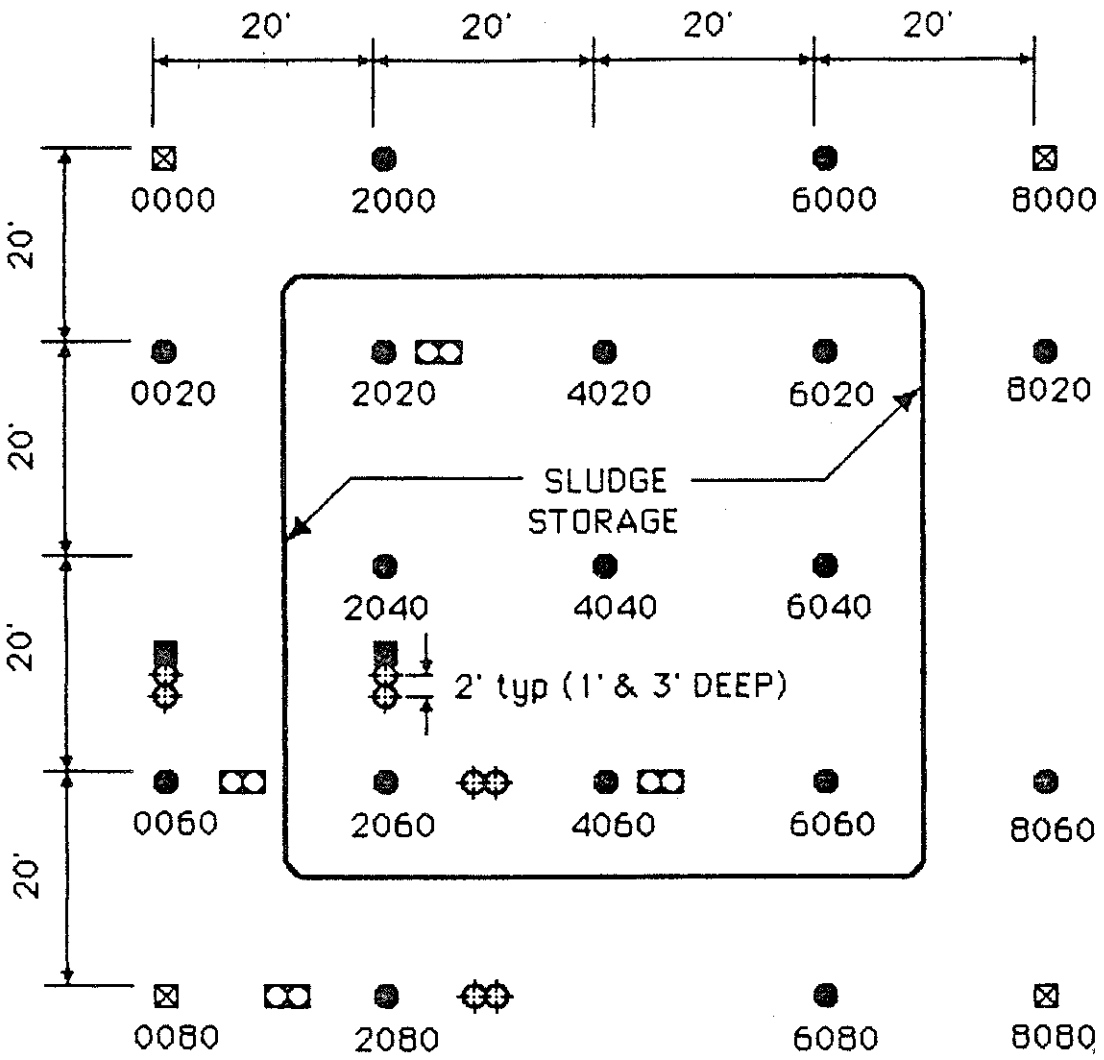
The design of the instrumented site layout consisted of a coordinate system with in-place suction lysimeter, neutron probe access pipes, shallow monitoring wells for perched water, soil sampling sites, and tensiometers. The location of each of the above mentioned pieces of equipment is shown in Figure III-1.0. A typical cross section of the instrumented site is shown on Figure III-2.0. As indicated in the attached figures, approximately one-half of the instruments were located under the sludge blanket and approximately one half were located around the perimeter of the sludge blanket.

B. Neutron Probe Sites

The moisture content in the underlying soil matrix was one of the soil characteristics monitored. This parameter was measured as a percent by weight of water in the dry soil and was used to indicate the movement of precipitation or leachate through the soil matrix. The neutron probe access sites consisted of 2-inch diameter aluminum pipes driven into very tight fitting drill holes in the soil to a depth of approximately 54 inches. The fit had to be tight in order to minimize the potential of water seeping down around the access pipe and affecting the soil moisture content of the grouting material instead of that of the native material.

FIGURE III-1.0

INSTRUMENTATION SITE LAYOUT



0000 COORDINATE LOCATIONS

⊠ MONITORING WELLS (4)

● NEUTRON PROBE SITES (17)

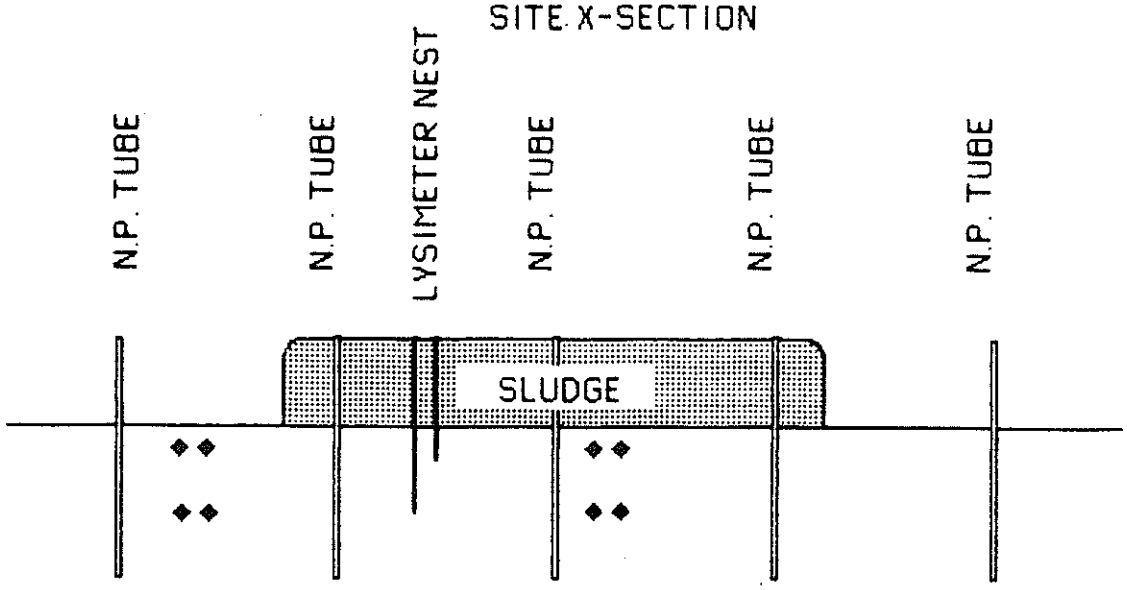
⊕ LYSIMETERS (8)

■ TENSIOMETERS (4)

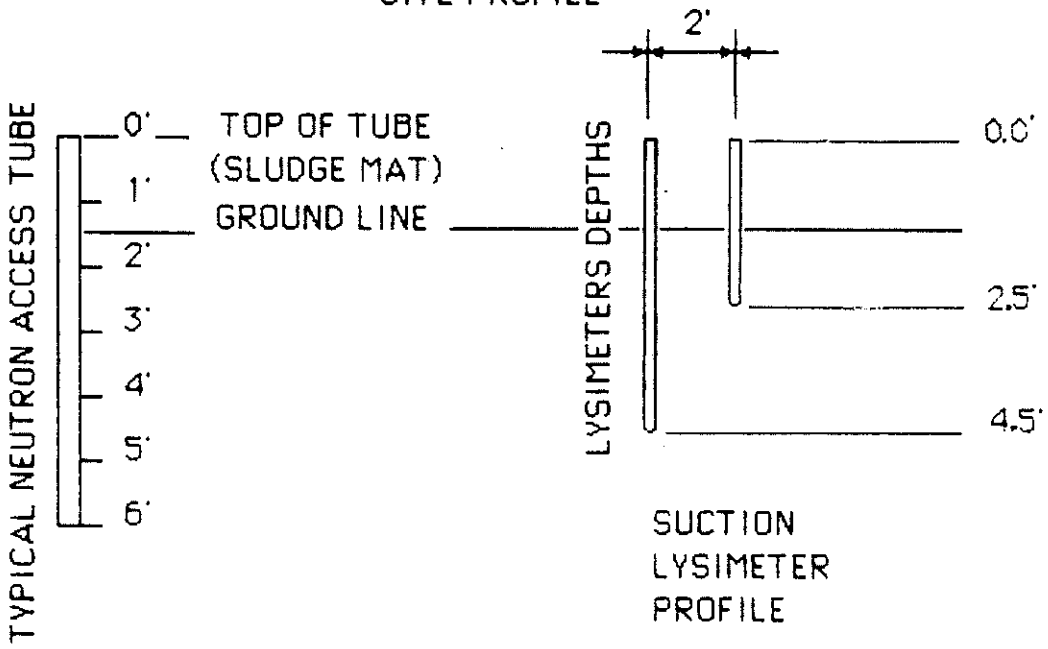
□ SOIL SAMPLES (1' & 3' DEEP)

FIGURE III-2.0

SITE X-SECTION



SITE PROFILE



SUCTION LYSIMETER PROFILE

NEUTRON PROBE ACCESS TUBE PROFILE

◆- SOIL SAMPLE SITE

The neutron probe access pipes were plugged with a rubber stopper to prevent precipitation from entering and disturbing the moisture content readings of the lower horizons. A Giddings soil sampler was used to install the access pipes in late July of 1988, in order to allow for the gathering of baseline moisture content data prior to the placing of the sludge blanket in early October of 1988.

A Campbell Pacific Nuclear (CPN) Corporation Model 503 DR hydroprobe moisture depth gauge was used to measure the soil moisture content at every 6 inches of depth. The CPN hydroprobe measured the subsurface moisture content in the underlying soils by using a fast neutron generating probe that contained 50 millicuries of Americium-Beryllium and a slow neutron detecting device. The probe was lowered into the 2 inch diameter aluminum access pipes where moisture content readings were taken at every 6 inches of depth.

The Americium-Beryllium neutron probe is a source of fast or high energy neutrons which are generated when an alpha particle from the Americium strikes a Beryllium atom and produces a fast neutron with an average energy of 5 million electron volts (MEV). The fast neutrons are slowed down by collisions with nuclei of matter in the soil and then absorbed by the surrounding soil matter. Because the mass of the nucleus of an atom of hydrogen is approximately the same as that of the fast neutron, the presence of hydrogen will result in a high field of thermal neutrons. Because hydrogen atoms are found in organics and because some of the heavier elements will also slow down the fast neutrons produced by the probe, it was necessary to field calibrate the neutron probe for the actual soil characteristics at the site. This calibration was accomplished by comparing actual in-situ soil moisture contents determined using gravimetric procedures with soil moisture contents estimated using the CPN neutron probe. The resulting thermal neutron flux sensed by the detector in the probe was calibrated to represent the hydrogen present in the soil which represents the water present in the soil.

C. SUCTION LYSIMETERS

The quality of the soil water under and adjacent to the sludge blanket was also monitored. Both nutrients and heavy metal concentrations were monitored using solutions that were collected using in-place suction lysimeters. Soil water from unsaturated soil was drawn into the suction lysimeter through a porous ceramic cup by creating a vacuum inside the plastic barrel of the lysimeter with a hand pump. The vacuum was created at least 24 hours prior to the collection of the soil water sample to allow time for the sample to collect. The suction lysimeters were placed at 1 foot and 3 foot depths in order to identify whether concentrations of nutrients and heavy metals varied with depth of soil.

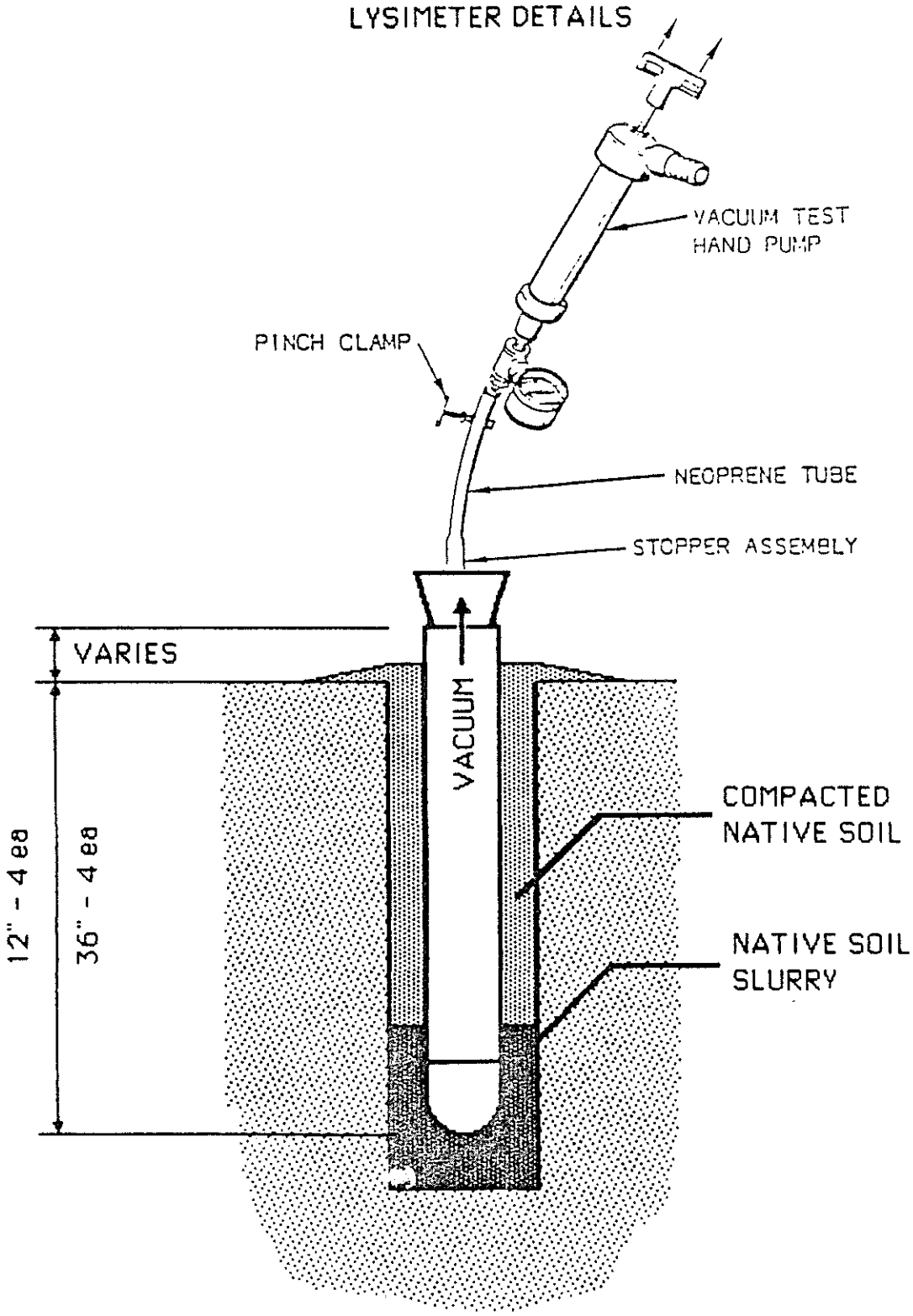
The suction lysimeters were constructed of porous ceramic cups cemented to rigid plastic tubes stoppered with a rubber cork and control valve. Details of the construction of a suction lysimeter are shown in Figure III-3.0. The suction lysimeters were installed to the required depth using a hand soil auger and were bedded in a slurry of native silt material. Prior to field installation the lysimeters had a vacuum applied and were placed in a water bath to saturate the ceramic cups. Once installed the lysimeters were filled with water in an attempt to bring them into equilibrium with the pressure in the soils. After 24 hours the lysimeters were evacuated and the solution discarded.

The effective operating range of pressures in the ceramic cup lysimeters used in this study was between 0 and 60 centibars (Everett and McMillion, 1985). Because of the lack of precipitation and the characteristics of the native soils, the moisture content of the soils was not high enough to allow use of the suction lysimeters except during late winter and early spring.

In order to build a soil water sampling device that can be successfully used in the vadose zone to withdraw moistures from the soil, the device must incorporate a porous ceramic cup that has pores so small that air from the soil cannot enter, even if the interior of the ceramic cup is under a vacuum. Despite the above restriction in pore size the pores must also be large enough to allow the free flow of soil water at a rate sufficient to make sample collection practical. The following equation, which defines

FIGURE III-3.0

LYSIMETER DETAILS



the relationship of the ceramic cup pore size to the "bubbling pressure" or "air entry value," was used to size the ceramic cups used in this study (Everett and McMillion, 1985):

$$D = 30Y/P$$

D = pore diameter in microns

P = bubbling pressure in millimeters of mercury

Y = surface tension of water in dynes/cm

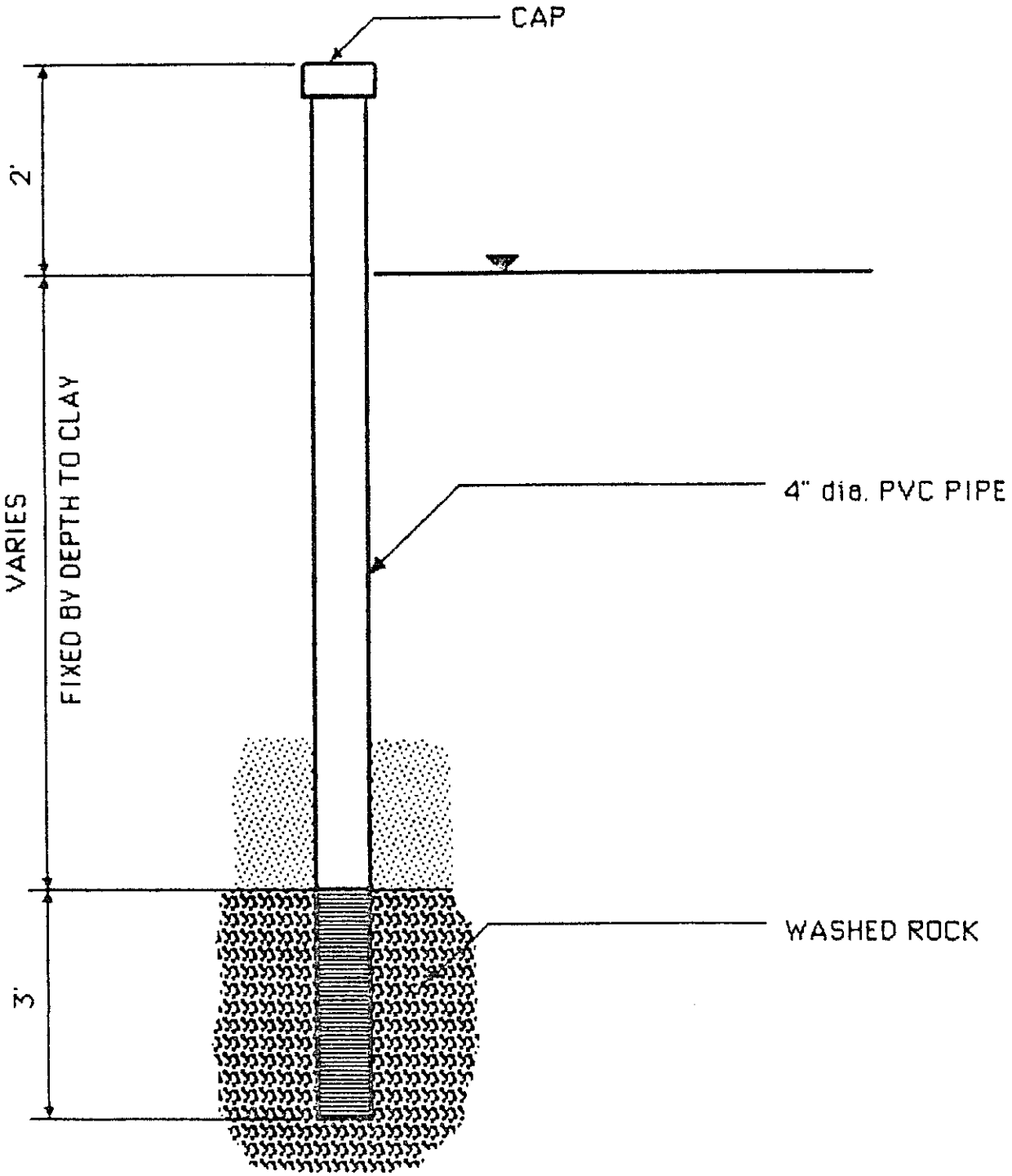
D. SHALLOW MONITORING WELLS

During the initial site investigation of the underlying soil profiles, a soil horizon was discovered which appeared to be a seasonal zone of saturation. This zone was located immediately above a heavy clay horizon near the bottom of the deepest heavy silt horizon. It was suspected from this observation that during the wet season of most years a perched water table forms. The presence of a drain tile located down-gradient of the site in the same general area further substantiated this conclusion.

In order to monitor the water quality of this perched water table, four shallow monitoring wells were installed as shown in Figure III-1.0. One well was installed in each corner of the instrumented site. The shallow monitoring wells were constructed as shown in Figure III-4.0. These monitoring wells had two main purposes. First, they afforded the opportunity to evaluate the impact that the sludge leachate could have on the underlying groundwater. This could be accomplished by monitoring the water quality parameters both up-gradient and down-gradient of the sludge blanket. Secondly, and probably most important, the monitoring wells afforded the opportunity to quickly assess the impact that the sludge leachate was having on the underlying soil water. If major negative impacts to the environment developed the sludge blanket could be removed and the study terminated.

FIGURE III-4.0

MONITORING WELL DESIGN



E. TENSIOMETERS

In order to facilitate soil water sample collection, a simple method of identifying when the soil moisture content was sufficient to allow use of the suction lysimeters had to be developed. During the summer of 1988, undisturbed soil samples were collected from the test site and by using pressure cells at the University of Idaho, soil/water retention curves were generated for the native soils at the test site. From the data generated in the laboratory, the relationships between soil suction and moisture content were established for the test site native soils. The results from the laboratory work indicated that the normal moisture content of the existing site soils were much too low to permit extraction of soil water with the suction lysimeters except during near-saturation conditions.

To determine when the conditions were acceptable for soil water extraction by the suction lysimeters tensiometers were used to monitor the soil suction. Four tensiometers were installed at the instrumented test site. Two tensiometers were installed under the sludge blanket near a pair of suction lysimeters at two different depths. A second pair of tensiometers were installed on the perimeter of the sludge blanket near a pair of suction lysimeters, again at two different depths. The sole intent of the tensiometers was to monitor the soil suction in the soil matrix and to indicate when the soil suction was less than 60 centibars.

The tensiometers selected were #2725 Jet Fill tensiometers as manufactured by Soilmoisture Equipment Corporation. Similar to the suction lysimeters in construction, the tensiometers consisted of porous ceramic cups cemented to rigid plastic tubes. Unlike the lysimeters, however, the rigid plastic tubes are small in diameter, kept constantly filled with solution, and were equipped with pressure transducers.

The water in the tensiometer tube is drawn from the tube via the porous ceramic cup by the surrounding soil. This results in a negative pressure in the tensiometer tube, that is sensed by the transducer. The soil tension reading taken from the tensiometer can be used with the saturation curve

data derived in the laboratory to estimate the soil moisture content in the vicinity of the tensiometer cup. When the readings on the tensiometers were 60 centibars or less the suction lysimeters were functional. The lower the reading on the tensiometer, the lower the vacuum needed to collect a soil water sample with the suction lysimeter.

F. Sludge Leachate Impermeable Containment

The main thrust of this study was to evaluate the impacts that stockpiled municipal sludge leachate could have on the underlying soil and soil water. Therefore, the monitoring was almost entirely designed to monitor quality parameters and not quantity of leachate. The sludge blanket was free draining and open to the atmosphere and to precipitation. The precipitation that fell on the sludge blanket had to evaporate, runoff, pass through the blanket, or be absorbed by the sludge. The monthly precipitation was recorded by the University of Idaho Agricultural Engineering Department at a gauge approximately one mile south of the site and the moisture content of the sludge blanket was recorded on a monthly basis.

In order to estimate the appoximate volume of leachate an impermeable containment area was constructed immediately north of the sludge blanket. This containment area was constructed of a 72 inch diameter plastic wading pool with neutron probe access pipes for monitoring the sludge moisture content on a monthly basis. This containment area, like the sludge blanket, was also open to the atmosphere and to precipitation. Precipitation that fell on the containment area had only three methods of escape; evaporation, runoff, or be absorbed by the sludge.

Because the two sludge areas are located adjacent to one another it was assumed that the rate of evaporation, the amount of precipitation, and the degree of runoff were the same for both areas. Therefore, any difference in moisture content between the two sludge stockpiles could be used to estimate the quantity of leachate that escaped the free draining sludge blanket and entered the soil.

G. State of Idaho Bureau of Laboratories

The soil water samples collected in the field were sent to the State of Idaho Bureau of Laboratories in Boise, Idaho, for testing. Baseline soil samples were collected by the sludge hauling contractor and the sludge characteristic data as supplied by the City of Lewiston were run by Alchem Laboratories in Boise, Idaho. Where possible, the results of the two laboratories were cross-checked to verify their accuracy. In one instance the two laboratories spent the better part of two weeks double checking the results of each others work on the atomic absorption unit looking for the reason for a difference in parameter values. The result was standardization of the background media and the spectrophotometer wave length used in the analysis.

In order to assure sample quality, all of the standard procedures for sampling and sample preservation were conducted in accordance with "Standard Methods for Examination of Water and Wastewater," 16th Edition, (APHA, 1985). Both of the laboratories that were used in this study are certified laboratories with well documented quality control procedures.

IV. EXPERIMENTAL PROCEDURE

A. Soil Moisture Content

To monitor the flow of soil water from precipitation and sludge leachate, the change in moisture contents in the soils underlying the test site were monitored by the neutron probe method. With neutron probe, the moisture content in the underlying soils was monitored throughout the soil profile.

Aluminum pipes were installed to a depth of 54 inches in the soil profile both under and adjacent to the sludge blanket. Once a month, throughout the study period, the neutron probe was used to measure the soil moisture content at every six inches of soil depth. The instrument was set up to give the moisture content measurements in terms of probe counts rather than percent soil moisture content.

To verify that the neutron probe was functioning properly, each time the instrument was used a measurement of the hydrogen in a wax shield mounted in the lid of the carrying case was checked. This measurement was called a "standard count." Because the "standard count" was always taken in exactly the same manner, it provided two means of verifying the validity of the counting function.

First, by comparing the new "standard count" with the previous "standard count" I could see if drift in the electronics had caused a significant change in the readings. (Because of its 430 year half life, changes due to the decay of the radioactive material are insignificant).

Second, because the "standard counts" are taken as a series of short counts rather than one long count, I was able to verify that the statistical distribution was normal and that electronic noise was not affecting the counts. The difference between the old "standard count" and the new "standard count" had to be within 0.707 of the square root of the average of the two counts 95% of the time. If the difference was greater or was continuously changing in the same direction, servicing of the instrument was required.

The neutron probe counts were field-calibrated to the actual soil conditions by inserting an aluminum pipe in the ground near the test site during the dry season. Readings at various depths were taken using the neutron probe. Those readings were compared to the actual soil moistures at the same depths measured using gravimetric moisture content methods. The above procedure was repeated during the wet part of the season. The neutron probe counts from both the dry and wet seasons were plotted against the actual soil moisture contents to generate an equation using linear regression analysis. The equation generated was used to convert neutron probe counts to actual soil moisture content values in percent water per weight of dry soil.

In order to detect any drift in the electronics of the instrument during the monthly readings of the probe sites, five different readings were taken on the carrying case calibration test plate at the beginning, middle and end of the monthly monitoring session.

The moisture contents at each of the neutron probe access pipes were taken at every 6 inches of depth and were recorded in the log book in terms of probe counts. The count readings were then converted in the office to soil moisture contents in terms of percentage of water weight to dry soil weight using a computer program and the equation generated from the field calibration data. The moisture content data were then plotted versus time and soil depth to visually analyze soil water migration.

The neutron probe moisture content readings began at the end of August, 1988, prior to the placement of the sludge blanket and continued once per month until the first of May, 1989. The only months missed during this period were January and February of 1989, when the neutron probe was out of service for repair.

B. Sludge Moisture Content

In order to approximate the volume of sludge leachate that passed through the sludge blanket, it was necessary to be able to monitor the variation of moisture content in the sludge caused by precipitation. The moisture in

the sludge blanket was measured monthly using the neutron probe at the same time that the soil moisture readings were taken. The probe count readings taken in the sludge were field-calibrated to actual sludge moisture content values, which were measured using gravimetric methods. The count readings generated by the neutron probe were plotted against the actual moisture content readings measured in the sludge. Using linear regression analysis an equation was generated that allowed the neutron probe counts to be converted to sludge moisture contents in terms of percent of water to dry weight of sludge

To determine if any of the water which fell on the sludge blanket in the form of precipitation leached through the sludge, an impermeable sludge containment basin was constructed using a plastic wading pool. Because moisture from precipitation could not pass through the floor of the plastic wading pool, the majority of the precipitation could be accounted for by an increase in moisture content in the sludge. The difference in the moisture content between the sludge in the plastic pool and the sludge in the blanket was used to identify the migration of leachate through the sludge to the underlying soil. It was assumed that the precipitation lost to evaporation and runoff was the same for the sludge in both the plastic wading pool and the noncontained sludge blanket area. The sludge moisture content readings were taken in conjunction with the soil moisture content readings once per month from October, 1988 to May, 1989.

C. Soil Characteristics

Prior to the placement of the municipal sludge blanket in early October of 1988, an investigation of soil conditions was conducted to determine the various soil layers and their properties. The results of this work is found in the appendix of this study. The first soil investigation work consisted of the generation of preliminary soil profiles using a hand auger. Shelby Brownfield, soil scientist for the State of Idaho, Division of Environmental Quality, profiled and mapped the various horizons and assisted in the selection of the instrumentation site.

During the summer of 1988, under the direction of Dr. John Hammel, of the University of Idaho, undisturbed soil samples were collected from the instrumentation site. The undisturbed soil samples were saturated in the laboratory and placed in pressure cells on capillary plates. The pressure cells were subjected to various pressures that simulated capillary tension. The pressures were adjusted upward from the low to the high settings in order to place several soil coupons in the same cell. Three coupons from each of the cells at every pressure setting were removed and the moisture content was calculated using gravimetric methods. The cell pressure versus the corresponding moisture content was plotted on a curve to generate a characteristic water retention curve for each of the sets of soil samples. A composite plot of these data can be found in Appendix B. This information was used to assess the potential for the success of the proposed suction lysimeters and to characterize the soils.

To select the porosity of the capillary cups for the proposed suction lysimeters the hydraulic conductivity of the site soils was estimated. To estimate the hydraulic conductivity of the site soils a Guelph Permeameter was used. The results of this work is also presented in the appendix. Using the Guelph Permeameter the field saturated hydraulic conductivity was estimated for the soils at depths of 12 and 36 inches. The rationale for selecting the 12-inch and 36-inch depths was based on the intent to install the suction lysimeters at these respective depths. At least three field saturated hydraulic conductivities were run at each of the two soil depths described above and the hydraulic conductivity selected was the average of the three.

D. Soil Parameters

In order to establish baseline soil parameter data for the soils underlying the proposed instrumentation site, soil samples were collected using a hand auger at specific sites and grab samples from the excavation for the shallow monitoring wells. The samples collected using the hand auger were collected in plastic zip lock bags, identified as to depth and location and shipped to the State of Idaho, Bureau of Laboratories in Boise for analysis. The grab samples collected from the excavation for the shallow monitoring wells were also placed in zip lock bags, identified as to depth

and location and shipped to Alchem Laboratories in Boise for analysis. These grab samples were taken at the four shallow well locations and at three different depths. the results from the two different laboratories were cross-referenced for comparison according to depths and parameters. Any major differences in the parameter results from the two laboratories were reconciled by the respective labs.

Table IV-1.0 lists the parameters that were used to generate the native soil baseline data. Once the sludge had been removed from the instrumented test site, the underlying soil was sampled for the same parameters as listed on table IV-1.0 to determine whether the sludge had caused an increase in concentration of these parameters.

TABLE IV-1.0

SLUDGE SAMPLING PARAMETERS

Parameters*	Units
N - Ammonia	ppm
N - Nitrate	ppm
TKN	ppm
Total Phosphorous	ppm
Potassium	ppm
Arsenic	ppm
Cadmium	ppm
Chromium	ppm
Copper	ppm
Lead	ppm
Mercury	ppm
Nickel	ppm
Silver	ppm
Zinc	ppm

* For all soil, soil water, and water samples

The collection of the soil parameter data listed in Table IV-1.0 was needed to determine if the stockpiling of sludge for one season would adversely affect the underlying soils by increasing the nutrient and heavy metal concentrations. Due to the expense of heavy metal sampling in soils, the sampling scheme was designed to only identify any increase of the above-mentioned parameters in the underlying soils and not to quantify the increase.

The baseline soil parameter data were collected during the late summer and early fall of 1988. After the sludge blanket had been in place for eight months and had been subjected to a full season of precipitation, soil samples were collected and analyzed for the parameters listed in Table IV-1.0. Any significant increase in nutrient and heavy metal concentrations in the soils sampled in the June 1989 analysis was attributed to the leaching of the sludge blanket.

E. Suction Lysimeter Sampling

To sample the soil water for the parameters identified in Table IV-1.0, when less than saturated conditions existed, it was necessary to install suction lysimeters. The suction lysimeters have rather limited service ranges because they can be operated only when the soil tension is 60-70 centibars or less. Near the upper soil tension values there is usually very little soil water available for the suction lysimeter to collect even when a vacuum is applied for over 24 hours. The resulting small volume of sample collected severely limits the amount of laboratory analysis that can be conducted on the collected sample. In addition it is often difficult to determine when the soil suction is low enough to permit the collection of a soil water sample. To eliminate the above-mentioned difficulty, two tensiometers were installed near one set of suction lysimeters located under the sludge blanket and two tensiometers were installed near another set of suction lysimeters located adjacent to the sludge blanket.

When the tensiometers indicated that the soil tension was less than 60 centibars, a hand pump was used to apply a vacuum of approximately 60-70 centibars in the barrel of the lysimeter. The vacuum was applied at least twenty-four hours in advance of the planned soil water sample collection. The sample was collected via a vacuum pump, Teflon Erlemeyer flask, and a Tygron tube. The sampling apparatus was flushed with at least one liter of distilled water prior to drawing a sample from

each of the lysimeters to prevent cross-contamination of the lysimeter sites. Following the collection of the sample the lysimeter was flushed with distilled water, evacuated, and the flushing solution discarded.

Because of the small volume of sample that was normally collected in the suction lysimeter, it was necessary to identify the priority of the parameters that the laboratory was to analyze. The nutrient parameter analysis required approximately 100 milliliters (ml) of solution and the heavy metal tests required approximately 400 milliliters (ml) of solution. The 100 ml portion of the sample was split out first and stabilized using a few drops of sulfuric acid. The remainder of the sample was then placed in a clean cubetainer and stabilized with nitric acid. The samples were then refrigerated or iced and sent to the laboratory in Boise for analysis. When the amount of sample available for heavy metal testing was insufficient to conduct tests for all of the parameters of interest, a list of priorities was selected based on previous sample results.

The rationale used in the soil water sampling scheme was as follows:

1. The concentrations of nutrient and heavy metal parameters in the soil water under the sludge blanket would be significantly higher than those concentrations found in the soil water adjacent to the sludge blanket, if sludge leachate was causing contamination.

2. The concentration levels of nutrient and heavy metal parameters in the soil water underlying the instrumented site would be affected by any leachate that moved through the soil matrix.

The suction lysimeters were used only when there was sufficient soil water content to reduce the soil matrix suction to below 60 centibars. This occurred only during the late winter and early spring seasons, therefore, this sampling procedure was only used a few times during the course of this study.

F. Shallow Monitoring Well Sampling

During the preliminary site investigation work conducted during the summer of 1988, a soil horizon was discovered which appeared to be affected by a seasonal perched water table. In anticipation of this seasonal perched water table, shallow monitoring wells were installed in the four corners of the instrumented site. The wells were installed in accordance with the procedures described in the previous section. In March of 1989, it was discovered that soil water had collected in three of the four wells. One of the wells was up-gradient of the sludge blanket and two of the wells were down-gradient of the sludge blanket and sludge pool.

The wells were sampled using the same apparatus as used to sample the suction lysimeters and the procedures used were the same, with the exception of the flushing of the well with distilled water. Due to the volume of soil water present in the monitoring wells it was not practical to flush or evacuate more than approximately one liter of the well sample prior to collecting a soil water sample. There was usually enough soil water present to collect the two liters of sample needed for the nutrient and the heavy metal lab analysis. The two liter soil water sample was integrated using a churn sampler to assure proper splitting technique when pouring the one liter sample for the nutrient analysis and the one liter sample for the heavy metal analysis. Following the sample collection, the nutrient sample was stabilized with 2 ml of sulfuric acid and the heavy metal sample was stabilized with 3 ml of nitric acid. The respective samples were then refrigerated or iced and shipped to the lab in Boise for analysis.

Water samples from the up-gradient well were considered to be unaffected by the sludge blanket and water samples from the down-gradient wells were considered as representative of soil water that was contaminated by the stockpiled municipal sludge. Because the perched water table only exists during the late winter and early spring, the shallow monitoring wells could only be used for sampling during a few months of the study period.

G. Laboratory Procedures

As previously discussed in this section, all of the laboratory analysis for this study was conducted by certified laboratories in Boise, Idaho. All of the soil water testing and the final soil parameter testing was conducted by the State of Idaho Bureau of Laboratories. The sludge parameter analysis and some of the baseline soil parameter analysis was conducted by Alchem Laboratories in Boise. The following Tables (IV-2 to IV-4) indicate the parameters and the test procedures used by the State of Idaho Bureau of Laboratories and/or Alchem Laboratories in conducting the analysis required for this research.

TABLE IV-2.0

SOIL WATER ANALYSIS PROCEDURES

Parameter	Test Procedures
TKN	Potentiometric ISE, EPA 351.4
N-Ammonia	Potentiometric ISE, EPA 350.3
N-Nitrate	Ion Chromatography, EPA 300.0
Total Phosphorous	Colorimetric Ascorbic Acid, EPA 365.2
Arsenic	Graphite Furnace, EPA 206.2
Cadmium	A.A. Direct Aspiration, EPA 213.1
Chromium	A.A. Direct Aspiration, EPA 218.1
Copper	A.A. Direct Aspiration, EPA 220.1
Lead	A.A. Direct Aspiration, EPA 239.1
Mercury	Manual Cold Vapor, EPA 245.1
Nickel	A.A. Direct Aspiration, EPA 249.1
Potassium	A.A. Direct Aspiration, EPA 258.1
Silver	A.A. Direct Aspiration, EPA 272.1
Zinc	A.A. Direct Aspiration, EPA 289.1

TABLE IV-3.0

* SOIL ANALYSIS PROCEDURES

Parameter	Test Procedures
TKN	Potentiometric ISE, EPA 351.4
N-Ammonia	Potentiometric ISE, EPA 350.3
N-Nitrate	Ion Chromatography, EPA 300.0
Total Phosphorous	Colorimetric Ascorbic Acid, EPA 365.2
Arsenic	Graphite Furnace, EPA 206.2
Cadmium	A.A. Direct Aspiration, EPA 213.1
Chromium	A.A. Direct Aspiration, EPA 218.1
Copper	A.A. Direct Aspiration, EPA 220.1
Lead	A.A. Direct Aspiration, EPA 239.1
Mercury	Manual Cold Vapor, EPA 245.1
Nickel	A.A. Direct Aspiration, EPA 249.1
Potassium	A.A. Direct Aspiration, EPA 258.1
Silver	A.A. Direct Aspiration, EPA 272.1
Zinc	A.A. Direct Aspiration, EPA 289.1

* Acid Digestions Are Required Prior To Running The Above Tests

TABLE IV-4.0

* SLUDGE ANALYSIS PROCEDURES

Parameter	Test Procedures
TKN	Potentiometric ISE, EPA 351.4
N-Ammonia	Potentiometric ISE, EPA 350.3
N-Nitrate	Ion Chromatography, EPA 300.0
Total Phosphorous	Colorimetric Ascorbic Acid, EPA 365.2
Arsenic	Graphite Furnace, EPA 206.2
Cadmium	A.A. Direct Aspiration, EPA 213.1
Chromium	A.A. Direct Aspiration, EPA 218.1
Copper	A.A. Direct Aspiration, EPA 220.1
Lead	A.A. Direct Aspiration, EPA 239.1
Mercury	Manual Cold Vapor, EPA 245.1
Nickel	A.A. Direct Aspiration, EPA 249.1
Potassium	A.A. Direct Aspiration, EPA 258.1
Silver	A.A. Direct Aspiration, EPA 272.1
Zinc	A.A. Direct Aspiration, EPA 289.1

* Acid Digestions Are Required Prior To Running The Above Tests

H. Quality Control

The Water Quality Bureau has developed a quality assurance program that complies with the EPA regulations for grant awards (40 CFR, Section 30). The Quality Assurance Plan (IDHW-DOE, 1984) describes quality assurance policy and management for the Division of Environmental Quality and was selected as the basis for the quality control procedures followed in this study.

In order to assure sample quality, standard operating procedures, routine calibration and maintenance of equipment, and adherence to preservation requirements and holding times, all procedures were conducted in accordance with "Standard Methods for Examination of Water and Wastewater," 16th Edition, APHA 1985. In addition, replicate soil and soil water samples were collected from at least one critical station with each round of routine sampling. The purpose of the replicate sampling was to assure established testing precision. Due to the extreme variability of the soil and soil water being tested, approved sample splitting techniques were followed whenever possible.

Soil sample extracts and soil water samples were routinely spiked in the laboratory to assure the accuracy of the lab test results. As with the replicate samples, the samples to be spiked were established using approved splitting procedures.

In order to verify the accuracy of the baseline soil data parameters some of the soil samples were submitted to two different laboratories. The lab results were cross-referenced by location, depth, and parameter and any major differences between lab results were reconciled by the two different labs. This exercise not only established repeatable baseline data for the native soils, it also enabled the respective laboratories to focus on the importance of selecting wave lengths and background data for certain heavy metals.

The degree of implementation of the water quality assurance plan was largely dictated by the availability of adequate soil water sample volume from the suction lysimeters. The shallow monitoring wells, however, produced sufficient water volume for quality assurance sampling and analysis.

V. RESULTS AND DISCUSSION

A. Leachate

In order for contaminants found in stockpiled municipal sludge to enter the underlying soil and soil water a mechanism of transport must be available. The most significant and direct mechanism for this transport is through the movement of soil water caused by precipitation and snow melt events. During a precipitation or snow melt event, water is either absorbed by the sludge blanket, conducted through the sludge blanket to the underlying soil, or is intercepted and removed as runoff from the surface of the sludge.

Water absorbed by the sludge blanket causes no immediate transport of contaminants to the underlying soil and soil water although at a later date this water may move downward in the form of leachate. If the precipitation event is a short term event, such as a seasonal rain storm, the chances are good that the absorbed water will be lost to evaporation when the precipitation ceases.

The water conducted through the sludge blanket, and emerging as leachate, carries with it some of the contaminants that are in the stockpiled sludge. The contaminants analyzed in this research were nutrients, heavy metals, and bacteria. The runoff from the sludge blanket carries with it particles of sludge which are deposited as sediments in the immediate vicinity of the sludge blanket. These deposits are then leached by precipitation and snow melt. Because these deposits are usually thin and discontinuous, they offer little resistance to the flow of water through them and thus they are readily leached by precipitation and snow melt.

Because of the important role that leachate plays in the transport of the contaminants found in sludge, it was important to characterize the parameters of a potential leachate solution. This was accomplished by comparing the State of Idaho drinking water standards to a leachate solution that was extracted from the sludge using the standard E.P. toxicity test accepted by the Environmental Protection Agency. (Table V-1.0)

Comparing the results of the two tests to the State of Idaho drinking water standards showed that the sludge leachate is normally low in heavy metals and is high in nitrogen as ammonia. The nitrogen as ammonia is readily converted to nitrogen as nitrate in an aerobic soil environment. The test results from the extracts generated in the E.P. toxicity tests listed on Table V-1.0 should be conservative estimated values for the leachate that actually forms when water passes through the sludge blanket. These values are conservative because two liters of demineralized water with a pH of 5.0 is used to wash 100 grams of the sludge in accordance with the standardized E.P. toxicity test method. The resulting solution is then filtered and collected for analysis. The analysis of the resulting solution is only usable in comparison to E.P.A. accepted maximum contaminant levels if the water to sludge material ratio is 20:1 by weight. The results of this analysis were considered to be conservative because in nature a mass washing of the stockpiled sludge by precipitation of this magnitude does not occur.

TABLE V-1.0

SLUDGE LEACHATE CHARACTERISTICS

PARAMETER	(1) DRINKING WATER STANDARDS mg/l	(2) SLUDGE LEACHATE ANALYSIS mg/l	(3) RESULT E.P. TOXICITY ANALYSIS mg/l
Ammonia as N		47.200	
Nitrate as N	10.000	<0.001	
TKN as N		68.700	
T. Phosphorous		17.900	
Potassium		6.300	
T. Arsenic	0.050	<0.10	0.011
T. Cadmium	0.010	<0.001	<0.005
T. Chromium	0.050	<0.010	<0.050
T. Copper	1.000	0.020	
T. Lead	0.050	0.009	<0.050
T. Mercury	0.002	<0.001	<0.001
T. Nickel		<0.050	
T. Silver	0.050	<0.001	<0.005
T. Zinc	5.000	0.455	

1) U.S. EPA maximum contaminant levels.
2) Analysis conducted by State of Idaho Bureau of Laboratories.
3) Data provide by the City of Lewiston.

B. Precipitation

With the above approximation of the water quality of the sludge leachate, the next item analyzed was the actual movement of the leachate through the underlying soil. Figure V-1.0 shows the monthly precipitation in inches of water for each of the months during which the sludge storage site was monitored. Approximately fourteen inches of water in the form of precipitation fell on the site during the term of this study. This represented approximately 56,000 gallons of potential leachate in the immediate vicinity of the sludge blanket.

C. Sludge Moisture Content

During the study the moisture content of the sludge in the blanket and in the impermeable containment basin was measured once per month. The results of these moisture content readings are presented on Table V-2.0. The sludge placed in the impermeable containment basin was placed at the same time that the sludge blanket was placed. The major difference was that the sludge blanket was free to drain to the underlying soil and the sludge in the impermeable containment basin was not free to drain. Table V-2.0 shows that the sludge in the containment basin consistently exhibited a higher moisture content than the sludge in the free draining blanket indicating that some of the precipitation passed through the sludge blanket in the form of leachate.

D. Soil Moisture Content

To observe the movement of leachate through the sludge blanket and the underlying soil, the moisture content in the underlying soil was measured using a neutron moisture probe at six inch depth increments once per month. The results of these measurements are shown in Figures V-3.0 to V-10.0. These figures show that the sludge blanket impeded, but did not completely prevent the downward flow of water through the underlying soils. For the first three months of the study the moisture content of the soil underlying the sludge blanket was not affected by the precipitation events, while the moisture content in the soils adjacent to the sludge blanket varied with the precipitation events.

FIGURE V-1.0

MONTHLY PRECIPITATION IN INCHES

MEASURED AT KRAUT GAUGE

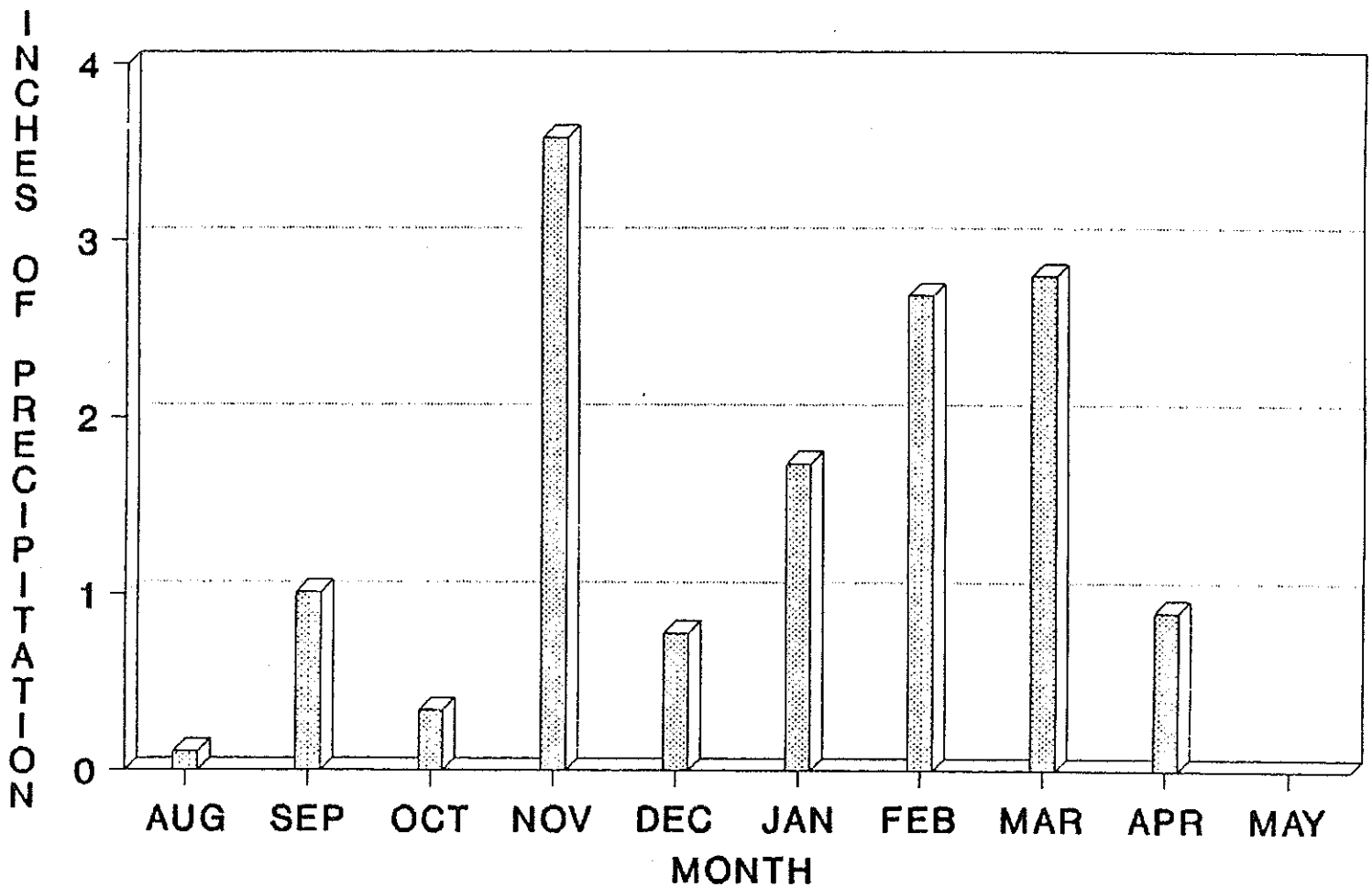
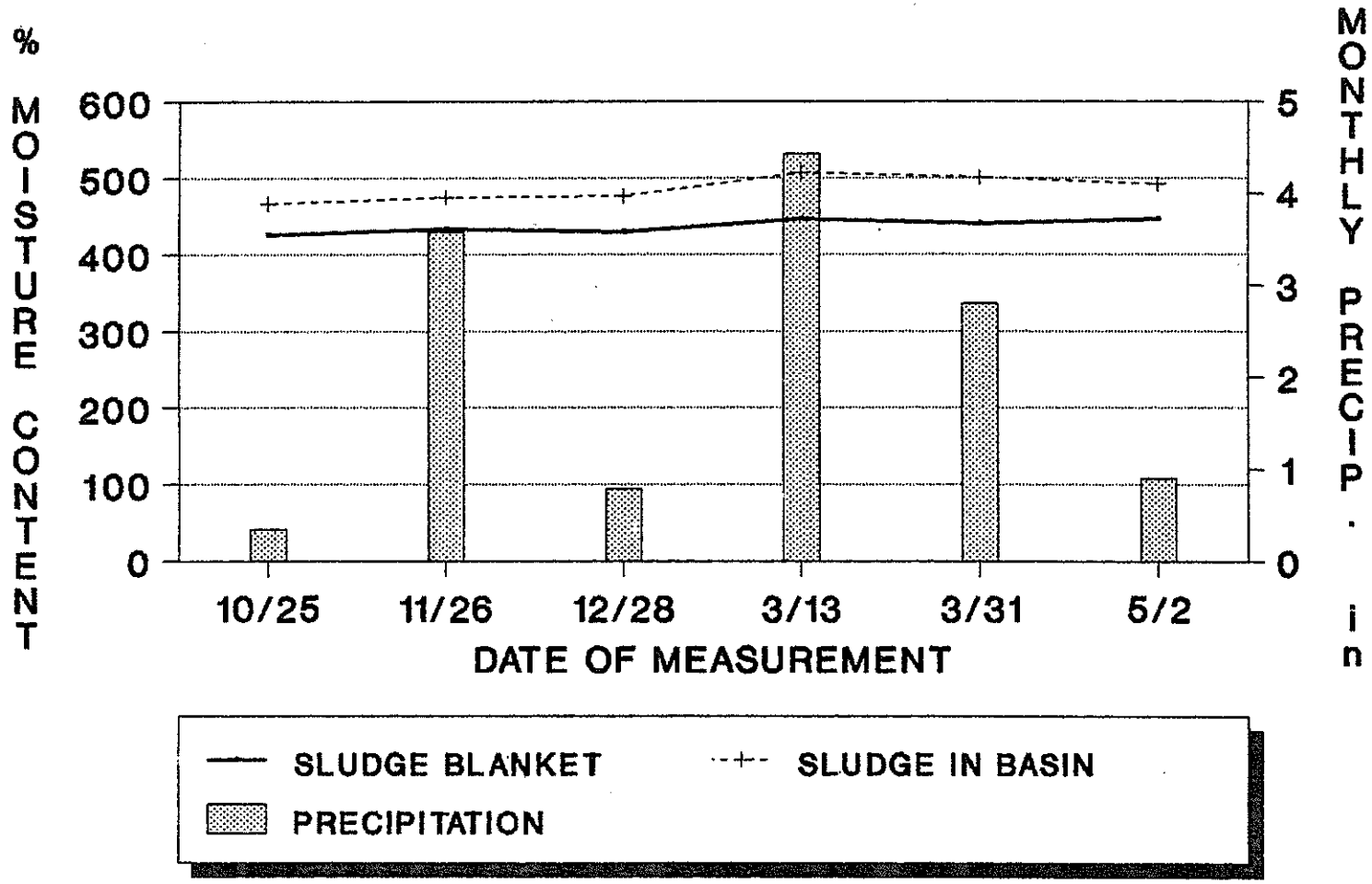


FIGURE V-2.0

MEAN MOISTURE CONTENT IN THE SLUDGE
IN THE POOL AND IN THE SLUDGE BLANKET



Because the neutron probe was out of service during the months of January and February, the moisture content for these months was not recorded. The absence of these data is not critical because during these months the sludge and the surrounding soil was frozen and very little downward movement of moisture could occur. In the middle of March temperatures began to rise and the year's major snow melt event occurred. Instead of waiting until the end of the month, as normally scheduled, the neutron probe readings were taken on March 13th at the peak of the snow melt.

The soil moisture content readings taken on March 13th show a jump in moisture content for all of the levels measured. It appears that when the snow melt occurred the sludge was inundated with water and leachate moved downward through the sludge blanket into the underlying soil. The time frame in which this spike of leachate occurred can be fairly well documented by the freezing conditions prior to March 13th and by careful analysis of the moisture content in the underlying soils at the various depths. At the six inch depth the soil moisture content peaked at approximately the middle of March. At the eighteen inch depth the moisture content peaked near the end of March, and at the forty-eight inch depth the moisture content did not peak until the end of April, showing a downward movement of moisture with time.

From the data presented in Figures V-3.0 to V-10.0 it appears that the sludge blanket significantly impeded the downward flow of leachate to the underlying soil, thus significantly reducing the amount of contaminant transported with the wetting front. It also appears from the data that the sludge was able to impede the downward flow of water until massive snow melt occurred over a short period of time.

E. Soil Water Under and Adjacent to the Sludge Blanket

To evaluate the impact of the sludge leachate on the soil water in the vicinity of the sludge blanket, suction lysimeters were installed both under and adjacent to the sludge blanket. A difficulty with using suction lysimeters to sample soil water is that if the moisture content in the soil is not fairly high, the lysimeters cannot pull water from the soil.

FIGURE V-3.0

MEAN MOISTURE CONTENT AT 6 INCHES
UNDER AND ADJACENT TO SLUDGE BLANKET

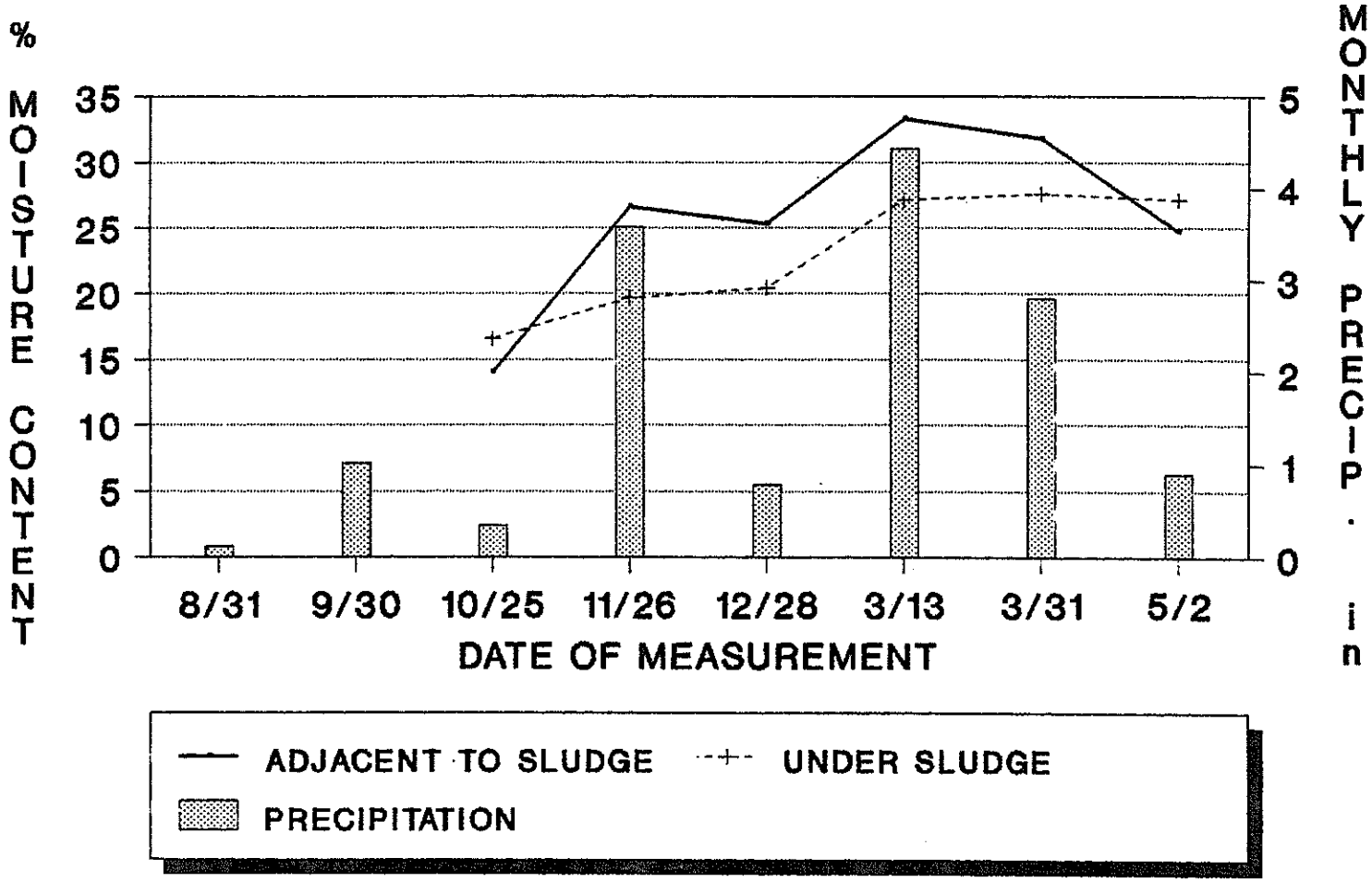


FIGURE V-4.0

MEAN MOISTURE CONTENT AT 12 INCHES
UNDER AND ADJACENT TO SLUDGE BLANKET

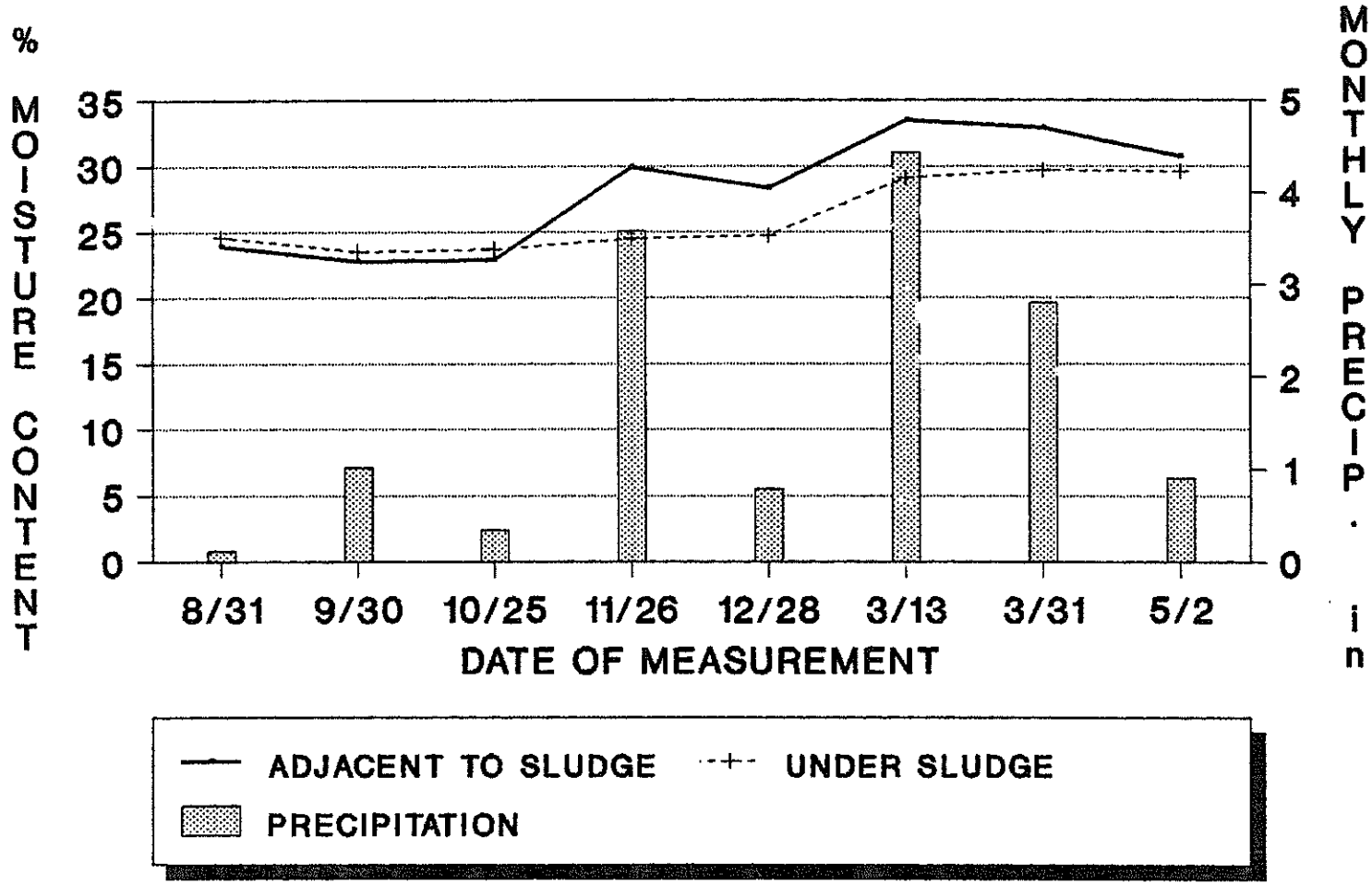


FIGURE V-5.0

MEAN MOISTURE CONTENT AT 18 INCHES
UNDER AND ADJACENT TO SLUDGE BLANKET

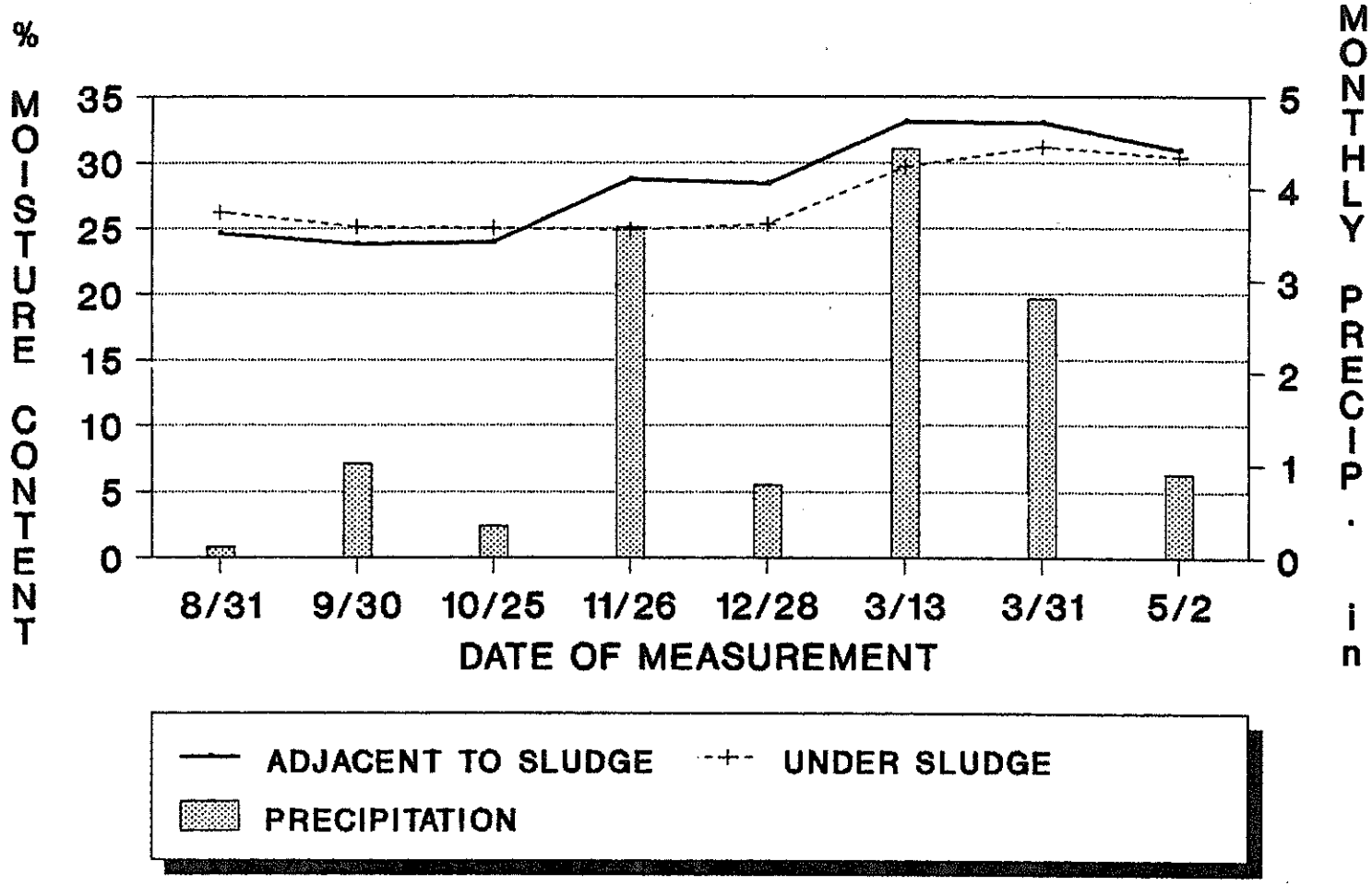


FIGURE V-6.0

MEAN MOISTURE CONTENT AT 24 INCHES
UNDER AND ADJACENT TO SLUDGE BLANKET

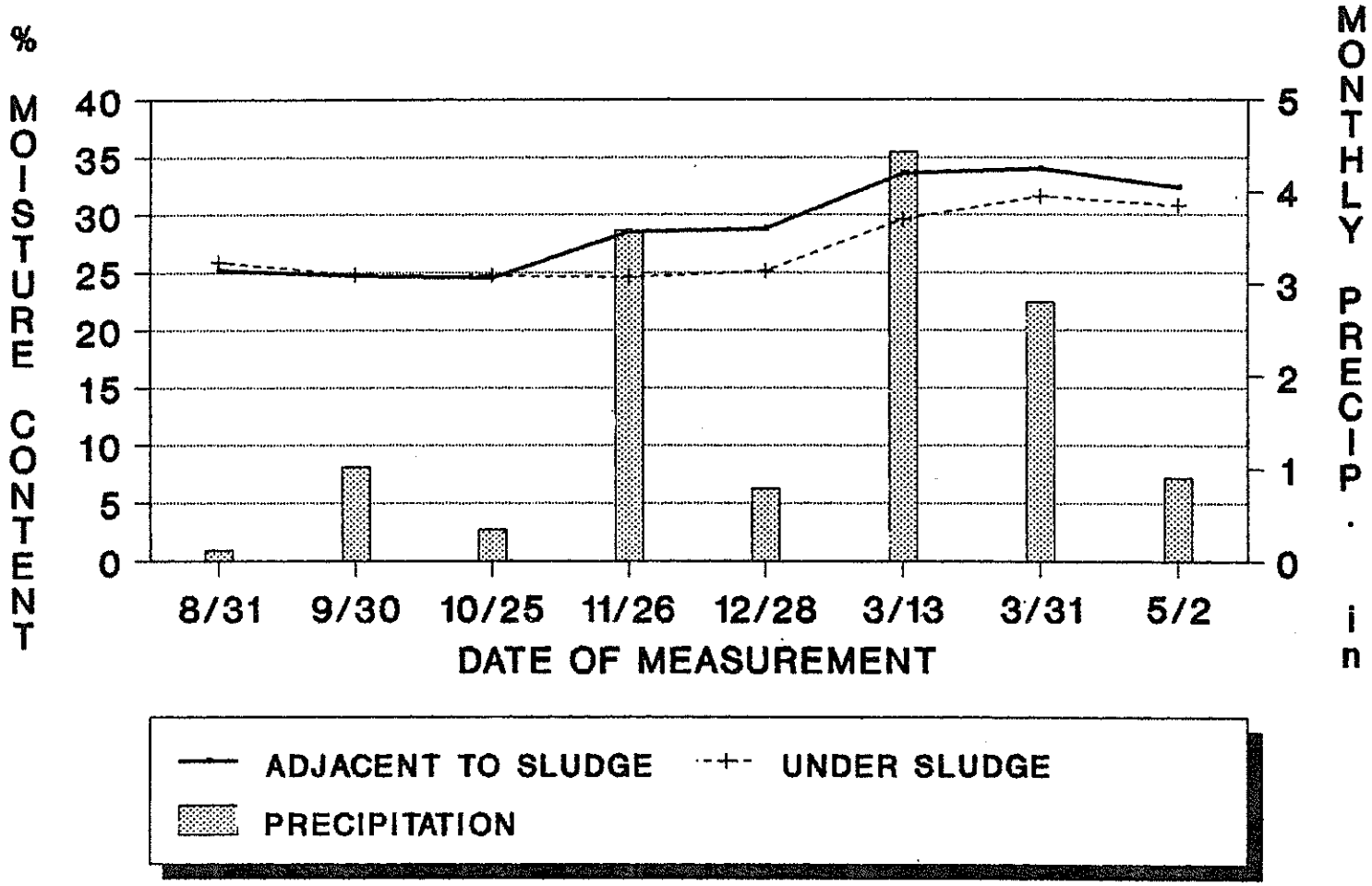


FIGURE V-7.0

MEAN MOISTURE CONTENT AT 30 INCHES
UNDER AND ADJACENT TO SLUDGE BLANKET

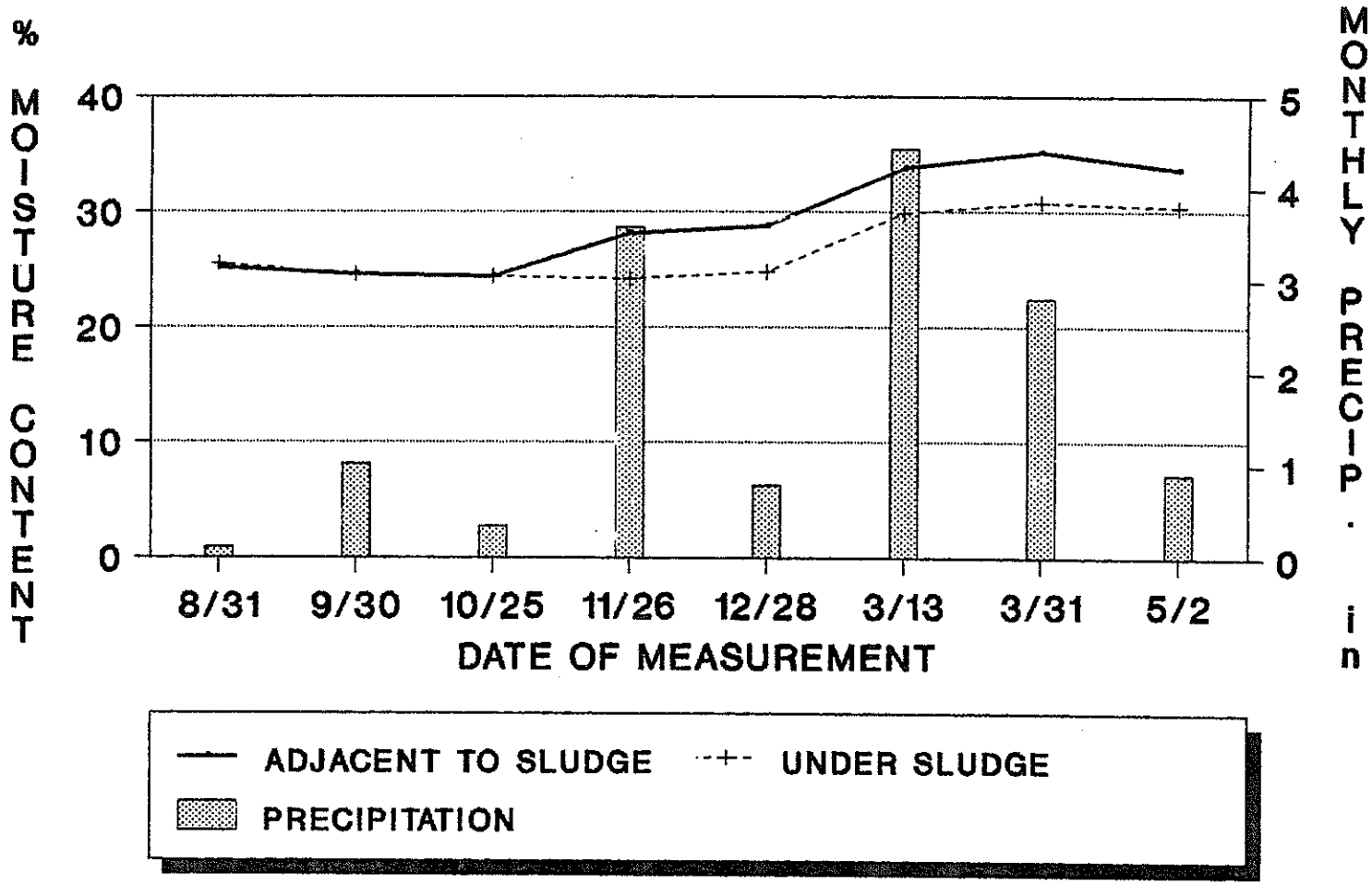


FIGURE V-8.0

MEAN MOISTURE CONTENT AT 36 INCHES
UNDER AND ADJACENT TO SLUDGE BLANKET

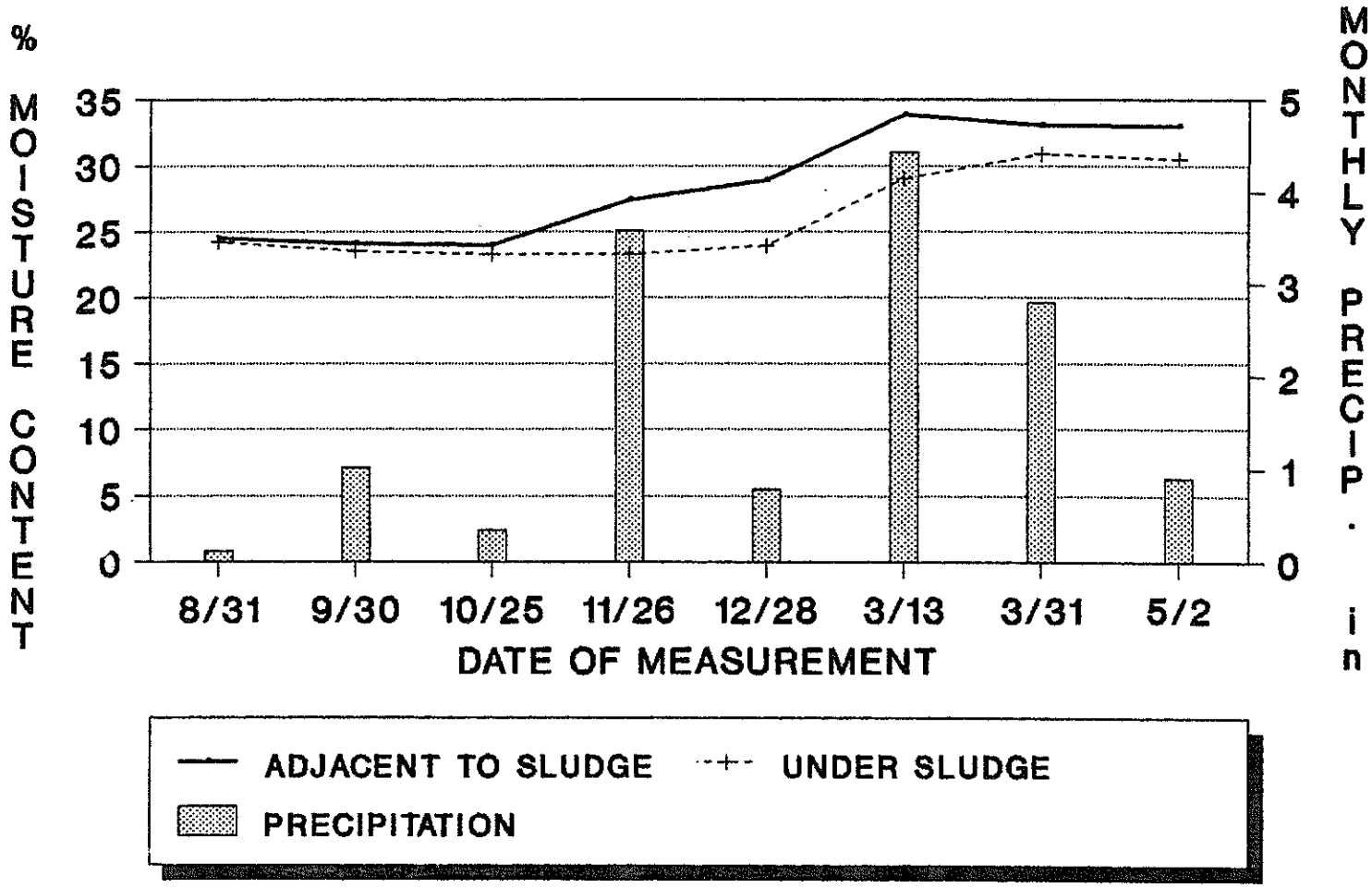


FIGURE V-9.0

MEAN MOISTURE CONTENT AT 42 INCHES
UNDER AND ADJACENT TO SLUDGE BLANKET

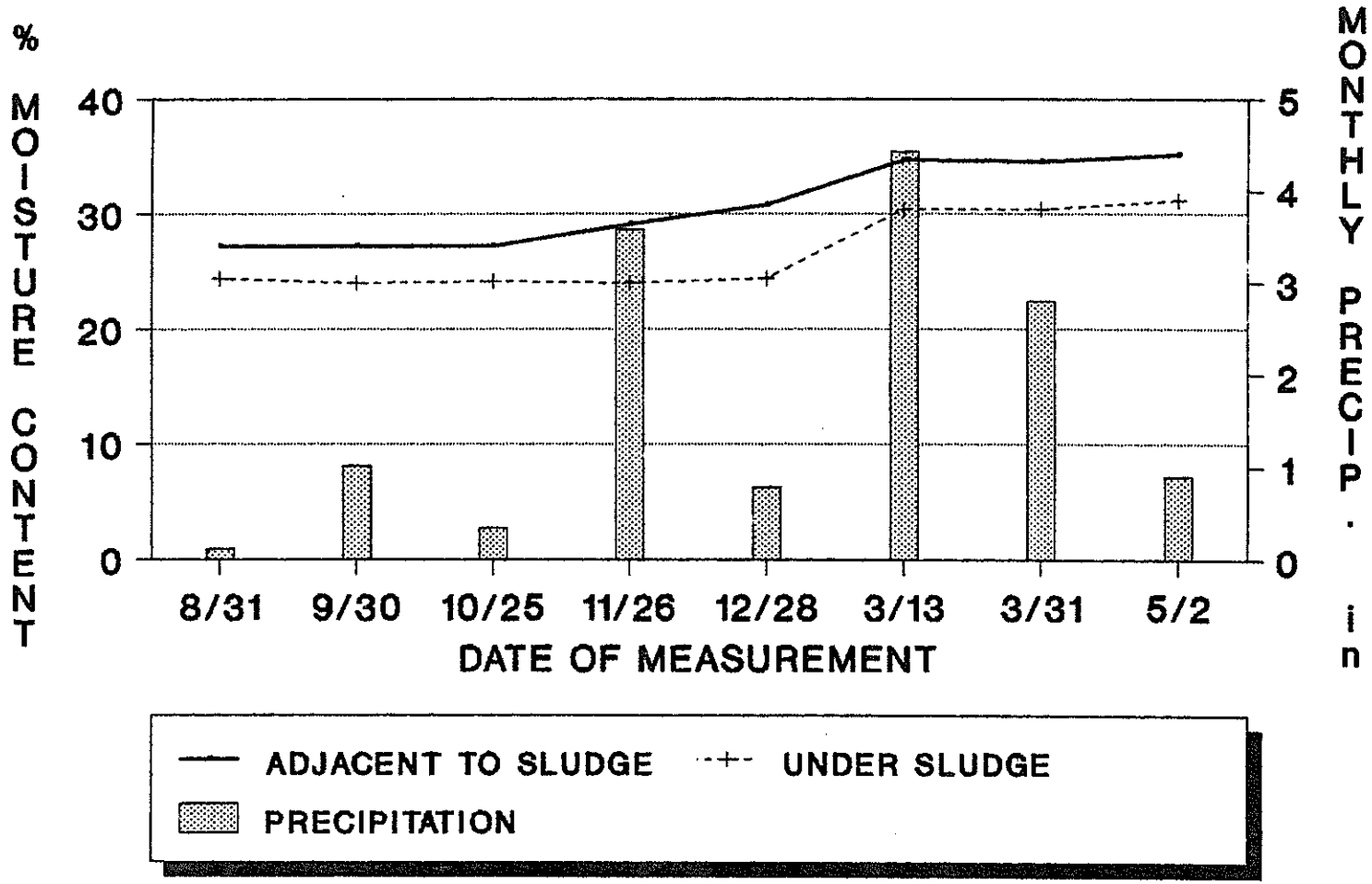
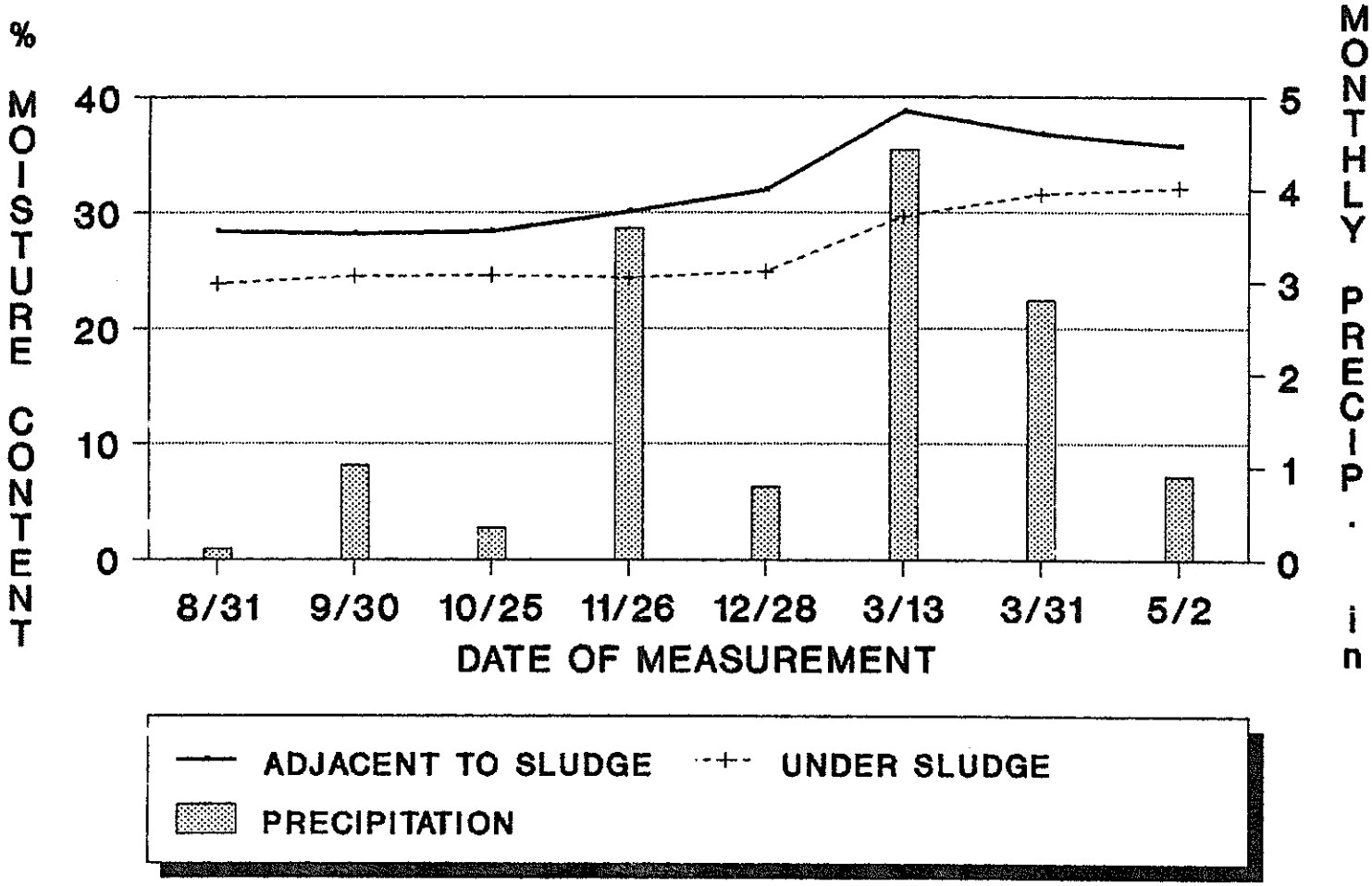


FIGURE V-10.0

MEAN MOISTURE CONTENT AT 48 INCHES
UNDER AND ADJACENT TO SLUDGE BLANKET



Because of the limitation of the suction lysimeters only one soil water sample from under the sludge blanket was collected. Three soil water samples were collected from the lysimeters located adjacent to the sludge blanket. Because the lysimeters located adjacent to the sludge blanket were also located down-gradient of the sludge blanket, they were affected by runoff from the sludge blanket.

Figures V-11.0 to V-14.0 show the nutrient concentration found in the soil water samples taken with the suction lysmeters. The heavy metal concentrations are not presented in figure form because the heavy metal concentrations in the soil water samples did not exceed the State of Idaho drinking water maximum contaminant levels.

The figures presented indicate that the runoff from the sludge blanket had a greater impact on the site soil water than the leachate, that passed through the sludge blanket. This is probably due to the quantity of the leachate movement rather than the strength of the nutrient concentration in the leachate. It is interesting to note that other than for the nitrate-nitrogen, all of the nutrient concentrations measured on May 2, 1989 are higher in the soil water samples taken adjacent to the sludge blanket than those taken under the blanket.

The inability of the suction lysimeters to successfully extract soil water samples from under the sludge blanket once more reinforces the fact that the sludge blanket is effective in impeding the downward movement of leachate through the blanket. This fact would tend to support the need for stacking the stockpiled sludge as high as possible to reduce the volume of leachate passing through it and to decrease the surface area exposed to the elements.

F. Soil Analyses at Twelve and Thirty-six Inch Depths

Prior to the placing of the sludge blanket, baseline soil samples were collected and analyzed for nutrients and heavy metals. The samples were collected at the twelve and thirty-six inch depths both under and adjacent to the sludge blanket. After the sludge blanket had been in place for one wet season, soil samples were again taken both under and adjacent to the sludge blanket and the results were presented in graph form. Figures V-15.0 to V-17.0 show the impact that the sludge blanket leachate and the runoff had on the nutrients and heavy metal concentrations in the soils at a depth of twelve inches.

FIGURE V-11.0

SOIL WATER NITROGEN AS NITRATE
UNDER AND ADJACENT TO SLUDGE BLANKET

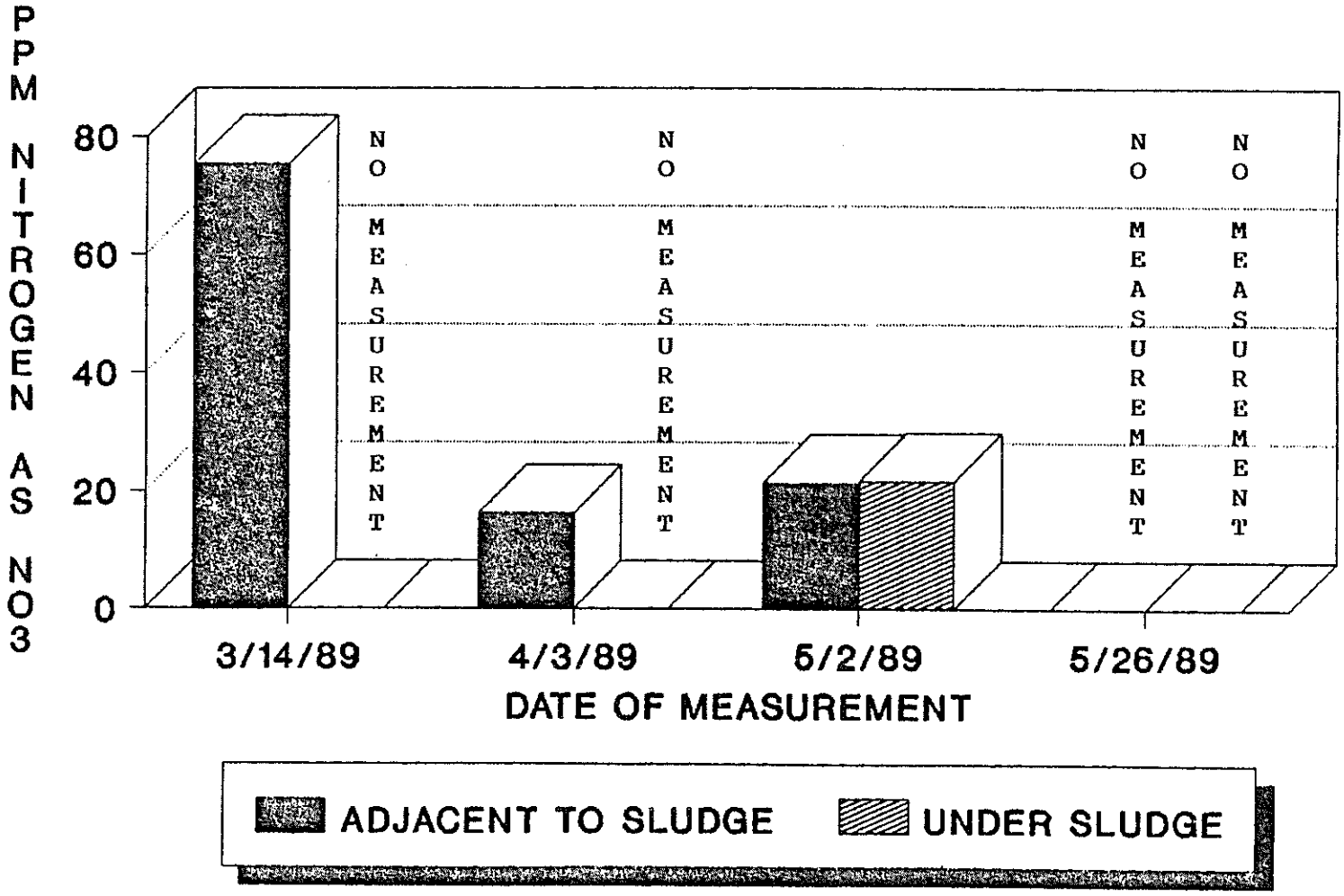


FIGURE V-12.0

SOIL WATER NITROGEN AS AMMONIA
UNDER AND ADJACENT TO SLUDGE BLANKET

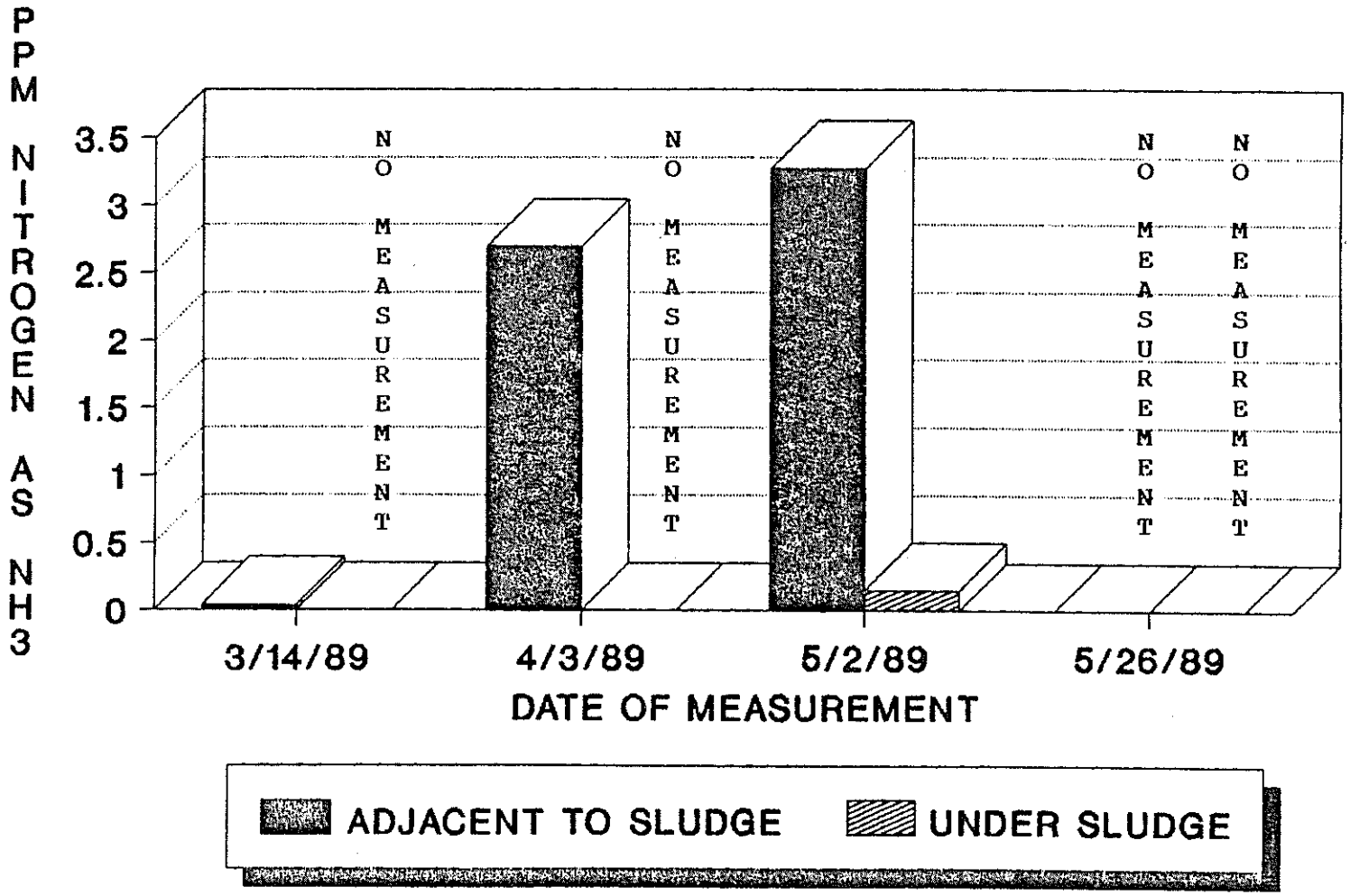


FIGURE V-13.0

SOIL WATER TOTAL KJELDAHL NITROGEN
UNDER AND ADJACENT TO SLUDGE BLANKET

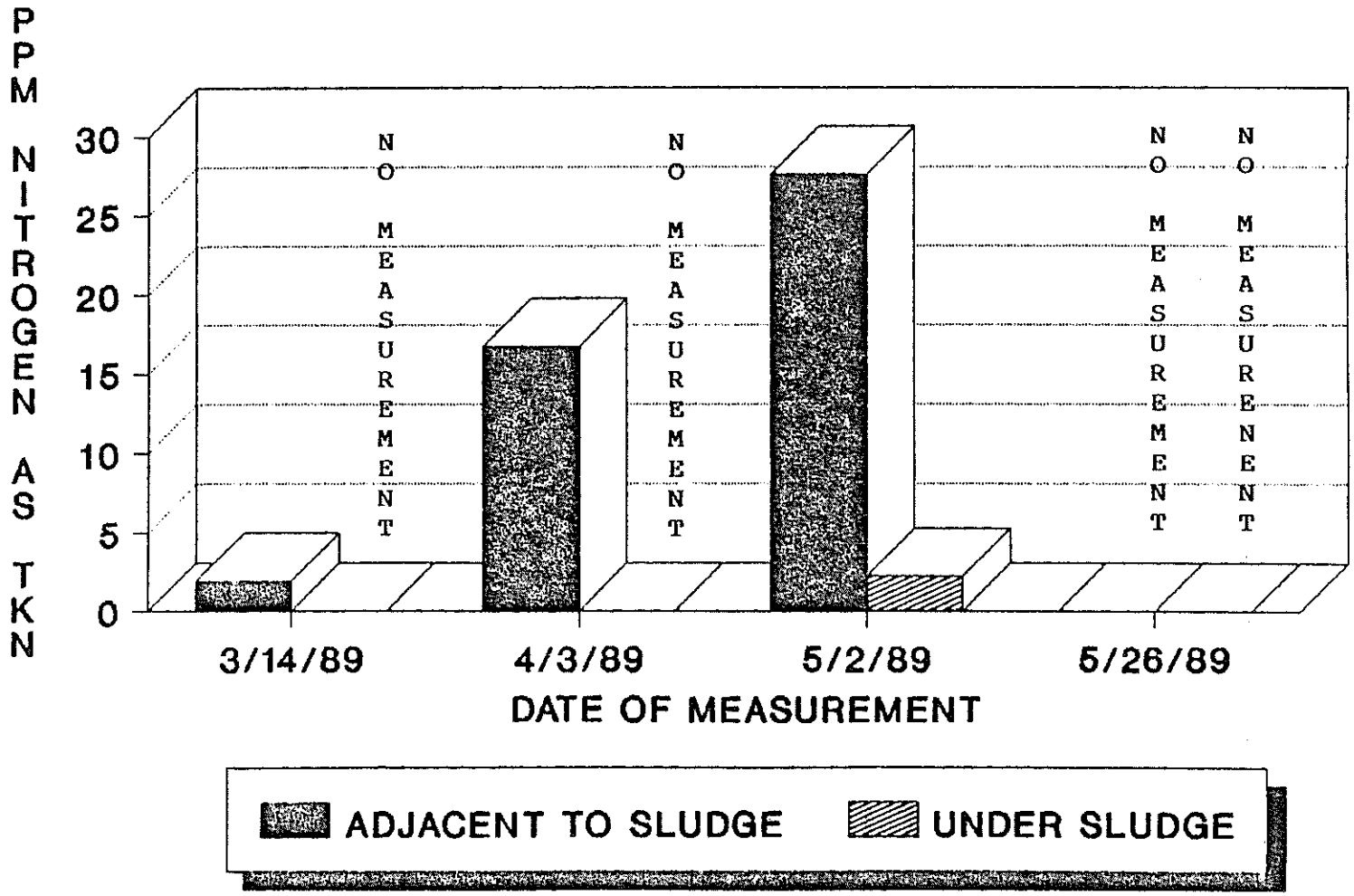
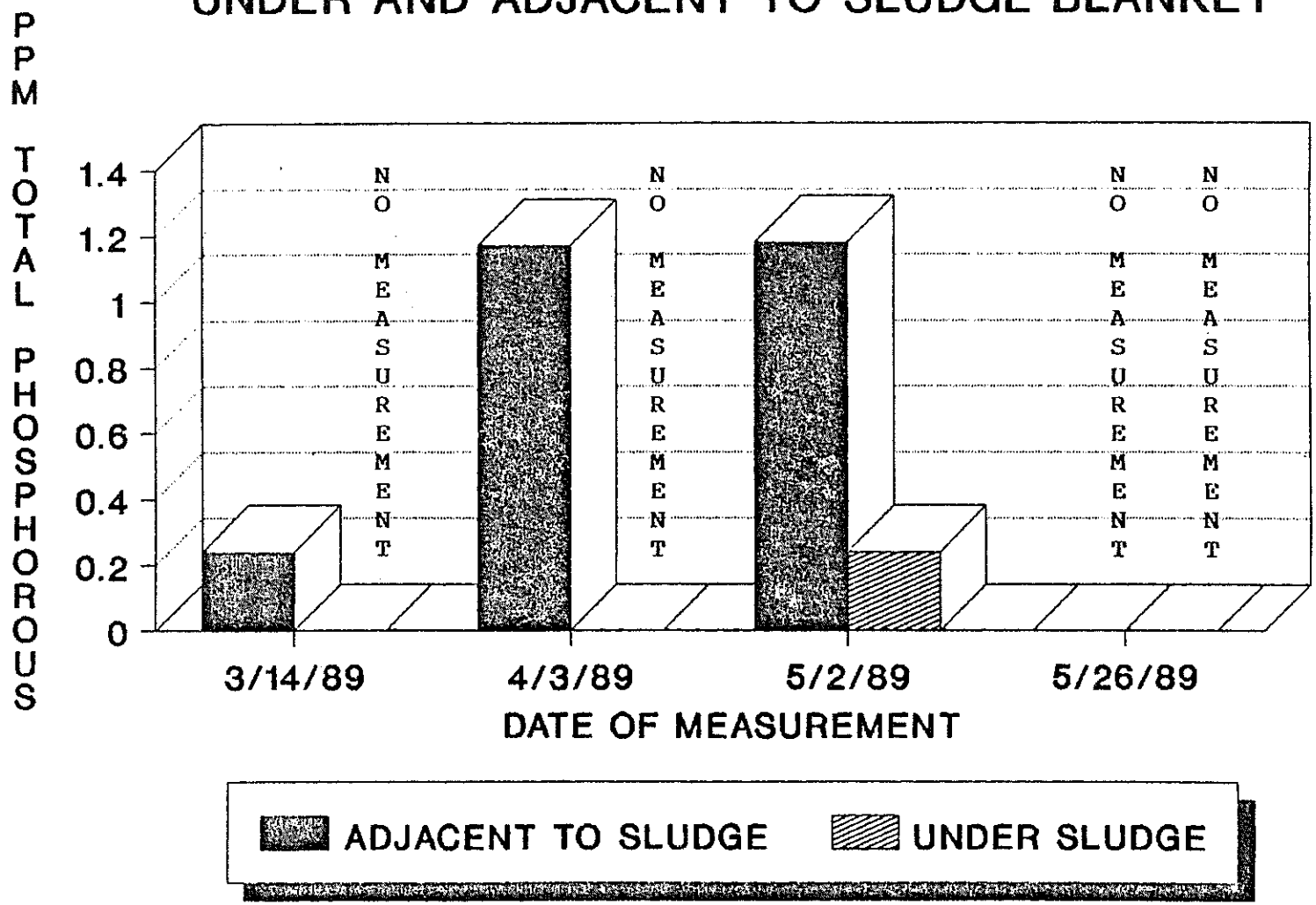


FIGURE V-14.0

SOIL WATER TOTAL PHOSPHOROUS
UNDER AND ADJACENT TO SLUDGE BLANKET



The figures show that the heavy metal concentrations in the soils at the twelve inch depth did not increase due to the presence of the sludge blanket. Figure V-16.0 indicates that runoff from the sludge blanket has caused an increase in the nitrate-nitrogen level in the soil adjacent to the sludge at the twelve inch depth. This increase is not seen with any of the other nutrients measured on May 2, and is not seen in the soils at the twelve inch depth under the sludge blanket. This once more reinforces the premise that sludge leachate volume through the sludge blanket did not significantly impact the underlying soil and soil water.

Figures V-18.0 to V-20.0 show the impact that the sludge blanket leachate and the runoff had on the nutrients and heavy metal concentrations in the soils at a depth of thirty-six inches. As with the soils at the twelve inch depth, these figures show that the heavy metal concentrations in the soils at this depth were not increased by the presence of the sludge blanket. Figure V-19.0 indicates that the runoff from the sludge blanket has caused an increase in the nitrate-nitrogen level in the soil both under and adjacent to the sludge blanket. This increase was not observed for any of the other nutrients and was smaller for the soil beneath the sludge blanket than for the soils adjacent to the sludge blanket. Higher nitrate-nitrogen concentrations at the 36 inch depth rather than at the 12 inch level further support the position that nutrient sources outside the sludge stockpile were effecting soil values.

G. Groundwater Gradients

Early in the soil investigation portion of the study a soil horizon was identified that indicated the presence of a seasonal perched water table. In order to monitor the impact that the sludge blanket would have on the water quality of the perched water table four monitoring wells were installed in the respective corners of the instrumented site. It was anticipated that two of the wells would be up-gradient and two of the wells would be down-gradient. Figures V-21.0 to V-23.0 show the actual perched water table hydraulic gradient and the phreatic surface of the water table as it fluctuated during the wet season of the year. These figures show that the perched water table slopes downward from the northeasterly corner to the northwesterly and southwesterly corners of the site.

FIGURE V-15.0

SOIL CONCENTRATIONS AT 12 INCHES
BASELINE, ADJACENT TO, AND UNDER SLUDGE

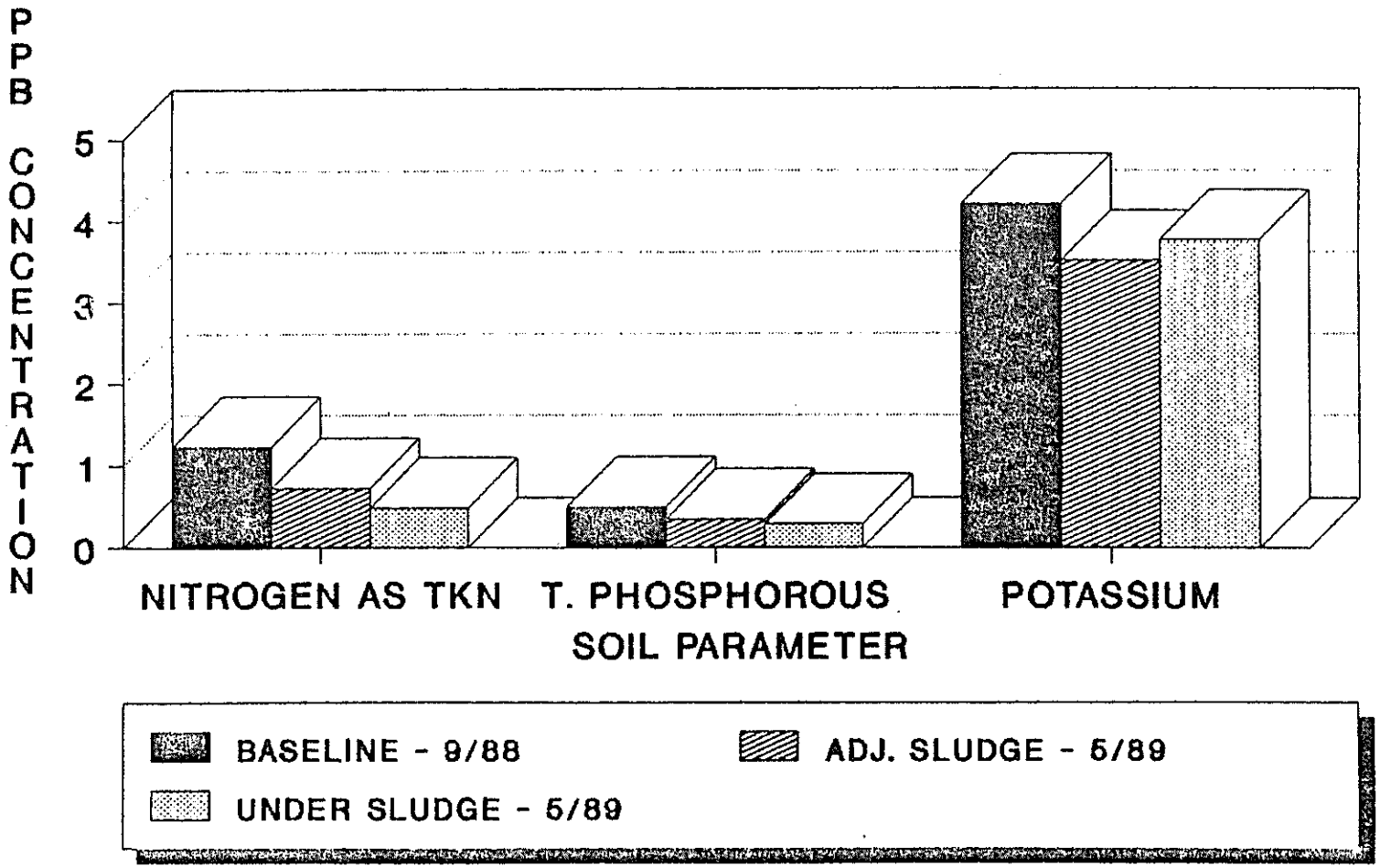


FIGURE V-16.0

SOIL CONCENTRATIONS AT 12 INCHES
BASELINE, ADJACENT TO, AND UNDER SLUDGE

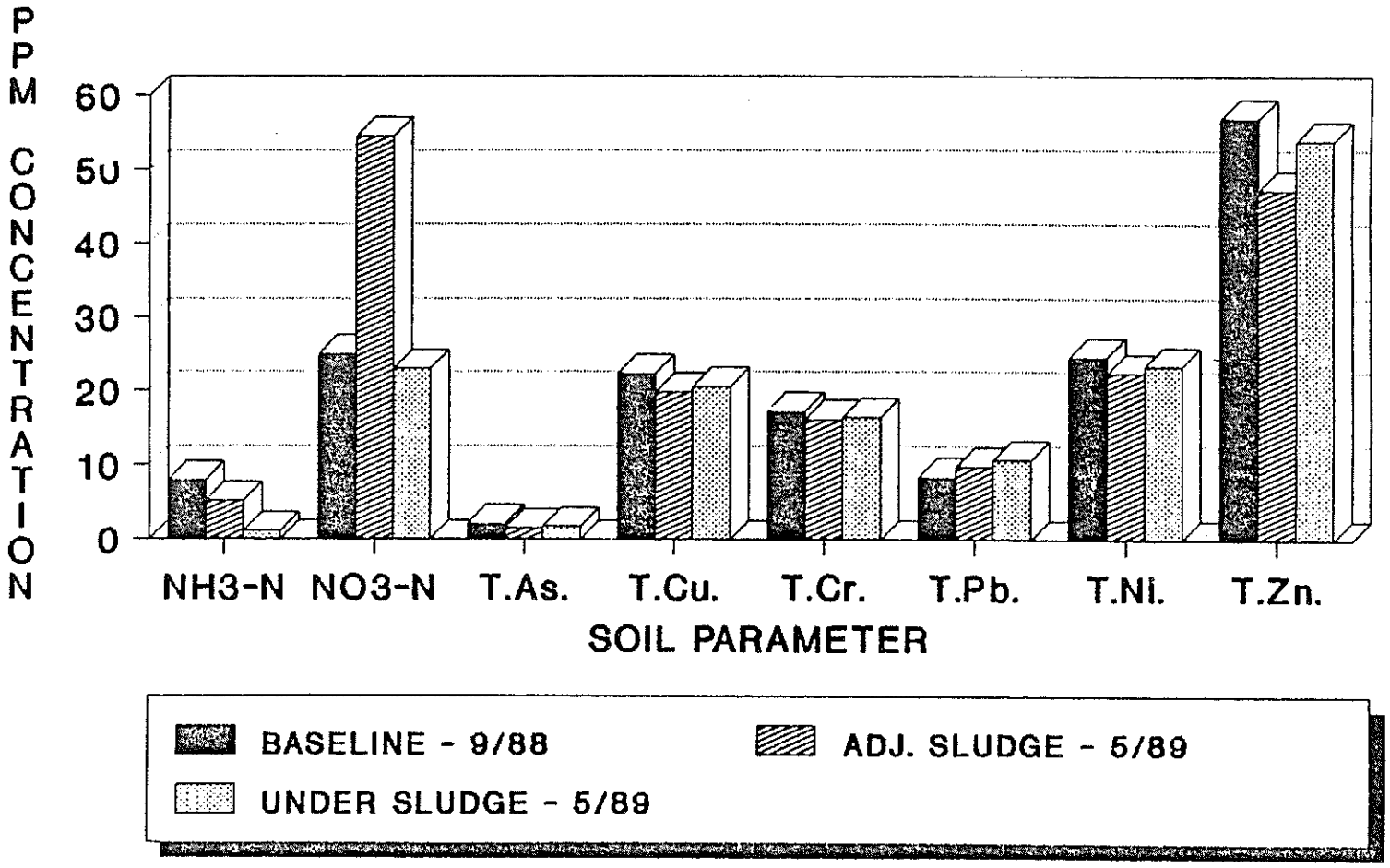


FIGURE V-17.0

SOIL CONCENTRATIONS AT 12 INCHES
BASELINE, ADJACENT TO, AND UNDER SLUDGE

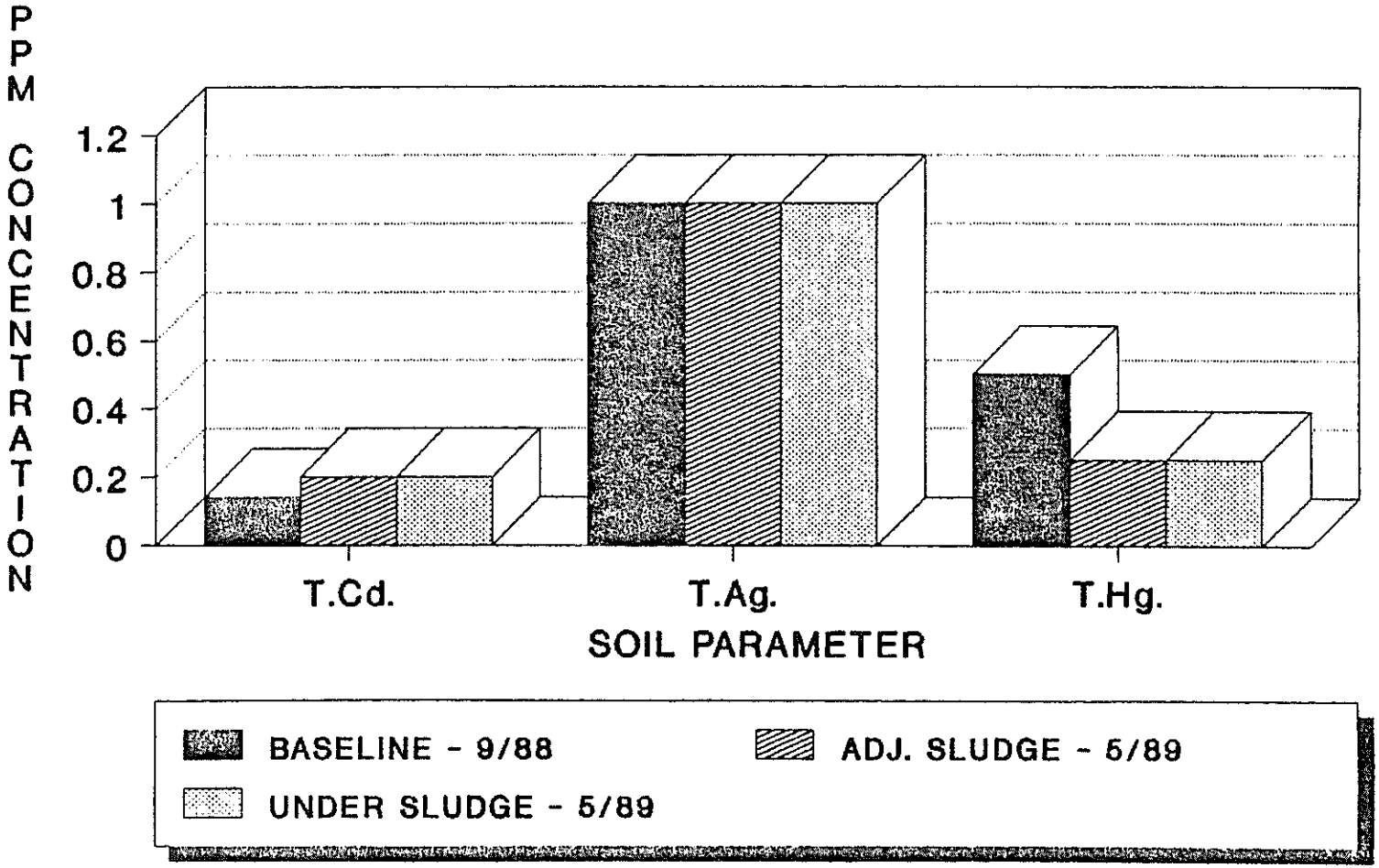


FIGURE V-18.0

SOIL CONCENTRATIONS AT 36 INCHES
BASELINE, ADJACENT TO, AND UNDER SLUDGE

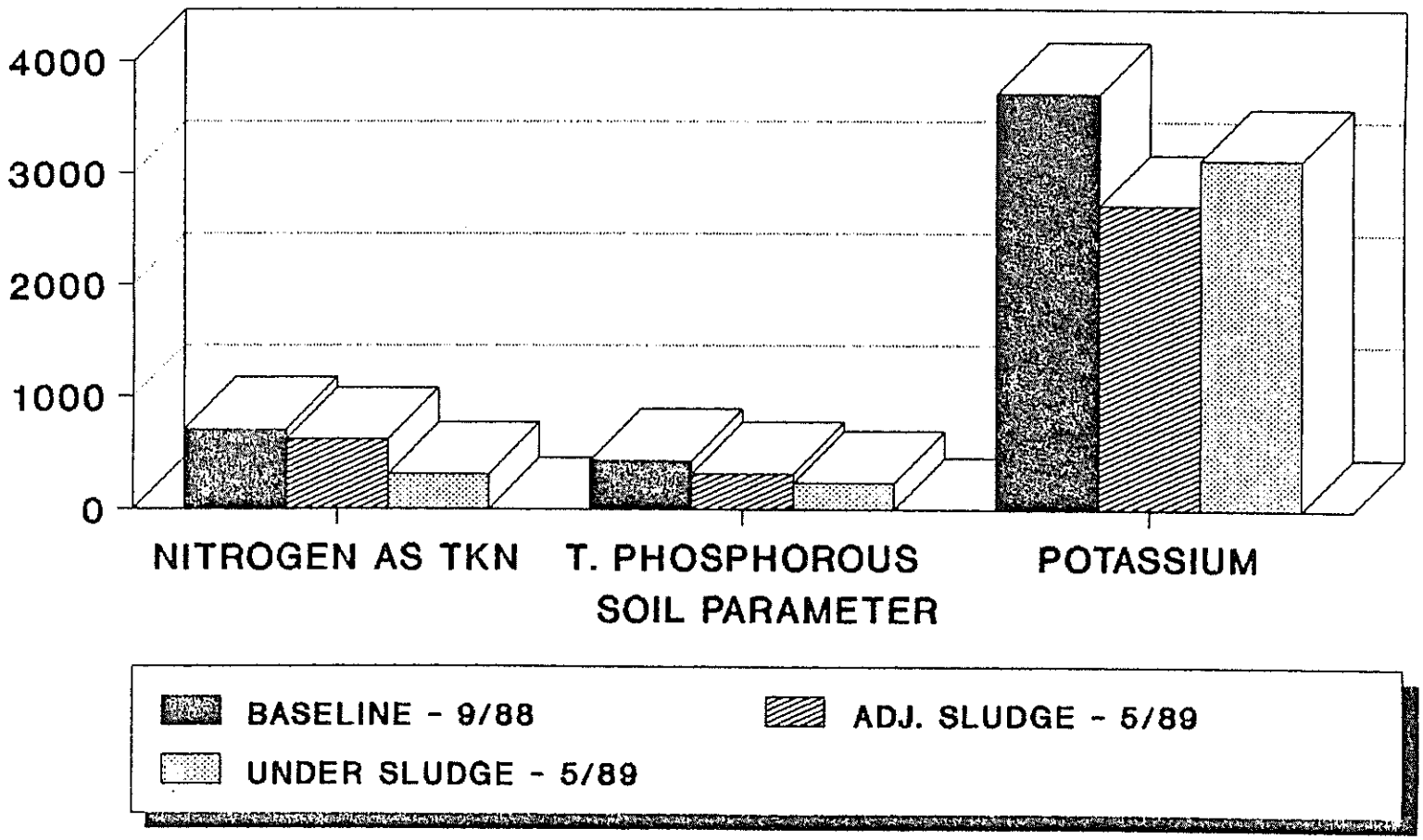


FIGURE V-19.0

SOIL CONCENTRATIONS AT 36 INCHES
BASELINE, ADJACENT TO, AND UNDER SLUDGE

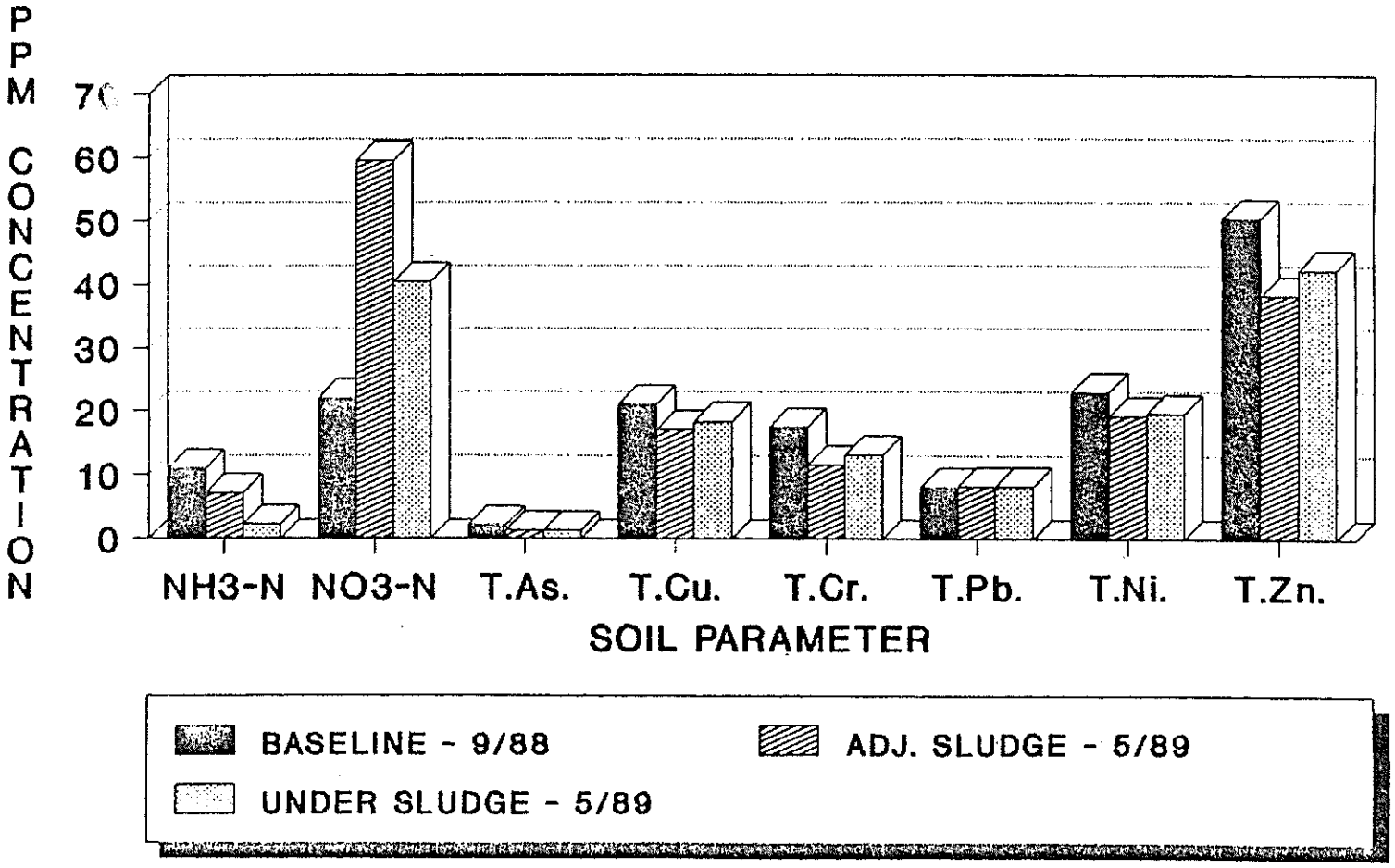


FIGURE V-20.0

SOIL CONCENTRATIONS AT 36 INCHES
BASELINE, ADJACENT TO, AND UNDER SLUDGE

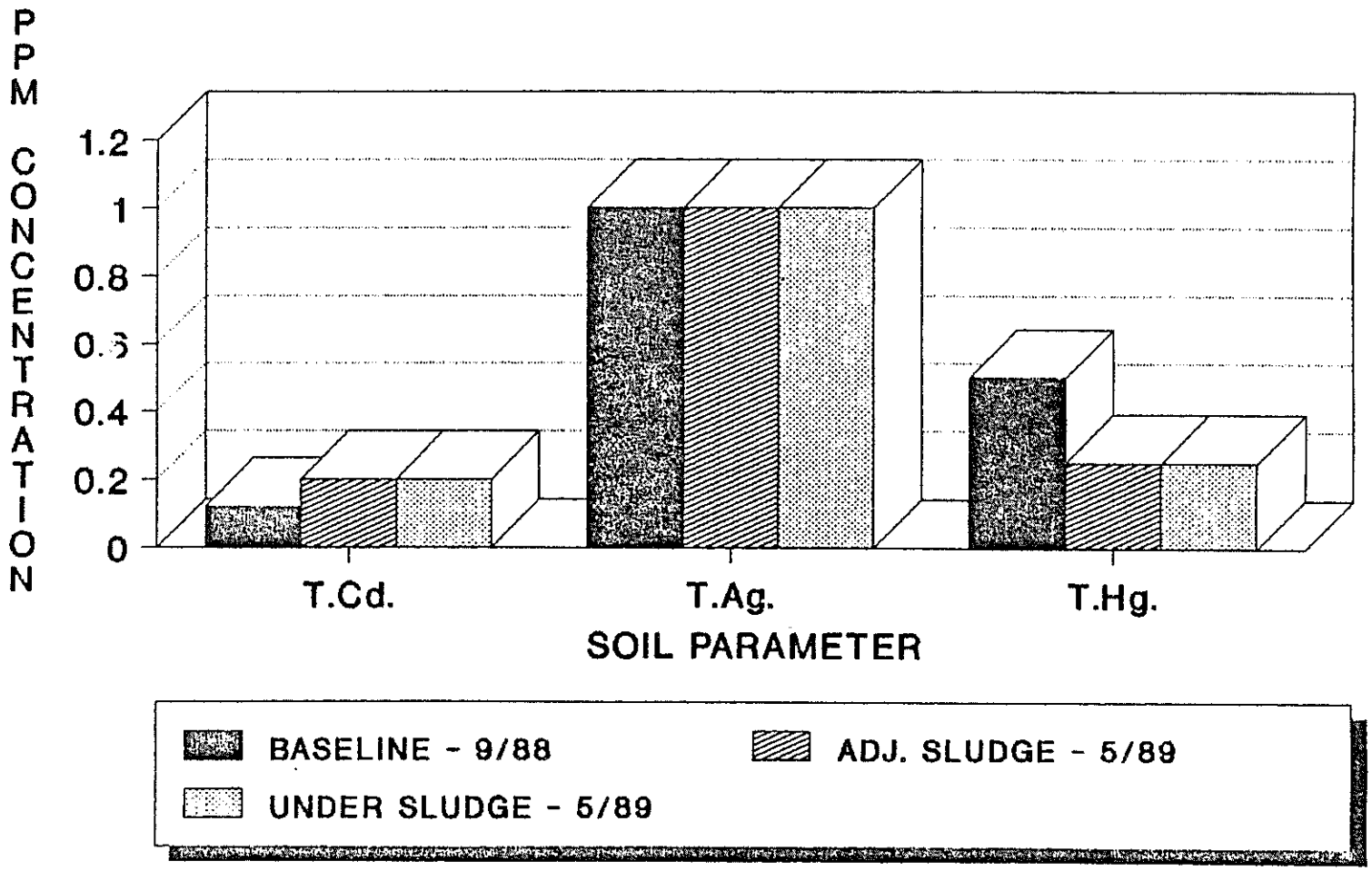


FIGURE V-21.0

SEASONAL PERCHED WATER SLOPES

STATION 8000 TO 0000

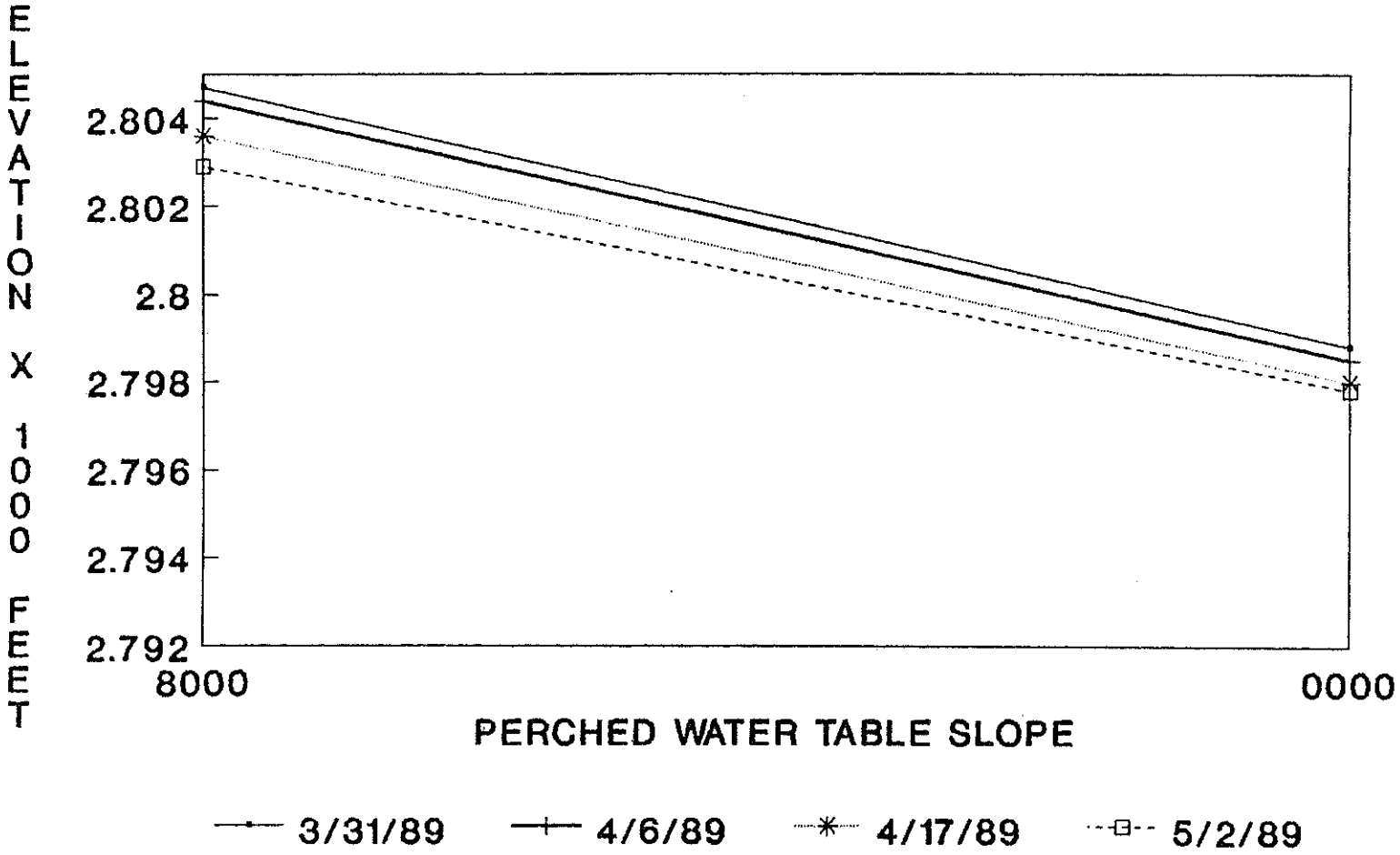


FIGURE V-22.0

SEASONAL PERCHED WATER SLOPES

STATION 0000 TO 0080

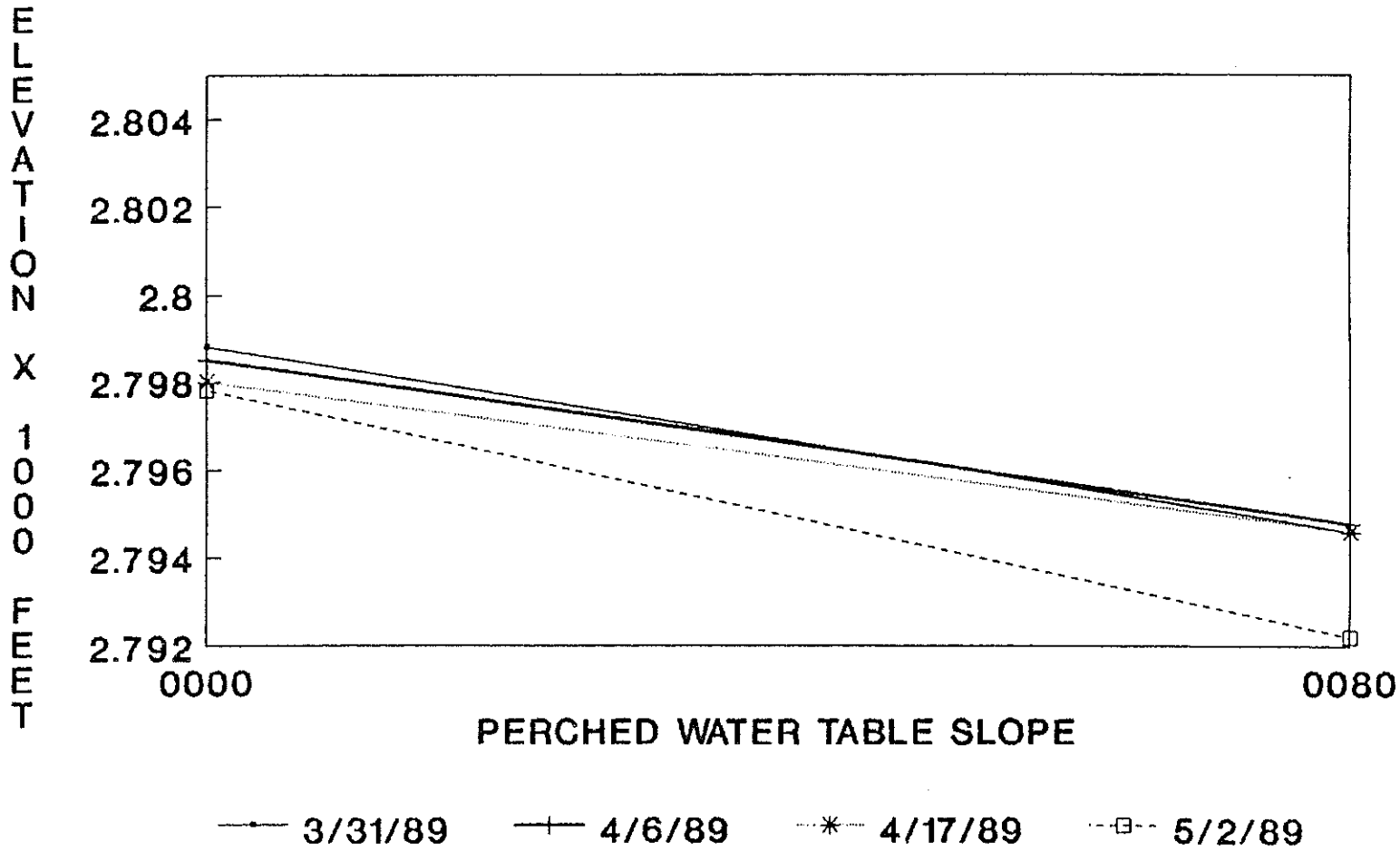
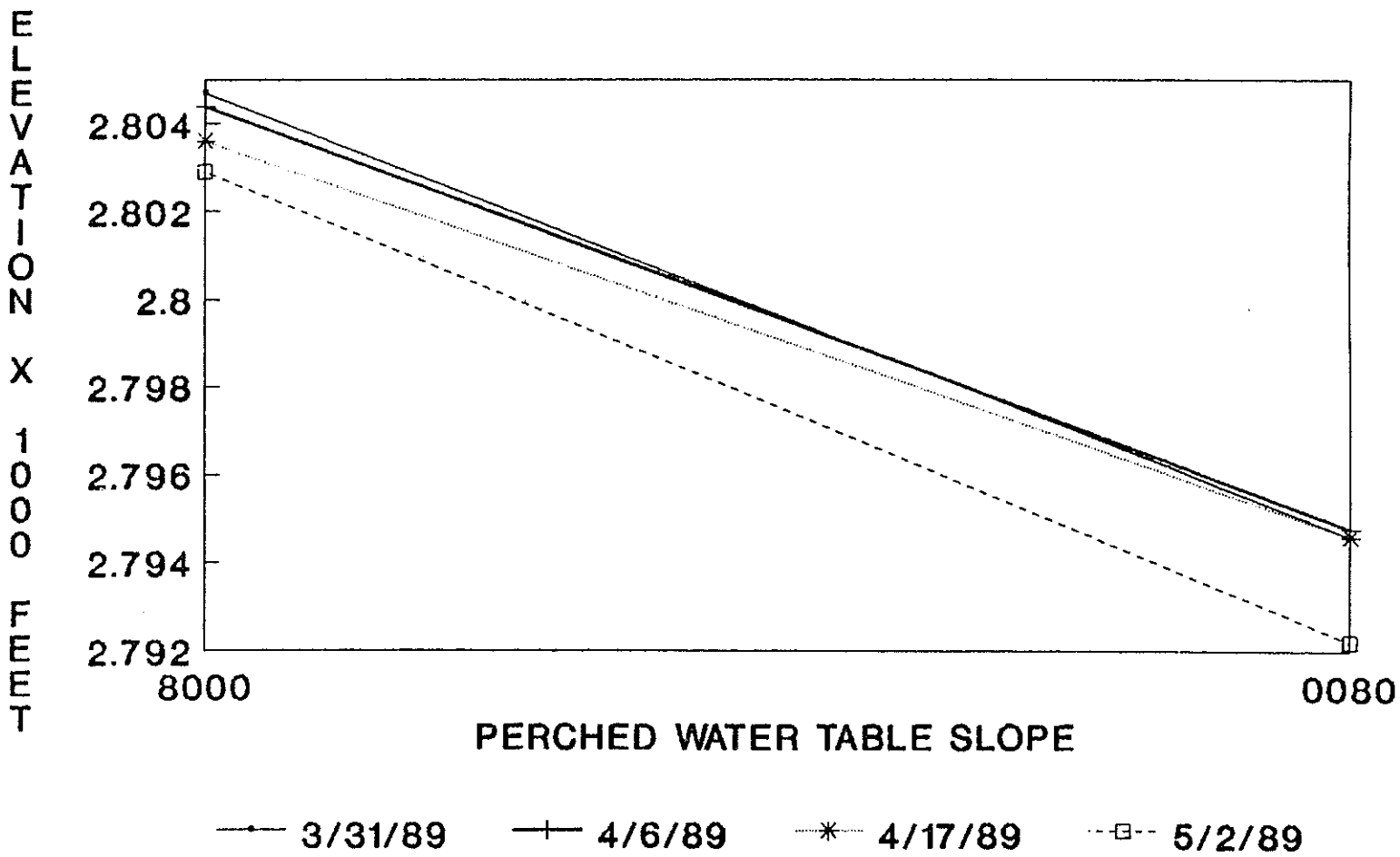


FIGURE V-23.0

SEASONAL PERCHED WATER SLOPES

STATION 8000 TO 0080



H. Shallow Monitoring Well Water Quality

Because the perched water table passed under the sludge blanket, it provided an excellent opportunity to assess the potential impacts that the sludge blanket could have on the underlying ground water. Figures V-24.0 to V-28.0 respectively, show the nutrient and potassium levels in the perched water table in three of the four shallow monitoring wells. The fourth monitoring well, designated as #8080 in the southeast corner of the site, remained a dry hole throughout the duration of the sampling. The heavy metal data were not plotted on a graph because the water quality analyses indicated that the heavy metal concentrations did not exceed the State of Idaho maximum contaminant levels for drinking water.

In the Figures V-24 to V-28 well #8000 is the northeast well and is the up-gradient well. Wells #0000 and #0080 are the northwest and southwest wells, respectively, and are down-gradient wells. From the water quality data presented on these figures it appears that the presence of the sludge blanket caused an increase in the nutrient and potassium levels in the down-gradient wells. From what was identified in the aforementioned paragraph on soil sample data, it appears that runoff from the sludge blanket is the major contributor to the nutrient enrichment of the perched water table.

To assess the risk to the public health, total, fecal and fecal strep coliform tests were run on the up-gradient and down-gradient wells. Fecal coliforms which are normally used to identify possible contamination of water due to human feces were not detected in any of the tests. The presence of fecal strep was detected in one of the tests, and the presence of total coliforms was identified as shown in Figure V-27.0. Figure V-27.0 clearly indicates that the down-gradient well #8080 only exceeded the up-gradient well #8000 in coliform bacteria count one time. The quality of the water sample taken from the down-gradient well on March 14th, 1989, had a total coliform count of 140 colonies per 100 milliliters. This was the maximum coliform count recorded during this study.

FIGURE V-24.0

GROUNDWATER NITROGEN AS NITRATE
SHALLOW MONITORING WELLS

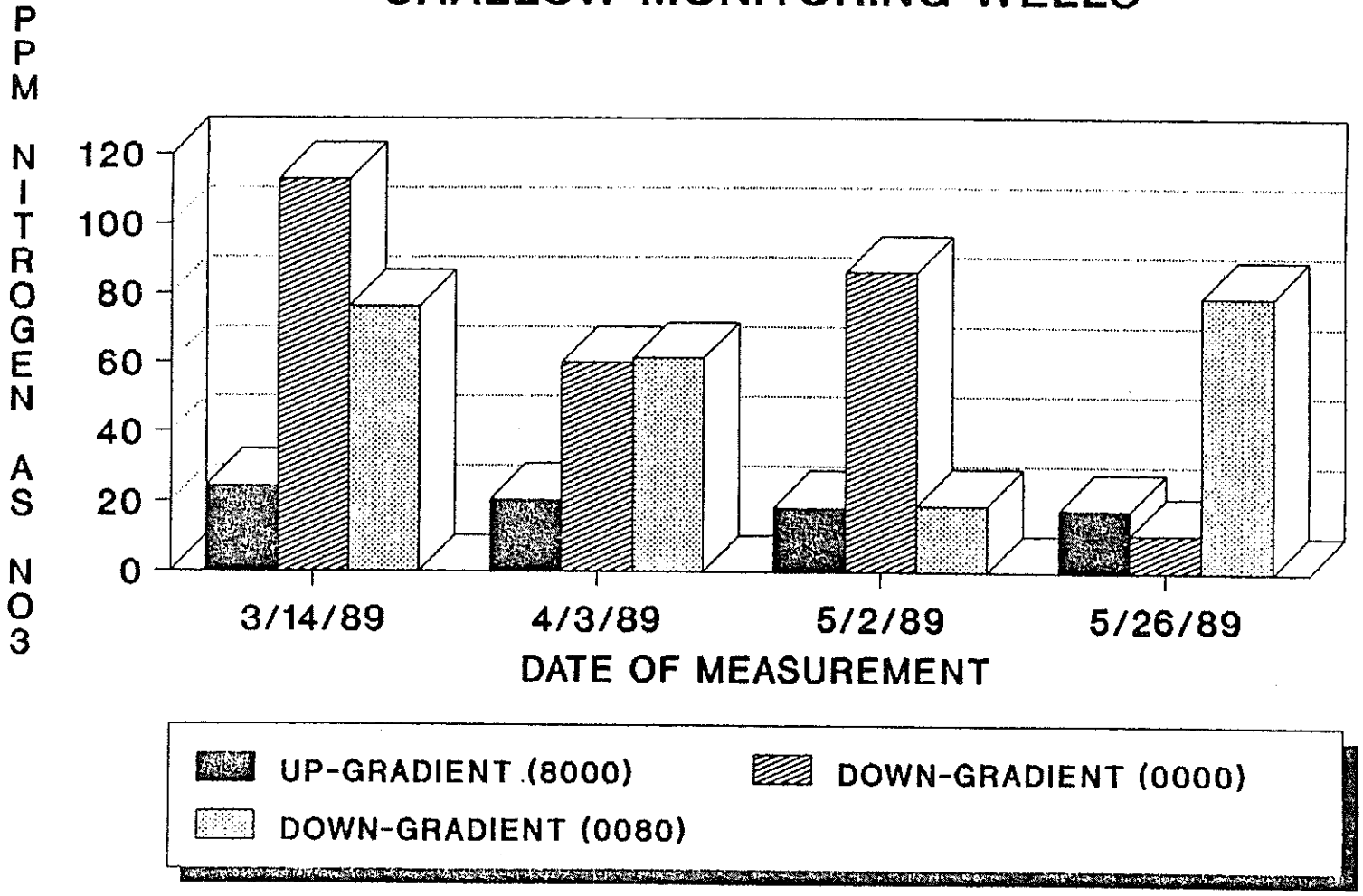


FIGURE V-25.0

GROUNDWATER NITROGEN AS AMMONIA

SHALLOW MONITORING WELLS

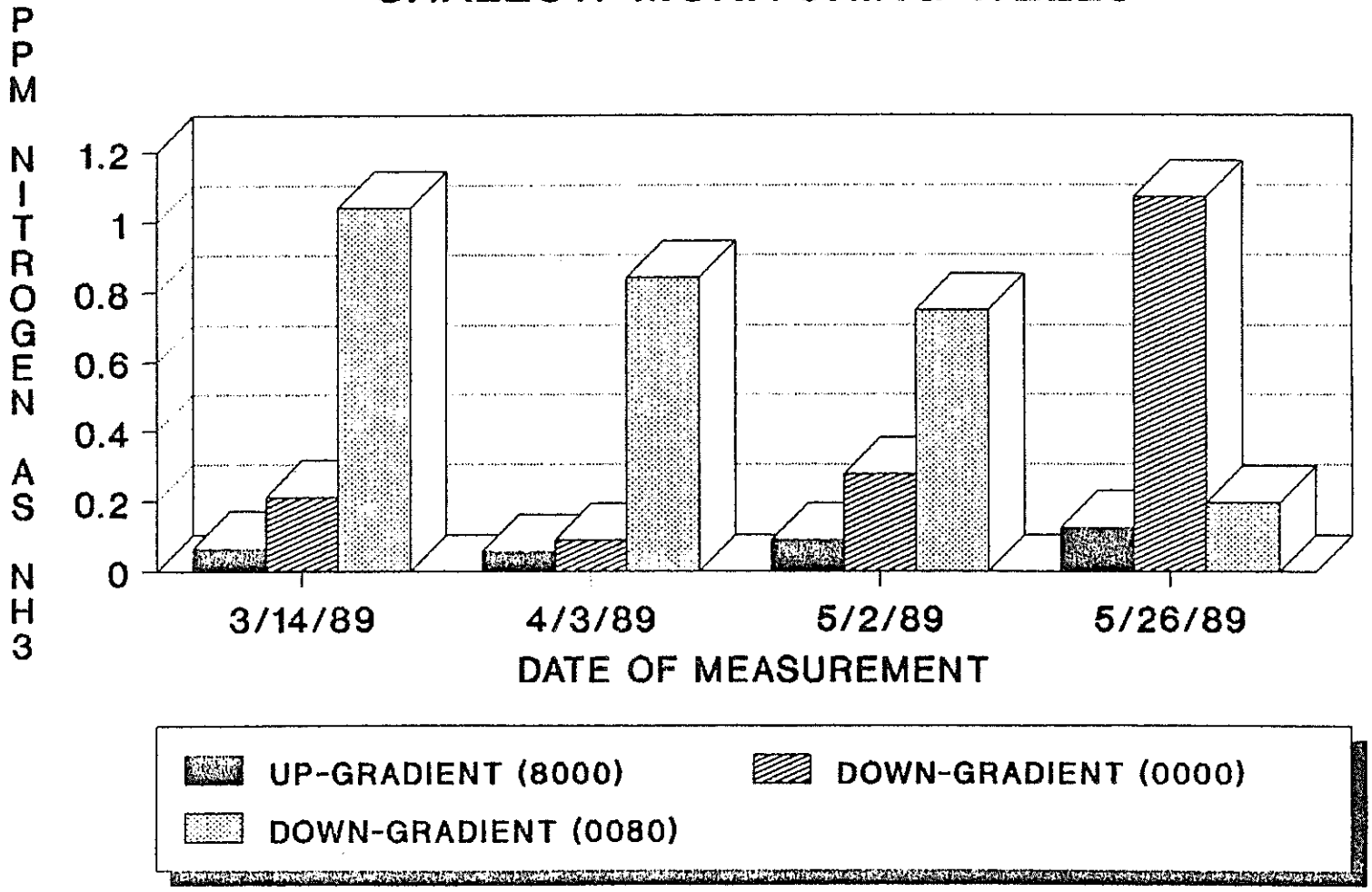


FIGURE V-26.0

GROUNDWATER NITROGEN AS TKN

SHALLOW MONITORING WELLS

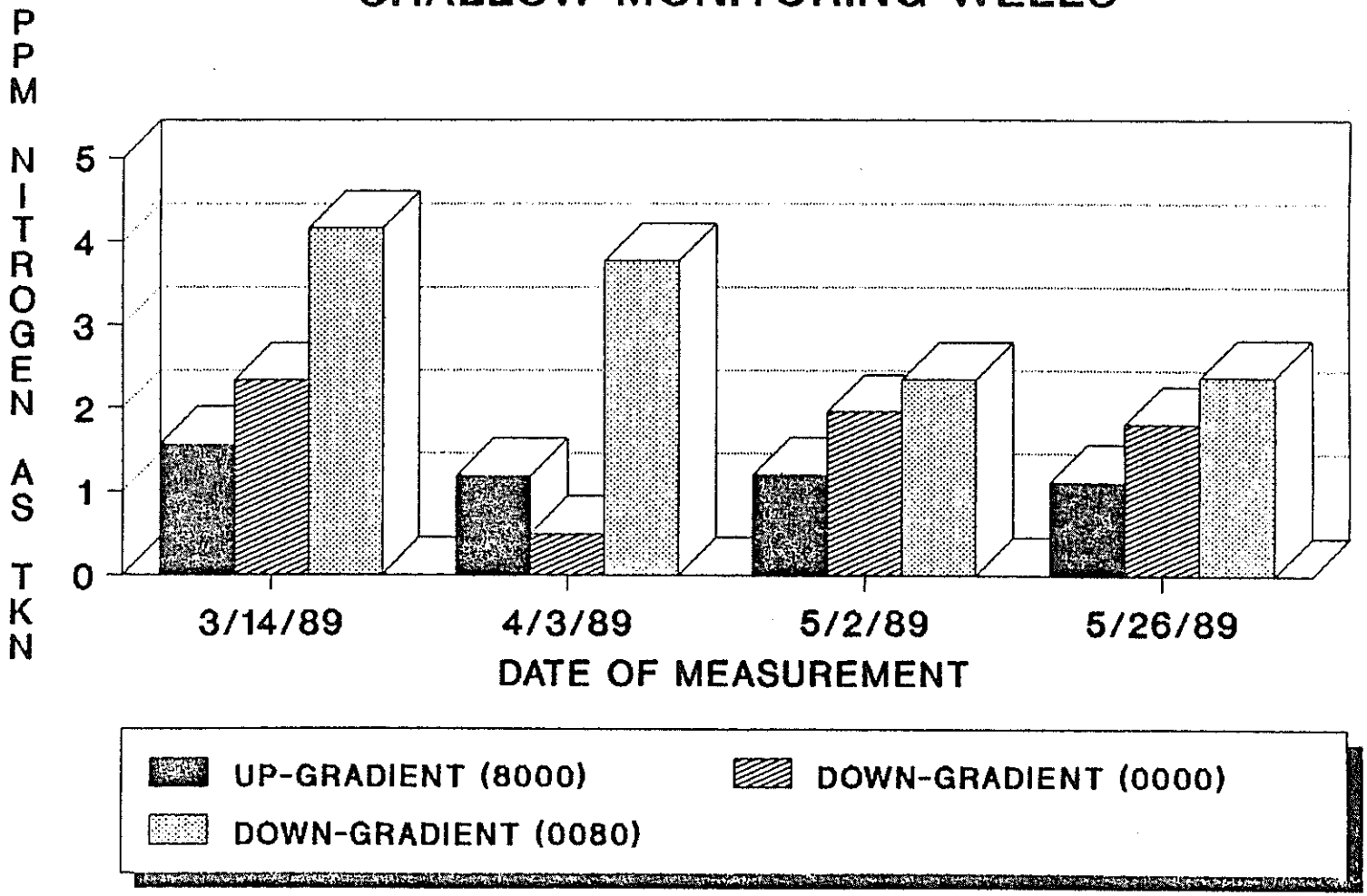


FIGURE V-27.0

GROUNDWATER TOTAL PHOSPHOROUS

SHALLOW MONITORING WELLS

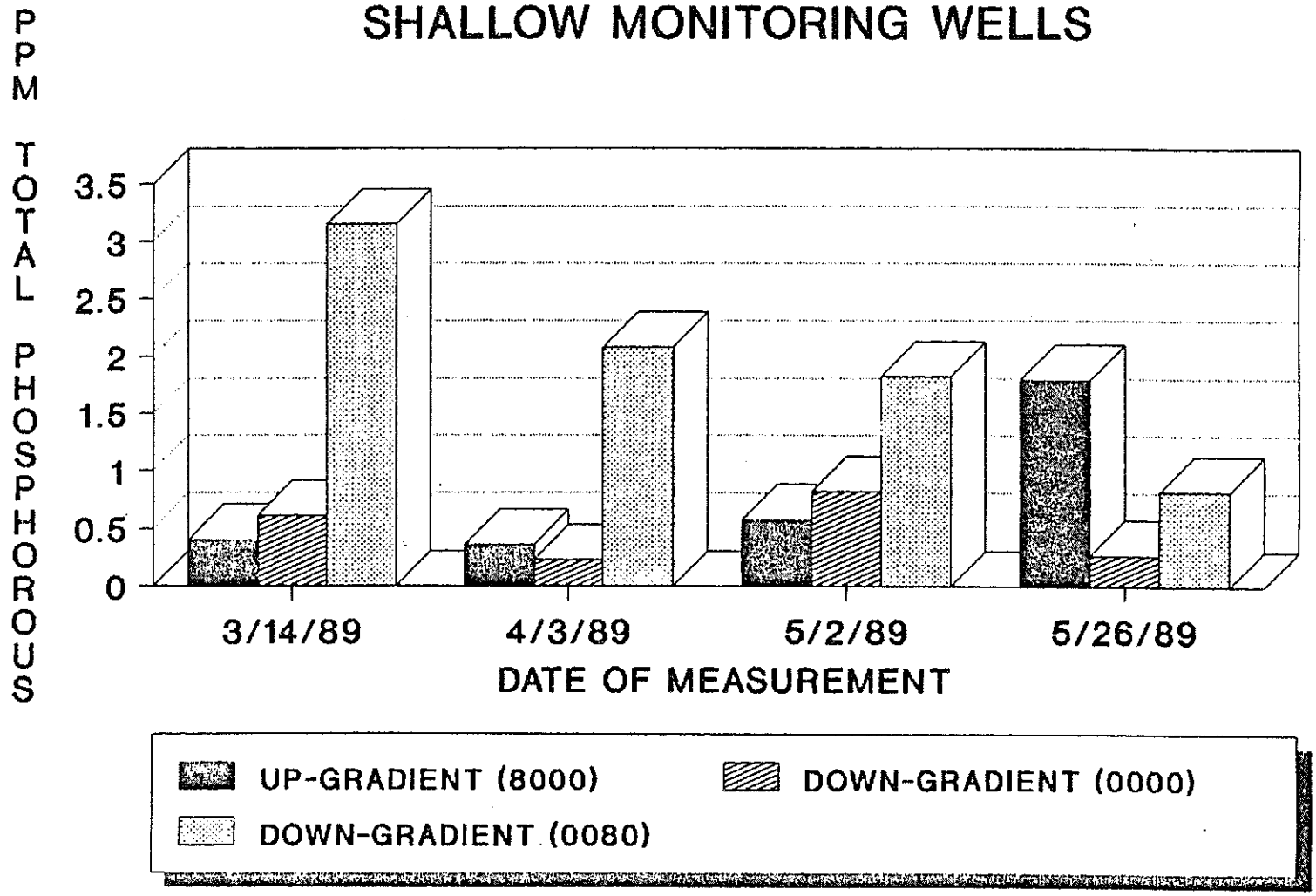


FIGURE V-28.0

GROUNDWATER POTASSIUM
SHALLOW MONITORING WELLS

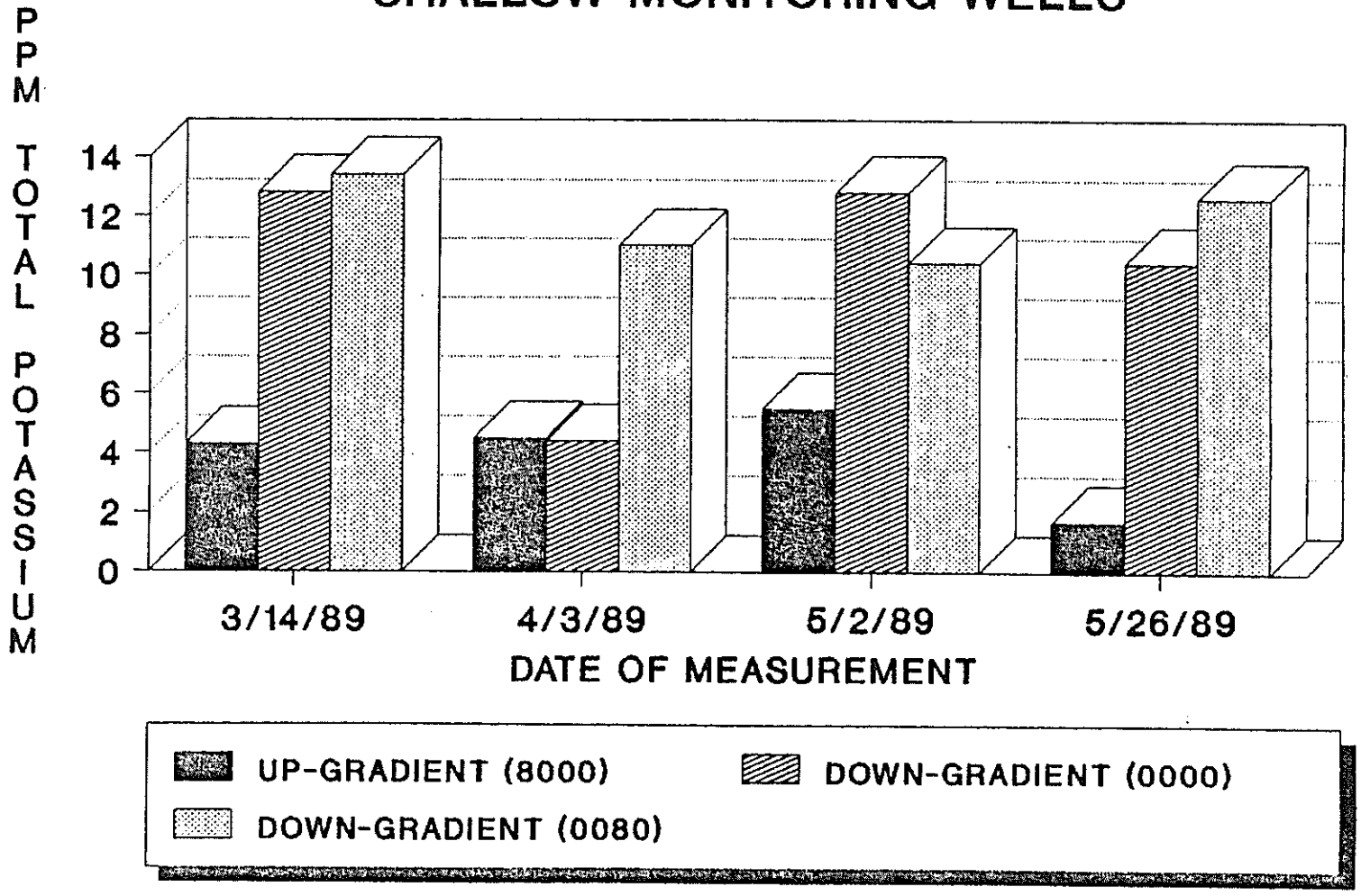
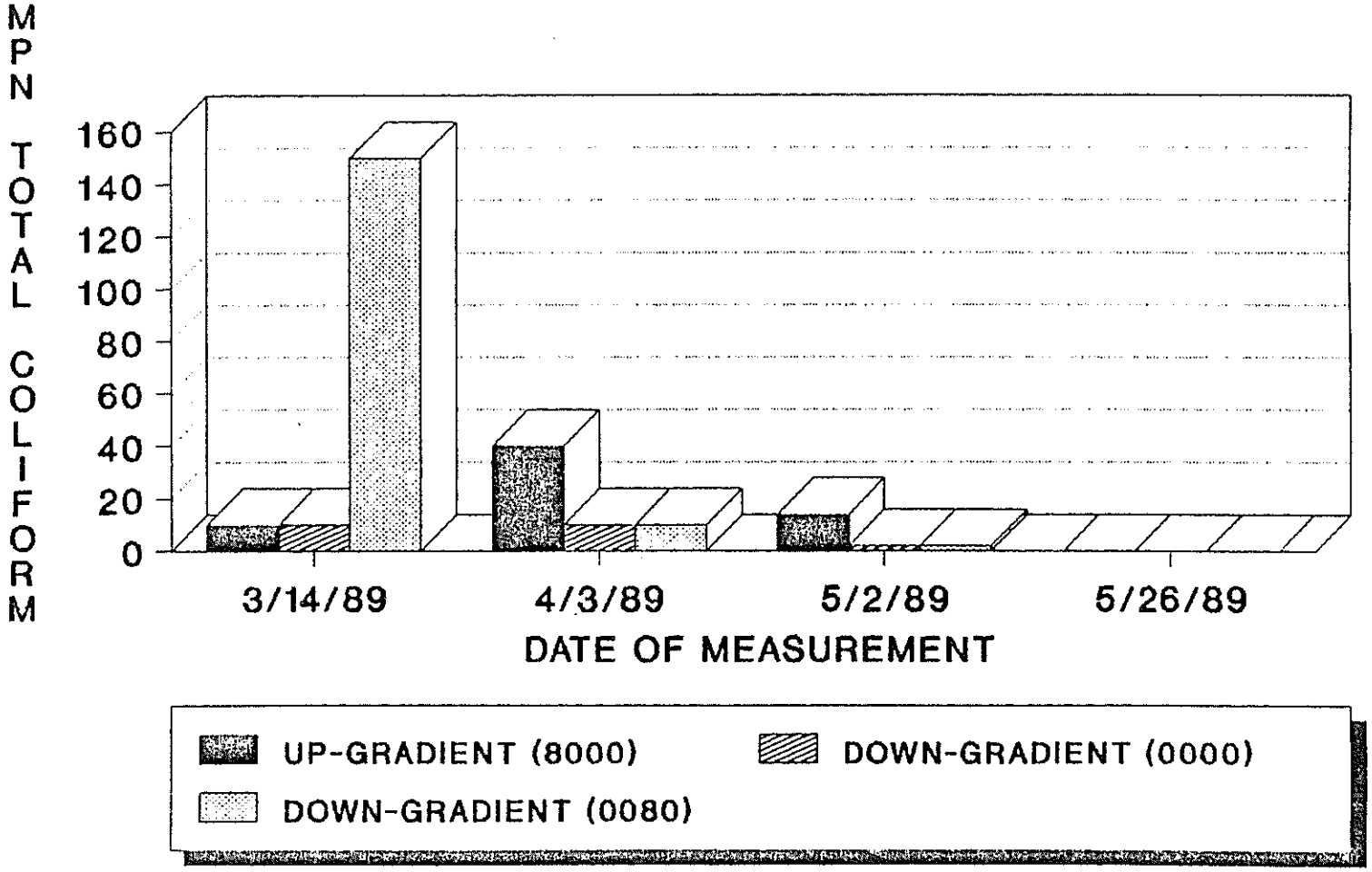


FIGURE V-29.0

GROUNDWATER TOTAL COLIFORM

SHALLOW MONITORING WELLS



I. Haxton Field Tile

To supplement the data from the heavily instrumented test site, an existing field tile which extended under the sludge stockpile placed last summer and fall was monitored for bacteria, nutrients, and heavy metals. The location of this field tile in relation to the access road and the instrumented sludge site is as shown on Figure V-30.0. The water quality data collected from this field tile is tabulated and presented on Figures V-31.0 to V-36.0.

The water quality analyses conducted on the water samples from the field tile indicated a slight nutrient enrichment during periods of high precipitation and/or snow melt events, but the heavy metal concentrations were all well below the State of Idaho maximum contaminant levels for drinking water. The significance of the nutrient enrichment identified on figures V-31.0 to V-35.0 cannot be fully defined without further sampling of other field tiles running out of other comparable fields without stockpiled sludge. The sample data point marked with a star and collected on May 26th is just such a tile. It is interesting to note that this field tile has measured nutrient values that either equal or exceed the values recorded for the Haxton tile on May 26th.

Of the nutrients presented on these figures the only one that exceeds the State of Idaho Drinking Water Standards is the nitrogen as nitrate. The State of Idaho drinking water maximum contaminant level for nitrogen as nitrate is 10 parts per million. The quality of the water from the field tile consistently met or exceeded the State of Idaho standards for secondary contact waters with respect to bacteria and in most cases they met primary contact standards.

FIGURE V-30.0

HAXTON FIELD TILE LOCATION

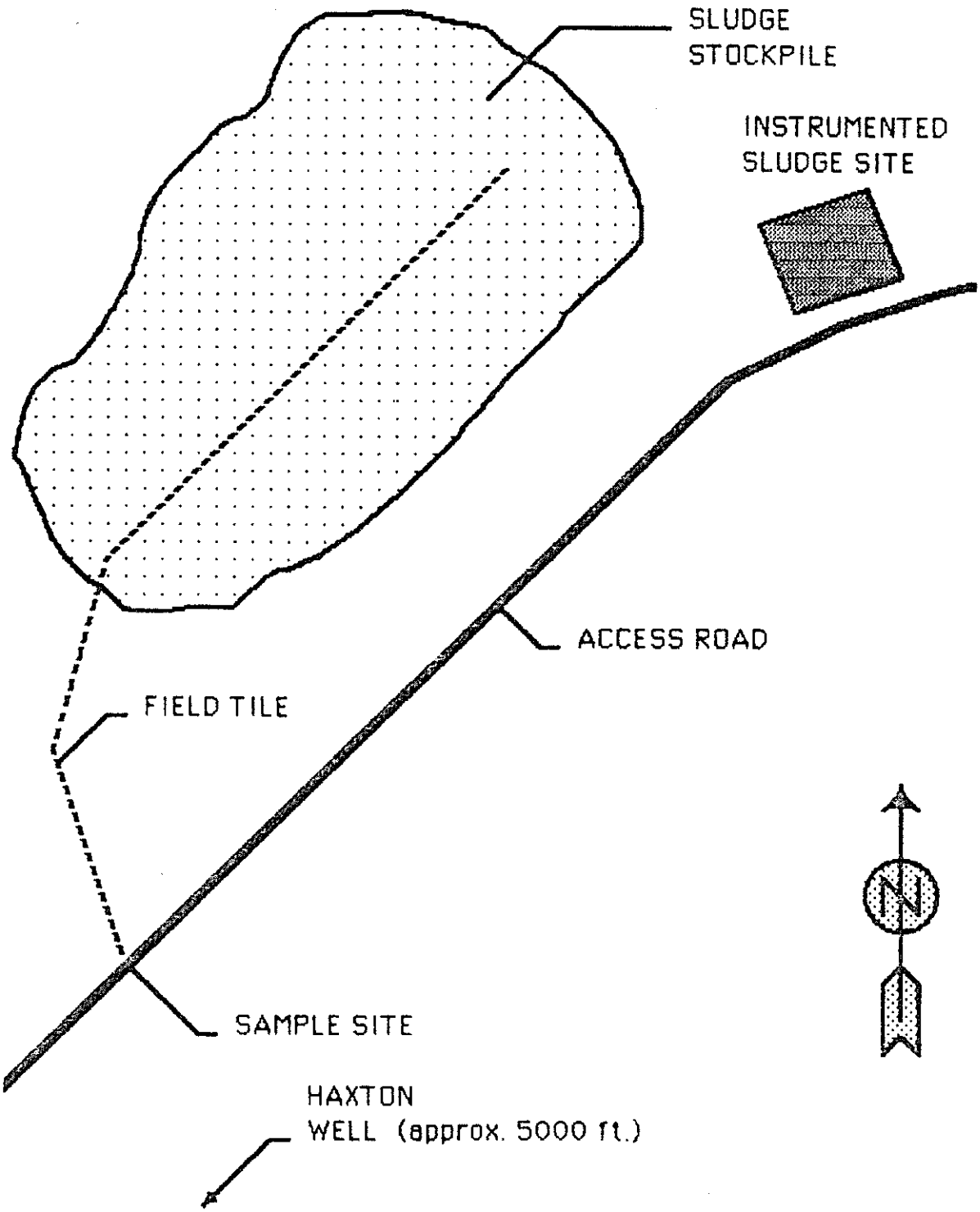


FIGURE V-31.0

SOIL WATER NITROGEN AS NITRATE

HAXTON FIELD TILE

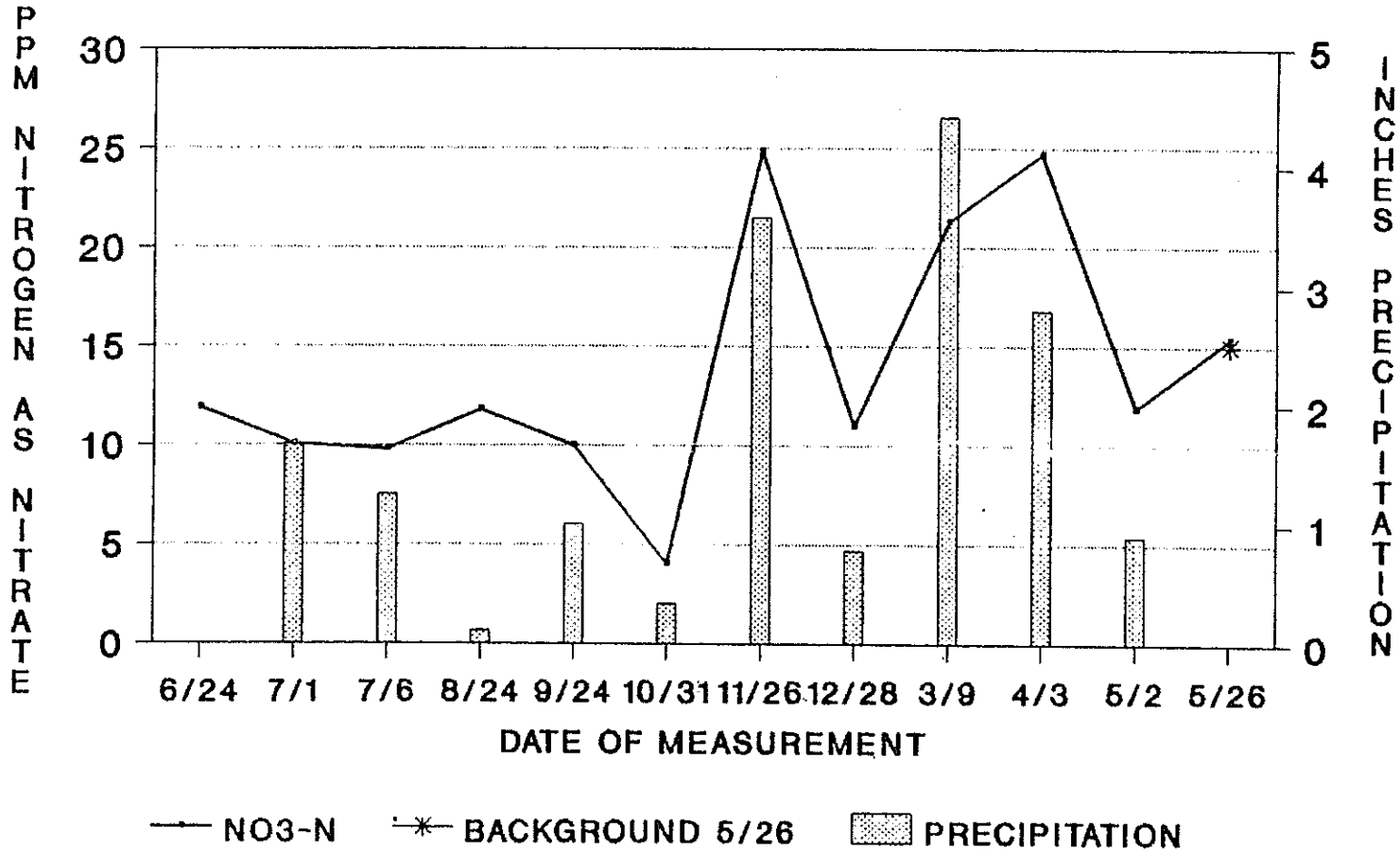


FIGURE V-32.0

SOIL WATER NITROGEN AS AMMONIA

HAXTON FIELD TILE

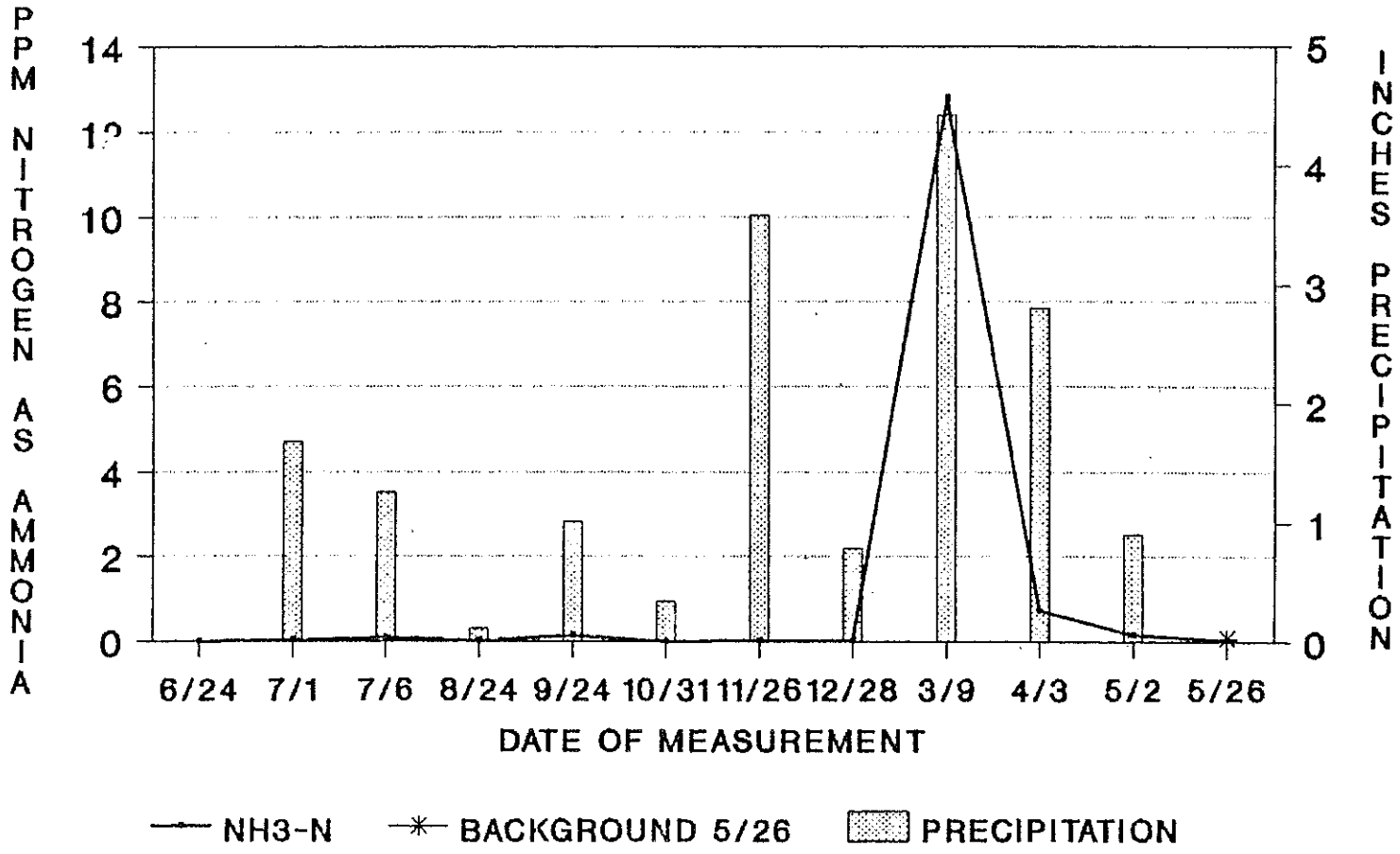


FIGURE V-33.0

SOIL WATER NITROGEN AS TKN

HAXTON FIELD TILE

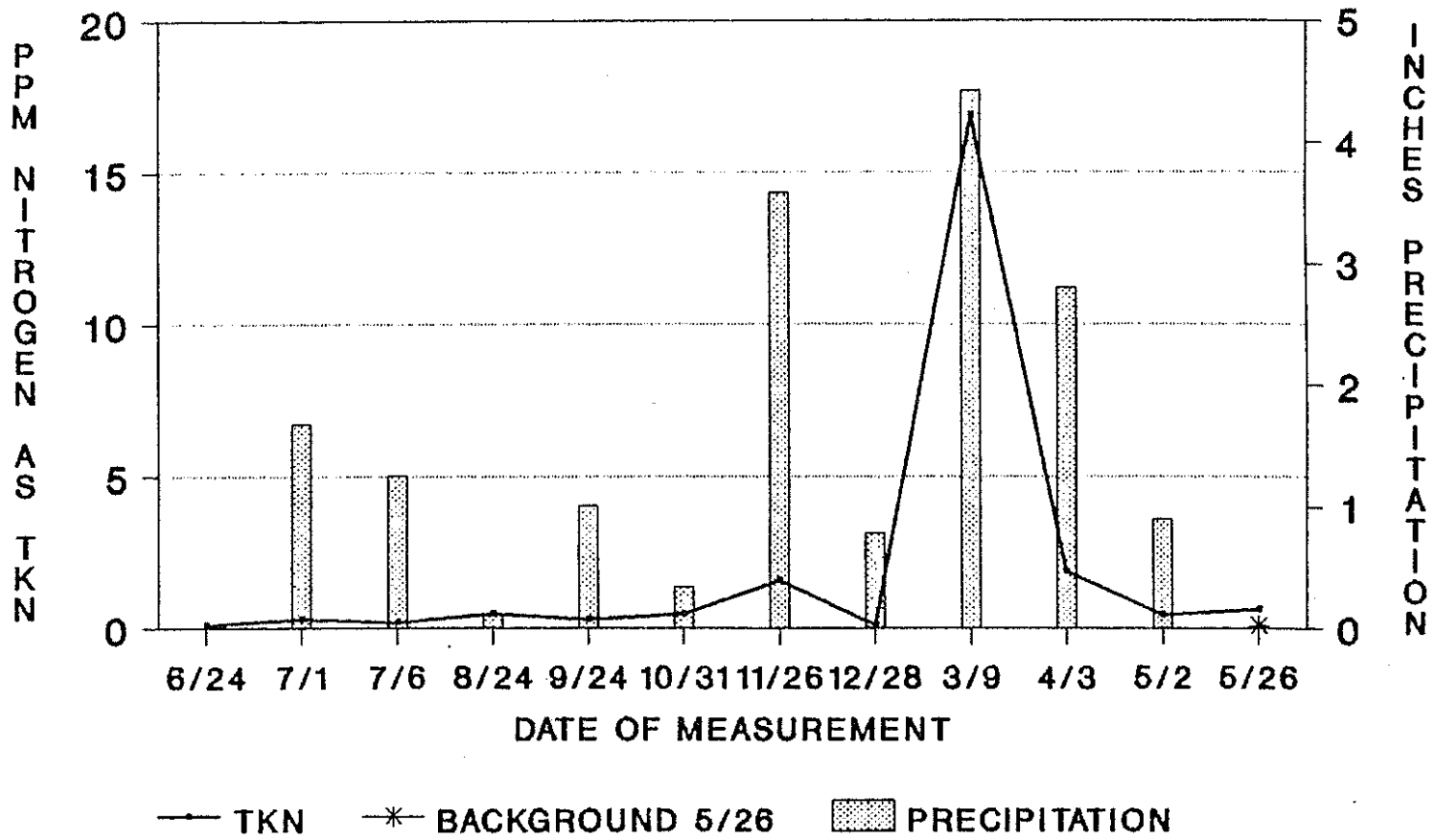


FIGURE V-34.0

SOIL WATER TOTAL PHOSPHOROUS

HAXTON FIELD TILE

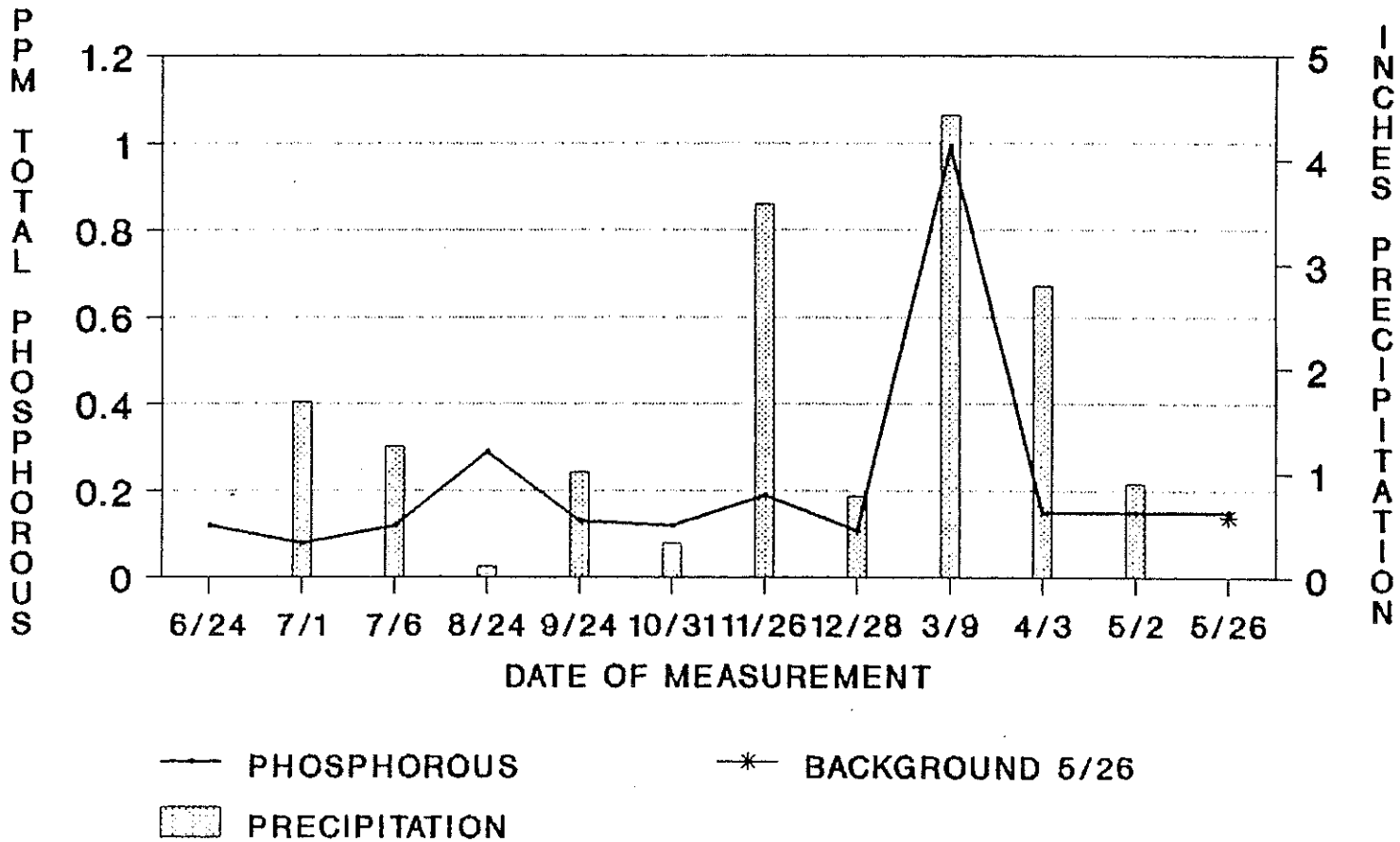


FIGURE V-35.0

SOIL WATER POTASSIUM

HAXTON FIELD TILE

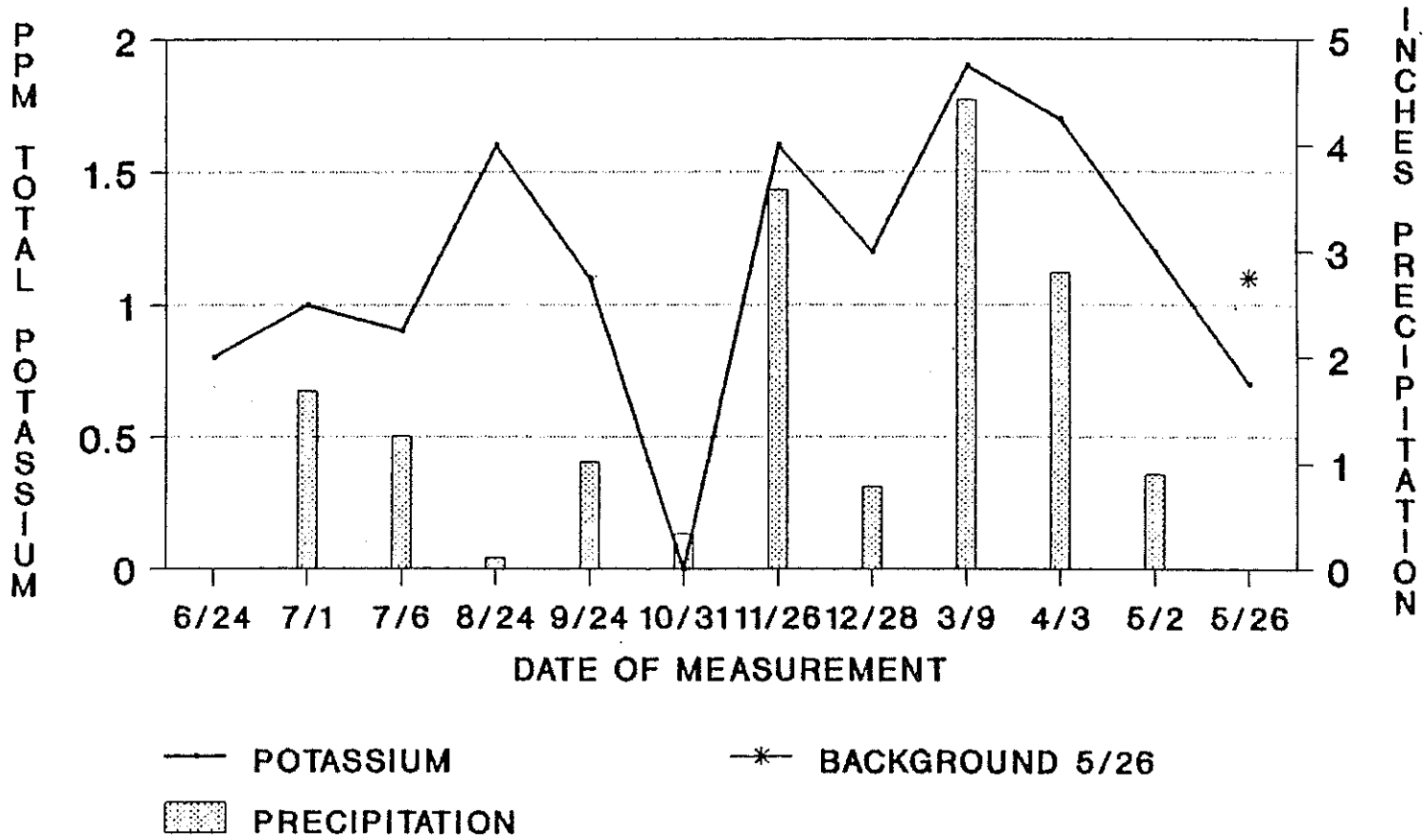
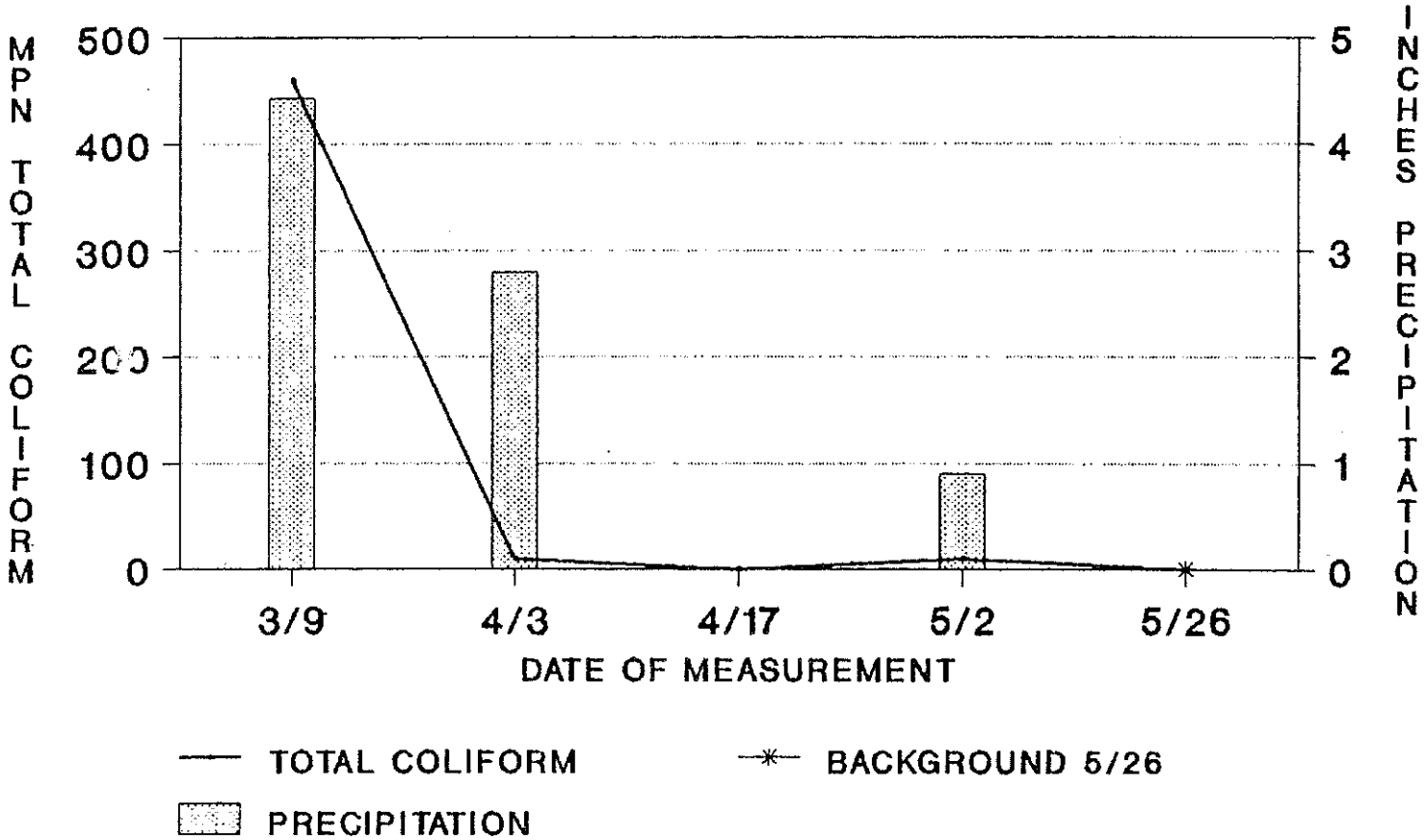


FIGURE V-36.0

SOIL WATER TOTAL COLIFORM

HAXTON FIELD TILE



J. Groundwater Quality Comparisons

In order to summarize the results of the water quality monitoring conducted at the various locations at the Haxton sludge stockpiling facility, Table V-2.0 was prepared. This table shows the maximum contaminant level recorded for each of the parameters examined in this study at each of the critical locations. In addition, the contaminant levels are compared to the State of Idaho maximum contaminant levels for drinking water. It should be noted that the only drinking water maximum contaminant level (MCL) ever exceeded was that of nitrogen as nitrate. Although the only drinking water MCL ever exceeded was nitrogen as nitrate, any of the other nutrients could have a detrimental effect on the surface water quality in the draninage below the sludge stockpile site if the nutrient enrichment is not controlled.

TABLE V-2.0

GROUNDWATER QUALITY COMPARISONS

PARAMETER	(1) DRINKING WATER MCL mg/l	HAXTON WELL mg/l	FIELD TILE mg/l	SMW "8000" mg/l	SMW "0080" mg/l
Ammonia as N		0.155	12.800	0.067	1.040
Nitrate as N	10.000	0.641	24.900	24.600	76.300
TKN as N		0.100	16.900	1.50	4.150
T. Phosphorous		0.090	0.990	0.400	3.150
Potassium		1.900	1.900	4.300	13.400
T. Arsenic	0.050	<0.010	<0.010	<0.010	<0.010
T. Cadmium	0.010	<0.001	<0.001	<0.001	<0.001
T. Chromium	0.050	<0.010	<0.010	<0.010	<0.010
T. Copper	1.000	0.180	0.010	0.020	0.040
T. Lead	0.050	<0.005	<0.005	<0.005	<0.005
T. Mercury	0.002	<0.001	<0.001	<0.001	<0.001
T. Nickel		<0.050	<0.050	<0.050	<0.050
T. Silver	0.050	0.015	<0.001	<0.001	<0.001
T. Zinc	5.000	0.116	0.834	0.029	0.053
T. Coliform*			460.000	40.000	150.000

* Total Coliform Bacteria in colonies per 100 ml.
1) EPA safe drinking water maximum contaminant level.

VI. SUMMARY AND CONCLUSIONS

Based on the data collected and analyzed in this study of the impacts of stockpiled municipal sludge on the underlying soil and soil water, we are able to present the following conclusions.

First, the heavy metals that are found in the City of Lewiston's wastewater sludge appear to be insoluble to precipitation and snow melt water leaching, based on the results of the E. P. toxicity tests. This is supported by the fact that if they were soluble, they would have been washed out of the sludge during the treatment process at the wastewater treatment plant. The importance E.P.A. has put on the solubility of heavy metals with regard to plant uptake, rather than contamination of the underlying soils and soil water due to heavy metal migration with the wetting front seems consistant with the study's findings.

Second, the stockpiled municipal sludge poses little threat to the public health through bacteria contamination of the underlying soil and soil water. Fecal coliform bacteria normally found in the intestines of warm blooded mammals were never identified in any of the water samples taken during this research. Total coliform bacteria counts were identified in both up-gradient and down-gradient shallow monitoring wells during periods of high precipitation and snow melt events but the concentrations never exceeded State of Idaho MCL's for waters used for secondary contact.

Third, the sludge blanket impeded the downward flow of water to the underlying soils. Although the sludge blanket was less than eighteen inches thick, it was quite effective in intercepting and storing precipitation from season storm events and reducing the potential risk of contaminant transport by water movement to the underlying soils. During the period of snow melt the massive loading of water on the sludge blanket caused some of the water to pass through the sludge to the underlying soils.

Fourth, the presence of the sludge blanket caused an increase in the nutrients in the soil water. This increase appeared to be more pronounced in the area immediately down-gradient and adjacent to the sludge blanket than in the soils under the sludge blanket. This is probably due to sludge pile runoff, that carried and deposited sediments of eroded sludge material in the immediate vicinity of the sludge blanket. These deposits

were very thin and were not capable of impeding the downward flow of water. The leachate from these runoff sediment deposits and the runoff water itself, which most likely picked up nutrients from the surface of the sludge blanket, were probably the leading cause of the soil water nutrient enrichment in the immediate vicinity of the sludge blanket. The increased nutrient levels may have been from water moving through the sludge or from upgradient nutrient sources, however, these contributions were most likely minimal considering a volume of water detected.

VII. RECOMMENDATIONS

Based on the data presented in this study, I recommend that if municipal wastewater sludge is to be stockpiled, the runoff from the stockpile must be adequately controlled. Figure VII-1.0 shows a suggested arrangement for the control and disposal of sludge stockpile runoff. In addition, the sludge stockpile should be monitored to prevent nutrient enrichment of the soil waters near the site.

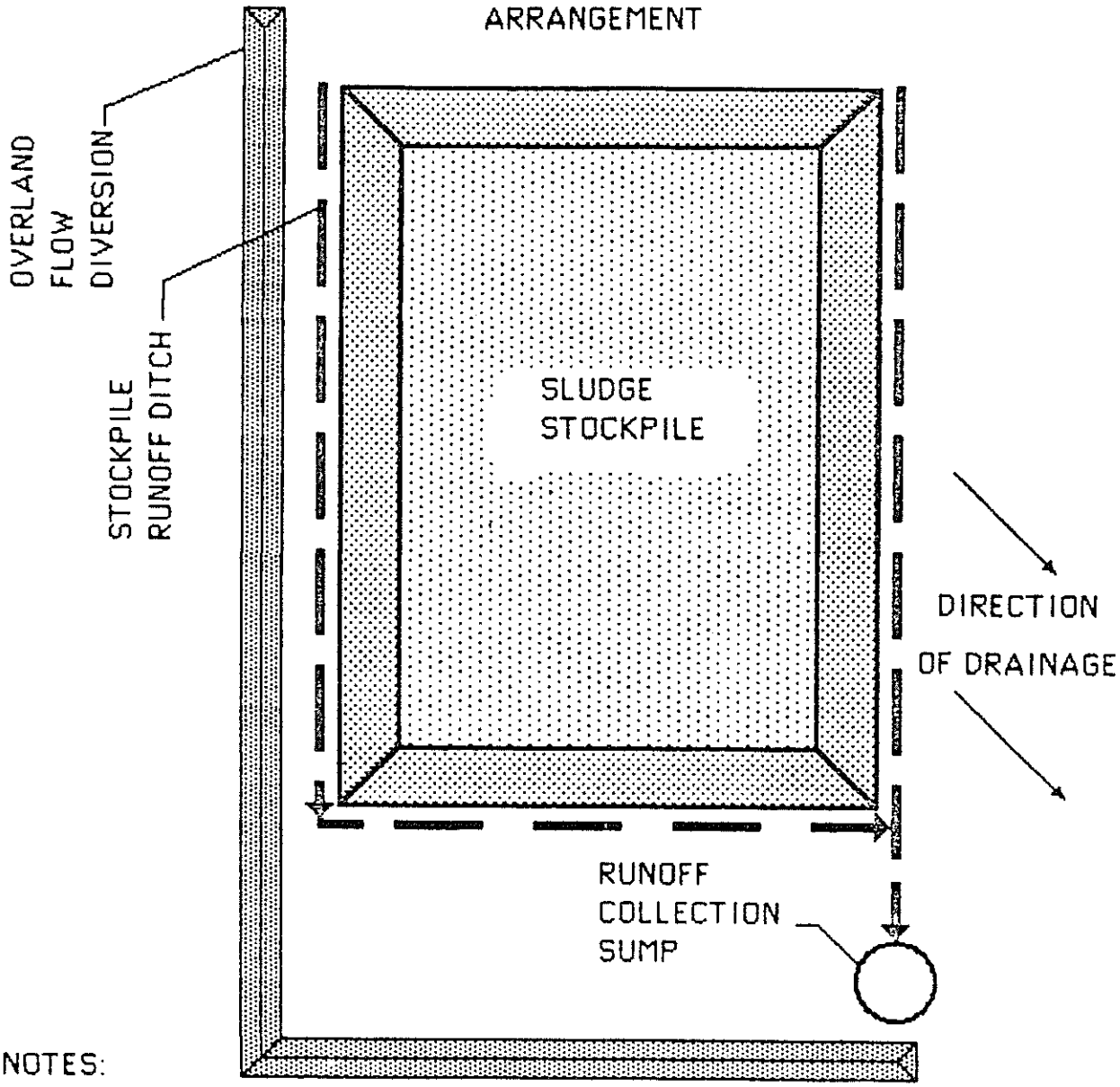
The sludge should be stacked as high as practical to increase its resistance to leachate flow and to reduce the total surface area of the stockpile exposed to the elements. The runoff water collected in the sump should be land-applied at agronomic rates to the surrounding fields. This system can be sized and managed so that the collected solutions will have to be land-applied only once per year.

Although monitoring of the site for heavy metals and coliform bacteria does not appear to be necessary, due to public concern and the ease of testing, fecal coliform bacteria testing should be included in the monitoring plan.

To assure a minimum of public exposure, only remote sites should be selected for the stockpiling of municipal sludge. The operator of these sites should implement a vector control program and the site should be adequately signed to provide notice as to its use. The operating plan filed by the operator with the appropriate regulatory agency should outline all of the above requirements.

FIGURE VI - 1.0

PROPOSED STOCKPILED SLUDGE ARRANGEMENT



NOTES:

1. Collection sump contents to be land applied at agronomic rates.
2. Sludge should be stockpiled to highest possible height.
3. Sludge shall be stockpiled no closer then 50 feet from ditches and surface water.

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APPENDIX A -1

SOIL PROFILES

FIGURE A-1.0

SOIL PROFILE #0000

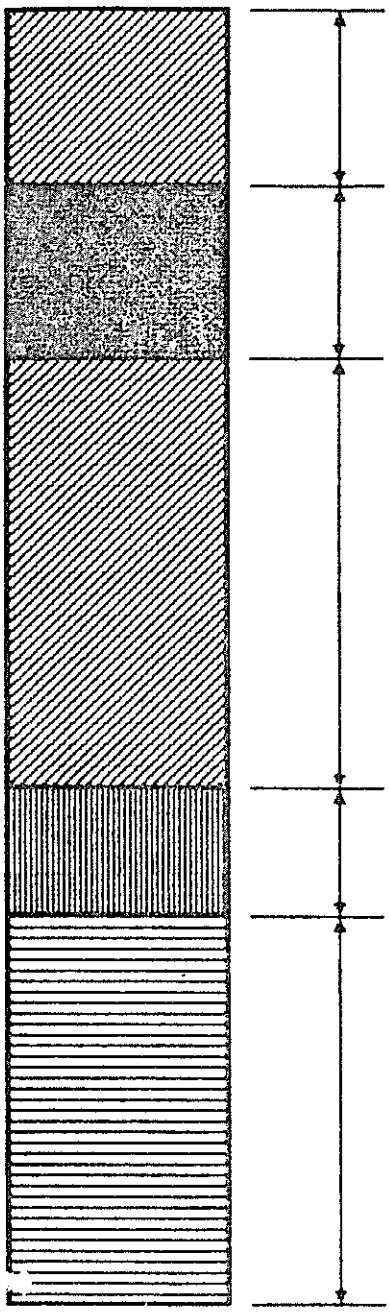
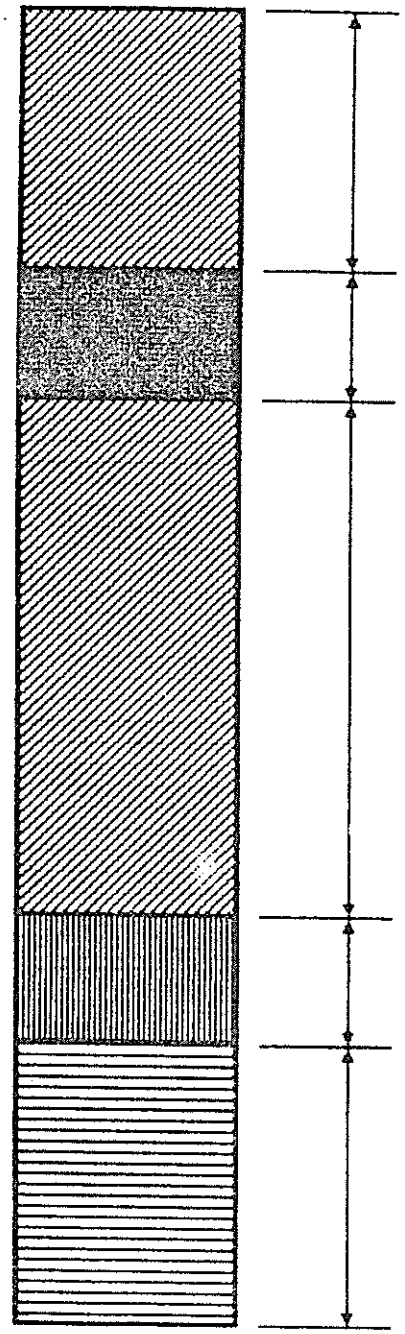


FIGURE A-2.0

SOIL PROFILE #0080



0- 12 inches 10 YR 2/2 Silt Loam

12-18 inches 10 YR 3/3 Heavy Silt Loam

18-42 inches 10 YR 5/3 Silt Loam

42-48 inches 10 YR 5/2-3/2 Silt Loam
Leached Zone

48-60 inches 10 YR 5/4 Silty Clay

FIGURE A-3.0

SOIL PROFILE #8000

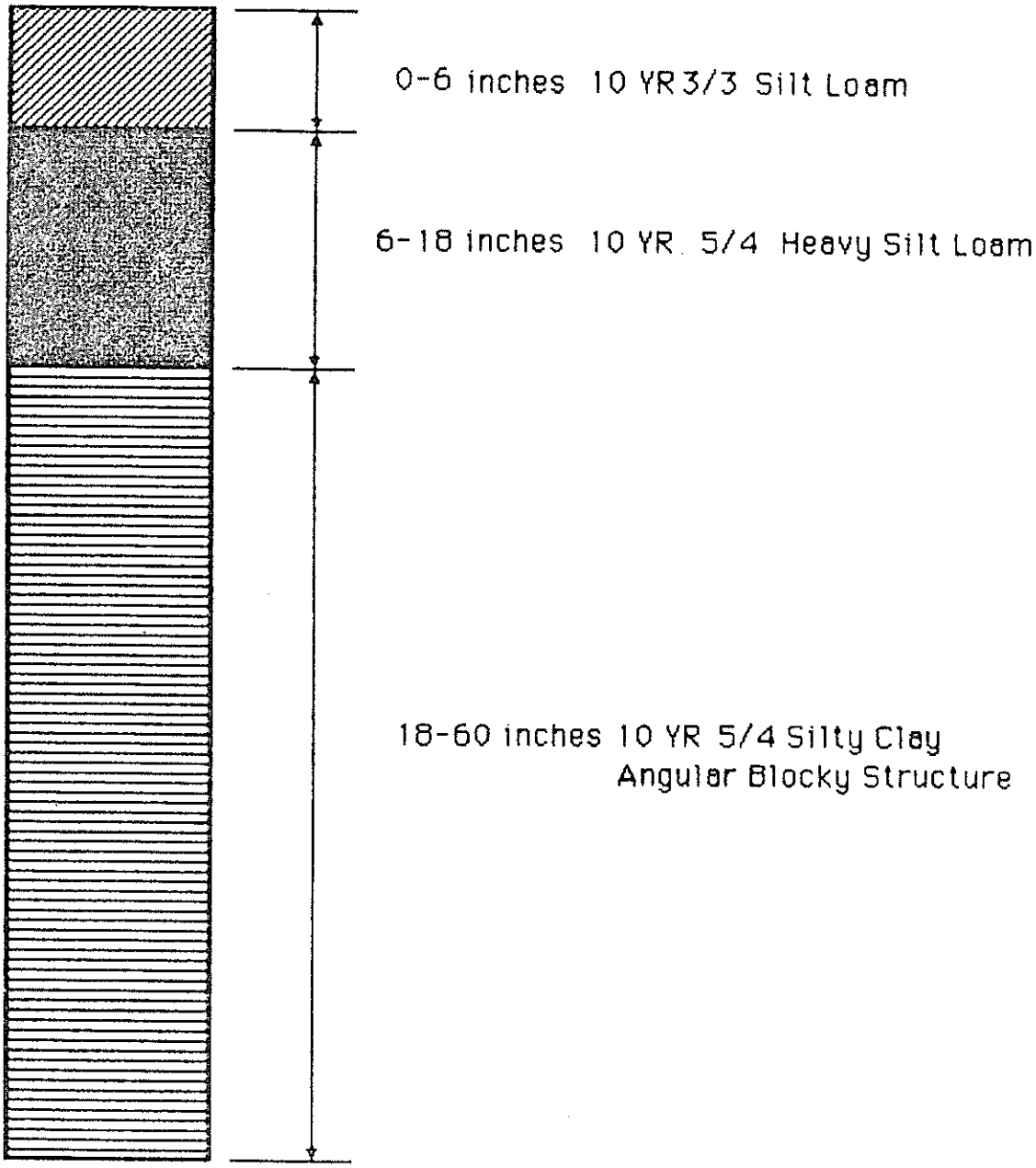
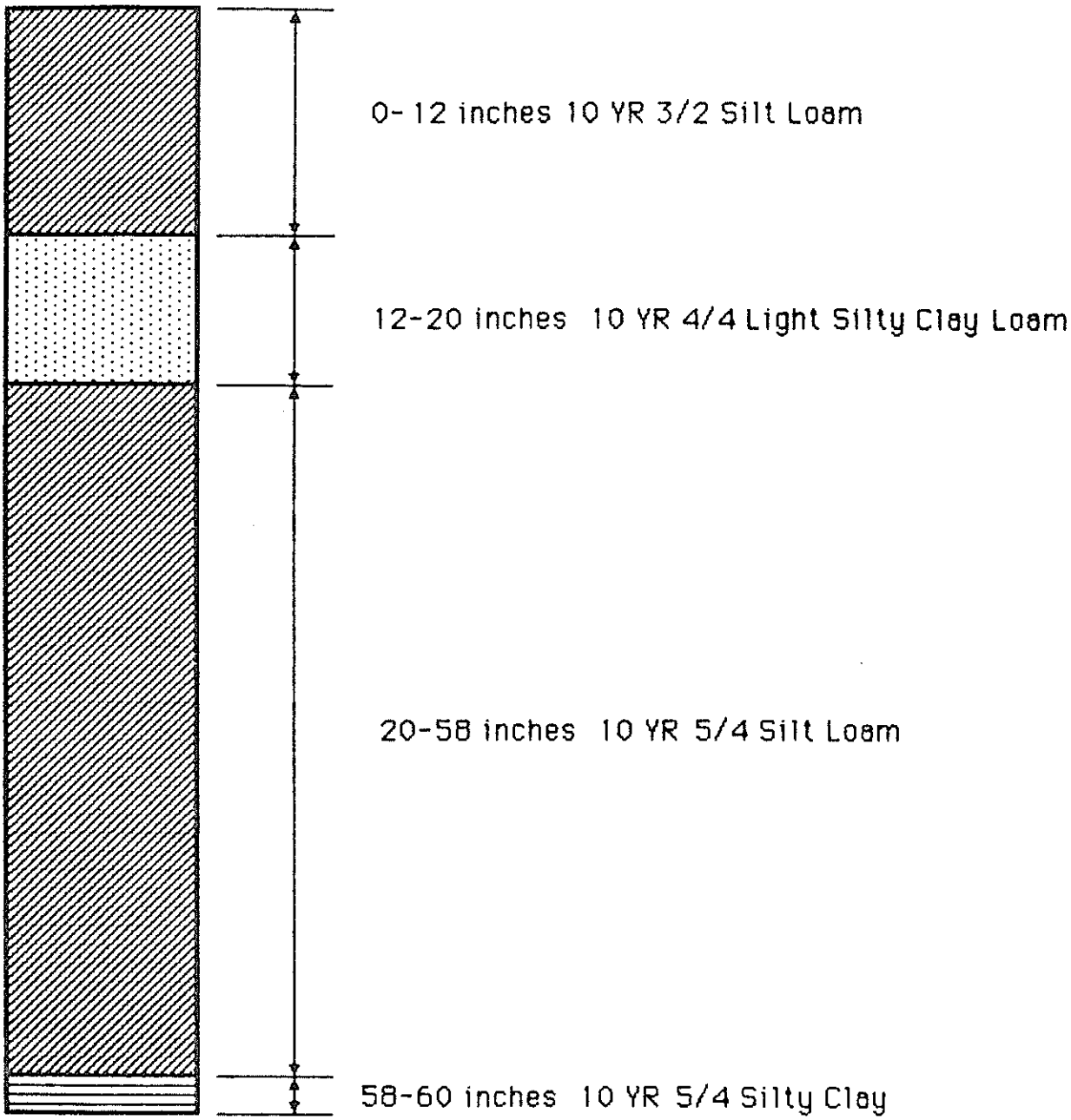


FIGURE A-4.0

SOIL PROFILE #8080

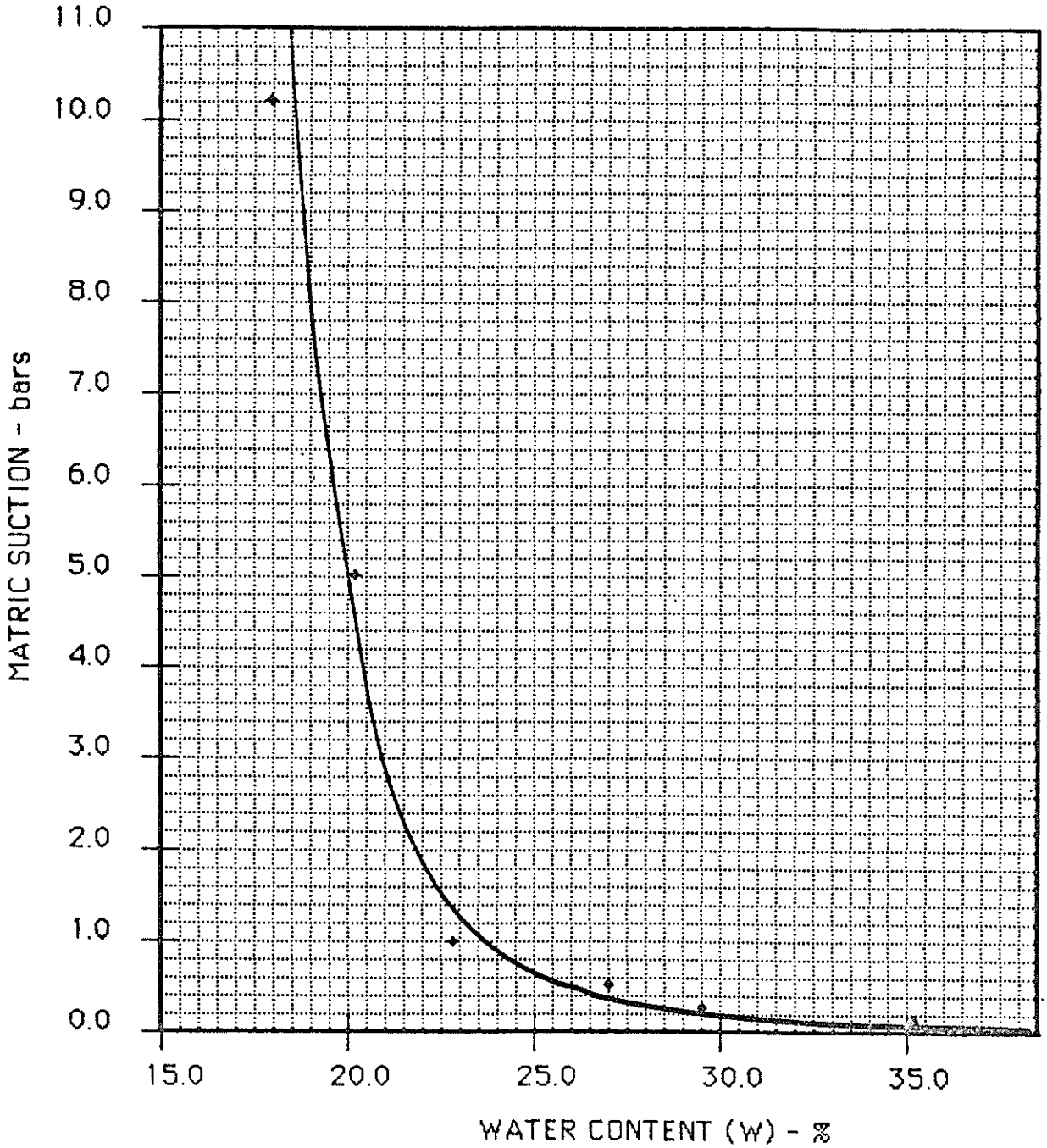


APPENDIX A-2

COMPOSITE SOIL/WATER RETENTION CURVE

FIGURE A-5.0

COMPOSITE SOIL/WATER RETENTION CURVE



APPENDIX A-3

GUELPH PERMEAMETER DATA

DESCRIPTION: GUELPH PERMEAMETER DATA SHEET
SITE: HAXTON FARM
SOIL TYPE: SILT (ML)

LOCATION	HYDRAULIC CONDUCTIVITY	MATRIC FLUX POTENTIAL	ALPHA PARAMETER
#0010071	0.000044	0.001263	0.0346
#0020071	0.000044	0.001263	0.0346
#2050075	0.000006	0.002239	0.0026
#4070075	0.000087	0.002525	0.0346
#8080064	0.000006	0.002239	0.0026
MEAN	0.0000374	0.0019058	0.0218

APPENDIX A-4

BASELINE SOIL SAMPLES

DEPTHS: UPPER 12 INCHES
DESCRIPTION: NUTRIENTS AND METALS (DRY BASIS)
TYPE: BASELINE SOIL SAMPLING

LOCATION	C.E.C. S.U.	pH S.U.	PCB ppm	TKN ppm	NH3-N ppm	NO3-N ppm	Chl. ppm	T. P ppm	T. As ppm	T. Cd ppm	T. Cu ppm
#0000015 *	22.0	5.5	-	1820.0	6.400	37.000	<1.0	692.0	-	-	20.00
#0080015 *	23.1	5.5	-	2580.0	9.400	25.000	<1.0	839.0	-	-	18.00
#8000015 *	18.4	5.3	-	1370.0	13.700	17.000	<1.0	466.0	-	-	21.00
#8080015 *	20.0	4.9	-	1760.0	4.300	32.000	<1.0	860.0	-	-	27.00
#0660030 **	-	-	-	673.5	7.700	46.900	-	296.6	2.50	0.20	23.70
#0860030 **	-	-	-	551.6	7.800	23.000	-	280.4	2.30	0.20	22.80
#1080030 **	-	-	-	717.2	5.400	28.200	-	322.8	2.00	0.20	22.50
#1280030 **	-	-	-	889.9	8.400	20.100	-	346.0	2.20	0.10	22.00
#2420030 ***	-	-	-	369.3	6.600	14.800	-	244.6	1.50	0.10	26.00
#2620030 ***	-	-	-	267.9	7.500	8.400	-	203.3	2.10	0.10	18.00
#4460030 ***	-	-	-	551.6	9.000	19.000	-	308.2	2.10	0.10	23.40
#4660030 ***	-	-	-	602.7	7.700	18.600	-	317.9	2.60	0.10	23.80
MEANS:											
15 CM	20.9	5.3	-	1882.5	8.450	27.750	<1.0	714.3	-	-	21.50
30 CM	-	-	-	578.0	7.513	22.375	-	290.0	2.16	0.14	22.78
COMBINED	20.9	5.3	-	NA	NA	NA	<1.0	NA	2.16	0.14	22.35

* Values Determined by Alchem Laboratories
** Out of Sludge Blanket
*** Under Sludge Blanket

DEPTHS: UPPER 12 INCHES
DESCRIPTION: NUTRIENTS AND METALS (DRY BASIS)
TYPE: BASELINE SOIL SAMPLING

T. Cr ppm	T. Ag ppm	T. Hg ppm	T.K ppm	T. Pb ppm	T.Ni ppm	T.Zn ppm	M.C. %
13.00	0.50	<.50	3060.0	-	22.00	50.20	9.1
12.00	0.70	<.50	4020.0	-	22.00	54.20	10.0
19.00	0.60	<.50	4140.0	-	26.00	57.10	6.7
16.00	0.60	<.50	4380.0	-	28.00	61.30	5.5
16.50	<1.00	<.25	4739.3	10.00	26.10	58.40	15.6
19.20	<1.00	<.25	4178.9	9.00	21.50	56.50	16.7
10.50	<1.00	<.25	4260.4	8.70	22.50	58.00	15.5
20.00	<1.00	<.25	3243.8	8.80	22.00	44.70	15.5
16.60	<1.00	<.25	4729.5	7.70	30.70	61.30	15.7
16.80	<1.00	<.25	4682.9	8.50	27.60	59.40	17.7
14.10	<1.00	<.25	4546.9	7.60	23.40	60.90	14.8
33.10	<1.00	<.25	4502.4	7.70	23.80	61.30	15.8
15.00	0.60	<.50	3900.0	-	24.50	55.70	-
18.35	<1.00	<.25	4360.5	8.50	24.70	57.56	-
17.23	<1.00	<.50	4207.0	8.50	24.63	56.94	-

DEPTHS: 36 INCHES
DESCRIPTION: NUTRIENTS AND METALS (DRY BASIS)
TYPE: BASELINE SOIL SAMPLING

LOCATION	C.E.C. S.U.	pH S.U.	PCB ppm	TKN ppm	NH3-N ppm	NO3-N ppm	Chl. ppm	T. P ppm	T. As ppm	T. Cd ppm	T. Cu ppm
#0000090 *	23.8	6.3	-	963.0	9.70	5.00	<1.0	669.0	-	-	27.00
#0080090 *	21.4	7.2	-	1300.0	15.30	10.00	<1.0	775.0	-	-	16.00
#8000050 *	16.9	6.3	-	691.0	5.40	10.00	<1.0	343.0	-	-	23.00
#8080090 *	17.3	7.3	-	991.0	26.60	44.00	<1.0	655.0	-	-	21.00
#0660090	-	-	-	636.2	6.10	27.40 **	-	301.9	2.30	0.10	20.00
#0860090	-	-	-	556.3	7.90	23.20 **	-	282.8	2.30	0.20	23.00
#1080090	-	-	-	594.3	6.20	25.20 **	-	303.1	2.70	0.10	21.90
#1280090	-	-	-	578.6	6.60	32.90 **	-	315.5	2.20	0.10	22.50
#2420090	-	-	-	222.7	5.60	6.60 ***	-	157.4	1.70	0.10	18.40
#2620090	-	-	-	187.5	6.10	5.60 ***	-	158.7	1.80	<0.10	17.00
#4460090	-	-	-	398.1	7.40	11.90 ***	-	266.9	1.80	<0.10	20.20
#4660090	-	-	-	314.1	8.30	61.30 ***	-	286.2	2.30	<0.10	21.40
MEANS:											
ALCHEM	19.9	6.8	-	986.3	14.25	17.25	<1.0	610.5	-	-	21.75
STATE	-	-	-	436.0	6.78	24.26	-	259.1	2.14	0.12	20.55
COMBINED	19.9	6.8	-	619.4	9.3	21.9	<1.0	376.2	2.14	0.12	20.95

* Values Determined by Alchem Laboratories
** Out of Sludge Blanket
*** Under Sludge Blanket

DEPTHS: UPPER 12 INCHES
DESCRIPTIONS: NUTRIENTS AND METALS (DRY BASIS)
TYPE: MAY 15, 1989

LOCATION	C.E.C. S.U.	pH S.U.	PCB ppm	TKN ppm	NH3-N ppm	NO3-N ppm	T. P ppm	T. As ppm	T. Cd ppm	T. Cu ppm	T. Cr ppm
#0460030**	-	6.2	-	718.14	9.78	18.03	296.98	1.72	0.18	19.11	18.25
#0660030**	-	5.9	-	691.87	4.33	134.76	369.07**	1.46	0.17	19.86	15.69
#2026030***	-	7.2	-	269.91	0.22	22.79	216.81	2.20	0.18	21.35	16.59
#2028030***	-	7.2	-	294.44	1.53	18.89	216.67***	1.92	0.19	21.00	17.11
#4280030**	-	6.4	-	605.54	4.12	28.14	342.22**	1.87	0.20	21.00	16.52
#4460030***	-	6.1	-	602.62	2.45	28.38	340.61***	1.72	0.24	19.98	17.25
#4480030**	-	6.1	-	894.57	2.73	37.27	384.45**	1.12	0.20	19.16	14.27
#4660030***	-	6.6	-	793.36	0.21	22.06	384.37***	1.07	0.30	20.24	14.99
MEANS:											
UNDER	-	6.8	-	490.08	1.10	23.03	289.62	1.7	0.2	20.6	16.5
ADJACENT		6.2		727.53	5.24	54.55	348.18	1.5	0.2	19.8	16.2

** Out of Sludge Blanket
*** Under Sludge Blanket

DEPTHS: UPPER 12 INCHES
DESCRIPTIONS: NUTRIENTS AND METALS (DRY BASIS)
TYPE: MAY 15, 1989

T. Ag ppm	T. Hg ppm	T.K ppm	T. Pb ppm	T.Ni ppm	T.Zn ppm	M.C. %
<0.1	<.25	3607.0	9.67	23.33	47.84	7.4
0.17	<.25	3264.0	10.63	22.12	42.33	11.4
<0.1	<.25	3843.0	12.20	26.70	53.10	9.6
<0.1	<.25	3647.0	10.70	21.00	49.70	10.0
<.1	<.25	3646.0	8.27	22.92	51.49	6.2
<.1	<.25	3728.0	9.64	23.14	57.50	8.4
<.1	<.25	3529.0	10.65	21.19	46.96	6.1
0.28	<.25	3844.0	10.17	22.38	55.40	6.6
<1	<.25	3765.5	10.7	23.3	53.9	8.7
<1	<.25	3511.5	9.8	22.4	47.2	7.8

DEPTHS: 36 INCHES
DESCRIPTION: NUTRIENTS AND METALS (DRY BASIS)
TYPE: MAY 15, 1989

LOCATION	C.E.C. S.U.	pH S.U.	PCB ppm	TKN ppm	NH3-N ppm	NO3-N ppm	T. P ppm	T. As ppm	T. Cd ppm	T. Cu ppm	T. Cr ppm
#0460090	-	7.8	-	463.0	19.120	54.110**	285.1	1.00	0.10	16.92	9.84
#0660090	-	7.2	-	639.2	8.670	84.350**	270.0	1.28	0.13	17.92	15.17
#2026090	-	7.4	-	299.3	0.220	19.280***	224.2	1.13	0.11	18.27	12.33
#2028090	-	7.4	-	225.1	3.010	20.250***	205.9	1.45	0.17	17.76	13.35
#4280090	-	8.1	-	498.3	0.220	23.750**	309.7	1.54	0.20	14.32	9.93
#4460090	-	7.6	-	309.3	4.170	42.720***	267.8	1.63	0.17	18.38	13.18
#4480090	-	7.9	-	878.6	0.220	76.170**	416.5	1.25	0.27	18.93	11.47
#4660090	-	7.4	-	418.7	1.430	79.330***	251.8	0.94	0.23	18.68	13.64
MEANS:											
UNDER	-	7.5	-	313.1	2.2	40.4	237.4	1.3	0.2	18.3	13.1
ADJACENT		7.8		619.8	7.1	59.6	320.3	1.3	0.2	17.0	11.6

** Out of Sludge Blanket
*** Under Sludge Blanket

DEPTHS: 36 INCHES
DESCRIPTION: NUTRIENTS AND METALS (DRY BASIS)
TYPE: MAY 15, 1989

T. Ag ppm	T. Hg ppm	T.K ppm	T. Pb ppm	T.Ni ppm	T.Zn ppm	M.C. %
<0.1	<.25	2489.0	8.19	18.08	34.76	13.7
0.12	<.25	2683.0	5.82	20.07	37.75	16.3
<0.1	<.25	2848.0	7.20	21.52	39.24	10.8
<0.1	<.25	2972.0	8.25	18.78	41.29	11.6
<.1	<.25	2649.0	11.03	18.76	36.85	9.9
<.1	<.25	3329.0	9.16	20.51	43.68	5.9
<.1	<.25	3004.0	7.80	20.04	43.65	10.2
0.28	<.25	3317.0	8.36	17.63	44.91	4.7
<1	<.25	3116.5	8.2	19.6	42.3	8.3
<1	<.25	2706.3	8.2	19.2	38.3	12.5

APPENDIX B

NEUTRON PROBE DATA - MOISTURE CONTENT

LOCATION: #0020
DESCRIPTION: NEUTRON PROBE.DATA
TYPE: MOISTURE CONTENT - %

DATE	CONST. "A"	CONST. "B"	45 cm	60 cm	75 cm	90 cm	105 cm	120 cm	135 cm	150 cm
8/31/88	20.90	-5.90	-	24.5	25.8	26.9	25.5	23.0	27.1	34.4
9/30/88	20.90	-5.90	-	23.9	25.4	26.6	25.4	22.4	27.4	34.2
10/25/88	20.90	-5.90	18.9	23.6	25.4	26.4	25.0	22.4	27.3	34.2
11/26/88	20.90	-5.90	30.0	29.7	28.5	29.2	26.8	23.1	27.2	33.7
12/28/88	20.90	-5.90	27.9	29.2	30.5	31.7	30.4	27.9	29.7	34.4
3/13/89	20.90	-5.90	33.2	35.0	38.7	39.2	36.8	32.7	31.5	40.6
3/31/89	20.90	-5.90	33.0	34.9	38.5	39.5	37.4	32.9	33.0	water
5/2/89	20.90	-5.90	29.7	32.5	34.5	34.5	36.4	35.5	32.7	water

LOCATION: #0060
DESCRIPTION: NEUTRON PROBE DATA
TYPE: MOISTURE CONTENT - %

DATE	CONST. "A"	CONST. "B"	45 cm	60 cm	75 cm	90 cm	105 cm	120 cm	135 cm	150 cm
8/31/88	20.90	-5.90	-	19.9	20.7	19.0	18.6	18.9	-	-
9/30/88	20.90	-5.90	-	19.4	20.7	18.7	18.1	18.5	-	-
10/25/88	20.90	-5.90	27.1	19.2	20.5	18.7	18.0	18.1	-	-
11/26/88	20.90	-5.90	26.6	29.9	24.2	18.6	17.6	18.1	-	-
12/28/88	20.90	-5.90	27.2	25.9	24.7	21.0	20.5	20.5	-	-
3/13/89	20.90	-5.90	34.9	34.2	32.2	30.3	33.0	36.7	-	-
3/31/89	20.90	-5.90	34.4	34.0	34.1	35.5	43.2	water	-	-
5/2/89	20.90	-5.90	31.6	31.9	32.3	35.7	39.4	water	-	-

LOCATION: #2000
DESCRIPTION: NEUTRON PROBE DATA
TYPE: MOISTURE CONTENT - %

DATE	CONST. "A"	CONST. "B"	45 cm	60 cm	75 cm	90 cm	105 cm	120 cm	135 cm	150 cm
8/31/88	20.93	-5.90	-	24.1	27.8	31.2	31.1	29.1	29.2	31.0
9/30/88	20.93	-5.90	-	22.1	26.9	30.3	30.1	28.6	29.2	30.9
10/25/88	20.93	-5.90	28.0	22.2	26.9	30.1	29.9	28.8	28.9	31.2
11/26/88	20.93	-5.90	25.9	30.0	31.4	32.8	31.7	28.9	29.2	31.6
12/28/88	20.93	-5.90	24.4	28.8	31.3	33.7	32.7	31.6	32.5	34.1
3/13/89	20.93	-5.90	31.2	34.4	36.6	38.2	36.1	32.5	34.2	37.1
3/31/89	20.93	-5.90	29.6	33.1	35.8	38.1	36.4	32.5	35.4	37.4
5/2/89	20.93	-5.90	20.5	29.5	32.4	35.7	35.2	32.6	36.9	water

LOCATION: #2020
DESCRIPTION: NEUTRON PROBE DATA
TYPE: MOISTURE CONTENT - %

DATE	CONST. "A"	CONST. "B"	15 cm	30 cm	45 cm	60 cm	75 cm	90 cm	105 cm	120 cm
8/31/88	20.90	-5.90	-	-	-	26.9	29.6	31.8	30.1	27.6
9/30/88	20.90	-5.90	-	-	-	26.4	29.2	31.3	29.1	27.2
10/25/88	20.90	-5.90	457.4	23.4	21.3	26.5	29.1	31.2	29.3	26.9
11/26/88	20.90	-5.90	455.3	24.2	21.6	25.7	28.4	30.6	28.6	26.7
12/28/88	20.90	-5.90	453.6	24.9	22.3	26.2	28.9	31.2	29.2	27.3
3/13/89	20.90	-5.90	435.6	25.7	27.9	33.9	37.8	37.8	35.6	31.3
3/31/89	20.90	-5.90	438.0	26.1	29.4	33.7	37.5	38.1	35.5	31.4
5/2/89	20.90	-5.90	458.9	26.3	29.7	32.6	35.3	36.7	34.9	31.3

LOCATION: #2020
DESCRIPTION: NEUTRON PROBE DATA
TYPE: MOISTURE CONTENT - %

135 cm	150 cm
29.1	33.8
29.3	33.8
29.3	33.9
29.1	33.5
29.3	34.0
33.3	38.0
35.0	water
37.6	water

LOCATION: #2040
DESCRIPTION: NEUTRON PROBE DATA
TYPE: MOISTURE CONTENT - %

DATE	CONST. "A"	CONST. "B"	15 cm	30 cm	45 cm	60 cm	75 cm	90 cm	105 cm	120 cm
8/31/88	20.90	-5.90	-	-	-	24.8	24.3	21.0	16.5	12.2
9/30/88	20.90	-5.90	-	-	-	23.4	23.6	20.3	16.8	12.6
10/25/88	20.90	-5.90	411.6	17.3	15.9	23.6	22.8	19.9	16.3	12.9
11/26/88	20.90	-5.90	426.1	26.4	24.5	25.4	23.2	20.2	16.2	12.4
12/28/88	20.90	-5.90	415.8	25.1	23.4	25.0	23.0	20.7	17.5	14.1
3/13/89	20.90	-5.90	448.5	34.1	32.0	31.1	31.6	32.3	35.0	37.9
3/31/89	20.90	-5.90	438.1	31.4	30.9	31.4	31.8	32.7	35.0	37.0
5/2/89	20.90	-5.90	451.0	30.8	29.9	31.3	31.0	31.7	33.1	35.1

LOCATION: #2040
DESCRIPTION: NEUTRON PROBE DATA
TYPE: MOISTURE CONTENT - %

135 cm	150 cm
10.6	10.0
10.7	10.1
10.8	10.1
10.7	10.2
12.4	12.6
39.7	water
water	water
34.4	34.4

LOCATION: #2060
DESCRIPTION: NEUTRON PROBE DATA
TYPE: MOISTURE CONTENT - %

DATE	CONST. "A"	CONST. "B"	15 cm	30 cm	45 cm	60 cm	75 cm	90 cm
8/31/88	20.90	-5.90	-	-	-	22.2	20.7	18.7
9/30/88	20.90	-5.90	-	-	-	21.7	20.6	18.2
10/25/88	20.90	-5.90	464.7	26.4	16.0	21.6	20.1	18.1
11/26/88	20.90	-5.90	459.3	27.2	17.4	21.9	19.4	17.4
12/28/88	20.90	-5.90	462.7	27.6	18.5	22.1	19.5	17.5
3/13/89	20.90	-5.90	473.8	30.1	20.9	22.8	19.7	18.2
3/31/89	20.90	-5.90	467.0	29.4	20.8	25.0	28.4	29.1
5/2/89	20.90	-5.90	470.2	29.3	21.5	27.5	28.7	28.9

LOCATION: #2060
DESCRIPTION: NEUTRON PROBE DATA
TYPE: MOISTURE CONTENT - %

105 cm	120 cm	135 cm	150 cm
18.0	17.8	18.1	17.5
17.6	17.6	17.9	17.5
17.3	17.3	17.5	17.7
16.9	16.7	17.3	16.9
17.1	16.8	17.4	17.0
18.0	18.4	19.4	19.1
30.[illegible]	32.5	34.5	35.2
30.3	31.9	34.2	34.9

LOCATION: #2080
DESCRIPTION: NEUTRON PROBE DATA
TYPE: MOISTURE CONTENT - %

DATE	CONST. "A"	CONST. "B"	45 cm	60 cm	75 cm	90 cm	105 cm	120 cm	135 cm	150 cm
8/31/88	20.90	-5.90	-	23.3	20.9	18.4	17.7	17.2	17.9	18.1
9/30/88	20.90	-5.90	-	22.6	20.2	18.2	16.9	16.9	17.8	18.0
10/25/88	20.90	-5.90	15.8	22.1	20.0	17.5	16.7	16.6	17.4	18.3
11/26/88	20.90	-5.90	29.2	30.5	28.7	26.0	25.4	25.6	25.6	25.2
12/28/88	20.90	-5.90	24.8	28.1	26.2	23.7	23.8	25.2	26.6	28.8
3/13/89	20.90	-5.90	35.6	33.7	31.5	31.0	32.4	35.1	37.7	38.7
3/31/89	20.90	-5.90	34.6	32.6	31.2	30.5	32.6	35.3	37.9	39.6
5/2/89	20.90	-5.90	24.8	29.8	29.6	29.2	31.2	34.3	37.5	38.7

LOCATION: #4020
DESCRIPTION: NEUTRON PROBE DATA
TYPE: MOISTURE CONTENT - %

DATE	CONST. "A"	CONST. "B"	15 cm	30 cm	45 cm	60 cm	75 cm	90 cm	105 cm	120 cm
8/31/88	20.90	-5.90	-	-	-	26.9	30.6	29.2	27.7	29.6
9/30/88	20.90	-5.90	-	-	-	26.0	29.9	28.9	27.6	29.6
10/25/88	20.90	-5.90	397.4	16.1	17.1	26.1	30.1	28.4	27.5	29.7
11/26/88	20.90	-5.90	395.2	18.5	17.4	25.7	29.5	28.1	26.8	29.4
12/28/88	20.90	-5.90	390.1	19.9	18.3	25.8	30.1	29.1	28.1	30.0
3/13/89	20.90	-5.90	405.3	23.8	26.1	31.6	36.0	33.5	30.9	33.9
3/31/89	20.90	-5.90	395.3	24.1	26.7	31.8	36.3	34.4	31.1	34.3
5/2/89	20.90	-5.90	428.7	24.3	26.8	31.3	34.5	33.3	31.2	34.0

LOCATION: #4020
DESCRIPTION: NEUTRON PROBE DATA
TYPE: MOISTURE CONTENT - %

135 cm	150 cm
28.8	30.8
29.1	31.5
29.0	31.2
28.5	31.1
29.2	31.1
33.4	35.6
33.5	36.2
33.8	37.2

LOCATION: #4040
DESCRIPTION: NEUTRON PROBE DATA
TYPE: MOISTURE CONTENT - %

DATE	CONST. "A"	CONST. "B"	15 cm	30 cm	45 cm	60 cm	75 cm	90 cm	105 cm	120 cm
9/30/88	20.90	-5.90	-	-	-	21.1	20.0	20.4	19.8	19.6
10/25/88	20.90	-5.90	443.4	18.2	16.5	20.7	20.2	20.3	19.7	19.3
11/26/88	20.90	-5.90	443.4	19.3	16.5	20.5	19.4	20.2	19.5	19.2
12/28/88	20.90	-5.90	437.7	21.1	17.2	20.5	20.0	20.9	20.9	21.5
3/13/89	20.90	-5.90	445.1	23.2	20.5	21.7	20.8	25.4	27.6	27.8
3/31/89	20.90	-5.90	416.5	22.2	21.7	23.1	26.9	30.4	29.1	28.8
5/2/89	20.90	-5.90	442.4	22.3	23.4	25.5	27.7	29.9	28.6	28.1

LOCATION: #4040
DESCRIPTION: NEUTRON PROBE DATA
TYPE: MOISTURE CONTENT - %

135 cm	150 cm
22.0	28.4
22.3	28.6
22.1	29.2
23.3	30.0
26.6	31.5
28.6	water
28.7	water

LOCATION: #4060
DESCRIPTION: NEUTRON PROBE DATA
TYPE: MOISTURE CONTENT - %

DATE	CONST. "A"	CONST. "B"	15 cm	30 cm	45 cm	60 cm	75 cm	90 cm	105 cm	120 cm
8/31/88	20.90	-5.90	-	-	-	22.8	23.9	22.7	22.2	23.4
9/30/88	20.90	-5.90	-	-	-	22.3	23.9	22.2	22.2	23.1
10/25/88	20.90	-5.90	464.0	26.3	16.4	22.6	23.6	22.0	21.7	22.5
11/26/88	20.90	-5.90	465.2	27.3	17.3	22.3	23.1	21.6	21.5	22.9
12/28/88	20.90	-5.90	465.1	27.7	18.0	22.0	23.0	21.5	21.4	22.3
3/13/89	20.90	-5.90	474.4	30.3	20.5	24.3	23.2	21.4	21.1	21.9
3/31/89	20.90	-5.90	472.4	29.5	20.4	24.3	23.3	21.3	21.2	22.4
5/2/89	20.90	-5.90	458.7	28.9	20.5	24.4	24.0	22.5	22.4	23.7

LOCATION: #4060
DESCRIPTION NEUTRON PROBE DATA
TYPE: MOISTURE CONTENT - %

135 cm	150 cm
22.6	25.0
21.6	24.3
22.4	24.7
22.2	24.5
21.8	24.1
21.8	24.3
21.9	24.1
23.2	24.9

LOCATION: #6000
DESCRIPTION: NEUTRON PROBE DATA
TYPE: MOISTURE CONTENT - %

DATE	CONST. "A"	CONST. "B"	45 cm	60 cm	75 cm	90 cm	105 cm	120 cm	135 cm	150 cm
8/31/88	20.90	-5.90	-	28.6	28.4	34.7	32.6	30.1	30.7	-
9/30/88	20.90	-5.90	-	28.0	27.6	34.4	32.4	29.8	30.6	-
10/25/88	20.90	-5.90	17.6	28.0	27.7	34.7	32.6	30.1	30.7	-
11/26/88	20.90	-5.90	28.6	32.0	30.2	34.8	33.7	33.5	34.1	-
12/28/88	20.90	-5.90	26.6	31.4	30.0	35.9	34.7	34.3	35.1	-
3/13/89	20.90	-5.90	33.9	33.3	31.2	35.9	35.1	35.4	39.0	-
3/31/89	20.90	-5.90	33.6	33.6	31.7	36.2	35.9	water	water	-
5/2/89	20.90	-5.90	24.6	30.9	30.8	35.8	35.4	water	water	-

LOCATION: #6020
DESCRIPTION: NEUTRON PROBE DATA
TYPE: MOISTURE CONTENT - %

DATE	CONST. "A"	CONST. "B"	15 cm	30 cm	45 cm	60 cm	75 cm	90 cm	105 cm	120 cm
8/31/88	20.90	-5.90	-	-	-	27.7	27.8	29.4	32.7	29.5
9/30/88	20.90	-5.90	-	-	-	26.3	26.8	28.6	32.7	29.6
10/25/88	20.90	-5.90	379.8	14.9	18.9	26.6	26.7	29.0	32.3	29.4
11/26/88	20.90	-5.90	374.2	17.0	19.0	26.0	26.3	28.5	32.0	29.1
12/28/88	20.90	-5.90	369.6	18.2	19.9	26.4	27.9	29.8	32.4	29.4
3/13/89	20.90	-5.90	413.1	31.7	33.9	32.2	31.3	32.0	39.1	water
3/31/89	20.90	-5.90	412.0	32.4	33.7	32.1	31.7	32.7	water	water
5/2/89	20.90	-5.90	424.9	30.5	32.1	31.4	31.3	32.8	water	water

LOCATION: #6020
DESCRIPTION: NEUTRON PROBE DATA
TYPE: MOISTURE CONTENT - %

135 cm	150 cm
29.5	-
29.4	-
29.5	-
29.2	-
29.2	-
water	-
water	-
water	-

LOCATION: #6040
DESCRIPTION: NEUTRON PROBE DATA
TYPE: MOISTURE CONTENT - %

DATE	CONST. "A"	CONST. "B"	15 cm	30 cm	45 cm	60 cm	75 cm	90 cm	105 cm	120 cm
8/31/88	20.90	-5.90	-	-	-	19.8	27.6	30.9	32.0	28.5
9/30/88	20.90	-5.90	-	-	-	19.5	27.2	30.1	31.7	28.3
10/25/88	20.90	-5.90	392.6	17.2	9.9	20.3	27.1	30.5	31.3	28.1
11/26/88	20.90	-5.90	436.2	29.1	21.4	27.0	30.1	32.1	33.2	29.8
12/28/88	20.90	-5.90	433.0	29.6	23.6	28.0	30.7	32.2	33.4	29.9
3/13/89	20.90	-5.90	446.8	37.8	31.9	31.7	34.7	36.4	33.2	32.6
3/31/89	20.90	-5.90	450.4	37.9	32.3	33.0	34.5	36.9	36.4	32.9
5/2/89	20.90	-5.90	418.8	35.6	30.6	31.8	32.6	34.8	35.5	32.6

LOCATION: #6040
DESCRIPTION: NEUTRON PROBE DATA
TYPE: MOISTURE CONTENT - %

135 cm	150 cm
32.7	-
32.7	-
32.6	-
33.4	-
33.6	-
35.5	-
water	-
water	-

LOCATION: #6060
DESCRIPTION: NEUTRON PROBE DATA
TYPE: MOISTURE CONTENT - %

DATE	CONST. "A"	CONST. "B"	15 cm	30 cm	45 cm	60 cm	75 cm	90 cm	105 cm	120 cm
8/31/88	20.90	-5.90	-	-	-	25.6	25.0	23.6	24.7	24.5
9/30/88	20.90	-5.90	-	-	-	24.9	24.6	23.4	24.0	24.3
10/25/88	20.90	-5.90	425.2	18.8	17.3	25.0	25.1	23.2	23.7	23.6
11/26/88	20.90	-5.90	454.3	27.7	21.9	25.9	24.3	23.0	23.3	23.4
12/28/88	20.90	-5.90	443.8	26.1	22.1	26.3	24.7	23.2	23.2	23.4
3/13/89	20.90	-5.90	470.7	33.0	29.8	32.1	31.6	29.3	28.8	27.9
3/31/89	20.90	-5.90	470.3	36.0	32.3	32.6	30.2	28.4	28.0	27.7
5/2/89	20.90	-5.90	458.7	32.6	29.8	30.7	28.0	26.6	27.2	27.1

LOCATION: #6060
DESCRIPTION: NEUTRON PROBE DATA
TYPE: MOISTURE CONTENT - %

135 cm	150 cm
24.2	26.0
23.7	25.9
23.8	25.9
23.5	25.6
23.4	25.0
33.0	water
28.9	30.9
26.6	28.8

LOCATION: #6080
DESCRIPTION: NEUTRON PROBE DATA
TYPE: MOISTURE CONTENT - %

DATE	CONST. "A"	CONST. "B"	45 cm	60 cm	75 cm	90 cm	105 cm	120 cm	135 cm	150 cm
8/31/88	20.90	-5.90	-	22.8	21.1	19.9	19.7	21.0	-	-
9/30/88	20.90	-5.90	-	20.3	19.5	18.6	18.9	19.9	-	-
10/25/88	20.90	-5.90	15.9	21.2	19.8	18.5	18.8	20.0	-	-
11/26/88	20.90	-5.90	27.0	29.6	28.8	28.7	29.9	31.5	-	-
12/28/88	20.90	-5.90	25.4	28.0	27.2	27.1	28.0	30.2	-	-
3/13/89	20.90	-5.90	33.0	32.6	31.9	31.9	32.7	34.2	-	-
3/31/89	20.90	-5.90	31.1	31.0	30.3	30.3	31.6	33.5	-	-
5/2/89	20.90	-5.90	23.8	28.5	28.3	28.2	29.5	31.6	-	-

LOCATION: #8020
DESCRIPTION: NEUTRON PROBE DATA
TYPE: MOISTURE CONTENT - %

DATE	CONST. "A"	CONST. "B"	45 cm	60 cm	75 cm	90 cm	105 cm	120 cm	135 cm	150 cm
8/31/88	20.90	-5.90	-	22.5	26.7	26.8	30.8	31.0	30.4	-
9/30/88	20.90	-5.90	-	21.6	25.9	26.6	30.2	30.7	30.6	-
10/25/88	20.90	-5.90	12.2	21.8	26.0	26.4	30.1	30.5	30.8	-
11/26/88	20.90	-5.90	24.3	28.6	29.5	29.2	30.9	30.5	30.3	-
12/28/88	20.90	-5.90	23.1	27.1	28.6	29.2	31.8	33.3	32.3	-
3/13/89	20.90	-5.90	34.7	33.5	32.1	31.0	33.0	34.4	35.6	-
3/31/89	20.90	-5.90	31.5	33.2	31.8	31.3	33.2	34.6	36.6	-
5/2/89	20.90	-5.90	24.1	29.1	30.0	30.4	32.6	34.4	38.3	-

LOCATION: #8060
DESCRIPTION: NEUTRON PROBE DATA
TYPE: MOISTURE CONTENT - %

DATE	CONST. "A"	CONST. "B"	45 cm	60 cm	75 cm	90 cm	105 cm	120 cm	135 cm	150 cm
8/31/88	20.90	-5.90	-	25.4	25.2	24.5	25.7	26.0	27.9	30.1
9/30/88	20.90	-5.90	-	24.2	24.5	23.9	24.8	25.7	27.8	30.0
10/25/88	20.90	-5.90	11.6	24.7	24.7	23.7	24.4	25.3	27.8	30.0
11/26/88	20.90	-5.90	21.0	29.4	28.6	28.9	28.9	27.7	28.4	29.8
12/28/88	20.90	-5.90	22.7	28.2	28.3	28.2	28.9	28.2	29.0	30.9
3/13/89	20.90	-5.90	29.8	31.4	30.5	31.3	31.6	30.2	30.2	water
3/31/89	20.90	-5.90	26.7	30.5	30.4	30.9	31.3	30.1	30.3	33.5
5/2/89	20.90	-5.90	18.5	28.4	29.0	29.5	30.1	29.5	30.5	32.8

APPENDIX C

NEUTRON PROBE DATA - COUNTS

LOCATION: #0020
DESCRIPTION: NEUTRON PROBE DATA
TYPE: COUNTS

DATE:	AUTO STANDARD	45 cm	60 cm	75 cm	90 cm	105 cm	120 cm	135 cm	150 cm
8/31/88	11812	-	17180	17895	18543	17746	16342	18636	22761
9/30/88	11842	-	16898	17740	18425	17752	16059	18863	22704
10/25/88	11861	14065	16768	17738	18350	17509	16059	18836	22742
11/26/88	11993	20586	20412	19734	20123	18747	16654	19000	22723
12/28/88	11933	19310	20022	20792	21465	20707	19308	20314	23006
3/13/89	11908	22261	23294	25384	25702	24333	21975	21284	26515
3/31/89	11863	22106	23135	25191	25793	24585	22032	22080	water
5/2/89	11899	20295	21837	22995	23023	24077	23591	21971	water

LOCATION: #0060
DESCRIPTION: NEUTRON PROBE DATA
TYPE: COUNTS

DATE:	AUTO STANDARD	45 cm	60 cm	75 cm	90 cm	105 cm	120 cm	135 cm	150 cm
8/31/88	11812	-	14597	15035	14062	13841	14003	-	-
9/30/88	11842	-	14311	15098	13946	13584	13849	-	-
10/25/88	11861	18754	14265	14966	13972	13570	13646	-	-
11/26/88	11993	18623	20539	17272	14079	13501	13786	-	-
12/28/88	11933	18927	18179	17499	15385	15063	15068	-	-
3/13/89	11908	23225	22867	21732	20651	22142	24274	-	-
3/31/89	11863	22863	22666	22681	23478	27864	water	-	-
5/2/89	11899	21367	21501	21771	23681	25817	water	-	-

LOCATION: #2000
DESCRIPTION: NEUTRON PROBE DATA
TYPE : COUNTS

DATE:	AUTO STANDARD	45 cm	60 cm	75 cm	90 cm	105 cm	120 cm	135 cm	150 cm
8/31/88	11812	-	16908	19023	20913	20867	19734	19832	20806
9/30/88	11842	-	15866	18538	20490	20370	19542	19888	20805
10/25/88	11861	19188	15911	18597	20395	20286	19690	19742	21015
11/26/88	11993	18221	20576	21393	22194	21552	19945	20129	21510
12/28/88	11933	17259	19812	21194	22601	21992	21367	21867	22797
3/13/89	11908	21136	22922	24154	25072	23904	21830	22810	24443
3/31/89	11863	20123	22101	23620	24942	23967	21774	23431	24556
5/2/89	11899	15003	20141	21770	23650	23378	21878	24329	water

LOCATION: #2020
DESCRIPTION: NEUTRON PROBE DATA
TYPE: COUNTS

DATE:	AUTO STANDARD	15 cm	30 cm	45 cm	60 cm	75 cm	90 cm	105 cm	120 cm
8/31/88	11812	-	-	-	18554	20064	21315	20319	18935
9/30/88	11842	-	-	-	18279	19887	21097	19836	18732
10/25/88	11861	30394	16627	15431	18378	19859	21030	19990	18642
11/26/88	11993	30570	17266	15780	18153	19690	20955	19775	18685
12/28/88	11933	30293	17611	16118	18339	19857	21190	20033	18954
3/13/89	11908	28890	18029	19286	22704	24883	24902	23633	21217
3/31/89	11863	28959	18174	20029	22485	24606	24959	23500	21176
5/2/89	11899	30601	18359	20293	21892	23461	24231	23201	21191

LOCATION: #2020
DESCRIPTION: NEUTRON PROBE DATA
TYPE: COUNTS

135 cm	150 cm
19768	22438
19922	22520
19975	22588
20100	22622
20118	22778
22346	25025
23197	water
24771	water

LOCATION: #2040
DESCRIPTION: NEUTRON PROBE DATA
TYPE: COUNTS

DATE:	AUTO STANDARD	15 cm	30 cm	45 cm	60 cm	75 cm	90 cm	105 cm	120 cm
8/31/88	11812	-	-	-	17350	17049	15192	12654	10257
9/30/88	11842	-	-	-	16604	16704	14863	12861	10464
10/25/88	11861	26992	13163	12379	16752	16294	14638	12624	10665
11/26/88	11993	28384	18539	17464	17946	16682	14975	12694	10512
12/28/88	11933	27473	17704	16727	17659	16508	15208	13340	11411
3/13/89	11908	29851	22767	21581	21106	21379	21789	23285	24928
3/31/89	11863	28966	21197	20888	21191	21389	21912	23214	24359
5/2/89	11899	30012	20873	20379	21201	21007	21391	22216	23371

LOCATION: #2040
DESCRIPTION: NEUTRON PROBE DATA
TYPE: COUNTS

135 cm	150 cm
9306	9002
9396	9072
9469	9107
9514	9254
10463	10561
25988	water
water	water
22928	22964

LOCATION: #2060
DESCRIPTION: NEUTRON PROBE DATA
TYPE: COUNTS

DATE:	AUTO STANDARD	15 cm	30 cm	45 cm	60 cm	75 cm	90 cm	105 cm	120 cm
8/31/88	11812	-	-	-	15866	15056	13875	13486	13400
9/30/88	11842	-	-	-	15615	15032	13683	13319	13343
10/25/88	11861	30932	18328	12419	15604	14748	13594	13157	13155
11/26/88	11993	30873	19001	13368	15981	14525	13386	13076	12940
12/28/88	11933	30968	19100	13928	15984	14526	13339	13104	12950
3/13/89	11908	31729	20528	15256	16340	14600	13709	13595	13846
3/31/89	11863	31108	20030	15162	17527	19457	19853	20605	21791
5/2/89	11899	31438	20056	15601	19021	19692	19827	20592	21537

LOCATION: #2060
DESCRIPTION: NEUTRON PROBE DATA
TYPE: COUNTS

135 cm	150 cm
13574	13242
13494	13235
13308	13406
13327	13057
13308	13083
14422	14243
22948	23311
22857	23230

LOCATION: #2080
DESCRIPTION: NEUTRON PROBE DATA
TYPE: COUNTS

DATE:	AUTO STANDARD	45 cm	60 cm	75 cm	90 cm	105 cm	120 cm	135 cm	150 cm
8/31/88	11812	-	16477	15152	13752	13360	13038	13453	13549
9/30/88	11842	-	16133	14763	13628	12896	12941	13410	13524
10/25/88	11861	12302	15873	14704	13272	12819	12774	13225	13715
11/26/88	11993	20117	20860	19840	18326	17953	18073	18097	17873
12/28/88	11933	17540	19400	18312	16914	16957	17762	18536	19784
3/13/89	11908	23663	22540	21310	21012	21820	23379	24824	25433
3/31/89	11863	22976	21869	21033	20640	21865	23365	24838	25853
5/2/89	11899	17481	20332	20192	19962	21123	22864	24726	25408

LOCATION: #4020
DESCRIPTION: NEUTRON PROBE DATA
TYPE: COUNTS

DATE:	AUTO STANDARD	15 cm	30 cm	45 cm	60 cm	75 cm	90 cm	105 cm	120 cm
8/31/88	11812	-	-	-	18522	20603	19859	19006	20073
9/30/88	11842	-	-	-	18084	20267	19699	18964	20135
10/25/88	11861	25940	12489	13052	18161	20418	19483	18983	20218
11/26/88	11993	26060	14028	13397	18118	20302	19483	18768	20236
12/28/88	11933	25550	14741	13839	18104	20555	19995	19397	20485
3/13/89	11908	26633	16946	18223	21340	23873	22426	20992	22672
3/31/89	11863	25791	17044	18477	21398	23965	22879	20977	22800
5/2/89	11899	28355	17212	18617	21174	23007	22335	21101	22696

LOCATION: #4020
DESCRIPTION: NEUTRON PROBE DATA
TYPE: COUNTS

135 cm	150 cm
19604	20715
19859	21208
19815	21052
19766	21210
20039	21152
22415	23643
22345	23896
22594	24532

LOCATION: #4040
DESCRIPTION: NEUTRON PROBE DATA
TYPE: COUNTS

DATE:	AUTO STANDARD	15 cm	30 cm	45 cm	60 cm	75 cm	90 cm	105 cm	120 cm
9/30/88	11842	-	-	-	15323	14677	14884	14562	14423
10/25/88	11861	29350	13650	12729	15102	14797	14842	14526	14316
11/26/88	11993	29677	14472	12855	15152	14533	14973	14552	14393
12/28/88	11933	29105	15394	13165	15096	14799	15301	15290	15670
3/13/89	11908	29597	16563	15014	15733	15238	17823	19083	19206
3/31/89	11863	27362	15925	15662	16434	18600	20605	19847	19678
5/2/89	11899	29371	16052	16667	17851	19139	20389	19635	19351

LOCATION: #4040
DESCRIPTION: NEUTRON PROBE DATA
TYPE: COUNTS

135 cm	150 cm
15832	19439
15987	19594
16087	20114
16688	20515
18518	21311
19600	water
19723	water

LOCATION: #4060
DESCRIPTION: NEUTRON PROBE DATA
TYPE: COUNTS

DATE:	AUTO STANDARD	15 cm	30 cm	45 cm	60 cm	75 cm	90 cm	105 cm	120 cm
8/31/88	11812	-	-	-	16229	16851	16156	15904	16561
9/30/88	11842	-	-	-	15959	16898	15914	15909	16445
10/25/88	11861	30883	18271	12663	16183	16767	15849	15639	16126
11/26/88	11993	31317	19077	13319	16176	16637	15757	15737	16525
12/28/88	11933	31153	19189	13658	15927	16524	15620	15596	16123
3/13/89	11908	31776	20617	15020	17216	16592	15579	15365	15855
3/31/89	11863	31506	20086	14913	17162	16590	15432	15379	16090
5/2/89	11899	30585	19824	15010	17242	17041	16178	16118	16832

LOCATION: #4060
DESCRIPTION: NEUTRON PROBE DATA
TYPE: COUNTS

135 cm	150 cm
16126	17447
15586	17098
16052	17379
16131	17449
15820	17136
15760	17202
15794	17015
16552	17540

LOCATION: #6000
DESCRIPTION: NEUTRON PROBE DATA
TYPE: COUNTS

DATE:	AUTO STANDARD	45 cm	60 cm	75 cm	90 cm	105 cm	120 cm	135 cm	150 cm
8/31/88	11812	-	19504	19368	22960	21749	20330	20700	-
9/30/88	11842	-	19225	18993	22843	21708	20211	20668	-
10/25/88	11861	13346	19243	19062	23028	21837	20453	20765	-
11/26/88	11993	19791	21728	20719	23363	22747	22593	22959	-
12/28/88	11933	18561	21277	20512	23862	23168	22953	23391	-
3/13/89	11908	22672	22353	21143	23815	23342	23522	25578	-
3/31/89	11863	22424	22420	21364	23893	23747	water	water	-
5/2/89	11899	17390	20945	20868	23757	23502	water	water	-

LOCATION: #6020
DESCRIPTION: NEUTRON PROBE DATA
TYPE: COUNTS

DATE:	AUTO STANDARD	15 cm	30 cm	45 cm	60 cm	75 cm	90 cm	105 cm	120 cm
8/31/88	11812	-	-	-	19014	19048	19975	21837	20029
9/30/88	11842	-	-	-	18217	18504	19547	21874	20093
10/25/88	11861	24637	11785	14081	18422	18522	19785	21651	20042
11/26/88	11993	24486	13115	14273	18310	18459	19721	21721	20103
12/28/88	11933	24025	13769	14756	18463	19276	20361	21890	20158
3/13/89	11908	27215	21402	22679	21693	21210	21600	25637	water
3/31/89	11863	27025	21739	22461	21575	21329	21912	water	water
5/2/89	11899	28069	20739	21646	21225	21179	22007	water	water

LOCATION: #6020
DESCRIPTION: NEUTRON PROBE DATA
TYPE: COUNTS

135 cm	150 cm
19982	-
20029	-
20098	-
20169	-
20042	-
water	-
water	-
water	-

LOCATION: #6040
DESCRIPTION: NEUTRON PROBE DATA
TYPE: COUNTS

DATE:	AUTO STANDARD	15 cm	30 cm	45 cm	60 cm	75 cm	90 cm	105 cm	120 cm
8/31/88	11812	-	-	-	14498	18921	20802	21415	19449
9/30/88	11842	-	-	-	14415	18767	20425	21291	19386
10/25/88	11861	25584	13101	8955	14884	18752	20645	21134	19302
11/26/88	11993	29142	20096	15645	18885	20676	21817	22455	20490
12/28/88	11933	28756	20248	16850	19342	20873	21755	22455	20435
3/13/89	11908	29721	24880	21536	21437	23157	24126	22302	21909
3/31/89	11863	29874	24888	21684	22083	22928	24270	24016	22015
5/2/89	11899	27619	23639	20756	21468	21906	23200	23568	21926

LOCATION: #6040
DESCRIPTION: NEUTRON PROBE DATA
TYPE: COUNTS

135 cm	150 cm
21806	-
21878	-
21842	-
22536	-
22528	-
23600	-
water	-
water	-

LOCATION: #6060
DESCRIPTION: NEUTRON PROBE DATA
TYPE: COUNTS

DATE:	AUTO STANDARD	15 cm	30 cm	45 cm	60 cm	75 cm	90 cm	105 cm	120 cm
8/31/88	11812	-	-	-	17828	17481	16684	17290	17164
9/30/88	11842	-	-	-	17430	17278	16615	16943	17106
10/25/88	11861	27999	14026	13155	17513	17582	16507	16825	16747
11/26/88	11993	30496	19278	15959	18220	17349	16579	16733	16831
12/28/88	11933	29558	18295	15985	18365	17476	16598	16621	16732
3/13/89	11908	31499	22145	20367	21644	21348	20039	19751	19286
3/31/89	11863	31355	23782	21684	21828	20500	19475	19234	19069
5/2/89	11899	30581	21891	20308	20831	19320	18501	18830	18792

LOCATION: #6060
DESCRIPTION: NEUTRON PROBE DATA
TYPE: COUNTS

135 cm	150 cm
16990	18033
16790	18032
16854	18022
16881	18085
16701	17654
22177	water
19780	20910
18488	19759

LOCATION: #6080
DESCRIPTION: NEUTRON PROBE DATA
TYPE: COUNTS

DATE:	AUTO STANDARD	45 cm	60 cm	75 cm	90 cm	105 cm	120 cm	135 cm	150 cm
8/31/88	11812	-	16234	15240	14574	14453	15191	-	-
9/30/88	11842	-	14873	14398	13869	14048	14618	-	-
10/25/88	11861	12375	15407	14575	13828	14008	14677	-	-
11/26/88	11993	18867	20353	19896	19878	20539	21448	-	-
12/28/88	11933	17887	19350	18916	18867	19360	20584	-	-
3/13/89	11908	22147	21914	21551	21537	22020	22866	-	-
3/31/89	11863	20980	20949	20568	20537	21267	22368	-	-
5/2/89	11899	16896	19609	19461	19392	20176	21365	-	-

LOCATION: #8020
DESCRIPTION: NEUTRON PROBE DATA
TYPE: COUNTS

DATE:	AUTO STANDARD	45 cm	60 cm	75 cm	90 cm	105 cm	120 cm	135 cm	150 cm
8/31/88	11812	-	16049	18415	18490	20729	20837	20519	-
9/30/88	11842	-	15564	18020	18398	20444	20741	20680	-
10/25/88	11861	10289	15707	18076	18357	20456	20637	20841	-
11/26/88	11993	17337	19771	20294	20131	21091	20879	20792	-
12/28/88	11933	16540	18818	19683	20033	21500	22364	21836	-
3/13/89	11908	23107	22470	21653	21042	22182	22983	23650	-
3/31/89	11863	21201	22183	21411	21124	22194	22970	24102	-
5/2/89	11899	17099	19915	20451	20691	21917	22925	25191	-

LOCATION: #8060
DESCRIPTION: NEUTRON PROBE DATA
TYPE: COUNTS

DATE:	AUTO STANDARD	45 cm	60 cm	75 cm	90 cm	105 cm	120 cm	135 cm	150 cm
8/31/88	11812	-	17686	17595	17166	17870	18050	19122	20322
9/30/88	11842	-	17036	17250	16904	17420	17917	19078	20335
10/25/88	11861	9948	17348	17372	16805	17215	17717	19138	20378
11/26/88	11993	15460	20277	19775	19953	19986	19272	19663	20460
12/28/88	11933	16303	19462	19541	19453	19841	19476	19914	20998
3/13/89	11908	20325	21259	20759	21184	21341	20590	20577	water
3/31/89	11863	18496	20667	20590	20895	21095	20441	20568	22352
5/2/89	11899	13915	19524	19861	20178	20489	20126	20742	22024

APPENDIX D

SLUDGE POOL NEUTRON PROBE DATA
Average Moisture Content

LOCATION: PROBES @ POOL
DESCRIPTION: NEUTRON PROBE DATA
TYPE: AVERAGE MOISTURE CONTENT - %

DATE:	AUTO STANDARD	NE	NW	SW	SE	MEAN	STDEV	M.C. %
9/30/88	11842	32152	31873	31938	31647	31903	208	478.5
10/25/88	11861	31176	31129	31252	30829	31097	185	466.9
11/26/88	11993	32291	31744	32134	32127	32074	233	475.3
12/28/88	11933	31954	32230	32069	31985	32060	124	477.3
3/13/89	11908	33988	34424	34259	34196	34217	180	507.2
3/31/89	11863	33380	33494	33788	33918	33645	250	501.2
5/2/89	11899	33037	33046	33225	33045	33088	91	492.3

DEPTH: PLASTIC WADING POOL
DESCRIPTION: SLUDGE IN PLASTIC WADING POOL
TYPE: SUMMARY

DATE	AUTO STANDARD	NE	NW	SW	SE
9/30/88	11842	32152	31873	31938	31647
10/25/88	11861	31176	31129	31252	30829
11/26/88	11993	32291	31744	32134	32127
12/28/88	11933	31954	32230	32069	31985
3/13/89	11908	33988	34424	34259	34196
3/31/89	11863	33380	33494	33788	33918

APPENDIX E

NEUTRON PROBE DATA - DEPTH SUMMARY-Outside Sludge

DEPTH: 45 cm
DESCRIPTION: SOIL ADJACENT TO SLUDGE BLANKET
TYPE: DEPTH SUMMARY

DATE	AUTO STANDARD	2000	6000	"0020	8020	"0060	8060	2080	6080
8/31/88	11812	-	-	-	-	-	-	-	-
9/30/88	11842	-	-	-	-	-	-	-	-
10/25/88	11861	9188	13346	14065	10289	8754	9948	12302	12375
11/26/88	11993	18221	19791	20586	17337	18623	15460	20117	18867
12/28/88	11933	17259	18561	19310	16540	18927	16303	17540	17887
3/13/89	11908	21136	22672	22261	23107	23225	20325	23663	22147
3/31/89	11863	20123	22424	22106	21201	22863	18496	22976	20980
5/2/89	11899	15003	17390	20295	17099	21367	13915	17481	16896

DEPTH: 45 cm
DESCRIPTION: SOIL ADJACENT TO SLUDGE BLANKET
TYPE: DEPTH SUMMARY

AVERAGE	STANDARD DEVIATION	ADJUSTED COUNT	INTERCEPT	SLOPE	MOISTURE CONTENT
-	-	-	-	-	-
-	-	-	-	-	-
11283	1992	0.951	-5.9	20.9	13.98
18625	1662	1.553	-5.9	20.9	26.56
17791	1091	1.491	-5.9	20.9	25.26
22317	1120	1.874	-5.9	20.9	33.27
21396	1533	1.804	-5.9	20.9	31.80
17431	2460	1.465	-5.9	20.9	24.72

DEPTH: 60 cm
DESCRIPTION: SOIL ADJACENT TO SLUDGE BLANKET
TYPE: DEPTH SUMMARY

DATE	AUTO STANDARD	2000	6000	"0020	8020	"0060	8060	2080	6080
8/31/88	11812	16908	19504	17180	16049	14597	17686	16477	16234
9/30/88	11842	15866	19225	16898	15564	14311	17036	16133	14873
10/25/88	11861	15911	19243	16768	15707	14265	17348	15873	15407
11/26/88	11993	20576	21728	20412	19771	20539	20277	20860	20353
12/28/88	11933	19812	21277	20022	18818	18179	19462	19400	19350
3/13/89	11908	22922	22353	23294	22470	22867	21259	22540	21914
3/31/89	11863	22101	22420	23135	22183	22666	20667	21869	20949
5/2/89	11899	20141	20945	21837	19915	21501	19524	23332	19609

DEPTH: 60 cm
DESCRIPTION: SOIL ADJACENT TO SLUDGE BLANKET
TYPE: DEPTH SUMMARY

AVERAGE	STANDARD DEVIATION	ADJUSTED COUNT	INTERCEPT	SLOPE	MOISTURE CONTENT
16829	1419	1.425	-5.9	20.9	23.88
16238	1520	1.371	-5.9	20.9	22.76
16315	1493	1.376	-5.9	20.9	22.85
20565	563	1.715	-5.9	20.9	29.94
19540	907	1.637	-5.9	20.9	28.32
22452	636	1.885	-5.9	20.9	33.51
21999	832	1.854	-5.9	20.9	32.86
20851	1322	1.752	-5.9	20.9	30.72

DEPTH: 75 cm
DESCRIPTION: SOIL ADJACENT TO SLUDGE BLANKET
TYPE: DEPTH SUMMARY

DATE	AUTO STANDARD	2000	6000	"0020	8020	"0060	8060	2080	6080
8/31/88	11812	19023	19368	17895	18415	15035	17595	15152	15240
9/30/88	11842	18538	18993	17740	18020	15098	17250	14763	14398
10/25/88	11861	18597	19062	17738	18076	14966	17372	14704	14575
11/26/88	11993	21393	20719	19734	20294	17272	19775	19840	19896
12/28/88	11933	21194	20512	20792	19683	17499	19541	18312	18916
3/13/89	11908	24154	21143	25384	21653	21732	20759	21310	21551
3/31/89	11863	23620	21364	25191	21411	22681	20590	21033	20568
5/2/89	11899	21770	20868	22995	20451	21771	19861	20192	19461

DEPTH: 75 cm
DESCRIPTION: SOIL ADJACENT TO SLUDGE BLANKET
TYPE: DEPTH SUMMARY

AVERAGE	STANDARD DEVIATION	ADJUSTED COUNT	INTERCEPT	SLOPE	MOISTURE CONTENT
17215	1807	1.457	-5.9	20.9	24.56
16850	1821	1.423	-5.9	20.9	23.84
16886	1845	1.424	-5.9	20.9	23.85
19865	1195	1.656	-5.9	20.9	28.72
19556	1272	1.639	-5.9	20.9	28.35
22211	1642	1.865	-5.9	20.9	33.08
22057	1646	1.859	-5.9	20.9	32.96
20921	1181	1.758	-5.9	20.9	30.85

DEPTH: 90 cm
DESCRIPTION: SOIL ADJACENT TO SLUDGE BLANKET
TYPE: DEPTH SUMMARY

DATE	AUTO STANDARD	2000	6000	"0020	8020	"0060	8060	2080	6080
8/31/88	11812	20913	22960	18543	18490	14062	17166	13752	14574
9/30/88	11842	20490	22843	18425	18398	13946	16904	13628	13869
10/25/88	11861	20395	23028	18350	18357	13972	16805	13272	13828
11/26/88	11993	22194	23363	20123	20131	14079	19953	18326	19878
12/28/88	11933	22601	23862	21465	20033	15385	19453	16914	18867
3/13/89	11908	25072	23815	25702	21042	20651	21184	21012	21537
3/31/89	11863	24942	23893	25793	21124	23478	20895	20640	20537
5/2/89	11899	23650	23757	23023	20691	23681	20178	19962	19392

DEPTH: 96 cm
DESCRIPTION: SOIL ADJACENT TO SLUDGE BLANKET
TYPE: DEPTH SUMMARY

AVERAGE	STANDARD DEVIATION	ADJUSTED COUNT	INTERCEPT	SLOPE	MOISTURE CONTENT
17558	3339	1.486	-5.9	20.9	25.17
17313	3381	1.462	-5.9	20.9	24.66
17251	3468	1.454	-5.9	20.9	24.50
19756	2766	1.647	-5.9	20.9	28.53
19823	2828	1.661	-5.9	20.9	28.82
22502	2036	1.890	-5.9	20.9	33.59
22663	2114	1.910	-5.9	20.9	34.03
21792	1902	1.831	-5.9	20.9	32.38

DEPTH: 105 cm
DESCRIPTION: SOIL ADJACENT TO SLUDGE BLANKET
TYPE: DEPTH SUMMARY

DATE	AUTO STANDARD	2000	6000	"0020	8020	"0060	8060	2080	6080
8/31/88	11812	20867	21749	17746	20729	13841	17870	13360	14453
9/30/88	11842	20370	21708	17752	20444	13584	17420	12896	14048
10/25/88	11861	20286	21837	17509	20456	13570	17215	12819	14008
11/26/88	11993	21552	22747	18747	21091	13501	19986	17953	20539
12/28/88	11933	21992	23168	20707	21500	15063	19841	16957	19360
3/13/89	11908	23904	23342	24333	22182	22142	21341	21820	22020
3/31/89	11863	23967	23747	24585	22194	27864	21095	21865	21267
5/2/89	11899	23378	23502	24077	21917	25817	20489	21123	20176

DEPTH: 105 cm
DESCRIPTION: SOIL ADJACENT TO SLUDGE BLANKET
TYPE: DEPTH SUMMARY

AVERAGE	STANDARD DEVIATION	ADJUSTED COUNT	INTERCEPT	SLOPE	MOISTURE CONTENT
17577	3376	1.488	-5.9	20.9	25.20
17278	3438	1.459	-5.9	20.9	24.59
17213	3470	1.451	-5.9	20.9	24.43
19515	2867	1.627	-5.9	20.9	28.11
19824	2688	1.661	-5.9	20.9	28.82
22636	1080	1.901	-5.9	20.9	33.83
23323	2249	1.966	-5.9	20.9	35.19
22560	1961	1.896	-5.9	20.9	33.73

DEPTH: 120 cm
DESCRIPTION: SOIL ADJACENT TO SLUDGE BLANKET
TYPE: DEPTH SUMMARY

DATE	AUTO STANDARD	2000	6000	"0020	8020	"0060	8060	2080	6080
8/31/88	11812	19734	20330	16342	20837	14003	18050	13038	15191
9/30/88	11842	19542	20211	16059	20741	13849	17917	12941	14618
10/25/88	11861	19690	20453	16059	20637	13646	17717	12774	14677
11/26/88	11993	19945	22593	16654	20879	13786	19272	18073	21448
12/28/88	11933	21367	22953	19308	22364	15086	19476	17762	20584
3/13/89	11908	21830	23522	21975	22983	24274	20590	23379	22866
3/31/89	11863	21774	water	22032	22970	water	20441	23365	22368
5/2/89	11899	21878	water	23591	22925	water	20126	22864	21365

DEPTH: 120 cm
DESCRIPTION: SOIL ADJACENT TO SLUDGE BLANKET
TYPE: DEPTH SUMMARY

AVERAGE	STANDARD DEVIATION	ADJUSTED COUNT	INTERCEPT	SLOPE	MOISTURE CONTENT
17191	2988	1.455	-5.9	20.9	24.52
16985	3037	1.434	-5.9	20.9	24.08
16957	3123	1.430	-5.9	20.9	23.98
19081	2851	1.591	-5.9	20.9	27.35
19863	2571	1.665	-5.9	20.9	28.89
22677	1162	1.904	-5.9	20.9	33.90
22158	1027	1.868	-5.9	20.9	33.14
22125	1263	1.859	-5.9	20.9	32.96

DEPTH: 135 cm
DESCRIPTION: SOIL ADJACENT TO SLUDGE BLANKET
TYPE: DEPTH SUMMARY

DATE	AUTO STANDARD	2000	6000	"0020	8020	"0060	8060	2080	6080
8/31/88	11812	19832	20700	18636	20519	-	19122	13453	-
9/30/88	11842	19888	20668	18863	20680	-	19078	13410	-
10/25/88	11861	19742	20765	18836	20841	-	19138	13225	-
11/26/88	11993	20129	22959	19000	20792	-	19663	18097	-
12/28/88	11933	21867	23391	20314	21836	-	19914	18536	-
3/13/89	11908	22810	25578	21284	23650	-	20577	24824	-
3/31/89	11863	23431	water	22080	24102	-	20568	24838	-
5/2/89	11899	24329	water	21971	25191	-	20742	24726	-

DEPTH: 135 cm
DESCRIPTION: SOIL ADJACENT TO SLUDGE BLANKET
TYPE: DEPTH SUMMARY

AVERAGE	STANDARD DEVIATION	ADJUSTED COUNT	INTERCEPT	SLOPE	MOISTURE CONTENT
18710	2695	1.584	-5.9	20.9	27.21
18765	2733	1.585	-5.9	20.9	27.22
18758	2832	1.581	-5.9	20.9	27.15
20107	1677	1.677	-5.9	20.9	29.14
20976	1725	1.758	-5.9	20.9	30.84
23121	1958	1.942	-5.9	20.9	34.68
23004	1698	1.939	-5.9	20.9	34.63
23392	1932	1.966	-5.9	20.9	35.19

DEPTH: 150 cm
DESCRIPTION: SOIL ADJACENT TO SLUDGE BLANKET
TYPE: DEPTH SUMMARY

DATE	AUTO STANDARD	2000	6000	"0020	8020	"0060	8060	2080	6080
8/31/88	11812	20806	-	22761	-	-	20322	13549	-
9/30/88	11842	20805	-	22704	-	-	20335	13524	-
10/25/88	11861	21015	-	22742	-	-	20378	13715	-
11/26/88	11993	21510	-	22723	-	-	20460	17873	-
12/28/88	11933	22797	-	23006	-	-	20998	19784	-
3/13/89	11908	24443	-	26515	-	-	water	25433	-
3/31/89	11863	24556	-	water	-	-	22353	25853	-
5/2/89	11899	water	-	water	-	-	22024	25408	-

DEPTH: 150 cm
DESCRIPTION: SOIL ADJACENT TO SLUDGE BLANKET
TYPE: DEPTH SUMMARY

AVERAGE	STANDARD DEVIATION	ADJUSTED COUNT	INTERCEPT	SLOPE	MOISTURE CONTENT
19360	4015	1.639	-5.9	20.9	28.35
19342	4012	1.633	-5.9	20.9	28.24
19463	3960	1.641	-5.9	20.9	28.39
20642	2064	1.721	-5.9	20.9	30.07
21646	1534	1.814	-5.9	20.9	32.01
25464	1036	2.138	-5.9	20.9	38.79
24254	1769	2.045	-5.9	20.9	36.83
23716	2393	1.993	-5.9	20.9	35.76

APPENDIX F

SLUDGE DATA

LOCATION: LEWISTON SLUDGE
DESCRIPTION: SLUDGE CHARACTERISTICS
TYPE: QUANTITY ANALYSIS

PARAMETERS	UNITS	QUANTITY	SLUDGE PROD. tons/day	WEIGHT PROD. lbs/day	PERCENT SOLIDS %	APPROX. CONC. mg/liter	EP TOXICITY mg/liter
AMMONIA NITROGEN	mg/g	1.64	1.6	5.248	18	295	-
ORGANIC NITROGEN	mg/g	6.68	1.6	21.376	18	1202	-
TOTAL KJELDAHL NITROGEN	mg/g	92.28	1.6	295.296	18	16610	-
TOTAL PHOSPHATE	mg/g	25.21	1.6	80.672	18	4538	-
TOTAL POTASSIUM	mg/kg	1991.5	1.6	6.373	18	358	-
ARSENIC	mg/kg	12.28	1.6	0.039	18	2	5
CADMIUM	mg/kg	12.06	1.6	0.039	18	2	1
COPPER	mg/kg	2970.25	1.6	9.505	18	535	-
LEAD	mg/kg	2154.75	1.6	6.895	18	388	5
NICKEL	mg/kg	564.26	1.6	1.806	18	102	-
SILVER	mg/kg	43.07	1.6	0.138	18	8	5
ZINC	mg/kg	1652.13	1.6	5.287	18	297	-

DEPTH: PLASTIC WADING POOL
DESCRIPTION: SLUDGE IN PLASTIC WADING POOL
TYPE: SUMMARY

AVERAGE	STANDARD DEVIATION	ADJUSTED COUNT	INTERCEPT	SLOPE	MOISTURE CONTENT
31903	208	2.694	47.7329	159.87	478.42
31097	185	2.622	47.7329	159.87	466.87
32074	233	2.674	47.7329	159.87	475.29
32060	124	2.687	47.7329	159.87	477.24
34217	180	2.873	47.7329	159.87	507.11
33645	250	2.836	47.7329	159.87	501.14

APPENDIX G

NEUTRON PROBE DATA - DEPTH SUMMARY-Under Sludge

DEPTH: 15 cm
DESCRIPTION: SLUDGE BLANKET
TYPE: SUMMARY

DATE	AUTO STANDARD	2020	4020	6020	2040	4040	6040	2060	4060
8/31/88	11812	-	-	-	-	-	-	-	-
9/30/88	11842	-	-	-	-	-	-	-	-
10/25/88	11861	30394	25940	24637	26992	29350	25584	30932	30883
11/26/88	11993	30570	26060	24486	28384	29677	29142	30873	31317
12/28/88	11933	30293	25550	24025	27473	29105	28756	30968	31153
3/13/89	11908	28890	26633	27215	29851	29597	29721	31729	31776
3/31/89	11863	28959	25791	27025	28966	27362	29874	31108	31506
5/2/89	11899	30601	28355	28069	30012	29371	27619	31438	30585

DEPTH: 15 cm
DESCRIPTION: SLUDGE BLANKET
TYPE: SUMMARY

6060	AVERAGE	STANDARD DEVIATION	ADJUSTED COUNT	INTERCEPT	SLOPE	MOISTURE CONTENT
-	-	-	-	-	-	-
-	-	-	-	-	-	-
27999	28079	2419	2.367	47.7329	159.87	426.20
30496	29001	2331	2.418	47.7329	159.87	434.32
29558	28542	2441	2.392	47.7329	159.87	430.12
31499	29657	1868	2.490	47.7329	159.87	445.89
31355	29105	2056	2.453	47.7329	159.87	439.96
30581	29626	1339	2.490	47.7329	159.87	445.77

DEPTH: 30 cm
DESCRIPTION: SOIL UNDER SLUDGE BLANKET
TYPE: DEPTH SUMMARY

DATE	AUTO STANDARD	2020	4020	6020	2040	4040	6040	2060	4060
8/31/88	11812	-	-	-	-	-	-	-	-
9/30/88	11842	-	-	-	-	-	-	-	-
10/25/88	11861	16627	12489	11785	13163	13650	13101	18328	18271
11/26/88	11993	17266	14028	13115	18539	14472	20096	19001	19077
12/28/88	11933	17611	14741	13769	17704	15394	21248	19100	19189
3/13/89	11908	18029	16946	21402	22767	16563	24880	20528	20617
3/31/89	11863	18174	17044	21739	21197	15925	24880	20030	20086
5/2/89	11899	18359	17212	20739	20873	16052	23639	20056	19824

DEPTH: 30 cm
DESCRIPTION: SOIL UNDER SLUDGE BLANKET
TYPE: DEPTH SUMMARY

6060	AVERAGE	STANDARD DEVIATION	ADJUSTED COUNT	INTERCEPT	SLOPE	MOISTURE CONTENT
-	-	-	-	-	-	-
-	-	-	-	-	-	-
14026	14604	2485	1.231	-5.9	20.9	19.83
10278	16208	3358	1.351	-5.9	20.9	22.35
18295	17450	2400	1.462	-5.9	20.9	24.66
22145	20431	2785	1.716	-5.9	20.9	29.96
23782	20317	2966	1.713	-5.9	20.9	29.89
21891	19849	2345	1.668	-5.9	20.9	28.96

DEPTH: 45 cm
DESCRIPTION: SOIL UNDER SLUDGE BLANKET
TYPE: DEPTH SUMMARY

DATE	AUTO STANDARD	2020	4020	6020	2040	4040	6040	2060	4060
8/31/88	11812	-	-	-	-	-	-	-	-
9/30/88	11842	-	-	-	-	-	-	-	-
10/25/88	11861	15431	13052	14081	12379	12729	8955	12419	12663
11/26/88	11993	15780	13397	14273	17464	12855	15645	13368	13319
12/28/88	11933	16118	13839	14756	16727	13165	16850	13928	13658
3/13/89	11908	19286	18223	22679	21581	15014	21536	15256	15020
3/31/89	11863	20029	18477	22461	20888	15662	21684	15162	14913
5/2/89	11899	20293	18617	21646	20379	16667	20756	15601	15010

DEPTH: 45 cm
DESCRIPTION: SOIL UNDER SLUDGE BLANKET
TYPE: DEPTH SUMMARY

6060	AVERAGE	STANDARD DEVIATION	ADJUSTED COUNT	INTERCEPT	SLOPE	MOISTURE CONTENT
-	-	-	-	-	-	-
-	-	-	-	-	-	-
13155	12763	1727	1.076	-5.9	20.9	16.59
15959	14673	1591	1.223	-5.9	20.9	19.67
15985	15003	1430	1.257	-5.9	20.9	20.38
20367	18774	3051	1.577	-5.9	20.9	27.05
21684	18996	3038	1.601	-5.9	20.9	27.57
20308	18809	2452	1.581	-5.9	20.9	27.14

DEPTH: 60 cm
DESCRIPTION: SOIL UNDER SLUDGE BLANKET
TYPE: DEPTH SUMMARY

DATE	AUTO STANDARD	2020	4020	6020	2040	4040	6040	2060	4060
8/31/88	11812	18554	18522	19014	17350	-	14498	15866	16229
9/30/88	11842	18279	18084	18217	16604	15323	14415	15615	15959
10/25/88	11861	18378	18161	18422	16752	15102	14884	15604	16183
11/26/88	11993	18153	18118	18310	17946	15152	18885	15981	16176
12/28/88	11933	18339	18104	18463	17659	15096	19342	15984	15927
3/13/89	11908	22704	21340	21693	21106	15733	21437	16340	17216
3/31/89	11863	22485	21398	21575	21191	16434	22083	17527	17162
5/2/89	11899	21892	21174	21225	21201	17851	21468	19021	17242

DEPTH: 60 cm
DESCRIPTION: SOIL UNDER SLUDGE BLANKET
TYPE: DEPTH SUMMARY

6060	AVERAGE	STANDARD DEVIATION	ADJUSTED COUNT	INTERCEPT	SLOPE	MOISTURE CONTENT
17828	17233	1572	1.459	-5.9	20.9	24.59
17430	16658	1418	1.407	-5.9	20.9	23.50
17513	16778	1407	1.415	-5.9	20.9	23.66
18220	17438	1306	1.454	-5.9	20.9	24.49
18365	17475	1445	1.464	-5.9	20.9	24.71
21644	19913	2675	1.672	-5.9	20.9	29.05
21828	20187	2405	1.702	-5.9	20.9	29.67
20831	20212	1715	1.699	-5.9	20.9	29.60

DEPTH: 75 cm
DESCRIPTION: SOIL UNDER SLUDGE BLANKET
TYPE: DEPTH SUMMARY

DATE	AUTO STANDARD	2020	4020	6020	2040	4040	6040	2060	4060
8/31/88	11812	20064	20603	19048	17049	-	18921	15056	16851
9/30/88	11842	19887	20267	18504	16704	14677	18767	15032	16898
10/25/88	11861	19859	20418	18522	16294	14797	18752	14748	16767
11/26/88	11993	19690	20302	18459	16682	14533	20676	14525	16637
12/28/88	11933	19857	20555	19276	16508	14799	20873	14526	16524
3/13/89	11908	24883	23873	21210	21379	15238	23157	14600	16592
3/31/89	11863	24606	23965	21329	21389	18600	22928	19457	16590
5/2/89	11899	23461	23007	21179	21007	19139	21906	19692	17041

DEPTH: 75 cm
DESCRIP SOIL UNDER SLUDGE BLANKET
TYPE: DEPTH SUMMARY

6060	AVERAGE	STANDARD DEVIATION	ADJUSTED COUNT	INTERCEPT	SLOPE	MOISTURE CONTENT
17481	18134	1852	1.535	-5.9	20.9	26.19
17278	17557	1970	1.483	-5.9	20.9	25.09
17582	17527	2048	1.478	-5.9	20.9	24.98
17349	17650	2306	1.472	-5.9	20.9	24.86
17476	17822	2413	1.493	-5.9	20.9	25.31
21348	20253	3822	1.701	-5.9	20.9	29.65
20500	21040	2588	1.774	-5.9	20.9	31.17
19320	20639	2044	1.735	-5.9	20.9	30.35

DEPTH: 90 cm
DESCRIPTION: SOIL UNDER SLUDGE BLANKET
TYPE: DEPTH SUMMARY

DATE	AUTO STANDARD	2020	4020	6020	2040	4040	6040	2060	4060
8/31/88	11812	21315	19859	19975	15192	-	20802	13875	16156
9/30/88	11842	21097	19699	19547	14863	14884	20425	13683	15914
10/25/88	11861	21030	19483	19785	14638	14842	20645	13594	15849
11/26/88	11993	20955	19483	19721	14975	14973	21817	13386	15757
12/28/88	11933	21190	19995	20361	15208	15301	21755	13339	15620
3/13/89	11908	24902	22426	21600	21789	17823	24126	13709	15579
3/31/89	11863	24959	22879	21912	21912	20605	24270	19853	15432
5/2/89	11899	24231	22335	22007	21391	20389	23200	19827	16176

DEPTH: 90 cm
DESCRIPTION: SOIL UNDER SLUDGE BLANKET
TYPE: DEPTH SUMMARY

6060	AVERAGE	STANDARD DEVIATION	ADJUSTED COUNT	INTERCEPT	SLOPE	MOISTURE CONTENT
16684	17982	2834	1.522	-5.9	20.9	25.92
16615	17414	2787	1.471	-5.9	20.9	24.83
16507	17375	2863	1.465	-5.9	20.9	24.72
16579	17516	3021	1.461	-5.9	20.9	24.63
16598	17707	3112	1.484	-5.9	20.9	25.11
20039	20221	3810	1.698	-5.9	20.9	29.59
19475	21255	2867	1.792	-5.9	20.9	31.55
18501	20895	2485	1.756	-5.9	20.9	30.80

DEPTH: 105 cm
DESCRIPTION: SOIL UNDER SLUDGE BLANKET
TYPE: DEPTH SUMMARY

DATE	AUTO STANDARD	2020	4020	6020	2040	4040	6040	2060	4060
8/31/88	11812	20319	19006	21837	12654	-	21415	13486	15904
9/30/88	11842	19836	18964	21874	12861	14562	21291	13319	15909
10/25/88	11861	19990	18983	21651	12624	14526	21134	13157	15639
11/26/88	11993	19775	18768	21721	12694	14552	22455	13076	15737
12/28/88	11933	20033	19397	21890	13340	15290	22455	13104	15596
3/13/89	11908	23633	20992	25637	23285	19083	22302	13595	15365
3/31/89	11863	23500	20977	water	23214	19847	24016	20605	15379
5/2/89	11899	23201	21101	water	22216	19635	23568	20592	16118

DEPTH: 105 cm
DESCRIPTION: SOIL UNDER SLUDGE BLANKET
TYPE: DEPTH SUMMARY

6060	AVERAGE	STANDARD DEVIATION	ADJUSTED COUNT	INTERCEPT	SLOPE	MOISTURE CONTENT
17290	17739	3507	1.502	-5.9	20.9	25.49
16943	17284	3376	1.460	-5.9	20.9	24.61
16825	17170	3414	1.448	-5.9	20.9	24.35
16733	17279	3602	1.441	-5.9	20.9	24.21
16621	17525	3531	1.469	-5.9	20.9	24.79
19751	20405	3937	1.714	-5.9	20.9	29.91
19234	20847	2835	1.757	-5.9	20.9	30.83
18830	20658	2466	1.736	-5.9	20.9	30.38

DEPTH: 120 cm
DESCRIPTION: SOIL UNDER SLUDGE BLANKET
TYPE: DEPTH SUMMARY

DATE	AUTO STANDARD	2020	4020	6020	2040	4040	6040	2060	4060
8/31/88	11812	18935	20073	20029	10257	-	19449	13400	16561
9/30/88	11842	18732	20135	20093	10464	14423	19386	13343	16445
10/25/88	11861	18642	20218	20042	10665	14316	19302	13155	16126
11/26/88	11993	18685	20236	20103	10512	14393	20490	12940	16525
12/28/88	11933	18964	20485	20158	11411	15670	20435	12950	16123
3/13/89	11908	21217	22672	water	24928	19206	21909	13846	15855
3/31/89	11863	21176	22800	water	24359	19678	22015	21791	16090
5/2/89	11899	21191	22692	water	23371	19351	21926	21537	16832

DEPTH: 120 cm
DESCRIPTION: SOIL UNDER SLUDGE BLANKET
TYPE: DEPTH SUMMARY

6060	AVERAGE	STANDARD DEVIATION	ADJUSTED COUNT	INTERCEPT	SLOPE	MOISTURE CONTENT
17164	16984	3526	1.438	-5.9	20.9	24.15
17106	16681	3358	1.409	-5.9	20.9	23.54
16747	16579	3335	1.398	-5.9	20.9	23.31
16831	16746	3539	1.396	-5.9	20.9	23.28
16732	16992	3317	1.424	-5.9	20.9	23.86
19286	19865	3637	1.668	-5.9	20.9	28.97
19069	20872	2554	1.759	-5.9	20.9	30.87
18792	20712	2203	1.741	-5.9	20.9	30.48

DEPTH: 135 cm
DESCRIPTION: SOIL UNDER SLUDGE BLANKET
TYPE: DEPTH SUMMARY

DATE	AUTO STANDARD	2020	4020	6020	2040	4040	6040	2060	4060
8/31/88	11812	19768	19604	19982	9306	-	21806	13574	16126
9/30/88	11842	19922	19859	20029	9306	15832	21878	13494	15586
10/25/88	11861	19975	19815	20098	9469	15987	21842	13308	16052
11/26/88	11993	20100	19766	20169	9514	16087	22536	13327	16131
12/28/88	11933	20118	20039	20042	10463	16688	22528	13308	15820
3/13/89	11908	22346	22415	water	25988	18518	23600	14422	15760
3/31/89	11863	23197	22345	water	water	19600	water	22948	15794
5/2/89	11899	24771	22594	water	22928	19723	water	22857	16552

DEPTH: 135 cm
DESCRIPTION: SOIL UNDER SLUDGE BLANKET
TYPE: DEPTH SUMMARY

6060	AVERAGE	STANDARD DEVIATION	ADJUSTED COUNT	INTERCEPT	SLOPE	MOISTURE CONTENT
16990	17145	4105	1.451	-5.9	20.9	24.44
16790	16966	3946	1.433	-5.9	20.9	24.04
16854	17044	3907	1.437	-5.9	20.9	24.13
16881	17168	4013	1.431	-5.9	20.9	24.02
16701	17301	3806	1.450	-5.9	20.9	24.40
22177	20653	4014	1.734	-5.9	20.9	30.35
19780	20611	2831	1.737	-5.9	20.9	30.41
18488	21130	2931	1.776	-5.9	20.9	31.21

DEPTH: 150 cm
DESCRIPTION: SOIL UNDER SLUDGE BLANKET
TYPE: DEPTH SUMMARY

DATE	AUTO STANDARD	2020	4020	6020	2040	4040	6040	2060	4060
8/31/88	11812	22438	20715	-	9002	-	-	13242	17447
9/30/88	11842	22520	21208	-	9072	19439	-	13235	17098
10/25/88	11861	22588	21052	-	9107	19594	-	13406	17379
11/26/88	11993	22622	21210	-	9254	20114	-	13057	17449
12/28/88	11933	22778	21152	-	10561	20515	-	13083	17136
3/13/89	11908	25025	23643	-	water	21311	-	14243	17202
3/31/89	11863	water	23896	-	water	water	-	23311	17015
5/2/89	11899	water	24532	-	22964	water	-	23230	17540

DEPTH: 150 cm
DESCRIPTION: SOIL UNDER SLUDGE BLANKET
TYPE: DEPTH SUMMARY

6060	AVERAGE	STANDARD DEVIATION	ADJUSTED COUNT	INTERCEPT	SLOPE	MOISTURE CONTENT
18033	16813	4950	1.423	-5.9	20.9	23.85
18032	17229	4688	1.455	-5.9	20.9	24.51
18022	17307	4657	1.459	-5.9	20.9	24.60
18085	17399	4741	1.451	-5.9	20.9	24.42
17654	17554	4436	1.471	-5.9	20.9	24.85
water	20285	4495	1.703	-5.9	20.9	29.70
20910	21283	3125	1.794	-5.9	20.9	31.60
19759	21605	2872	1.816	-5.9	20.9	32.05

APPENDIX H

SOIL WATER HAXTON FIELD TILE

LOCATION: HAXTON FIELD TILE
DESCRIPTION: NUTRIENT AND METAL CONCENTRATIONS
TYPE: SOIL WATER

DATE	pH S.U.	TKN mg/l	NH3-N mg/l	NO3-N mg/l	T. P mg/l	T. As µmg/l	T. Cd µmg/l	T. Cu µmg/l	T. Cr µmg/l	T. Ag µmg/l	T. Hg µmg/l	T.K mg/l	T. Pb µmg/l
6/24/88	-	.130	.000	11.900	.120	<10	<1	<10	-	<1	<.5	.80	<5
7/1/88	-	.300	.033	10.100	.080	<10	<1	-	<10	<1	<.5	1.00	<5
7/6/88	-	.180	.098	9.820	.120	<10	<1	-	<10	<1	<.5	.90	<5
8/24/88	-	.460	.024	11.800	.290	<10	<1	<10	<10	<1	<.5	1.60	<5
9/26/88	-	.280	.144	10.000	.130	<10	<1	<10	<10	<1	<.5	1.10	<5
10/31/89	-	.470	<.004	4.050	.120	<10	<1	<10	<10	<1	<.5	-	<5
11/30/89	-	1.570	.025	24.900	.190	<10	<1	<10	<10	<1	<.5	1.60	<5
12/28/89	7.300	.110	.019	11.000	.110	<10	<1	<10	<10	<1	<.5	1.20	<5
12/28/89	-	.090	.011	11.000	.110	<10	<1	<10	<10	<1	<.5	1.10	<5
2/2/89	-	16.060	7.210	16.160	1.070	<10	<1	310	<10	25	<.5	4.90	<5
3/9/89	-	16.900	12.800	21.300	.990	<10	<1	<10	<10	<1	<.5	1.90	<5
4/3/89	-	1.880	.734	24.700	.150	<10	<1	<10	10	<1	<.5	1.70	<5
5/2/89	-	.450	.163	11.900	.150	<10	<1	<10	<10	<1	<.5	1.20	<5
5/26/89	-	630	.038	15.400	.150	-	-	-	-	-	-	.70	-

LOCATION: HAXTON FIELD TILE
DESCRIPTION: NUTRIENT AND METAL CONCENTRATIONS
TYPE: SOIL WATER

T.Ni µmg/l	T.Zn µmg/l	Chlor. mg/l
<50	<2	-
<50	<2	-
<50	<2	-
<50	3	-
<50	<2	1.0
<50	<2	-
<50	<2	-
<50	<2	-
<50	<2	-
70	5	-
<50	834	-
<50	5	-
<50	6	-
-	-	-

APPENDIX I

MONITORING WELL DATA

LOCATION: NW MONITORING WELL #0000
DESCRIPTION: NUTRIENT AND METAL CONCENTRATIONS
TYPE: SOIL WATER

DATE	pH S.U.	TKN mg/l	NH3-N mg/l	NO3-N mg/l	T. P mg/l	T. As mg/l	T. Cd mg/l	T. Cu mg/l	T. Cr mg/l	T. Ag mg/l	T. Hg mg/l	T.K mg/l	T. Pb mg/l
3/14/89	-	2.33	0.21	113.00	0.61	<10	<1	10.00	<10	<1	<.5	12.80	<5
4/3/89	-	0.49	0.09	60.90	0.23	<10	<1	10.00	<10	<1	<.5	4.40	<5
5/2/89	-	1.95	0.28	86.10	0.82	<10	<1	20.00	<10	<1	<.5	12.80	6
5/26/89	-	2.46	1.07	10.90	1.80	-	-	-	-	-	-	10.40	-

LOCATION: NW MONITORING WELL #0000
DESCRIPTION: NUTRIENT AND METAL CONCENTRATIONS
TYPE: SOIL WATER

T.Ni mg/l	T.Zn mg/l
<50	184
<50	4
<50	17
-	-

LOCATION: NE MONITORING WELL #8000
DESCRIPTION: NUTRIENT AND METAL CONCENTRATIONS
TYPE: SOIL WATER

DATE	pH S.U.	TKN mg/l	NH3-N mg/l	NO3-N mg/l	T. P mg/l	T. As mg/l	T. Cd mg/l	T. Cu mg/l	T. Cr mg/l	T. Ag mg/l	T. Hg mg/l	T.K mg/l	T. Pb mg/l
3/14/89	-	1.61	0.07	25.20	0.40	<10	<1	10.00	<10	<1	<.5	4.50	<5
3/14/89	-	1.51	0.07	23.90	0.40	<10	<1	10.00	<10	<1	<.5	4.10	<5
4/3/89	-	1.18	0.06	20.60	0.36	<10	<1	20.00	<10	<1	<.5	4.50	<5
5/2/89	-	1.19	0.09	18.60	0.58	<10	<1	10.00	<10	<1	<.5	5.50	<5
5/26/89	-	1.11	0.13	17.80	0.27	-	-	-	-	-	-	1.70	-

LOCATION: NE MONITORING WELL #8000
DESCRIPTION: NUTRIENT AND METAL CONCENTRATIONS
TYPE: SOIL WATER

T.Ni mg/l	T.Zn mg/l
<50	23
<50	29
<50	2
<50	27
-	-

LOCATION: SW MONITORING WELL #0080
DESCRIPTION: NUTRIENT AND METAL CONCENTRATIONS
TYPE: SOIL WATER

DATE	pH S.U.	TKN mg/l	NH3-N mg/l	NO3-N mg/l	T. P mg/l	T. As mg/l	T. Cd mg/l	T. Cu mg/l	T. Cr mg/l	T. Ag mg/l	T. Hg mg/l	T.K mg/l	T. Pb mg/l
3/14/89	-	4.15	1.04	76.30	3.15	<10	<1	40.00	<10	<1	<.5	13.60	<5
3/14/89	-	-	1.05	-	-	<10	<1	40.00	<10	<1	<.5	13.20	<5
4/3/89	-	3.76	0.84	61.30	2.08	<10	<1	20.00	<10	<1	<.5	11.00	<5
5/2/89	-	2.34	0.75	19.00	1.82	<10	<1	10.00	<10	<1	<.5	10.40	8
5/26/89	-	2.37	0.20	78.90	0.82	-	-	-	-	-	-	12.60	-

LOCATION: SW MONITORING WELL #0080
DESCRIPTION: NUTRIENT AND METAL CONCENTRATIONS
TYPE: SOIL WATER

T.Ni mg/l	T.Zn mg/l
<50	53
<50	47
<50	7
<50	6
-	-

LOCATION: SE MONITORING WELL #8080
DESCRIPTION: NUTRIENT AND METAL CONCENTRATIONS
TYPE: SOIL WATER

DATE	pH S.U.	TKN mg/l	NH3-N mg/l	NO3-N mg/l	T. P mg/l	T. As mg/l	T. Cd mg/l	T. Cu mg/l	T. Cr mg/l	T. Ag mg/l	T. Hg mg/l	T.K mg/l	T. Pb mg/l
3/14/89	(DRY HOLE)												
3/14/89	(DRY HOLE)												
4/3/89	(DRY HOLE)												
5/2/89	(DRY HOLE)												
5/26/89	(DRY HOLE)												

LOCATION: SE MONITORING WELL #8080
DESCRIPTION: NUTRIENT AND METAL CONCENTRATIONS
TYPE: SOIL WATER

T.Ni	T.Zn
mg/l	mg/l