PANEL WETLANDS

A CASE HISTORY OF PARTIALLY SUBMERGED PYRITIC URANIUM TAILINGS UNDER WATER

MEND Project 3.12.2

Sponsored by:

Canadian Centre for Mineral and Energy Technology
Ontario Ministry of Northern Development and Mines

February 1993

Panel Wetlands - A Case History of Partially Submerged Pyritic Uranium Tailings Under Water

N.K. Davé

Division Report MSL 93-32(CR)February 1993

Work performed for

Ontario Ministry of Northern Development and Mines (MNDM)
Canada Centre for Mineral and Energy Technology (CANMET)
Mine Environmental Neutral Drainage (MEND) program
under Contract No. X91-03701 ELL224

PANEL WETLANDS: A CASE HISTORY OF PARTIALLY SUBMERGED PYRITIC URANIUM TAILINGS UNDER WATER

N.K. Davé*

EXECUTIVE SUMMARY

For the Mine Environmental Neutral Drainage (MEND) Program, an environmental survey of the Panel wetlands area in Elliot Lake, Ontario was conducted in 1991. The survey was undertaken by the Surface Environmental Research group of the Elliot Lake Laboratory, Mineral Sciences Laboratories, CANMET, Energy, Mines and Resources Canada, in collaboration with Rio Algom Limited, Elliot Lake, Ontario.

The broad objectives of the survey were to:

- Determine the surface and groundwater hydrogeochemistry of the Panel wetlands tailings basin;
- Establish whether the existing natural wetlands and water cover on acid generating tailings were providing any treatment to acid mine drainage, and to evaluate their controls on acid generation and migration of contaminants associated with the oxidation of pyrite;
- Characterize wetlands tailings/sediment substrate for metals, sulphide and sulphate sulphur speciation, and its oxidizing/reducing microbe populations, and to determine their roles in various geochemical and biological interactions; and
- Characterize wetlands vegetation for metals and radionuclide uptake.

The survey results were as follows:

Key words:

*Research Scientist, Elliot Lake Laboratory, CANMET, Energy, Mines and Resources Canada, Elliot Lake, Ontario, Canada

- The Panel wetlands study site was a small basin located in a bedrock valley containing partially submerged pyritic uranium tailings. It had a total area of 14.5 ha, and contained approximately 236,000 tonnes of tailings spread over an area of 12.9 ha. Approximately 88% of the tailings

area was underwater, leaving an area of 1.6 ha in the western part of the basin where the tailings were exposed. The average thickness of the tailings in the basin was 0.92 m.

- The tailings were deposited in the basin as a result of a tailings spill upstream in the late 1950s which completely filled the western and central part of the basin, and spread a thin layer of tailings to the eastern part of the basin. Underneath the tailings, the basin contained a layer of peat 0.3 to 4 m thick, underlain by sand and gravel deposits.

- The eastern part of the basin contained ponded water, 0.4 to 1.4 m deep. A shallow water layer, 0.1 to 0.5 m deep, extended throughout the west/central part of the basin which supported a dense vegetative cover consisting of cattails, marshland grasses, sedges, sphagnum and other acidophilic mosses. The deep ponded water contained submergent vegetation such as pondweeds.

- A beaver dam at the east end of the basin regulated the water level and its discharge flow. The basin contained a total water volume of approximately 24,000 m^3, with an average depth of 0.2 m.

- The site had a total catchment and drainage area of approximately 49 ha. On an annual basis the site received a total net precipitation of approximately 138,920 m^3 (calculated from mean annual precipitation data) corresponding to an average flow of 4.4 L/s or 9 L/s per km^2. The drainage water volume was estimated to be six times the volume of the water contained in the basin which corresponded to a dilution factor of 6.

- At the extreme west end of the site, there was an acidic tailings pond impounded by a clay core cross-valley dam. No visible seepage of acidic water from this pond was observed towards the basin.

- The surface water flow from the site was towards the east. It was irregular and intermittent, and was measured at 16.5 L/m in the fall.

- In general, the groundwater flow was also from west to east. Sub-surface water from exposed tailings areas in the western section of the basin discharged into the central water body. In this section the water table was 0.2 to 2.0 m below surface, and the groundwater flow was upwards and towards the east. The measured horizontal and vertical gradients ranged from 0.003 to 0.015 and from 0 to -0.15, respectively. Upward vertical gradients were highest in the fall. Sub-surface discharge from the western part of the basin to the central pond was estimated at 380 to 1800 m^3/a which was less than 2 to 8% of the total surface water volume of the basin.

- In the eastern part of the basin, the groundwater flow was also towards the east but in a downward direction. The measured horizontal and vertical gradients ranged from 0.0002 to 0.001, and from -0.72 to 0.14, respectively.

- The surface water in the basin was slightly to moderately acidic in the exposed and vegetated western parts of the basin with low to medium concentrations of dissolved solids (600 to 2000 mg/L), iron (1 to 80 mg/L), calcium (150-500 mg/L), and sulphate (50 to 1000 mg/L).

- In the central and eastern parts of the basin where a permanent water body existed, the surface water was near neutral to moderately alkaline, pH (6.2 to 9.8), with low concentrations of dissolved solids (100 to 300 mg/L), iron (0.002 to 0.4), calcium (30 to 50 mg/L), and sulphate (50 to 100 mg/L).

- There was no strong seasonal dependence of the surface water quality except pH in the central and eastern parts of the basin which increased from 7.5 to 9.8 in the summer.

- The groundwater at shallow depths in the basin was mostly tailings derived porewater with slightly acidic to near neutral pH (5.7 to 7.8), low to moderate acidity (10 to 200 mg $CaCO_3$/L), low to high alkalinity (0 to 1400 mg $CaCO_3$/L), low to moderate iron (0.5 to 70 mg/L), high Ca (400 to 800 mg/L), high sulphate (800 to 1500 mg/L), and high Ra-226 (280 to 10,900 mBq/L). There was no strong seasonal dependence except for dissolved iron concentration which was variable.

- The soil substrate in the basin mostly consisted of tailings except near the far east end where the original peat sediments existed. The paste pH of the substrate varied from near neutral to highly acidic, 7.5 to 2.1.

- Thiobacillus ferro-oxidans (TF) and sulphate reducing bacteria (SRB) were present in all soil substrate and sediment samples from exposed and shallow water cover sites in the western part of the basin. At deep water sites near the centre and towards the east, the bacterial counts for TF reduced drastically to insignificant numbers (0 to 100). Sulphate reducing bacteria populations at these sites exceeded those for Thiobacillus ferro-oxidans. There were no clear trends in SRB distribution profiles along the length of the basin.

- The sulphur speciation data also showed that both sulphide and sulphate concentration were variable within and between sites without clear trends. Sulphate reduction was clearly evidenced by a strong smell of H_2S in the groundwater at deep water central and eastern locations.

- Tailings were oxidizing in the exposed and shallow water covered and vegetated part of the basin. In exposed areas, oxidation was taking place near the surface in the unsaturated zone and in the vicinity of the water table. In vegetated areas, oxidation of both organic matter and tailings was taking place from surface to the root zone of the substrate. Because of fine grained tailings and their high degree of moisture saturation, the overall oxidation rates were low producing low pH (3.4 to 5.5) surface drainage and sub-surface water.

- In the vegetation zone, no improvement in the surface water quality was noted as it drained from exposed areas towards the ponded water. Both the surface and groundwater data indicated that the vegetation was oxidizing the substrate rather than providing the treatment. Some iron was precipitated and removed as ferric hydroxide in the vegetation zone.

- The acidic surface drainage from exposed tailings and vegetated areas was diluted by a factor of 6 to 10 as it drained and mixed with the ponded water. The groundwater from western and central sections of the basin was also discharging in the ponded water where it neutralized the acidic surface water and precipitated dissolved iron, aluminum and manganese as hydroxides when the waters mixed.

- The pH of the ponded water increased from 7.5 to 9.5 in the summer which was attributed to the bacterial reduction of nitrates in the organic sediments, and to the photosynthetic process of some submergent vegetation (pondweeds) producing ammonia and hydroxyl ions, respectively.

This phenomenon needs to be further investigated.

- From water quality data for surface drainage from exposed and shallow water cover vegetated areas, and pond water near the discharge end, the annual rates of total iron production, as a result of pyrite oxidation, and iron discharged from the system were calculated as 183.7 kg/y and 9 kg/y, respectively. These values corresponded to an annual pyrite oxidation and iron discharge rates of 1.11 and 0.04 mg Fe per kg of tailings in the basin per year.

- The existing wetland system, because of its various physical, chemical and biological controls, retained or recycled approximately 96% of the total iron produced as a result of pyrite oxidation. It was estimated that at these rates it would take approximately 31.7 x 10^3 y for all the pyrite to oxidize, and 926 x 10^3 y for all the mobilized iron to leave the system, assuming that the rate did not change with time.

- For calcium and Ra-226, the corresponding times for their complete removal from the system were calculated as approximately 708 y and 40 x 10^3 y, respectively.

- For cattails and grasses, the observed metal uptake levels were similar to those observed at other pyritic uranium tailings, base metals and gold tailings sites. High concentration of iron, aluminum, calcium, and other heavy metals were observed in pondweeds and sphagnum moss, but their contribution to the total bio-mass production and metals retention and removal load was very small compared to cattails and grasses which were the most abundant species.

- In all vegetation, the observed metal concentrations were below plant toxicity levels with little or no significant accumulation warranting concerns related to wind dispersion or animal forage. No symptoms of plant toxicity were observed.

- Ra-226 concentrations in the wetland vegetation (30 to 3800 mBq/g) were significantly elevated in all the species compared to background levels of 10 to 20 mBq/g in terrestrial vegetation for local and distant controls.

It can be concluded that the wetland/water system in the Panel wetlands basin was effectively controlling the acidic drainage from partially submerged pyritic uranium tailings. The system would continue to function as long as the water cover was maintained. Its performance could be further improved if all the tailings were completely submerged.

It is recommended that the sediment oxidation-reduction dynamics and the photosynthetic process of submerged plants in the eastern part of the basin should further be investigated in order to understand the seasonal behaviour of the observed high pHs in the summer.

RÉSUMÉ

Une étude environnementale du marécage de Panel, dans la région d'Elliot Lake en Ontario, a été entreprise en 1991 pour le Programme de neutralisation des eaux de drainage dans l'environnement minier (NEDEM). L'étude a été faite par le Laboratoire de terrain pour la R-D environnementale d'Elliot Lake, Laboratoires des sciences minérales, CANMET, Énergie, Mines et Ressources Canada, en collaboration avec la Rio Algom Limited d'Elliot Lake en Ontario.

L'étude avait pour grands objectifs :

. de déterminer l'hydrogéochimie souterraine et de surface du bassin de résidus du marécage de Panel;

. d'établir si le marécage naturel existant et l'eau qui recouvre les résidus générateurs d'acide peuvent se révéler capables de traiter le drainage minier acide et de contrôler la production d'acide associée à l'oxydation de la pyrite;

. de caractériser le substrat résidus/sédiments du marécage pour déterminer les espèces de métaux, de sulfates et de sulfures, ses populations microbiennes oxydantes et réductrices et leur rôle dans les diverses interactions géochimiques et biologiques; et

. de caractériser la végétation du marécage quant à son assimilation des métaux et des radionucléïdes.

L'étude a donné les résultats suivants :

. Le lieu de l'étude, soit le marécage de Panel, est un petit bassin situé dans une vallée de roche de fond contenant des résidus d'uranium pyriteux partiellement submergés. La superficie totale est de 14,5 ha et le bassin renferme environ 236 000 tonnes de résidus

répartis sur une superficie de 12,9 ha. Environ 88% de la superficie des résidus étaient submergés ce qui laisse 1,6 ha dans la partie occidentale où les résidus sont exposés. L'épaisseur moyenne de la couche de résidus dans le bassin était de 0,92m.

- Les résidus ont été déposés dans le bassin suite à un déversement en amont, vers la fin des années 1950, qui a complètement rempli les parties occidentale et centrale du bassin. Une mince couche s'était répandue vers la partie orientale du bassin. Sous les résidus, le bassin comportait une couche de tourbe de 0,3 à 4 m. d'épaisseur qui repose sur des dépôts de sable et de gravier.

- La partie orientale du bassin présentait des eaux marécageuses de 0,4 à 1,4 m de profondeur. Un plan d'eau peu profonde de 0,1 à 0,5 m recouvre les parties occidentale et centrale du bassin et alimente un couvert végétal dense constitué de quenouilles, d'herbes des marais, de carex, de sphaigne et d'autres mousses acidophiles. Les eaux stagnantes profondes contiennent une végétation partiellement submergée comme les potamots luisants.

- Un barrage de castor, à l'extrémité est, régularise le niveau des eaux et leur écoulement. Le bassin renferme un volume total d'environ 24 000 m^3 d'eau d'une profondeur moyenne de 0,2 m.

- Le site possède une superficie totale de captage et de drainage d'environ 49 ha. Le site reçoit annuellement une précipitation totale nette d'environ 138 920 m^3 (calculée d'après la moyenne des données de précipitations annuelles) ce qui correspond à un écoulement moyen de 4,4 l/s ou de 9 l/s par km^2. Le volume des eaux de drainage a été évalué à six fois le volume de l'eau contenue dans le bassin, ce qui représente un facteur de dilution de 6.

- À l'extrémité occidentale se trouvent un réservoir d'eau de drainage acide et un bassin de résidus retenus par un barrage, à noyau d'argile, transversal à la vallée. Aucun suintement d'eau acide vers le bassin n'a été observé.

- L'écoulement de surface à partir du site se faisait vers l'est. Il était irrégulier et intermittent et il a été mesuré à 16,5 l/s durant l'automne.

- De façon générale, les eaux souterraines coulent aussi d'ouest en est. Les eaux, sous la surface des résidus exposés dans la partie occidentale du bassin, se déversent dans la masse centrale des eaux. À cet endroit, la nappe phréatique était de 0,2 à 2 m sous la surface et l'écoulement des eaux souterraines se faisait en remontant, en direction de l'est. Les gradients horizontaux et verticaux mesurés variaient de 0,003 à 0,015 et de 0 à -0,15 respectivement. Les gradients verticaux ascendants étaient à leur plus haut niveau en automne. L'écoulement sous la surface, qui se faisait de la partie occidentale du bassin vers l'étang central, a été évalué de 380 à 1 800 m^3/a ce qui représente moins de 2 à 8% du volume total des eaux de surface du bassin.

- Dans la partie orientale du bassin, l'écoulement des eaux souterraines se faisait aussi vers l'est mais vers le bas. Les gradients horizontaux et verticaux mesurés variaient de 0,0002 à 0,001 et de -0,72 à 0,14 respectivement.

- Les eaux de surface dans le bassin variaient de légèrement à modérément acides dans les parties occidentales du bassin exposées et couvertes de végétation et présentaient des concentrations de faibles à moyennes en solides dissous (600 à 2 000 mg/l), en fer (1 à 80 mg/l), en calcium (150-500 mg/l) et en sulfate (50 à 1 000 mg/l).

- Dans les parties centrale et orientale du bassin où existe un plan d'eau permanent, les eaux de surface variaient de neutres à modérément alcalines, pH (6,2 à 9,8) et avaient de faibles concentrations en solides dissous (100 à 300 mg/l), en fer (0,002 à 0,4 mg/l), en calcium (30 à 50 mg/l) et en sulfate (50 à 100 mg/l).

- La qualité des eaux de surface n'était pas fortement dépendante du cycle saisonnier sauf le pH dans les parties centrale et orientale du bassin qui augmentait de 7,5 à 9,8 en été.

- Les eaux souterraines à faibles profondeurs dans le bassin étaient en majeure partie des eaux interstitielles venant des résidus, d'un pH légèrement acide ou à peu près neutre (5,7 à 7,8), d'une acidité faible à modérée (10 à 200 mg de $CaCO_3$/l), d'une alcalinité faible à forte (de 0 à 1 400 mg de $CaCO_3$/l) d'une concentration faible à modérée en fer (0,5 à 70 mg/l), forte en Ca (400 à 800 mg/l), forte en sulfate (800 à 1 500 mg/l) et forte en Ra-226 (280 à 10 900 mBq/l). Le cycle saisonnier n'avait pas beaucoup d'influence sauf en ce qui concerne les concentrations en fer dissous qui étaient variables.

- Le substrat dans le bassin consistait surtout en résidus sauf à l'extrémité orientale où existaient les sédiments de tourbe originale. Le pH de la pâte variait d'à peu près neutre à fortement acide (7,5 à 2,1).

- *Thiobacillus ferro-oxidans* (Tf) et les bactéries sulfato-réductrices (BSR) étaient présents dans tous les échantillons de substrats et de sédiments prélevés dans les endroits exposés et faiblement submergés dans la partie occidentale du bassin. En eaux profondes, près du centre et vers l'est, les comptes bactériens, en ce qui regarde *Thiobacillus ferro-oxidans*, baissaient fortement à des quantités insignifiantes (0 à 100). Les populations de bactéries sulfato-réductrices, à ces endroits, étaient supérieures à celles de *Thiobacillus ferro-oxidans*. Il n'a pas été relevé de tendances significatives des profils de répartition des BSR sur la longueur du bassin.

- Les données sur les espèces de soufre ont montré aussi que les concentrations en sulfures et en sulfates étaient variables à l'intérieur des sites et entre eux sans tendances claires. La réduction des sulfates était évidente à cause des senteurs de H_2S qui se dégageaient des eaux souterraines aux endroits à eaux profondes du centre et de l'est.

- Les résidus étaient oxydants dans les parties exposées, légèrement submergées et couvertes de végétation. Dans les parties exposées, l'oxydation se faisait près de la surface dans la zone non saturée et près de la nappe phréatique. Dans les parties couvertes de végétation, l'oxydation de la matière organique et des résidus se faisait de la surface à la zone de racine du substrat. À cause de la fine granulométrie des résidus et de leur forte saturation en humidité, les taux globaux d'oxydation étaient faibles, produisant des eaux de drainage de surface et sous la surface d'un pH peu élevé (3,4 à 5,5).

- Dans la zone de végétation, il n'a pas été observé d'amélioration de la qualité des eaux de surface drainées des régions exposées vers les eaux stagnantes. Les données sur les eaux de surface et souterraines indiquaient que la végétation oxydait le substrat plutôt que d'en effectuer le traitement. Un peu de fer était précipité et éliminé sous forme d'hydroxyde ferrique dans la zone de végétation.

- Les eaux de drainage acide de surface provenant des résidus exposés et des zones couvertes de végétation était diluées selon un facteur de 6 à 10 alors qu'elles étaient drainées et mêlées aux eaux stagnantes. Les eaux souterraines des parties occidentales et centrales du bassin se déchargeaient aussi dans les eaux stagnantes où elles neutralisaient les eaux de surface acides. Le fer, l'aluminium et le manganèse dissous étaient aussi précipités lorsque les eaux se mêlaient.

- Le pH des eaux stagnantes augmentait de 7,5 à 9,5 durant l'été, ce qui était attribué à la réduction bactérienne des nitrates dans les sédiments organiques et par le procédé de photosynthèse de la végétation partiellement submergée (potamots luisants); chaque action produisant respectivement de l'ammoniac et des ions hydroxyles. Il faudrait étudier ce phénomène plus à fond.

- Selon les données sur la qualité de l'eau concernant le drainage de surface provenant des zones exposées et des zones légèrement submergées et porteuses de végétation et des eaux stagnantes près de la décharge, les taux annuels de la production totale de fer provenant de l'oxydation de la pyrite et du fer sorti du système ont été calculé à 183,7 et 9 kg par année respectivement. Ces valeurs correspondent à des taux annuels d'oxydation de la pyrite et de décharge du fer de 1,11 et 0,04 de Fe par kg de résidus dans le bassin.

- Le système existant du marécage, à cause des divers contrôles physiques, chimiques et biologiques, retient ou recycle environ 96% du fer total produit par l'oxydation de la pyrite. Il a été évalué qu'à ce rythme il faudra environ 31,7 x10^3 années pour que toute la pyrite soit oxydée et 926 x 10^3 années pour que tout le fer en cause quitte le système, à condition que le rythme ne change pas avec le temps.

- Dans les cas du calcium et du Ra-226, les temps correspondants pour leur complète élimination ont été établis à environ 708 années et 40 x 10^3 années respectivement.

- En ce qui concerne les quenouilles et les herbes, les niveaux observés d'absorption des métaux étaient semblables à ceux qui ont été trouvés pour d'autres résidus d'uranium pyriteux ainsi que d'autres résidus de mines de métaux de base et de mines d'or. De fortes concentrations de fer, d'aluminium, de calcium et d'autres métaux lourds ont été observées dans les potamots luisants et les sphaignes mais leur contribution à la production de la biomasse totale et à la charge de rétention et d'élimination des métaux était très minime comparativement aux quenouilles et herbes qui étaient les espèces les plus abondantes.

- Dans toute la végétation, les concentrations observées de métaux étaient en-deça des niveaux de phytotoxicité et présentaient des accumulations minimes ou peu significatives ne justifiant aucune inquiétude quant à la dispersion par les vents ou à l'ingestion par les animaux. Aucun symptôme de phytotoxicité n'a été observé.

- Les concentrations de Ra-226 dans la végétation marécageuse (30 à 3 800 mBq/g) étaient significativement fortes dans toutes les espèces comparativement aux niveaux de fond qui étaient de 10 à 20 mBq/g dans les spécimens de végétation terrestre prélevés localement ou à des endroits plus éloignés.

Il est possible de conclure que le système eaux/marécage de Panel contrôlait effectivement le drainage acide provenant des résidus d'uranium pyriteux partiellement submergés. Le système devrait continuer à fonctionner aussi longtemps que la couverture d'eau sera maintenue. Sa performance pourrait être améliorée si les résidus étaient complètement submergés.

Il est recommandé que la dynamique d'oxydation-réduction des sédiments et le processus de photosynthèse des plantes submergées, dans la partie orientale du bassin, fassent l'objet d'autres recherches afin d'élucider le comportement saisonnier qui produit les pH élevés durant l'été.

CONTENTS

TABLES

FIGURES

1. INTRODUCTION

For the Mine Environmental Neutral Drainage (MEND) Treatment Program, an extensive environmental survey of Panel Wetlands area in Elliot Lake, Ontario, was conducted during the field season of 1991. Field investigations were undertaken by the Elliot Lake Laboratory, CANMET in collaboration with Rio Algom Limited, Elliot Lake. The shared funding for the project was provided by the Ontario Ministry of Northern Development and Mines (MNDM), CANMET and Rio Algom Limited. The survey included measurements of surface and ground water quality parameters, their seasonal fluctuations, water flow conditions, tailings solids and sediment characterization for oxidation-reduction profiles, bacterial enumeration and vegetation uptake of metals and radionuclides (see Appendices A and B).

1.1 WETLANDS AND ACID MINE DRAINAGE

Constructed or man-made wetlands are increasingly being used for the treatment of municipal and industrial waste water, acidic drainage from coal wastes and slurry ponds, and for the management of water resources and wild life. Wetlands have been effective for treating acid mine drainage from coal mines (Brodie et al. 1989), and moderately acidic seepages (pH >3) from metal mines containing low to intermediate concentrations of dissolved Fe (up to 300 mg/L) and Mn (up to 50 mg/L) (Wieder et al. 1989). The technology is still under experimental stages for the treatment of highly acidic metal mine effluents (pH ? 1.5) containing high concentrations of dissolved Fe (>1000 mg/L), SO_4 (>5000 mg/L), and other metals such as As, Cd, Pb, Hg, Cu, Ni, Mn and Zn (Davé and Lim 1989; Wildeman and Laudon 1989; Howard and Emerick et al. 1989; Howard and Hestmark et al. 1989; Weneric et al. 1989; Karathanasis and Thompson 1991; Calabrese et al. 1991; Kleinmann et al. 1991). For pyritic uranium mines, U, Th and their radionuclide progenies are also present.

The most important but least understood function of wetlands is water quality improvement. Wetlands provide effective and low cost treatment for many types of water pollution by removing or converting large quantities of pollutants from point sources (municipal and certain industrial waste water effluents), and non-point sources (mine, agriculture and urban run-off), including organic matter, suspended solids, metals and excess nutrients.

The goal of using wetlands technology for acid mine drainage treatment is to provide a low cost system for immobilizing pollutants for long periods of time. Among the possible removal mechanisms are (Wildeman and Laudon 1989):

- Filtering suspended and colloidal material from water;
- Uptake of contaminants into roots and leaves of live plants;
- Adsorption or exchange of contaminants into soil and plant materials;
- Precipitation and neutralization through the generation of NH_3 and HCO_3^- alkalinity by bacterial decay of biological material; and
- Precipitation of metals in the oxidizing and reducing zones catalyzed by bacterial activity.

Although the above processes work simultaneously in a wetland system, the last mechanism has been identified as dominant in geochemistry of metals removal (Wildeman et al. 1989). Microbes - bacterial, fungi, algae and protozoa alter contaminant substances to obtain nutrients or energy to carry out their life cycles and immobilize dissolved metals by oxidation reduction reactions. The effectiveness of wetlands managed for waste water treatment is dependent on developing and maintaining optimal environments for desirable microbial populations.

Short term data developed to date for many constructed wetlands for acid mine drainage treatment preclude their use as stand alone systems for total abandonment. The long term performance characteristics, maintenance needs, and costs associated with current constructed wetland designs are not yet established. In the U.S., the Office of Surface Mining, Reclamation and Enforcement, which oversees state agency enforcement of water quality standards at mining sites, does not at present, view constructed wetlands as viable water treatment systems unless they are backed up with chemical systems (Hedin 1989; Hammer and Bastian 1989). Because of their enormous potential as resources and wild life habitat, natural wetlands are not recommended for use as treatment systems for municipal and industrial effluents.

Another potential application of the wetlands technology is in the area of prevention and control of acid mine drainage in conjunction with the development of a shallow water cover or wet barriers on the reactive waste. The water cover curtails the entry of oxygen, which is one of the key ingredients (others being sulphide minerals and water) for the chemical or biologically assisted oxidation process, and hence controls acid generation and concomitant leaching and contaminant migration. Establishment of wetlands in such systems will provide additional controlling measures by:

- Acting as a barrier to wind and wave induced erosion of the reactive material, and hence its resuspension and further oxidation. This process is further reduced with the build-up of decaying vegetative matter, algae and micro-vegetation as a cover layer.

- Acting as a moisture retaining cover layer in the littoral zone which is subjected to leaching and exposure during periods of dry summer and drought conditions.

- Supporting biological activities of appropriate oxidizing and reducing microbes in the sediment and substrate layers producing NH_3 and HCO^-_3 alkalinities and metal precipitates in the process of sulphate reduction. The required organic carbon for cell development of such microbes is supplied by the oxidation of the decaying vegetation.

The most significant result of flooding is the isolation of the soil/waste substrate system from atmospheric oxygen, which activates several biological and chemical processes that change the system from aerobic and oxidizing to anaerobic and reducing. However, there is an aerobic and oxidizing zone in the immediate vicinity of the soil water interface and strata containing plant roots (rhizosphere) as the wetlands plants have the unique ability to transport oxygen to support their roots growing in anaerobic substrate. Oxidation of sulphide minerals, metallic ions such as Fe^{+2}, Mn^{+2}, etc., decaying organic matter and nitrification processes dominate in this zone. In the reducing zone, the dominant processes are: ammoniafication, denitrification, reduction of Fe^{+3}, Mn^{+4}, SO_4^{-2} (producing H_2S) and organic matter with the production of methane (methogenesis). Dissolved hydrogen sulphide, produced in the microbial process of sulphate reduction (dissimilarity sulphate reduction, DSR), precipitates soluble metal ions as insoluble metal sulphides. Thus there is a dynamic equilibrium between oxidizing and reducing processes in a wetlands system which controls the release of nutrients and immobilization of contaminants.

1.2 BACKGROUND TO PRESENT STUDY

Wetlands are known to establish on flooded metal sulphide waste basins but their interactions with the substrate in water quality management are not fully understood. At present, there are no operational or experimental sites where the wetlands flooding concept is utilized. Rio Algom's Quirke Mine, at their tailings site in Elliot Lake, Ontario, is undertaking the development of a saturated/shallow water cover (wet barrier) wetlands system on a 65 ha pyritic uranium tailings site for final decommissioning (Davé et al. 1990). Earlier experiments of establishing wetlands directly on highly reactive sulphidic wastes without proper hydrological controls were not very successful (Davé and Muchelutti 1991; Orford

1986). Various test plots with water cover, wetlands, sewage sludge, etc., were established on top of unsaturated and porous pyrrhotite tailings where saturated and/or flooded conditions were maintained by irrigation from nearby water sources. The plots quickly dried out in summer drought conditions, or had operational problems associated with the irrigation system. The results were inconclusive because of a poorly flooded and operational wetlands system.

Wet barriers research is jointly undertaken by: CANMET, Elliot Lake Laboratory and Rio Algom Limited, where various field and laboratory experiments are being conducted to study the feasibility of a water cover on tailings in situ, oxidation/reduction and leaching characteristics of acid producing pyritic uranium tailings and waste rock. During the course of these investigations, a field survey of wetlands growing on tailings, their immediate vicinity, or receiving contaminated effluent from the Elliot Lake mining district was undertaken to evaluate their physical, chemical and biological characteristics, controlling growth, survival and propagation potential (Davé et al. 1990).

The survey revealed that at most sites the wetlands were directly established on tailings and their influence on water quality was difficult to assess. At one of the sites - Panel Dam 'A' which supported wetlands vegetation on a tailings spill, a dramatic improvement in water quality was observed. The pH increased from 3 to 6.6, and electrical conductance decreased from 1100 to 300 µs/cm. This site was the largest in size and supported a very healthy, dense and self-sustaining vegetation consisting of cattails, sphagnum moss, shrubs, and pond weeds, etc. The substrate consisted of an organic layer, 15 to 20 cm in thickness, on top of oxidized and unoxidized tailings slimes. The water quality was observed to be improving with distance from the exposed tailings beach near the perimeter on the western side of the tailings basin to completely submerged and ponded conditions towards the centre and eastern side. Further studies at this site were required to establish whether wetlands alone were responsible for such an improvement in the observed water quality.

An extensive survey of the Panel wetlands area was conducted during the field season of 1991. The survey included the area hydrology and flow conditions, surface and groundwater quality parameters, their seasonal fluctuations, tailings solids and sediment characterization for metals and sulphur oxidizing and reducing bacterial enumeration and vegetation uptake of metals and radionuclides. Various parameters were measured for three seasons: spring, summer and fall of 1991. Results to date are discussed in this report.

2. OBJECTIVES

The objectives of this study were to:

- Determine surface and groundwater hydrogeochemistry of the Panel wetlands tailings basin;

- Establish if the existing natural wetlands and water cover on acid generating tailings were providing any treatment to acid mine drainage, and evaluate their controls on acid generation and migration of contaminants associated with the oxidation of pyrite;

- Characterize wetlands tailings/sediment substrate for metals, sulphide and sulphate sulphur speciation, and its oxidizing/reducing microbe populations, and determine their roles in various geochemical and biological interactions; and

- Characterize wetlands vegetation for metals and radionuclide uptake.

3. SITE DESCRIPTION

The Panel wetlands study site is located approximately 25 km northeast of the city of Elliot Lake, Ontario (Figure 1). It is situated southeast of the Panel tailings area and immediately east of Panel Dam 'A' (Figure 2). It has an area of approximately 14.5 ha, and is located in a valley which drains towards the southeast. During the initial operation of the Panel Mine (1957 to 1961), tailings were spilled in the western part of the basin which now forms part of the substrate, approximately 0.2 to 4.5 m in thickness. The tailings have dispersed to the eastern section of the basin and the majority of them are underwater, except uplands along the shore line and in the western part where they are exposed (Figures 3 to 7).

Oxidized tailings were visible all along the exposed dry land, flats, beaches, and shallow water cover areas, where an approximately 5 to 10 cm thick oxidized layer had covered the unoxidized tailings. Unsaturated and dry oxidized tailings were characterized by a yellowish-green colour (jarosite precipitates) compared to saturated oxidized tailings which were brownish-orange (ferric precipitates). The unoxidized and saturated tailings were greyish-black in colour with the characteristic odour of hydrogen sulphide gas (Figures 8 and 9).

With the exception of some exposed tailings flats, mostly in the western section, the whole basin consisted of a lush green wetlands vegetation containing cattails (Typha latifolia), sedges, reed and other marshland grasses, sphagnum moss and pond weed species (Figures 10 to 13). Cattails were dominant in the shallow water, with mosses and sedges as the main species growing on saturated tailings and pond weed and other submerged hydrophytes in the deep open waters (Figures 14 to 19).

The whole basin was water-logged and contained ponded water ranging in depth from 0.1 m in the western part to 1.5 m in the eastern section of the basin. The water level in the basin was regulated by a beaver dam in the east through which the water exited periodically towards Rochester Creek (Figure 2).

The littoral zone was up to 20 cm thick in areas, but the decayed organic layer was shallow, 3 to 5 cm in depth. The depth of the root zone extended 20 to 30 cm.

Prior to 1979, effluent from a section of the Panel tailings drained through the basin (Figure 2), which severely impeded the water quality. A low permeability dam 'A' was completed in 1979, since then the water quality in the basin has been improving steadily (Figures 20 to 24).

4. METHODS

4.1 BATHYMETRY SURVEY

A bathymetry survey of the Panel wetlands area was conducted to obtain water depth profiles of the basin. Water depths were measured along various transects along the basin using a ruler for shallow water and a portable depth sounder for deep water. Depth measurements were taken at locations shown in Figure 25. The measured depths were accurate within ? 1.0 and 5.0 cm, respectively for shallow (<50 cm) and deep (>50 cm) waters.

The data were analyzed using a Surfer™ program which provided topographic depth profile contours, three-dimensional surface plots, and computed values of the surface area and fill volume of the ponded water.

4.2 SURFACE HYDROLOGY AND LAND SURVEYS

Surface hydrology and land surveys of the wetlands area were conducted to determine boundaries of ponded (open) water, inflow/outflow channels and flow volumes, areas under vegetation cover and exposed tailings in the basin.

The hydrology of the basin was governed by its east-west valley configuration where no permanent inflow streams were observed.

Input flows occurred mostly during spring thaw and rainfall events as general drainage and sub-surface seepage to the area. The output flow from the system was regulated by a beaver dam at the end of the basin in the east. It was irregular and intermittent, but when the situation permitted discharge flow was measured using a graduated bucket. In general, the flows were estimated based on the drainage topography and average annual net precipitation for the area.

Other surveys were conducted using mapping procedures.

4.3 TAILINGS THICKNESS (DEPTH) SURVEY

A geophysical (seismic sounding) survey of the basin was undertaken to estimate the thickness

---

TM Golden Software Inc.

of deposited tailings in the basin. This survey was originally conducted in 1977 by Golder and Associates, under a contract from Rio Algom Limited prior to the construction of Dam 'A' (Figure 2) in the basin in 1979. These data were used to calculate tailings thickness profiles along the basin at locations shown in Figure 26. Similar to the bathymetric survey, a Surfer™ program was used to produce tailings thickness contours, their area and volume, etc.

4.4 SURFACE AND GROUNDWATER SAMPLING

The present study consisted of extensive sampling of surface and groundwater throughout the basin during spring, summer and fall of 1991. Spring samples were collected in late May to early June, summer samples in late July to mid-August, and fall samples in late September to early October. Surface water samples were collected along various transects and at various depths (surface, mid-depth and bottom) to determine system variability along the water column and its flow path. The sampling locations for surface water are shown in Figure 27.

At a given sampling site, the water depth was first measured. A combination dissolved oxygen/ temperature probe (YSI model 58 dissolved oxygen meter) was then lowered to the required sampling depth and both sample temperature and dissolved oxygen concentration were measured in situ in the field where situations permitted. For other locations, these parameters were measured immediately following sample collection.

At shallow depths (<30 cm), water samples were obtained from a single mid-depth location using a grab-sampler. At deeper depths (>30 cm), water samples were obtained from near surface (10 cm below surface), mid-depth and near bottom (10 cm above bottom) locations in the water column. The samples were obtained by either a depth sampler or a suction sampler lowered to the appropriate sampling depth.

During and after rainfall events, surface run-off and background water samples were also collected from sites shown in Figure 28.

The collected water samples were brought to shore at a field sample processing site where they were first filtered with a combination of a glass fiber pre-filter and an 0.45 μm membrane filter. The sample pH, electrical conductance (Ec), and redox potential (Eh), were then measured and recorded as field values. The filtered samples were stored in a cool location and transported to the laboratory within three hours of collection and filtration.

Groundwater samples were collected at various locations and depths by installing piezometer nests. For this study, piezometers were installed at seven locations and at depths of 0.3, 1.0 and 1.5 m at each location (nest), along transects parallel to surface and groundwater flow regimes. The piezometers were 3.2 cm diameter schedule 80 PVC pipes with a Vion™ screened drive wellpoint at the bottom. At a given location, the piezometer was driven to the required depth by hammering such that the centre of the screened section represented the piezometer pressure or sampling point at that depth. Immediately following installation and periodically thereafter, the piezometers were bailed out and the recharge water level and its quality were monitored until equilibrium conditions were established prior to sampling. At deep water locations, the piezometers were attached to a wooden deck for stability and ease of sampling. Figure 29 shows the groundwater sampling locations. The groundwater samples were obtained with a suction sampler or a bailer for dissolved oxygen measurements.

For groundwater samples, field sample temperature and dissolved oxygen concentration were measured immediately following sample collection. The samples were then processed similarly to surface water samples as described above. For all samples, appropriate field sample blanks were also prepared by passing and collecting de-ionized water through the same sample collection and filtration system.

In the laboratory, the sample temperature, pH, electrical conductance (Ec), and redox potential (Eh), were again measured and recorded as laboratory values. For some samples, depending on their chemistry, it was expected that sample exposure and handling might affect the in situ field parameters.

For detailed chemical characterization, the water samples were analyzed for total acidity, alkalinity, total dissolved solids, SO_4^{-2}, and total dissolved metals: Al, Ca, Cu, Fe, Mg, Mn, Ni, Pb, Th, U, Zn and Ra-226.

4.5 SOIL SUBSTRATE/TAILINGS AND SEDIMENT SAMPLING

At locations close to the piezometer sites (Figure 29), soil/tailings substrate and sediment samples were collected for solid phase total metals and radionuclide characterization, and sulphide and sulphate sulphur speciation. Soil and tailings substrate samples were obtained from depths up to 0.30 m using a 35 mm diameter soil auger. Several samples were collected at a given site and pooled together in a sample container jar to constitute a representative sample. Each sample was given the same identification as that of the piezometer at that site.

Sediment samples at selected sites were obtained by a specially designed sediment sampler made of a high density PVC tube, 50 mm diameter and 1.5 m long with its bottom end sharpened. The sampling tube was lowered at a given site and gently hammered into the sediment to a depth of approximately 0.3 m. The tube was then capped with a rubber stopper fitted with a suction tube. Using a hand held suction pump, a slight vacuum was then applied to the sampling tube. The tube was then gradually rotated with a downward pressure to cap the bottom and then slowly raised. The sample was retrieved into a sample jar by breaking the suction and letting the sample slide out into the container. At some locations, a slight positive pressure was required for sample retrieval in overcoming sediment sampling tube friction. Surface water collected in the sampling tube during sampling was discarded.

Similar to liquid samples, all solid samples were also stored in a cool place and transported to the laboratory within a few hours of sampling.

In the laboratory, the wet solid samples were first individually homogenized by mixing. A portion of the homogenized sample (usually 50 g) was transferred and mixed with 50 mL of de-ionized water in a glass beaker for approximately 30 minutes. The sample mixture was then allowed to stand for another 30 minutes or until the supernatant was clear. The paste pH of the sample was then determined by measuring the pH of the supernatant solution.

The remaining portions of the samples were oven dried in a nitrogen environment at 70°C to a constant weight, and their moisture contents measured. The dried solid samples were then pulverized to -44 µm particle size and further homogenized by mixing in a ball mill. The samples were analyzed for total Al, Ca, Cu, Fe, Mn, Ni, Pb, Th, U, Zn and Ra-226 contents.

4.6 SOIL/TAILINGS SUBSTRATE AND SEDIMENT SAMPLING FOR BACTERIAL ENUMERATION

For bacterial enumeration, special soil/tailings substrate and sediment samples were collected after fall sampling (November 1991) from locations close to the piezometer sites as mentioned previously. The samples were obtained by driving thin walled aluminum or steel tubes, approximately 35 mm diameter into the ground to a depth of approximately 0.30 m, and withdrawing the intact samples together with their solids and upper column water. The sample tubes were then sealed at both ends and transported to the laboratory in vertical positions.

At the laboratory, the samples were split into two 0.15 m upper and lower sections. Each section was then further sub-divided into two parts, one each for Thiobacillus ferro-oxidans and sulphate reducing bacteria enumerations. For the latter, the samples were processed and preserved in an oxygen free environment. All samples were preserved in sterile containers and stored at 4°C until processed.

The samples were processed for bacterial enumeration and sulphur speciation.

4.7 VEGETATION SAMPLING

Wetland vegetation samples were also obtained from sites close to the piezometer locations. The sampling consisted of marshland plants including cattails, wetland grasses, pond weeds and sphagnum moss. At each location individual plant species were collected from an area 3 m x 3 m as composite sample. For all samples, only above ground plant parts were collected and bagged individually.

In the laboratory, the vegetation samples were first washed with distilled water, rinsed and air dried. The samples were then cleaned of dried plant parts (if any) and dried slowly in an oven at 70°C to a constant weight and their moisture contents determined. The dried samples were then chopped in a vegetation grinder to a size less than 1 mm and homogenized individually.

A portion of the vegetation sample (approximately 25 g) was transferred to a clean platinum crucible and gradually heated to 550°C in a muffle furnace. The sample was kept at that temperature for approximately 12 hours, and the sample container tapped occasionally to expose un-ignited residue, if any. The furnace was then gradually cooled and the ash weight of the sample recorded. The loss on ignition (LOI) of the sample was thus determined.

The vegetation samples were also analyzed for total Al, Ca, Cu, Fe, Mn, Ni, Pb, Th, U, Zn and Ra-226 contents.

5. ANALYTICAL PROCEDURES AND QUALITY CONTROL

5.1 SAMPLE DIGESTIONS

The sample digestion procedure varied depending on the nature of the sample, presence of volatile elements, e.g., Pb and organic matrix, etc. For tailings, soil, sediment and vegetation samples, the following procedures were followed.

5.1.1 Tailings Samples

Tailings samples (0.5 to 1 g) were completely dissolved, first by destroying the silica matrix with a hydrofluoric acid (HF) digestion in a platinum crucible at moderate temperatures followed by a dilute nitric acid (HNO_3) dissolution. The sample/solution mixture was brought to a boil, cooled and filtered. The filtrate was transferred to a pre-acid washed sample bottle. The residue (if any) was then heated in a muffle furnace at 550°C for approximately 12 hours and cooled slowly. The residue was mixed with a lithium borate flux (1:5 ratio), heated in the platinum crucible at a high temperature until a clear melt was obtained and then slowly cooled. The mixture was then dissolved in dilute nitric acid (HNO_3) as above and the solution was added to the filtrate in the sample bottle. The final volume of the solution was brought up to 1 L by adding de-ionized water if necessary.

For volatile elements, the samples were dissolved in nitric acid (after silica destruction) in high pressure teflon vessels in a microwave digestion oven. The samples were then dissolved in dilute nitric acid as above.

5.1.2 Soil Sediment and Vegetation Samples

Because of the organic contents in the sample matrix, these samples were first dry ashed in a muffle furnace. A small portion of the dried sample (0.5 to 1 g) was heated in a platinum crucible in the furnace and slowly ashed by increasing the temperature in steps of 100°C and finally at 550°C for 12 hours. The sample crucible was occasionally stirred to ensure complete ashing. The furnace was then gradually cooled (overnight) and the ashed sample was digested similar to the tailings sample procedure above.

The microwave digestion procedure, similar to that for tailings, was also followed for volatile elements. In this case the samples were not dry ashed. For Ra-226 analysis, all samples were digested and dissolved using hydrochloric acid.

5.2 SAMPLE PRESERVATION

All solution samples were stabilized with hydrochloric acid for Ra-226 and SO_4^{-2} and nitric acid for metals in the ratio of 10 mL per litre of sample. The samples were stored in a cool place prior to analysis.

5.3 ANALYTICAL METHODS

5.3.1 Elemental Analysis

Quantitative analysis of dissolved metals in solution samples was performed using a Thermo Jarrel Ash Inductively Coupled Argon Plasma-Atomic Emission Spectrophotometer (ICAP-AES), model Polyscan 61E. Elemental concentrations were measured following appropriate wavelength calibration, standardization, matrix matching, inter-element correction and quality control.

The samples were analyzed in triplicate where the analytical variance among replicates was typically less than 3%. For variations greater than 5%, the instrument was automatically recalibrated and the analyses repeated. Typical detection limits for the ICAP-AES were below 0.05 mg/L.

5.3.2 Ra-226 Analysis

For Ra-226 determination, the alpha-spectrometric technique of Lim and Davé (1981) was followed.

Radium was chemically separated in a two-step process, first as a radium-barium sulphate with lead sulphate as a carrier using concentrated sulphuric acid followed by dissolution of the sulphate precipitate in an ammoniacal solution of EDTA (Ethylene Diamine Tetra Acetic Acid) and selective precipitation of radium-barium sulphate at pH 4.8 using glacial acetic acid.

A known amount of Ba-133 tracer (gamma emitter) was also added to the starting sample for chemical recovery factor correction. The final precipitate was filtered on a millipore filter paper and the concentration of Ra-226 on the sample was measured by alpha-spectrometry using a solid-state silicon surface barrier detector. Ra-226 activity was calculated by measuring total counts under the 4.78 MeV alpha-energy decay peak with an energy selection width of 4.0 to 4.9 MeV. Chemical recovery of Ra-226 in the precipitate was calculated by measuring the recovery of Ba-133 tracer using its 356 KeV gamma energy peak and a gamma-spectrometer with NaI(Tl) detector.

5.3.3 Sulphur Speciation

For soil/tailings substrate and sediment samples, sulphur speciation was carried out by measuring total sulphur, total sulphate sulphur and calculating total sulphide sulphur concentrations.

The total sulphur concentration was measured using a LECO furnace sulphur analyzer. A measured amount of dry pulverized sample was ignited at a high temperature in an electric spark furnace and the total sulphur concentration was determined by measuring the total quantity of evolved sulphur dioxide gas using gas chromatography.

The total sulphate sulphur concentration of the sample was determined by acid leaching and digesting of the sample with dilute hydrochloric acid where all the acid soluble sulphate was dissolved and its concentration measured using liquid ion chromatography.

5.3.4 Sulphate Analysis - Solution Samples

For solution samples, the sulphate concentration was measured using a Ba-133 radioisotopic tracer technique.

The method consisted of precipitating sulphate as Ba (Ba-133) $S0_4$ by the addition of a precipitating solution containing a fixed ratio of $BaCl_2$/(Ba-133)Cl_2 concentrations. Sulphate concentration was determined by measuring the recovery of Ba-133 radioisotope using a gamma spectroscopy system as described above. By fixing the concentration ratio of $BaCl_2$/(Ba-133)Cl_2, three precipitating solutions, A, B and C were used to measure total sulphate in the ranges of 10 to 100 mg, 1 to 10 mg, and 0 to 1 mg SO_4^{-2}, respectively.

5.4 QUALITY ASSURANCE/QUALITY CONTROL (QA/QC)

The QA/QC program consisted of analyzing all solution samples in triplicate. All solid sediment and vegetation samples were digested in duplicate.

For quality control, matrix matched control samples consisting of CANMET Certified Reference Standards for Uranium, Base Metal Tailings and Ore, together with field and reagent blank samples were processed concurrently through the analytical procedures. For dissolved metals, instrumental analytical standard deviations were set at the 5% variation level for quality control (QC) table check and correction. The overall precision and accuracy of the analytical results were between ? 5 to 10% levels depending on the element concentration. For Ra-226 analysis, typical standard deviations were less than 10% for low concentrations (~300 mBq/L), and less than 3% for high concentrations (~100 mBq/L).

6. BACTERIAL ENUMERATION

The soil/tailings substrate and sediment samples were enumerated for Thiobacillus ferro-oxidans (TF) and sulphate-Reducing Bacteria (SRB). The former oxidizing micro-organisms require oxygen and carbon for their metabolic processes and catalyze oxidation of iron and sulphur producing acid mine drainage. The latter reducing bacteria work in the absence of oxygen and reduce soluble sulphate to H_2S which then precipitates dissolved metals as insoluble metal sulphides, thereby counteracting the effects of Thiobacillus ferro-oxidans.

The bacterial enumerations were carried out by the Biotechnology section of the Environmental Laboratory, Mineral Sciences Laboratories, CANMET, Ottawa. The detailed procedure and results are described by Lortie et al. (Appendix C).

The number of Thiobacillus ferro-oxidans bacteria per gram of solid sample was estimated by the most probable numbers method (MPN) using tenfold dilutions up to 10^{-9} and five replicate tubes per dilution. The growth medium used for TF consisted of 0.0174 g/L of K_2HPO_4, 0.12 g/L of $MgSO_4$? 7 H_2O, 0.066 g/L of $(NH_4)_2$ SO_4 sterilized by autoclaving, and 33.34 g/L of $FeSO_4$ solution filtered and sterilized with 100 mL of distilled water adjusted to pH 2.5. The method consisted of dispensing 1 mL of sample paste using a sterile syringe to 9 mL of growth medium solution in a sterile tube. After mixing thoroughly, 1 mL of this solution was transferred to another sterile test tube containing 9 mL of the growth medium solution, making a tenfold dilution. Nine such serial dilutions (10^{-9} folds) with a total of 45 test tubes per sample were used. Control tubes used here were not inoculated with samples. The test tubes were incubated at room temperature for four weeks before recording the results. A positive result was indicated by a ring of growth of TF at the top of the medium with a rusty brown colouration and by oxidized iron deposits.

For sulphate-reducing bacteria, the growth medium consisted of 0.5 g of KH_2PO_4, 1 g of NH_4Cl, 1 g of $CaSO_4$, 2 g of $MgSO_4$? $7H_2O$, 2.92 g of sodium lactate (60%), 1.28 g of sodium acetate, 1 g of yeast extract, and 1 mL of resazurin (0.1%) per litre of distilled water. The pH of the medium was adjusted to 7.2 with NaOH(5N) solution.

The medium was then heated and reduced by addition of nitrogen. Once the medium was completely reduced, as indicated by the colour change of resazurin, 0.5 mL of a reducing solution of Na_2S? $9H_2O$ (2.5% W/V) per litre of the medium was added and the medium solution was transferred to an anaerobic glove box. Similar to the TF procedure above, nine successive serial dilutions of 45 tubes were also prepared for SRBs per sample. All sample bottles and controls were capped with rubber stoppers and incubated at room temperature in the dark for 4 weeks. A positive result was indicated by the blackening of the medium caused by the presence of H_2S produced by SRBs.

7. RESULTS

7.1 BATHYMETRY SURVEY

Table 1 shows the bathymetry survey data for the wetlands study site taken during the fall survey. Figures 30 and 31 show, respectively, the water depth contour profile, and three-dimensional water depth surface plot (perspective view). For the basin, the computed average depth, surface area and water volume were, respectively, 0.19 m, 130,230 m^2, and 24,210 m^3. The basin was very shallow in the west and mostly covered with vegetation. In the eastern half of the basin, the ponded water depth increased towards the east, and at places measured 1.0 to 1.4 m Vegetation was only present at shallow water depths along the shore line in this area.

Throughout the basin, the undisturbed ponded water was very clear. The bottom surface was clearly visible at all depths with most areas containing bare and vegetation covered tailings.

The basin was susceptible to east-west gusting winds with a wind fetch of approximately 1 km. During the sampling period, no evidence of wind-induced wave action related sediment erosion and re-suspension was observed. The vegetation cover, mostly cattail plants standing 1 to 2 m high, acted as a wind and wave barrier.

Depending on weather conditions and the time of day, biological life, such as minnows, frogs, leeches, snakes, and various water insects and native birds were frequently seen in the area.

7.2 TAILINGS THICKNESS PROFILES

Table 2 and Figures 32 and 33 show, respectively, the tailings depth data, contour map of tailings thickness profiles, and three-dimensional perspective views of distributed tailings surface in the basin. The tailings were distributed throughout the basin, but a majority of them were contained in the western half of the basin (Figure 33). In this section, the thickness of tailings varied between 1 and 4 m approximately. The computed average thickness, distribution area, and total volume (mass) of tailings in the basin were, respectively, 0.92 m, 128,570 m^2 and 117,770 m^3 (236,000 tonnes). Figure 34 shows cross-section of the basin through the middle.

Sediment profiles from the eastern half of the basin showed that a thin veneer of tailings was underlain by organic rich bog-peat type sediments. This suggested that prior to deposition of the tailings, the basin was a fresh water marsh or a very shallow lake with a deep channel in the middle. The bottom of the basin contained a peat layer, 0.3 to 4 m thick, underlain by sand and gravel deposits in a bedrock valley. Deposition of tailings by spills in the western part of the basin has filled this section with some tailings extending to the eastern end of the basin. Natural vegetation has re-colonized and reclaimed the basin since then. Tailings have formed a part of the soil substrate where wetland vegetation appeared to be self-sustaining and flourishing.

7.3 AREA HYDROLOGY

7.3.1 Surface Water

The Panel wetlands site has a total surface area of approximately 14.5 ha and the perimeter is 3.1 km.

Approximately 13.0 ha of the site is under a water cover during high water level periods of spring and fall. The basin is thus approximately 90% under a water cover or is water saturated at least once a year. The tailings in the basin are distributed over an area of approximately 12.9 ha with dry and exposed tailings covering an area of 1.6 ha. A total of 8.8 ha (60%) has a vegetation cover. Figure 35 shows the distribution of exposed tailings, vegetation and water cover at the site.

The site has a total catchment and drainage area of approximately 49 ha. The recorded annual precipitation and evaporation for the general area for the past ten years were, respectively, 966 mm/a and 682.8 mm/a. On an annual basis, the site receives a total net precipitation of approximately 138,920 m^3 corresponding to an average flow of 4.4 L/s, or 9 L/s per km^2 (15.4 L/s per km^2 for open water season, May to November). The total drainage volume is approximately six times that of the surface water contained in the basin, thus representing a dilution factor of six.

At the west end of the site, there is an extensive tailings effluent reservoir (Figure 2) which contained untreated acidic seepage and other drainage from the existing and now inactive tailings areas. A clay core dam across the bedrock valley (Dam 'A'), extending down to the bedrock which was grouted, marks the west boundary of the wetlands basin. To the east, at the end of the basin, is a small beaver dam which regulated the water level in the basin. Overflow from the east beaver dam was irregular and intermittent during dry periods. It was measured at approximately 16.5 L/m during the fall sampling in October 1991 (no rain). A majority of the flow probably occurred during the spring run-off and fall precipitation which was not measured.

There are no permanent streams that drained into the basin except intermittent drainage channels along the hillside and relief areas. A single channel collected the drainage from the exposed tailings on the west side and joined the main water body towards the middle (Figure 35). During dry sampling periods, this channel contained water puddles throughout but there was no appreciable surface flow. Also there was no apparent seepage from the acid water reservoir upstream that contributed flow to this channel.

The surface drainage from the acid water reservoir exits along its south-west corner where the effluent is treated prior to its discharge into a different watershed. There is no emergency overflow or spillway in Dam 'A' that drained towards the wetlands basin. The dam also has a free board level of approximately 2 m.

7.3.2 Groundwater

The groundwater hydrology of the area was established by a series of piezometer nests installed along the west-east flow direction (P_1 to P_9), and across various transects (P_2 to P_7), as illustrated in Figure 29. The piezometers were installed during the late spring of the 1991 field season. Stable groundwater elevation data were thus obtained for summer and fall sampling periods only. Piezometric tip elevation surveys were carried out during the winter of 1991 to 1992 and in the spring of 1992.

Figures 36 and 37 shows the water table elevation in the basin in relation to ground and surface water elevations. The piezometer pressure contours are shown in Figures 38 and 39 for the two sampling seasons. In general, the groundwater flow was from west to east. Sub-surface water from exposed tailings areas in the western section discharged into the ponded water body in the centre of the basin. In this section, the generalized flow was upward and towards the east. The measured horizontal and vertical gradients ranged from 0.003 to 0.015 and 0 to -0.15, respectively. The negative gradient indicated that the net vertical flow was in the upward direction. In the fall, the upward vertical gradients were the highest.

In the eastern half of the basin, the groundwater flow was also towards the east, but in a downward direction (Figures 38 and 39). The measured horizontal and vertical gradients ranged from 0.0002 to 0.001, and -0.72 to 0.14, respectively, in this area. Near the centre of the pond (P_7), the vertical flow component was transient, shifting in direction from recharge (positive slope) to discharge (negative slope) depending on the season.

Piezometer P_1 was located in the bedrock formation immediately east of the toe of dam 'A'. It was installed in 1979 when Dam 'A' was constructed to monitor seepage through fractures in the bedrock. The well log data showed that this piezometer was located in a slightly fractured (at shallow depths) but otherwise competent rock. The rising head hydraulic conductivity of the formation was 10^{-7} m/s (Vivyurka 1992). The horizontal hydraulic gradient at this site was measured as 0.18 during the sampling period in 1991. The cross-sectional area at this site was 450 m^2 (50 m width x 9 m depth), and the calculated seepage volume was approximately 260 m^3/a.

For a cross-section area measuring 200 m wide and 2 m deep near the centre, the annual sub-surface discharge volume from the western basin to the central water pond was calculated, using a horizontal hydraulic conductivity of 10^{-5} m/s for fine tailings, as approximately 380 to 1800 m^3/a. This volume represented less than 2 to 8% of the total surface water volume in the basin. A majority of the drainage in the basin thus occurred as surface drainage and upward groundwater discharge to the pond.

The small lateral groundwater flow also indicated minimal or very little seepage from the acidic tailings pond upstream of the wetlands basin. This was further confirmed by the lack of visible seepage near Dam 'A' and from downstream water quality.

7.4 WATER CHEMISTRY

7.4.1 Surface Water

7.4.1.1 Preliminary (1990) survey results

Table 3 gives the surface water quality results obtained during the initial survey conducted in August and October of 1990. The data were limited to certain key parameters and only a brief discussion is provided below.

The pH of the ponded water on exposed tailings near the west end and Dam 'A' was only slightly acidic to near neutral (pH 5.7 to 7.2) for sites 1, 2 and 3 (Figure 27). The measured electrical conductance (Ec) varied from 750 to 1270 µs/cm.

For one sample (2BS), the measured values for various parameters were: Al, <0.03 mg/L; Ca, 323 mg/L; Fe, 0.013 mg/L; Mg, 22.9 mg/L; Mn, 0.22 mg/L; Pb, 0.07 mg/L; SO_4^{-2}, 841 mg/L; and dissolved Ra-226, 360 mBq/L. All other elements were near or below detection limits.

For sites located further east in vegetated and open surface water locations, the pH varied from acidic range (4 to 5), to alkaline (8 to 9). Low pH's (4 to 5) were obtained for shallow water and vegetated areas (sites 4B, 6B and 6C). High pH's (8 to 9) were obtained in the summer for deep water areas where floating pond weed type vegetation (7D and 9B) was observed. In the fall (October 1990), the observed pH's at these locations were lower, 5.8 to 6.5.

Along the length of the pond, the electrical conductance decreased from 550 to 180 µs/cm, Ca from 130 to approximately 50 mg/L, and SO_4^{-2} from 300 to 65 mg/L. Fe values varied from 0.93 to 0.05 mg/L, Mg from 6 to 1.1 mg/L, and Mn from 0.1 to <0.002 mg/L. Dissolved Ra-226 concentrations increased from 380 to 1025 mBq/L with distance along the pond. All samples had low or no acidity, and for only one sample at site 6C, the measured acidity was 18.5 mg $CaCO_3$/L. Alkalinity decreased from a high of 177 mg $CaCO_3$/L for shallow water, sample 3B, to approximately 30 to 33.5 mg $CaCO_3$/L, for deep water samples in the eastern part of the basin.

In the tailings pond upstream, the water was fairly acidic (pH = 3.0) with high electrical conductance (Ec = 3000 µs/cm); high redox potential (Eh = 701 mV); acidity at 230 mg $CaCO_3$/L; total dissolved Al, 12.3 mg/L; Ca, 519 mg/L; total Fe, 12.7 mg/L; Mg, 87 mg/L; Mn, 3.7 mg/L; Pb, 0.6 mg/L; U, 0.9 mg/L; total Cu, Ni, and Zn at 1.1 mg/L; SO_4^{-2} concentration at 2085 mg/L; and total dissolved Ra-226 at 7642 mBq/L. This water quality was typical of acidic drainage from other operating tailings sites in the area.

7.4.1.2 Detailed (1991) survey results

The surface water quality results for the detailed 1991 field survey for the three seasons: spring, summer and fall, are given in Tables 4, 5 and 6, respectively. Figures 40 to 47 show the spatial and seasonal variations of pH, Ec, Alkalinity, SO_4^{-2}, Fe, Ca, Mg and Ra-226, respectively.

pH: In the spring, pH's of water samples from shallow water cover and vegetated areas were again acidic, ranging in values from 3.4 to 5.5 (sites 4B, 4C, 5A, 5B, 3C, 6A, 6G and 7G). Near the exposed tailings sites, the pH was one to two orders of magnitude higher, 6.3 to 6.8 for sites 1, 2B, 2C and 3B (Figure 27). For all other deep water locations, the observed pHs were near neutral to slightly alkaline varying from 6.2 to 8.7. In general, pHs were lower in the western part of the basin where the water depth was shallow, than in the eastern part of the basin where a deep water cover existed.

In the summer, the water in the basin receded and no surface water samples could be collected at low pH sites. For all other sites, the measured pHs varied from 6.4 to 7.8 at locations in the western section, 6.2 to 9.8 in the central section, and 8.7 to 9.5 in the eastern section of the basin (Figure 40). The highest pHs (9.5 to 9.8) were recorded for sites 7B, 9A, 9B and 9C. At these sites a dense cover of floating pond weed was observed. Slightly lower pHs (8 to 9) were observed at locations away from pondweed areas.

In the fall, lower acidic pHs (3.2 to 4.6) were again observed at shallow water cover sites in the west (site 5E and 5F), where water samples could be obtained. At other locations, the observed pHs ranged from 6.1 to 8.1, which were similar or only slightly higher than spring pHs. The localized high pH phenomenon was thus related to the particular plant species metabolic and most probably photosynthetic cycles. No diurnal measurements were made to further establish these effects.

Acidity/Alkalinity: Acidity and alkalinity were only measured in summer and fall samples. In the summer, all samples but one had no acidity. In one sample from 5F site (shallow water), a very small acidity was measured (2 to 5 mg $CaCO_3$/L). Most of the summer samples had alkalinity in the range of 25 to 170 mg $CaCO_3$/L. The measured alkalinity was high in shallow water samples from the western half of the basin (35 to 170 mg $CaCo_3$/L). No significant increase in alkalinity was observed at locations where high pHs were measured, e.g., 7B, 9A and 9B, etc. (Figure 42).

In fall samples, high acidity values (29 to 75 mg $CaCO_3$/L) were observed at two locations, 5E and 5F. All other samples had no acidity. High alkalinity values (103 to 120 mg $CaCO_3$/L) were measured in very shallow water samples (2B, 2C and 3B). At other locations in the western half of the basin, the observed alkalinity was low in the range of 8 to 47 mg $CaCO_3$/L. For samples from the eastern half of the basin, the fall alkalinity values were higher (20 to 63 mg/L) than those measured in the summer.

The most probable source of high alkalinity was believed to be from residual alkalinity present in the tailings solids and porewater. Additional alkalinity in this zone may also be produced by reduction of nitrates to ammonia in reducing environments.

Electrical Conductance (Ec) and Total Dissolved Solids (TDS): The electrical conductance, Ec, profiles for surface water samples are shown in Figure 41. In general, both Ec and TDS values were higher in shallow water samples from western locations than those from the eastern part of the basin for all seasons. At western locations, Ec values ranged from 180 to 1980 µs/cm in the spring, 660 to 1380 µs/cm in the summer, and 870 to 1800 µs/cm in the fall samples. At a given location, the lowest values were obtained in the summer.

In the eastern part of the basin, because of its relatively large water body, there were less variations in measured Ec and TDS values between sites. At these locations, the lowest values were obtained in spring and summer samples where the measured Ec values ranged from 150 to 480 µs/cm and 170 to 590 µs/cm, respectively. Ec values decreased with distance from intermediate values near the central part of the basin to low values near the discharge end.

Sulphate: Sulphate profiles, shown in Figure 43, were similar in characteristics to those for Ec. Sulphate values were the highest (300 to 800 mg/L) in the exposed western part of the basin, intermediate (100 to 300 mg/L) in the central part, and lowest (50 to 100 mg/L) near the discharge end of the eastern part, for all three seasons. In a given area, sulphate values increased from spring to summer to fall. No significant variation in the sulphate concentration with depth in the upper lying water column was observed to establish sulphate influx and bacterial reduction of sulphate in the sediment layer immediately below the water column.

Dissolved Oxygen: Dissolved oxygen was measured only in summer and fall samples. In the summer, at shallow water depths in the western part of the basin (4B, 5C, 5D, 5F, 6B, 7A, 7D, 7G, and 8A) the dissolved oxygen concentrations were low and below saturation, ranging from 0.2 to 5 mg/L. Low concentrations (0.2 to 1 mg/L) were observed at locations where the water depth was less than 30 cm, had a dense vegetation cover and where a 5 to 10 cm layer of decaying organic matter covered the tailings substrate. The data suggested that biological and/or chemical oxygen demands were high at these locations and where, because of thick vegetation, the water column was inadequately mixed to maintain oxygen concentration at saturated levels.

At other locations where the water was open, deep, and well mixed, the dissolved oxygen concentrations were near saturation values throughout the water column and no oxycline was observed.

Redox Potential (Eh): Redox potentials, Eh (NHE) for most of the samples were greater than 300 mV for the three seasons. In general, the Eh values were high in the spring, intermediate (350 to 400 mV) in the fall, and slightly lower (300 to 350 mV) in the summer. The data indicated reduction of oxygen during warm summer months, and hence a corresponding decrease in Eh (Faulkner and Richardson 1989).

Iron, Manganese and Aluminum: Iron concentration profiles, shown in Figure 44, were similar to those for sulphate and Ec. There were two distinct zones of iron concentrations, exposed and shallow water zone in the west where iron concentrations were high (1 to 80 mg/L), and central and eastern parts of the basin where iron concentrations were low (0.002 to 0.4 mg/L). In the exposed and shallow water zone, iron concentrations were higher in the spring and summer than in the fall. In the eastern zone and near the discharge, iron concentrations were lower in the spring and fall, and slightly higher in the summer. Unlike sulphate, a zone with intermediate concentrations of iron was absent.

Manganese and aluminum profiles were similar to those for iron.

Calcium and Magnesium: Calcium and magnesium profiles (Figures 45 and 46) were also very similar to those for sulphate and Ec. There were three distinct concentration zones for calcium, a high concentration zone (150 to 500 mg/L) in the western part of the basin, an intermediate concentration zone (50 to 150 mg/L) in the central part of the basin, and a low concentration zone (30 to 50 mg/L) in the east. Similar zones existed for magnesium except magnesium concentrations were much lower (1 to 40 mg/L). In general, concentrations in a given area increased from spring to summer to fall.

Other Metals: Concentrations of other metals: Cu, Ni, Pb, Th, U and Zn were either very low or below detection. In some isolated cases, elevated levels of Pb and Zn were observed, e.g., fall sample 5F (Pb ~0.9, and Zn ~0.2 mg/L), which correlated well with the corresponding increased concentrations in Fe, Al and Mn.

Ra-226: Ra-226 concentrations, shown in Figure 47, were similar in characteristics to those for iron where two concentrations zones existed. In the western and central parts of the basin, Ra-226 levels were high (500 to 4000 mBq/L) which decreased to intermediate levels (300 to 500 mBq/L) in the eastern part of the basin. On average, Ra-226 concentrations decreased by a factor of 2 compared to sulphate, iron and calcium, where the reduction was in excess of 6. Also Ra-226 concentrations were higher in the spring and fall than in the summer for a given area.

7.4.2 Rain Run-Off and Surface Drainage Water

The rain run-off and surface drainage water quality data are given in Table 7. Sample RR #1 was taken near Dam 'A', and above the areas where tailings were deposited (Figure 28). Water samples collected at this location represented the background water quality of the surface drainage entering the basin. The soil at this site was typical of the area overburden covered with a thin organic layer on top. The measured water quality parameters at this location were: pH, 6.04; Eh, 485 mV; Ec, 66 µs/cm; acidity, 9.1 mg $CaCO_3$/L; alkalinity, 8.1 mg $CaCO_3$/L; Fe total 0.04 mg/L; Ca 5.4 mg/L; Mg 0.3 mg/L; Al, 0.1 mg/L; Mn, 0.03 mg/L; SO_4 8.1 mg/L; and Ra-226, 11.9 mBq/L. Other metals were below detection levels. These results are to be compared with those for the background water quality lake samples taken at the discharge end of the Rochester Lake, located on the other side of the drainage basin (Falls, Table 4).

Other rain run-off and surface drainage samples were taken at locations where water was either entering the basin over exposed tailings, or draining as sub-surface seepage from areas containing tailings covered with vegetation. The water chemistry at these locations varied depending on the site, but was typical of exposed tailings containing oxidation reaction products characterized by low pH, high dissolved iron, calcium and sulphate etc. (Table 7). At one location, RR #5, the drainage water quality had near neutral pH of 6.73 with intermediate concentrations of Ca, 197 mg/L; Mg, 2.6 mg/L; SO_4, 370 mg/L; and Ra-226; 508 mBq/L.

These results were similar to those for surface water samples from exposed and shallow water cover areas in the western part of the basin (Tables 4 to 6).

7.4.3 Groundwater

Tables 8 and 9 give the groundwater quality results for summer and fall sampling periods, respectively. The spatial variations of various water quality parameters are shown in Figures 48 to 55, respectively, for pH, Ec, alkalinity, sulphate, iron, calcium, magnesium and Ra-226.

Similar to the surface water quality, these results are discussed separately for various measured parameters and their spatial distribution.

pH: The groundwater pH was fairly uniform throughout the basin. In the western part of the basin where the water table depth was variable, from 0.2 to 2.0 m below the surface to approximately 0.4 m above the surface, the pHs were slightly acidic (~5.7) to near neutral and decreased slightly with increasing depth (P_2 and P_3). The pHs were also slightly higher in the fall than in the summer (Figure 48).

At the piezometer site P_1, which was located in the bedrock at a depth of 9 m immediately east of dam 'A', the pH was near neutral (6.7 to 7.3) which also increased slightly in the fall. At this location the groundwater has been at neutral pH since the installation of the monitoring well in 1979, but SO_4^{-2} and total dissolved solids have steadily increased from 200 mg/L range in 1979 to 2000 mg/L range in 1992 (Vivyurka, 1992).

For piezometer nests P_5, P_7, P_8 and P_9, the groundwater quality was also characterized by slightly acidic to near neutral pHs, except for the shallow depth piezometer (0.304 m) at location P_5-D where the pHs were moderately alkaline (10.2 to 10.6). At this location, the surface water depth was approximately 0.4 m. For all locations, the pHs decreased slightly with depth and were slightly elevated in the fall.

Acidity/Alkalinity: The acidity and alkalinity of the groundwater samples were highly variable depending on the sample location and its depth. Low to moderate acidity (10 to 200 mg $CaCO_3$/L) was measured in summer samples from shallow depth piezometers P_2-A, P_2-B, P_3-A, P_3-C and P_5-F. In the fall, acidity was only present at low levels, 20 to 24 mg $CaCO_3$/L, in samples P_3-C (0.8 m) and P_5-B (0.91 m), and at intermediate levels (110 to 120 mg $CaCO_3$/L) in sample P_3-A (0.91 m). In all other samples, no acidity was present.

The measured alkalinity varied over a wide range, from 0 to 500 mg $CaCO_3$/L. In the western part of the basin, the alkalinities were generally low to moderate (0 to 500 mg $CaCO_3$/L) except for P_3-B (0.91 m) where they were high (600 to 800 mg $CaCO_3$/L). At central and eastern locations, the alkalinities were moderate to high (100 to 1400 mg $CaCO_3$/L). Alkalinities in excess of 1000 mg $CaCO_3$/L were observed at locations P_5-D (1.5 m), P_7-D (0.3 m), P_8-B (0.3 m), and P_9-B (0.3 m). Similar values were obtained at these locations in the fall except for P_9-B (0.3 m) where the alkalinity had decreased to 530 mg $CaCO_3$/L. The corresponding increase in the groundwater pH at these high alkalinity sites was not observed.

Neither acidity or alkalinity displayed any trends with depth.

Electrical Conductance (Ec) and Total Dissolved Solids (TDS): The groundwater electrical conductance and total dissolved solids concentrations were high in the western part of the basin at all depths and at shallow depths in the eastern part (Figure 49). The measured values for Ec and TDS were, respectively, in the range of 1200 to 4000 μs/cm, and 1000 to 3000 mg/L. There were no significant changes between summer and fall values, except some displacement of the high concentration peak with depth.

For all other locations in the eastern part, P_7-B, P_8-B and P_9-B, and one location P_5-B in the west, both Ec and TDS decreased with increasing depth, from approximately 3000 to 200 μs/cm or mg/L. Also there were no seasonal changes. At these locations, the tailings thickness was in the order of 1 m, and the measured Ec or TDS corresponded to the tailings pore water quality containing dissolved gypsum

($CaSO_4$).

Dissolved Oxygen (DO): The dissolved oxygen concentrations in most of the groundwater samples were very low, less than 1 to 2 mg/L. Slightly elevated DO levels (2 to 5 mg/L) were observed at a few sites: P_2-A (0.9 m), P_5-F (1.5 m), P_3-A (0.9 m), and P_3-C (0.8 m), but these results were not reproducible in a subsequent sampling. It is believed that the actual DO concentrations were very low (<1 mg/L) in all groundwater samples and that small amounts of oxygen might have been introduced during sampling and measuring procedures which were unavoidable. No seasonal or depth-related variations in DO concentrations were observed.

At many of the deep piezometers and water cover sites, a moderate to strong smell of H_2S was present in the sampled groundwater which suggested sulphate reduction and the absence of oxygen.

Redox Potential (Eh): The groundwater reduction-oxidation potentials, Eh (NHE) were observed to vary within and between sites for the two sampling periods. A majority of the samples had Eh values ranging between 100 and 300 mV for both seasons. Very few samples had Eh values below 100 mV, and only one fall sample P_8-B (1.2 m) had an Eh value of 39 mV. Similarly, there were few groundwater samples having Eh values higher than 300 mV. In the fall, only sample P_3-A (0.91 m) had a slightly high Eh (406 mV) which correlated with its observed high acidity and low pH.

At these Eh and pH values in groundwater, only Fe^{+2} and Mn^{+2} are stable in the solution phase and where Fe^{+3} precipitated to the solid phase (Eh to pH stability diagrams, Collins and Buol 1970). Many of the observed Eh and pHs were in the solid/liquid transition zone for Fe^{+2} and Fe^{+3} stability. The dissolved iron concentrations in groundwater were thus highly variable with slight changes in Eh and pH values.

Sulphate: The groundwater sulphate concentration profiles, shown in Figure 51, were similar to those for electrical conductance (Ec) and total dissolved solid (TDS). Sulphate concentrations were high (800 to 1500 mg/L) at most sites and depths in the western part of the basin (P_1, P_2-A, P_2-B, P_3-A), at shallow depths for other locations and in the eastern part of the basin (P_3-B, P_5-B, P_5-F, P_7-B, P_8-B and P_9-B). At latter locations, sulphate concentrations decreased to less than 50 mg/L with increasing depth, as was observed for Ec.

At all locations, the measured sulphate concentrations were slightly lower in the fall than their summer values.

Iron, Manganese and Aluminum: Figure 52 shows the groundwater iron profiles for the two seasons. Iron concentrations were high and variable in the exposed and shallow part of the western basin. At a given site, the concentration varied with depth, as well as with sampling time, within a season. For example, at site P_5-F, the groundwater iron concentrations at depths 0.3, 0.91 and 1.52 m were, respectively, 11.5, 5.6 and 0.8 mg/L in July, and 67.2, 8.7 and 4.1 mg/L in August. Also in this area, the highest concentration of iron did not occur near the water table (shallow depth), but at mid-depth. Variations between seasons were less pronounced.

Near the central and eastern part of the basin, the iron concentrations increased gradually with increasing depth. The highest iron concentrations (28 to 33 mg/L) were observed at P_8-B (0.91 m depth) which decreased to the range of 2 to 5 mg/L along the east at P_9-B. At these sites, the concentrations were lower in the fall than in the summer.

Similar to iron, manganese and aluminum concentrations were also higher in the western half of the basin and decreased with increasing distance in the eastern section. However, within a sampling period, both manganese and aluminum concentrations were fairly consistent at a given depth and site. With increasing depth, the concentration of each element decreased. The concentrations of aluminum were slightly higher in the fall than their summer values. For manganese the trend was reversed.

Calcium and Magnesium: The groundwater calcium and magnesium profiles are shown in Figures 53 and 54. At shallow depths (0.3 m), calcium concentrations were high (400 to 800 mg/L) throughout the basin and where the highest values were obtained at the eastern locations P_7-B to P_9-B (610 to 820 mg/L). The concentration decreased with depth at all locations, but the decrease was more pronounced in the eastern part of the basin. At intermediate and deeper depths (0.91 and 1.52 m) calcium concentrations were higher in the western part of the basin than in the east. At location P_5-D, calcium concentration was high throughout the sampling depth, and where the groundwater pH was high (10.2) at shallow depth.

At a given site and depth, calcium concentrations were fairly uniform and seasonal variations were not detected.

Magnesium concentrations were generally high (20 to 60 mg/L) in the western part of the basin, low (5 to 10 mg/L) in the central part of the basin, and intermediate (10 to 40 mg/L) in the east. Similar to calcium, the concentrations decreased with depth, but the effect was more pronounced in the east. At P_5-D, the concentrations increased from 0.2 to 26 mg/L with increasing depth. There was also very little seasonal variations in magnesium concentrations.

Other Metals: The observed concentrations of other metals, Cu, Ni, Pb, Th, U and Zn in the groundwater were either very low or below detection limits throughout the basin for both seasons.

Ra-226: Ra-226 concentration profiles, shown in Figure 55, varied both with site and season. The measured concentrations varied over a wide range, from a low of 280 mBq/L at site P_5-D (0.9 m) in September 1991 to a high of 10,900 mBq/L at P_5-B (0.9 m) in July 1991. At most sites, groundwater Ra-226 concentrations fluctuated within a range of 1000 to 3000 mBq/L. Ra-226 concentrations in general, were higher in the eastern part of the basin than in the west and had a slight positive correlation with decreasing sulphate concentrations and increasing alkalinity. From the observed data, no clear depth or seasonal trends could be established.

At the Dam 'A' site P_1, Ra-226 concentrations were significantly low, in the range of 300 to 800 mBq/L compared to 7640 mBq/L, in the acidic tailings pond upstream.

7.5 SOIL/TAILINGS SUBSTRATE AND SEDIMENT CHEMISTRY

Tables 10 and 11 give, respectively, the solid phase paste pH and chemical composition of the soil/tailings substrate and sediment samples from the wetlands basin.

The paste pH for samples 2A, 3A, 3C, 5B, 5E and 5F (see Figure 27 for locations) was moderately to highly acid, varying in range from 2.1 to 5.9. At locations 2B, 2C and 3B, which were centrally located along the transect, the paste pHs had near neutral values, 7.0 to 7.5. In all but one sample (3B), the pH of the top 15 cm section of the substrate was lower than the bottom 15 cm of the sample. For samples 2A, 3C and 5B, the top section pHs were 0.5 to 2.0 units lower than those for the bottom part of the sample.

The substrate chemical composition data showed that it consisted mostly of tailings containing 2.6 to

5.2% Fe (5.5 to 11% pyrite), 1.8 to 4.5 % Al, 0.2 to 3.3% Ca, 0.03 to 0.1% Mg, 0.01 to 0.08% Pb, 0.02 to 0.06% Th, 0.01% U, 6.8 to 16 Bq/g Ra-226, and trace amounts of Cu, Mn, Ni and Zn. From these data, the average pyrite content of the tailings was calculated as 7.6 ? 1.7%, assuming that all the iron was present in the form of pyrite mineral only. This result, when compared with the original pyrite content of 7.5% (range 5 to 10%) for tailings in the Elliot Lake area (based on the pyrite content of the orebody, Davé et al. 1982) suggested that total iron was relatively undepleted in the tailings substrate in the basin.

7.6 BACTERIAL ENUMERATION AND SULPHUR SPECIATION

Tables 12 and 13 give bacterial enumeration and sulphur speciation results. Thiobacillus ferro-oxidans (TF) were present in almost all exposed and shallow water cover sites in the western part of the basin. At these sites, the most probable number (bacterial counts) or population density of TF bacteria was generally higher in the top 15 cm of the sample than in the bottom half section. The highest number was obtained for site 2A-top, 1.4 x 10^8 per gram of tailings, where the water table was about 0.8 m below the ground surface. At this site the paste pH was also low, 2.08 to 3.34 (Table 8), as was for sample 3A (2.25 to 2.36) where the bacterial count was high ~1.7 x 10^7. Bacterial counts were 2 to 4 orders of magnitude lower at sites 2B and 3B where the paste pHs were near neutral.

At other shallow water cover and vegetated sites, the TF bacterial counts were low to moderate, 10^3 to 10^5. Wetland plants have the unique ability to transport atmospheric gases including oxygen down into the roots to enable their roots to survive in an anaerobic environment. An aerobic region, called the rhizosphere surrounds each root hair and supports large microbial populations, including TF, that conduct desirable modifications of nutrients, metallic ions and other compounds (Hammer and Bastian 1989).

At deep water cover sites, 5D, 7B, 8B and 9B, the bacterial counts for TF reduced drastically to insignificant numbers (0 to 100). These results suggested that although the upper lying water column above the sediment was well oxygenated, the dissolved oxygen concentration was rapidly depleted in the sediment/tailings interface to support Thiobacillus ferro-oxidans activity at any significant level.

Sulphate reducing bacteria (SRB) were also present at all sampling sites, but their populations were significantly higher than Thiobacillus ferro-oxidans only at the deep water cover sites 5D, 7B, 8B and 9B. At these sites, and with increasing depth, a strong smell of H_2S was also noted in groundwater samples which probably suggested higher SRB activity further below. These results were substantiated by decreasing groundwater sulphate concentrations with depth (Tables 8 and 9).

The SRB populations varied over a wide range, 3 x 10^2 to 5 x 10^6, but there were no consistent trends within or between samples, probably because of shallow sampling depths. The data, however, clearly demonstrated that both oxidizing (aerobic) and reducing (anaerobic) environments co-existed in a saturated or partially saturated substrate in the basin.

The sulphur speciation results are given in Table 13. Figures 56 and 57 show, respectively, the distribution of Thiobacillus ferro-oxidans and sulphate reducing bacteria populations, and relative concentrations of total sulphide and sulphate sulphurs along the length of the basin for both top and bottom sections.

Similar to SRBs, the sulphur speciation data also showed that both sulphide and sulphate concentrations were variable within and between sites without clear trends. The measured values were in the range, 0.09 to 6.68 for total sulphur (% S), 0.05 to 4.98 for total sulphate (% S), and 0.04 to 4.04 for total sulphide (% S). From these data, the residual average pyrite concentration was calculated as 4.05% (range 0.08 to 7.64). There was no correlation between site location and residual pyrite or sulphate concentration.

It should be mentioned that for bacterial enumeration and sulphur speciation only one core sample was taken per site which was further split into various sub-sections without homogenization. This was done to avoid cross-contamination and introduction of air, for example, in SRB samples. The observed results thus reflected the sample heterogeneity. Caution should be exercised when comparing these results with those for the soil/tailings substrate samples where, in the latter case, several core samples were taken from a given site, mixed and homogenized to form a composite sample.

7.7 VEGETATION UPTAKE

Table 14 gives the results of metals and radionuclide (Ra-226) concentrations in various plant species of the wetlands area, cattails, marshland grasses, pondweeds and sphagnum moss. The percent moisture content and loss of ignition (LOI) results are also included in the above table. Of the four species analyzed, cattails had the lowest concentration of Al (3 to 135 µg/g), Fe (24 to 212 µg/g), Pb (3 to 10 µg/g), Th (<2 µg/g), U (<20 µg/g), Ra-226 (30 to 440 mBq/g), intermediate concentrations of Ca

(10,000 to 17,000 µg/g), and Mg (50 to 900 µg/g), and the highest concentration of Mn in the range of 74 to 580 µg/g.

Grasses had intermediate levels of all elements except for one sample (Grass #3, site 2B), where significantly high levels of Al (337 µg/g), Pb (248 µg/g) and U (60 µg/g) were obtained.

Sphagnum moss had the highest accumulation of Al (460 to 1330 µg/g), Fe (22,000 to 63,000 µg/g), Pb (62 to 65 µg/g), Ra-226 (340 to 1300 mBq/g), Th (33 to 44 µg/g) and U (50 to 80 µg/g), was low in Ca (3300 to 6400 µg/g) and Mg (200 to 400 µg/g) and the lowest in Mn (<2 µg/g).

Pondweeds had the highest accumulation of Al (570 to 1380 µg/g), Ca (116,000 to 140,000 µg/g) and Ra-226 (2500 to 3800 mBq/g), intermediate accumulation of Fe (4300 to 7400 µg/g), Mg (860 to 1100 µg/g), Mn (80 to 210 µg/g), U (30 to 40 µg/g), and the lowest accumulation of Pb (10 to 20 µg/g) and Th (~10 µg/g).

Concentrations of other heavy metals Cu, Ni, and Zn were low in all species. These metals were present at trace or very low levels in the soil/tailings substrate.

Cattails were the most abundant species in the basin followed by grasses in bio-mass production, nutrients and metals uptake and recycle. Sphagnum moss was growing at locations near the hillside in areas away from the direct sunlight and under tree and plant canopies. Pondweeds were growing only at isolated locations in the deep water. Although, the highest metal levels were obtained for the latter two species, their relative contribution to the total metals retention and removal loads in the basin was very small to insignificant. These two species were, however, good bio-indicators of metals and radionuclides uptake from soil substrates and water. Czarnowska (1992) has used mosses as bio-indicators of environmental pollution from air fallout and substrate deposits, in assessing the degree of pollution of forested, urban and industrial areas on both local and regional scales.

The nutrient requirements and bio-accumulation of metals, their tolerances and phyto-toxicity levels vary according to plant species and tissues, their metabolic rates and physiological characteristics. The bio-availability of nutrients and other minerals is dependent on the substrate physical, chemical and biological compositions. The measured tailings substrate and plant metal levels at the Panel wetlands site were similar to those observed at other pyritic uranium, base metals and gold tailings sites (Cloutier et al.

1985; Davé 1992).

The observed metal concentrations were also below plant toxicity levels with little or no significant accumulation warranting concerns related to wind dispersion or animal forage. During vegetation sampling, no symptoms of plant metal toxicity were observed.

Ra-226 concentrations in the wetland vegetation (30 to 3800 mBq/g) were significantly elevated in many species compared to background levels of 10 to 20 mBq/g, obtained previously in the terrestrial vegetation samples from local and distant control sites (Davé et al. 1984, 1985). For the emergent vegetation: cattails and grasses, the measured Ra-226 levels were comparable to those obtained from other tailings sites in the area, 300 to 1200 mBq/g (Davé et al. 1984, 1985; Mirka et al. 1992). Concentrations in the vascular plants (mosses and pondweeds) were higher, 300 to 3800 mBq/g, than other species.

Animals foraging from these plants in the basin could have significant dietary intake and retention of Ra-226 in bone tissues, as radium is a chemical analog of calcium. In a previous study, Mirka et al. (1992) observed bio-accumulation of Ra-226 in bones of muskrats living in the Panel wetlands basin. Although Ra-226 levels were high in the submergent or floating vegetation like pondweed, it is believed that because of its low abundance and relatively small bio-mass compared to cattails and grasses in the basin, its contribution to the dietary load of Ra-226 in large animals like moose, who prefer water plants, was very small.

8. DISCUSSION

The results have suggested that the tailings were oxidizing in the exposed and shallow water covered and vegetated parts of the basin. In exposed areas, oxidation was taking place near the surface in the unsaturated zone and in the vicinity of the water table. In vegetated areas, oxidation of both organic matter and tailings was taking place from surface to the root zone of the substrate. Because of the fine grained tailings and their high degree of moisture saturation, the overall oxidation rates were low. As a result, low pH (3.4 to 5.5) surface drainage and sub-surface water was produced with low to medium concentrations of total dissolved solids, 600 to 2000 mg/L, iron 1 to 80 mg/L, and sulphate 100 to 800 mg/L. The total acidity of this water was low, 5 to 80 mg $CaCO_3$/L.

In the vegetation zone, no improvement in the surface water quality was noted as it drained from exposed areas towards the ponded water. In fact both the surface and groundwater data showed that the vegetation was oxidizing the substrate rather than providing the treatment. In the surface water some iron was further oxidized to Fe^{+3} and precipitated as ferric hydroxide in the vegetation zone. The degree of oxidation and liberation of iron from the decaying organic matter in the vegetative substrate layer and tailings underneath was not assessed.

The groundwater at shallow depths in the basin was mostly tailings derived porewater with slightly acidic to near neutral pH (5.7 to 7.8) and low to moderate acidity (10 to 200 mg $CaCO_3$/L). Moderate acidity and slightly low pH porewater was only observed in a shallow zone near the water table in the western part of the basin. The oxidation derived tailings porewater from the unsaturated zone was readily neutralized by residual or generated alkalinity in the saturated zone underneath as it migrated downwards. Because of its neutral pH and low Eh values, some iron and manganese (Fe^{+2} and Mn^{+2}) remained in solution in the saturated zone. In this zone the tailings porewater was saturated with gypsum.

The surface water from exposed tailings and vegetated areas drained towards the ponded water in the centre of the basin. The groundwater from high elevations in the west and north-south also discharged towards the ponded water in the middle. The acidity of the surface water was thus neutralized by the groundwater. Dissolved iron, aluminum and manganese were also precipitated when the three waters mixed in the pond. Because of near neutral to alkaline pHs of the ponded water with its high Eh, dissolved iron (discharged through the groundwater regime as Fe^{+2}) was quickly oxidized to Fe^{+3}, hydrolyzed and precipitated. Dissolved iron concentrations in the ponded water were thus low.

Based on the area hydrology and annual net precipitation, a dilution factor of 7 was estimated between the drainage volume of water from exposed and vegetated areas, and the total volume of water (drainage plus ponded) in the rest of the basin. From surface water calcium concentrations, the calculated dilution factor ranged from 6 to 10 which was comparable to the above estimated value.

The increase in the pH of the ponded water from 7.5 to 9.5 in the summer could not be associated with the mixing of the groundwater or the above dilution factor. Because high pHs were only observed during warm months of the year and in the pond water, this phenomenon was attributed to both, the bacterial reduction of nitrates in the organic sediments and photosynthetic process of some submerged plants (pondweeds) producing ammonia and hydroxyl ions, respectively. These conclusions were based on a limited field data and further investigations in this area are required to understand the roles played by various biological processes that control and regulate the pH in such a system.

The groundwater calcium concentrations at shallow depths (0.3 m) below the ponded water at locations P_7-B, P_8-B and P_9-B were high (600 to 825 mg/L) in the summer and did not correspond to the observed sulphate levels (1040 to 1100 mg/L) for gypsum solubility of approximately 2000 mg/L. At these locations, the groundwater had a characteristic smell of H_2S, indicating sulphate reduction. With the decrease in sulphate concentration in the tailings (substrate) porewater as a result of the bacterial sulphate reduction, the solubility equilibrium of gypsum was shifted in the forward direction, thereby increasing calcium concentration in the solution.

From a seasonally averaged dissolved iron concentration (0.065 ? 0.06 mg/L) of the ponded water in the eastern part of the basin and the calculated total annual discharge volume (138,920 m^3), the total annual efflux of iron from the basin was calculated as approximately 9 kg/y. Similarly, from the average iron concentration of 9.6 mg/L in the surface drainage from exposed and shallow water cover areas, an annual total iron production rate of 183.7 kg/y was calculated. These values corresponded to an annual pyrite oxidation and iron discharge rates of 1.11 and 0.04 mg Fe per kg of tailings in the basin per year, respectively. Because of its various physical, chemical and biological controls, the existing wetland system retained or recycled 96% of the total iron produced by pyrite oxidation. At these rates, it will take approximately 31.7 x 10^3 y for all the pyrite contained in the tailings to oxidize and, 926.4 x 10^3 y for all the mobilized iron to leave the system.

For calcium (at 34 mg/L) and Ra-226 (at 452 mBq/L) the corresponding times for their complete removal from the system were calculated as approximately 708 y and 40.1 x 10^3 y, respectively. Because the solubility of $RaSO_4$ is controlled by the sulphate ion concentration, the retention time for Ra-226 may be shortened following complete removal of gypsum. In the above calculations, it was also assumed that the radioactive decay of Ra-226 (half-life of 1650 y) affected the solid and liquid fraction activities equally.

It is believed that the wetland water system was effectively controlling the acidic drainage from partially submerged pyritic uranium tailings. The system would continue to function as long as the water cover was maintained. Its performance could be further improved with the installation of a permanent water cover such that all the tailings were completely submerged.

9. SUMMARY AND CONCLUSIONS

- The Panel wetlands study site was a small basin located in a bedrock valley containing partially submerged pyritic uranium tailings. It had a total area of 14.5 ha, and contained approximately 236,000 tonnes of tailings spread over an area of 12.9 ha. Approximately 88% of the tailings area was underwater leaving an area of 1.6 ha in the western part of the basin where the tailings were exposed. The average thickness of the tailings in the basin was 0.92 m.

- The tailings were deposited in the basin as a result of a tailings spill upstream in the late 1950s which completely filled the western and central part of the basin, and spread a thin layer of tailings to the eastern part of the basin. Underneath the tailings, the basin contained a layer of peat 0.3 to 4 m thick, underlain by sand and gravel deposits.

- The eastern part of the basin contained ponded water, 0.4 to 1.4 m deep. A shallow water layer, 0.1 to 0.5 m deep, extended throughout the west/central part of the basin which supported a dense vegetative cover consisting of cattails, marshland grasses, sedges, sphagnum and other acidophilic mosses. The deep ponded water contained submergent vegetation such as pondweeds.

- A beaver dam at the east end of the basin regulated the water level and its discharge flow. The basin contained a total water volume of approximately 24,000 m^3, with an average depth of 0.2 m.

- The site had a total catchment and drainage area of approximately 49 ha. On an annual basis, the site received a total net precipitation of approximately 138,920 m^3 (calculated from mean annual precipitation data) corresponding to an average flow of 4.4 L/s or 9 L/s per km^2. The drainage water volume was estimated to be six times the volume of water contained in the basin which corresponded to a dilution factor of 6.

- At the extreme west end of the site, there was an acidic tailings pond impounded by a clay core cross-valley dam. No visible seepage of acidic water from this pond was observed towards the basin.

- The surface water flow from the site was towards the east. It was irregular and intermittent, and was measured at 16.5 L/m in the fall.

- In general, the groundwater flow was also from west to east. Sub-surface water from exposed tailings areas in the western section of the basin discharged into the central water body. In this section the water table was 0.2 to 2.0 m below the surface, and the groundwater flow was upwards and towards the east. The measured horizontal and vertical gradients ranged from 0.003 to -0.015 and from 0 to -0.15, respectively. Upward vertical gradients were highest in the fall. Sub-surface discharge from the western part of the basin to the central pond was estimated at 380 to 1800 M^3/a which was less than 2 to 8% of the total surface water volume of the basin.

- In the eastern part of the basin, the groundwater flow was also towards the east but in a downward direction. The measured horizontal and vertical gradients ranged from 0.0002 to 0.001, and from -0.72 to 0.14, respectively.

- The surface water in the basin was slightly to moderately acidic in the exposed and vegetated western parts of the basin with low to medium concentrations of dissolved solids (600 to 2000 mg/L), iron (1 to 80 mg/L), calcium (150-500 mg/L), and sulphate (50 to 1000 mg/L).

- In the central and eastern parts of the basin where a permanent water body existed, the surface water was near neutral to moderately alkaline, pH (6.2 to 9.8), with low concentrations of dissolved solids (100 to 300 mg/L), iron (0.002 to 0.4 mg/L), calcium (30 to 50 mg/L), and sulphate (50 to 100 mg/L).

- There was no strong seasonal dependence of the surface water quality except pH in the central and eastern parts of the basin which increased from 7.5 to 9.8 in the summer.

- The groundwater at shallow depths in the basin was mostly tailings derived porewater with slightly acidic to near neutral pH (5.7 to 7.8), low to moderate acidity (10 to 200 mg $CaCO_3$/L), low to high alkalinity (0 to 1400 mg $CaCO_3$/L), low to moderate iron (0.5 to 70 mg/L), high Ca (400 to 800 mg/L), high sulphate (800 to 1500 mg/L), and high Ra-226 (280 to 10,900 mBq/L). There was no strong seasonal dependence except for dissolved iron concentration which was variable.

- The soil substrate in the basin mostly consisted of tailings except near the far east end where the original peat sediments existed. The paste pH of the substrate varied from near neutral to highly acidic, 7.5 to 2.1.

- Thiobacillus ferro-oxidans (TF) and sulphate reducing bacteria (SRB) were present in all soil substrate and sediment samples from exposed and shallow water cover sites in the western part of the basin. At deep water sites near the centre and towards the east, the bacterial counts for TF reduced drastically to insignificant numbers (0 to 100). Sulphate reducing bacteria populations at these sites exceeded those for Thiobacillus ferro-oxidans. There were no clear trends in SRB distribution profiles along the length of the basin.

- The sulphur speciation data also showed that both sulphide and sulphate concentration were variable within and between sites without clear trends. Sulphate reduction was clearly evidenced by a strong smell of H_2S in the groundwater at deep water central and eastern locations.

- Tailings were oxidizing in the exposed and shallow water covered and vegetated part of the basin. In exposed areas, oxidation was taking place near the surface in the unsaturated zone and in the vicinity of the water table. In vegetated areas, oxidation of both organic matter and tailings was taking place from surface to the root zone of the substrate. Because of fine grained tailings and their high degree of moisture saturation, the overall oxidation rates were low, producing low pH (3.4 to 5.5) surface drainage and sub-surface water.

- In the vegetation zone, no improvement in the surface water quality was noted as it drained from exposed areas towards the ponded water. Both the surface and groundwater data indicated that the vegetation was oxidizing the substrate rather than providing the treatment. Some iron was precipitated and removed as ferric hydroxide in the vegetation zone.

- The acidic surface drainage from exposed tailings and vegetated areas was diluted by a factor of

6 to 10 as it drained and mixed with the ponded water. The groundwater from western and central sections of the basin was also discharging in the ponded water where it neutralized the acidic surface water and precipitated dissolved iron, aluminum and manganese as hydroxides when the waters mixed.

- The pH of the ponded water increased from 7.5 to 9.5 in the summer which was attributed to the bacterial reduction of nitrates in the organic sediments, and to the photosynthetic process of some submergent (pondweeds) producing ammonia and hydroxyl ions, respectively. This phenomenon needs to be further investigated.

- From water quality data for surface drainage from exposed, shallow water covered and vegetated areas, and pond water near the discharge end, the annual rates of total iron production, as a result of pyrite oxidation, and iron discharged from the system were calculated as 183.7 kg/y and 9 kg/y, respectively. These values corresponded to an annual pyrite oxidation and iron discharge rate of 1.11 and 0.04 mg Fe per kg of tailings in the basin per year.

- The existing wetland system, because of its various physical, chemical and biological controls, retained or recycled approximately 96% of the total iron produced as a result of pyrite oxidation. It was estimated that at these rates it would take approximately 31.7 x 10^3 y for all the pyrite to oxidize, and 926 x 10^3 y for all the mobilized iron to leave the system, assuming that the rate did not change with time.

- For calcium and Ra-226, the corresponding times for their complete removal from the system were calculated as approximately 708 y and 40 x 10^3 y, respectively.

- For cattails and grasses, the observed metal uptake levels were similar to those observed at other pyritic uranium tailings, base metals and gold tailings sites. High concentrations of iron, aluminum, calcium, and other heavy metals were observed in pondweeds and sphagnum moss, but their contribution to the total bio-mass production and metals retention and removal load was very small compared to cattails and grasses which were the most abundant species.

- In all vegetation, the observed metal concentrations were below plant toxicity levels with little or no significant accumulation warranting concerns related to wind dispersion or animal forage. No symptoms of plant toxicity were observed.

- Ra-226 concentrations in the wetlands vegetation (30 to 3800 mBq/g) were significantly elevated in all the species compared to background levels of 10 to 20 mBq/g in terrestrial vegetation for local and distant controls.

It can be concluded that the wetland/water system in the Panel wetlands basin was effectively controlling the acidic drainage from partially submerged pyritic uranium tailings. The system would continue to function as long as the water cover was maintained. Its performance could be improved further if all the tailings were completely submerged.

10. RECOMMENDATIONS

It is recommended that the sediment oxidation reduction dynamics and the photosynthetic process of the submerged plants in the eastern parts of the basin should further be investigated in order to understand the seasonal behaviour of the observed high pHs in the summer.

11. ACKNOWLEDGMENTS

The author wishes to gratefully acknowledge the financial support for the project from the Ontario Ministry of Northern Development and Mines (MNDM). Thanks are also due to Rio Algom Limited, Elliot Lake Division, for their continued support and participation in this study, and especially to Mr. A. Vivyurka for providing much needed information and many helpful suggestions. Many people from CANMET: Ms. Y. Boucher, Ms. J. Collins (co-op student), Ms. L. Coté, Ms. D. Horne, and Mr. T. Lim of the Elliot Lake Laboratory, Ms. L. Wilson and Mr. M. Chenier of the Environmental Laboratory, Ottawa, and Mr. J. Marques, IAEA Fellow, Empressa Nacional de Urano, Portugal, worked laboriously on this project. Their contribution and effort is gratefully acknowledged. The author is always indebted to Mrs. A. Webster for her help in report preparation.

12. REFERENCES

Broadie, G.A., Hammer, D.A. and Tomljanovich, D.A., "Treatment of acidic drainage with a constructed wetland at the Tennessee Valley Authority 950 coal mine". Proc. 1st Int. Conf. on Constructed Wetlands for Wastewater Treatment, Chattanooga, Tennessee, 1988. D.A. Hammer (Ed.), Lewis Publishers Inc., Michigan, pp. 201-210, 1989.

Calabrese, J.P., Sexstone, A.J., Bhumbla, D.K., Dissonette, G.K. and Sencindiver, J.C., "Application of constructed cattail wetlands for the removal of iron from acid mine drainage". Proc. 2nd Int. Conf. on Abatement of Acidic Drainage, Montreal, Canada,

September 1991. Mine Environmental Neutral Drainage, MEND, vol. 3, pp. 559-575, 1991.

Cloutier, N.R., Clulow, F.V., Lim, T.P. and Davé, N.K., "Metals (Cu, Ni, Fe, Co, Zn, Pb) and Ra-226 levels in meadow voles Microtus Pennsylvanicus living on nickel and uranium mine tailings in Ontario, Canada: environmental and tissue levels". Environ. Pollut. (Series B), vol. 10, pp. 19-46, 1985.

Collins, J.F. and Buol, S.W., "Effects of fluctuations in the Eh-pH environment of iron and/or manganese equilibria". Soil Science 110:111-118, 1970.

Czarnowska, K. and Gworek, B., "Heavy metal content of moss from Kampinos National Park in Poland". Environ. Geochem. and Health, vol. 14, No. 1, pp. 9-14, 1992.

Davé, N.K., Lim, T.P., Vivyurka, A.J., Dubrovski, N., Morin, K., Smyth, D.J.A., Gillham, R.W. and Cherry, J.A., "Hydrogeochemical evolution of an inactive pyritic uranium tailings basin and retardation of contaminant migration in a surrounding aquifer". In: Proc. I.A.E.A. Conf. on Management of Waste from Uranium Mining and Milling, Alberqueque, NM, 1982. IAEA, Vienna, IEAE-SM-262/14, pp. 215-229, 1982.

Davé, N.K., Lim, T.P. and Cloutier, N.R., "Radionuclide uptake by various plants growing on uranium tailings, Elliot Lake, Ontario". Division Report MRP/MRL 84-19(TR), CANMET, Energy, Mines and Resources Canada, 1984.

Davé, N.K., Lim, T.P. and Cloutier, N.R., "Ra-226 concentrations in blueberries Vacinium angustifolium ait. near an inactive uranium tailings site in Elliot Lake, Ontario, Canada". Environ. Pollut. (Series B), vol. 10, No. 4, pp. 301-314, 1985.

Davé, N.K. and Lim, T.P., "Wetlands and their role in treating acid mine drainage - a literature review". Division Report MRL 89-107(LS), CANMET, Energy, Mines and Resources Canada, 1988.

Davé, N.K. and Lim, T.P., "Development of wet barriers on pyritic uranium tailings, Elliot Lake, Ontario. Phase 1". Division Report MRL 90-050(OPJ), CANMET, Energy, Mines and Resources Canada. Proc. Acid Mine Drainage Conf., Vancouver, May 1990. Bitech Publishers, Vancouver, B.C., 1990.

Davé, N.K. and Michelutti, R., "Field evaluation of wet cover alternatives for high sulphide tailings.

Proc. 2nd Int. Conf. on Abatement of Acidic Drainage, Montreal, Canada, September 1991. Mine Environmental Neutral Drainage, MEND, pp. 61-82, 1991.

Davé, N.K. and Weatherell, C., "Environmental monitoring of the waste management facility at Renabie Gold Mines pre-decommissioning phase". Division Report MSL 93-6(CR), CANMET, Energy, Mines and Resources Canada, 1992.

Faulkner, S.P. and Richardson, C.J., "Physical and chemical characteristics of freshwater wetland soils". Proc. 1st Int. Conf. on Constructed Wetlands for Wastewater Treatment, Chattanooga, Tennessee, 1988. D.A. Hammer (Ed.), Lewis Publishers Inc., Michigan, pp. 41-72, 1989.

Hammer, D.A. and Bastian, R.K., "Wetlands ecosystems, natural water purifiers?". Proc. 1st Int. Conf. on Constructed Wetlands for Wastewater Treatment, Chattanooga, Tennessee, 1988. D.A. Hammer (Ed.), Lewis Publishers Inc., Michigan, pp. 5-19, 1989.

Hedin, R.S., "Treatment of acid coal mine drainage with constructed wetlands". In: Wetlands Ecology, Productivity and Values: Emphasis on Pennsylvania. Pennsylvania Academy of Sciences, 1989.

Howard, E.A., Emerick, J.C. and Wildeman, T.R., "Design and construction of a research site for passive mine drainage treatment in Idaho Springs, Colorado". Proc. 1st Int. Conf. on Constructed Wetlands for Wastewater Treatment, Chattanooga, Tennessee, 1988. D.A. Hammer (Ed.), Lewis Publishers Inc., Michigan, pp. 761-765, 1989.

Howard, E.A., Hestmark, M.C. and Margulies, T.D., "Determining feasibility of using forest products or on site materials in the treatment of acid mine drainage in Colorado". Proc. 1st Int. Conf. on Constructed Wetlands for Wastewater Treatment, Chattanooga, Tennessee, 1988. D.A. Hammer (Ed.), Lewis Publishers Inc., Michigan, pp.774-779, 1989.

Karathanasis, A.D. and Thomson, Y.L., "Metal speciation and retention patterns in a high metal load acid mine constructed wetland of southeastern Kentucky". Proc. 2nd Int. Conf. on Abatement of Acidic Drainage, Montreal, Canada, September 1991. Mine Environmental Neutral Drainage, MEND, vol. 2, pp. 485-498, 1991.

Kleinmann, R.L.P., Edenborn, H.M. and Hedin, R.S., "Biological treatment of mine water - an overview". Proc. 2nd Int. Conf. on Abatement of Acidic Drainage, Montreal, Canada, September 1991. Mine Environmental Neutral Drainage, MEND, vol. 4, pp. 27-42, 1991.

Lim, T.P. and Davé, N.K., "A rapid method of radium-226 analysis in water samples using an alpha-spectroscopic technique". CIM Bull. 74:97-105, 1981.

Mirka, M.A., Clulow, F.V., Davé, N.K. and Lim, T.P., "Radium-226 in cattails (typha latifolia) and bone of muskrat (Ontatra zibethica) from a watershed with U tailings near Elliot Lake, Canada". Paper submitted to Environ. Pollut (Series B), 1992.

Orford, G., "The development of a vegetative cover on the Levac tailings area, preliminary work. 1985, final report". D.S.S. Contract No. OSQ85-00102, CANMET, Energy, Mines and Resources Canada, 1986.

Wenerick, W.R., Stevens, S.E. Jr., Webster, H.J., Stark, L.R. and De Veau, E., "Tolerance of three wetlands plant species to acid mine drainage". Proc. 1st Int. Conf. on Constructed Wetlands for Wastewater Treatment, Chattanooga, Tennessee, 1988. D.A. Hammer (Ed.), Lewis Publishers Inc., Michigan, pp. 801-807, 1989.

Wieder, R.K., Tchobanoglous, G. and Tuttle, R.W., "Preliminary considerations regarding constructed wetlands for wastewater treatment". Proc. 1st Int. Conf. on Constructed Wetlands for Wastewater Treatment, Chattanooga, Tennessee, 1988. D.A. Hammer (Ed.), Lewis Publishers Inc., Michigan, pp. 297-306, 1989.

Wildeman, T.R. and Laudon, L.S. "Use of wetlands for treatment of environmental problems in mining". Proc. 1st Int. Conf. on Constructed Wetlands for Wastewater Treatment, Chattanooga, Tennessee, 1988. D.A. Hammer (Ed.), Lewis Publishers Inc., Michigan, pp. 221-231, 1989.

Vivyurka, A.J. Personal communication. Rio Algom Limited, Elliot Lake, Ontario, 1992.

Table 1 - Panel wetlands: surface water depths at various locations in the basin.

SURFACE WATER DEPTH PANEL WETLANDS

SITE #	SITE CODE	NORTHING (m)	EASTING (m)	WATER DEPTH (cm)	SITE #	SITE CODE	NORTHING (m)	EASTING (m)	WATER DEPTH (cm)
1	P	4550.99	7303.76	0.00	7	A	4602.44	7711.20	45.00
1	P	4550.99	7303.76	0.00	7	B	4613.92	7708.89	36.00
2	A	4567.06	7328.01	0.00	7	C	4625.68	7707.25	30.48
2	A	4567.06	7328.01	1.27	7	D	4649.48	7707.09	12.70
2	B	4572.50	7323.67	0.00	7	E	4674.90	7704.24	15.24
2	B	4572.50	7323.67	0.00	7	F	4696.37	7702.26	10.16
2	B	4572.31	7323.37	0.00	7	G	4723.97	7699.11	7.62
2	B	4572.31	7323.37	1.27	7	M	4657.17	7777.54	15.24
2	B	4572.10	7323.15	0.00	7	N	4664.51	7780.62	15.24
2	B	4572.10	7323.15	2.54	7	P	4614.13	7710.12	37.50
2	C	4575.74	7321.66	0.00	7	P	4614.12	7709.91	37.00
2	C	4575.74	7321.66	3.18	7	P	4614.02	7709.68	37.00
3	A	4586.86	7368.13	0.00	7	P	4614.13	7710.12	36.00
3	A	4586.86	7368.13	1.27	7	P	4614.13	7710.12	36.00
3	B	4602.41	7359.07	6.35	7	P	4614.12	7709.91	36.00
3	B	4602.41	7359.07	6.35	7	P	4614.12	7709.91	36.00
3	B	4602.26	7358.78	2.54	7	P	4614.12	7709.91	36.00
3	B	4602.26	7358.78	2.54	7	P	4614.12	7709.91	36.00
3	B	4602.06	7358.45	0.00	7	p	4614.13	7710.12	36.00
3	B	4602.06	7358.45	2.54	7	p	4614.12	7709.91	36.00
3	C	4631.31	7344.80	0.00	7	p	4614.12	7709.91	36.00
3	C	4631.31	7344.80	1.27	8	A	4618.96	7851.34	13.97
4	A	4531.58	7501.49	0.00	8	B	4633.70	7804.01	57.15
4	B	4577.26	7461.90	0.00	8	C	4656.27	7845.54	18.42
4	B	4577.26	7461.90	43.00	8	D	4612.40	7941.93	47.63
4	C	4610.19	7439.33	0.00	8	D	4613.00	7943.36	15.24
4	D	4646.94	7421.03	0.00	8	E	4652.16	7956.42	54.61
5	A	4569.65	7536.20	0.00	8	F	4694.66	7970.92	43.18
5	B	4586.92	7524.96	0.00	8	F	4690.17	7969.09	15.24
5	B	4586.00	7525.98	0.00	8	P	4632.61	7812.40	42.00
5	B	4586.00	7525.98	2.54	8	P	4632.61	7812.40	44.00
5	B	4585.82	7525.68	0.00	8	P	4632.69	7812.63	42.00
5	B	4585.82	7525.68	2.54	8	P	4632.69	7812.63	44.00
5	B	4585.63	7525.40	0.00	8	P	4632.78	7812.81	42.00
5	B	4585.63	7525.40	2.54	8	P	4632.78	7812.81	45.00
5	C	4610.19	7439.33	10.16	9	A	4514.21	8012.91	41.91
5	C	4602.68	7518.40	0.00	9	B	4562.64	7986.97	97.79

Cont.

Table 1 - cont.

SURFACE WATER DEPTH PANEL WETLANDS

SITE #	SITE CODE	NORTHING (m)	EASTING (m)	WATER DEPTH (cm)	SITE #	SITE CODE	NORTHING (m)	EASTING (m)	WATER DEPTH (cm)
5	D	4628.30	7500.89	50.80	9	B	4562.64	7986.97	48.26
5	D	4629.70	7501.94	48.00	9	B	4562.64	7986.97	128.00
5	D	4629.70	7501.94	51.00	9	C	4585.09	8029.67	63.50
5	D	4629.52	7501.79	48.00	9	P	4562.49	7984.88	72.00
5	D	4629.52	7501.79	55.00	9	P	4562.49	7984.88	72.00
5	D	4629.29	7501.61	48.00	9	P	4562.51	7985.08	72.00
5	D	4629.29	7501.61	48.00	9	P	4562.51	7985.08	74.00
5	E	4648.54	7488.93	0.00	9	P	4562.50	7985.31	72.00
5	F	4662.33	7482.00	0.00	9	P	4562.50	7985.31	74.00
5	F	4662.33	7482.00	0.00	10	A	4470.59	8090.15	41.91
5	F	4662.33	7482.00	0.00	10	A	4473.58	8092.07	60.96
5	F	4662.12	7481.77	0.00	10	B	4502.00	8108.35	105.00
5	F	4662.12	7481.77	0.00	10	B	4502.00	8108.35	52.00
5	F	4661.95	7481.65	0.00	10	C	4533.41	8126.56	62.23
5	F	4661.95	7481.65	1.27	10	C	4528.64	8123.99	60.96
6	A	4594.26	7618.22	10.16	11	A	4427.87	8120.24	93.98
6	B	4609.02	7611.40	8.26	11	A	4427.87	8120.24	46.99
6	C	4637.70	7597.53	15.24	11	A	4430.91	8122.49	91.44
6	D	4655.30	7585.99	27.94	11	B	4454.61	8140.31	121.29
6	D	4655.30	7585.99	38.00	11	B	4454.61	8140.31	60.96
6	E	4674.14	7574.40	0.00	11	C	4481.35	8160.37	63.50
6	F	4688.12	7570.71	27.94	11	C	4476.69	8156.42	60.96
6	F	4688.12	7570.71	35.00	12	A	4424.13	8183.01	46.99
6	G	4708.41	7561.64	0.00	12	B	4430.67	8193.18	49.53
7	A	4602.44	7711.20	33.02	12	C	4434.80	8200.88	49.53

Table 2 - Panel wetlands: tailings thickness at various locations in the basin.

PANEL WETLANDS TAILINGS THICKNESS DATA

SAMPLE SITE	EASTING (m)	NORTHING (m)	THICKNESS (m)	SAMPLE SITE	EASTING (m)	NORTHING (m)	THICKNESS (m)
T-81	7341.227	4638.334	0.51816	T-126	7670.237	4587.216	0.762
T-78	7328.77	4604.452	1.8288	T-125	7652.15	4624.328	1.524
T-77	7341.02	4577.047	1.0668	T-129	7670.292	4680.143	1.43256
T-76	7312.472	4566.538	1.0668	T-130	7654.281	4736.659	0.3048
T-80	7352.879	4621.801	1.3716	T-131	7701.406	4739.829	0.3048
T-82	7375.081	4642.634	1.0668	T-128	7695.322	4635.715	1.0668
T-79	7370.792	4590.443	0.97536	T-127	7716.823	4594.759	0.9144
T-83	7390.961	4615.135	1.524	T-132	7717.679	4695.572	0.9144
T-108	7392.787	4564.121	0.762	T-133	7734.087	4650.818	1.0668
T-85	7409.051	4648.313	2.1336	T-134	7752.106	4607.326	0.762
T-107	7400.611	4584.579	1.0668	T-139	7769.785	4701.162	0.1524
T-84	7420.511	4625.151	1.524	T-138	7785.945	4670.036	0.42672
T-110	7416.665	4537.07	0.4572	T-137	7799.844	4625.886	0.82296
T-109	7425.471	4559.534	1.6764	T-135	7769.117	4564.953	0.4572
T-86	7436.129	4598.777	2.7432	T-136	7813.484	4582.732	0.39624
T-87	7447.526	4639.4	2.8956	T-141	7851.096	4656.981	0.33528
T-88	7441.073	4662.105	0.9144	T-140	7861.95	4632.064	0.6096
T-112	7461.172	4524.957	0.4572	T-142	7867.65	4609.6	0.4572
T-111	7454.21	4562.789	1.6764	T-145	7881.668	4735.796	0.21336
T-89	7466.393	4613.425	2.7432	T-144	7900.675	4693.816	0.1524
T-91	7480.194	4650.943	2.8956	T-143	7918.436	4651.324	0.9144
T-92	7468.837	4676.357	0.762	T-151	7933.798	4583.171	0.4572
T-90	7497.568	4623.834	3.5052	T-146	7949.44	4610.201	0.3048
T-114	7477.86	4589.514	1.8288	T-148	7947.306	4724.12	0.54864
T-113	7484.8	4568.44	2.286	T-147	7980.143	4674.007	0.88392
T-115	7505.142	4545.232	0.70104	T-149	7996.766	4647.014	1.09728
T-116	7514.429	4583.96	2.286	T-150	8021.495	4693.512	0.762
T-118	7507.245	4604.284	1.2192	T-155	8027.74	4609.768	0.3048
T-94	7515.816	4667.393	2.4384	T-154	8011.427	4587.487	0.67056
T-11	7534.052	4571.378	0.18288	T-152	7982.13	4548.454	1.3716
T-119	7541.663	4601.587	2.286	T-153	7970.197	4526.088	0.36576
T-95	7536.662	4643.942	3.81	T-158	8054.819	4546.098	0.09144
T-97	7550.445	4683.459	3.048	T-156	8035.351	4513.033	0.67056
T-98	7538.56	4711.87	1.3716	T-157	8028.338	4499.839	0.24384
T-100	7561.36	4736.086	0.9144	T-161	8120.622	4530.047	0.21336
T-99	7561.478	4722.58	1.3716	T-159	8087.194	4477.347	0.27432
T-96	7564.822	4655.948	2.5908	T-160	8083.159	4466.929	0.3048
T-121	7563.277	4618.537	1.0668	T-163	8157.478	4477.844	0
T-120	7565.791	4574.661	0.3048	T-162	8139.532	4442.414	0
T-101	7583.723	4696.511	4.7244	T-164	8126.023	4414.403	0
T-102	7599.844	4669.765	1.3716	T-165	8173.261	4418.826	0
T-123	7593.071	4629.43	1.73736	T-166	8192.942	4441.887	0
T-122	7591.059	4588.392	0.9144	T-167	8201.049	4402.062	0
T-106	7616.129	4737.445	0.762	T-168	8207.923	4416.881	0
T-105	7620.25	4709.718	3.81	T-172	8199.144	4377.282	0
T-103	7630.013	4680.661	3.048	T-169	8152.653	4373.118	0
T-104	7637.544	4649.587	3.6576	T-171	8119.18	4353.809	0
T-124	7618.973	4599.77	1.43256	T-170	8149.645	4317.309	0

Table 3 - Panel wetlands: surface water quality, 1990.

LOCATION	DATE	SITE #	1	2	NORTHING (m)	EASTING (m)	ABOVE M.S.L. GROUND OR TOP_P_ELEV (m)	ABOVE M.S.L. GROUND ELEV. (m)	Field F_pH pH	LAB. L_pH pH	LAB. EH (mV)	LAB. EH(NHE) (mV)	Field F_Ec Ec
Hold Pond	14-Aug-90	1		S	4495.80	7254.24	380.79	380.79	3.0	3.10	457	701	3000
Toe of A	14-Aug-90	1	P	W	4495.80	7330.44	370.42	370.42	5.7	N.A.	N.A.	N.A.	705
Surface	14-Aug-90	2	A	S	4567.06	7328.01	371.10	371.10	DRY				
Surface	14-Aug-90	2	B	S	4572.50	7323.67	370.92	370.92	6.8	7.86	300	544	1170
Surface	14-Aug-90	2	C	S	4575.74	7321.66	370.82	370.82	DRY				
50m E. toe of A	14-Aug-90	2	P	W	4511.04	7330.44	368.90	368.90	6.5	N.A.	N.A.	N.A.	1063
Surface	14-Aug-90	3	A	S	4586.86	7368.13	370.62	370.62	DRY				
Surface	14-Aug-90	3	B	S	4602.41	7359.07	370.35	370.35	7.2	7.97	270	514	1272
Surface	14-Aug-90	3	C	S	4631.31	7344.80	370.66	370.66	DRY				
Surface	21-Aug-90	4	B	S	4577.26	7461.90	370.01	370.01	7.2	N.A.	N.A.	N.A.	555
Surface	26-Oct-90	4	B	S	4577.26	7461.90	370.01	370.01	4.9	N.A.	N.A.	N.A.	420
Surface	21-Aug-90	5	A	S	4569.65	7536.20	369.92	369.92	6.9	N.A.	N.A.	N.A.	550
Surface	21-Aug-90	5	B	S	4586.92	7524.96	370.00	370.00	6.8	N.A.	N.A.	N.A.	570
Surface	26-Oct-90	5	B	S	4586.92	7524.96	370.00	370.00	4.9	N.A.	N.A.	N.A.	407
Surface	21-Aug-90	5	C	S	4602.68	7518.40	369.80	369.80	6.9	N.A.	N.A.	N.A.	555
Surface	21-Aug-90	6	A	S	4594.26	7618.22	369.87	369.87	6.3	6.97	4	248	369
Surface	21-Aug-90	6	B	S	4609.02	7611.40	369.87	369.87	6.5	7.24	149	393	541
Surface	26-Oct-90	6	B	S	4609.02	7611.40	369.87	369.87	5.0	N.A.	N.A.	N.A.	420
Surface	21-Aug-90	6	C	S	4637.70	7597.53	369.81	369.81	4.6	4.16	355	599	405
Surface	21-Aug-90	7	D	S	4649.48	7707.09	369.74	369.74	8.8	N.A.	N.A.	N.A.	268
Surface	29-Aug-90	7	D	S	4649.48	7707.09	369.74	369.74	9.0	8.92	159	403	294
Surface	26-Oct-90	7	D	S	4649.48	7707.09	369.74	369.74	5.8	N.A.	N.A.	N.A.	366
Surface	21-Aug-90	8	A	S	4618.96	7851.34	369.52	369.52	7.4	7.74	218	462	255
Surface	21-Aug-90	8	B	S	4633.70	7812.24	369.59	369.59	7.4	7.83	210	454	251
Surface	21-Aug-90	8	C	S	4656.27	7845.53	369.58	369.58	6.5	7.15	210	454	217
Surface	21-Aug-90	9	B	S	4562.64	7986.97	369.26	369.26	8.6	N.A	N.A.	N.A.	222
Surface	26-Oct-90	9	B	S	4562.64	7986.97	369.26	369.26	6.5	8.35	156	400	185

Cont.

Table 3 - cont.

LOCATION	DATE	SITE #	1	2	LAB. L_EC Ec	Field F_T(C) Temp.(C)	ACIDITY (mg/L)	ALKALINITY (mg/L)	Fe TOTAL (mg/L)	Cu (mg/L)	Zn (mg/L)	Ca (mg/L)	Mg (mg/L)	Pb (mg/L)	Th (mg/L)
Hold Pond	14-Aug-90	1		S	3150	19.7	229.1	0.0	12.70	0.064	0.806	519.0	86.7	0.576	0.400
Toe of A	14-Aug-90	1	P	W	N.A.	17.7	N.A.	N.A.							
Surface	14-Aug-90	2	A	S											
Surface	14-Aug-90	2	B	S	1390	17.7	0.0	117.7	0.01	<0.002	0.012	323.1	22.9	0.071	<0.015
Surface	14-Aug-90	2	C	S											
50m E. toe of A	14-Aug-90	2	P	W	N.A.	16.7	N.A.	N.A.							
Surface	14-Aug-90	3	A	S											
Surface	14-Aug-90	3	B	S	1540	18.6	0.0	176.6	0.01	<0.002	0.009	400.0	28.9	<0.025	<0.015
Surface	14-Aug-90	3	C	S											
Surface	21-Aug-90	4	B	S	N.A.	19.9	N.A.	N.A.							
Surface	26-Oct-90	4	B	S	N.A.	12.8	N.A.	N.A.							
Surface	21-Aug-90	5	A	S	N.A.	19.9	N.A.	N.A.							
Surface	21-Aug-90	5	B	S	N.A.	21.6	N.A.	N.A.							
Surface	26-Oct-90	5	B	S	N.A.	12.8	N.A.	N.A.							
Surface	21-Aug-90	5	C	S	N.A.	20.1	N.A.	N.A.							
Surface	21-Aug-90	6	A	S	N.A.	18.6	0.0	71.1	0.62	0.022	0.015	79.7	1.6	<0.025	<0.015
Surface	21-Aug-90	6	B	S	N.A.	15.3	N.A.	N.A.	0.05	<0.002	0.032	130.2	5.7	<0.025	<0.015
Surface	26-Oct-90	6	B	S	N.A.	12.8	N.A.	N.A.							
Surface	21-Aug-90	6	C	S	N.A.	22.4	18.5	0.0	0.93	<0.002	0.015	86.6	1.1	<0.025	<0.015
Surface	21-Aug-90	7	D	S	N.A.	23.6	N.A.	N.A.							
Surface	29-Aug-90	7	D	S	293	23.3	0.0	30.5	0.09	0.022	0.002	57.6	2.4	<0.025	<0.015
Surface	26-Oct-90	7	D	S	N.A.	7.2	N.A.	N.A.							
Surface	21-Aug-90	8	A	S	N.A.	23.6	0.0	47.7	0.09	0.079	0.017	53.3	1.9	<0.025	<0.015
Surface	21-Aug-90	8	B	S	N.A.	24.3	0.0	46.7	0.05	0.028	0.002	49.8	1.7	<0.025	<0.015
Surface	21-Aug-90	8	C	S	N.A.	22.1	0.0	59.9	0.39	0.225	0.005	46.9	1.6	<0.025	<0.015
Surface	21-Aug-90	9	B	S	N.A.	22.9	N.A.	N.A.							
Surface	26-Oct-90	9	B	S	218	7.2	0.0	33.5							

Cont.

Table 3 - cont.

LOCATION	DATE	SITE #	1	2	Al (mg/L)	Mn (mg/L)	U (mg/L)	Ni (mg/L)	Ra-226 (mBq/L)	Ra-226 (pCi/L)	SULPHATE (mg/L)
Hold Pond	14-Aug-90	1		S	12.270	3.663	0.862	0.288	7642	206.5	2085
Toe of A	14-Aug-90	1	P	W					N.A.	N.A.	N.A.
Surface	14-Aug-90	2	A	S					N.A.	N.A.	N.A.
Surface	14-Aug-90	2	B	S	<0.030	0.225	<0.100	<0.005	360	9.7	841
Surface	14-Aug-90	2	C	S					N.A.	N.A.	N.A.
50m E. toe of A	14-Aug-90	2	P	W					N.A.	N.A.	N.A.
Surface	14-Aug-90	3	A	S					N.A.	N.A.	N.A.
Surface	14-Aug-90	3	B	S	0.164	0.376	<0.100	<0.005	453	12.2	972
Surface	14-Aug-90	3	C	S					N.A.	N.A.	N.A.
Surface	21-Aug-90	4	B	S					N.A.	N.A.	N.A.
Surface	26-Oct-90	4	B	S					N.A.	N.A.	N.A.
Surface	21-Aug-90	5	A	S					N.A.	N.A.	N.A.
Surface	21-Aug-90	5	B	S					N.A.	N.A.	N.A.
Surface	26-Oct-90	5	B	S					N.A.	N.A.	N.A.
Surface	21-Aug-90	5	C	S					N.A.	N.A.	N.A.
Surface	21-Aug-90	6	A	S	<0.030	0.117	<0.100	<0.005	376	10.2	114
Surface	21-Aug-90	6	B	S	<0.030	0.013	<0.100	<0.005	457	12.4	330
Surface	26-Oct-90	6	B	S					N.A.	N.A.	N.A.
Surface	21-Aug-90	6	C	S	<0.030	0.035	<0.100	<0.005	1450	39.2	208
Surface	21-Aug-90	7	D	S					N.A.	N.A.	N.A.
Surface	29-Aug-90	7	D	S	<0.030	<0.002	<0.100	<0.005	789	21.3	118
Surface	26-Oct-90	7	D	S					N.A.	N.A.	N.A.
Surface	21-Aug-90	8	A	S	<0.030	<0.002	<0.100	<0.005	1025	27.7	77
Surface	21-Aug-90	8	B	S	<0.030	<0.002	<0.100	<0.005	912	24.7	78
Surface	21-Aug-90	8	C	S	<0.030	0.041	<0.100	0.018	891	24.1	65
Surface	21-Aug-90	9	B	S					N.A.	N.A.	N.A.
Surface	26-Oct-90	9	B	S					N.A.	N.A.	N.A.

Table 4 - Panel wetlands: surface water quality, spring 1991.

LOCATION	DATE	SITE #	1	2	NORTHING (m)	EASTING (m)	ABOVE M.S.L GROUND OR TOP_P_ELEV (m)	ABOVE M.S.L. GROUND ELEV. (m)	Field F_pH pH	LAB. L_pH pH	LAB. EH (mV)	LAB. EH(NHE) (mV)	Field F_Ec Ec	LAB. L_Ec Ec
Falls	4-Jun-91	Pnl_falls		S	4480.56	8229.60	375.00	375.00	7.4	7.01	225	469	38	37
Hold Pond	4-Jun-91	1		S	4550.99	7303.76	371.10	371.10	3.4				1982	
Surface	5-Jun-91	1		S	4550.99	7303.76	371.10	371.10	6.4	6.81	-134	110	1138	1069
Surface	4-Jun-91	2	A	S	4567.06	7328.01	371.10	371.10	DRY				DRY	
Surface	5-Jun-91	2	B	S	4572.50	7323.67	370.92	370.92	6.9	7.14	194	438	1664	1787
Surface	5-Jun-91	2	C	S	4575.74	7321.66	370.82	370.82	6.3	7.34	66	310	1493	1574
Surface	4-Jun-91	3	A	S	4586.86	7368.13	370.62	370.62	*N.S.S.				*N.S.S.	
Surface	5-Jun-91	3	B	S	4602.41	7359.07	370.35	370.35	6.6	7.29	106	350	1892	2020
Surface	5-Jun-91	3	C	S	4631.31	7344.80	370.66	370.66	5.4	4.90	314	558	176	190
Surface	24-May-91	4	A	S	4531.58	7501.49	369.51	369.51	6.3	6.55	228	472	705	736
Surface	22-May-91	4	B	S	4577.26	7461.90	370.01	370.01	3.6	3.36	388	632	1168	1193
Surface	24-May-91	4	C	S	4610.19	7439.33	369.92	369.92	3.4	3.31	446	690	587	555
Surface	22-May-91	4	D	S	4646.94	7421.03	370.56	370.56	DRY				DRY	
Surface	22-May-91	5	A	S	4569.65	7536.20	369.92	369.92	5.5	4.17	293	537	684	627
Surface	22-May-91	5	B	S	4586.92	7524.96	370.00	370.00	4.2	3.74	359	603	1269	1252
Surface	22-May-91	5	C	S	4602.68	7518.40	369.80	369.80	6.2	6.80	271	515	501	478
Surface	5-Jun-91	5	D	S	4628.30	7500.89	369.64	369.64	6.9	7.21	239	483	492	539
Mid-Depth	4-Jun-91	5	D	M	4628.30	7500.89	369.64	369.64	6.1	7.36	245	489	490	504
Surface	5-Jun-91	5	E	S	4648.54	7488.93	369.61	369.61	6.9	7.23	239	483	488	554
Comb	5-Jun-91	5	E	M	4648.54	7488.93	369.61	369.61	6.4	7.50	231	475	498	509
Surface	5-Jun-91	5	F	S	4661.79	7481.20	369.79	369.79	6.7	6.97	238	482	496	269
Surface	5-Jun-91	5	G	S					3.7	3.53	402	646	781	830
Surface	24-May-91	6	A	S	4594.26	7618.22	369.87	369.87	4.5	4.32	345	589	202	198
Surface	24-May-91	6	B	S	4608.89	7611.40	369.87	369.87	7.0	7.39	245	489	316	318
Surface	24-May-91	6	C	S	4637.70	7597.53	369.81	369.81	6.7	7.15	253	497	437	417
Surface	24-May-91	6	D	S	4655.30	7585.99	369.81	369.81	6.7	7.05	262	506	493	467
Mid-Depth	4-Jun-91	6	D	M	4655.30	7585.99	369.81	369.81	6.5	7.63	234	478	491	556
Surface	24-May-91	6	E	S	4674.14	7574.40	369.78	369.78	6.8	7.50	257	501	493	471
Mid-Depth	4-Jun-91	6	E	M	4674.14	7574.40	369.78	369.78	6.5	7.57	227	471	485	550
Surface	24-May-91	6	F	S	4688.12	7570.71	369.64	369.64	6.8	7.12	268	512	494	467
Mid-Depth	4-Jun-91	6	F	M	4688.12	7570.71	369.64	369.64	6.6	7.59	251	495	491	547
Surface	24-May-91	6	G	S	4708.41	7561.64	369.98	369.98	5.1	5.02	371	615	186	179

Cont.

Table 4 - cont.

LOCATION	DATE	SITE #	1	2	NORTHING (m)	EASTING (m)	ABOVE M.S.L GROUND OR TOP_P_ELEV (m)	ABOVE M.S.L. GROUND ELEV. (m)	Field F_pH pH	LAB. L_pH pH	LAB. EH (mV)	LAB. EH(NHE) (mV)	Field F_Ec Ec	LAB. L_Ec Ec
Surface	24-May-91	7	A	S	4602.44	7711.20	369.61	369.61	7.1	7.42	267	511	280	272
Surface	24-May-91	7	B	S	4613.92	7708.89	369.63	369.63	6.9	7.37	266	510	295	269
Mid-Depth	4-Jun-91	7	B	M	4613.92	7708.89	369.63	369.63	7.0	7.62	256	500	244	226
Surface	24-May-91	7	C	S	4625.68	7707.25	369.61	369.61	6.9	7.27	264	508	276	267
Mid-Depth	4-Jun-91	7	C	M	4625.68	7707.25	369.61	369.61	7.1	7.62	256	500	263	245
Surface	24-May-91	7	D	S	4649.48	7707.09	369.74	369.74	6.6	7.74	198	442	250	244
Surface	24-May-91	7	E	S	4674.90	7704.24	360.61	360.61	6.8	7.49	213	457	261	254
Surface	24-May-91	7	F	S	4696.36	7702.26	369.72	369.72	6.8	7.39	225	469	262	255
Surface	24-May-91	7	G	S	4723.97	7699.11	369.79	369.79	4.4	4.38	361	605	332	324
Surface	5-Jun-91	7	H	S					6.4	6.79	288	532	167	154
Surface	5-Jun-91	7	I	S					6.7	7.42	262	506	227	211
Surface	5-Jun-91	7	J	S					6.8	7.57	225	469	222	251
Mid-Depth	4-Jun-91	7	J	M					7.1	7.82	231	475	233	249
Surface	5-Jun-91	7	K	S					6.8	7.74	227	471	219	244
Mid-Depth	4-Jun-91	7	K	M					7.1	7.71	225	469	226	242
Surface	5-Jun-91	7	L	S					6.8	7.62	231	475	212	237
Mid-Depth	4-Jun-91	7	L	M					7.0	7.57	236	480	236	480
Surface	5-Jun-91	7	M	S	4657.17	7777.54	369.69	369.69	6.3	7.37	247	491	234	252
Mid-Depth	4-Jun-91	7	M	M	4657.17	7777.54	369.69	369.69	6.8	7.29	245	489	245	250
Surface	5-Jun-91	7	N	S	4664.51	7780.62	369.75	369.75	7.5	7.10	241	485	237	256
Surface	22-May-91	8	A	S	4618.96	7851.34	360.38	360.38	6.7	6.68	N.A.	N.A.	156	156
Surface	22-May-91	8	B	S	4633.70	7804.01	369.59	369.59	7.1	7.10	N.A.	N.A.	166	166
Mid-Depth	4-Jun-91	8	B	M	4633.70	7804.01	369.59	369.59	7.0	7.56	246	490	222	222
Surface	22-May-91	8	C	S	4656.27	7845.54	369.58	369.58	6.2	6.16	N.A.	N.A.	173	173
Mid-Depth	22-May-91	8	C	M	4656.27	7845.54	369.58	369.58	6.2	N.A.	N.A.	N.A.	173	N.A.
Surface	22-May-91	8	D	S	4612.40	7941.93	369.51	369.51	7.2	7.16	N.A.	N.A.	156	156
Mid-Depth	4-Jun-91	8	D	M	4612.40	7941.93	369.51	369.51	7.1	7.74	243	487	211	204
Surface	22-May-91	8	E	S	4652.16	7956.42	369.51	369.51	7.2	7.20	N.A.	N.A.	157	157
Mid-Depth	4-Jun-91	8	E	M	4652.16	7956.42	369.51	369.51	7.2	7.89	247	491	209	204
Surface	22-May-91	8	F	S	4694.66	7970.92	369.36	369.36	7.3	7.32	N.A.	N.A.	158	158
Mid-Depth	4-Jun-91	8	F	M	4694.66	7970.92	369.36	369.36	7.4	7.82	239	483	204	198
Surface	22-May-91	9	A	S	4514.21	8012.91	369.58	369.58	7.1	N.A.	N.A.	N.A.	155	155

Cont.

Table 4 - cont.

LOCATION	DATE	SITE #	1	2	NORTHING (m)	EASTING (m)	ABOVE M.S.L GROUND OR TOP_P_ELEV (m)	ABOVE M.S.L. GROUND ELEV. (m)	Field F_pH pH	LAB. L_pH pH	LAB. EH (mV)	LAB. EH(NHE) (mV)	Field F_Ec Ec	LAB. L_Ec Ec
Mid-Depth	4-Jun-91	9	A	M	4514.21	8012.91	369.58	369.58	8.4	8.19	179	423	269	211
Surface	22-May-91	9	B	S	4562.64	7986.97	369.36	369.36	7.2	7.18	N.A.	N.A.	153	153
Mid-Depth	4-Jun-91	9	B	M	4562.64	7986.97	369.36	369.36	8.7	8.61	147	391	212	206
Surface	22-May-91	9	C	S	4585.09	8029.67	369.36	369.36	7.0	7.04	N.A.	N.A.	153	153
Mid-Depth	4-Jun-91	9	C	M	4585.09	8029.67	369.36	369.36	8.6	8.33	157	401	211	210
Surface	4-Jun-91	10	A	S	4470.59	8090.15	369.26	369.26	7.6	8.35	152	396	186	210
Mid-Depth	4-Jun-91	10	A	M	4470.59	8090.15	369.26	369.26	8.8	8.60	150	394	203	201
Surface	4-Jun-91	10	B	S	4502.00	8108.35	369.26	369.26	7.9	8.52	144	388	185	207
Mid-Depth	4-Jun-91	10	B	M	4502.00	8108.35	369.26	369.26	8.1	8.29	155	399	209	205
Surface	4-Jun-91	10	C	S	4533.41	8126.56	369.35	369.35	7.7	8.31	160	404	155	211
Mid-Depth	4-Jun-91	10	C	M	4533.41	8126.56	369.35	369.35	8.3	8.11	167	207	208	207
Surface	22-May-91	11	A	S	4427.87	8120.24	369.26	369.26	6.1	7.35	N.A.	N.A.	157	157
Mid-Depth	4-Jun-91	11	A	M	4427.87	8120.24	369.26	369.26	7.7	7.82	190	434	209	206
Surface	22-May-91	11	B	S	4454.61	8140.31	369.26	369.26	7.1	7.39	230	474	152	152
Mid-Depth	4-Jun-91	11	B	M	4454.61	8140.31	369.26	369.26	7.9	7.91	183	427	210	208
Surface	22-May-91	11	C	S	4481.35	8160.37	369.30	369.30	7.0	7.53	166	410	154	154
Mid-Depth	4-Jun-91	11	C	M	4481.35	8160.37	369.30	369.30	8.5	8.10	167	411	213	207
Surface	22-May-91	12	A	S	4424.13	8183.01	369.40	369.40	7.4	7.74	223	467	154	154
Mid-Depth	4-Jun-91	12	A	M	4424.13	8183.01	369.40	369.40	8.1	7.90	184	428	212	205
Surface	22-May-91	12	B	S	4430.67	8193.18	369.44	369.44	7.2	7.70	161	405	155	155
Mid-Depth	4-Jun-91	12	B	M	4430.67	8193.18	369.44	369.44	8.1	7.92	185	429	213	208
Surface	22-May-91	12	C	S	4434.80	8200.88	369.47	369.47	7.4	7.53	178	422	160	160
Mid-Depth	4-Jun-91	12	C	M	4434.80	8200.88	369.47	369.47	8.0	7.87	189	433	217	209

Cont.

Table 4 - cont.

LOCATION	DATE	SITE #	1	2	Field F_T(C) Temp.(C)	Fe TOTAL (mg/L)	Cu (mg/L)	Zn (mg/L)	Ca (mg/L)	Mg (mg/L)	Pb (mg/L)	Th (mg/L)	Al (mg/L)	Mn (mg/L)	U (mg/L)	Ni (mg/L)
Falls	4-Jun-91	Pnl_falls		S	26.3	0.02	<0.002	<0.002	2.9	0.5	<0.025	<0.015	<0.030	<0.002	<0.100	<0.005
Hold Pond	4-Jun-91	1		S	22.7											
Surface	5-Jun-91	1		S	20.5	26.89	0.003	<0.002	137.7	11.3	<0.025	<0.015	<0.030	3.693	<0.100	<0.005
Surface	4-Jun-91	2	A	S	DRY											
Surface	5-Jun-91	2	B	S	23.2	2.13	0.003	0.024	351.8	19.5	<0.025	<0.015	<0.030	8.209	<0.100	0.009
Surface	5-Jun-91	2	C	S	23.1	16.56	0.010	<0.002	311.0	17.7	<0.025	<0.015	<0.030	4.052	<0.100	0.008
Surface	4-Jun-91	3	A	S	*N.S.S.											
Surface	5-Jun-91	3	B	S	23.3	1.35	0.007	<0.002	443.0	24.2	0.003	<0.015	<0.030	3.868	<0.100	0.010
Surface	5-Jun-91	3	C	S	22.4	11.90	0.020	<0.002	18.3	0.8	<0.025	<0.015	<0.030	<0.002	<0.100	<0.005
Surface	24-May-91	4	A	S	22.6	0.20	0.004	0.011	110.2	5.2	<0.025	<0.015	<0.030	0.244	<0.100	<0.005
Surface	22-May-91	4	B	S	24.6	38.37	0.068	0.107	160.4	6.0	0.095	<0.015	0.949	0.601	<0.100	0.043
Surface	24-May-91	4	C	S	27.1	2.33	0.008	0.011	43.2	0.9	0.081	<0.015	<0.030	<0.002	<0.100	<0.005
Surface	22-May-91	4	D	S	DRY											
Surface	22-May-91	5	A	S	28.8	13.91	0.009	0.023	93.4	0.5	0.050	<0.015	0.318	<0.002	<0.100	0.006
Surface	22-May-91	5	B	S	26.2	12.66	0.008	0.018	209.5	1.7	0.091	<0.015	0.137	0.040	<0.100	<0.005
Surface	22-May-91	5	C	S	26.4	0.01	0.004	<0.002	70.3	2.8	<0.025	<0.015	<0.030	<0.002	<0.100	<0.005
Surface	5-Jun-91	5	D	S	21.2	<0.002	0.006	<0.002	88.6	3.4	<0.025	<0.015	<0.030	<0.002	<0.100	<0.005
Mid-Depth	4-Jun-91	5	D	M	21.0	<0.002	<0.002	<0.002	87.6	3.5	<0.025	<0.015	<0.030	<0.002	<0.100	<0.005
Surface	5-Jun-91	5	E	S	21.0	<0.002	0.004	<0.002	85.4	3.3	<0.025	<0.015	<0.030	<0.002	<0.100	<0.005
Comb	5-Jun-91	5	E	M	21.6	<0.002	<0.002	<0.002	86.0	3.5	<0.025	<0.015	<0.030	<0.002	<0.100	<0.005
Surface	5-Jun-91	5	F	S	21.0	<0.002	0.012	0.110	89.1	3.4	<0.025	<0.015	<0.030	<0.002	<0.100	0.181
Surface	5-Jun-91	5	G	S	19.9	6.25	0.020	0.004	135.9	2.9	0.047	<0.015	<0.030	<0.002	<0.100	<0.005
Surface	24-May-91	6	A	S	26.2	1.07	0.007	0.009	23.6	0.4	<0.025	<0.015	<0.030	<0.002	<0.100	<0.005
Surface	24-May-91	6	B	S	25.1	<0.002	<0.002	<0.002	49.6	1.5	<0.025	<0.015	<0.030	<0.002	<0.100	<0.005
Surface	24-May-91	6	C	S	26.7	0.32	<0.002	<0.002	71.2	2.4	<0.025	<0.015	<0.030	<0.002	<0.100	<0.005
Surface	24-May-91	6	D	S	27.4	<0.002	<0.002	<0.002	78.4	2.9	<0.025	<0.015	<0.030	<0.002	<0.100	<0.005
Mid-Depth	4-Jun-91	6	D	M	21.2	<0.002	0.016	<0.002	84.4	3.4	<0.025	<0.015	<0.030	<0.002	<0.100	<0.005
Surface	24-May-91	6	E	S	27.3	<0.002	<0.002	<0.002	79.6	2.8	<0.025	<0.015	<0.030	<0.002	<0.100	<0.005
Mid-Depth	4-Jun-91	6	E	M	20.8	<0.002	<0.002	<0.002	85.7	3.6	<0.025	<0.015	<0.030	<0.002	<0.100	<0.005
Surface	24-May-91	6	F	S	27.5	<0.002	<0.002	<0.002	78.2	2.8	<0.025	<0.015	<0.030	<0.002	<0.100	<0.005
Mid-Depth	4-Jun-91	6	F	M	20.5	<0.002	0.058	<0.002	83.7	3.5	<0.025	<0.015	<0.030	<0.002	<0.100	<0.005
Surface	24-May-91	6	G	S	26.2	0.00	0.006	<0.002	23.1	1.7	0.006	<0.015	<0.030	<0.002	<0.100	<0.005

Cont.

Table 4 - cont.

LOCATION	DATE	SITE #	1	2	Field F_T(C) Temp.(C)	Fe TOTAL (mg/L)	Cu (mg/L)	Zn (mg/L)	Ca (mg/L)	Mg (mg/L)	Pb (mg/L)	Th (mg/L)	Al (mg/L)	Mn (mg/L)	U (mg/L)	Ni (mg/L)
Surface	24-May-91	7	A	S	25.1	<0.002	<0.002	<0.002	43.3	1.3	<0.025	<0.015	<0.030	<0.002	<0.100	<0.005
Surface	24-May-91	7	B	S	25.4	0.20	<0.002	<0.002	48.0	1.4	<0.025	<0.015	<0.030	<0.002	<0.100	<0.005
Mid-Depth	4-Jun-91	7	B	M	22.2	0.03	0.004	<0.002	38.9	1.4	<0.025	<0.015	0.211	<0.002	<0.100	<0.005
Surface	24-May-91	7	C	S	25.3	<0.002	<0.002	<0.002	42.4	1.2	<0.025	<0.015	<0.030	<0.002	<0.100	<0.005
Mid-Depth	4-Jun-91	7	C	M	22.1	0.02	<0.002	<0.002	44.2	1.6	0.027	<0.015	<0.030	<0.002	<0.100	<0.005
Surface	24-May-91	7	D	S	25.6	<0.002	<0.002	<0.002	38.5	1.0	0.003	<0.015	<0.030	<0.002	<0.100	<0.005
Surface	24-May-91	7	E	S	25.6	<0.002	<0.002	<0.002	41.9	1.2	<0.025	<0.015	<0.030	<0.002	<0.100	<0.005
Surface	24-May-91	7	F	S	25.5	<0.002	0.002	<0.002	39.2	1.2	0.003	<0.015	<0.030	<0.002	<0.100	<0.005
Surface	24-May-91	7	G	S	25.7	<0.002	0.002	<0.002	39.1	0.8	0.003	<0.015	<0.030	<0.002	<0.100	<0.005
Surface	5-Jun-91	7	H	S	22.2	0.04	0.027	<0.002	25.7	0.8	<0.025	<0.015	<0.030	<0.002	<0.100	<0.005
Surface	5-Jun-91	7	I	S	21.2	0.04	0.036	0.016	38.2	1.1	<0.025	<0.015	<0.030	<0.002	<0.100	<0.005
Surface	5-Jun-91	7	J	S	20.8	0.05	0.007	<0.002	37.8	1.1	<0.025	<0.015	<0.030	<0.002	<0.100	<0.005
Mid-Depth	4-Jun-91	7	J	M	22.5	0.04	0.022	<0.002	38.5	1.3	<0.025	<0.015	<0.030	<0.002	<0.100	<0.005
Surface	5-Jun-91	7	K	S	20.9	0.07	0.398	0.013	36.7	1.1	<0.025	<0.015	<0.030	<0.002	<0.100	0.013
Mid-Depth	4-Jun-91	7	K	M	23.0	0.05	0.013	<0.002	37.3	1.3	0.003	<0.015	<0.030	<0.002	<0.100	<0.005
Surface	5-Jun-91	7	L	S	20.7	0.17	0.073	<0.002	36.1	1.1	<0.025	<0.015	<0.030	<0.002	<0.100	<0.005
Mid-Depth	4-Jun-91	7	L	M	23.0	0.03	0.063	<0.002	36.5	1.3	<0.025	<0.015	<0.030	<0.002	<0.100	<0.005
Surface	5-Jun-91	7	M	S	21.7	0.01	0.080	<0.002	41.3	1.1	<0.025	<0.015	<0.030	<0.002	<0.100	<0.005
Mid-Depth	4-Jun-91	7	M	M	24.2	<0.002	0.065	0.012	40.1	1.2	<0.025	<0.015	<0.030	<0.002	<0.100	0.044
Surface	5-Jun-91	7	N	S	21.7	<0.002	0.064	<0.002	42.2	1.3	<0.025	<0.015	<0.030	<0.002	<0.100	<0.005
Surface	22-May-91	8	A	S	25.5	0.08	<0.002	<0.002	28.3	0.9	<0.025	<0.015	<0.030	<0.002	<0.100	<0.005
Surface	22-May-91	8	B	S	24.5	0.04	<0.002	<0.002	30.4	0.9	<0.025	<0.015	<0.030	<0.002	<0.100	<0.005
Mid-Depth	4-Jun-91	8	B	M	23.0	0.05	0.004	<0.002	36.6	1.3	<0.025	<0.015	<0.030	<0.002	<0.100	<0.005
Surface	22-May-91	8	C	S	26.0	0.05	0.002	<0.002	30.1	0.9	<0.025	<0.015	<0.030	<0.002	<0.100	<0.005
Mid-Depth	22-May-91	8	C	M	N.A.											
Surface	22-May-91	8	D	S	N.A.	0.05	<0.002	<0.002	29.2	0.8	<0.025	<0.015	<0.030	<0.002	<0.100	<0.005
Mid-Depth	4-Jun-91	8	D	M	23.2	0.08	0.002	<0.002	34.7	1.2	<0.025	<0.015	<0.030	0.006	<0.100	<0.005
Surface	22-May-91	8	E	S	26.0	0.03	<0.002	<0.002	29.0	0.9	<0.025	<0.015	<0.030	<0.002	<0.100	<0.005
Mid-Depth	4-Jun-91	8	E	M	22.9	0.07	0.003	<0.002	34.3	1.1	<0.025	<0.015	<0.030	<0.002	<0.100	<0.005
Surface	22-May-91	8	F	S	26.0	0.03	<0.002	<0.002	28.6	0.9	<0.025	<0.015	<0.030	<0.002	<0.100	<0.005
Mid-Depth	4-Jun-91	8	F	M	23.0	0.08	<0.002	<0.002	33.4	1.1	<0.025	<0.015	<0.030	<0.002	<0.100	<0.005
Surface	22-May-91	9	A	S	26.9	0.02	<0.002	<0.002	26.8	0.8	<0.025	<0.015	<0.030	<0.002	<0.100	<0.005

Cont.

Table 4 - cont.

LOCATION	DATE	SITE #	1	2	Field F_T(C) Temp.(C)	Fe TOTAL (mg/L)	Cu (mg/L)	Zn (mg/L)	Ca (mg/L)	Mg (mg/L)	Pb (mg/L)	Th (mg/L)	Al (mg/L)	Mn (mg/L)	U (mg/L)	Ni (mg/L)
Mid-Depth	4-Jun-91	9	A	M	23.6	<0.002	0.003	<0.002	31.1	1.1	<0.025	<0.015	<0.030	<0.002	<0.100	<0.005
Surface	22-May-91	9	B	S	25.3	0.02	<0.002	<0.002	27.7	0.8	<0.025	<0.015	<0.030	<0.002	<0.100	<0.005
Mid-Depth	4-Jun-91	9	B	M	22.8	0.00	<0.002	<0.002	30.3	1.0	<0.025	<0.015	<0.030	<0.002	<0.100	<0.005
Surface	22-May-91	9	C	S	25.2	0.03	0.007	0.002	26.9	0.8	<0.025	<0.015	<0.030	<0.002	<0.100	<0.005
Mid-Depth	4-Jun-91	9	C	M	22.4	0.01	<0.002	<0.002	30.7	1.1	<0.025	<0.015	<0.030	<0.002	<0.100	<0.005
Surface	4-Jun-91	10	A	S	26.4	0.01	<0.002	<0.002	27.4	0.8	<0.025	<0.015	<0.030	<0.002	<0.100	<0.005
Mid-Depth	4-Jun-91	10	A	M	21.8	<0.002	0.002	<0.002	29.8	1.1	<0.025	<0.015	<0.030	<0.002	<0.100	<0.005
Surface	4-Jun-91	10	B	S	26.3	0.02	<0.002	<0.002	27.3	0.8	<0.025	<0.015	<0.030	<0.002	<0.100	<0.005
Mid-Depth	4-Jun-91	10	B	M	23.6	<0.002	<0.002	<0.002	30.5	1.1	<0.025	<0.015	<0.030	<0.002	<0.100	<0.005
Surface	4-Jun-91	10	C	S	25.7	0.01	<0.002	<0.002	28.1	0.9	<0.025	<0.015	<0.030	<0.002	<0.100	<0.005
Mid-Depth	4-Jun-91	10	C	M	22.9	<0.002	0.002	<0.002	29.9	1.1	<0.025	<0.015	<0.030	<0.002	<0.100	<0.005
Surface	22-May-91	11	A	S	22.5	0.01	0.003	<0.002	27.7	0.9	<0.025	<0.015	<0.030	<0.002	<0.100	<0.005
Mid-Depth	4-Jun-91	11	A	M	24.1	0.03	0.003	<0.002	28.7	1.0	<0.025	<0.015	<0.030	<0.002	<0.100	<0.005
Surface	22-May-91	11	B	S	23.0	0.02	<0.002	<0.002	27.5	0.8	0.003	<0.015	<0.030	<0.002	<0.100	<0.005
Mid-Depth	4-Jun-91	11	B	M	24.3	0.04	0.002	<0.002	30.3	1.0	<0.025	<0.015	<0.030	<0.002	<0.100	0.009
Surface	22-May-91	11	C	S	27.4	0.01	0.004	<0.002	27.2	0.8	<0.025	<0.015	<0.030	<0.002	<0.100	<0.005
Mid-Depth	4-Jun-91	11	C	M	24.6	0.00	0.002	<0.002	29.0	1.0	<0.025	<0.015	<0.030	<0.002	<0.100	<0.005
Surface	22-May-91	12	A	S	26.8	0.04	0.004	<0.002	26.4	0.8	<0.025	<0.015	<0.030	<0.002	<0.100	<0.005
Mid-Depth	4-Jun-91	12	A	M	24.1	0.01	<0.002	<0.002	29.3	1.0	<0.025	<0.015	<0.030	<0.002	<0.100	<0.005
Surface	22-May-91	12	B	S	30.0	0.02	0.006	<0.002	26.9	0.8	<0.025	<0.015	<0.030	<0.002	<0.100	<0.005
Mid-Depth	4-Jun-91	12	B	M	24.7	0.01	<0.002	<0.002	28.9	1.0	<0.025	<0.015	<0.030	<0.002	<0.100	<0.005
Surface	22-May-91	12	C	S	28.1	0.03	0.003	<0.002	26.5	0.5	<0.025	<0.015	<0.030	<0.002	<0.100	<0.005
Mid-Depth	4-Jun-91	12	C	M	25.2	<0.002	<0.002	<0.002	30.3	1.1	<0.025	<0.015	<0.030	<0.002	<0.100	<0.005

Cont.

Table 4 - cont.

LOCATION	DATE	SITE #	1	2	Ra-226 (mBq/L)	Ra-226 (pCi/L)	SULPHATE (mg/L)
Falls	4-Jun-91	Pnl_falls		S	20	0.5	4
Hold Pond	4-Jun-91	1		S	N.A.	N.A.	N.A.
Surface	5-Jun-91	1		S	46	1.2	323
Surface	4-Jun-91	2	A	S	DRY	DRY	DRY
Surface	5-Jun-91	2	B	S	788	21.3	711
Surface	5-Jun-91	2	C	S	369	10.0	555
Surface	4-Jun-91	3	A	S	434	11.7	*N.S.S.
Surface	5-Jun-91	3	B	S	N.A.	N.A.	847
Surface	5-Jun-91	3	C	S	686	18.6	43
Surface	24-May-91	4	A	S	844	22.8	208
Surface	22-May-91	4	B	S	1363	36.9	503
Surface	24-May-91	4	C	S	1958	52.9	106
Surface	22-May-91	4	D	S	DRY	DRY	DRY
Surface	22-May-91	5	A	S	1839	49.7	251
Surface	22-May-91	5	B	S	1778	48.0	386
Surface	22-May-91	5	C	S	623	16.8	146
Surface	5-Jun-91	5	D	S	512	13.8	182
Mid-Depth	4-Jun-91	5	D	M	528	14.3	190
Surface	5-Jun-91	5	E	S	573	15.5	165
Comb	5-Jun-91	5	E	M	538	14.5	170
Surface	5-Jun-91	5	F	S	466	12.6	174
Surface	5-Jun-91	5	G	S	1036	28.0	328
Surface	24-May-91	6	A	S	684	18.5	50
Surface	24-May-91	6	B	S	185	5.0	81
Surface	24-May-91	6	C	S	342	9.3	101
Surface	24-May-91	6	D	S	589	15.9	139
Mid-Depth	4-Jun-91	6	D	M	526	14.2	176
Surface	24-May-91	6	E	S	524	14.2	153
Mid-Depth	4-Jun-91	6	E	M	565	15.3	161
Surface	24-May-91	6	F	S	582	15.7	140
Mid-Depth	4-Jun-91	6	F	M	537	14.5	184
Surface	24-May-91	6	G	S	589	15.9	33

Cont.

Table 4 - cont.

LOCATION	DATE	SITE #	1	2	Ra-226 (mBq/L)	Ra-226 (pCi/L)	SULPHATE (mg/L)
Surface	24-May-91	7	A	S	446	12.0	79
Surface	24-May-91	7	B	S	529	14.3	84
Mid-Depth	4-Jun-91	7	B	M	883	23.9	58
Surface	24-May-91	7	C	S	557	15.0	76
Mid-Depth	4-Jun-91	7	C	M	658	17.8	70
Surface	24-May-91	7	D	S	416	11.2	59
Surface	24-May-91	7	E	S	475	12.8	73
Surface	24-May-91	7	F	S	528	14.3	51
Surface	24-May-91	7	G	S	1253	33.9	112
Surface	5-Jun-91	7	H	S	259	7.0	46
Surface	5-Jun-91	7	I	S	650	17.6	56
Surface	5-Jun-91	7	J	S	781	21.1	57
Mid-Depth	4-Jun-91	7	J	M	744	20.1	43
Surface	5-Jun-91	7	K	S	682	18.4	58
Mid-Depth	4-Jun-91	7	K	M	843	22.8	26
Surface	5-Jun-91	7	L	S	834	22.6	54
Mid-Depth	4-Jun-91	7	L	M	859	23.2	54
Surface	5-Jun-91	7	M	S	719	19.4	54
Mid-Depth	4-Jun-91	7	M	M	753	20.4	27
Surface	5-Jun-91	7	N	S	749	20.2	53
Surface	22-May-91	8	A	S	647	17.5	41
Surface	22-May-91	8	B	S	631	17.0	44
Mid-Depth	4-Jun-91	8	B	M	857	23.2	53
Surface	22-May-91	8	C	S	730	19.7	54
Mid-Depth	22-May-91	8	C	M	N.A.	N.A.	N.A.
Surface	22-May-91	8	D	S	700	18.9	45
Mid-Depth	4-Jun-91	8	D	M	1021	27.6	52
Surface	22-May-91	8	E	S	725	19.6	47
Mid-Depth	4-Jun-91	8	E	M	1084	29.3	44
Surface	22-May-91	8	F	S	677	18.3	45
Mid-Depth	4-Jun-91	8	F	M	902	24.4	52
Surface	22-May-91	9	A	S	572	15.5	43

Cont.

Table 4 - cont.

LOCATION	DATE	SITE #	1	2	Ra-226 (mBq/L)	Ra-226 (pCi/L)	SULPHATE (mg/L)
Mid-Depth	4-Jun-91	9	A	M	459	12.4	45
Surface	22-May-91	9	B	S	511	13.8	43
Mid-Depth	4-Jun-91	9	B	M	490	13.3	49
Surface	22-May-91	9	C	S	531	14.4	33
Mid-Depth	4-Jun-91	9	C	M	536	14.5	49
Surface	4-Jun-91	10	A	S	439	11.9	18
Mid-Depth	4-Jun-91	10	A	M	458	12.4	41
Surface	4-Jun-91	10	B	S	344	9.3	30
Mid-Depth	4-Jun-91	10	B	M	460	12.4	37
Surface	4-Jun-91	10	C	S	471	12.7	38
Mid-Depth	4-Jun-91	10	C	M	403	10.9	40
Surface	22-May-91	11	A	S	526	14.2	15
Mid-Depth	4-Jun-91	11	A	M	533	14.4	37
Surface	22-May-91	11	B	S	536	14.5	23
Mid-Depth	4-Jun-91	11	B	M	512	13.8	37
Surface	22-May-91	11	C	S	506	13.7	32
Mid-Depth	4-Jun-91	11	C	M	454	12.3	43
Surface	22-May-91	12	A	S	553	14.9	39
Mid-Depth	4-Jun-91	12	A	M	425	11.5	42
Surface	22-May-91	12	B	S	526	14.2	23
Mid-Depth	4-Jun-91	12	B	M	435	11.7	46
Surface	22-May-91	12	C	S	610	16.5	34
Mid-Depth	4-Jun-91	12	C	M	446	12.0	36

Table 5 - Panel wetlands: surface water quality, summer 1991.

LOCATION	DATE	SITE #	1	2	NORTHING (m)	EASTING (m)	ABOVE M.S.L. GROUND OR TOP_P_ELEV (m)	ABOVE M.S.L. GROUND ELEV. (m)
Surface	15-Aug-91	4	B	S	4577.26	7461.90	370.01	370.01
Surface	15-Aug-91	5	C	S	4602.68	7518.40	369.92	369.92
Surface	19-Jul-91	5	D	S	4628.30	7500.89	369.64	369.64
Bottom	19-Jul-91	5	D	B	4628.30	7500.89	369.64	369.64
Surface	16-Aug-91	5	D	S	4628.30	7500.89	369.64	369.64
Surface	15-Aug-91	5	F	S	4661.79	7481.20	369.79	369.79
Surface	15-Aug-91	6	B	S	4608.89	7611.40	369.87	369.87
Surface	16-Aug-91	6	D	S	4655.30	7585.99	369.81	369.81
Surface	16-Aug-91	6	F	S	4688.12	7570.71	369.64	369.64
Surface	15-Aug-91	7	A	S	4602.44	7711.20	369.61	369.61
Surface	19-Jul-91	7	B	S	4613.92	7708.89	369.63	369.63
Comb	19-Jul-91	7	B	M	4613.92	7708.89	369.63	369.63
Bottom	19-Jul-91	7	B	B	4613.92	7708.89	369.63	369.63
Surface	16-Aug-91	7	D	S	4649.48	7707.09	369.74	369.74
Surface	15-Aug-91	7	G	S	4723.97	7699.11	369.79	369.79
Surface	15-Aug-91	8	A	S	4618.96	7851.34	360.38	360.38
Surface	19-Jul-91	8	B	S	4633.70	7804.01	369.59	369.59
Interface	19-Jul-91	8	B	B	4633.70	7804.01	369.59	369.59
Surface	14-Aug-91	8	B	S	4633.70	7804.01	369.59	369.59
Comb	14-Aug-91	8	B	M	4633.70	7804.01	369.59	369.59
Bottom	12-Aug-91	8	B	B	4633.70	7804.01	369.59	369.59
Surface	15-Aug-91	8	C	S	4656.27	7845.54	369.58	369.58
Surface	12-Aug-91	8	D	S	4612.40	7941.93	369.51	369.51
Comb	14-Aug-91	8	D	M	4612.40	7941.93	369.51	369.51
Surface	12-Aug-91	8	D	B	4612.40	7941.93	369.51	369.51
Surface	12-Aug-91	8	E	S	4652.16	7956.42	369.51	369.51
Comb	14-Aug-91	8	E	M	4652.16	7956.42	369.51	369.51
Bottom	12-Aug-91	8	E	B	4652.16	7956.42	369.51	369.51
Surface	12-Aug-91	8	F	S	4694.66	7970.92	369.36	369.36

Cont.

Table 5 - cont.

LOCATION	DATE	SITE #	1	2	NORTHING (m)	EASTING (m)	ABOVE M.S.L. GROUND OR TOP_P_ELEV (m)	ABOVE M.S.L. GROUND ELEV. (m)
Comb	14-Aug-91	8	F	M	4694.66	7970.92	369.36	369.36
Bottom	12-Aug-91	8	F	B	4694.66	7970.92	369.36	369.36
Surface	15-Aug-91	9	A	S	4514.21	8012.91	369.58	369.58
Surface	19-Jul-91	9	B	S	4562.64	7986.97	369.36	369.36
Bottom	19-Jul-91	9	B	B	4562.64	7986.97	369.36	369.36
Surface	15-Aug-91	9	B	S	4562.64	7986.97	369.36	369.36
Middle	12-Aug-91	9	B	M	4562.64	7986.97	369.36	369.36
Bottom	12-Aug-91	9	B	B	4562.64	7986.97	369.36	369.36
Surface	12-Aug-91	9	C	S	4585.09	8029.67	369.36	369.36
Comb	14-Aug-91	9	C	M	4585.09	8029.67	369.36	369.36
Bottom	12-Aug-91	9	C	B	4585.09	8029.67	369.36	369.36
Surface	15-Aug-91	10	A	S	4470.59	8090.15	369.26	369.26
Surface	15-Aug-91	10	B	S	4502.00	8108.35	369.26	369.26
Surface	12-Aug-91	10	B	M	4502.00	8108.35	369.26	369.26
Surface	12-Aug-91	10	B	B	4502.00	8108.35	369.26	369.26
Surface	15-Aug-91	10	C	S	4533.41	8126.56	369.35	369.35
Bottom	12-Aug-91	10	C	B	4533.41	8126.56	369.35	369.35
Surface	15-Aug-91	11	A	S	4427.87	8120.24	369.26	369.26
Middle	12-Aug-91	11	A	M	4427.87	8120.24	369.26	369.26
Bottom	12-Aug-91	11	A	B	4427.87	8120.24	369.26	369.26
Surface	15-Aug-91	11	B	S	4454.61	8140.31	369.26	369.26
Middle	12-Aug-91	11	B	M	4454.61	8140.31	369.26	369.26
Bottom	12-Aug-91	11	B	B	4454.61	8140.31	369.26	369.26
Surface	15-Aug-91	11	C	S	4481.35	8160.37	369.30	369.30
Bottom	12-Aug-91	11	C	B	4481.35	8160.37	369.30	369.30
Surface	15-Aug-91	12	A	S	4424.13	8183.01	369.40	369.40
Surface	15-Aug-91	12	B	S	4430.67	8193.18	369.44	369.44
Surface	15-Aug-91	12	C	S	4434.80	8200.88	369.47	369.47

Cont.

Table 5 - cont.

LOCATION	DATE	SITE #	1	2	Field D.O.(ppm)	Field F_pH pH	LAB. L_pH pH	LAB. EH (mV)	LAB. EH(NHE) (mV)	Field F_Ec Ec
Surface	15-Aug-91	4	B	S	0.2	6.4	6.46	10	254	991
Surface	15-Aug-91	5	C	S	1.8	6.9	7.07	95	339	828
Surface	19-Jul-91	5	D	S	4.1	7.8	N.A.	N.A.	N.A.	660
Bottom	19-Jul-91	5	D	B	N.A.	7.8	N.A.	N.A.	N.A.	668
Surface	16-Aug-91	5	D	S	7.6	7.4	7.49	151	395	700
Surface	15-Aug-91	5	F	S	0.9	6.6	6.18	7	251	1376
Surface	15-Aug-91	6	B	S	0.7	6.5	6.81	89	333	907
Surface	16-Aug-91	6	D	S	9.3	7.9	7.81	131	375	691
Surface	16-Aug-91	6	F	S	7.4	7.3	7.37	112	356	692
Surface	15-Aug-91	7	A	S	3.2	6.5	7.16	85	329	314
Surface	19-Jul-91	7	B	S	N.A.	9.6	N.A.	N.A.	N.A.	253
Comb	19-Jul-91	7	B	M						
Bottom	19-Jul-91	7	B	B	N.A.	9.6	N.A.	N.A.	N.A.	256
Surface	16-Aug-91	7	D	S	1.8	7.1	7.24	107	351	231
Surface	15-Aug-91	7	G	S	1.0	6.3	6.49	78	322	592
Surface	15-Aug-91	8	A	S	0.3	7.1	7.26	77	321	220
Surface	19-Jul-91	8	B	S	10.2	9.3	N.A.	N.A.	N.A.	242
Interface	19-Jul-91	8	B	B	10.0	9.4	N.A.	N.A.	N.A.	242
Surface	14-Aug-91	8	B	S	10.0	9.0				220
Comb	14-Aug-91	8	B	M			8.86	53	297	217
Bottom	12-Aug-91	8	B	B	8.0	9.1				218
Surface	15-Aug-91	8	C	S	1.7	7.1	7.31	106	350	216
Surface	12-Aug-91	8	D	S	10.9	8.2				214
Comb	14-Aug-91	8	D	M			8.60	83	327	
Surface	12-Aug-91	8	D	B	10.0	8.8				216
Surface	12-Aug-91	8	E	S	10.5	8.6				218
Comb	14-Aug-91	8	E	M			8.71	77	321	
Bottom	12-Aug-91	8	E	B	10.0	9.1				223
Surface	12-Aug-91	8	F	S	10.0	9.3				211

Cont.

Table 5 - cont.

LOCATION	DATE	SITE #	1	2	Field D.O.(ppm)	Field F_pH pH	LAB. L_pH pH	LAB. EH (mV)	LAB. EH(NHE) (mV)	Field F_Ec Ec
Comb	14-Aug-91	8	F	M			9.46	56	300	
Bottom	12-Aug-91	8	F	B	10.0	9.4				212
Surface	15-Aug-91	9	A	S	10.0	9.7	9.62	43	287	181
Surface	19-Jul-91	9	B	S	N.A.	9.9	N.A.	N.A.	N.A.	192
Bottom	19-Jul-91	9	B	B	N.A.	9.5	N.A.	N.A.	N.A.	206
Surface	15-Aug-91	9	B	S	10.0	9.6				172
Middle	12-Aug-91	9	B	M	10.0	9.6	9.20	114	358	177
Bottom	12-Aug-91	9	B	B	9.8	9.4				182
Surface	12-Aug-91	9	C	S	10.0	9.6				188
Comb	14-Aug-91	9	C	M			9.54	42	286	
Bottom	12-Aug-91	9	C	B	10.0	9.8				190
Surface	15-Aug-91	10	A	S	10.0	9.5	9.02	108	352	178
Surface	15-Aug-91	10	B	S	10.4	9.2	8.29	117	361	174
Surface	12-Aug-91	10	B	M	10.0	9.1				178
Surface	12-Aug-91	10	B	B	10.0	8.7				187
Surface	15-Aug-91	10	C	S	10.0	9.1	8.44	115	359	179
Bottom	12-Aug-91	10	C	B	8.0	9.0				180
Surface	15-Aug-91	11	A	S	9.8	9.0	8.27	121	365	175
Middle	12-Aug-91	11	A	M	9.3	8.8				169
Bottom	12-Aug-91	11	A	B	9.7	8.6				175
Surface	15-Aug-91	11	B	S	9.3	9.2	8.43	114	358	173
Middle	12-Aug-91	11	B	M	8.7	8.9				173
Bottom	12-Aug-91	11	B	B	9.2	8.7				172
Surface	15-Aug-91	11	C	S	9.3	9.0	8.22	116	360	174
Bottom	12-Aug-91	11	C	B	9.2	8.9				173
Surface	15-Aug-91	12	A	S	10.0	8.9	8.10	116	360	171
Surface	15-Aug-91	12	B	S	9.5	9.0	8.10	113	357	173
Surface	15-Aug-91	12	C	S	10.3	9.0	8.19	111	355	171

Cont.

Table 5 - cont.

LOCATION	DATE	SITE #	1	2	LAB. L_EC Ec	Field F_T(C) Temp.(C)	T.D.S. (mg/L)	ACIDITY (mg/L)	ALKALINITY (mg/L)	Fe TOTAL (mg/L)
Surface	15-Aug-91	4	B	S	1110	25.0	910	0.0	35	3.90
Surface	15-Aug-91	5	C	S	846	21.8	720	0.0	79	0.01
Surface	19-Jul-91	5	D	S	N.A.	26.2	N.A.	N.A.	N.A.	
Bottom	19-Jul-91	5	D	B	N.A.	N.A.	N.A.	N.A.	N.A.	
Surface	16-Aug-91	5	D	S	785	22.4	663	0.0	144	0.00
Surface	15-Aug-91	5	F	S	1229	27.0	1160	2.5	54	85.64
Surface	15-Aug-91	6	B	S	915	18.8	580	0.0	173	0.67
Surface	16-Aug-91	6	D	S	778	21.3	462	0.0	148	<0.002
Surface	16-Aug-91	6	F	S	774	20.8	538	0.0	134	0.01
Surface	15-Aug-91	7	A	S	291	20.6	110	0.0	84	0.11
Surface	19-Jul-91	7	B	S	N.A.	N.A.	N.A.	N.A.	N.A.	
Comb	19-Jul-91	7	B	M						0.12
Bottom	19-Jul-91	7	B	B	N.A.	N.A.	N.A.	N.A.	N.A.	
Surface	16-Aug-91	7	D	S	269	17.7	75	0.0	112	0.07
Surface	15-Aug-91	7	G	S	697	17.4	500	0.0	47	0.38
Surface	15-Aug-91	8	A	S	221	20.7	600	0.0	25	0.15
Surface	19-Jul-91	8	B	S	N.A.	29.1	63	N.A.	N.A.	0.08
Interface	19-Jul-91	8	B	B	N.A.	29.4				
Surface	14-Aug-91	8	B	S		24.6				
Comb	14-Aug-91	8	B	M	217		N.A.	0.0	30	0.05
Bottom	12-Aug-91	8	B	B		24.7				
Surface	15-Aug-91	8	C	S	224	19.5	137	0.0	30	0.07
Surface	12-Aug-91	8	D	S		25.8				
Comb	14-Aug-91	8	D	M	211		313	0.0	30	0.05
Surface	12-Aug-91	8	D	B		25.1				
Surface	12-Aug-91	8	E	S		26.0				
Comb	14-Aug-91	8	E	M	209		213	0.0	30	0.09
Bottom	12-Aug-91	8	E	B		25.3				
Surface	12-Aug-91	8	F	S		26.0				

Cont.

Table 5 - cont.

LOCATION	DATE	SITE #	1	2	LAB. L_EC Ec	Field F_T(C) Temp.(C)	T.D.S. (mg/L)	ACIDITY (mg/L)	ALKALINITY (mg/L)	Fe TOTAL (mg/L)
Comb	14-Aug-91	8	F	M	203		250	0.0	30	0.08
Bottom	12-Aug-91	8	F	B		25.5				
Surface	15-Aug-91	9	A	S	177	26.0	25	0.0	25	0.21
Surface	19-Jul-91	9	B	S	N.A.	N.A.	N.A.	N.A.	N.A.	0.15
Bottom	19-Jul-91	9	B	B	N.A.	N.A.	N.A.	N.A.	N.A.	
Surface	15-Aug-91	9	B	S		25.7	137	0.0	29	0.14
Middle	12-Aug-91	9	B	M	176	25.3				
Bottom	12-Aug-91	9	B	B		23.0				
Surface	12-Aug-91	9	C	S		25.8				
Comb	14-Aug-91	9	C	M	174		200	0.0	30	0.06
Bottom	12-Aug-91	9	C	B		24.9				
Surface	15-Aug-91	10	A	S	170	24.8	62	0.0	28	0.09
Surface	15-Aug-91	10	B	S	177	24.2	200	0.0	30	0.12
Surface	12-Aug-91	10	B	M		24.1				
Surface	12-Aug-91	10	B	B		24.2				
Surface	15-Aug-91	10	C	S	178	24.5	87	0.0	29	0.11
Bottom	12-Aug-91	10	C	B		24.4				
Surface	15-Aug-91	11	A	S	173	24.6	175	0.0	28	0.12
Middle	12-Aug-91	11	A	M		24.4				
Bottom	12-Aug-91	11	A	B		23.9				
Surface	15-Aug-91	11	B	S	172	24.7	125	0.0	29	0.10
Middle	12-Aug-91	11	B	M		24.0				
Bottom	12-Aug-91	11	B	B		24.1				
Surface	15-Aug-91	11	C	S	173	24.7	87	0.0	29	0.12
Bottom	12-Aug-91	11	C	B		24.2				
Surface	15-Aug-91	12	A	S	172	25.0	125	0.0	29	0.15
Surface	15-Aug-91	12	B	S	177	24.8	125	0.0	26	0.14
Surface	15-Aug-91	12	C	S	178	24.8	125	0.0	30	0.14

Cont.

Table 5 - cont.

LOCATION	DATE	SITE #	1	2	Cu (mg/L)	Zn (mg/L)	Ca (mg/L)	Mg (mg/L)	Pb (mg/L)	Th (mg/L)	Al (mg/L)
Surface	15-Aug-91	4	B	S	0.007	0.016	255.2	15.9	0.006	<0.015	0.216
Surface	15-Aug-91	5	C	S	<0.002	0.013	199.3	9.0	<0.025	<0.015	0.174
Surface	19-Jul-91	5	D	S							
Bottom	19-Jul-91	5	D	B							
Surface	16-Aug-91	5	D	S	<0.002	<0.002	169.5	10.5	<0.025	<0.015	0.147
Surface	15-Aug-91	5	F	S	<0.002	0.022	280.4	5.3	<0.025	0.049	0.264
Surface	15-Aug-91	6	B	S	<0.002	0.010	226.8	8.3	<0.025	<0.015	0.194
Surface	16-Aug-91	6	D	S	<0.002	<0.002	170.4	11.1	<0.025	<0.015	0.139
Surface	16-Aug-91	6	F	S	<0.002	<0.002	167.2	10.7	<0.025	<0.015	0.155
Surface	15-Aug-91	7	A	S	<0.002	0.040	45.8	2.1	0.028	<0.015	0.033
Surface	19-Jul-91	7	B	S							
Comb	19-Jul-91	7	B	M	<0.002	<0.002	54.8	2.3	<0.025	<0.015	<0.030
Bottom	19-Jul-91	7	B	B							
Surface	16-Aug-91	7	D	S	<0.002	<0.002	66.2	1.8	<0.025	<0.015	<0.030
Surface	15-Aug-91	7	G	S	<0.002	0.017	134.3	0.8	<0.025	<0.015	0.123
Surface	15-Aug-91	8	A	S	<0.002	0.020	39.5	1.6	<0.025	<0.015	<0.030
Surface	19-Jul-91	8	B	S	0.012	<0.002	48.9	2.0	<0.025	<0.015	<0.030
Interface	19-Jul-91	8	B	B							
Surface	14-Aug-91	8	B	S							
Comb	14-Aug-91	8	B	M	<0.002	<0.002	41.0	1.8	<0.025	<0.015	<0.030
Bottom	12-Aug-91	8	B	B							
Surface	15-Aug-91	8	C	S	<0.002	0.006	46.8	2.1	<0.025	<0.015	0.035
Surface	12-Aug-91	8	D	S							
Comb	14-Aug-91	8	D	M	<0.002	0.003	36.7	1.6	<0.025	<0.015	0.040
Surface	12-Aug-91	8	D	B							
Surface	12-Aug-91	8	E	S							
Comb	14-Aug-91	8	E	M	<0.002	0.011	35.8	1.5	<0.025	<0.015	0.035
Bottom	12-Aug-91	8	E	B							
Surface	12-Aug-91	8	F	S							

Cont.

Table 5 - cont.

LOCATION	DATE	SITE #	1	2	Cu (mg/L)	Zn (mg/L)	Ca (mg/L)	Mg (mg/L)	Pb (mg/L)	Th (mg/L)	Al (mg/L)
Comb	14-Aug-91	8	F	M	<0.002	<0.002	36.0	1.6	<0.025	<0.015	<0.030
Bottom	12-Aug-91	8	F	B							
Surface	15-Aug-91	9	A	S	<0.002	<0.002	35.2	1.6	<0.025	<0.015	0.038
Surface	19-Jul-91	9	B	S	<0.002	<0.002	41.2	1.8	<0.025	<0.015	<0.030
Bottom	19-Jul-91	9	B	B							
Surface	15-Aug-91	9	B	S	<0.002	<0.002	37.5	1.7	<0.025	<0.015	<0.030
Middle	12-Aug-91	9	B	M							
Bottom	12-Aug-91	9	B	B							
Surface	12-Aug-91	9	C	S							
Comb	14-Aug-91	9	C	M	<0.002	<0.002	35.3	1.7	<0.025	<0.015	<0.030
Bottom	12-Aug-91	9	C	B							
Surface	15-Aug-91	10	A	S	<0.002	<0.002	34.8	1.6	<0.025	<0.015	<0.030
Surface	15-Aug-91	10	B	S	<0.002	<0.002	36.4	1.6	<0.025	<0.015	<0.030
Surface	12-Aug-91	10	B	M							
Surface	12-Aug-91	10	B	B							
Surface	15-Aug-91	10	C	S	<0.002	<0.002	38.9	1.8	<0.025	<0.015	<0.030
Bottom	12-Aug-91	10	C	B							
Surface	15-Aug-91	11	A	S	<0.002	<0.002	37.1	1.8	<0.025	<0.015	<0.030
Middle	12-Aug-91	11	A	M							
Bottom	12-Aug-91	11	A	B							
Surface	15-Aug-91	11	B	S	<0.002	<0.002	36.9	1.7	<0.025	<0.015	<0.030
Middle	12-Aug-91	11	B	M							
Bottom	12-Aug-91	11	B	B							
Surface	15-Aug-91	11	C	S	<0.002	<0.002	37.7	1.8	<0.025	<0.015	<0.030
Bottom	12-Aug-91	11	C	B							
Surface	15-Aug-91	12	A	S	<0.002	<0.002	36.3	1.7	<0.025	<0.015	<0.030
Surface	15-Aug-91	12	B	S	<0.002	<0.002	37.8	1.8	<0.025	<0.015	<0.030
Surface	15-Aug-91	12	C	S	<0.002	<0.002	34.3	1.5	<0.025	<0.015	<0.030

Cont.

Table 5 - cont.

LOCATION	DATE	SITE #	1	2	Mn (mg/L)	U (mg/L)	Ni (mg/L)	Ra-226 (mBq/L)	Ra-226 (pCi/L)	SULPHATE (mg/L)
Surface	15-Aug-91	4	B	S	0.430	<0.100	0.015	957	25.9	607
Surface	15-Aug-91	5	C	S	0.078	<0.100	0.017	919	24.8	412
Surface	19-Jul-91	5	D	S						
Bottom	19-Jul-91	5	D	B						
Surface	16-Aug-91	5	D	S	<0.002	<0.100	0.015	158	4.3	383
Surface	15-Aug-91	5	F	S	0.080	<0.100	<0.005	2765	74.7	663
Surface	15-Aug-91	6	B	S	0.086	<0.100	<0.005	619	16.7	349
Surface	16-Aug-91	6	D	S	<0.002	<0.100	0.010	421	11.4	362
Surface	16-Aug-91	6	F	S	<0.002	<0.100	<0.005	452	12.2	336
Surface	15-Aug-91	7	A	S	<0.002	<0.100	<0.005	474	12.8	94
Surface	19-Jul-91	7	B	S						
Comb	19-Jul-91	7	B	M	<0.002	<0.100	0.009	349	9.4	67
Bottom	19-Jul-91	7	B	B						
Surface	16-Aug-91	7	D	S	<0.002	<0.100	<0.005	873	23.6	24
Surface	15-Aug-91	7	G	S	<0.002	<0.100	0.006	1585	42.8	290
Surface	15-Aug-91	8	A	S	<0.002	<0.100	<0.005	325	8.8	51
Surface	19-Jul-91	8	B	S	<0.002	<0.100	0.005	465	12.6	61
Interface	19-Jul-91	8	B	B						
Surface	14-Aug-91	8	B	S						
Comb	14-Aug-91	8	B	M	<0.002	<0.100	0.011	300	8.1	66
Bottom	12-Aug-91	8	B	B						
Surface	15-Aug-91	8	C	S	<0.002	<0.100	0.010	327	8.8	59
Surface	12-Aug-91	8	D	S						
Comb	14-Aug-91	8	D	M	<0.002	<0.100	0.005	359	9.7	53
Surface	12-Aug-91	8	D	B						
Surface	12-Aug-91	8	E	S						
Comb	14-Aug-91	8	E	M	<0.002	<0.100	0.005	373	10.1	68
Bottom	12-Aug-91	8	E	B						
Surface	12-Aug-91	8	F	S						

Cont.

Table 5 - cont.

LOCATION	DATE	SITE #	1	2	Mn (mg/L)	U (mg/L)	Ni (mg/L)	Ra-226 (mBq/L)	Ra-226 (pCi/L)	SULPHATE (mg/L)
Comb	14-Aug-91	8	F	M	<0.002	<0.100	0.007	401	10.8	60
Bottom	12-Aug-91	8	F	B						
Surface	15-Aug-91	9	A	S	<0.002	<0.100	0.006	153	4.1	61
Surface	19-Jul-91	9	B	S	<0.002	<0.100	0.010	174	4.7	33
Bottom	19-Jul-91	9	B	B						
Surface	15-Aug-91	9	B	S	<0.002	<0.100	0.009	211	5.7	59
Middle	12-Aug-91	9	B	M						
Bottom	12-Aug-91	9	B	B						
Surface	12-Aug-91	9	C	S						
Comb	14-Aug-91	9	C	M	<0.002	<0.100	<0.005	171	4.6	60
Bottom	12-Aug-91	9	C	B						
Surface	15-Aug-91	10	A	S	<0.002	<0.100	0.006	357	9.6	57
Surface	15-Aug-91	10	B	S	<0.002	<0.100	<0.005	44	1.2	52
Surface	12-Aug-91	10	B	M						
Surface	12-Aug-91	10	B	B						
Surface	15-Aug-91	10	C	S	<0.002	<0.100	<0.005	226	6.1	35
Bottom	12-Aug-91	10	C	B						
Surface	15-Aug-91	11	A	S	<0.002	<0.100	0.006	354	9.6	37
Middle	12-Aug-91	11	A	M						
Bottom	12-Aug-91	11	A	B						
Surface	15-Aug-91	11	B	S	<0.002	<0.100	<0.005	360	9.7	44
Middle	12-Aug-91	11	B	M						
Bottom	12-Aug-91	11	B	B						
Surface	15-Aug-91	11	C	S	<0.002	<0.100	<0.005	363	9.8	43
Bottom	12-Aug-91	11	C	B						
Surface	15-Aug-91	12	A	S	<0.002	<0.100	<0.005	449	12.1	58
Surface	15-Aug-91	12	B	S	<0.002	<0.100	0.006	381	10.3	56
Surface	15-Aug-91	12	C	S	<0.002	<0.100	<0.005	357	9.6	55

Table 6 - Panel wetlands: surface water quality, fall 1991.

LOCATION	DATE	SITE #	1	2	NORTHING (m)	EASTING (m)	ABOVE M.S.L. GROUND OR TOP_P_ELEV (m)	ABOVE M.S.L. GROUND ELEV. (m)	Field D.O.(ppm)	Field F_pH pH	LAB. EH (mV)
Surface	25-Sep-91	2	B	S	4572.50	7323.67	370.92	370.92	10.8	7.2	73
Surface	25-Sep-91	2	C	S	4575.74	7321.66	370.82	370.82	10.0	7.3	79
Surface	25-Sep-91	3	B	S	4602.41	7359.07	370.35	370.35	10.0	6.7	87
Surface	25-Sep-91	4	B	S	4577.26	7461.90	370.01	370.01	7.5	6.2	139
Surface	24-Sep-91	5	C	S	4602.68	7518.40	369.80	369.80	10.0	6.2	127
Surface	24-Sep-91	5	D	S	4628.30	7500.89	369.64	369.64	10.0	7.3	126
Surface	16-Oct-91	5	D	S	4628.30	7500.89	369.64	369.64	10.6	6.4	128
Middle	16-Oct-91	5	D	M	4628.30	7500.89	369.64	369.64	10.2	6.1	106
Bottom	16-Oct-91	5	D	B	4628.30	7500.89	369.64	369.64	9.1	6.2	103
Surface	25-Sep-91	5	E	S	4648.54	7488.93	369.61	369.61	10.0	4.6	271
Surface	25-Sep-91	5	F	S	4661.79	7481.20	369.79	369.79	10.0	3.3	410
Surface	16-Oct-91	5	F	S	4661.79	7481.20	369.79	369.79	5.2	N.A.	N.A.
Surface	25-Sep-91	6	B	S	4608.89	7611.40	369.87	369.87	9.5	7.3	120
Surface	25-Sep-91	6	D	S	4655.30	7585.99	369.81	369.81	11.1	7.3	150
Surface	24-Sep-91	6	E	S	4674.14	7574.40	369.78	369.78	N.A.	N.A.	N.A.
Surface	25-Sep-91	6	F	S	4688.12	7570.71	369.64	369.64	10.8	6.8	150
Surface	25-Sep-91	7	A	S	4602.44	7711.20	369.61	369.61	10.6	7.4	107
Surface	17-Oct-91	7	B	S	4613.92	7708.89	369.63	369.63	N.A.	7.7	117
Bottom	17-Oct-91	7	B	B	4613.92	7708.89	369.63	369.63	N.A.	7.6	123
Surface	25-Sep-91	7	D	S	4649.48	7707.09	369.74	369.74	6.6	7.4	121
Surface	17-Oct-91	7	D	S	4649.48	7707.09	369.74	369.74	N.A.	N.A.	N.A.
Surface	25-Sep-91	7	G	S	4723.97	7699.11	369.79	369.79	5.9	7.1	70
Surface	17-Oct-91	8	B	S	4633.70	7804.01	369.59	369.59	9.6	7.7	105
Bottom	17-Oct-91	8	B	B	4633.70	7804.01	369.59	369.59	7.1	7.8	105
Surface	17-Oct-91	9	B	S	4562.64	7986.97	369.36	369.36	11.4	8.0	100
Middle	17-Oct-91	9	B	M	4562.64	7986.97	369.36	369.36	11.1	8.1	110
Bottom	17-Oct-91	9	B	B	4562.64	7986.97	369.36	369.36	10.7	8.1	109

Cont.

Table 6 - cont.

LOCATION	DATE	SITE #	1	2	LAB. EH(NHE) (mV)	Field F_Ec Ec	Field F_T(C) Temp.(C)	T.D.S. (mg/L)	ACIDITY (mg/L)	ALKALINITY (mg/L)	Fe TOTAL (mg/L)
Surface	25-Sep-91	2	B	S	317	1473	10.6	1429	0	120	0.37
Surface	25-Sep-91	2	C	S	323	1803	10.6	1514	0	116	0.16
Surface	25-Sep-91	3	B	S	331	1236	10.4	1875	0	104	0.22
Surface	25-Sep-91	4	B	S	383	1541	9.5	1475	0	22	0.01
Surface	24-Sep-91	5	C	S	371	920	10.8	725	0	26	<0.002
Surface	24-Sep-91	5	D	S	370	925	16.5	750	0	23	0.24
Surface	16-Oct-91	5	D	S	372	878	4.7	528	N.A.	N.A.	0.28
Middle	16-Oct-91	5	D	M	350	862	4.8	612	0	1	0.18
Bottom	16-Oct-91	5	D	B	347	903	4.8	613	0	8	0.18
Surface	25-Sep-91	5	E	S	515	1072	10.1	840	29	1	2.76
Surface	25-Sep-91	5	F	S	654	1696	11.5	1488	75	0	12.24
Surface	16-Oct-91	5	F	S	N.A.	N.A.	3.1	N.A.	N.A.	N.A.	
Surface	25-Sep-91	6	B	S	364	881	10.8	771	0	47	0.03
Surface	25-Sep-91	6	D	S	394	897	12.6	825	0	24	0.62
Surface	24-Sep-91	6	E	S	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	
Surface	25-Sep-91	6	F	S	394	941	12.7	813	0	22	0.27
Surface	25-Sep-91	7	A	S	351	342	9.8	238	0	55	0.02
Surface	17-Oct-91	7	B	S	361	368	N.A.	222	0	16	0.06
Bottom	17-Oct-91	7	B	B	367	716	N.A.	441	0	20	0.02
Surface	25-Sep-91	7	D	S	365	349	11.4	250	0	63	0.01
Surface	17-Oct-91	7	D	S	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	
Surface	25-Sep-91	7	G	S	314	589	11.5	533	0	15	0.07
Surface	17-Oct-91	8	B	S	349	338	6.2	198	0	35	0.12
Bottom	17-Oct-91	8	B	B	349	387	6.5	233	0	36	0.04
Surface	17-Oct-91	9	B	S	344	229	6.6	135	0	46	0.08
Middle	17-Oct-91	9	B	M	354	237	6.4	127	0	46	0.06
Bottom	17-Oct-91	9	B	B	353	235	6.9	131	0	50	0.05

Cont.

Table 6 - cont.

LOCATION	DATE	SITE #	1	2	Cu (mg/L)	Zn (mg/L)	Ca (mg/L)	Mg (mg/L)	Pb (mg/L)	Th (mg/L)	Al (mg/L)	Mn (mg/L)
Surface	25-Sep-91	2	B	S	<0.002	<0.002	352.4	33.3	<0.025	<0.015	0.382	0.124
Surface	25-Sep-91	2	C	S	<0.002	<0.002	359.7	33.4	<0.025	<0.015	0.345	0.119
Surface	25-Sep-91	3	B	S	<0.002	0.009	504.4	40.7	<0.025	<0.015	0.554	0.145
Surface	25-Sep-91	4	B	S	<0.002	0.077	344.1	26.9	0.003	<0.015	0.662	0.172
Surface	24-Sep-91	5	C	S	<0.002	<0.002	217.7	9.7	<0.025	<0.015	0.252	0.006
Surface	24-Sep-91	5	D	S	<0.002	<0.002	207.0	10.9	<0.025	<0.015	0.261	0.009
Surface	16-Oct-91	5	D	S	0.003	0.057	153.9	6.8	0.014	<0.015	0.279	0.071
Middle	16-Oct-91	5	D	M	0.002	0.051	147.9	6.6	<0.025	<0.015	0.315	*N.S.S.
Bottom	16-Oct-91	5	D	B	<0.002	0.030	151.4	6.8	<0.025	<0.015	0.300	0.068
Surface	25-Sep-91	5	E	S	<0.002	0.074	220.2	6.0	0.056	<0.015	2.759	0.090
Surface	25-Sep-91	5	F	S	0.070	0.211	331.6	4.4	0.887	0.041	9.377	0.151
Surface	16-Oct-91	5	F	S								
Surface	25-Sep-91	6	B	S	<0.002	<0.002	220.9	6.5	<0.025	<0.015	0.223	0.004
Surface	25-Sep-91	6	D	S	<0.002	<0.002	204.0	10.9	<0.025	<0.015	0.295	0.009
Surface	24-Sep-91	6	E	S								
Surface	25-Sep-91	6	F	S	<0.002	<0.002	206.2	10.9	<0.025	<0.015	0.256	0.006
Surface	25-Sep-91	7	A	S	<0.002	<0.002	62.6	2.9	<0.025	<0.015	0.071	<0.002
Surface	17-Oct-91	7	B	S	<0.002	0.029	57.9	2.5	<0.025	<0.015	0.151	0.008
Bottom	17-Oct-91	7	B	B	0.001	0.047	121.0	5.4	<0.025	<0.015	0.215	0.026
Surface	25-Sep-91	7	D	S	0.028	0.045	72.8	2.2	0.030	<0.015	0.048	<0.002
Surface	17-Oct-91	7	D	S								
Surface	25-Sep-91	7	G	S	<0.002	<0.002	126.2	1.0	<0.025	<0.015	0.133	0.003
Surface	17-Oct-91	8	B	S	0.003	0.038	50.1	2.3	<0.025	<0.015	0.180	0.016
Bottom	17-Oct-91	8	B	B	<0.002	0.010	62.3	2.7	<0.025	<0.015	0.180	0.007
Surface	17-Oct-91	9	B	S	0.002	0.049	36.2	1.5	0.002	<0.015	0.134	<0.002
Middle	17-Oct-91	9	B	M	0.004	0.057	37.2	1.5	<0.025	<0.015	0.121	<0.002
Bottom	17-Oct-91	9	B	B	<0.002	0.023	36.8	1.5	<0.025	<0.015	0.103	<0.002

Cont.

Table 6 - cont.

LOCATION	DATE	SITE #	1	2	U (mg/L)	Ni (mg/L)	Ra-226 (mBq/L)	Ra-226 (pCi/L)	SULPHATE (mg/L)
Surface	25-Sep-91	2	B	S	<0.100	0.014	242	6.6	654
Surface	25-Sep-91	2	C	S	<0.100	<0.005	228	6.2	700
Surface	25-Sep-91	3	B	S	<0.100	0.006	354	9.6	985
Surface	25-Sep-91	4	B	S	<0.100	0.048	1515	40.9	743
Surface	24-Sep-91	5	C	S	<0.100	<0.005	548	14.8	421
Surface	24-Sep-91	5	D	S	<0.100	<0.005	387	10.5	440
Surface	16-Oct-91	5	D	S	<0.100	0.009	1103	29.8	373
Middle	16-Oct-91	5	D	M	*N.S.S.	<0.005	715	19.3	382
Bottom	16-Oct-91	5	D	B	<0.100	0.015	577	15.6	365
Surface	25-Sep-91	5	E	S	<0.100	0.027	2017	54.5	512
Surface	25-Sep-91	5	F	S	<0.100	0.074	4258	115.1	825
Surface	16-Oct-91	5	F	S			N.A.	N.A.	N.A.
Surface	25-Sep-91	6	B	S	<0.100	<0.005	520	14.0	418
Surface	25-Sep-91	6	D	S	<0.100	<0.005	567	15.3	430
Surface	24-Sep-91	6	E	S			N.A.	N.A.	N.A.
Surface	25-Sep-91	6	F	S	<0.100	0.006	490	13.2	432
Surface	25-Sep-91	7	A	S	<0.100	<0.005	1009	27.3	83
Surface	17-Oct-91	7	B	S	<0.100	<0.005	619	16.7	101
Bottom	17-Oct-91	7	B	B	<0.100	0.005	694	18.7	262
Surface	25-Sep-91	7	D	S	<0.100	<0.005	572	15.4	84
Surface	17-Oct-91	7	D	S			N.A.	N.A.	N.A.
Surface	25-Sep-91	7	G	S	<0.100	0.006	1072	29.0	247
Surface	17-Oct-91	8	B	S	0.1054	<0.005	744	20.1	110
Bottom	17-Oct-91	8	B	B	<0.100	0.020	608	16.4	113
Surface	17-Oct-91	9	B	S	<0.100	0.013	581	15.7	52
Middle	17-Oct-91	9	B	M	<0.100	<0.005	461	12.5	60
Bottom	17-Oct-91	9	B	B	<0.100	<0.005	543	14.7	54

Table 7 - Panel wetlands: background and rain run-off water quality, summer and fall 1991.

LOCATION	DATE	SITE #	Field F_pH pH	LAB. EH (mV)	LAB. EH(NHE) (mV)	Field F_Ec Ec	ACIDITY (mg/L)	ALKALINITY (mg/L)	Fe TOTAL (mg/L)	Cu (mg/L)
Rain-Runoff	31-Jul-91	RR#1	3.4	487	731	69	N.A.	N.A.	7.16	0.055
Rain-Runoff	31-Jul-91	RR#2	3.6	458	702	927	N.A.	N.A.	1.18	0.012
Rain-Runoff	31-Jul-91	RR#3	3.5	489	733	1406	N.A.	N.A.	2.00	0.045
Rain-Runoff	31-Jul-91	RR#4	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	1.34	0.002
Rain-Runoff	31-Jul-91	RR#5	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	0.20	<0.002
Rain-Runoff	18-Sep-91	RR#6	6.0	241	485	66	9	8.1	0.04	<0.002
Rain-Runoff	18-Sep-91	RR#7	5.4	198	442	1062	8	6.1	0.56	<0.002
Rain-Runoff	18-Sep-91	RR#8	3.4	N.A.	N.A.	1062	69	0.0	1.54	0.014
Rain-Runoff	18-Sep-91	RR#9	3.4	N.A.	N.A.	798	69	0.0	1.12	0.030
Rain-Runoff	18-Sep-91	RR#10	6.7	142	386	871	0	24.4	0.04	<0.002
Rain-Runoff	18-Sep-91	RR#11	4.0	381	625	105	41	0.0	0.53	<0.002
Rain-Runoff	18-Sep-91	RR#12	4.3	297	541	303	41	0.0	1.37	<0.002
Rain-Runoff	18-Sep-91	RR#13	5.8	194	438	333	2	17.3	0.03	<0.002

Cont.

Table 7 - cont.

LOCATION	DATE	SITE #	Zn (mg/L)	Ca (mg/L)	Mg (mg/L)	Pb (mg/L)	Th (mg/L)	Al (mg/L)	Mn (mg/L)	U (mg/L)
Rain-Runoff	31-Jul-91	RR#1	0.027	465.2	0.9	0.191	0.106	2.652	0.076	<0.100
Rain-Runoff	31-Jul-91	RR#2	0.087	194.0	2.4	0.229	0.018	2.438	0.172	<0.100
Rain-Runoff	31-Jul-91	RR#3	0.008	372.4	0.6	0.053	0.029	0.694	0.047	<0.100
Rain-Runoff	31-Jul-91	RR#4	0.028	299.6	2.7	0.190	<0.015	1.053	0.116	<0.100
Rain-Runoff	31-Jul-91	RR#5	0.063	92.9	20.4	<0.025	<0.015	3.457	0.864	<0.100
Rain-Runoff	18-Sep-91	RR#6	<0.002	5.4	0.3	<0.025	<0.015	0.113	0.032	<0.100
Rain-Runoff	18-Sep-91	RR#7	<0.002	259.4	7.7	<0.025	<0.015	0.286	0.185	<0.100
Rain-Runoff	18-Sep-91	RR#8	0.132	218.7	2.6	0.536	<0.015	4.052	0.174	<0.100
Rain-Runoff	18-Sep-91	RR#9	0.111	133.8	1.5	0.363	<0.015	3.526	0.083	<0.100
Rain-Runoff	18-Sep-91	RR#10	<0.002	197.4	2.6	<0.025	<0.015	0.185	0.029	<0.100
Rain-Runoff	18-Sep-91	RR#11	0.022	7.7	1.0	0.053	<0.015	1.006	0.209	<0.100
Rain-Runoff	18-Sep-91	RR#12	0.038	44.8	2.8	<0.025	<0.015	0.694	0.374	<0.100
Rain-Runoff	18-Sep-91	RR#13	<0.002	61.8	2.8	<0.025	<0.015	0.120	0.076	<0.100

Cont.

Table 7 – cont.

LOCATION	DATE	SITE #	Ni (mg/L)	Ra-226 (mBq/L)	Ra-226 (pCi/L)	SULPHATE (mg/L)
Rain-Runoff	31-Jul-91	RR#1	0.011	1922	51.9	6
Rain-Runoff	31-Jul-91	RR#2	0.030	1320	35.7	493
Rain-Runoff	31-Jul-91	RR#3	0.014	112	3.0	812
Rain-Runoff	31-Jul-91	RR#4	0.010	796	21.5	668
Rain-Runoff	31-Jul-91	RR#5	0.012	68	1.8	239
Rain-Runoff	18-Sep-91	RR#6	0.013	12	0.3	8
Rain-Runoff	18-Sep-91	RR#7	0.027	2247	60.7	555
Rain-Runoff	18-Sep-91	RR#8	0.057	2198	59.4	502
Rain-Runoff	18-Sep-91	RR#9	0.049	1840	49.7	294
Rain-Runoff	18-Sep-91	RR#10	<0.005	508	13.7	370
Rain-Runoff	18-Sep-91	RR#11	0.012	1267	34.3	18
Rain-Runoff	18-Sep-91	RR#12	0.017	2552	69.0	114
Rain-Runoff	18-Sep-91	RR#13	0.008	2580	69.7	131

Table 8 - Panel wetlands: ground water quality, summer 1991.

LOCATION	DATE	SITE #	1	DEPTH (cm)	DEPTH OF WATER INSIDE_P (cm)	DEPTH OF WATER OUTSD_P (cm)	TOP TO GROUND (cm)	DEPTH OF POND (cm)	NORTHING (m)	EASTING (m)	ABOVE M.S.L. GROUND OR TOP_P_ELEV (m)
Piezometer	18-Jul-91	1	P	914.40	261.0	61.0	61.0	0.0	4550.99	7303.76	373.61
Piezometer	20-Aug-91	1	P	914.40	217.0	61.0	61.0	0.0	4550.99	7303.76	373.61
Piezometer	18-Jul-91	2	A	91.44	112.0	30.5	30.5	0.0	4567.06	7328.01	371.10
Piezometer	20-Aug-91	2	A	91.44	78.0	30.5	30.5	0.0	4567.06	7328.01	371.10
Piezometer	18-Jul-91	2	B	30.48	DRY	35.6	35.6	0.0	4572.50	7323.67	370.92
Piezometer	20-Aug-91	2	B	30.48	58.0	35.6	35.6	0.0	4572.50	7323.67	370.92
Piezometer	18-Jul-91	2	B	91.44	84.0	30.5	30.48	0.0	4572.31	7323.37	370.86
Piezometer	20-Aug-91	2	B	91.44	53.0	30.5	30.48	0.0	4572.31	7323.37	370.86
Piezometer	18-Jul-91	2	B	152.40	85.0	30.5	30.48	0.0	4572.10	7323.15	370.88
Piezometer	20-Aug-91	2	B	152.40	54.0	30.5	30.48	0.0	4572.10	7323.15	370.88
Piezometer	18-Jul-91	2	C	91.44	77.0	30.5	30.48	0.0	4575.74	7321.66	370.82
Piezometer	20-Aug-91	2	C	91.44	57.0	30.5	30.48	0.0	4575.74	7321.66	370.82
Piezometer	18-Jul-91	3	A	91.44	1.0	30.5	30.5	0.0	4586.86	7368.13	370.62
Piezometer	20-Aug-91	3	A	91.44	77.0	30.5	30.5	0.0	4586.86	7368.13	370.62
Piezometer	18-Jul-91	3	B	30.48	55.0	36.8	36.8	0.0	4602.41	7359.07	370.35
Piezometer	20-Aug-91	3	B	30.48	55.0	36.8	36.8	0.0	4602.41	7359.07	370.35
Piezometer	18-Jul-91	3	B	91.44	54.0	30.5	30.5	0.0	4602.40	7358.78	370.33
Piezometer	20-Aug-91	3	B	91.44	54.0	30.5	30.5	0.0	4602.40	7358.78	370.33
Piezometer	18-Jul-91	3	B	152.40	91.0	30.5	30.5	0.0	4572.10	7358.45	370.88
Piezometer	20-Aug-91	3	B	152.40	50.0	30.5	30.5	0.0	4572.10	7358.45	370.88
Piezometer	18-Jul-91	3	C	81.28	97.0	41.9	41.9	0.0	4631.31	7344.80	370.66
Piezometer	20-Aug-91	3	C	81.28	87.0	41.9	41.9	0.0	4631.31	7344.80	370.66
Piezometer	19-Jul-91	5	B	30.48	DRY	30.5	30.5	0.0	4586.00	7525.98	370.32
Piezometer	19-Aug-91	5	B	30.48	54.5	30.5	30.5	0.0	4586.00	7525.98	370.32
Piezometer	19-Jul-91	5	B	91.44	69.0	30.5	30.5	0.0	4585.82	7525.68	370.33
Piezometer	19-Aug-91	5	B	91.44	55.0	30.5	30.5	0.0	4585.82	7525.68	370.33
Piezometer	19-Jul-91	5	B	152.40	73.0	30.5	30.5	0.0	4585.63	7525.40	370.33
Piezometer	19-Aug-91	5	B	152.40	58.0	30.5	30.5	0.0	4585.63	7525.40	370.33
P-dock	19-Jul-91	5	D	30.48	56.8	56.0	92.0	36.0	4629.70	7501.94	370.09
P-dock	19-Aug-91	5	D	30.48	56.0	56.0	92.0	36.0	4629.70	7501.94	370.09

Cont.

Table 8 - cont.

LOCATION	DATE	SITE #	1	DEPTH (cm)	DEPTH OF WATER INSIDE_P (cm)	DEPTH OF WATER OUTSD_P (cm)	TOP TO GROUND (cm)	DEPTH OF POND (cm)	NORTHING (m)	EASTING (m)	ABOVE M.S.L. GROUND OR TOP_P_ELEV (m)
P-dock	19-Jul-91	5	D	91.44	56.8	52.0	88.0	36.0	4629.52	7501.79	370.14
P-dock	19-Aug-91	5	D	91.44	52.0	52.0	88.0	36.0	4629.52	7501.79	370.14
P-dock	19-Jul-91	5	D	152.40	57.3	59.0	95.0	36.0	4629.29	7501.61	370.27
P-dock	19-Aug-91	5	D	152.40	57.0	59.0	95.0	36.0	4629.29	7501.61	370.27
Piezometer	18-Jul-91	5	F	30.48	33.0	30.5	30.5	0.0	4662.33	7482.00	370.09
Piezometer	20-Aug-91	5	F	30.48	31.0	30.5	30.5	0.0	4662.33	7482.00	370.09
Piezometer	18-Jul-91	5	F	91.44	40.0	33.0	33.0	0.0	4662.12	7481.77	370.09
Piezometer	20-Aug-91	5	F	91.44	36.0	33.0	33.0	0.0	4662.12	7481.77	370.09
Piezometer	18-Jul-91	5	F	152.40	82.0	31.8	31.8	0.0	4661.95	7481.65	370.10
Piezometer	20-Aug-91	5	F	152.40	47.0	33.0	31.8	0.0	4661.95	7481.65	370.10
P-dock	19-Jul-91	7	B	30.48	52.0	53.5	89.5	36.0	4614.13	7710.12	370.22
P-dock	19-Aug-91	7	B	30.48	51.0	52.0	89.0	37.0	4614.13	7710.12	370.22
P-dock	19-Jul-91	7	B	91.44	80.5	41.0	77.0	36.0	4614.12	7709.91	370.08
P-dock	19-Aug-91	7	B	91.44	42.0	40.0	77.0	37.0	4614.12	7709.91	370.08
P-dock	19-Jul-91	7	B	114.30	170.0	92.0	128.0	36.0	4614.12	7709.68	370.66
P-dock	19-Aug-91	7	B	114.30	108.0	91.0	128.0	37.0	4614.12	7709.68	370.66
P-dock	19-Jul-91	8	B	30.48	40.0	41.0	85.0	44.0	4632.78	7812.81	370.10
P-dock	19-Aug-91	8	B	30.48	39.0	40.0	85.0	45.0	4632.78	7812.81	370.10
P-dock	19-Jul-91	8	B	91.44	52.0	41.0	85.0	44.0	4632.69	7812.63	370.10
P-dock	19-Aug-91	8	B	91.44	39.0	40.0	85.0	45.0	4632.69	7812.63	370.10
P-dock	19-Jul-91	8	B	118.11	84.0	81.0	125.0	44.0	4632.61	7812.40	370.56
P-dock	19-Aug-91	8	B	118.11	79.0	80.0	125.0	45.0	4632.61	7812.40	370.56
P-dock	19-Jul-91	9	B	30.48	62.0	65.0	140.0	75.0	4562.50	7985.31	370.25
P-dock	19-Aug-91	9	B	30.48	63.5	63.0	140.0	77.0	4562.50	7985.31	370.25
P-dock	19-Jul-91	9	B	91.44	47.0	50.0	125.0	75.0	4562.51	7985.08	369.98
P-dock	17-Aug-91	9	B	91.44	46.0	48.0	125.0	77.0	4562.51	7985.08	369.98
P-dock	19-Jul-91	9	B	152.40	76.0	78.0	153.0	75.0	4562.49	7984.88	370.13
P-dock	19-Aug-91	9	B	152.40	74.5	76.0	153.0	77.0	4562.49	7984.88	370.13

Cont.

Table 8 - cont.

LOCATION	DATE	SITE #	1	DEPTH (cm)	HYDRAULIC HYD_ELEV (m)	ELEVATION ELEV_HEAD (m)	PRESSURE PRESS_HEAD (m)	WATER TABLE DEPTH (m)	WATER TABLE ELEV. (m)	ABOVE M.S.L. GROUND ELEV. (m)
Piezometer	18-Jul-91	1	P	914.40	371.00	364.47	6.534			373.005
Piezometer	20-Aug-91	1	P	914.40	371.44	364.47	6.974			373.005
Piezometer	18-Jul-91	2	A	91.44	369.98	369.88	0.099			370.797
Piezometer	20-Aug-91	2	A	91.44	370.32	369.88	0.439			370.797
Piezometer	18-Jul-91	2	B	30.48	DRY	370.26	DRY	0.290	370.276	370.566
Piezometer	20-Aug-91	2	B	30.48	370.34	370.26	0.080			370.566
Piezometer	18-Jul-91	2	B	91.44	370.02	369.64	0.379	0.290	370.262	370.552
Piezometer	20-Aug-91	2	B	91.44	370.33	369.64	0.689			370.552
Piezometer	18-Jul-91	2	B	152.40	370.03	369.05	0.979	0.290	370.286	370.576
Piezometer	20-Aug-91	2	B	152.40	370.34	369.05	1.289			370.576
Piezometer	18-Jul-91	2	C	91.44	370.05	369.61	0.449			370.520
Piezometer	20-Aug-91	2	C	91.44	370.25	369.61	0.649			370.520
Piezometer	18-Jul-91	3	A	91.44	370.61	369.40	1.209			370.315
Piezometer	20-Aug-91	3	A	91.44	369.85	369.40	0.449			370.315
Piezometer	18-Jul-91	3	B	30.48	369.80	369.68	0.123	0.140	369.840	369.980
Piezometer	20-Aug-91	3	B	30.48	369.80	369.68	0.123			369.980
Piezometer	18-Jul-91	3	B	91.44	369.79	369.11	0.679	0.140	369.889	370.029
Piezometer	20-Aug-91	3	B	91.44	369.79	369.11	0.679			370.029
Piezometer	18-Jul-91	3	B	152.40	369.97	369.05	0.919	0.140	370.436	370.576
Piezometer	20-Aug-91	3	B	152.40	370.38	369.05	1.329			370.576
Piezometer	18-Jul-91	3	C	81.28	369.69	369.43	0.262			370.241
Piezometer	20-Aug-91	3	C	81.28	369.79	369.43	0.362			370.241
Piezometer	19-Jul-91	5	B	30.48	DRY	369.71	DRY	0.140	369.878	370.018
Piezometer	19-Aug-91	5	B	30.48	369.78	369.71	0.065			370.018
Piezometer	19-Jul-91	5	B	91.44	369.64	369.11	0.529	0.140	369.884	370.024
Piezometer	19-Aug-91	5	B	91.44	369.78	369.11	0.669			370.024
Piezometer	19-Jul-91	5	B	152.40	369.60	368.50	1.099	0.140	369.881	370.021
Piezometer	19-Aug-91	5	B	152.40	369.75	368.50	1.249			370.021
P-dock	19-Jul-91	5	D	30.48	369.53	368.87	0.657	-0.350	369.523	369.173
P-dock	19-Aug-91	5	D	30.48	369.53	368.87	0.665			369.173

Cont.

Table 8 - cont.

LOCATION	DATE	SITE #	1	DEPTH (cm)	HYDRAULIC HYD_ELEV (m)	ELEVATION ELEV_HEAD (m)	PRESSURE PRESS_HEAD (m)	WATER TABLE DEPTH (m)	WATER TABLE ELEV. (m)	ABOVE M.S.L. GROUND ELEV. (m)
P-dock	19-Jul-91	5	D	91.44	369.58	368.35	1.227	-0.350	369.614	369.264
P-dock	19-Aug-91	5	D	91.44	369.62	368.35	1.274			369.264
P-dock	19-Jul-91	5	D	152.40	369.70	367.80	1.902	-0.350	369.671	369.321
P-dock	19-Aug-91	5	D	152.40	369.70	367.80	1.904			369.321
Piezometer	18-Jul-91	5	F	30.48	369.76	369.48	0.280	-0.050	369.835	369.785
Piezometer	20-Aug-91	5	F	30.48	369.78	369.48	0.300			369.785
Piezometer	18-Jul-91	5	F	91.44	369.69	368.85	0.845	-0.050	369.813	369.763
Piezometer	20-Aug-91	5	F	91.44	369.73	368.85	0.885			369.763
Piezometer	18-Jul-91	5	F	152.40	369.28	368.26	1.022	-0.050	369.834	369.784
Piezometer	20-Aug-91	5	F	152.40	369.63	368.26	1.371			369.784
P-dock	19-Jul-91	7	B	30.48	369.70	369.02	0.680	-0.400	369.726	369.326
P-dock	19-Aug-91	7	B	30.48	369.71	369.03	0.685			369.331
P-dock	19-Jul-91	7	B	91.44	369.28	368.40	0.879	-0.400	369.711	369.311
P-dock	19-Aug-91	7	B	91.44	369.66	368.40	1.264			369.311
P-dock	19-Jul-91	7	B	114.30	368.96	368.24	0.723	-0.400	369.780	369.380
P-dock	19-Aug-91	7	B	114.30	369.58	368.24	1.343			369.380
P-dock	19-Jul-91	8	B	30.48	369.70	368.95	0.755	-0.450	369.700	369.250
P-dock	19-Aug-91	8	B	30.48	369.71	368.95	0.765			369.250
P-dock	19-Jul-91	8	B	91.44	369.58	368.34	1.244	-0.450	369.701	369.251
P-dock	19-Aug-91	8	B	91.44	369.71	368.34	1.374			369.251
P-dock	19-Jul-91	8	B	118.11	369.72	368.13	1.591	-0.450	369.760	369.310
P-dock	19-Aug-91	8	B	118.11	369.77	368.13	1.641			369.310
P-dock	19-Jul-91	9	B	30.48	369.63	368.55	1.085	-0.450	369.304	368.854
P-dock	19-Aug-91	9	B	30.48	369.62	368.55	1.070			368.854
P-dock	19-Jul-91	9	B	91.44	369.51	367.81	1.694	-0.450	369.179	368.729
P-dock	17-Aug-91	9	B	91.44	369.52	367.81	1.704			368.729
P-dock	19-Jul-91	9	B	152.40	369.37	367.08	2.294	-0.450	369.050	368.600
P-dock	19-Aug-91	9	B	152.40	369.39	367.08	2.309			368.600

Cont.

Table 8 - cont.

LOCATION	DATE	SITE #	1	DEPTH (cm)	WATER ELEV. (m)	Field D.O.(ppm)	Field F_pH pH	LAB. EH (mV)	LAB. EH(NHE) (mV)	Field F_Ec Ec	Field F_T(C) Temp.(C)
Piezometer	18-Jul-91	1	P	914.40	-	0.3	6.9	-136	108	2350	7.8
Piezometer	20-Aug-91	1	P	914.40	-	0.5	6.7	-78	166	2140	7.8
Piezometer	18-Jul-91	2	A	91.44	-	3.6	6.4	70	314	2920	14.4
Piezometer	20-Aug-91	2	A	91.44	-	0.4	6.7	-116	129	2270	14.2
Piezometer	18-Jul-91	2	B	30.48	-	DRY	DRY		DRY	DRY	DRY
Piezometer	20-Aug-91	2	B	30.48	-	0.7	7.4	27	271	2350	16.0
Piezometer	18-Jul-91	2	B	91.44	-	0.7	6.7	-53	191	3180	12.3
Piezometer	20-Aug-91	2	B	91.44	-	0.3	6.8	-148	96	2320	13.7
Piezometer	18-Jul-91	2	B	152.40	-	1.0	6.5	-104	140	2965	9.8
Piezometer	20-Aug-91	2	B	152.40	-	0.3	6.5	-116	128	2020	10.9
Piezometer	18-Jul-91	2	C	91.44	-	1.0	6.9	14	258	1850	10.9
Piezometer	20-Aug-91	2	C	91.44	-	0.6	6.7	-133	112	1381	11.9
Piezometer	18-Jul-91	3	A	91.44	-	1.6	6.1	47	291	3350	16.3
Piezometer	20-Aug-91	3	A	91.44	-	0.5	5.7	-56	189	1911	16.2
Piezometer	18-Jul-91	3	B	30.48	-	DRY	DRY		DRY	DRY	DRY
Piezometer	20-Aug-91	3	B	30.48	-	1.1	7.1	40	284	2350	15.2
Piezometer	18-Jul-91	3	B	91.44	-	1.9	7.0	114	358	3890	12.9
Piezometer	20-Aug-91	3	B	91.44	-	0.4	6.8	49	293	2790	12.8
Piezometer	18-Jul-91	3	B	152.40	-	1.2	6.2	-97	147	1277	8.6
Piezometer	20-Aug-91	3	B	152.40	-	0.4	6.3	-59	185	523	9.9
Piezometer	18-Jul-91	3	C	81.28	-	1.3	6.4	-18	226	1367	14.0
Piezometer	20-Aug-91	3	C	81.28	-	0.5	5.7	-4	240	520	14.6
Piezometer	19-Jul-91	5	B	30.48	-	DRY	DRY		DRY	DRY	DRY
Piezometer	19-Aug-91	5	B	30.48	-	1.1	7.8	142	386	2150	19.0
Piezometer	19-Jul-91	5	B	91.44	-	0.8	6.8	149	393	704	13.6
Piezometer	19-Aug-91	5	B	91.44	-	0.5	6.4	-99	145	619	14.5
Piezometer	19-Jul-91	5	B	152.40	-	1.3	6.7	156	400	588	10.2
Piezometer	19-Aug-91	5	B	152.40	-	0.4	7.3	15	259	281	11.1
P-dock	19-Jul-91	5	D	30.48	369.533	0.3	10.2	-16	228	2651	21.1
P-dock	19-Aug-91	5	D	30.48	369.533	1.9	10.2	-68	176	1985	20.3

Cont.

Table 8 - cont.

LOCATION	DATE	SITE #	1	DEPTH (cm)	WATER ELEV. (m)	Field D.O.(ppm)	Field F_pH pH	LAB. EH (mV)	LAB. EH(NHE) (mV)	Field F_Ec Ec	Field F_T(C) Temp.(C)
P-dock	19-Jul-91	5	D	91.44	369.624	0.4	6.8	-92	152	4170	16.8
P-dock	19-Aug-91	5	D	91.44	369.624	0.4	6.7	-172	72	2730	17.5
P-dock	19-Jul-91	5	D	152.40	369.681	0.5	6.6	165	409	2670	18.7
P-dock	19-Aug-91	5	D	152.40	369.681	0.5	6.9	45	289	3110	15.3
Piezometer	18-Jul-91	5	F	30.48	-	1.6	6.2	2	246	3540	16.3
Piezometer	20-Aug-91	5	F	30.48	-	0.7	6.2	-103	141	2170	15.6
Piezometer	18-Jul-91	5	F	91.44	-	1.4	6.1	-99	145	2240	13.6
Piezometer	20-Aug-91	5	F	91.44	-	0.5	6.4	-132	112	1246	14.3
Piezometer	18-Jul-91	5	F	152.40	-	2.4	5.8	3	247	636	10.4
Piezometer	20-Aug-91	5	F	152.40	-	0.5	6.0	-34	210	136	11.0
P-dock	19-Jul-91	7	B	30.48	369.686	0.5	6.8	146	390	3130	22.3
P-dock	19-Aug-91	7	B	30.48	369.701	0.5	6.9	38	282	3010	19.1
P-dock	19-Jul-91	7	B	91.44	369.671	0.3	6.1	69	313	553	14.5
P-dock	19-Aug-91	7	B	91.44	369.681	0.3	6.0	-51	193	462	14.7
P-dock	19-Jul-91	7	B	114.30	369.740	0.3	5.9	33	277	664	12.9
P-dock	19-Aug-91	7	B	114.30	369.750	0.4	5.8	-51	193	335	13.5
P-dock	19-Jul-91	8	B	30.48	369.690	0.3	7.2	112	356	3230	23.8
P-dock	19-Aug-91	8	B	30.48	369.700	0.4	6.9	39	283	2990	18.9
P-dock	19-Jul-91	8	B	91.44	369.691	0.2	6.6	-69	175	975	16.2
P-dock	19-Aug-91	8	B	91.44	369.701	0.5	6.4	-142	103	801	16.0
P-dock	19-Jul-91	8	B	118.11	369.750	0.2	6.6	-47	197	647	13.6
P-dock	19-Aug-91	8	B	118.11	369.760	0.6	6.6	-13	231	457	14.2
P-dock	19-Jul-91	9	B	30.48	369.604	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
P-dock	19-Aug-91	9	B	30.48	369.624	0.5	6.8	12	256	3438	19.8
P-dock	19-Jul-91	9	B	91.44	369.479	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
P-dock	17-Aug-91	9	B	91.44	369.499	0.4	6.2	29	273	673	16.1
P-dock	19-Jul-91	9	B	152.40	369.350	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
P-dock	19-Aug-91	9	B	152.40	369.370	0.4	5.9	-85	159	236	13.0

Cont.

Table 8 - cont.

LOCATION	DATE	SITE #	1	DEPTH (cm)	T.D.S. (mg/L)	ACIDITY (mg/L)	ALKALINITY (mg/L)	Fe TOTAL (mg/L)	Cu (mg/L)	Zn (mg/L)	Ca (mg/L)
Piezometer	18-Jul-91	1	P	914.40		0	175	3.85	<0.002	0.013	415.1
Piezometer	20-Aug-91	1	P	914.40	2263	0	197	2.99	<0.002	0.028	432.5
Piezometer	18-Jul-91	2	A	91.44		68	69	<0.002	0.109	0.032	630.9
Piezometer	20-Aug-91	2	A	91.44		0	146	25.24	<0.002	0.022	544.5
Piezometer	18-Jul-91	2	B	30.48		DRY	DRY	DRY			
Piezometer	20-Aug-91	2	B	30.48		0	86	0.47	<0.002	<0.002	550.5
Piezometer	18-Jul-91	2	B	91.44		0	70	1.88	<0.002	0.477	630.5
Piezometer	20-Aug-91	2	B	91.44		10	93	73.90	<0.002	0.083	532.4
Piezometer	18-Jul-91	2	B	152.40		20	119	22.94	<0.002	0.193	538.9
Piezometer	20-Aug-91	2	B	152.40	2525	34	73	66.57	<0.002	0.042	422.0
Piezometer	18-Jul-91	2	C	91.44		0	119	<0.002	0.014	0.017	328.3
Piezometer	20-Aug-91	2	C	91.44		0	95	12.31	<0.002	<0.002	269.5
Piezometer	18-Jul-91	3	A	91.44		216	3	56.85	0.111	1.179	576.3
Piezometer	20-Aug-91	3	A	91.44		192	32	69.23	<0.002	0.019	421.1
Piezometer	18-Jul-91	3	B	30.48		DRY	DRY				
Piezometer	20-Aug-91	3	B	30.48		0	355	0.14	<0.002	<0.002	504.5
Piezometer	18-Jul-91	3	B	91.44		0	626	<0.002	0.035	0.023	761.5
Piezometer	20-Aug-91	3	B	91.44		0	794	8.66	<0.002	0.429	764.2
Piezometer	18-Jul-91	3	B	152.40	350	0	190	3.51	0.112	0.826	211.3
Piezometer	20-Aug-91	3	B	152.40	350	0	128	11.98	<0.002	0.019	80.0
Piezometer	18-Jul-91	3	C	81.28	412	15	22	2.24	0.018	0.272	238.1
Piezometer	20-Aug-91	3	C	81.28		34	6	12.85	<0.002	<0.002	100.8
Piezometer	19-Jul-91	5	B	30.48		DRY	DRY				
Piezometer	19-Aug-91	5	B	30.48		0	143	0.06	<0.002	0.055	432.2
Piezometer	19-Jul-91	5	B	91.44	500	N.A.	N.A.	0.56	<0.002	0.062	200.7
Piezometer	19-Aug-91	5	B	91.44	520	0	161	0.42	<0.002	<0.002	120.0
Piezometer	19-Jul-91	5	B	152.40		N.A.	N.A.	0.01	<0.002	1.024	147.1
Piezometer	19-Aug-91	5	B	152.40	210	0	132	1.67	<0.002	0.014	42.3
P-dock	19-Jul-91	5	D	30.48		0	41	<0.002	0.312	0.003	542.8
P-dock	19-Aug-91	5	D	30.48		0	39	0.06	0.354	<0.002	514.4

Cont.

Table 8 - cont.

LOCATION	DATE	SITE #	1	DEPTH (cm)	T.D.S. (mg/L)	ACIDITY (mg/L)	ALKALINITY (mg/L)	Fe TOTAL (mg/L)	Cu (mg/L)	Zn (mg/L)	Ca (mg/L)
P-dock	19-Jul-91	5	D	91.44		0	148	2.63	0.038	0.065	596.6
P-dock	19-Aug-91	5	D	91.44	3088	0	238	72.78	<0.002	0.014	601.9
P-dock	19-Jul-91	5	D	152.40		N.A.	N.A.	9.09	<0.002	<0.002	833.3
P-dock	19-Aug-91	5	D	152.40		0	1143	1.84	<0.002	0.008	728.9
Piezometer	18-Jul-91	5	F	30.48		54	30	11.51	0.005	0.532	613.9
Piezometer	20-Aug-91	5	F	30.48		111	0	67.29	<0.002	0.087	519.0
Piezometer	18-Jul-91	5	F	91.44		0	85	5.62	0.003	0.021	397.9
Piezometer	20-Aug-91	5	F	91.44	1237	0	91	8.73	<0.002	0.013	312.4
Piezometer	18-Jul-91	5	F	152.40		0	50	0.82	0.032	0.431	89.3
Piezometer	20-Aug-91	5	F	152.40	170	0	49	4.10	0.026	0.021	17.8
P-dock	19-Jul-91	7	B	30.48		N.A.	N.A.	0.03	<0.002	0.038	676.7
P-dock	19-Aug-91	7	B	30.48		0	1048	0.25	<0.002	0.008	802.2
P-dock	19-Jul-91	7	B	91.44		N.A.	N.A.	3.16	<0.002	0.009	89.4
P-dock	19-Aug-91	7	B	91.44	288	0	211	8.20	0.025	0.013	34.6
P-dock	19-Jul-91	7	B	114.30		N.A.	N.A.	12.62	<0.002	0.006	127.1
P-dock	19-Aug-91	7	B	114.30	212	0	130	8.67	<0.002	0.018	32.6
P-dock	19-Jul-91	8	B	30.48		N.A.	N.A.	0.12	<0.002	0.013	605.2
P-dock	19-Aug-91	8	B	30.48	3160	0	1227	8.63	<0.002	0.008	780.5
P-dock	19-Jul-91	8	B	91.44		N.A.	N.A.	32.63	<0.002	0.136	170.2
P-dock	19-Aug-91	8	B	91.44	475	0	354	27.73	<0.002	0.008	108.3
P-dock	19-Jul-91	8	B	118.11		N.A.	N.A.	13.26	<0.002	0.045	123.0
P-dock	19-Aug-91	8	B	118.11	290	0	225	10.15	<0.002	0.013	66.0
P-dock	19-Jul-91	9	B	30.48		N.A.	N.A.				
P-dock	19-Aug-91	9	B	30.48	3262	0	1371	0.18	<0.002	0.008	825.1
P-dock	19-Jul-91	9	B	91.44		N.A.	N.A.				
P-dock	17-Aug-91	9	B	91.44	363	0	294	1.89	<0.002	0.008	78.9
P-dock	19-Jul-91	9	B	152.40		N.A.	N.A.				
P-dock	19-Aug-91	9	B	152.40	175	0	94	5.26	<0.002	0.031	23.3

Cont.

Table 8 - cont.

LOCATION	DATE	SITE #	1	DEPTH (cm)	Mg (mg/L)	Pb (mg/L)	Th (mg/L)	Al (mg/L)	Mn (mg/L)	U (mg/L)	Ni (mg/L)
Piezometer	18-Jul-91	1	P	914.40	56.2	<0.025	<0.015	0.402	1.088	<0.100	<0.005
Piezometer	20-Aug-91	1	P	914.40	56.9	<0.025	<0.015	0.432	1.319	<0.100	0.014
Piezometer	18-Jul-91	2	A	91.44	36.1	<0.025	<0.015	0.633	1.067	<0.100	0.056
Piezometer	20-Aug-91	2	A	91.44	26.9	<0.025	<0.015	0.549	0.851	<0.100	0.017
Piezometer	18-Jul-91	2	B	30.48							
Piezometer	20-Aug-91	2	B	30.48	26.5	<0.025	<0.015	0.679	2.656	<0.100	0.030
Piezometer	18-Jul-91	2	B	91.44	28.2	<0.025	<0.015	0.670	2.509	<0.100	0.021
Piezometer	20-Aug-91	2	B	91.44	23.4	<0.025	<0.015	0.580	1.049	<0.100	0.012
Piezometer	18-Jul-91	2	B	152.40	21.5	<0.025	<0.015	0.509	1.855	<0.100	0.006
Piezometer	20-Aug-91	2	B	152.40	16.9	<0.025	<0.015	0.460	1.405	<0.100	<0.005
Piezometer	18-Jul-91	2	C	91.44	18.0	<0.025	<0.015	0.334	0.572	<0.100	0.019
Piezometer	20-Aug-91	2	C	91.44	19.5	<0.025	0.023	0.300	0.574	<0.100	0.012
Piezometer	18-Jul-91	3	A	91.44	10.4	0.092	0.023	0.324	0.491	<0.100	0.037
Piezometer	20-Aug-91	3	A	91.44	11.1	<0.025	<0.015	1.233	0.539	<0.100	0.020
Piezometer	18-Jul-91	3	B	30.48							
Piezometer	20-Aug-91	3	B	30.48	22.9	<0.025	<0.015	0.544	0.962	<0.100	0.014
Piezometer	18-Jul-91	3	B	91.44	19.2	<0.025	<0.015	0.770	0.539	<0.100	0.027
Piezometer	20-Aug-91	3	B	91.44	16.1	<0.025	<0.015	0.832	1.019	<0.100	0.014
Piezometer	18-Jul-91	3	B	152.40	4.8	<0.025	<0.015	0.233	0.393	<0.100	0.010
Piezometer	20-Aug-91	3	B	152.40	2.7	0.078	<0.015	0.194	0.132	<0.100	0.019
Piezometer	18-Jul-91	3	C	81.28	1.9	<0.025	<0.015	0.265	<0.002	<0.100	0.031
Piezometer	20-Aug-91	3	C	81.28	2.0	<0.025	<0.015	0.111	<0.002	<0.100	0.006
Piezometer	19-Jul-91	5	B	30.48							
Piezometer	19-Aug-91	5	B	30.48	5.3	<0.025	<0.015	0.509	0.029	<0.100	0.035
Piezometer	19-Jul-91	5	B	91.44	5.8	<0.025	<0.015	0.262	0.122	<0.100	<0.005
Piezometer	19-Aug-91	5	B	91.44	4.4	<0.025	<0.015	0.165	0.122	<0.100	<0.005
Piezometer	19-Jul-91	5	B	152.40	12.0	0.026	<0.015	0.097	<0.002	<0.100	0.018
Piezometer	19-Aug-91	5	B	152.40	9.0	<0.025	<0.015	0.025	<0.002	<0.100	0.014
P-dock	19-Jul-91	5	D	30.48	0.7	<0.025	<0.015	1.423	<0.002	<0.100	0.058
P-dock	19-Aug-91	5	D	30.48	0.2	<0.025	<0.015	0.784	<0.002	<0.100	0.051

Cont.

Table 8 - cont.

LOCATION	DATE	SITE #	1	DEPTH (cm)	Mg (mg/L)	Pb (mg/L)	Th (mg/L)	Al (mg/L)	Mn (mg/L)	U (mg/L)	Ni (mg/L)
P-dock	19-Jul-91	5	D	91.44	22.1	<0.025	<0.015	1.026	0.571	<0.100	0.014
P-dock	19-Aug-91	5	D	91.44	25.1	<0.025	<0.015	0.679	0.321	<0.100	0.013
P-dock	19-Jul-91	5	D	152.40	25.6	<0.025	<0.015	0.749	0.034	<0.100	<0.005
P-dock	19-Aug-91	5	D	152.40	22.1	<0.025	<0.015	0.838	0.046	<0.100	0.007
Piezometer	18-Jul-91	5	F	30.48	4.3	<0.025	<0.015	0.652	0.146	<0.100	0.019
Piezometer	20-Aug-91	5	F	30.48	3.4	<0.025	0.059	0.599	0.145	<0.100	0.009
Piezometer	18-Jul-91	5	F	91.44	5.3	<0.025	<0.015	0.415	0.240	<0.100	0.012
Piezometer	20-Aug-91	5	F	91.44	4.8	0.028	<0.015	0.338	0.219	<0.100	<0.005
Piezometer	18-Jul-91	5	F	152.40	2.2	0.027	<0.015	0.133	0.056	<0.100	0.024
Piezometer	20-Aug-91	5	F	152.40	1.7	<0.025	<0.015	0.084	0.014	<0.100	<0.005
P-dock	19-Jul-91	7	B	30.48	19.3	<0.025	<0.015	0.268	0.026	<0.100	0.021
P-dock	19-Aug-91	7	B	30.48	19.3	<0.025	<0.015	0.959	0.256	<0.100	<0.005
P-dock	19-Jul-91	7	B	91.44	7.7	<0.025	<0.015	0.090	0.060	<0.100	0.011
P-dock	19-Aug-91	7	B	91.44	3.9	<0.025	<0.015	0.145	0.033	<0.100	0.007
P-dock	19-Jul-91	7	B	114.30	6.1	<0.025	<0.015	0.128	0.106	<0.100	0.008
P-dock	19-Aug-91	7	B	114.30	3.9	<0.025	<0.015	0.141	0.045	<0.100	0.008
P-dock	19-Jul-91	8	B	30.48	27.7	<0.025	<0.015	0.284	0.019	<0.100	0.017
P-dock	19-Aug-91	8	B	30.48	28.4	<0.025	<0.015	0.968	0.144	<0.100	0.023
P-dock	19-Jul-91	8	B	91.44	19.2	<0.025	<0.015	0.113	0.528	<0.100	0.011
P-dock	19-Aug-91	8	B	91.44	16.8	<0.025	<0.015	0.119	0.562	<0.100	0.013
P-dock	19-Jul-91	8	B	118.11	12.9	<0.025	<0.015	0.065	0.396	<0.100	0.015
P-dock	19-Aug-91	8	B	118.11	11.5	<0.025	<0.015	0.063	0.411	<0.100	0.014
P-dock	19-Jul-91	9	B	30.48							
P-dock	19-Aug-91	9	B	30.48	39.1	0.038	<0.015	1.003	0.445	<0.100	0.011
P-dock	19-Jul-91	9	B	91.44							
P-dock	17-Aug-91	9	B	91.44	11.0	<0.025	<0.015	0.106	0.034	<0.100	<0.005
P-dock	19-Jul-91	9	B	152.40							
P-dock	19-Aug-91	9	B	152.40	3.0	<0.025	<0.015	0.089	0.021	<0.100	0.009

Cont.

Table 8 - cont.

LOCATION	DATE	SITE #	1	DEPTH (cm)	Ra-226 (mBq/L)	Ra-226 (pCi/L)	SULPHATE (mg/L)
Piezometer	18-Jul-91	1	P	914.40	358	9.7	831
Piezometer	20-Aug-91	1	P	914.40	799	21.6	1140
Piezometer	18-Jul-91	2	A	91.44	*N.S.S.	*N.S.S.	*N.S.S.
Piezometer	20-Aug-91	2	A	91.44	1907	51.5	1357
Piezometer	18-Jul-91	2	B	30.48	DRY	DRY	DRY
Piezometer	20-Aug-91	2	B	30.48	*N.S.S.	*N.S.S.	*N.S.S.
Piezometer	18-Jul-91	2	B	91.44	866	23.4	1491
Piezometer	20-Aug-91	2	B	91.44	1038	28.0	1532
Piezometer	18-Jul-91	2	B	152.40	1132	30.6	1303
Piezometer	20-Aug-91	2	B	152.40	1195	32.3	1231
Piezometer	18-Jul-91	2	C	91.44	559	15.1	677
Piezometer	20-Aug-91	2	C	91.44	973	26.3	715
Piezometer	18-Jul-91	3	A	91.44	*N.S.S.	*N.S.S.	1082
Piezometer	20-Aug-91	3	A	91.44	2301	62.2	1299
Piezometer	18-Jul-91	3	B	30.48	DRY	DRY	DRY
Piezometer	20-Aug-91	3	B	30.48	*N.S.S.	*N.S.S.	*N.S.S.
Piezometer	18-Jul-91	3	B	91.44	527	14.2	1198
Piezometer	20-Aug-91	3	B	91.44	706	19.1	1167
Piezometer	18-Jul-91	3	B	152.40	1056	28.5	342
Piezometer	20-Aug-91	3	B	152.40	1773	47.9	123
Piezometer	18-Jul-91	3	C	81.28	*N.S.S.	*N.S.S.	549
Piezometer	20-Aug-91	3	C	81.28	1618	43.7	151
Piezometer	19-Jul-91	5	B	30.48	DRY	DRY	DRY
Piezometer	19-Aug-91	5	B	30.48	*N.S.S.	*N.S.S.	*N.S.S.
Piezometer	19-Jul-91	5	B	91.44	10914	295.0	292
Piezometer	19-Aug-91	5	B	91.44	2341	63.3	153
Piezometer	19-Jul-91	5	B	152.40	4266	115.3	200
Piezometer	19-Aug-91	5	B	152.40	4603	124.0	18
P-dock	19-Jul-91	5	D	30.48	503	13.6	1274
P-dock	19-Aug-91	5	D	30.48	368	10.0	1224

Cont.

Table 8 - cont.

LOCATION	DATE	SITE #	1	DEPTH (cm)	Ra-226 (mBq/L)	Ra-226 (pCi/L)	SULPHATE (mg/L)
P-dock	19-Jul-91	5	D	91.44	608	16.4	1563
P-dock	19-Aug-91	5	D	91.44	1633	44.1	1340
P-dock	19-Jul-91	5	D	152.40	1907	51.5	1017
P-dock	19-Aug-91	5	D	152.40	1801	49.0	1047
Piezometer	18-Jul-91	5	F	30.48	1872	50.6	1365
Piezometer	20-Aug-91	5	F	30.48	1311	35.4	1400
Piezometer	18-Jul-91	5	F	91.44	2297	62.1	934
Piezometer	20-Aug-91	5	F	91.44	2354	64.0	756
Piezometer	18-Jul-91	5	F	152.40	1807	48.8	138
Piezometer	20-Aug-91	5	F	152.40	*N.S.S	*N.S.S	13
P-dock	19-Jul-91	7	B	30.48	2622	70.9	1084
P-dock	19-Aug-91	7	B	30.48	3763	101.7	1048
P-dock	19-Jul-91	7	B	91.44	5714	154.4	56
P-dock	19-Aug-91	7	B	91.44	3048	82.4	17
P-dock	19-Jul-91	7	B	114.30	2701	73.0	152
P-dock	19-Aug-91	7	B	114.30	4301	116.2	25
P-dock	19-Jul-91	8	B	30.48	1469	40.0	1033
P-dock	19-Aug-91	8	B	30.48	2002	54.1	1098
P-dock	19-Jul-91	8	B	91.44	1694	45.8	105
P-dock	19-Aug-91	8	B	91.44	1570	42.4	17
P-dock	19-Jul-91	8	B	118.11	5075	137.2	106
P-dock	19-Aug-91	8	B	118.11	2220	60.0	85
P-dock	19-Jul-91	9	B	30.48	N.A.	N.A.	N.A.
P-dock	19-Aug-91	9	B	30.48	4286	115.8	1044
P-dock	19-Jul-91	9	B	91.44	N.A.	N.A.	N.A.
P-dock	17-Aug-91	9	B	91.44	1677	45.3	27
P-dock	19-Jul-91	9	B	152.40	N.A.	N.A.	N.A.
P-dock	19-Aug-91	9	B	152.40	1043	28.2	14

Tabke 9 - Panel wetlands: groundwater quality, fall 1991.

LOCATION	DATE	SITE #	1	DEPTH (cm)	DEPTH OF WATER INSIDE_P (cm)	DEPTH OF WATER OUTSD_P (cm)	TOP TO GROUND (cm)	DEPTH OF POND (cm)	NORTHING (m)	EASTING (m)
Piezometer	23-Sep-91	1	P	914.4	162.0	61.0	61.0	0.0	4550.99	7303.76
Piezometer	15-Oct-91	1	P	914.4	132.0	61.0	61.0	0.0	4550.99	7303.76
Piezometer	23-Sep-91	2	A	91.4	41.0	28.5	30.5	2.0	4567.06	7328.01
Piezometer	15-Oct-91	2	A	91.4	49.0	28.5	30.5	2.0	4567.06	7328.01
Piezometer	23-Sep-91	2	B	30.5	34.0	31.1	35.6	4.5	4572.50	7323.67
Piezometer	15-Oct-91	2	B	30.5	32.0	31.1	35.6	4.5	4572.50	7323.67
Piezometer	23-Sep-91	2	B	91.4	26.0	26.0	30.48	4.5	4572.31	7323.37
Piezometer	15-Oct-91	2	B	91.4	20.0	26.0	30.48	4.5	4572.31	7323.37
Piezometer	23-Sep-91	2	B	152.4	29.0	26.0	30.48	4.5	4572.10	7323.15
Piezometer	15-Oct-91	2	B	152.4	22.0	26.0	30.48	4.5	4572.10	7323.15
Piezometer	23-Sep-91	2	C	91.4	37.0	22.5	30.48	8.0	4575.74	7321.66
Piezometer	15-Oct-91	2	C	91.4	23.0	22.5	30.48	8.0	4575.74	7321.66
Piezometer	23-Sep-91	3	A	91.4	20.0	30.5	30.5	0.0	4586.86	7368.13
Piezometer	15-Oct-91	3	A	91.4	29.0	30.5	30.5	0.0	4586.86	7368.13
Piezometer	23-Sep-91	3	B	30.5	31.0	32.8	36.8	4.0	4602.41	7359.07
Piezometer	15-Oct-91	3	B	30.5	27.0	32.8	36.8	4.0	4602.41	7359.07
Piezometer	23-Sep-91	3	B	91.4	30.0	26.5	30.5	4.0	4602.40	7358.78
Piezometer	15-Oct-91	3	B	91.4	26.0	26.5	30.5	4.0	4602.40	7358.78
Piezometer	23-Sep-91	3	B	152.4	30.0	26.5	30.5	4.0	4572.10	7323.15
Piezometer	15-Oct-91	3	B	152.4	22.0	26.5	30.5	4.0	4572.10	7323.15
Piezometer	23-Sep-91	3	C	81.4	50.0	33.9	41.9	8.0	4631.31	7344.80
Piezometer	15-Oct-91	3	C	81.4	30.0	33.9	41.9	8.0	4631.31	7344.80
Piezometer	24-Sep-91	5	B	30.5	41.0	30.5	30.5	0.0	4586.00	7525.98
Piezometer	17-Oct-91	5	B	30.5	32.0	30.5	30.5	0.0	4586.00	7525.98
Piezometer	24-Sep-91	5	B	91.4	41.0	30.5	30.5	0.0	4585.82	7525.68
Piezometer	17-Oct-91	5	B	91.4	32.0	30.5	30.5	0.0	4585.82	7525.68
Piezometer	24-Sep-91	5	B	152.4	40.0	30.5	30.5	0.0	4585.63	7525.40
Piezometer	17-Oct-91	5	B	152.4	30.0	30.5	30.5	0.0	4585.63	7525.40
P-dock	24-Sep-91	5	D	30.5	45.0	32.0	92.0	60.0	4629.70	7501.94
P-dock	16-Oct-91	5	D	30.5	31.0	32.0	92.0	60.0	4629.70	7501.94

Cont.

Table 9 - cont.

LOCATION	DATE	SITE #	1	DEPTH (cm)	DEPTH OF WATER INSIDE_P (cm)	DEPTH OF WATER OUTSD_P (cm)	TOP TO GROUND (cm)	DEPTH OF POND (cm)	NORTHING (m)	EASTING (m)
P-dock	24-Sep-91	5	D	91.4	43.3	28.0	88.0	60.0	4629.52	7501.79
P-dock	16-Oct-91	5	D	91.4	31.0	28.0	88.0	60.0	4629.52	7501.79
P-dock	24-Sep-91	5	D	152.4	47.7	35.0	95.0	60.0	4629.29	7501.61
P-dock	16-Oct-91	5	D	152.4	36.0	35.0	95.0	60.0	4629.29	7501.61
Piezometer	23-Sep-91	5	F	30.5	22.5	27.5	30.5	3.0	4662.33	7482.00
Piezometer	16-Oct-91	5	F	30.5	12.0	27.5	30.5	3.0	4662.33	7482.00
Piezometer	23-Sep-91	5	F	91.4	18.5	30.0	33.0	3.0	4662.12	7481.77
Piezometer	16-Oct-91	5	F	91.4	10.0	30.0	33.0	3.0	4662.12	7481.77
Piezometer	23-Sep-91	5	F	152.4	23.0	28.8	31.8	3.0	4661.95	7481.65
Piezometer	16-Oct-91	5	F	152.4	7.0	28.8	31.8	3.0	4661.95	7481.65
P-dock	25-Sep-91	7	B	30.5	43.0	55.7	89.5	33.8	4614.13	7710.12
P-dock	17-Oct-91	7	B	30.5	32.0	55.2	89.0	33.8	4614.13	7710.12
P-dock	25-Sep-91	7	B	91.4	30.0	43.2	77.0	33.8	4614.12	7709.91
P-dock	17-Oct-91	7	B	91.4	17.0	43.2	77.0	33.8	4614.12	7709.91
P-dock	25-Sep-91	7	B	114.3	83.0	94.2	128.0	33.8	4614.02	7709.68
P-dock	17-Oct-91	7	B	114.3	70.0	94.2	128.0	33.8	4614.02	7709.68
P-dock	24-Sep-91	8	B	30.5	N.A.	46.0	85.0	39.0	4632.78	7812.81
P-dock	17-Oct-91	8	B	30.5	19.0	46.0	85.0	39.0	4632.78	7812.81
P-dock	24-Sep-91	8	B	91.4	N.A.	46.0	85.0	39.0	4632.69	7812.63
P-dock	17-Oct-91	8	B	91.4	18.0	46.0	85.0	39.0	4632.69	7812.63
P-dock	24-Sep-91	8	B	118.3	N.A.	86.0	125.0	39.0	4632.61	7812.40
P-dock	17-Oct-91	8	B	118.3	58.0	86.0	125.0	39.0	4632.61	7812.40
P-dock	24-Sep-91	9	B	30.5	N.A.	60.2	140.0	79.8	4562.50	7985.31
P-dock	17-Oct-91	9	B	30.5	42.0	60.2	140.0	79.8	4562.50	7985.31
P-dock	24-Sep-91	9	B	91.4	N.A.	45.2	125.0	79.8	4562.51	7985.08
P-dock	17-Oct-91	9	B	91.4	27.0	45.2	125.0	79.8	4562.51	7985.08
P-dock	24-Sep-91	9	B	152.4	N.A.	73.2	153.0	79.8	4562.49	7984.88
P-dock	17-Oct-91	9	B	152.4	56.0	73.2	153.0	79.8	4562.49	7984.88

Cont.

Table 9 - cont.

LOCATION	DATE	SITE #	1	DEPTH (cm)	ABOVE M.S.L. GROUND OR TOP_P_ELEV (m)	HYDRAULIC HYD_ELEV (m)	ELEVATION ELEV_HEAD (m)	PRESSURE PRESS_HEAD (m)	WATER TABLE DEPTH (m)	WATER TABLE ELEV. (m)
Piezometer	23-Sep-91	1	P	914.4	373.61	371.99	364.47	7.52		
Piezometer	15-Oct-91	1	P	914.4	373.61	372.29	364.47	7.82		
Piezometer	23-Sep-91	2	A	91.4	371.10	370.69	369.88	0.81		
Piezometer	15-Oct-91	2	A	91.4	371.10	370.61	369.88	0.73		
Piezometer	23-Sep-91	2	B	30.5	370.92	370.58	370.26	0.32	-0.030	370.596
Piezometer	15-Oct-91	2	B	30.5	370.92	370.60	370.26	0.34		
Piezometer	23-Sep-91	2	B	91.4	370.86	370.60	369.64	0.96	-0.030	370.582
Piezometer	15-Oct-91	2	B	91.4	370.86	370.66	369.64	1.02		
Piezometer	23-Sep-91	2	B	152.4	370.88	370.59	369.05	1.54	-0.030	370.606
Piezometer	15-Oct-91	2	B	152.4	370.88	370.66	369.05	1.61		
Piezometer	23-Sep-91	2	C	91.4	370.82	370.45	369.61	0.85		
Piezometer	15-Oct-91	2	C	91.4	370.82	370.59	369.61	0.99		
Piezometer	23-Sep-91	3	A	91.4	370.62	370.42	369.40	1.02		
Piezometer	15-Oct-91	3	A	91.4	370.62	370.33	369.40	0.93		
Piezometer	23-Sep-91	3	B	30.5	370.35	370.04	369.68	0.36	0.000	369.980
Piezometer	15-Oct-91	3	B	30.5	370.35	370.08	369.68	0.40		
Piezometer	23-Sep-91	3	B	91.4	370.33	370.03	369.11	0.92	0.000	370.029
Piezometer	15-Oct-91	3	B	91.4	370.33	370.07	369.11	0.96		
Piezometer	23-Sep-91	3	B	152.4	370.88	370.58	369.05	1.53	0.000	370.576
Piezometer	15-Oct-91	3	B	152.4	370.88	370.66	369.05	1.61		
Piezometer	23-Sep-91	3	C	81.4	370.66	370.16	369.43	0.73		
Piezometer	15-Oct-91	3	C	81.4	370.66	370.36	369.43	0.93		
Piezometer	24-Sep-91	5	B	30.5	370.32	369.91	369.71	0.20	0.050	369.968
Piezometer	17-Oct-91	5	B	30.5	370.32	370.00	369.71	0.29		
Piezometer	24-Sep-91	5	B	91.4	370.33	369.92	369.11	0.81	0.050	369.974
Piezometer	17-Oct-91	5	B	91.4	370.33	370.01	369.11	0.90		
Piezometer	24-Sep-91	5	B	152.4	370.33	369.93	368.50	1.43	0.050	369.971
Piezometer	17-Oct-91	5	B	152.4	370.33	370.03	368.50	1.53		
P-dock	24-Sep-91	5	D	30.5	370.09	369.64	368.87	0.77	-0.550	369.723
P-dock	16-Oct-91	5	D	30.5	370.09	369.78	368.87	0.91		

Cont.

Table 9 - cont.

LOCATION	DATE	SITE #	1	DEPTH (cm)	ABOVE M.S.L. GROUND OR TOP_P_ELEV (m)	HYDRAULIC HYD_ELEV (m)	ELEVATION ELEV_HEAD (m)	PRESSURE PRESS_HEAD (m)	WATER TABLE DEPTH (m)	WATER TABLE ELEV. (m)
P-dock	24-Sep-91	5	D	91.4	370.14	369.71	368.35	1.36	-0.550	369.814
P-dock	16-Oct-91	5	D	91.4	370.14	369.83	368.35	1.48		
P-dock	24-Sep-91	5	D	152.4	370.27	369.79	367.80	2.00	-0.550	369.871
P-dock	16-Oct-91	5	D	152.4	370.27	369.91	367.80	2.11		
Piezometer	23-Sep-91	5	F	30.5	370.09	369.86	369.48	0.38	-0.120	369.905
Piezometer	16-Oct-91	5	F	30.5	370.09	369.97	369.48	0.49		
Piezometer	23-Sep-91	5	F	91.4	370.09	369.91	368.85	1.06	-0.120	369.883
Piezometer	16-Oct-91	5	F	91.4	370.09	369.99	368.85	1.14		
Piezometer	23-Sep-91	5	F	152.4	370.10	369.87	368.26	1.61	-0.120	369.904
Piezometer	16-Oct-91	5	F	152.4	370.10	370.03	368.26	1.77		
P-dock	25-Sep-91	7	B	30.5	370.22	369.79	369.02	0.77	-0.500	370.284
P-dock	17-Oct-91	7	B	30.5	370.22	369.90	369.03	0.87		
P-dock	25-Sep-91	7	B	91.4	370.08	369.78	368.40	1.38	-0.500	369.826
P-dock	17-Oct-91	7	B	91.4	370.08	369.91	368.40	1.51		
P-dock	25-Sep-91	7	B	114.3	370.72	369.89	368.30	1.59	-0.500	369.811
P-dock	17-Oct-91	7	B	114.3	370.72	370.02	368.30	1.72		
P-dock	24-Sep-91	8	B	30.5	370.10	N.A.	369.40	N.A.	-0.650	369.900
P-dock	17-Oct-91	8	B	30.5	370.10	370.37	369.40	0.96		
P-dock	24-Sep-91	8	B	91.4	370.10	N.A.	368.34	N.A.	-0.650	369.901
P-dock	17-Oct-91	8	B	91.4	370.10	369.92	368.34	1.58		
P-dock	24-Sep-91	8	B	118.3	370.56	N.A.	368.12	N.A.	-0.650	369.957
P-dock	17-Oct-91	8	B	118.3	370.56	369.98	368.12	1.85		
P-dock	24-Sep-91	9	B	30.5	370.25	N.A.	368.55	N.A.	-0.980	369.834
P-dock	17-Oct-91	9	B	30.5	370.25	369.83	368.55	1.28		
P-dock	24-Sep-91	9	B	91.4	369.98	N.A.	367.81	N.A.	-0.980	369.709
P-dock	17-Oct-91	9	B	91.4	369.98	369.71	367.81	1.89		
P-dock	24-Sep-91	9	B	152.4	370.13	N.A.	367.08	N.A.	-0.980	369.580
P-dock	17-Oct-91	9	B	152.4	370.13	369.57	367.08	2.49		

Cont.

Table 9 - cont.

LOCATION	DATE	SITE #	1	DEPTH (cm)	ABOVE M.S.L. GROUND ELEV. (m)	WATER ELEV. (m)	Field D.O.(ppm)	Field F_pH pH	LAB. EH (mV)	LAB. EH(NHE) (mV)
Piezometer	23-Sep-91	1	P	914.4	373.00	-	1.3	6.9	-98	146
Piezometer	15-Oct-91	1	P	914.4	373.00	-	0.2	7.3	75	319
Piezometer	23-Sep-91	2	A	91.4	370.80	-	3.5	6.7	-99	145
Piezometer	15-Oct-91	2	A	91.4	370.80	-	3.7	7.7	-40	204
Piezometer	23-Sep-91	2	B	30.5	370.57	-	1.5	7.5	-37	207
Piezometer	15-Oct-91	2	B	30.5	370.57	-	0.6	7.6	105	349
Piezometer	23-Sep-91	2	B	91.4	370.55	-	0.5	6.8	-112	132
Piezometer	15-Oct-91	2	B	91.4	370.55	-	0.3	6.6	-97	147
Piezometer	23-Sep-91	2	B	152.4	370.58	-	1.0	6.5	-85	159
Piezometer	15-Oct-91	2	B	152.4	370.58	-	0.3	6.5	-95	149
Piezometer	23-Sep-91	2	C	91.4	370.52	-	0.4	6.7	-73	171
Piezometer	15-Oct-91	2	C	91.4	370.52	-	0.9	7.0	-82	162
Piezometer	23-Sep-91	3	A	91.4	370.31	-	4.5	5.9	31	275
Piezometer	15-Oct-91	3	A	91.4	370.31	-	0.9	4.8	162	406
Piezometer	23-Sep-91	3	B	30.5	369.98	-	2.9	7.2	-33	211
Piezometer	15-Oct-91	3	B	30.5	369.98	-	0.4	7.5	-112	132
Piezometer	23-Sep-91	3	B	91.4	370.03	-	1.6	7.1	-65	179
Piezometer	15-Oct-91	3	B	91.4	370.03	-	0.2	7.1	-150	94
Piezometer	23-Sep-91	3	B	152.4	370.58	-	1.4	6.4	-37	207
Piezometer	15-Oct-91	3	B	152.4	370.58	-	0.6	6.8	173	417
Piezometer	23-Sep-91	3	C	81.4	370.24	-	0.9	5.9	-49	195
Piezometer	15-Oct-91	3	C	81.4	370.24	-	5.0	6.4	39	283
Piezometer	24-Sep-91	5	B	30.5	370.02	-	0.4	6.9	-57	187
Piezometer	17-Oct-91	5	B	30.5	370.02	-	0.8	7.5	-165	79
Piezometer	24-Sep-91	5	B	91.4	370.02	-	0.5	6.0	41	285
Piezometer	17-Oct-91	5	B	91.4	370.02	-	0.2	7.8	55	299
Piezometer	24-Sep-91	5	B	152.4	370.02	-	0.5	7.0	99	343
Piezometer	17-Oct-91	5	B	152.4	370.02	-	0.2	7.7	81	325
P-dock	24-Sep-91	5	D	30.5	369.17	369.77	0.5	10.6	47	291
P-dock	16-Oct-91	5	D	30.5	369.17	369.77	0.2	10.5	32	276

Cont.

Table 9 - cont.

LOCATION	DATE	SITE #	1	DEPTH (cm)	ABOVE M.S.L. GROUND ELEV. (m)	WATER ELEV. (m)	Field D.O.(ppm)	Field F_pH pH	LAB. EH (mV)	LAB. EH(NHE) (mV)
P-dock	24-Sep-91	5	D	91.4	369.26	369.86	0.3	6.8	-1	243
P-dock	16-Oct-91	5	D	91.4	369.26	369.86	0.1	6.9	-142	102
P-dock	24-Sep-91	5	D	152.4	369.32	369.92	0.6	6.9	74	318
P-dock	16-Oct-91	5	D	152.4	369.32	369.92	0.1	7.2	-63	181
Piezometer	23-Sep-91	5	F	30.5	369.79	369.82	1.2	6.6	-78	166
Piezometer	16-Oct-91	5	F	30.5	369.79	369.82	0.2	6.7	-147	97
Piezometer	23-Sep-91	5	F	91.4	369.76	369.79	0.6	6.1	32	276
Piezometer	16-Oct-91	5	F	91.4	369.76	369.79	0.2	6.9	42	286
Piezometer	23-Sep-91	5	F	152.4	369.78	369.81	0.7	6.3	33	277
Piezometer	16-Oct-91	5	F	152.4	369.78	369.81	0.7	6.5	114	358
P-dock	25-Sep-91	7	B	30.5	369.33	369.66	0.7	6.9	94	338
P-dock	17-Oct-91	7	B	30.5	369.33	369.67	0.2	7.4	-6	238
P-dock	25-Sep-91	7	B	91.4	369.31	369.65	0.5	6.7	7	251
P-dock	17-Oct-91	7	B	91.4	369.31	369.65	0.2	8.0	-161	84
P-dock	25-Sep-91	7	B	114.3	369.44	369.78	0.4	6.2	-69	176
P-dock	17-Oct-91	7	B	114.3	369.44	369.78	0.2	7.4	-140	105
P-dock	24-Sep-91	8	B	30.5	369.25	369.64				
P-dock	17-Oct-91	8	B	30.5	369.25	369.64	0.2	7.6	84	328
P-dock	24-Sep-91	8	B	91.4	369.25	369.64				
P-dock	17-Oct-91	8	B	91.4	369.25	369.64	0.2	7.0	-166	78
P-dock	24-Sep-91	8	B	118.3	369.31	369.70				
P-dock	17-Oct-91	8	B	118.3	369.31	369.70	0.2	7.2	-205	39
P-dock	24-Sep-91	9	B	30.5	368.85	369.65				
P-dock	17-Oct-91	9	B	30.5	368.85	369.65	0.2	7.3	66	310
P-dock	24-Sep-91	9	B	91.4	368.73	369.53				
P-dock	17-Oct-91	9	B	91.4	368.73	369.53	0.1	7.5	-54	190
P-dock	24-Sep-91	9	B	152.4	368.60	369.40				
P-dock	17-Oct-91	9	B	152.4	368.60	369.40	0.1	7.7	-67	177

Cont.

Table 9 - cont.

LOCATION	DATE	SITE #	1	DEPTH (cm)	Field F_Ec Ec	Field F_T(C) Temp.(C)	T.D.S. (mg/L)	ACIDITY (mg/L)	ALKALINITY (mg/L)	Fe TOTAL (mg/L)	Cu (mg/L)
Piezometer	23-Sep-91	1	P	914.4	2820	8.2		0	184	3.33	<0.002
Piezometer	15-Oct-91	1	P	914.4	2370	10.4		N.A.	N.A.		
Piezometer	23-Sep-91	2	A	91.4	2870	11.5	2446	0	212	15.52	<0.002
Piezometer	15-Oct-91	2	A	91.4	2530	7.6		0	227		
Piezometer	23-Sep-91	2	B	30.5	2140	11.5		*N.S.S.	*N.S.S.	13.20	<0.002
Piezometer	15-Oct-91	2	B	30.5	1820	7.6		0	68		
Piezometer	23-Sep-91	2	B	91.4	2820	12.6	2338	0	132	66.19	<0.002
Piezometer	15-Oct-91	2	B	91.4	2370	8.9		0	115	33.48	<0.002
Piezometer	23-Sep-91	2	B	152.4	2350	11.3	2067	0	96	58.70	<0.002
Piezometer	15-Oct-91	2	B	152.4	2010	9.9		N.A.	N.A.	40.39	0.025
Piezometer	23-Sep-91	2	C	91.4	1730	11.4	1185	0	97	11.10	<0.002
Piezometer	15-Oct-91	2	C	91.4	1471	8.6		0	110	2.86	<0.002
Piezometer	23-Sep-91	3	A	91.4	2580	11.5	2058	119	27	64.38	<0.002
Piezometer	15-Oct-91	3	A	91.4	2010	7.2		111	0	46.38	<0.002
Piezometer	23-Sep-91	3	B	30.5	2320	11.5		0	276	8.77	<0.002
Piezometer	15-Oct-91	3	B	30.5	2380	7.8		N.A.	N.A.		
Piezometer	23-Sep-91	3	B	91.4	3380	12.0	2741	0	865	42.48	<0.002
Piezometer	15-Oct-91	3	B	91.4	2910	8.4		0	893	23.58	<0.002
Piezometer	23-Sep-91	3	B	152.4	431	10.7		0	130	8.67	<0.002
Piezometer	15-Oct-91	3	B	152.4	324	9.0		0	124		
Piezometer	23-Sep-91	3	C	81.4	735	12.4		20	21	13.46	<0.002
Piezometer	15-Oct-91	3	C	81.4	855	9.0		N.A.	N.A.		
Piezometer	24-Sep-91	5	B	30.5	2120	10.9		0	73	16.37	<0.002
Piezometer	17-Oct-91	5	B	30.5	2070	7.2		N.A.	N.A.	14.03	<0.002
Piezometer	24-Sep-91	5	B	91.4	718	11.8	440	24	160	0.42	<0.002
Piezometer	17-Oct-91	5	B	91.4	711	7.2		N.A.	N.A.	0.13	<0.002
Piezometer	24-Sep-91	5	B	152.4	272	11.7	83	0	115	0.87	<0.002
Piezometer	17-Oct-91	5	B	152.4	261	8.5		N.A.	N.A.	0.30	<0.002
P-dock	24-Sep-91	5	D	30.5	2626	13.5	2028	0	44	<0.002	<0.002
P-dock	16-Oct-91	5	D	30.5	2440	5.5		0	51	0.80	<0.002

Cont.

Table 9 - cont.

LOCATION	DATE	SITE #	1	DEPTH (cm)	Field F_Ec Ec	Field F_T(C) Temp.(C)	T.D.S. (mg/L)	ACIDITY (mg/L)	ALKALINITY (mg/L)	Fe TOTAL (mg/L)	Cu (mg/L)
P-dock	24-Sep-91	5	D	91.4	3018	14.7		0	262	72.65	<0.002
P-dock	16-Oct-91	5	D	91.4	3050	8.2		N.A.	N.A.		
P-dock	24-Sep-91	5	D	152.4	4240	16.3		0	1050	3.96	<0.002
P-dock	16-Oct-91	5	D	152.4	3810	N.A.		N.A.	N.A.		
Piezometer	23-Sep-91	5	F	30.5	2200	12.3	2121	0	63	58.67	<0.002
Piezometer	16-Oct-91	5	F	30.5	2323	8.2		0	102	61.38	<0.002
Piezometer	23-Sep-91	5	F	91.4	1271	12.3		0	93	1.78	<0.002
Piezometer	16-Oct-91	5	F	91.4	1014	7.8		N.A.	N.A.		
Piezometer	23-Sep-91	5	F	152.4	158	11.4	100	0	35	3.23	<0.002
Piezometer	16-Oct-91	5	F	152.4	142	8.2		0	38	0.28	<0.002
P-dock	25-Sep-91	7	B	30.5	3820	10.7	2965	0	1143	0.11	<0.002
P-dock	17-Oct-91	7	B	30.5	3780	6.9		0	1035	0.20	<0.002
P-dock	25-Sep-91	7	B	91.4	520	11.5	350	0	166	1.29	<0.002
P-dock	17-Oct-91	7	B	91.4	547	8.0		0	173	1.43	<0.002
P-dock	25-Sep-91	7	B	114.3	380	11.2	206	0	110	8.33	<0.002
P-dock	17-Oct-91	7	B	114.3	410	8.2		0	94	8.28	<0.002
P-dock	24-Sep-91	8	B	30.5				N.A.	N.A.		
P-dock	17-Oct-91	8	B	30.5	3710	7.8	2616	0	1066	0.16	<0.002
P-dock	24-Sep-91	8	B	91.4				N.A.	N.A.		
P-dock	17-Oct-91	8	B	91.4	1020	8.3	448	0	386	23.11	0.007
P-dock	24-Sep-91	8	B	118.3				N.A.	N.A.		
P-dock	17-Oct-91	8	B	118.3	571	9.1	234	0	219	8.79	0.005
P-dock	24-Sep-91	9	B	30.5				N.A.	N.A.		
P-dock	17-Oct-91	9	B	30.5	3330	7.8	1741	0	534	0.02	<0.002
P-dock	24-Sep-91	9	B	91.4				N.A.	N.A.		
P-dock	17-Oct-91	9	B	91.4	722	8.6	334	0	266	1.04	0.029
P-dock	24-Sep-91	9	B	152.4				N.A.	N.A.		
P-dock	17-Oct-91	9	B	152.4	266	10.1	140	0	73	3.40	<0.002

Cont.

Table 9 - cont.

LOCATION	DATE	SITE #	1	DEPTH (cm)	Zn (mg/L)	Ca (mg/L)	Mg (mg/L)	Pb (mg/L)	Th (mg/L)	Al (mg/L)	Mn (mg/L)
Piezometer	23-Sep-91	1	P	914.4	<0.002	485.6	68.8	<0.025	<0.015	0.509	1.362
Piezometer	15-Oct-91	1	P	914.4							
Piezometer	23-Sep-91	2	A	91.4	<0.002	680.1	34.5	<0.025	<0.015	0.711	0.897
Piezometer	15-Oct-91	2	A	91.4							
Piezometer	23-Sep-91	2	B	30.5	0.005	450.9	29.6	<0.025	<0.015	0.544	1.092
Piezometer	15-Oct-91	2	B	30.5							
Piezometer	23-Sep-91	2	B	91.4	0.022	560.1	25.0	<0.025	<0.015	0.582	0.791
Piezometer	15-Oct-91	2	B	91.4	0.026	518.6	20.8	<0.025	<0.015	0.466	0.780
Piezometer	23-Sep-91	2	B	152.4	0.009	497.2	22.2	<0.025	0.019	0.552	1.412
Piezometer	15-Oct-91	2	B	152.4	0.127	434.5	17.4	<0.025	<0.015	0.488	1.295
Piezometer	23-Sep-91	2	C	91.4	0.011	303.4	19.6	0.159	<0.015	0.355	0.544
Piezometer	15-Oct-91	2	C	91.4	0.016	275.1	21.0	<0.025	<0.015	0.299	0.613
Piezometer	23-Sep-91	3	A	91.4	0.039	534.6	16.3	<0.025	<0.015	1.145	0.552
Piezometer	15-Oct-91	3	A	91.4	0.128	507.3	16.6	0.315	<0.015	3.302	0.684
Piezometer	23-Sep-91	3	B	30.5	0.179	517.7	28.0	0.202	<0.015	0.023	0.601
Piezometer	15-Oct-91	3	B	30.5							
Piezometer	23-Sep-91	3	B	91.4	0.014	726.5	18.2	<0.025	<0.015	0.894	0.860
Piezometer	15-Oct-91	3	B	91.4	0.007	820.3	15.6	<0.025	<0.015	0.603	0.946
Piezometer	23-Sep-91	3	B	152.4	0.006	67.4	3.8	0.400	<0.015	0.293	0.093
Piezometer	15-Oct-91	3	B	152.4							
Piezometer	23-Sep-91	3	C	81.4	<0.002	129.8	3.2	0.152	0.018	0.327	0.045
Piezometer	15-Oct-91	3	C	81.4							
Piezometer	24-Sep-91	5	B	30.5	0.022	494.0	6.4	<0.025	<0.015	0.359	0.185
Piezometer	17-Oct-91	5	B	30.5	0.019	384.2	4.9	<0.025	<0.015	0.454	0.236
Piezometer	24-Sep-91	5	B	91.4	0.040	158.3	4.8	<0.025	<0.015	0.211	0.131
Piezometer	17-Oct-91	5	B	91.4	0.040	125.6	4.8	<0.025	<0.015	0.187	0.058
Piezometer	24-Sep-91	5	B	152.4	0.013	40.2	10.5	0.080	<0.015	0.079	0.033
Piezometer	17-Oct-91	5	B	152.4	0.058	31.6	8.2	0.097	<0.015	0.129	0.055
P-dock	24-Sep-91	5	D	30.5	<0.002	642.8	0.1	<0.025	<0.015	0.775	0.013
P-dock	16-Oct-91	5	D	30.5	0.022	535.7	0.2	<0.025	<0.015	0.771	0.003

Cont.

Table 9 - cont.

LOCATION	DATE	SITE #	1	DEPTH (cm)	Zn (mg/L)	Ca (mg/L)	Mg (mg/L)	Pb (mg/L)	Th (mg/L)	Al (mg/L)	Mn (mg/L)
P-dock	24-Sep-91	5	D	91.4	0.004	677.9	27.9	<0.025	<0.015	0.698	0.309
P-dock	16-Oct-91	5	D	91.4							
P-dock	24-Sep-91	5	D	152.4	<0.002	836.6	28.5	<0.025	<0.015	1.068	0.053
P-dock	16-Oct-91	5	D	152.4							
Piezometer	23-Sep-91	5	F	30.5	<0.002	668.0	4.8	<0.025	0.069	0.708	0.103
Piezometer	16-Oct-91	5	F	30.5	0.013	472.2	3.3	<0.025	0.060	0.478	0.085
Piezometer	23-Sep-91	5	F	91.4	<0.002	270.5	6.6	<0.025	<0.015	0.351	0.124
Piezometer	16-Oct-91	5	F	91.4							
Piezometer	23-Sep-91	5	F	152.4	<0.002	22.8	2.0	0.046	<0.015	0.246	0.009
Piezometer	16-Oct-91	5	F	152.4	0.045	14.8	1.5	0.069	<0.015	0.131	0.009
P-dock	25-Sep-91	7	B	30.5	0.028	875.7	20.6	<0.025	<0.015	1.035	0.178
P-dock	17-Oct-91	7	B	30.5	0.021	861.3	22.1	<0.025	<0.015	0.903	0.074
P-dock	25-Sep-91	7	B	91.4	<0.002	63.2	8.2	<0.025	<0.015	0.151	0.030
P-dock	17-Oct-91	7	B	91.4	0.012	52.0	6.3	<0.025	<0.015	0.228	0.030
P-dock	25-Sep-91	7	B	114.3	<0.002	33.5	4.7	<0.025	<0.015	0.243	0.024
P-dock	17-Oct-91	7	B	114.3	0.035	27.7	3.9	<0.025	<0.015	0.249	0.043
P-dock	24-Sep-91	8	B	30.5							
P-dock	17-Oct-91	8	B	30.5	0.004	376.5	28.5	<0.025	<0.015	0.429	0.037
P-dock	24-Sep-91	8	B	91.4							
P-dock	17-Oct-91	8	B	91.4	0.078	41.7	17.5	<0.025	<0.015	0.133	0.063
P-dock	24-Sep-91	8	B	118.3							
P-dock	17-Oct-91	8	B	118.3	0.056	54.8	11.8	<0.025	<0.015	0.110	0.215
P-dock	24-Sep-91	9	B	30.5							
P-dock	17-Oct-91	9	B	30.5	0.014	454.3	30.9	<0.025	<0.015	0.542	0.062
P-dock	24-Sep-91	9	B	91.4							
P-dock	17-Oct-91	9	B	91.4	0.087	77.5	10.2	0.048	<0.015	0.213	0.048
P-dock	24-Sep-91	9	B	152.4							
P-dock	17-Oct-91	9	B	152.4	0.021	21.8	2.2	0.234	<0.015	0.177	0.056

Cont.

Table 9 - cont.

LOCATION	DATE	SITE #	1	DEPTH (cm)	U (mg/L)	Ni (mg/L)	Ra-226 (mBq/L)	Ra-226 (pCi/L)	SULPHATE (mg/L)
Piezometer	23-Sep-91	1	P	914.4	<0.100	0.024	654	17.7	1059
Piezometer	15-Oct-91	1	P	914.4			N.A.	N.A.	N.A.
Piezometer	23-Sep-91	2	A	91.4	<0.100	0.008	2004	54.2	1312
Piezometer	15-Oct-91	2	A	91.4			1607	43.4	1257
Piezometer	23-Sep-91	2	B	30.5	<0.100	0.029	*N.S.S.	*N.S.S.	905
Piezometer	15-Oct-91	2	B	30.5			717	19.4	1202
Piezometer	23-Sep-91	2	B	91.4	<0.100	0.011	1604	43.4	1121
Piezometer	15-Oct-91	2	B	91.4	<0.100	0.015	1391	37.6	935
Piezometer	23-Sep-91	2	B	152.4	<0.100	0.006	1323	35.8	902
Piezometer	15-Oct-91	2	B	152.4	<0.100	0.011	1033	27.9	1000
Piezometer	23-Sep-91	2	C	91.4	<0.100	<0.005	562	15.2	519
Piezometer	15-Oct-91	2	C	91.4	<0.100	<0.005	819	22.1	574
Piezometer	23-Sep-91	3	A	91.4	<0.100	0.006	2391	64.6	1094
Piezometer	15-Oct-91	3	A	91.4	<0.100	<0.005	2532	68.4	1237
Piezometer	23-Sep-91	3	B	30.5	<0.100	0.019	1150	31.1	777
Piezometer	15-Oct-91	3	B	30.5			N.A.	N.A.	N.A.
Piezometer	23-Sep-91	3	B	91.4	<0.100	0.009	1863	50.4	721
Piezometer	15-Oct-91	3	B	91.4	<0.100	<0.005	2632	71.1	945
Piezometer	23-Sep-91	3	B	152.4	<0.100	0.008	4414	119.3	32
Piezometer	15-Oct-91	3	B	152.4			N.A.	N.A.	N.A.
Piezometer	23-Sep-91	3	C	81.4	<0.100	0.022	4111	111.1	169
Piezometer	15-Oct-91	3	C	81.4			N.A.	N.A.	N.A.
Piezometer	24-Sep-91	5	B	30.5	<0.100	0.023	1938	52.4	1036
Piezometer	17-Oct-91	5	B	30.5	<0.100	0.030	3698	100.0	805
Piezometer	24-Sep-91	5	B	91.4	<0.100	<0.005	5154	139.3	149
Piezometer	17-Oct-91	5	B	91.4	<0.100	<0.005	726	19.6	143
Piezometer	24-Sep-91	5	B	152.4	<0.100	0.010	1709	46.2	9
Piezometer	17-Oct-91	5	B	152.4	<0.100	0.010	717	19.4	12
P-dock	24-Sep-91	5	D	30.5	<0.100	0.056	277	7.5	1263
P-dock	16-Oct-91	5	D	30.5	<0.100	0.031	1152	31.1	1210

Cont.

Table 9 - cont.

LOCATION	DATE	SITE #	1	DEPTH (cm)	U (mg/L)	Ni (mg/L)	Ra-226 (mBq/L)	Ra-226 (pCi/L)	SULPHATE (mg/L)
P-dock	24-Sep-91	5	D	91.4	<0.100	0.018	1354	36.6	1402
P-dock	16-Oct-91	5	D	91.4			N.A.	N.A.	N.A.
P-dock	24-Sep-91	5	D	152.4	<0.100	0.019	2464	66.6	971
P-dock	16-Oct-91	5	D	152.4			N.A.	N.A.	N.A.
Piezometer	23-Sep-91	5	F	30.5	<0.100	0.019	594	16.0	21
Piezometer	16-Oct-91	5	F	30.5	<0.100	0.014	707	19.1	1055
Piezometer	23-Sep-91	5	F	91.4	<0.100	<0.005	3359	90.8	383
Piezometer	16-Oct-91	5	F	91.4			N.A.	N.A.	N.A.
Piezometer	23-Sep-91	5	F	152.4	<0.100	0.064	1565	42.3	22
Piezometer	16-Oct-91	5	F	152.4	<0.100	0.010	840	22.7	8
P-dock	25-Sep-91	7	B	30.5	<0.100	0.006	4289	115.9	1069
P-dock	17-Oct-91	7	B	30.5	<0.100	0.011	3914	105.8	1060
P-dock	25-Sep-91	7	B	91.4	<0.100	0.008	1090	29.5	36
P-dock	17-Oct-91	7	B	91.4	<0.100	<0.005	2123	57.4	22
P-dock	25-Sep-91	7	B	114.3	<0.100	0.008	3935	106.4	19
P-dock	17-Oct-91	7	B	114.3	<0.100	<0.005	2825	76.3	19
P-dock	24-Sep-91	8	B	30.5			N.A.	N.A.	N.A.
P-dock	17-Oct-91	8	B	30.5	<0.100	<0.005	1637	44.2	939
P-dock	24-Sep-91	8	B	91.4			N.A.	N.A.	N.A.
P-dock	17-Oct-91	8	B	91.4	<0.100	<0.005	2425	65.5	4
P-dock	24-Sep-91	8	B	118.3			N.A.	N.A.	N.A.
P-dock	17-Oct-91	8	B	118.3	<0.100	<0.005	3161	85.4	4
P-dock	24-Sep-91	9	B	30.5			N.A.	N.A.	N.A.
P-dock	17-Oct-91	9	B	30.5	<0.100	<0.005	3131	84.6	779
P-dock	24-Sep-91	9	B	91.4			N.A.	N.A.	N.A.
P-dock	17-Oct-91	9	B	91.4	<0.100	<0.005	1271	34.3	32
P-dock	24-Sep-91	9	B	152.4			N.A.	N.A.	N.A.
P-dock	17-Oct-91	9	B	152.4	<0.100	<0.005	939	25.4	12

Table 10 - Panel wetlands: soil/tailings substrate, paste pH.

PANEL WETLANDS: SOIL/TAILINGS SUBSTRATE AND SEDIMENT PASTE PH

SAMPLE LOCATION I.D.			DATE	CODE_2	LAB. L_pH pH
2	A	Solid paste	16-Jul-91	TOP	2.08
2	A	Solid paste	16-Jul-91	BOTTOM	3.34
2	B	Solid paste	14-Jul-91	TOP	7.02
2	B	Solid paste	14-Jul-91	BOTTOM	7.55
2	C	Solid paste	14-Jul-91	TOP	7.20
2	C	Solid paste	14-Jul-91	BOTTOM	7.28
3	A	Solid paste	14-Jul-91	TOP	2.25
3	A	Solid paste	14-Jul-91	BOTTOM	2.36
3	B	Solid paste	14-Jul-91	TOP	7.14
3	B	Solid paste	14-Jul-91	BOTTOM	7.12
3	C	Solid paste	14-Jul-91	TOP	2.54
3	C	Solid paste	14-Jul-91	BOTTOM	3.04
5	B	Solid paste	14-Jul-91	TOP	3.34
5	B	Solid paste	14-Jul-91	BOTTOM	5.89
5	E-F	Solid paste	14-Jul-91	TOP	4.54
5	E-F	Solid paste	14-Jul-91	BOTTOM	4.65

Table 11 - Panel wetlands: chemical composition of soil/tailings substrate and sediment.

PANEL MARSHLAND SOIL SAMPLES-COLLECTED AUGUST '90

SAMPLE LOCATION	Ra-226 (mBq/g)	Moisture (%)	Fe (µg/g)	Ni (µg/g)	Cu (µg/g)	Zn (µg/g)	Ca (µg/g)	Mg (µg/g)	Pb (µg/g)	Th (µg/g)	U (µg/g)	Al (µg/g)	Mn (µg/g)
2AS	10331.0	45.2	30487	25	88	212	22826	437	331	618	<100	32339	<2
2BS	7050.0	40.4	33709	<4	34	39	2416	546	131	161	<100	23756	<2
2CS	13131.6	25.0	42419	13	65	88	17714	772	460	580	<100	39086	<2
3AS	7780.2	27.4	30110	4	25	8	9222	387	256	380	<100	25370	<2
3BS	10642.2	31.5	38325	8	11	48	32829	1118	830	396	<100	30581	120
3CS	12239.5	37.2	26157	37	221	111	20019	391	355	290	<100	26694	<2
6AS	15969.2	38.4	31980	12	89	48	24723	613	481	574	<100	45960	<2
6BS	9309.9	38.8	41538	6	24	30	5407	497	223	329	<100	28452	<2
6CS	9233.5	33.8	27067	7	34	43	12846	327	273	306	<100	24596	<2
8AS	6855.7	28.9	48657	11	58	85	2130	260	154	210	<100	18954	<2
8BS	9721.6	28.9	52639	14	35	49	7512	415	233	350	<100	28463	<2
8CS	14353.8	40.3	34960	76	155	311	14260	601	497	550	<100	43690	<2

Table 12 - Panel wetlands: distribution of Thiobacillus ferro-oxidans and sulphate reducing bacteria in the basin.

PANEL WETLANDS: BACTERIAL COUNT

Estimation of Bacterial Numbers by the Most Probable Number Technique

Sample Name	Thiobacillus Ferrooxidans Most Probable Number	Sulphate-Reducing Bacteria Most Probable Number
2A-T	1.4E+08	7.0E+03
2A-B	2.3E+05	2.8E+03
2B-T	7.9E+02	7.9E+05
2B-B	1.3E+05	3.5E+03
2C-T	1.3E+05	3.5E+05
2C-B	1.3E+05	7.9E+06
3A-T	1.7E+07	2.8E+03
3A-B	2.3E+05	7.0E+03
3B-T	7.9E+03	1.1E+04
3B-B	2.2E+03	4.9E+04
3C-T	7.9E+05	2.3E+03
3C-B	2.8E+05	9.5E+02
5B-T	5.4E+05	1.1E+06
5B-B	4.9E+03	3.5E+02
5F-T	7.9E+03	2.8E+05
5F-B	2.3E+02	3.3E+05
5T*	3.3E+03	3.3E+03
5B*	2.3E+01	7.0E+03
7B-T*	4.9E+01	4.9E+06
7B-B*	4.5E+00	8.4E+03
8T*	1.3E+02	4.9E+06
8B*	2.0E+00	2.2E+05
9T*	7.8E+00	2.3E+04
9B*	0.0E+00	2.2E+04

Table 13 – Panel wetlands: distribution of total sulphide and sulphate sulphur in the basin.

PANEL WETLANDS: SULPHUR SPECIATION

Sample Name	Total Sulphur (%S)	Sulphide Sulphur (%S)	Sulphate Sulphur (%S)	Pyrite % FeS2
2A-T	4.49	1.54	2.95	5.58
2A-B	6.61	2.57	4.04	7.64
2B-T	0.09	0.05	0.04	0.08
2B-B	0.84	0.62	0.22	0.42
2C-T	1.46	0.06	1.40	2.65
2C-B	2.47	0.05	2.42	4.57
3A-T	4.34	1.43	2.91	5.50
3A-B	4.06	1.18	2.88	5.44
3B-T	4.60	1.77	2.83	5.35
3B-B	4.53	1.58	2.95	5.58
3C-T	4.79	3.96	0.83	1.57
3C-B	5.53	1.83	3.70	6.99
5B-T	5.20	1.55	3.63	6.90
5B-B	6.68	2.73	3.95	7.46
5F-T	5.33	1.60	3.73	7.05
5F-B	4.72	2.67	2.05	3.87
5T*	5.55	4.98	0.57	1.08
5B*	6.05	3.39	2.66	5.03
7B-T*	1.15	0.63	0.52	0.98
7B-B*	0.76	0.25	0.51	0.96
8T*	3.44	0.76	2.68	5.07
8B*	0.39	0.15	0.24	0.45
9T*	5.62	3.29	2.33	4.40
9B*	1.02	0.10	0.92	1.74

Table 14 - Panel wetlands: metals and Ra-226 concentrations in wetland vegetation.

PANEL WETLANDS VEGETATION SAMPLES
AREA 1-6
SITE A,B,C, and UNDERWATER (U)
VEGETATION = V

CATTAIL (C) **GRASS (G1) (Scripus)** **MOSS (M) (Sphagnum and polytrichum)**
GRASS (G2) (Carex Flacca) **POND WEED (PW)**
GRASS (G3) (Juncus) **GRASS (G4) (Phragmites)**

SAMPLE LOCATION I.D.				Ra-226 dry_avg mBq/g	Moisture (%)	L.O.I. (%)	Fe (µg/g)	Ni (µg/g)	Cu (µg/g)	Zn (µg/g)	Ca (µg/g)	Mg (µg/g)	Pb (µg/g)	Th (µg/g)	U (µg/g)	Al (µg/g)	Mn (µg/g)
2	A	V	C	36.6	72.8	92.7	35	1	4	11	14952	52	3	<2	<20	<4	212
2	A	V	G2	335.1	60.3	89.8	74	1	4	18	7600	56	23	<2	<20	3	94
2	A	V	G3	364.6	68.9	81.4	83	1	10	36	26117	1894	56	<2	<20	66	28
2	B	V	C	31.0	72.2	92.2	24	1	4	8	14485	489	<3	<2	<20	<4	579
2	B	V	G3	287.5	71.0	75.1	571	1	6	22	31680	2257	10	<2	<20	275	108
2	C	V	G1	526.5	54.1	92.3	63	1	14	40	2092	590	1	<2	<20	<4	91
3	A	V	C	106.8	63.7	93.5	212	3	4	17	10039	405	6	1	<20	135	119
3	A	V	G2	216.5	50.2	93.9	287	1	9	24	3351	475	7	3	<20	207	19
3	A	V	G4	146.2	49.8	96.2	159	<1	2	19	1462	189	<3	<2	<20	<4	<2
3	B	V	C	31.8	65.0	92.5	43	1	4	7	11603	568	<3	<2	<20	<4	333
3	B	V	G3	161.5	76.3	73.2	709	3	29	83	35089	2607	248	4	60	337	<1
3	C	V	C	82.5	61.3	94.4	44	2	3	14	16708	282	3	1	<20	<4	53
3	C	V	G1	148.1	44.1	93.9	37	2	4	18	2443	234	9	1	<20	<4	16
6	A	V	C	495.9	60.7	95.2	87	1	4	10	11030	337	2	1	<20	<4	43
6	A	V	G2	621.2	58.3	93.4	81	2	9	23	3069	431	8	1	<20	<4	146
6	A	V	M	1298.5	95.8	87.9	22113	7	20	8	6404	210	65	44	81	1334	<2
6	B	V	C	98.6	75.5	93.8	109	2	5	16	12351	899	<3	21	<20	<4	429
6	C	V	C	327.4	68.4	94.8	48	2	3	10	13542	545	10	<2	<20	<5	84
6	C	V	G1	757.3	58.8	92.4	286	3	9	27	1915	675	6	<2	<20	48	71
7	D	V	PW	3799.6	87.3	71.0	7411	18	18	61	116169	1093	17	7	40	573	210
8	A	V	C	327.6	78.2	94.9	59	2	5	10	10059	694	8	2	<20	<4	85
8	A	V	G2	1103.0	58.2	94.6	767	1	13	20	5499	774	3	1	<20	66	37
8	C	V	C	438.3	75.2	95.4	109	3	4	11	11341	466	19	<2	<20	<4	74
8	C	V	M	336.8	93.1	85.0	63056	1	5	14	3359	394	62	33	56	460	<2
9	B	V	PW	2507.2	86.8	63.7	4321	1	14	24	141682	862	10	8	30	1379	79

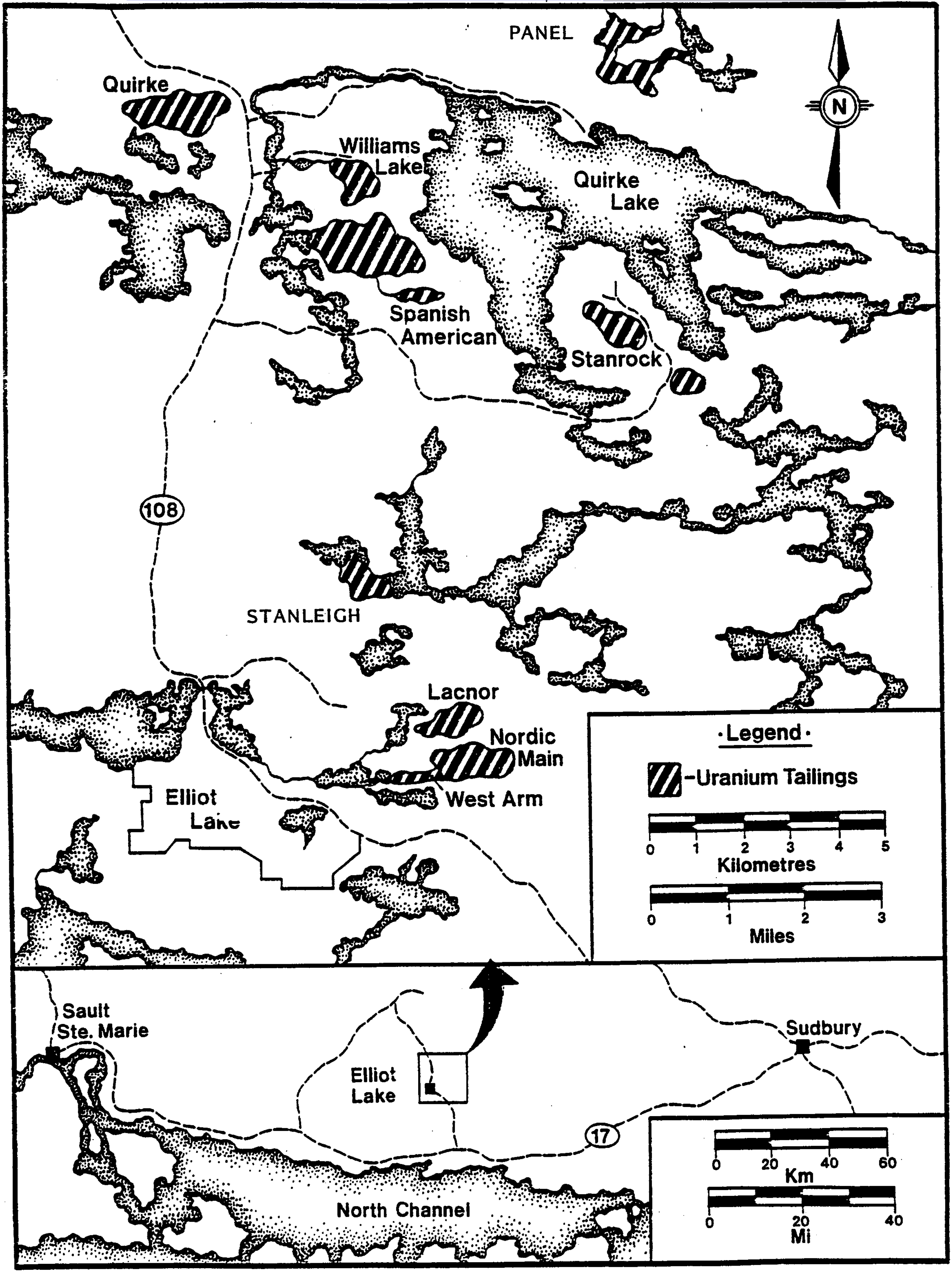


Fig. 1 – Generalized location of Panel tailings area, Elliot Lake, Ontario.

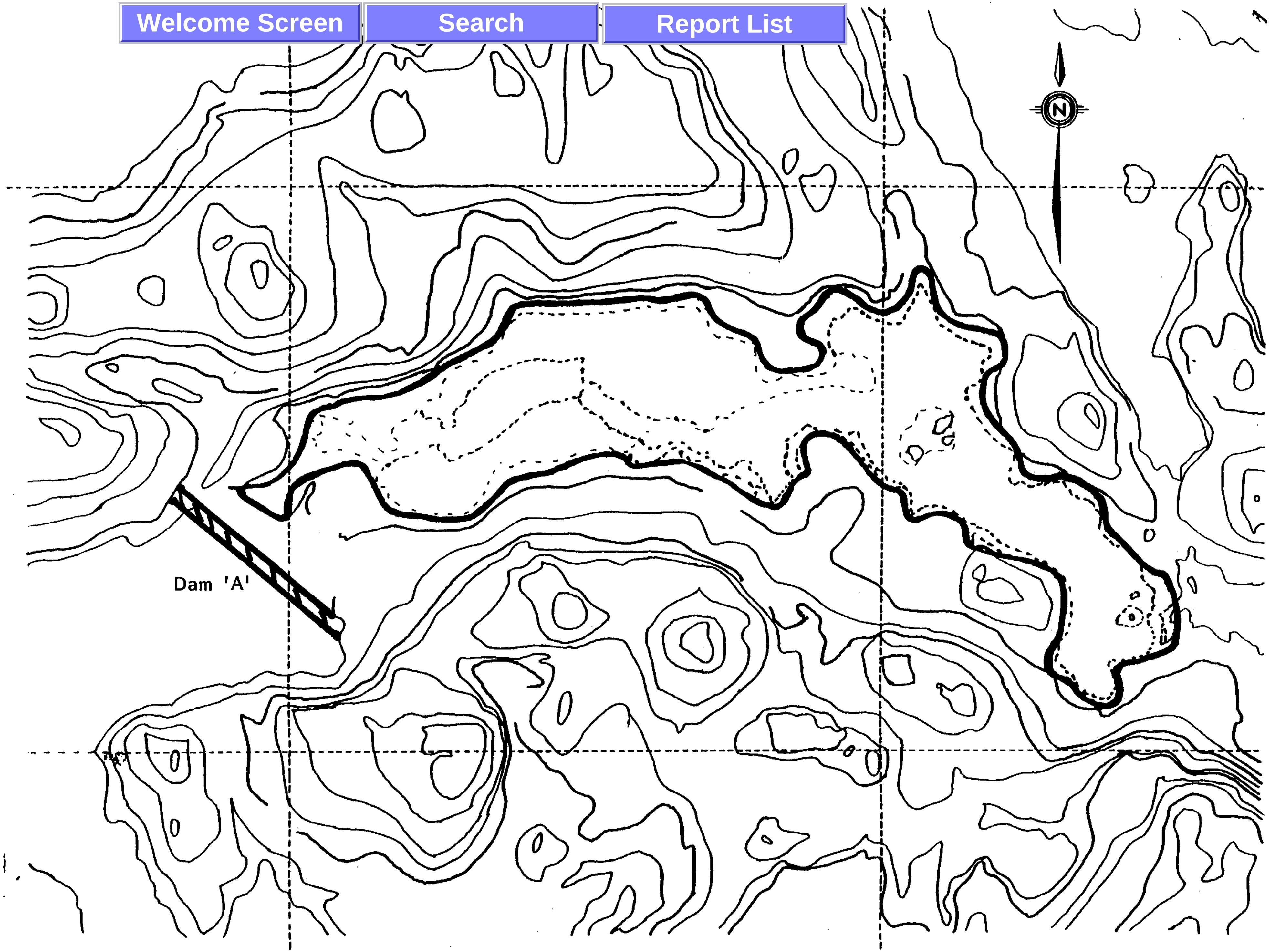


Fig. 2 - Location of Panel wetlands basin east of dam 'A'.

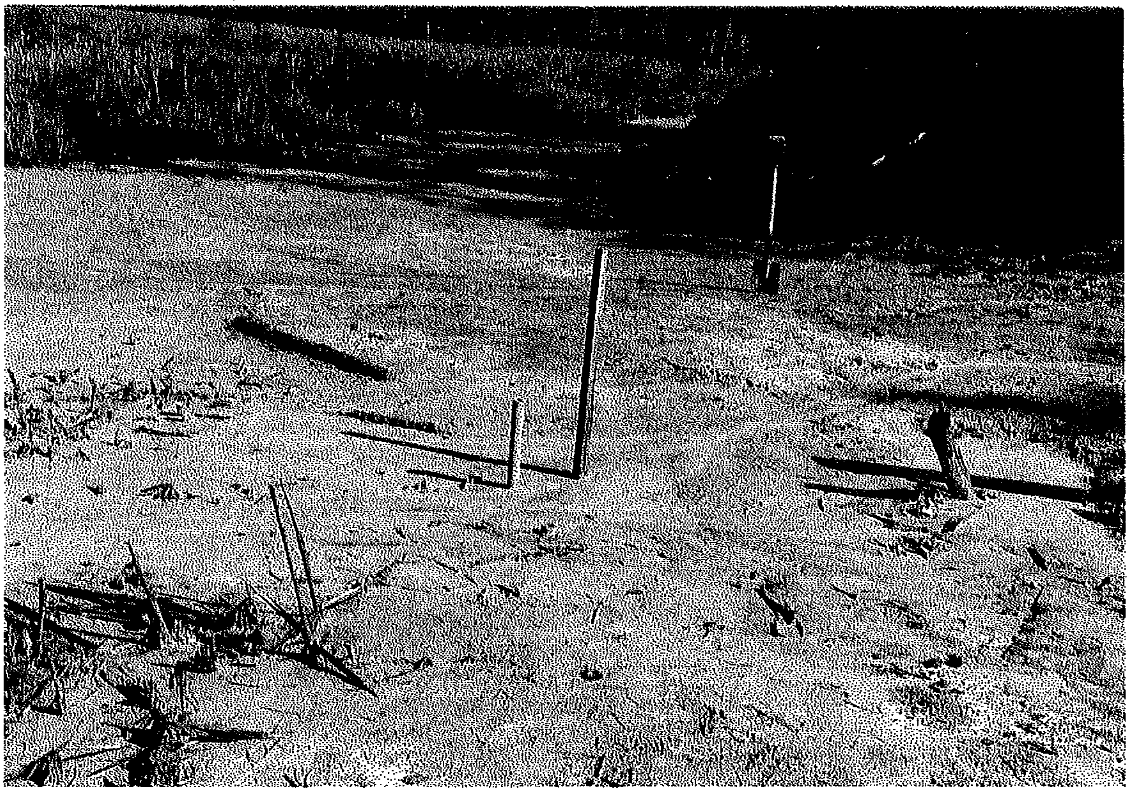


Fig. 3 - Oxidized and exposed surface of tailings (unsaturated), western part of the basin.

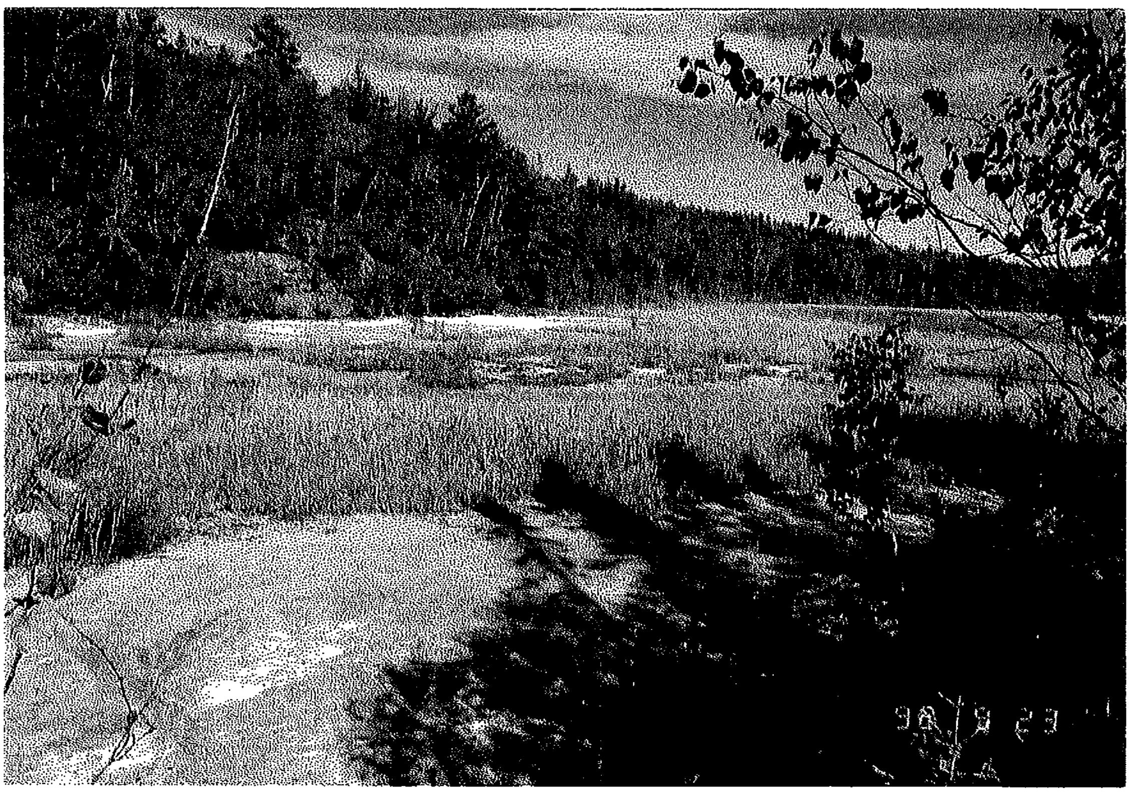


Fig. 4 - Oxidized and exposed surface of tailings with partially saturated and vegetation covered areas, western basin.

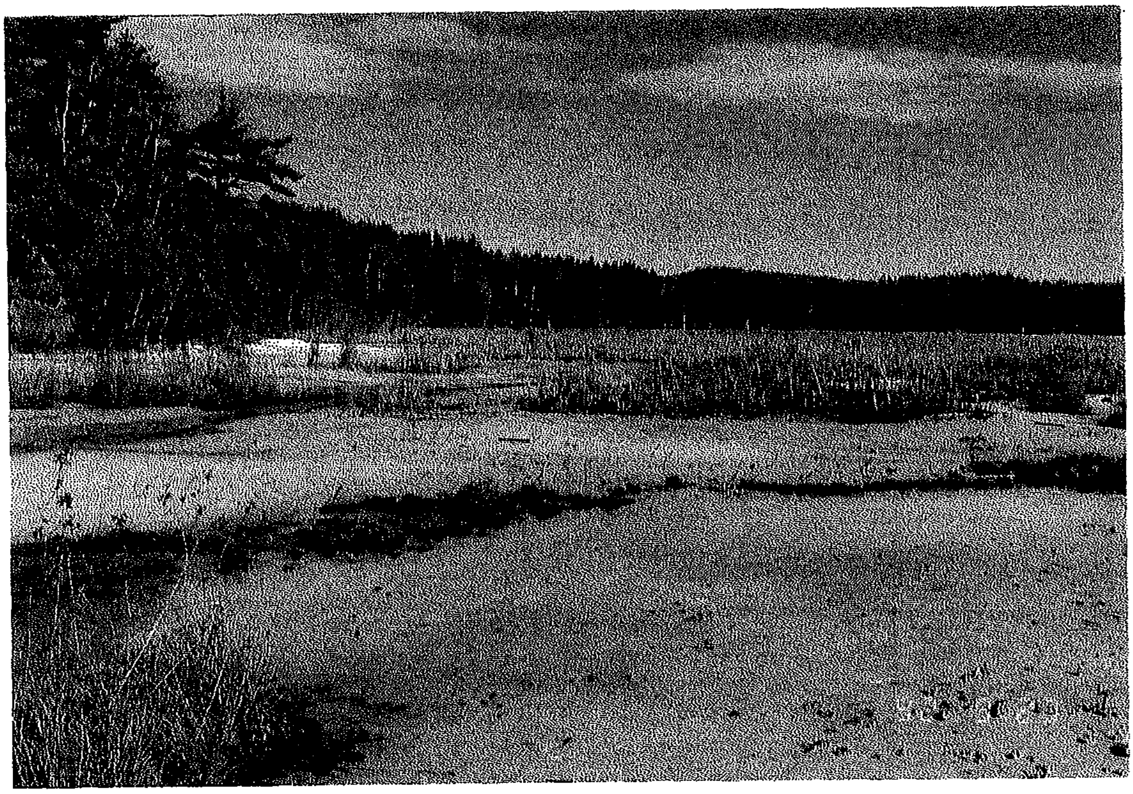


Fig. 5 - Oxidized and exposed surface of tailings with partially saturated and vegetated areas, northwest part of the basin.

Fig. 6 - Oxidized and partially exposed tailings with vegetation, southwestern basin.

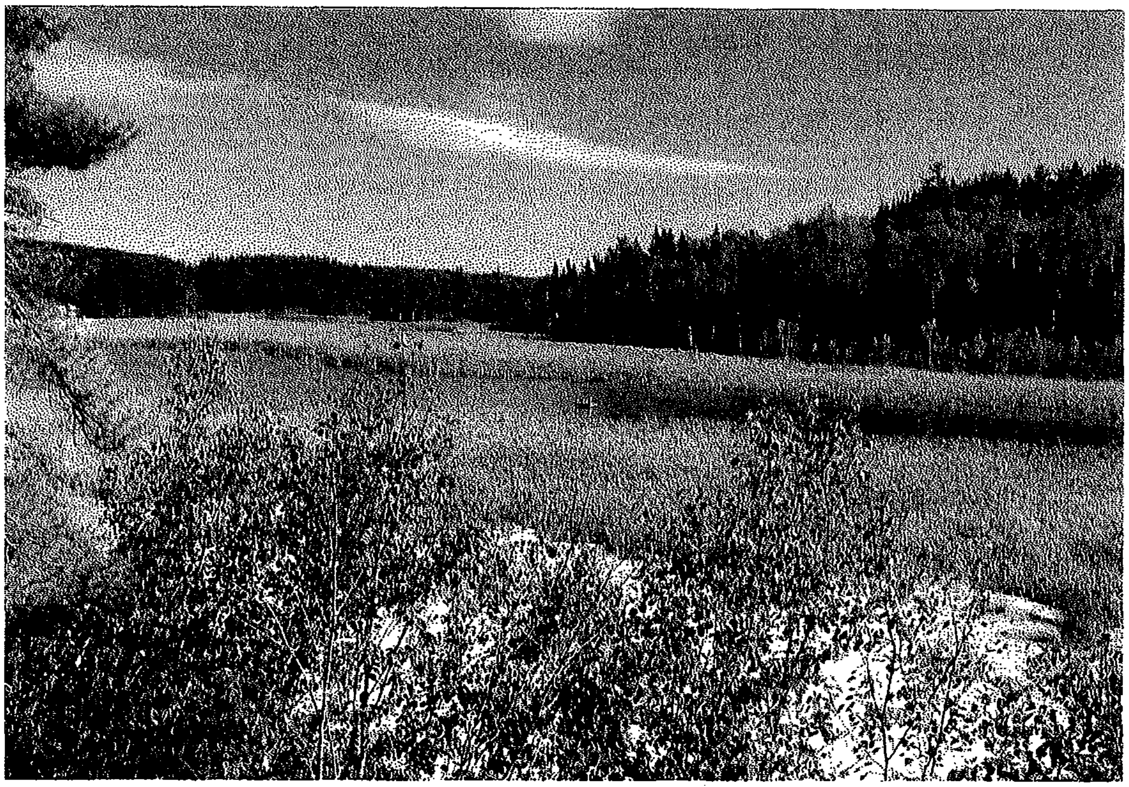


Fig. 7 - Panel wetlands area looking towards east with open water in the centre and exposed tailings in the western part.

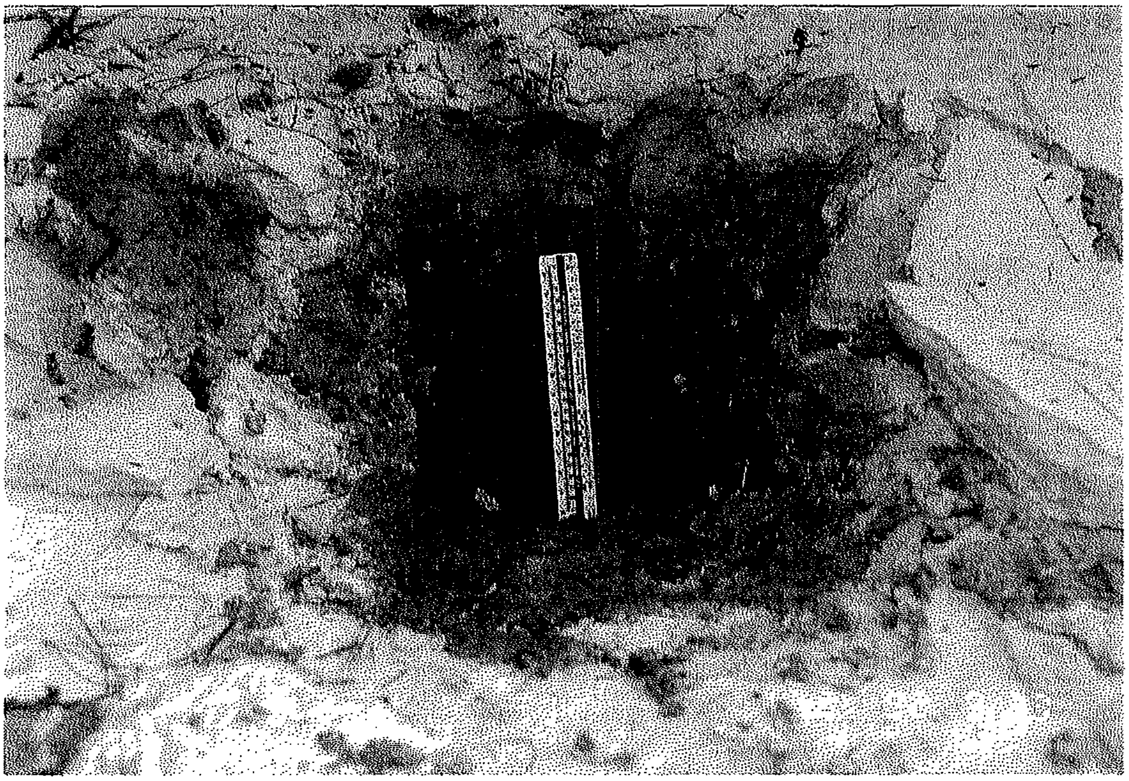


Fig. 8 - Oxidized and unoxidized tailings profile (note length of ruler is 15 cm).

Fig. 9 - Oxidized and unoxidized tailings profile showing a clear band. Note the ruler is 15 cm high.

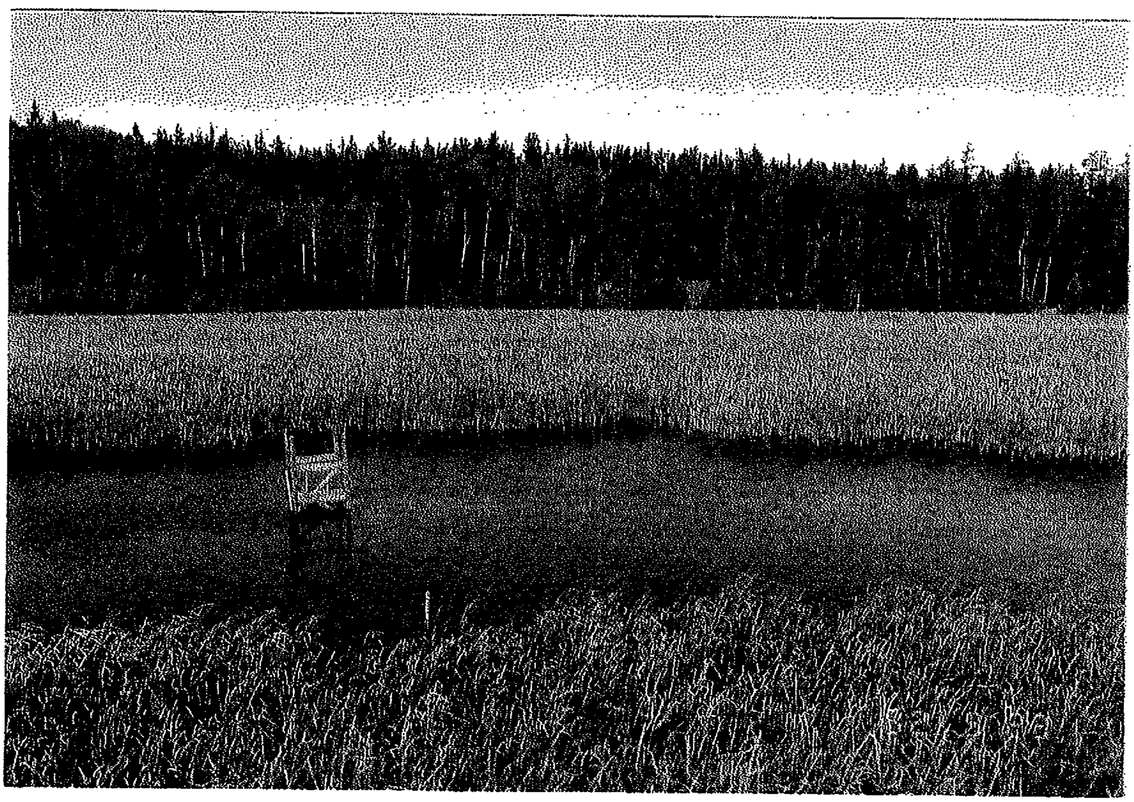


Fig. 10 - Panel wetlands, central area with open water in the middle and dense vegetation around (sampling station No. 7).

Fig. 11 - Panel wetlands, typical emergent vegetation (view looking north).

Fig. 12 - Panel wetlands: tailings covered with cattail stands.

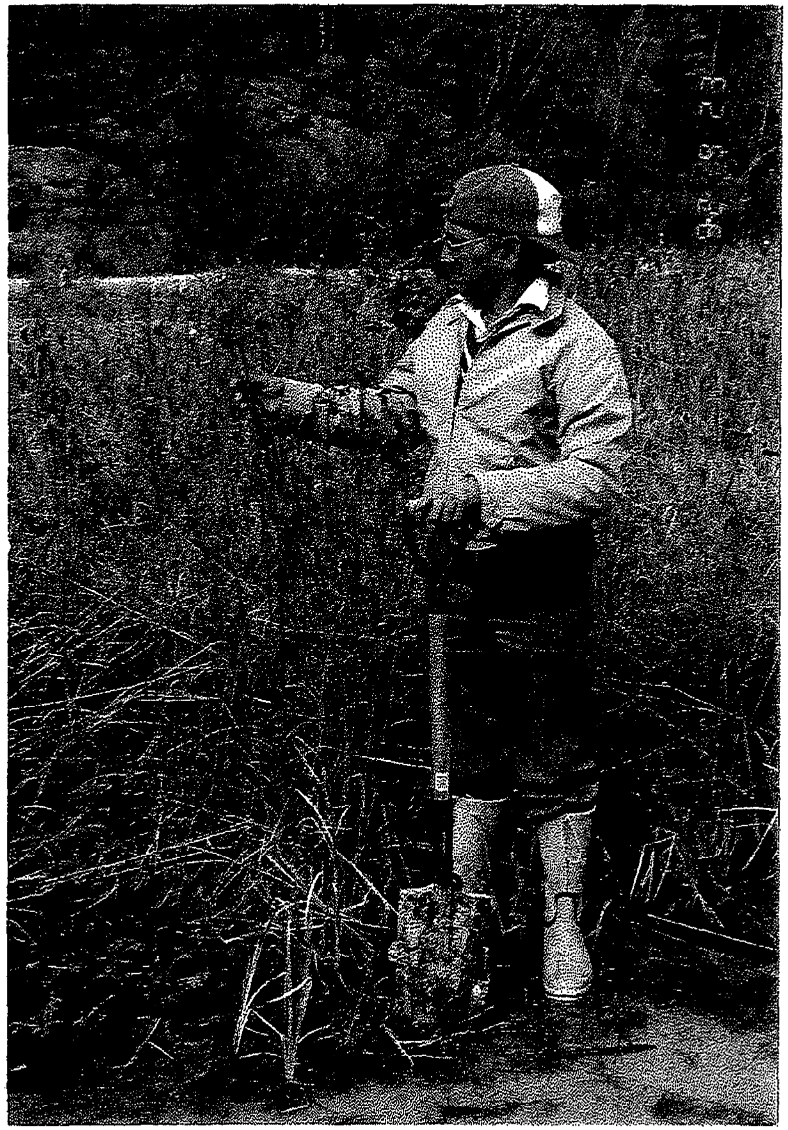


Fig. 13 - Panel wetlands: grass cover on tailings (looking north from southwest).

Fig. 14 - Panel wetlands: tailings covered with sphagnum moss.

Fig. 15 - Panel wetlands: tailings covered with sphagnum moss (southwest side).

Fig. 16 - Panel wetlands: tailings covered with sphagnum moss, southwest side with fall colours.

Fig. 17 - Panel wetlands: tailings covered with sphagnum moss with sedges, fall colouring of moss and flowers.

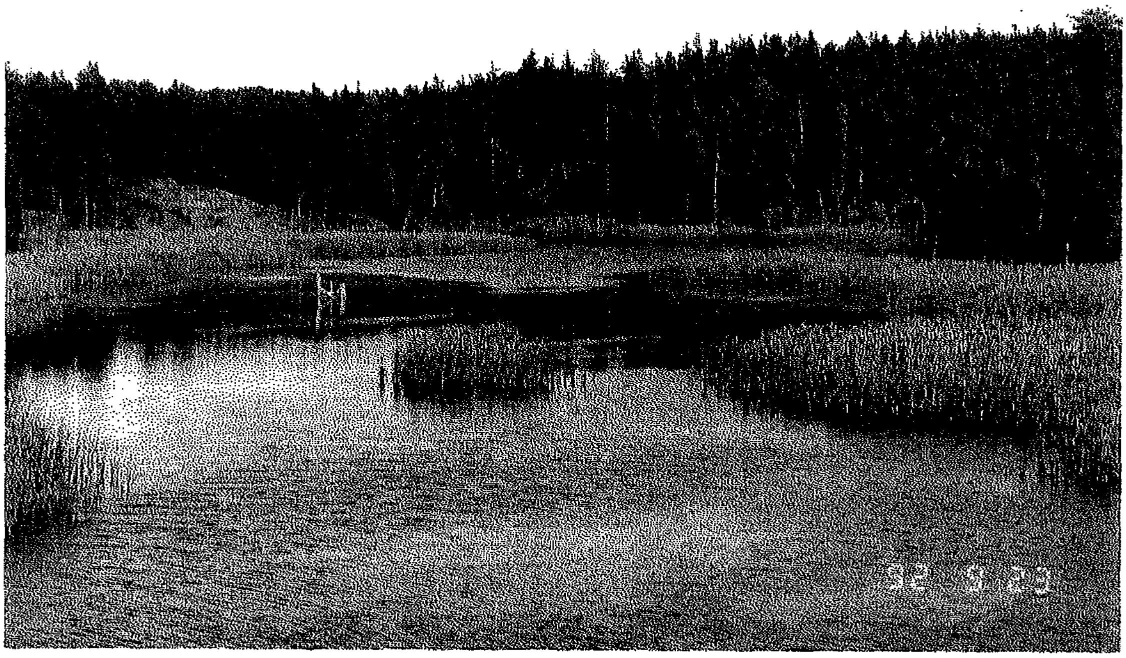


Fig. 18 - Panel wetlands with vegetation and open water central pond, looking east.

Fig. 19 - Panel wetlands: shallow water cover with wild life (frogs). Note the oxidation of iron.

Welcome Screen | Search | Report List

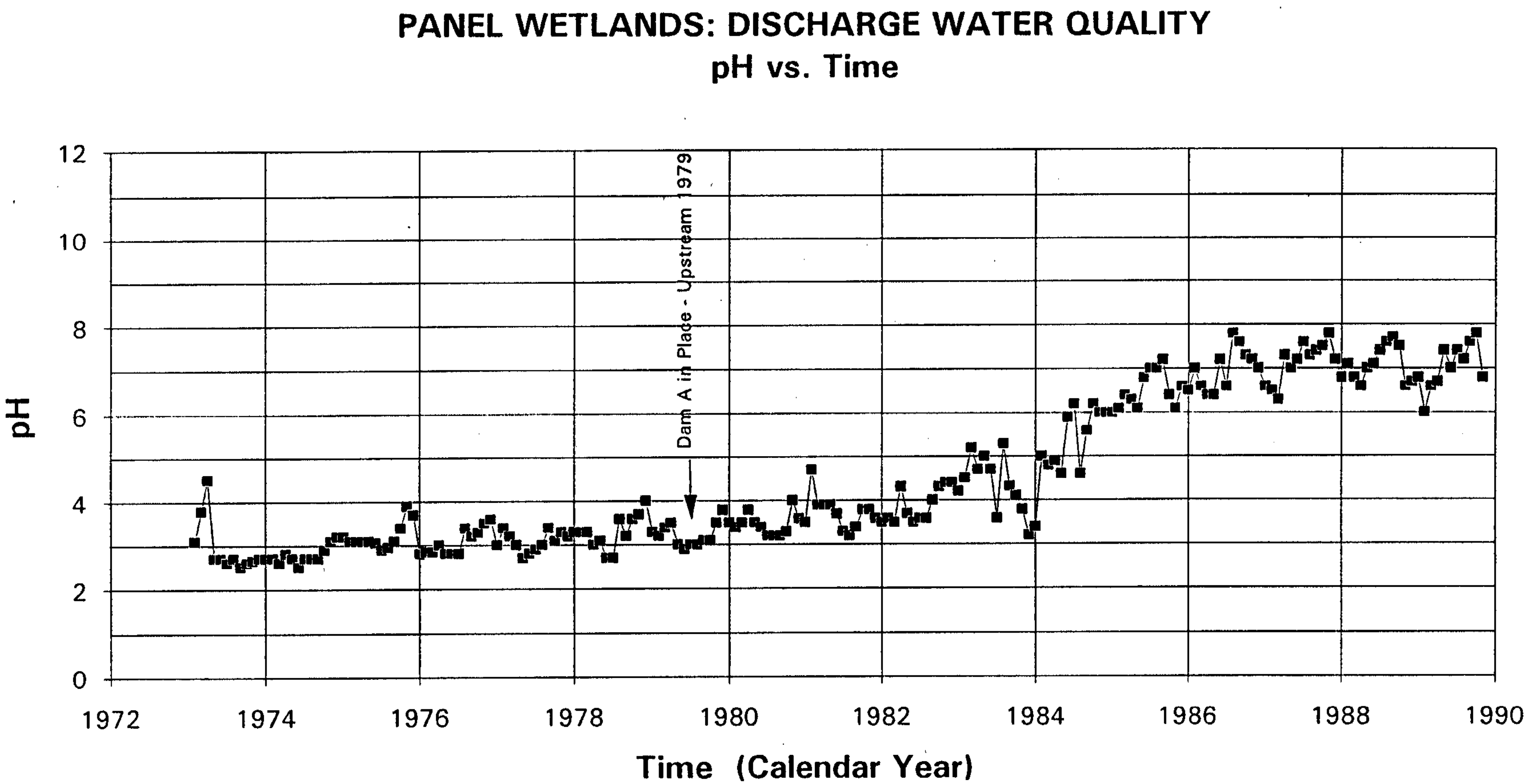


Fig. 20 - Panel wetlands, discharge water quality, pH versus time.

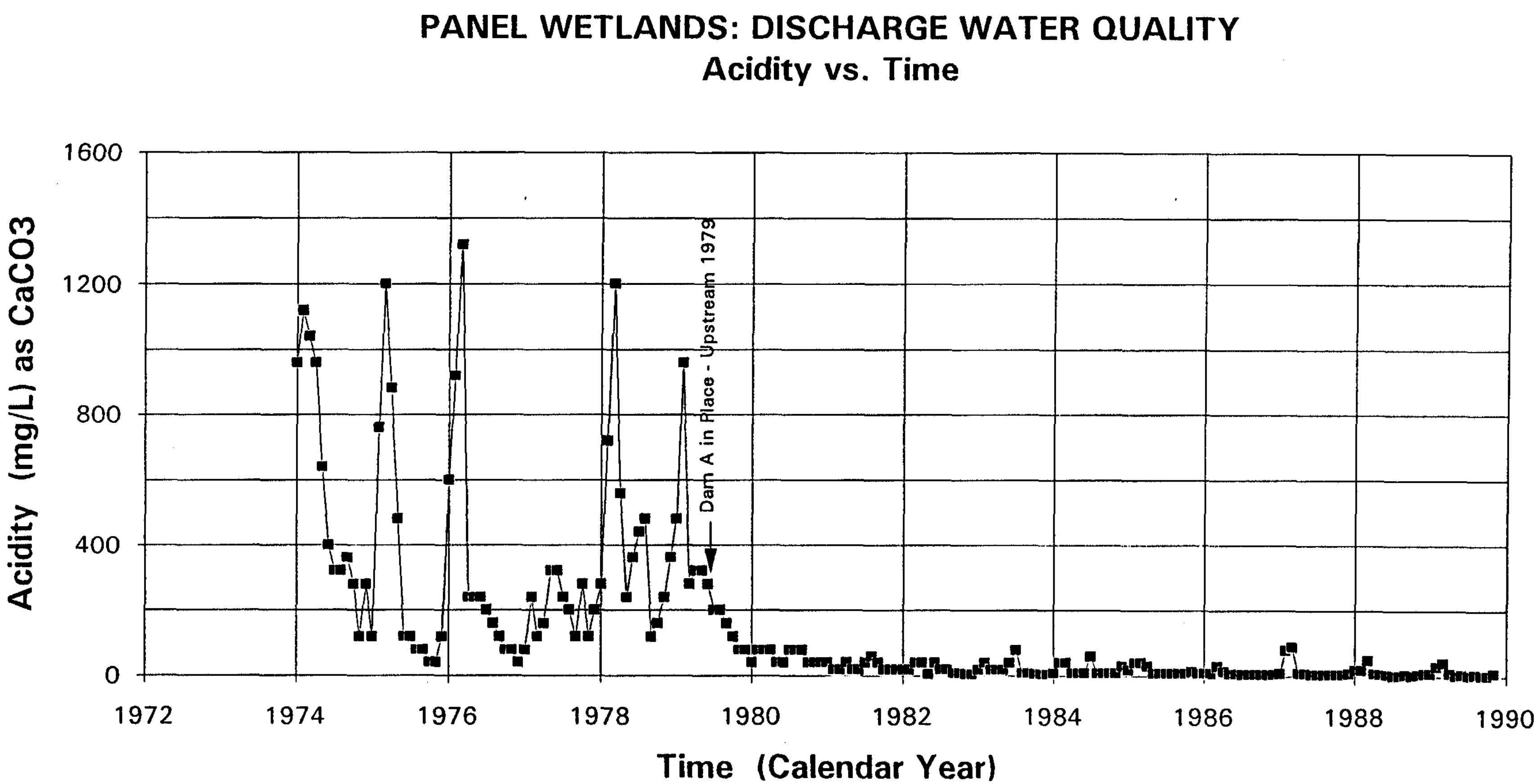


Fig. 21 - Panel wetlands, discharge water quality, acidity versus time.

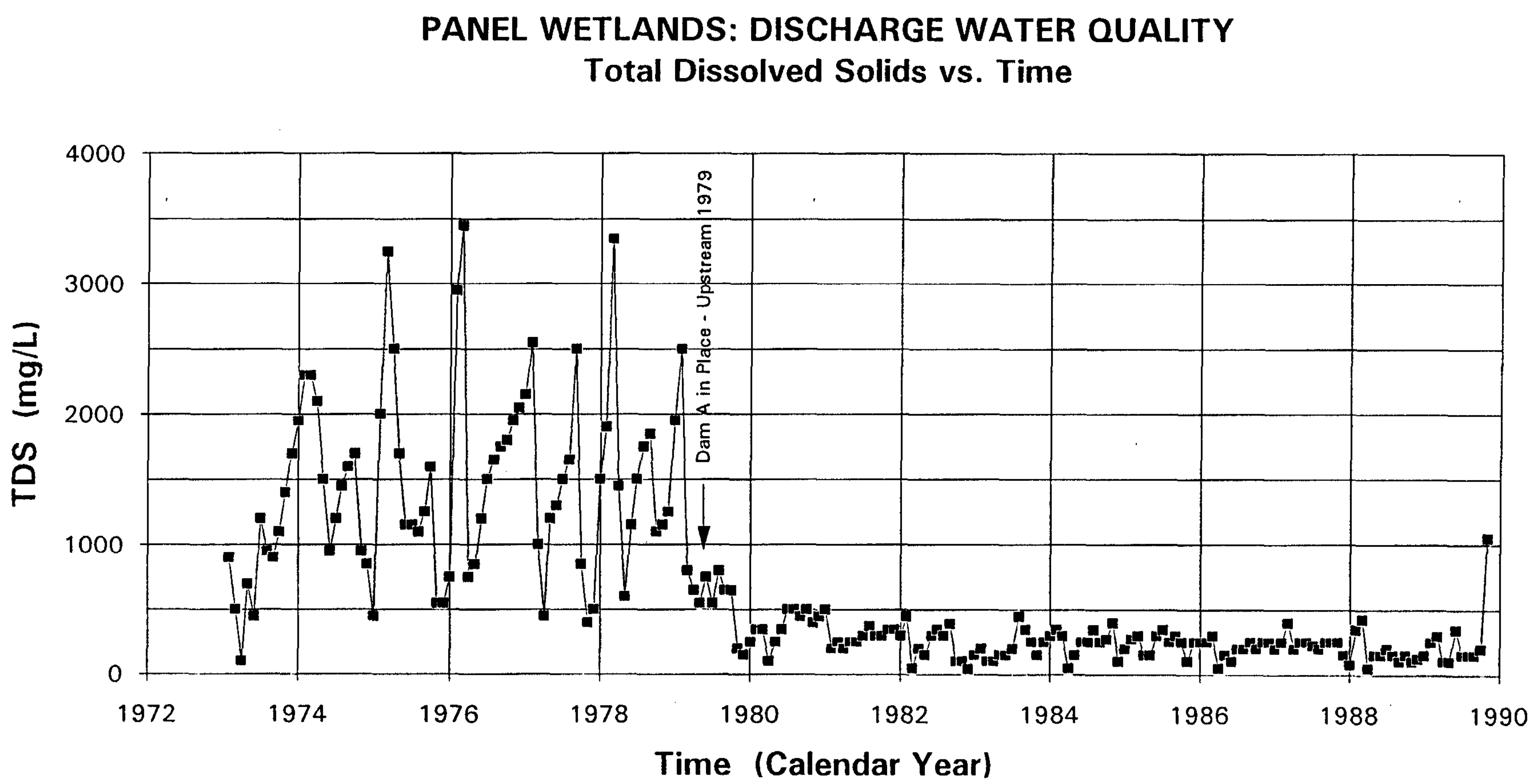


Fig. 22 - Panel wetlands, discharge water quality, total dissolved solids versus time.

Welcome Screen | Search | Report List

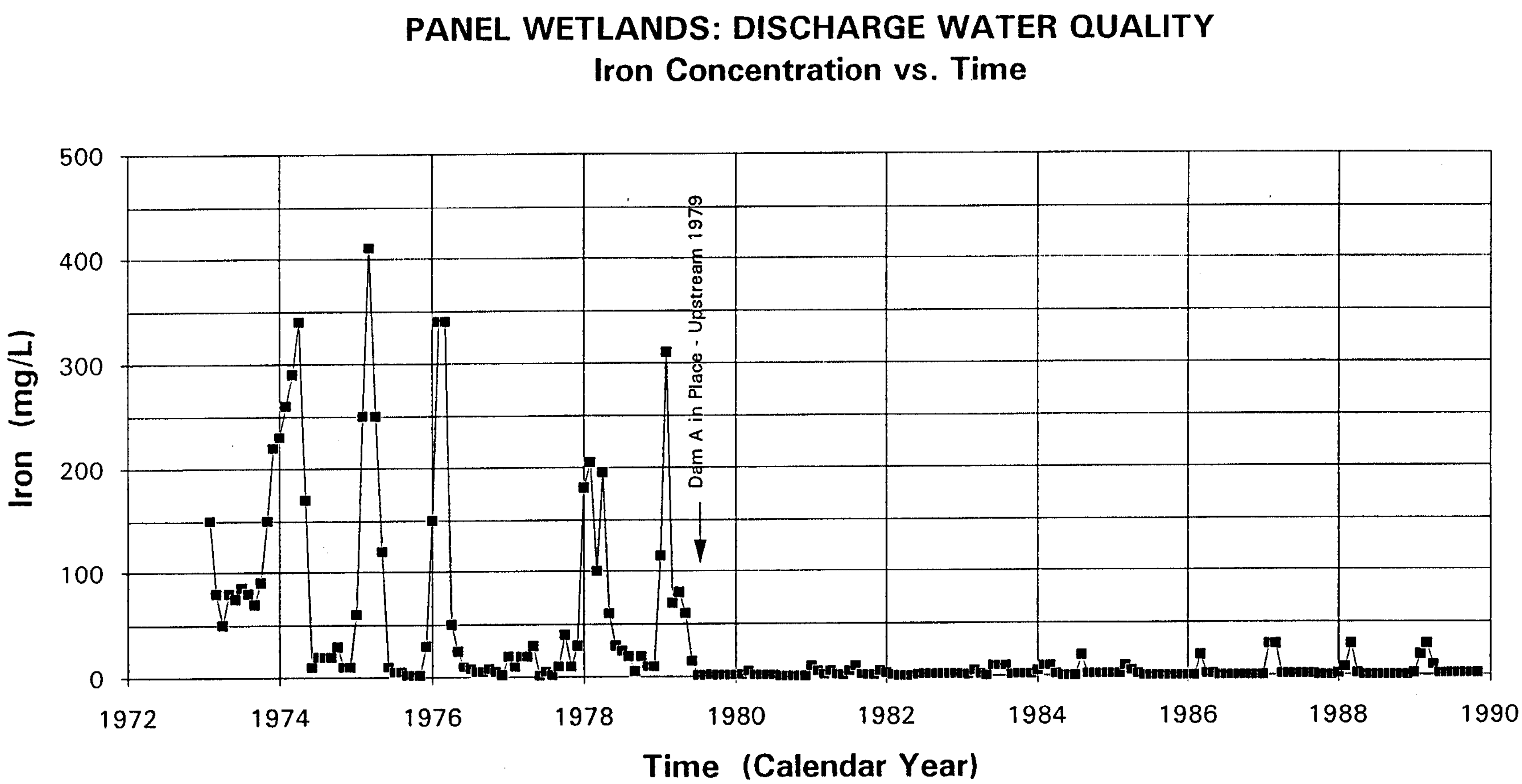


Fig. 23 - Panel wetlands, discharge water quality, iron versus time.

Welcome Screen | Search | Report List

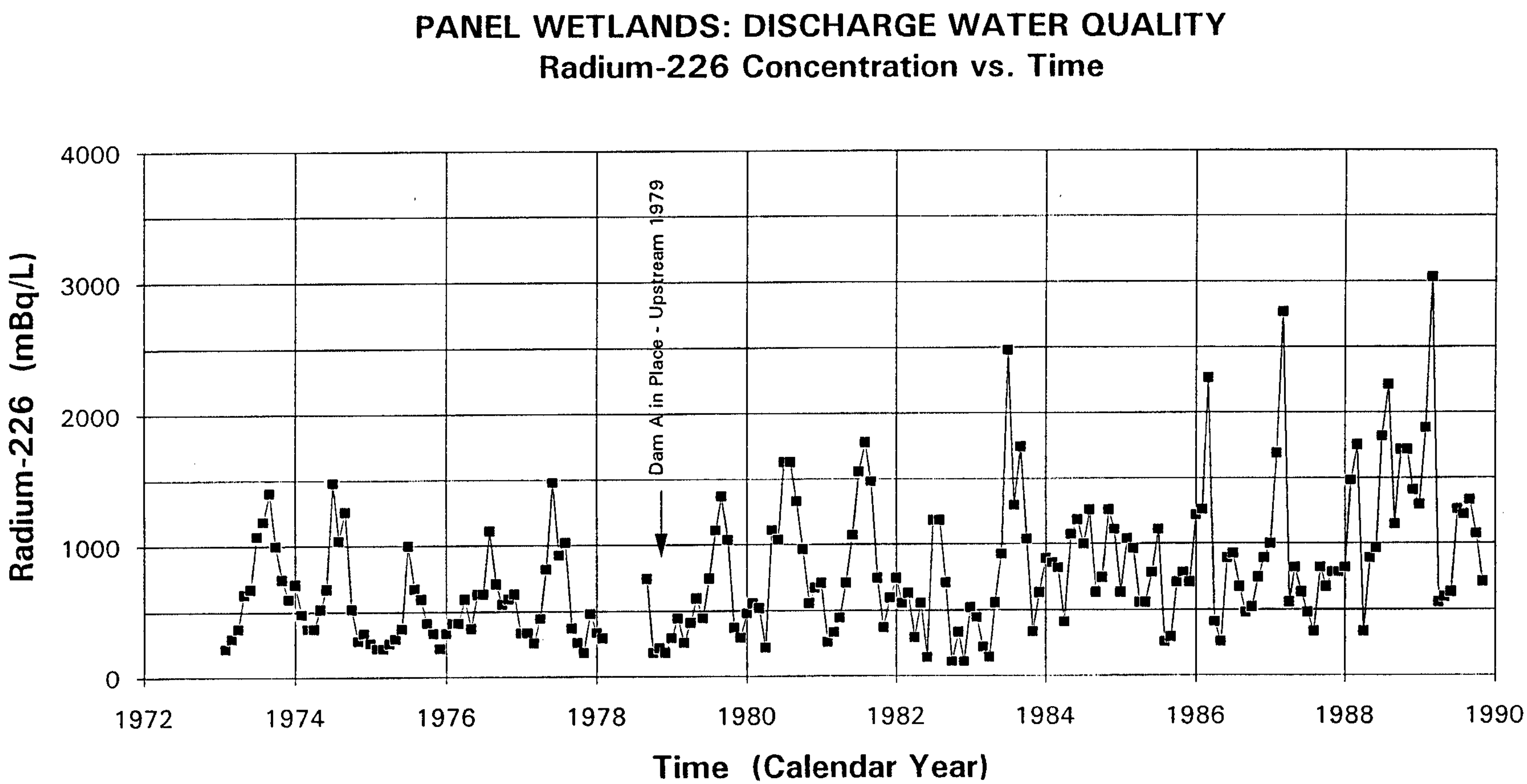


Fig. 24 - Panel wetlands, discharge water quality, Ra-226 versus time.

PANEL WETLANDS: SURFACE WATER DEPTH SOUNDING LOCATIONS

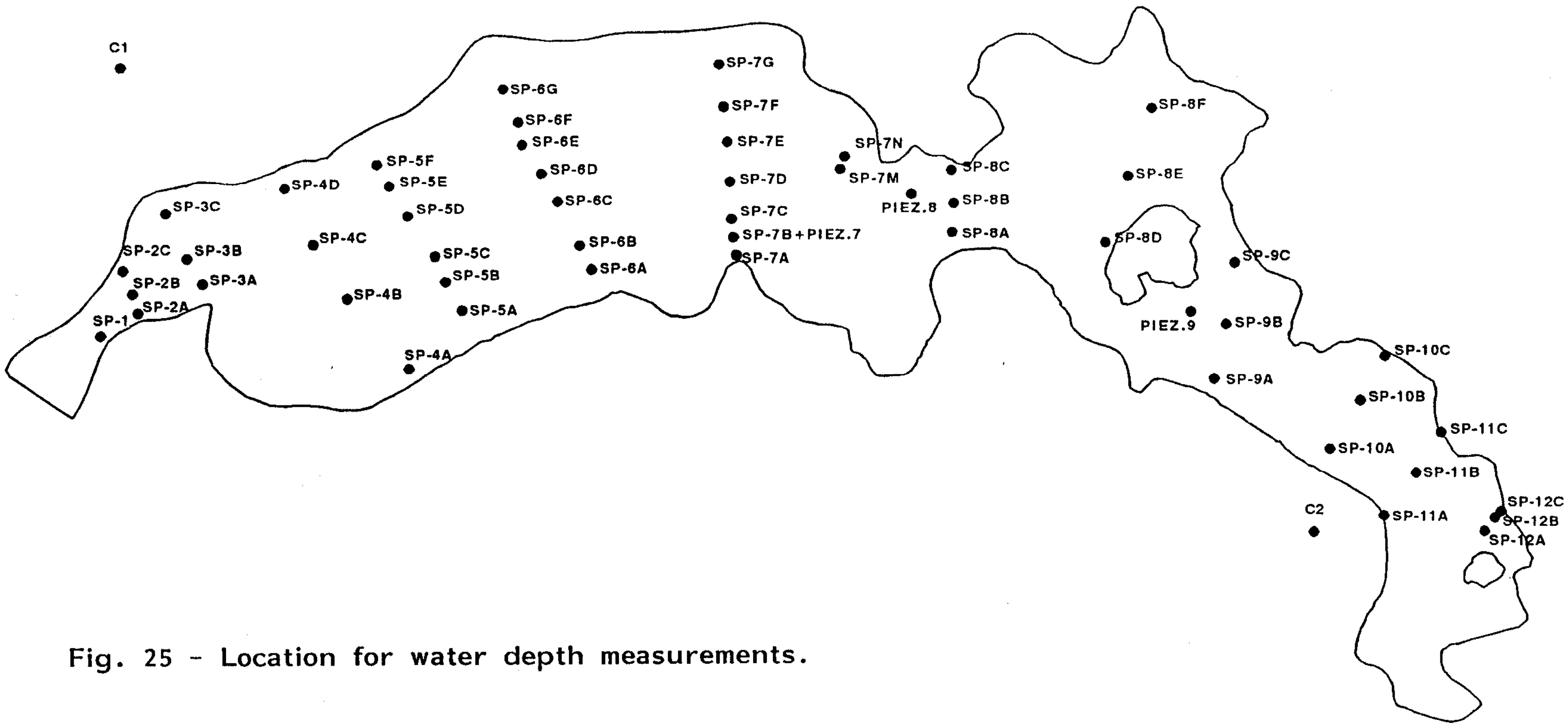


Fig. 25 - Location for water depth measurements.

PANEL WETLANDS: DEPTH SOUNDING LOCATIONS FOR TAILINGS THICKNESS MEASUREMENTS

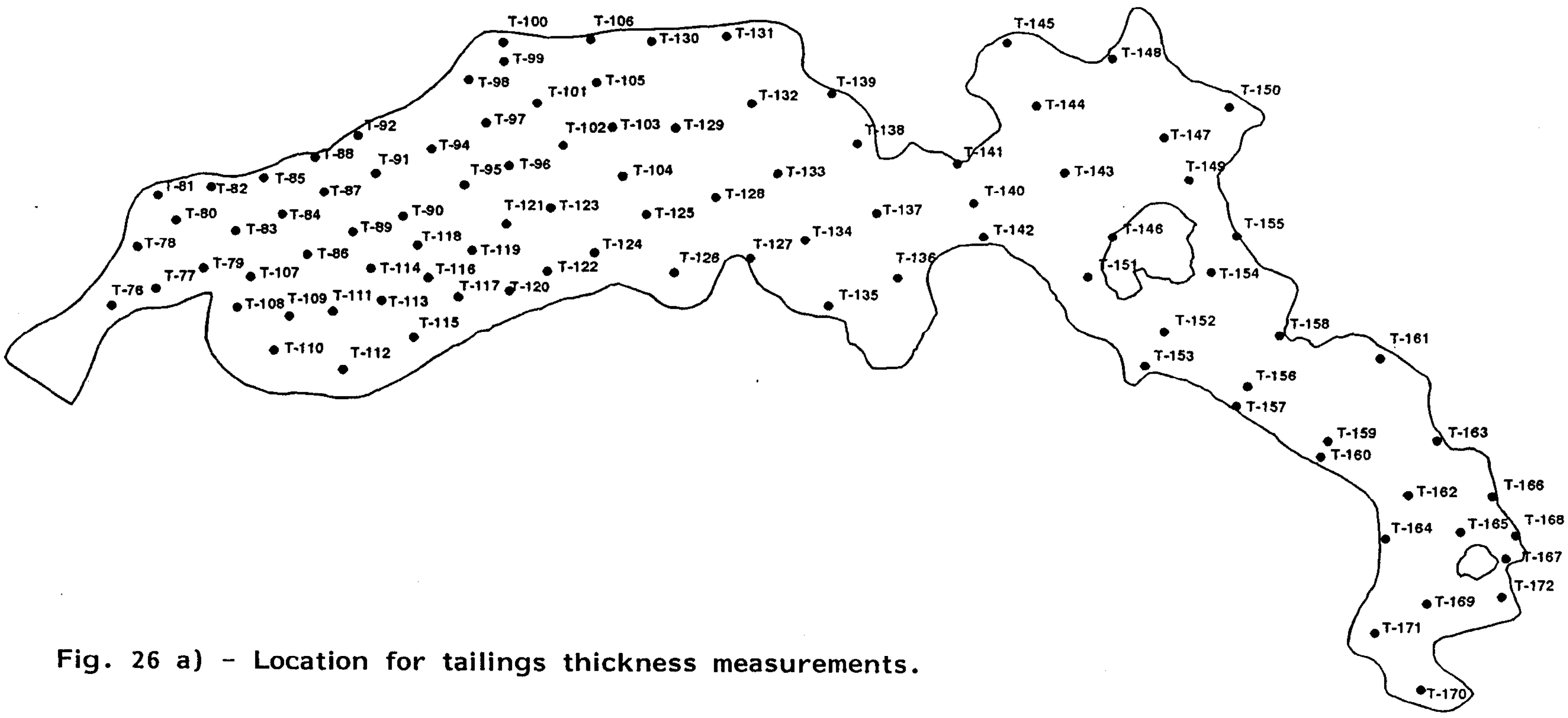


Fig. 26 a) - Location for tailings thickness measurements.

PANEL WETLANDS: EXPOSED TAILINGS AREA

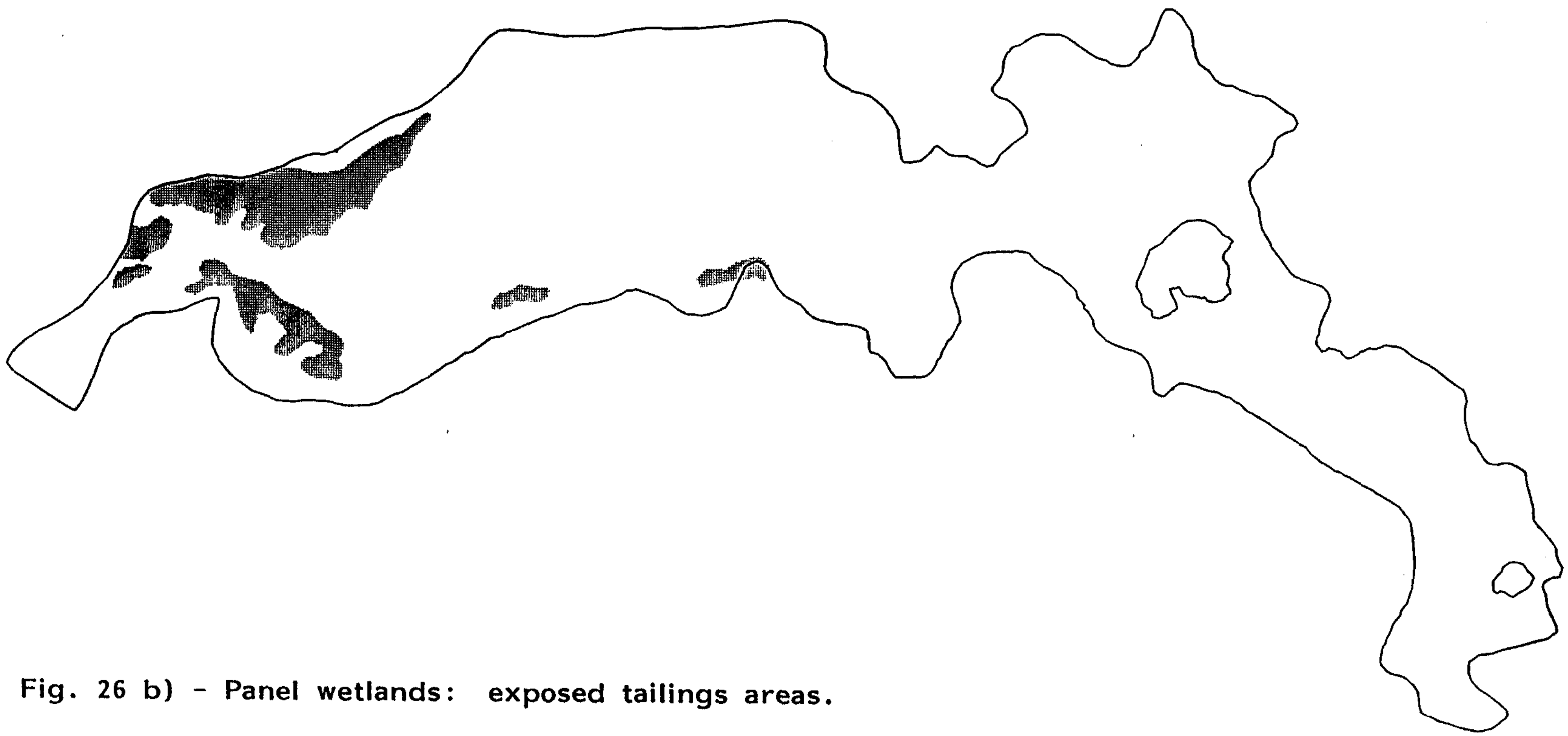


Fig. 26 b) - Panel wetlands: exposed tailings areas.

PANEL WETLANDS: SURFACE WATER SAMPLING LOCATIONS

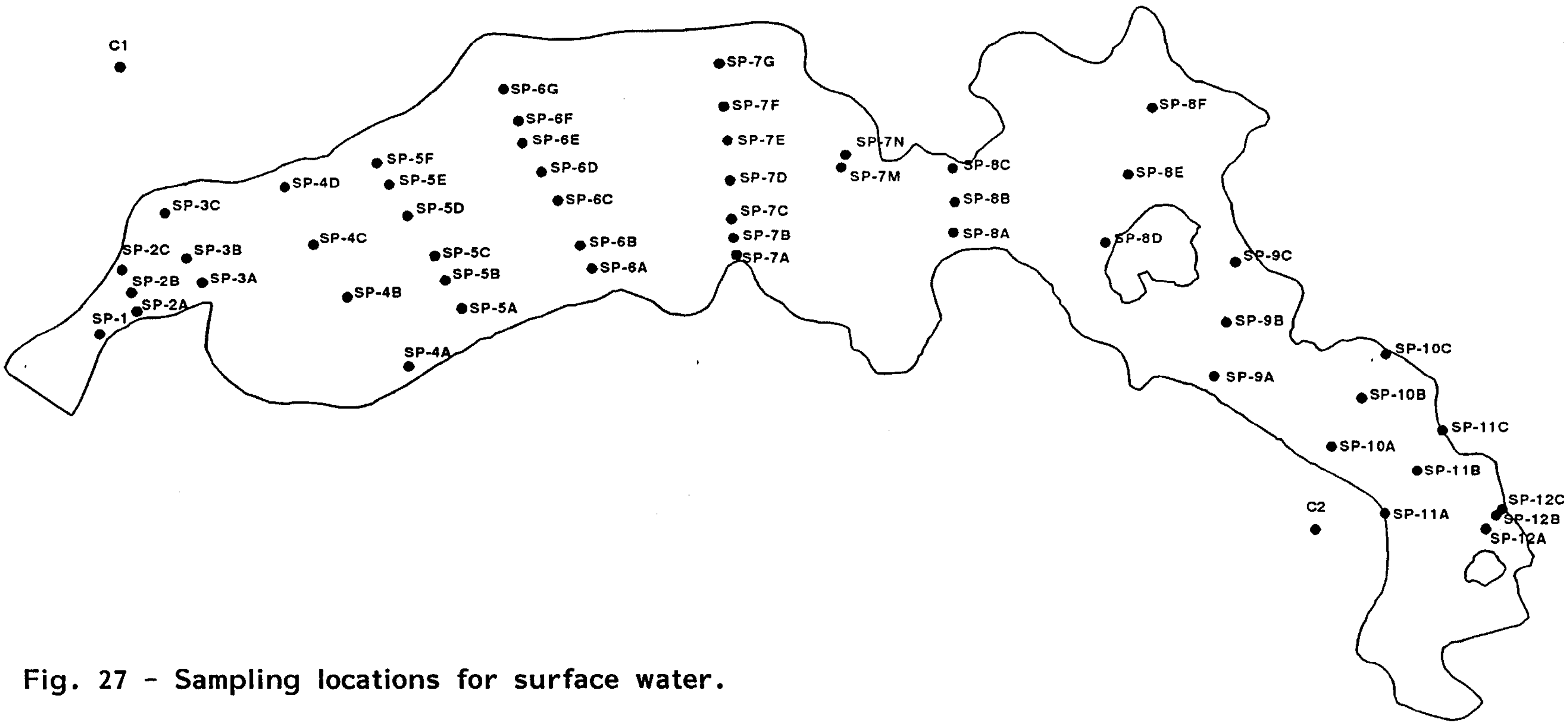


Fig. 27 - Sampling locations for surface water.

PANEL WETLANDS: SURFACE WATER SAMPLING LOCATIONS

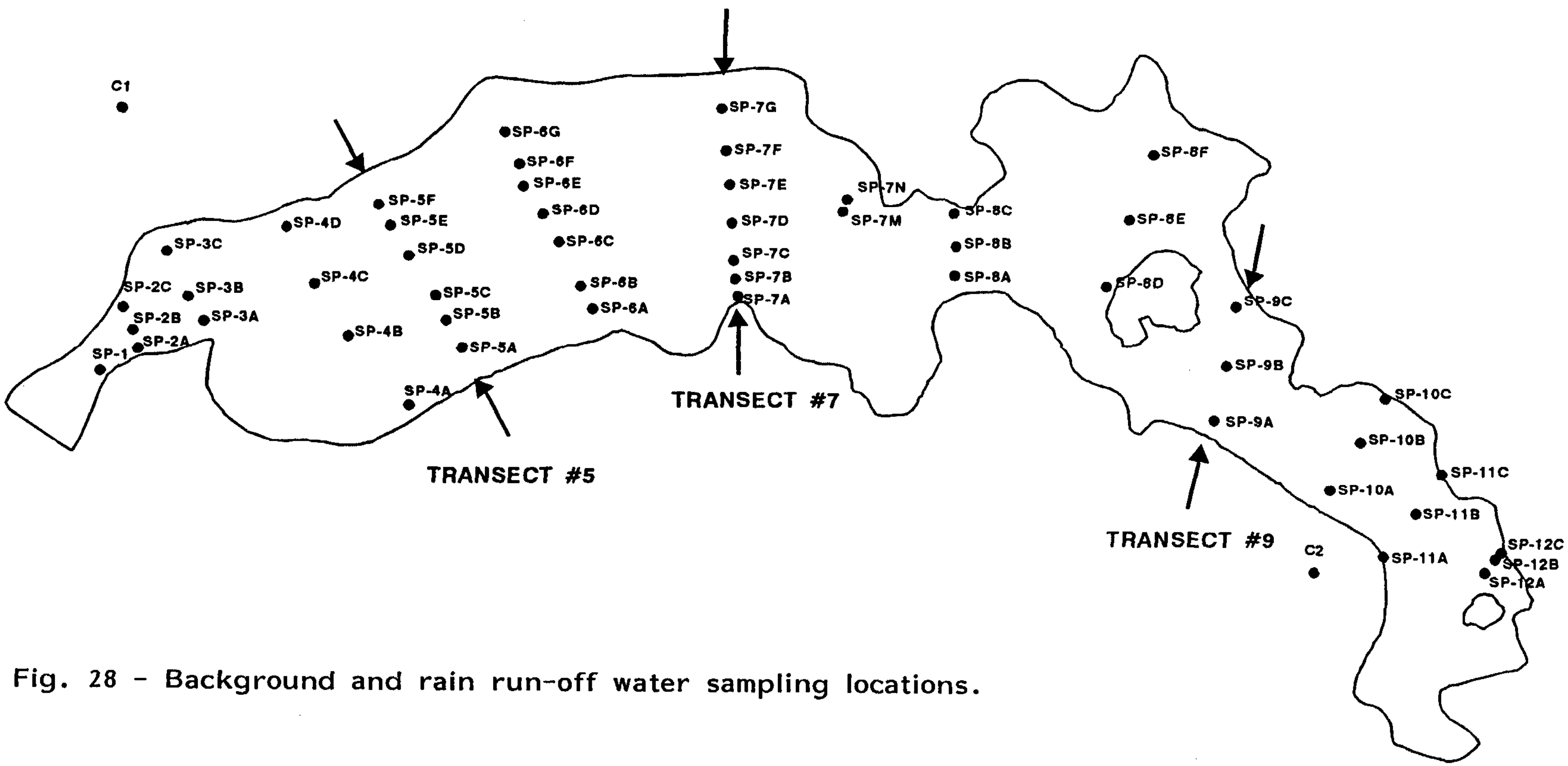


Fig. 28 - Background and rain run-off water sampling locations.

PANEL WETLANDS: GROUNDWATER SAMPLING LOCATIONS

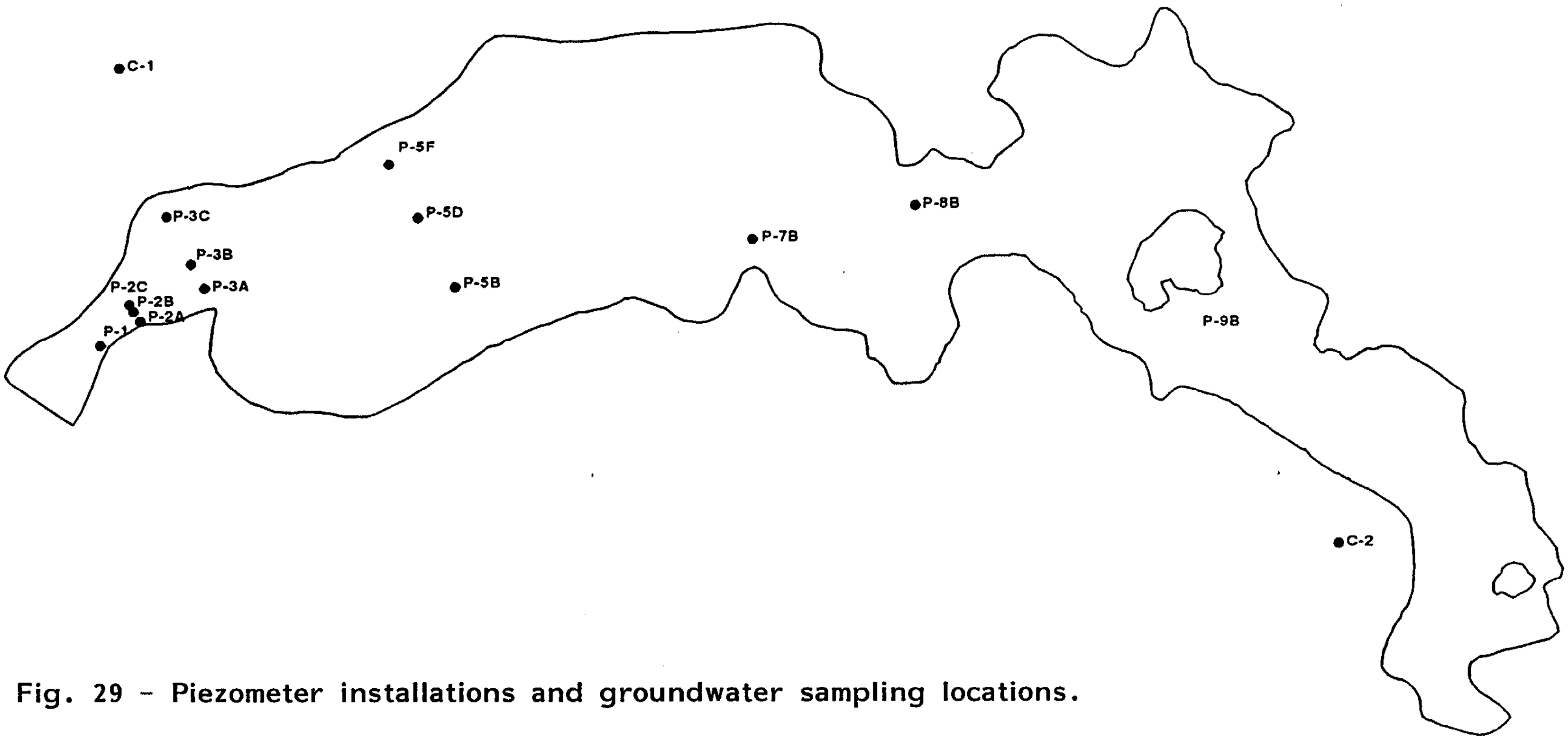


Fig. 29 - Piezometer installations and groundwater sampling locations.

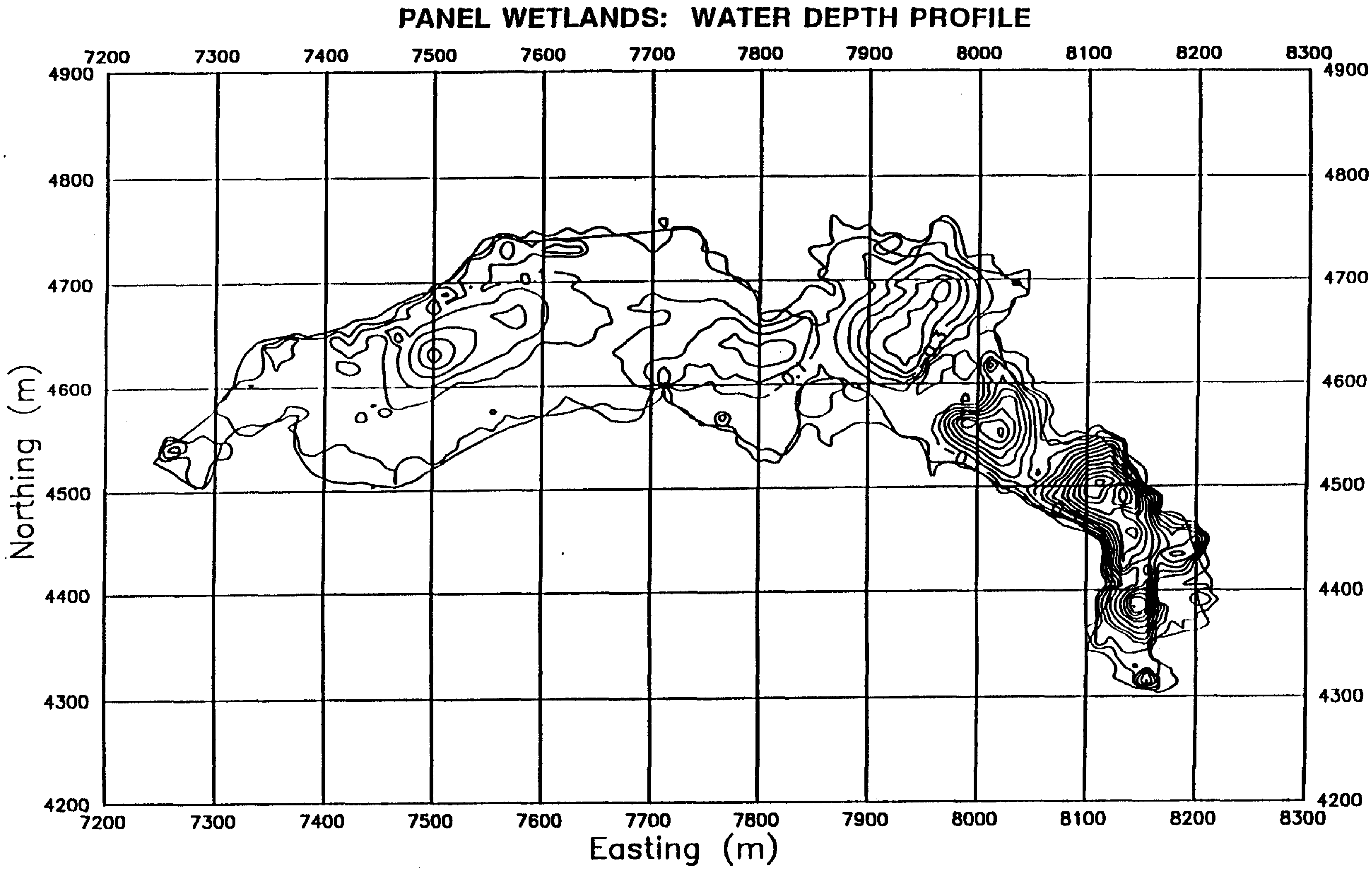


Fig. 30 - Panel wetlands: depth contours (contour interval 0.1 m).

WATER AND SURFACE ELEVATION CONTOURS IN PANEL WETLANDS AREA

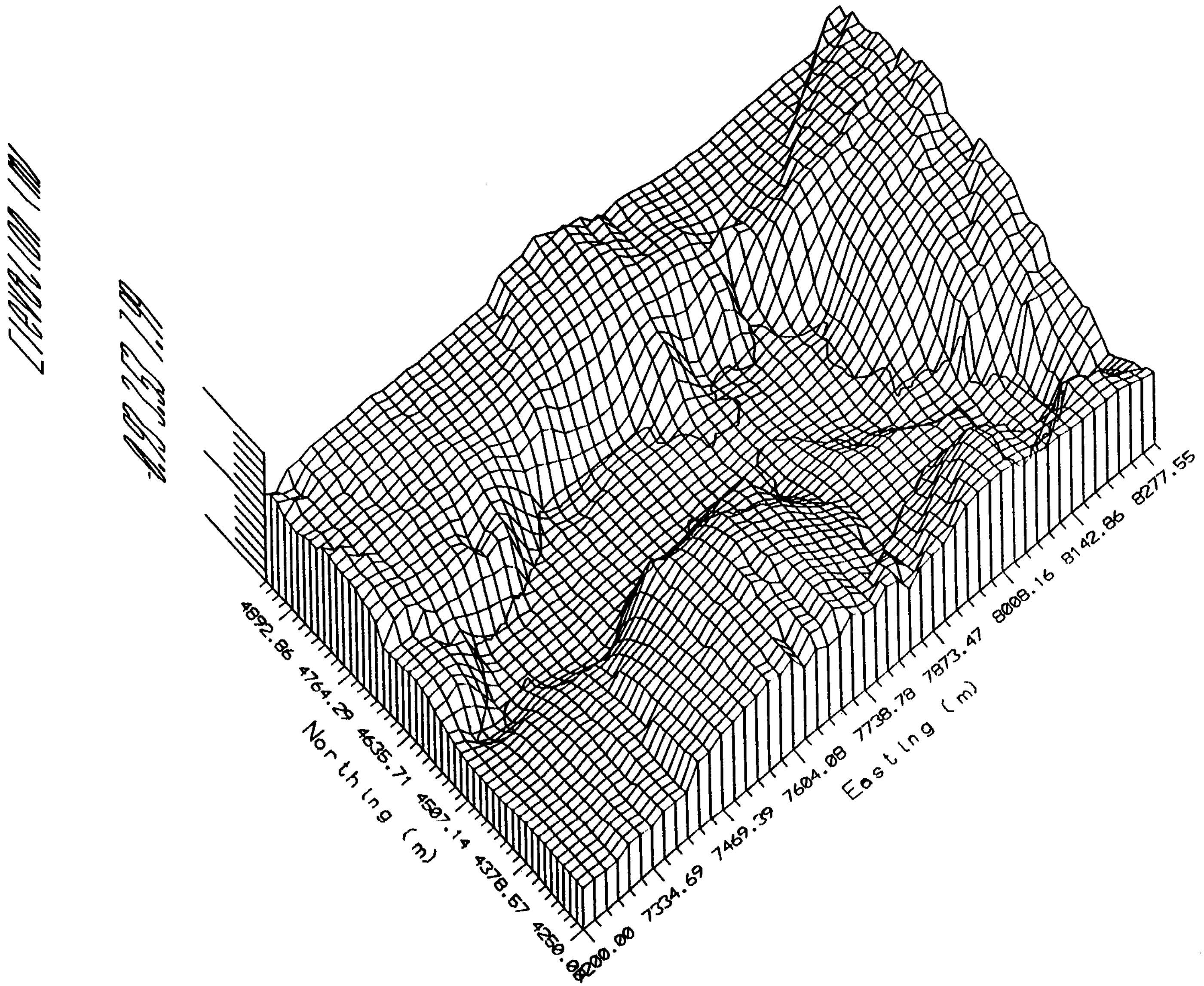


Fig. 31 - Water depth 3-D surface perspective view.

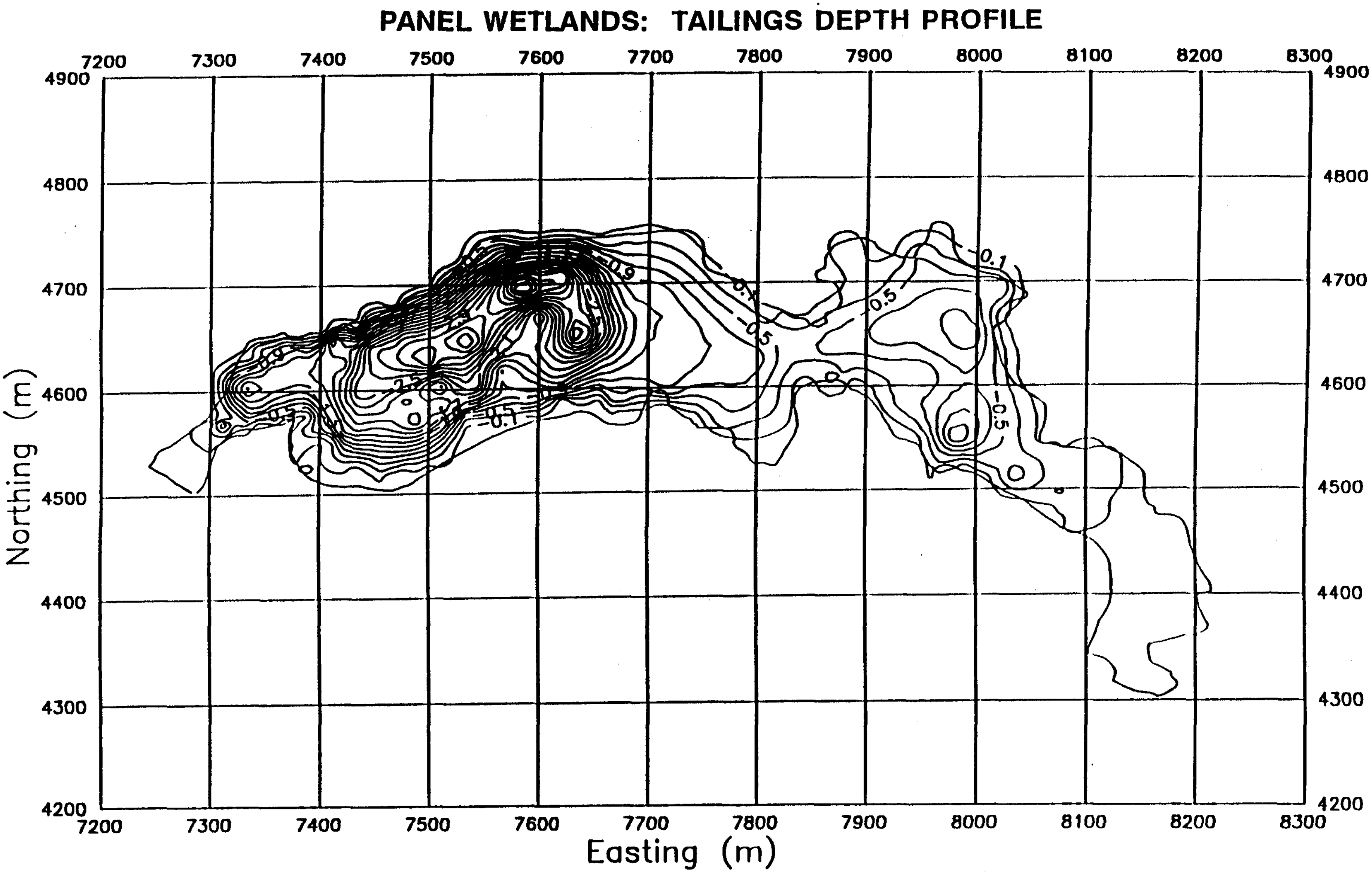


Fig. 32 - Panel wetlands: tailings thickness contours (contour interval 0.2 m).

PANEL WETLANDS: TAILINGS THICKNESS 3D PROFILE

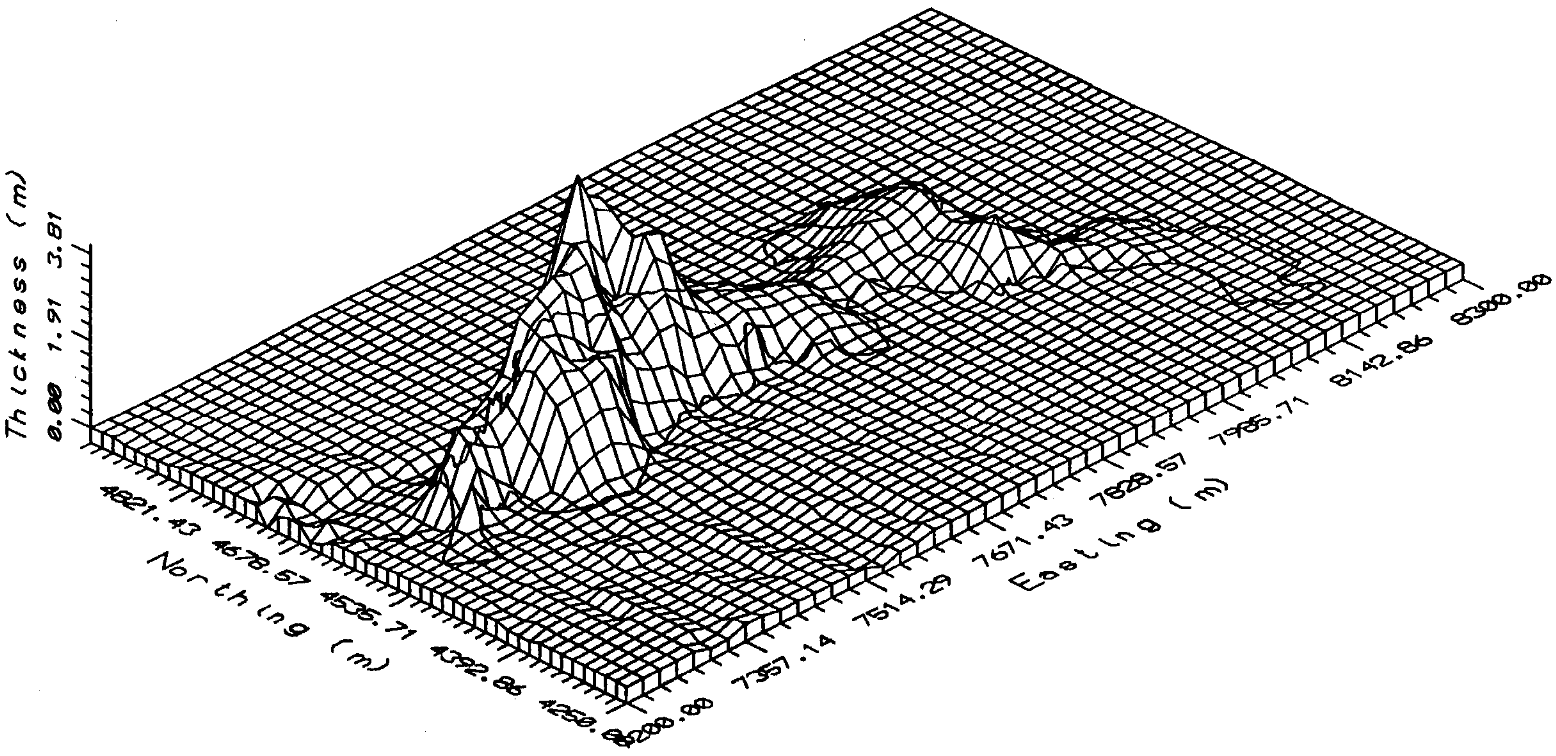


Fig. 33 - Panel wetlands: tailings thickness 3-D surface perspective view.

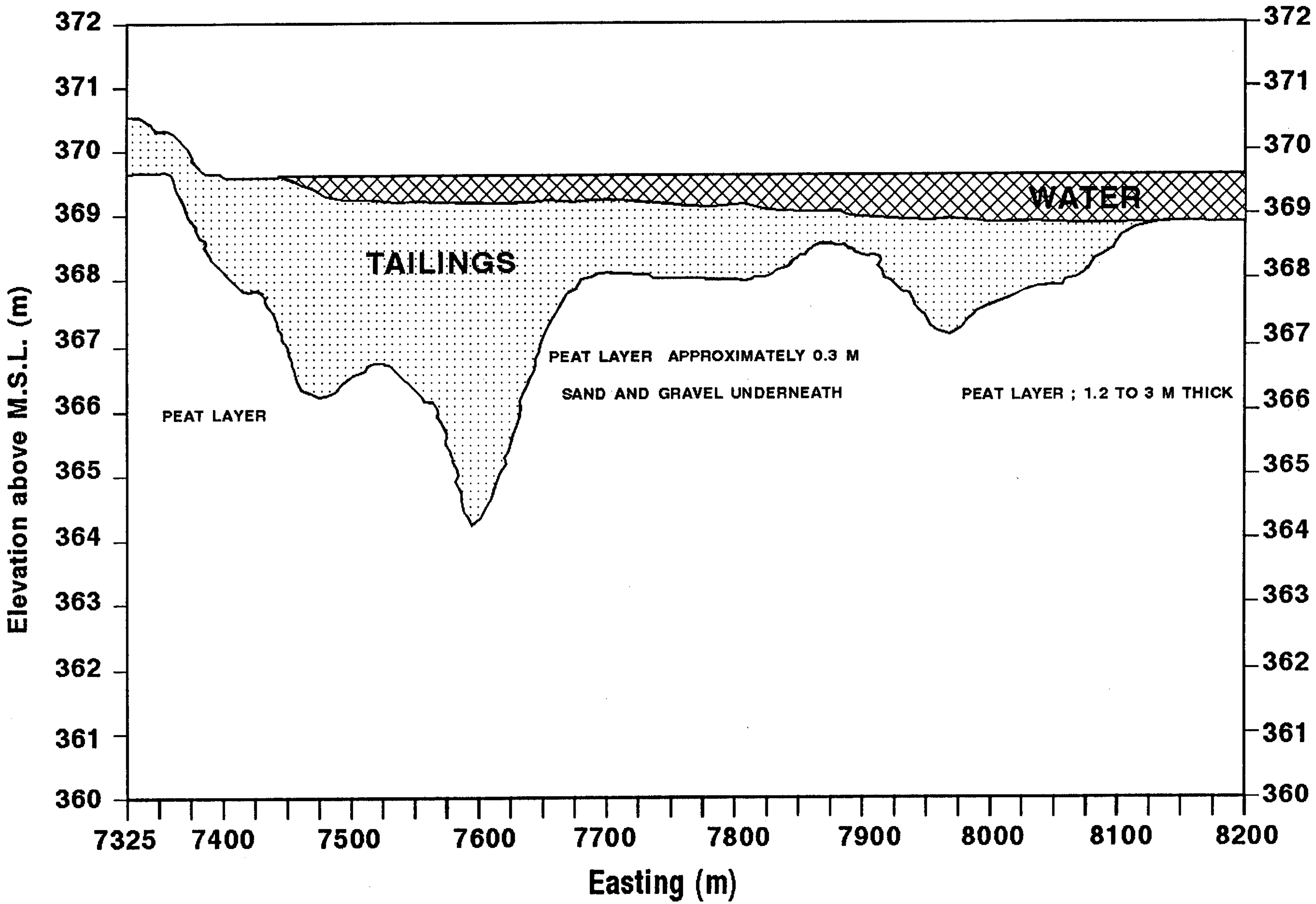


Fig. 34 - Tailings thickness cross-sectional profile.

PANEL WETLANDS: TAILINGS VEGETATION AND WATER COVERED AREAS

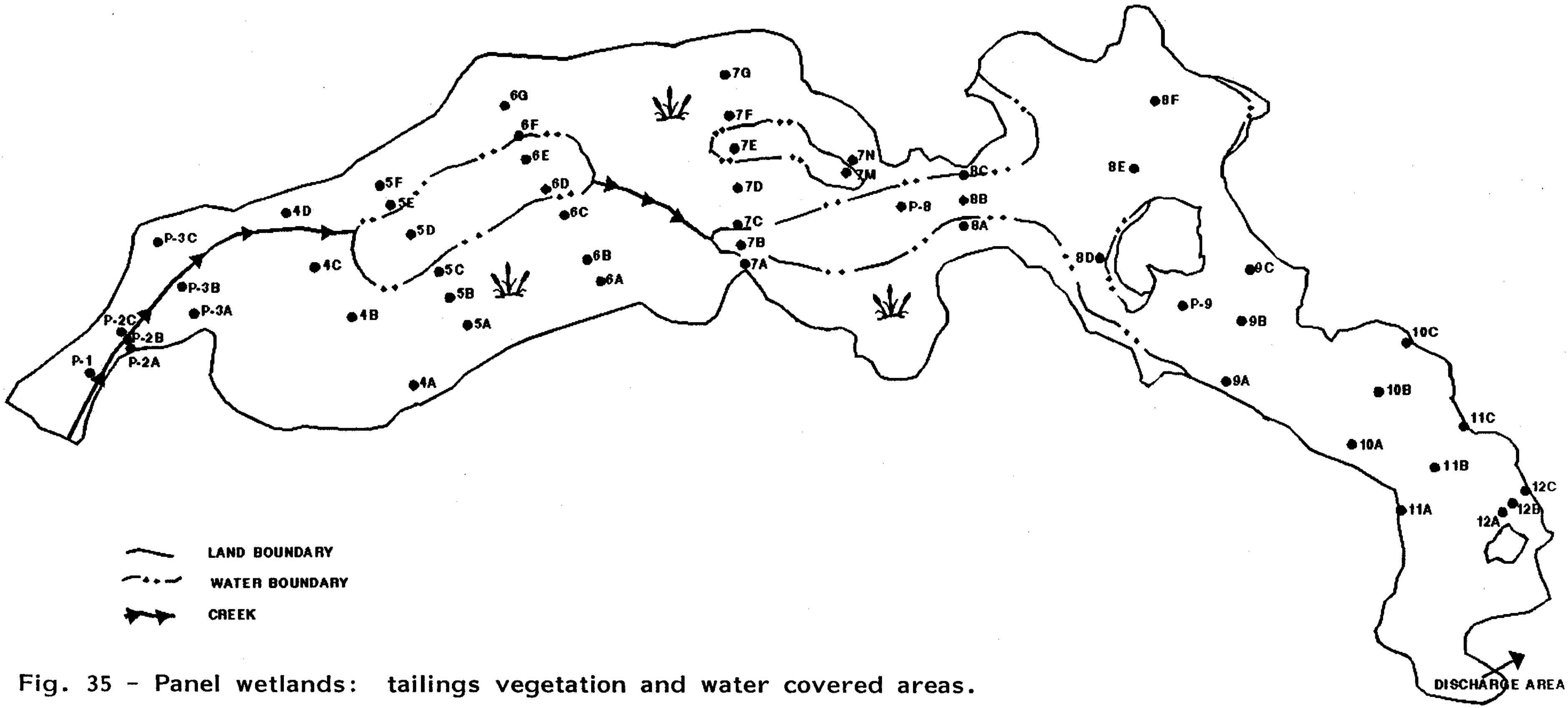


Fig. 35 - Panel wetlands: tailings vegetation and water covered areas.

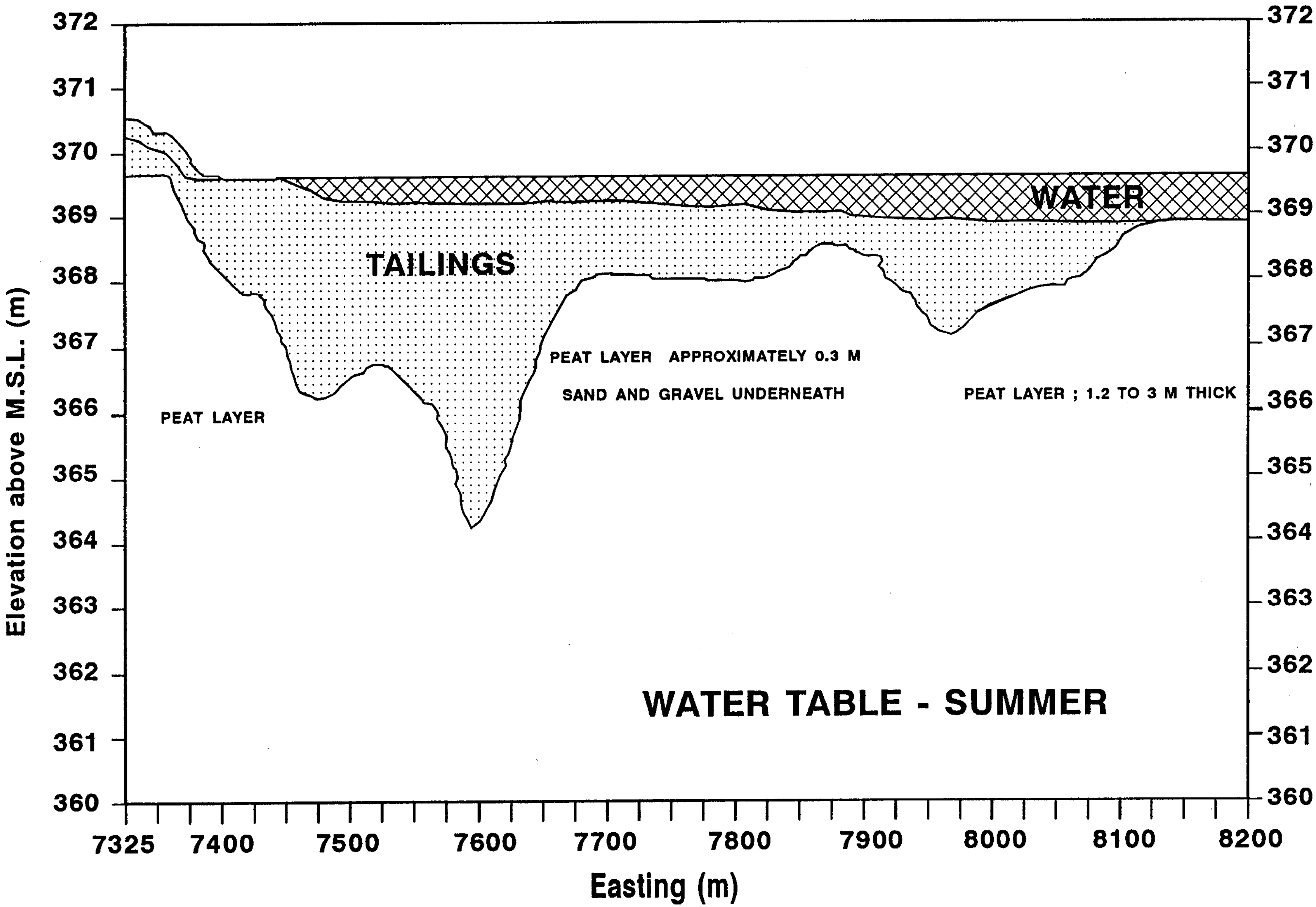


Fig. 36 - Panel wetlands: summer water table elevation.

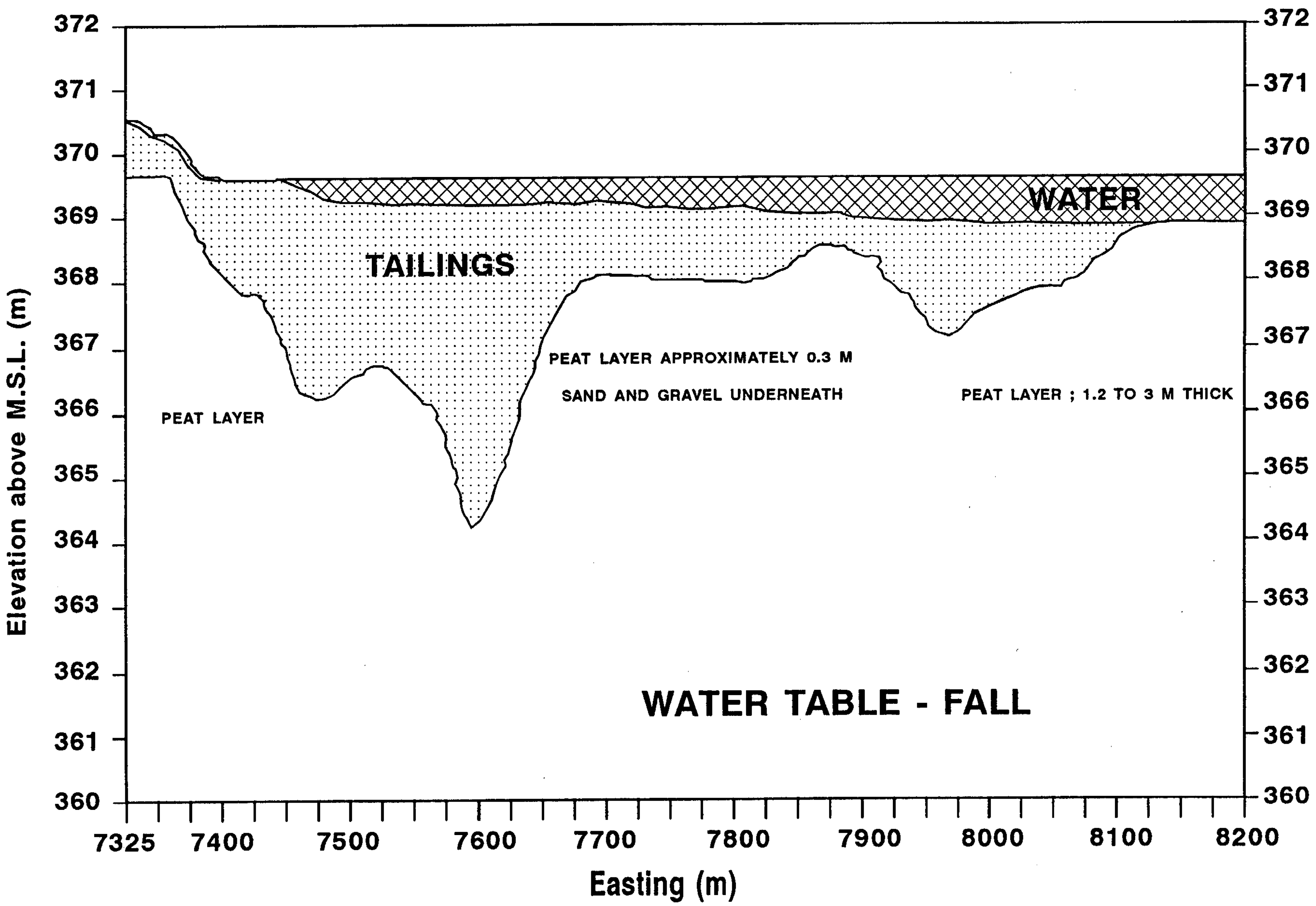


Fig. 37 - Panel wetlands: fall water table elevations.

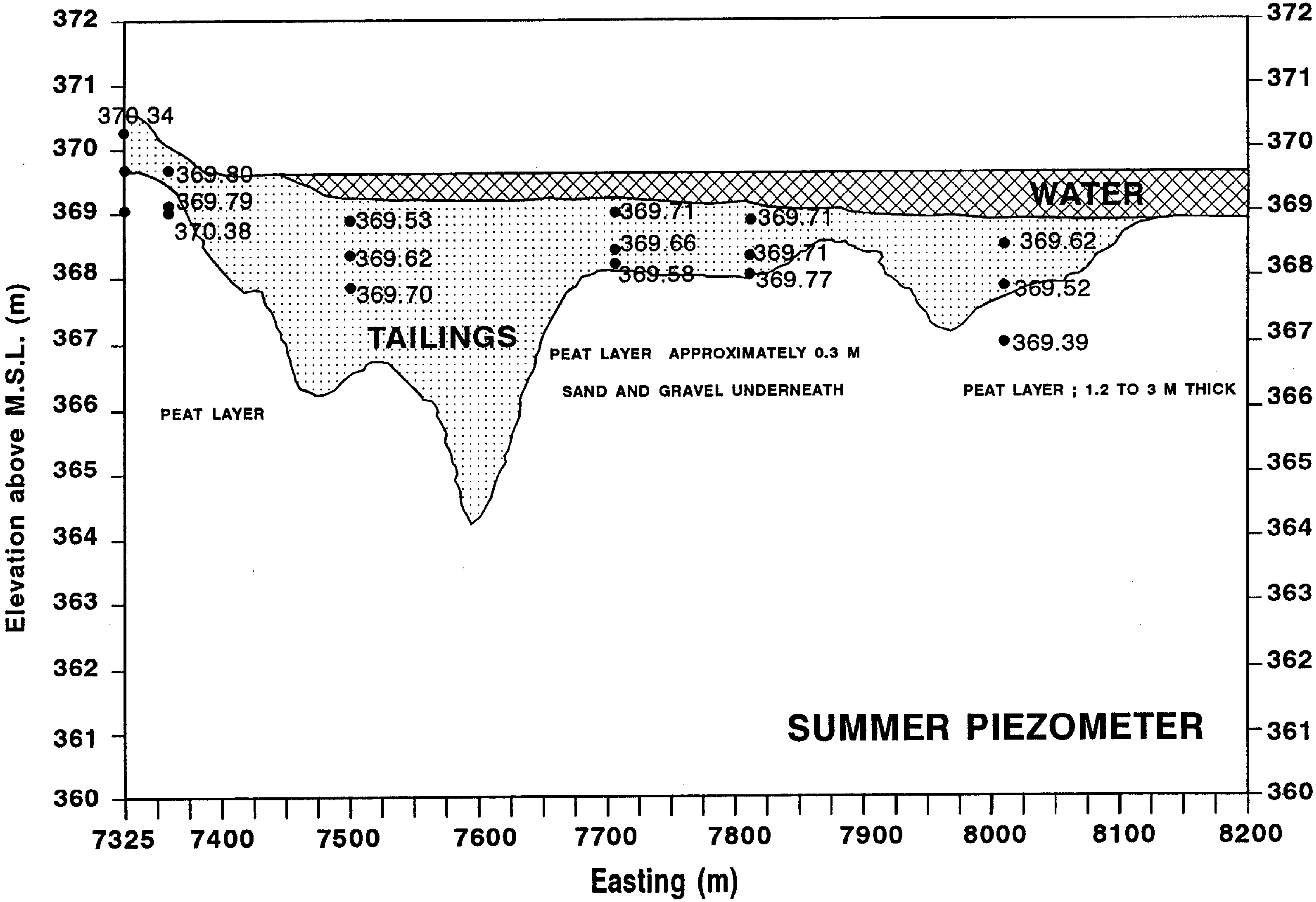


Fig. 38 a) - Piezometric tip and pressure elevations, summer 1991.

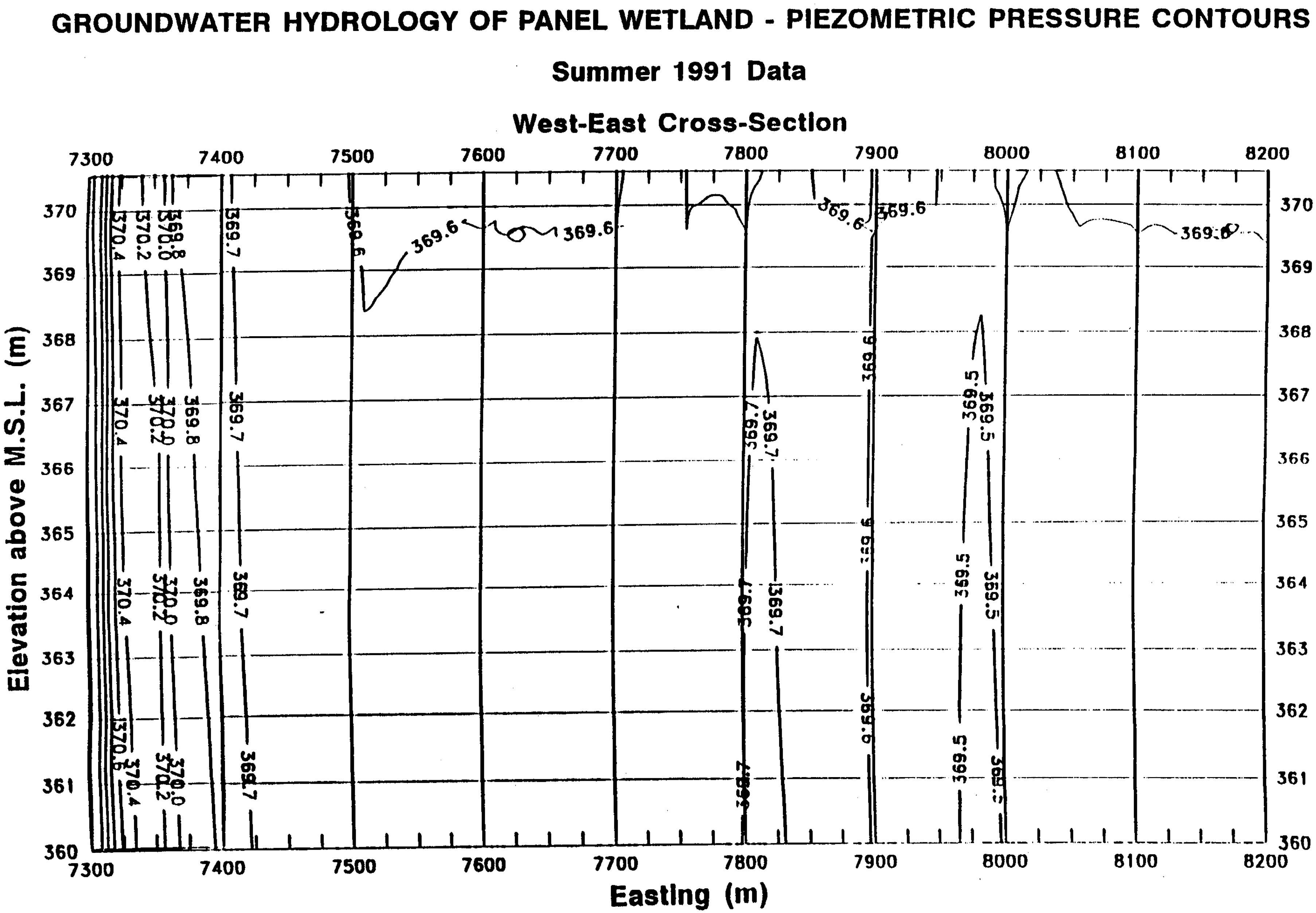


Fig. 38 b) Piezometric pressure contours, summer 1991.

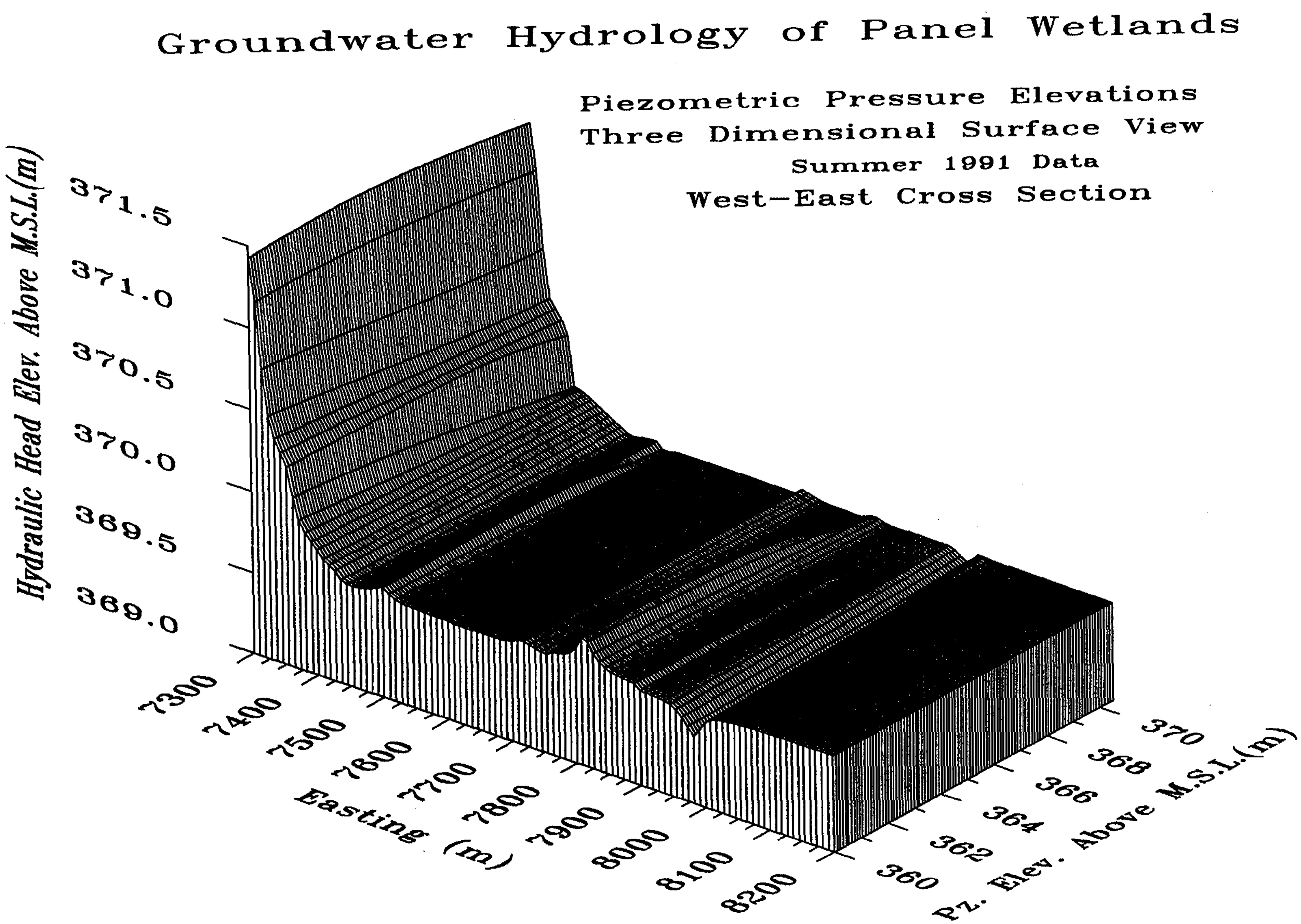


Fig. 38 c) - Piezometric pressure elevations, three dimensional view, summer 1991.

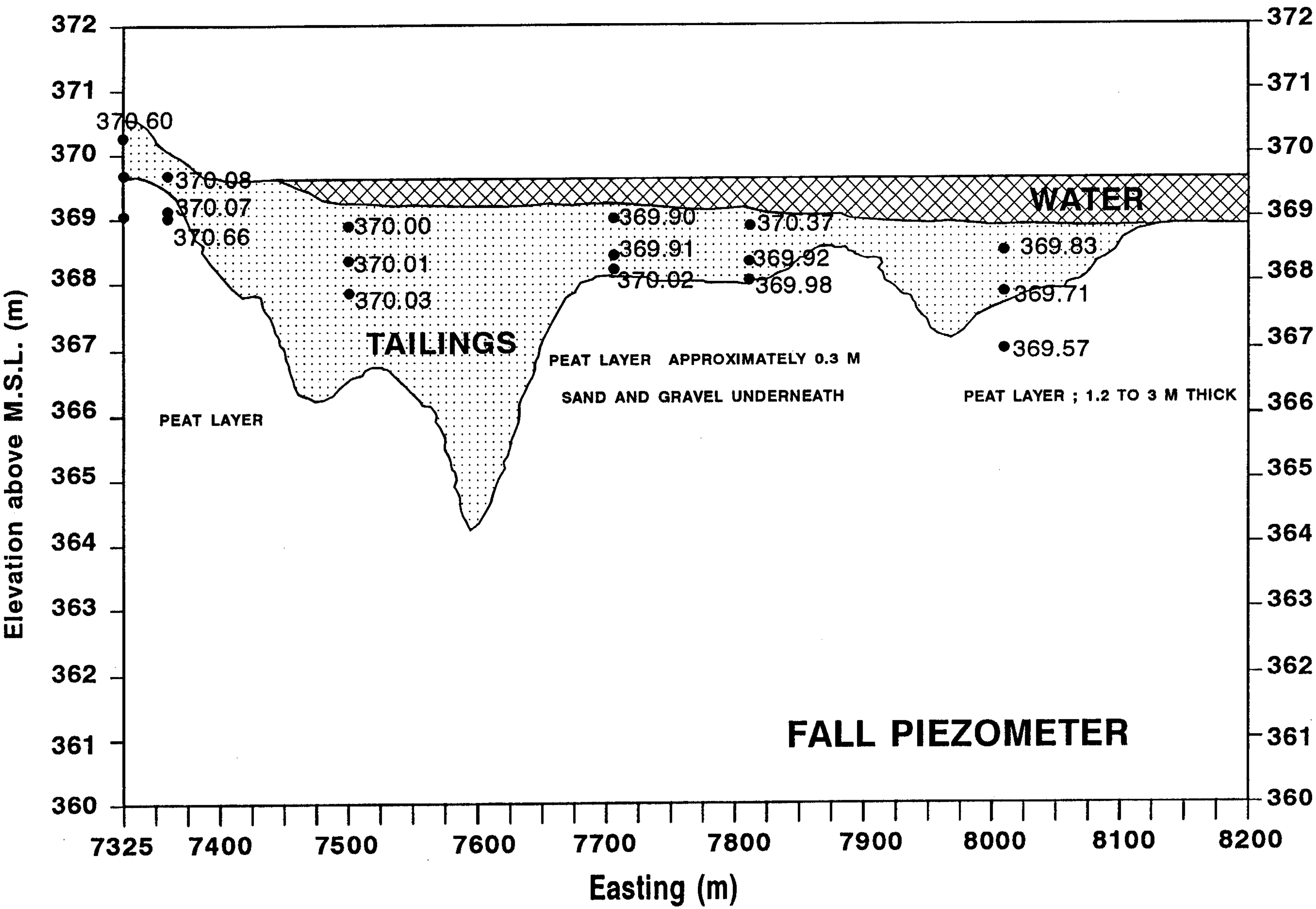


Fig. 39 a) - Piezometric tip and pressure elevations, fall 1991.

Welcome Screen | Search | Report List

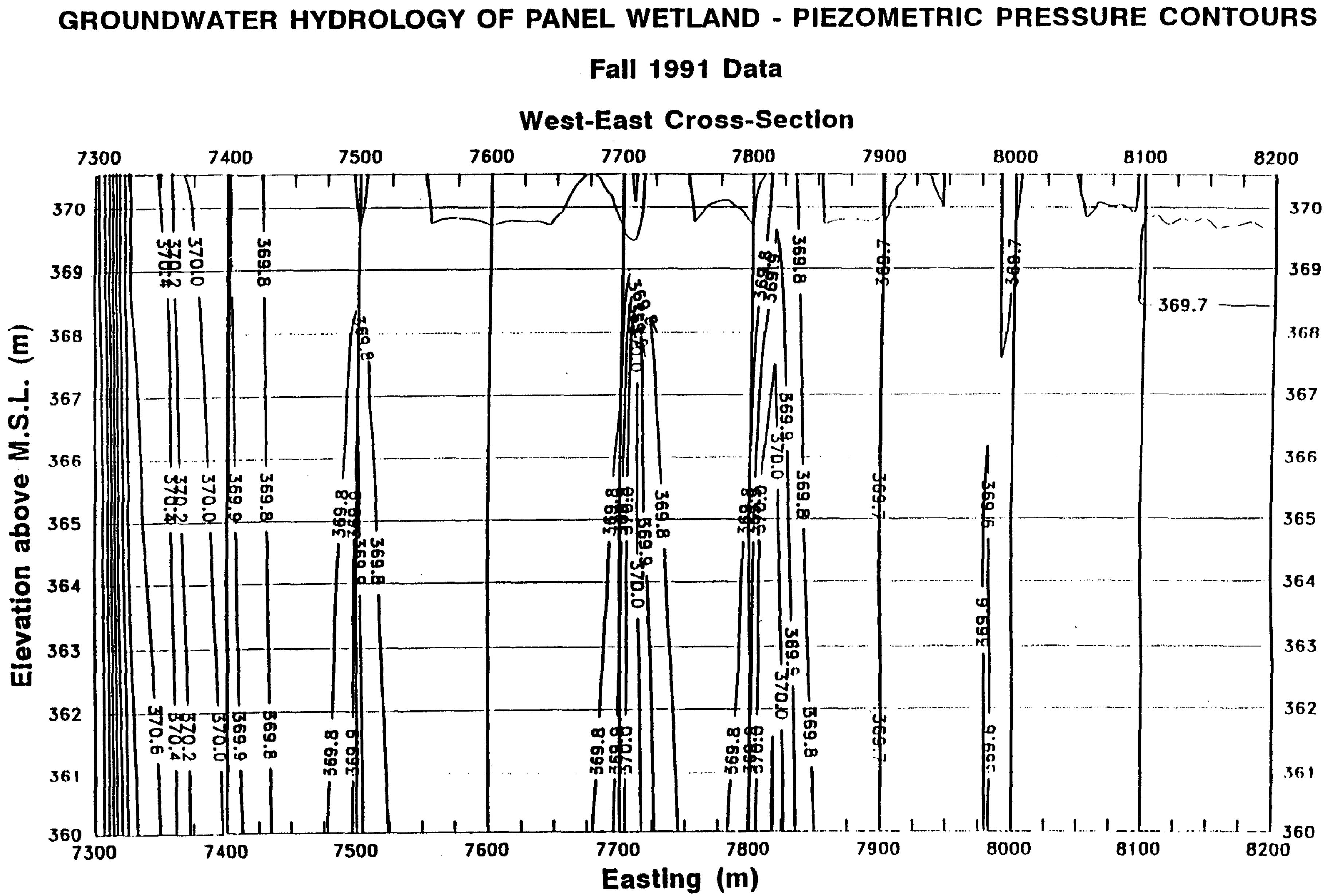


Fig. 39 b) - Piezometric pressure contours, fall 1991.

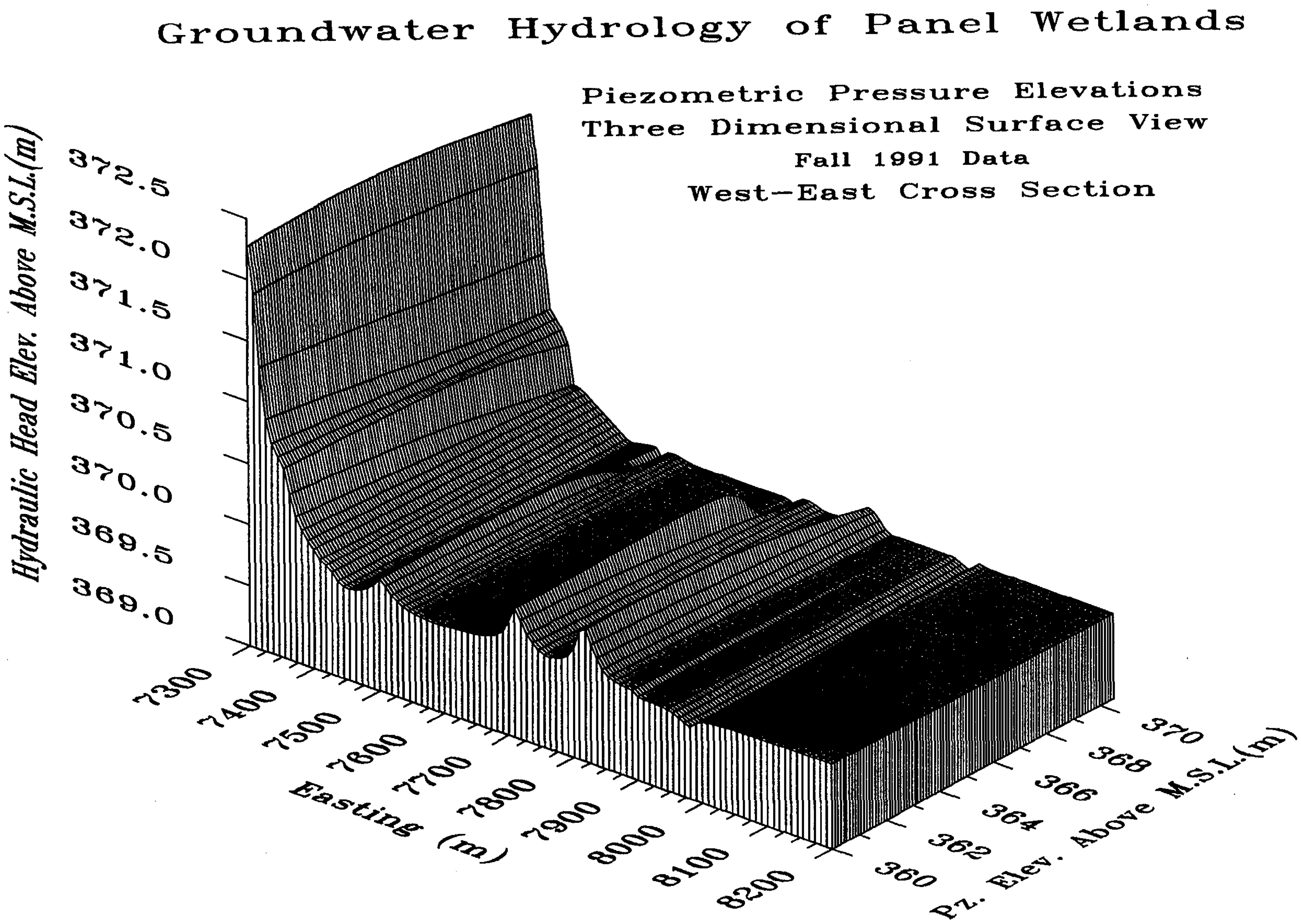


Fig. 39 c) - Piezometric pressure elevations, three-dimensional view, fall 1991.

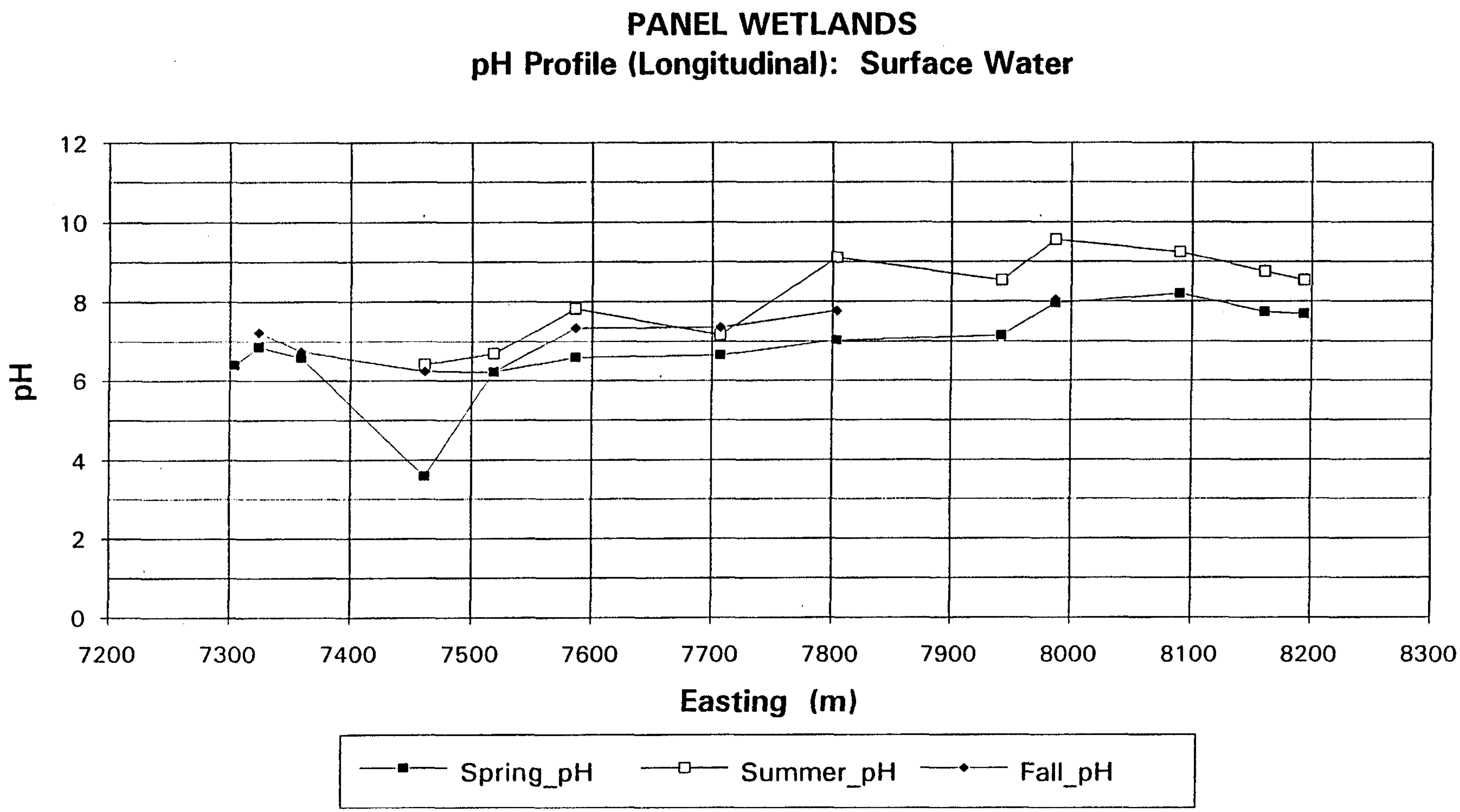


Fig. 40 - Surface water pH profiles (longitudinal).

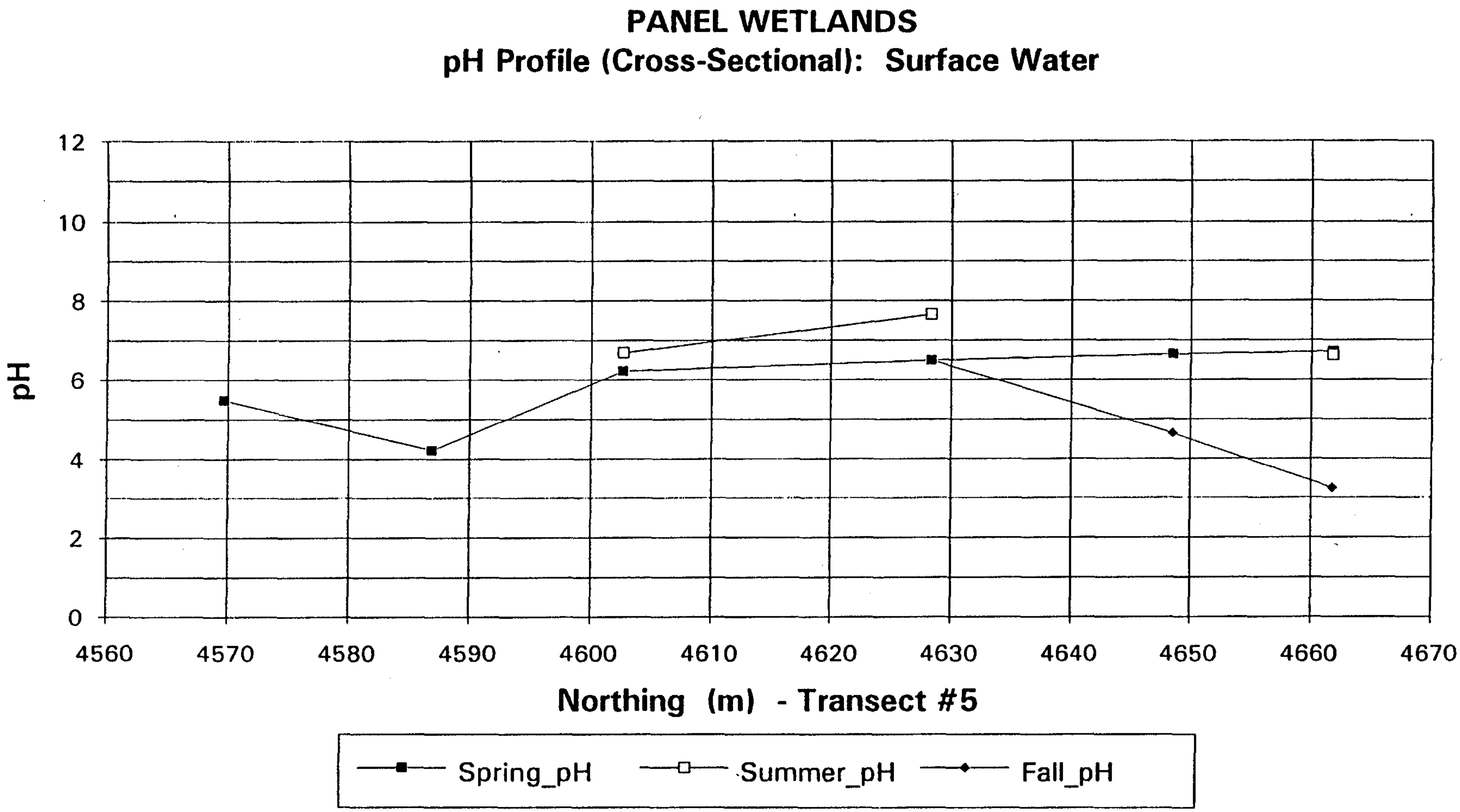


Fig. 40 a) - Surface water pH profiles (cross-sectional transect #5).

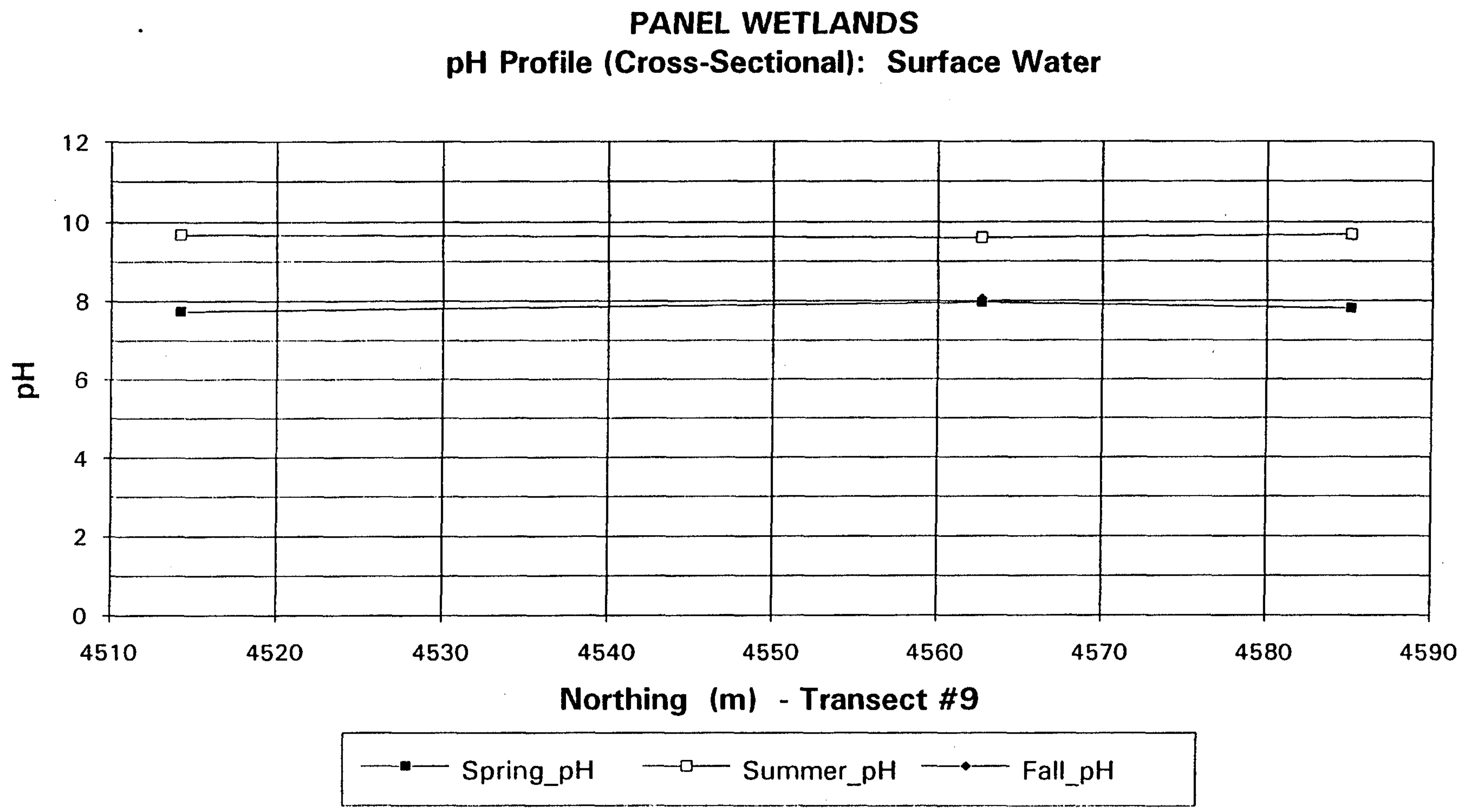


Fig. 40 b) - Surface water pH profiles (cross-sectional transect #9).

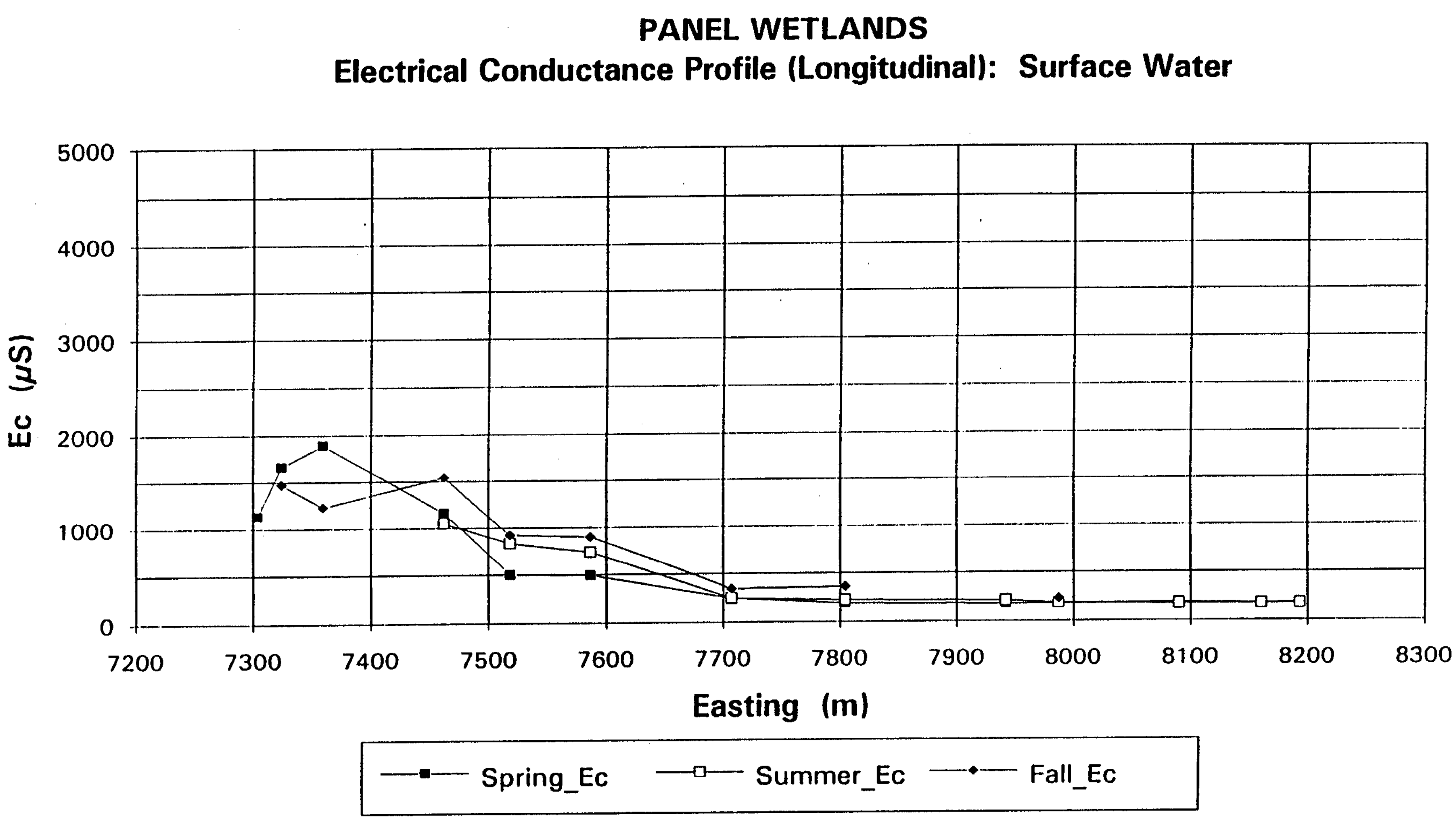


Fig. 41 - Surface water Ec profiles (longitudinal).

146

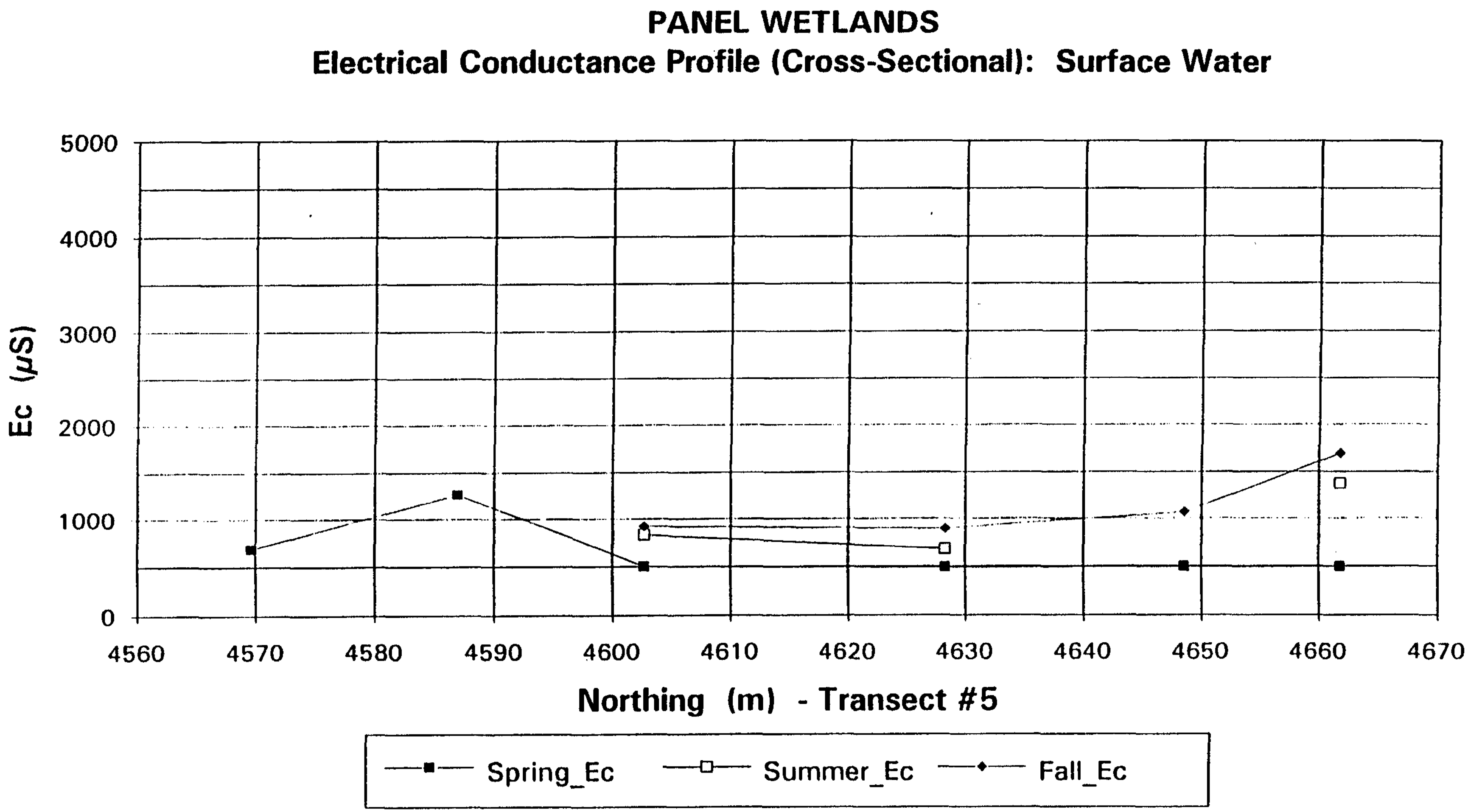


Fig. 41 a) - Surface water Ec profiles (cross-sectional transect #5).

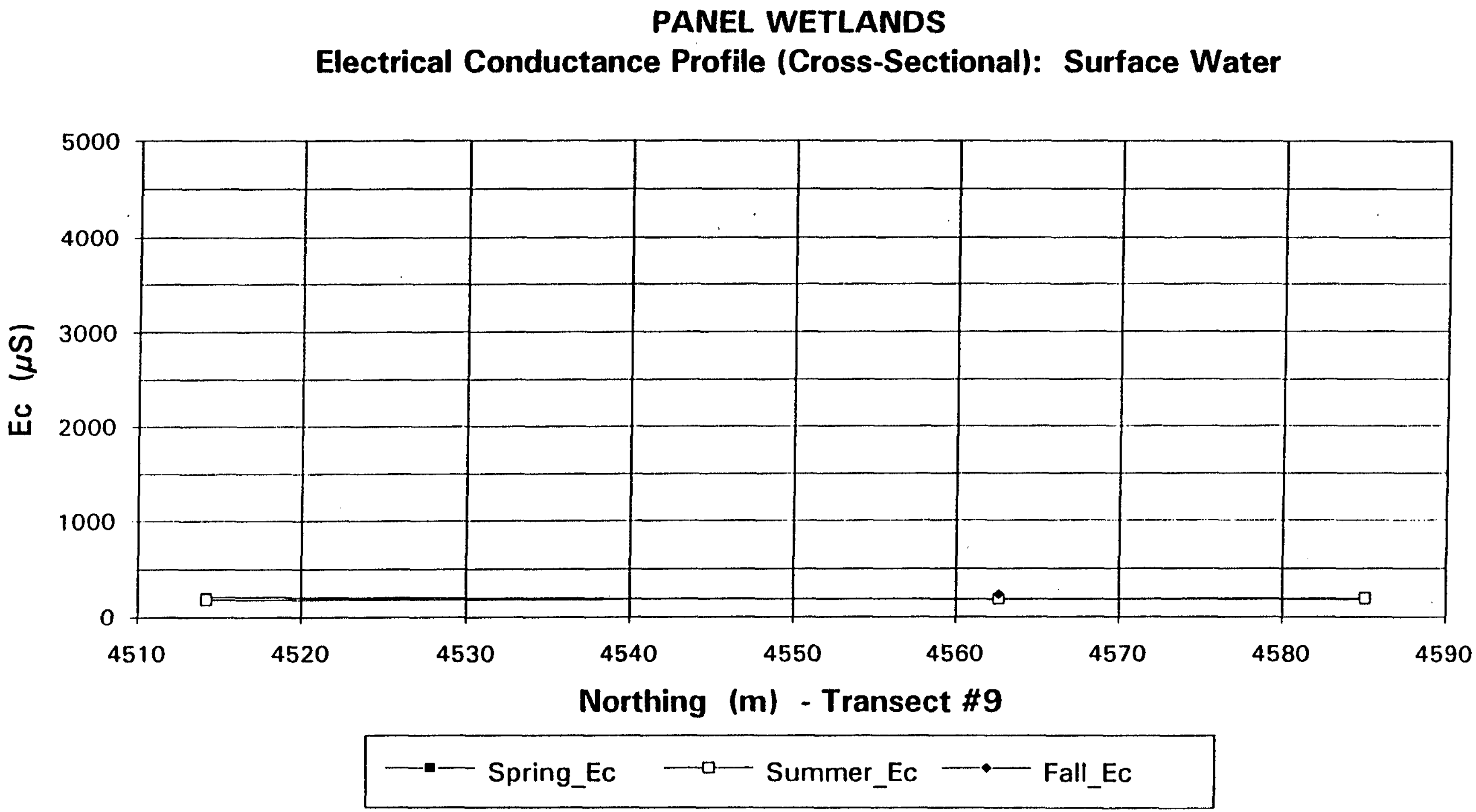


Fig. 41 b) - Surface water Ec profiles (cross-sectional transect #9).

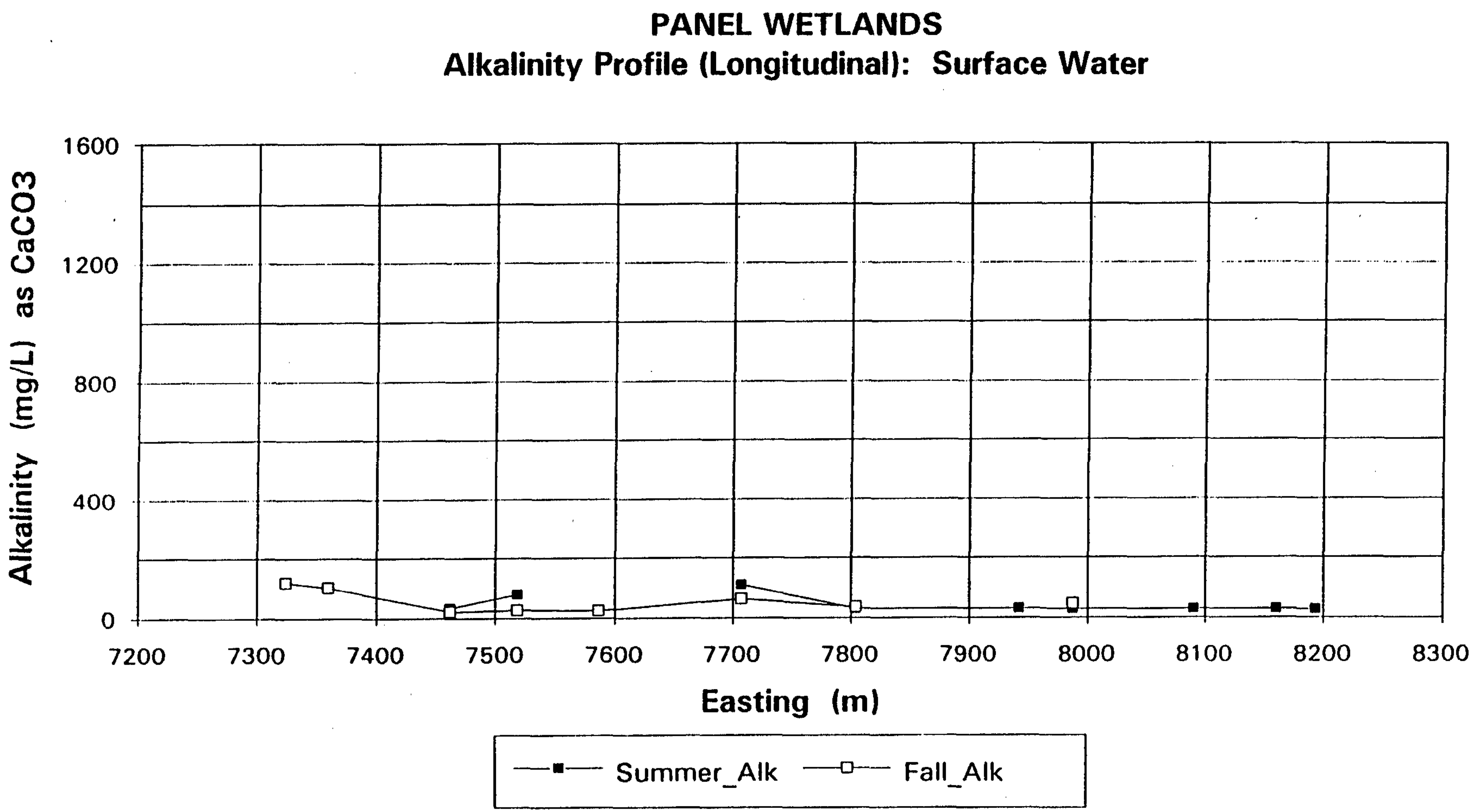


Fig. 42 - Surface water alkalinity profiles (longitudinal).

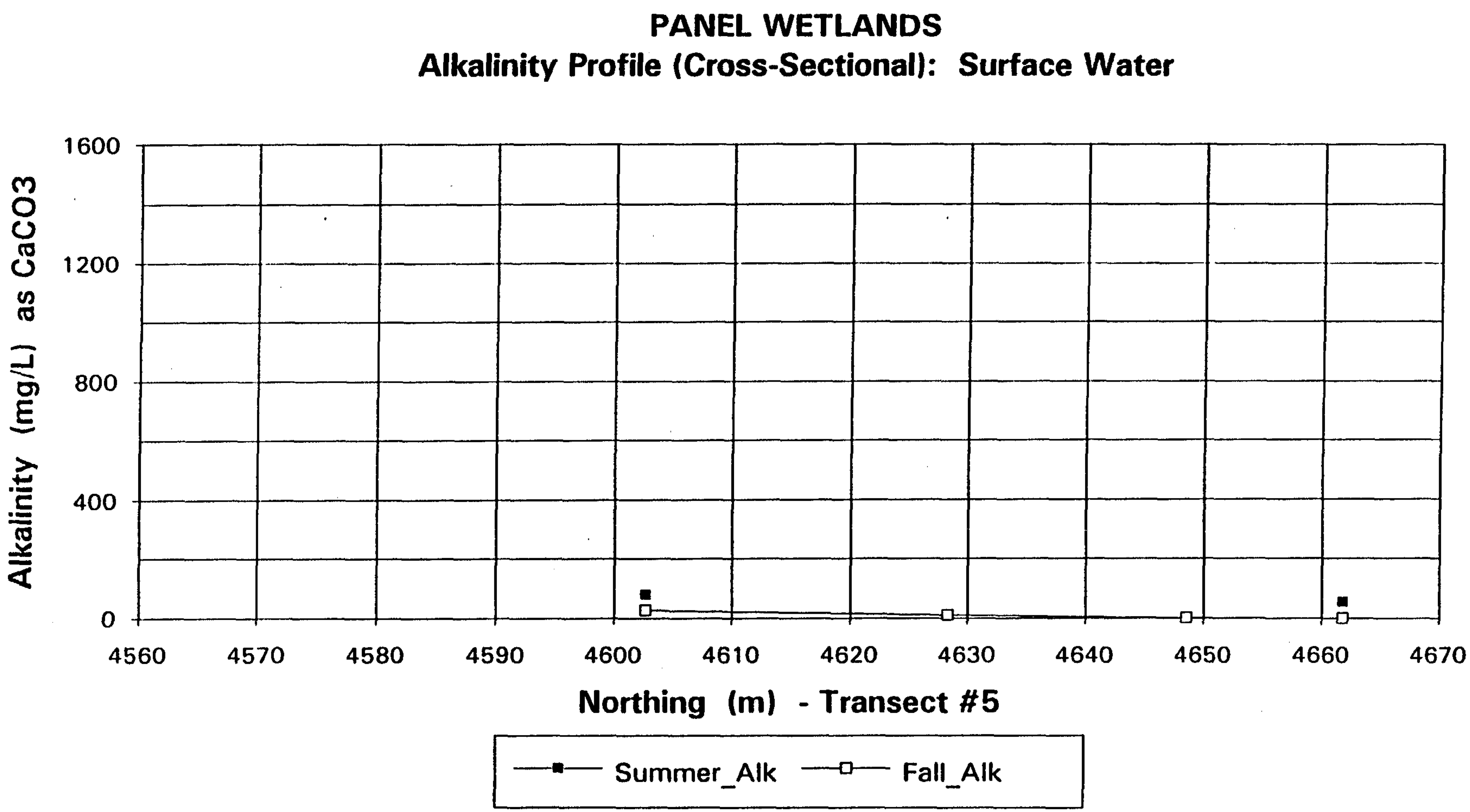


Fig. 42 a) - Surface water alkalinity profile (cross-sectional transect #5).

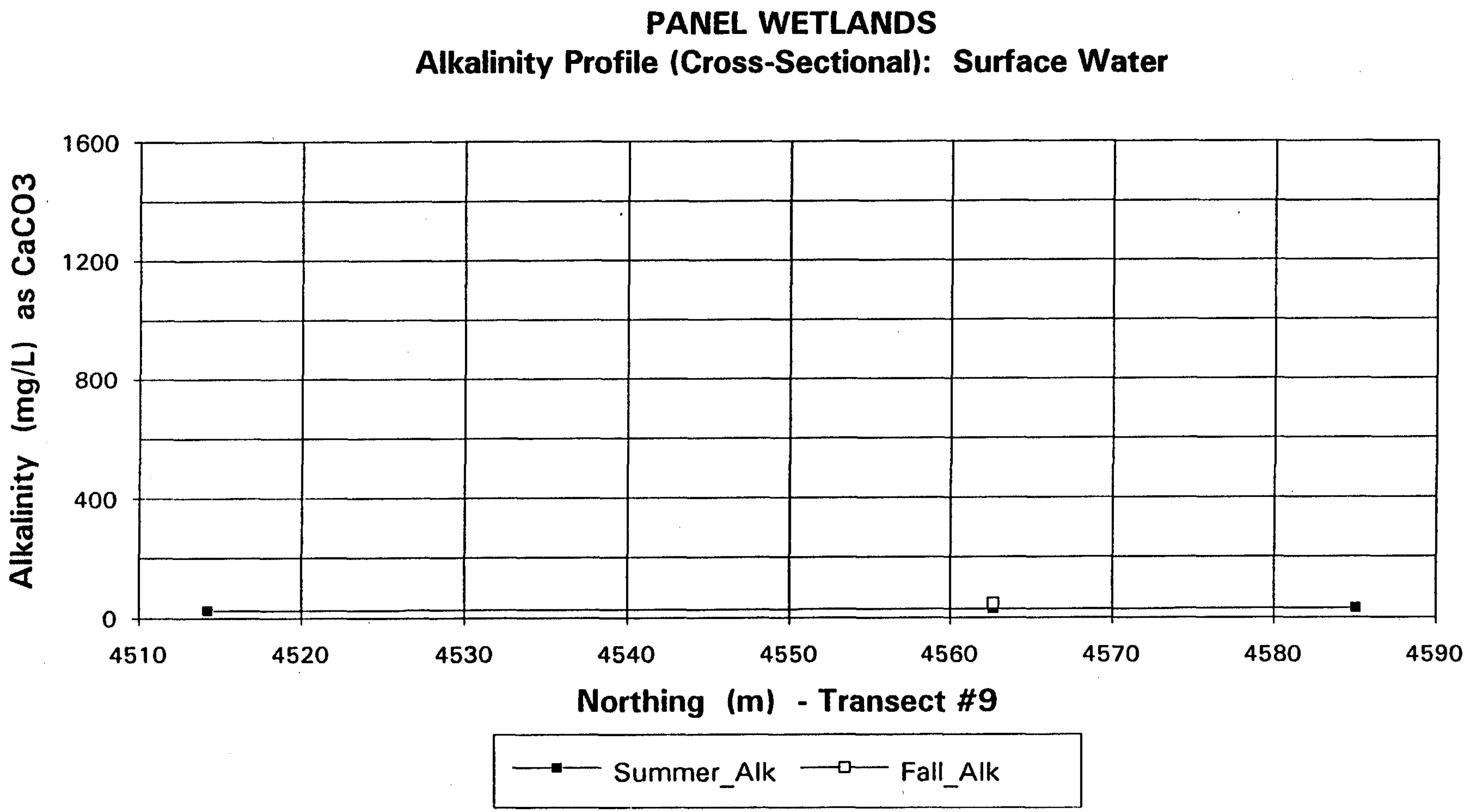


Fig. 42 b) - Surface water alkalinity profile (cross-sectional transect #9).

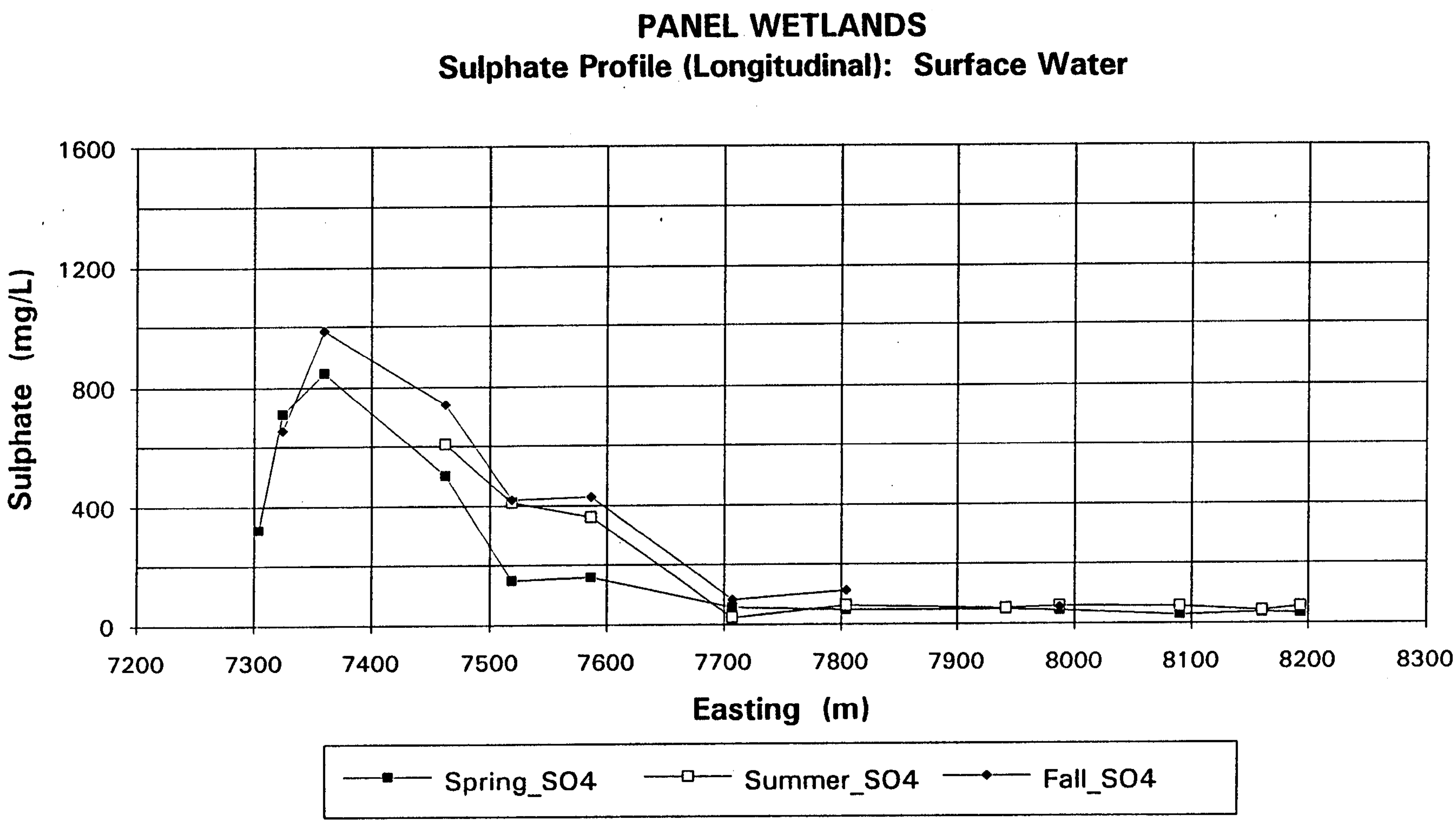


Fig. 43 - Surface water sulphate profile (longitudinal).

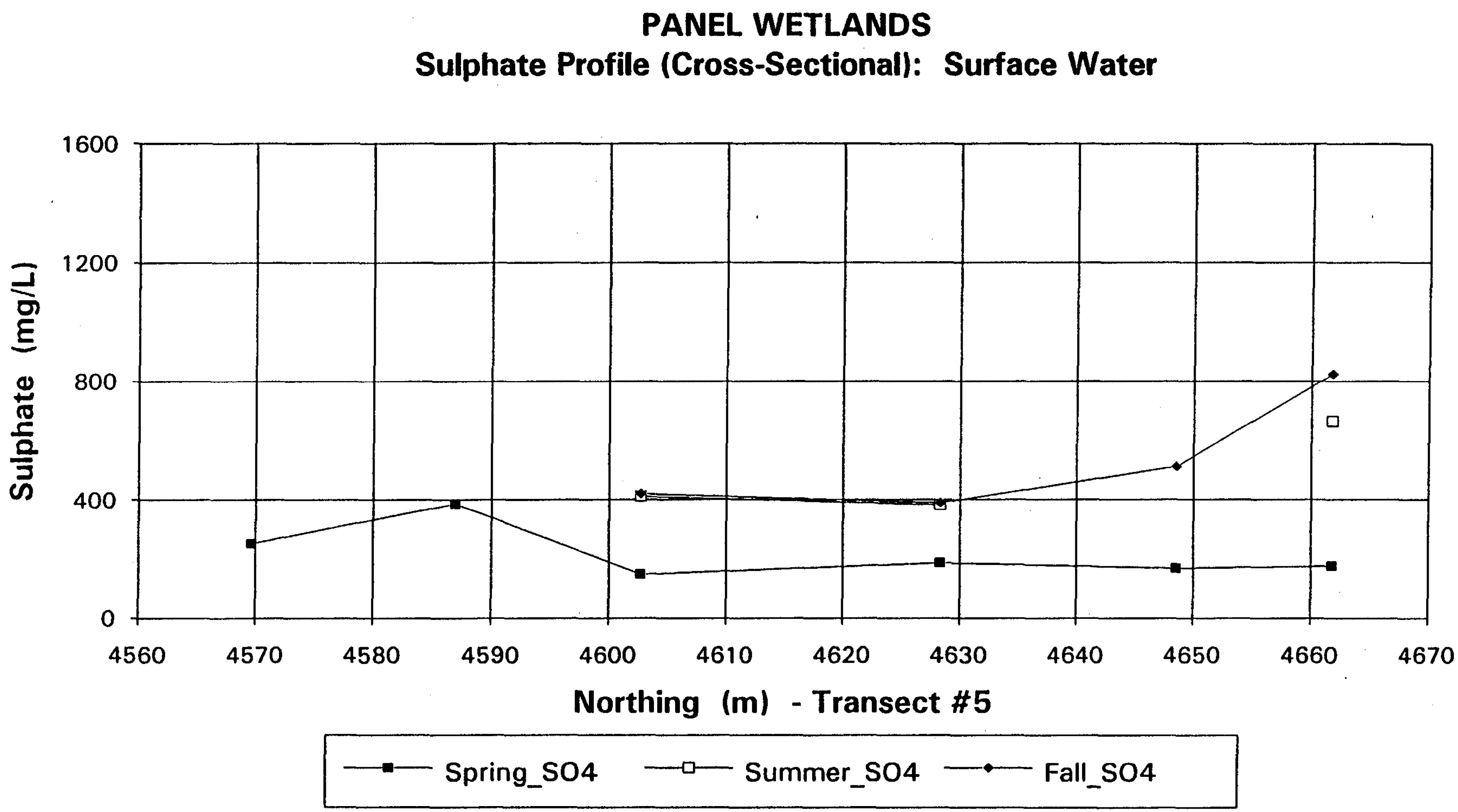


Fig. 43 a) - Surface water sulphate profile (cross-sectional transect #5).

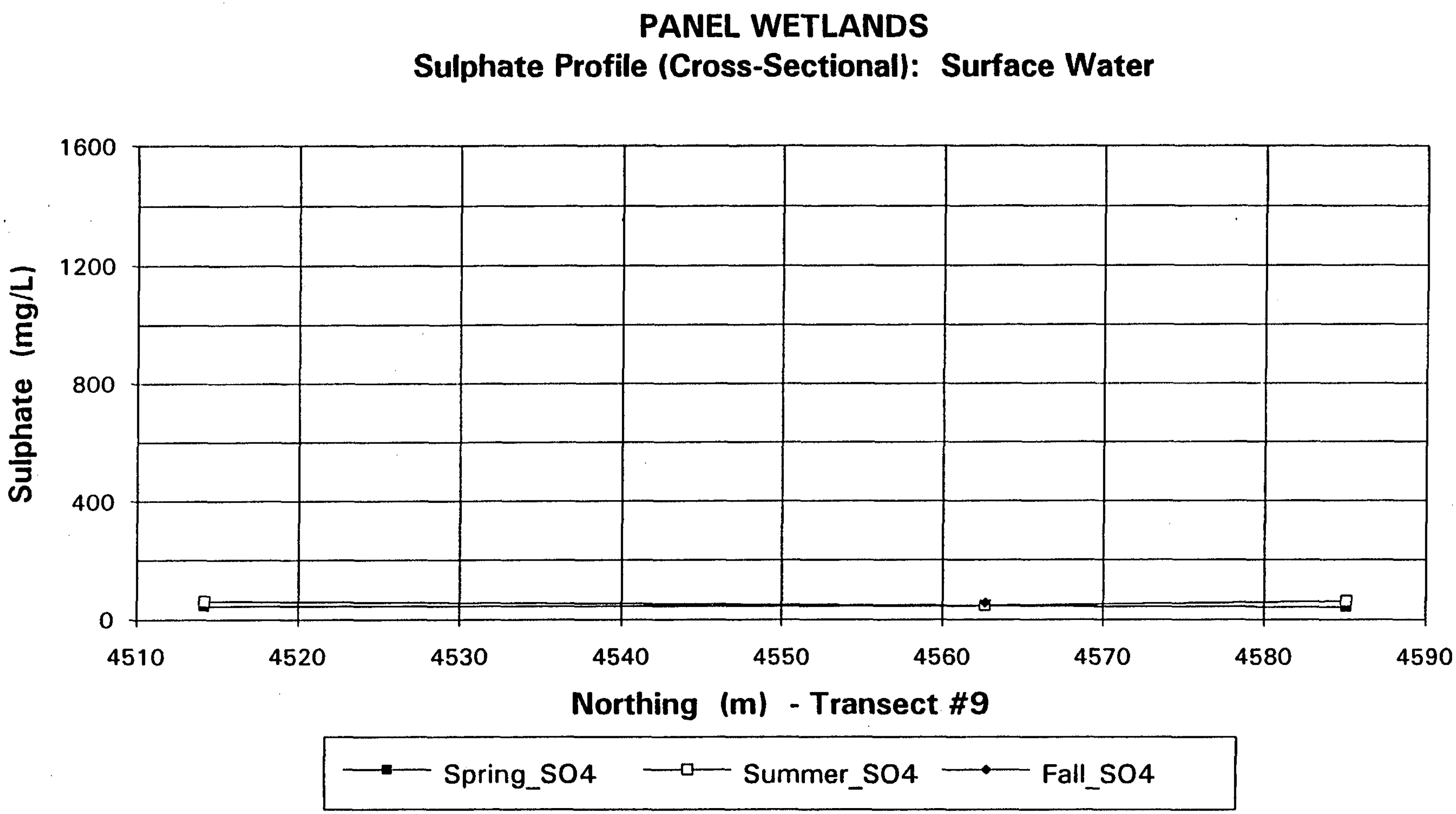


Fig. 43 b) - Surface water sulphate profile (cross-sectional transect #9)

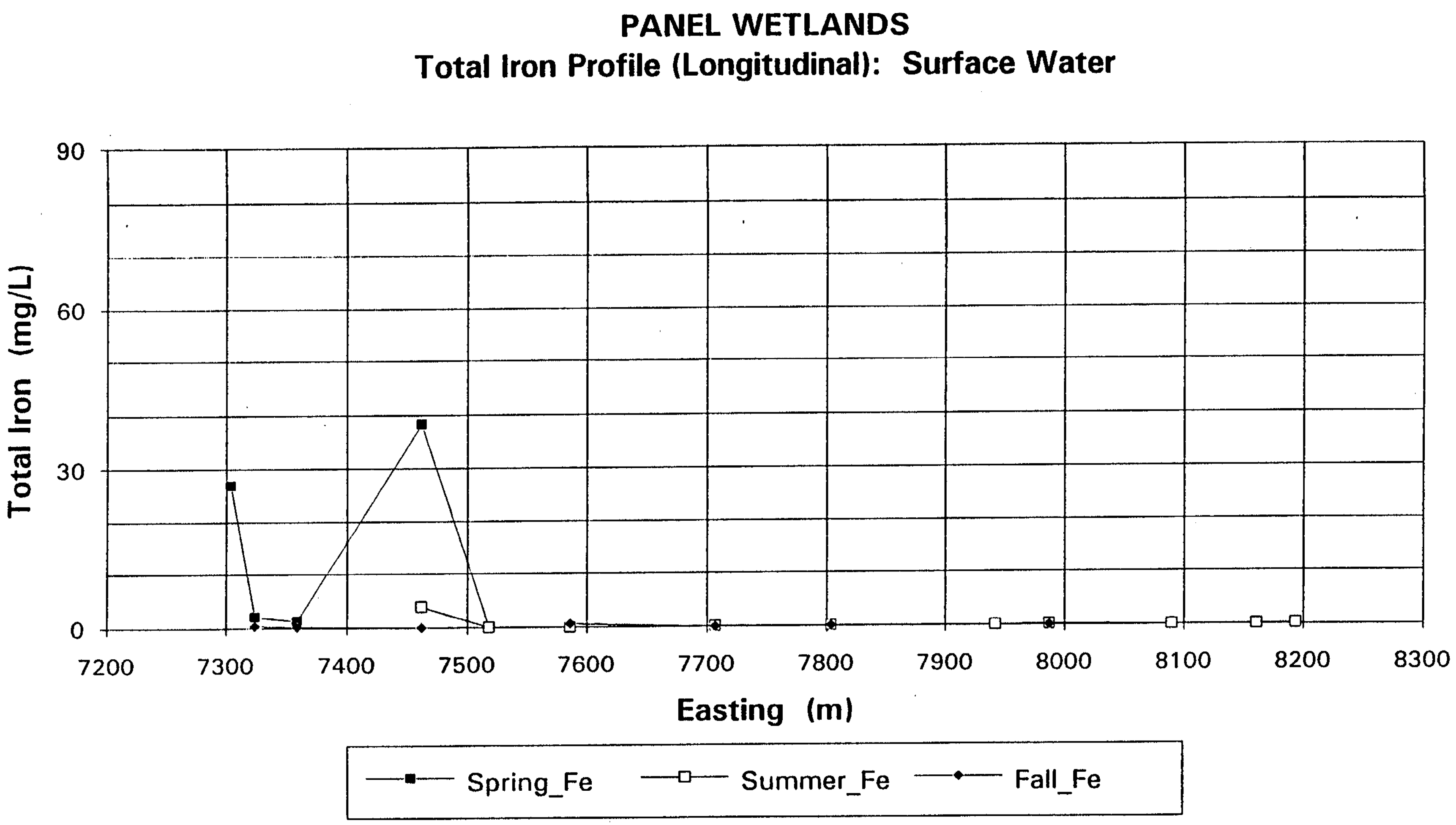


Fig. 44 - Surface water total iron profile (longitudinal).

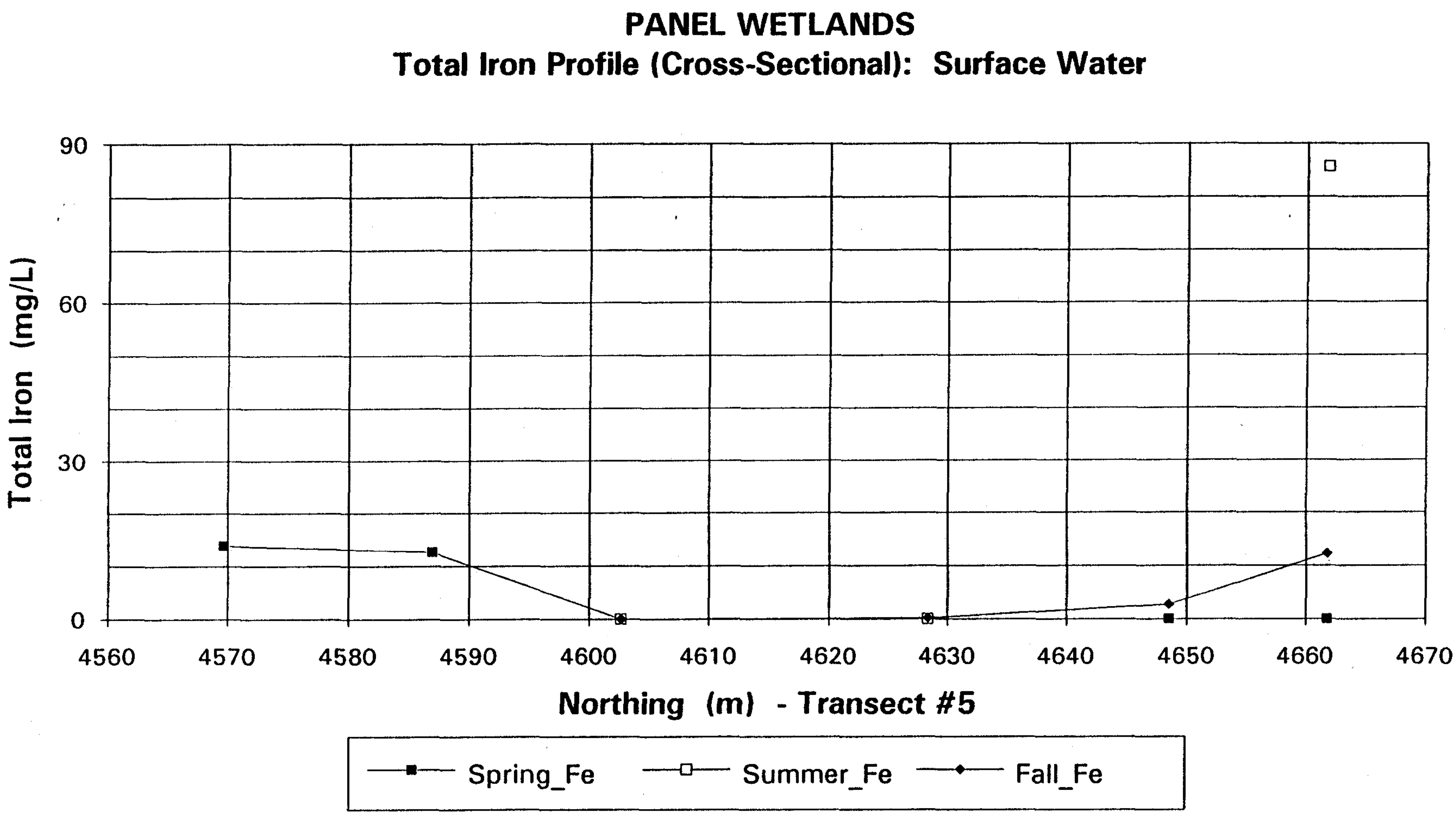


Fig. 44 a) - Surface water total iron profile (cross-sectional transect #5).

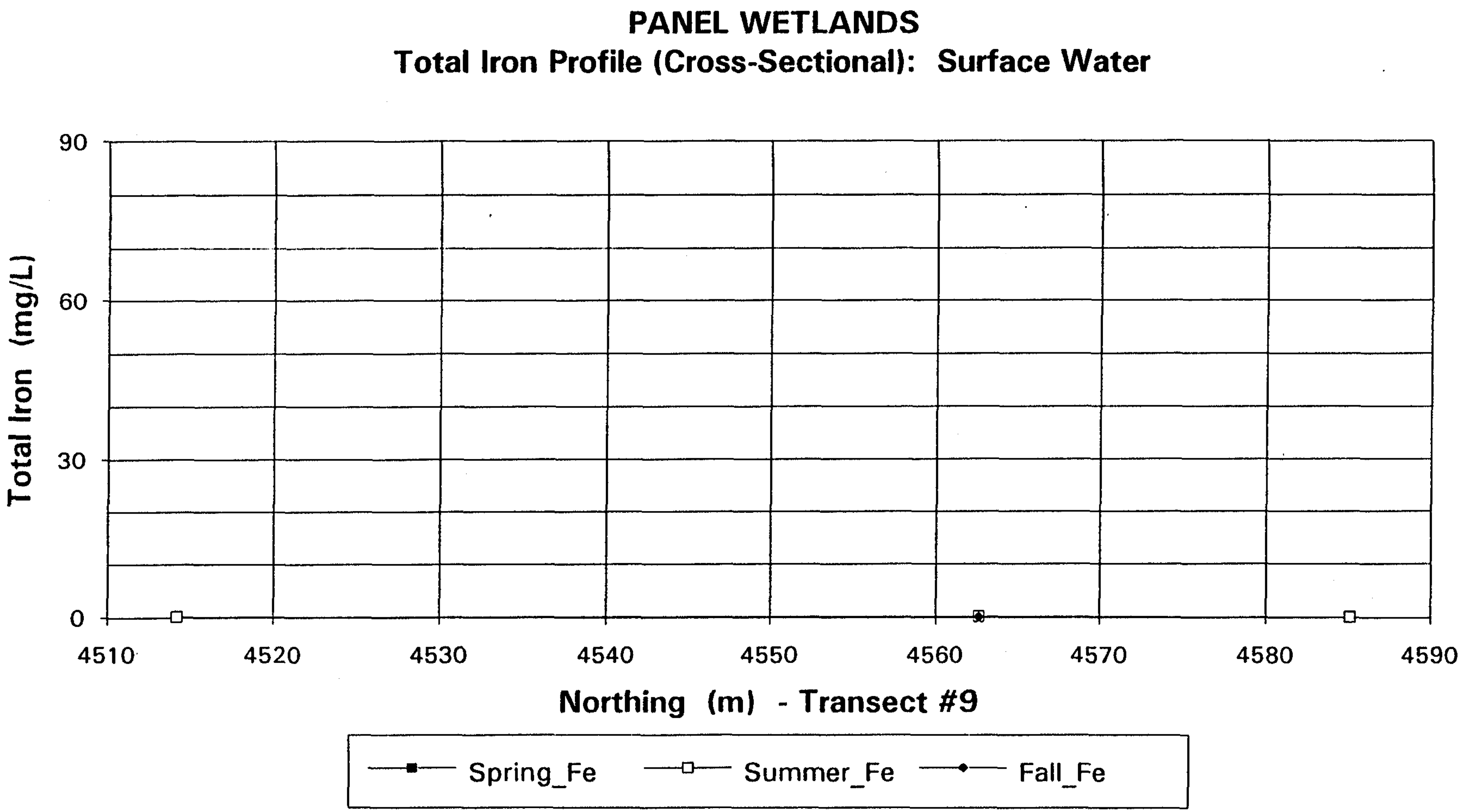


Fig. 44 b) - Surface water total iron profile (cross-sectional transect #9).

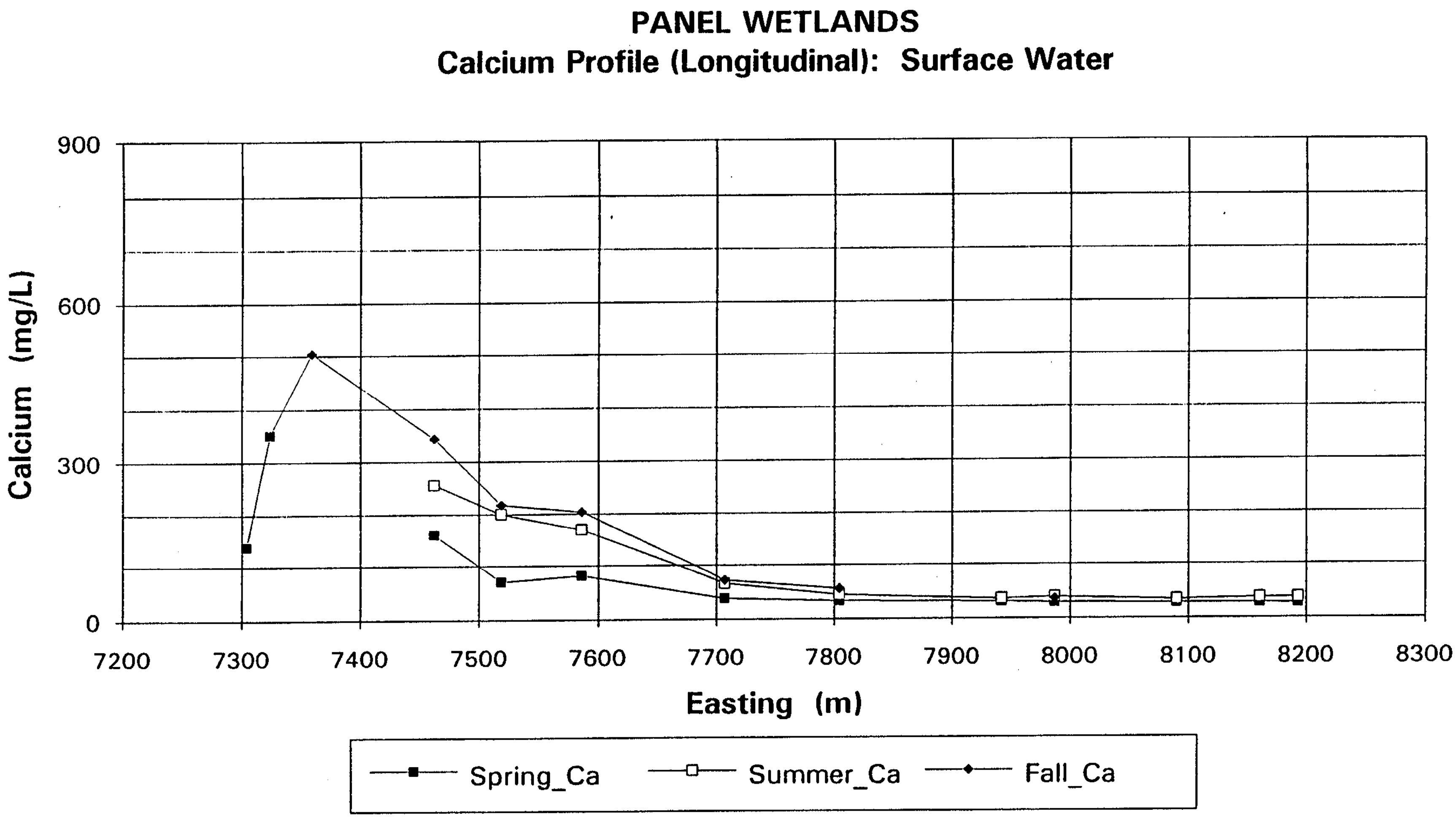


Fig. 45 - Surface water calcium profile (longitudinal).

158

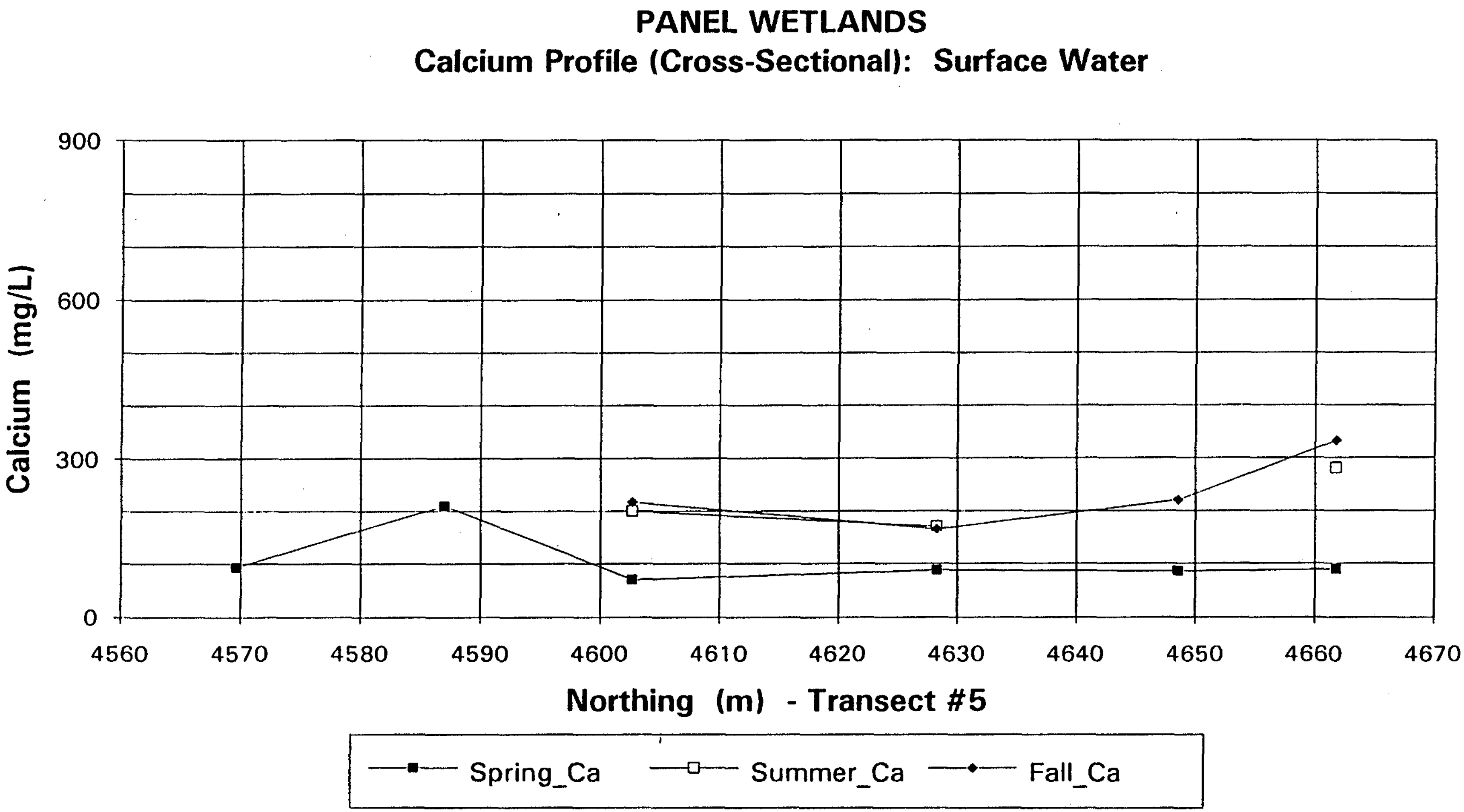


Fig. 45 a) - Surface water calcium profile (cross-sectional transect #5).

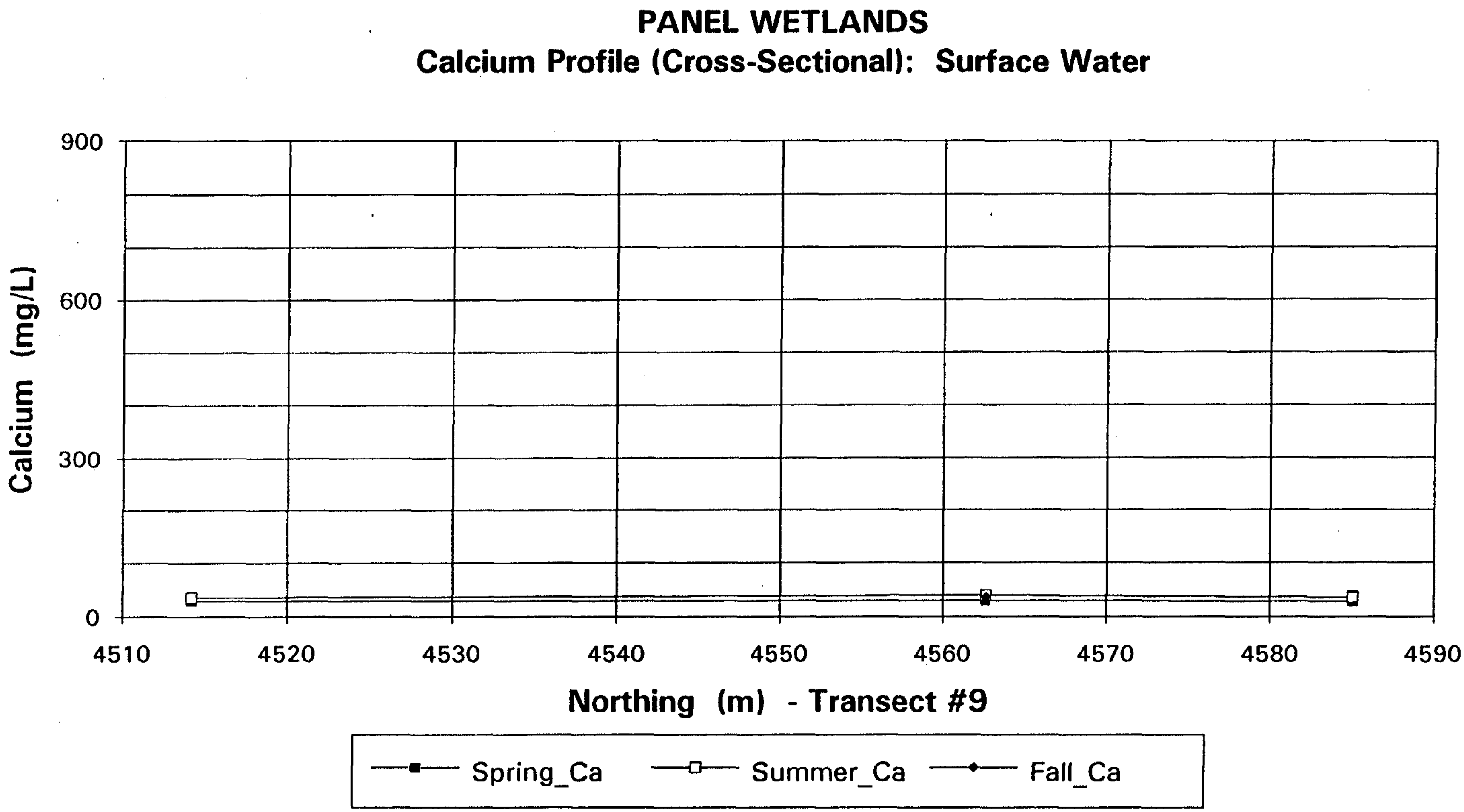


Fig. 45 b) - Surface water calcium profile (cross-sectional transect #9).

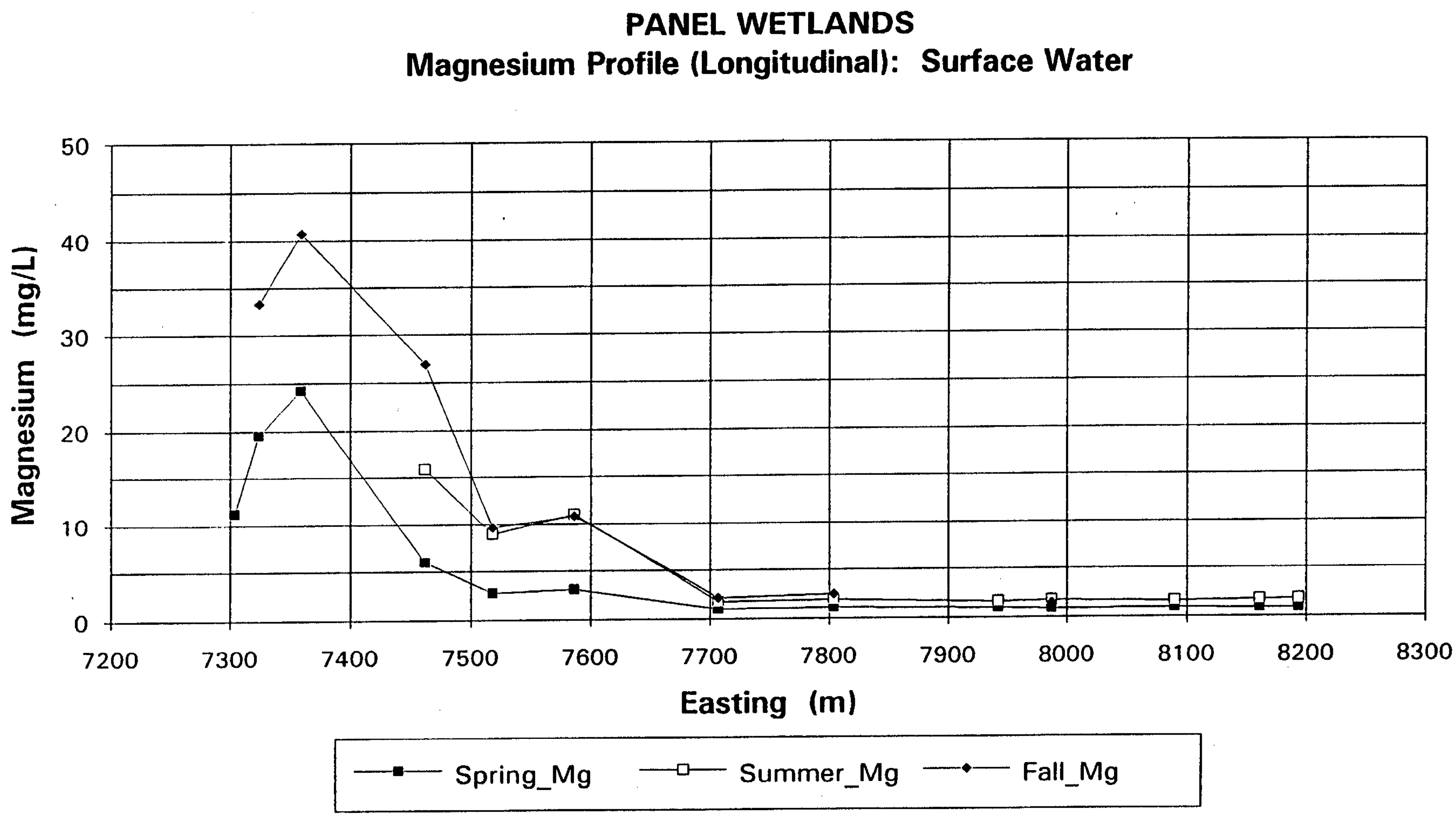


Fig. 46 - Surface water magnesium profile (longitudinal).

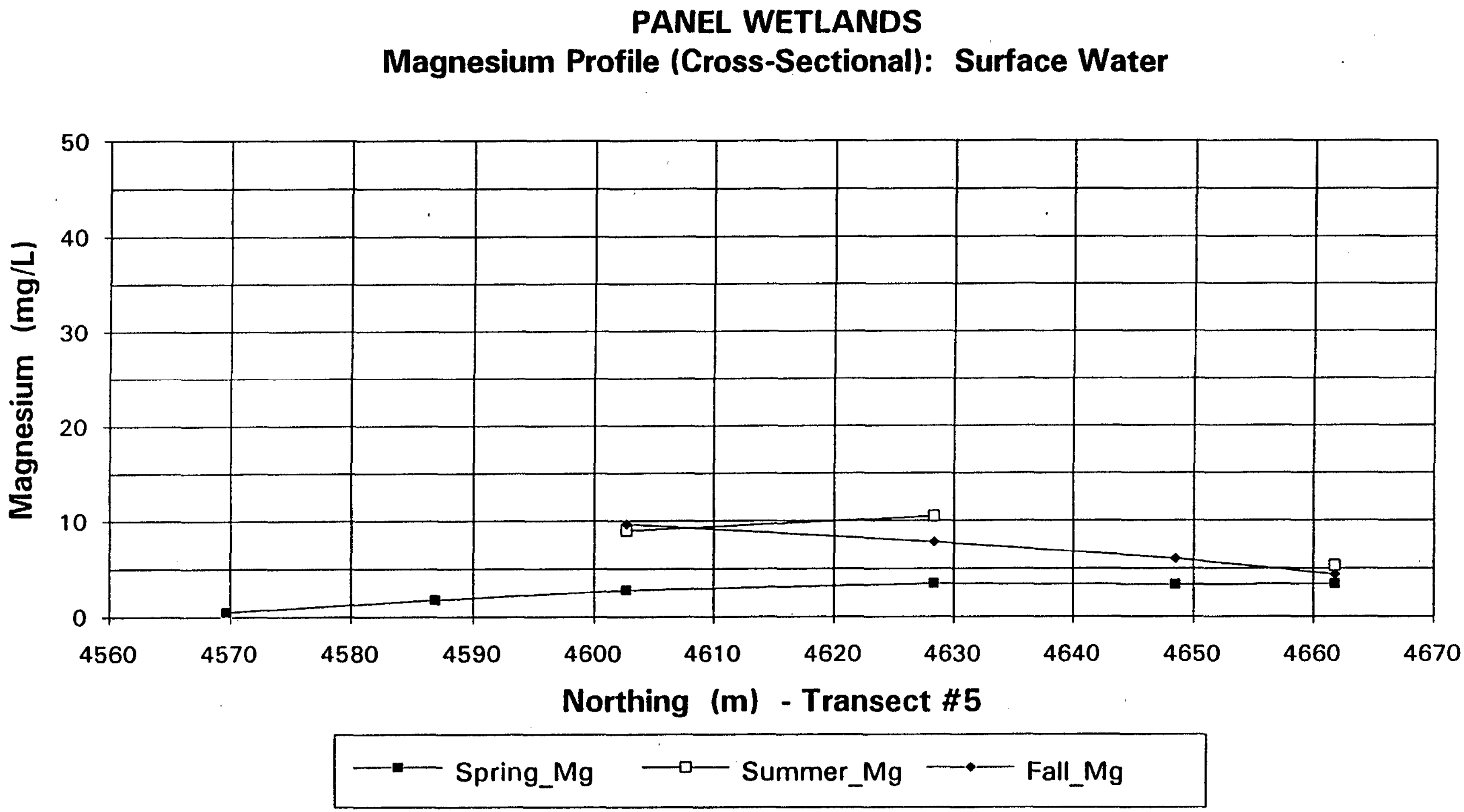


Fig. 46 a) - Surface water magnesium profile (cross-sectional transect #5).

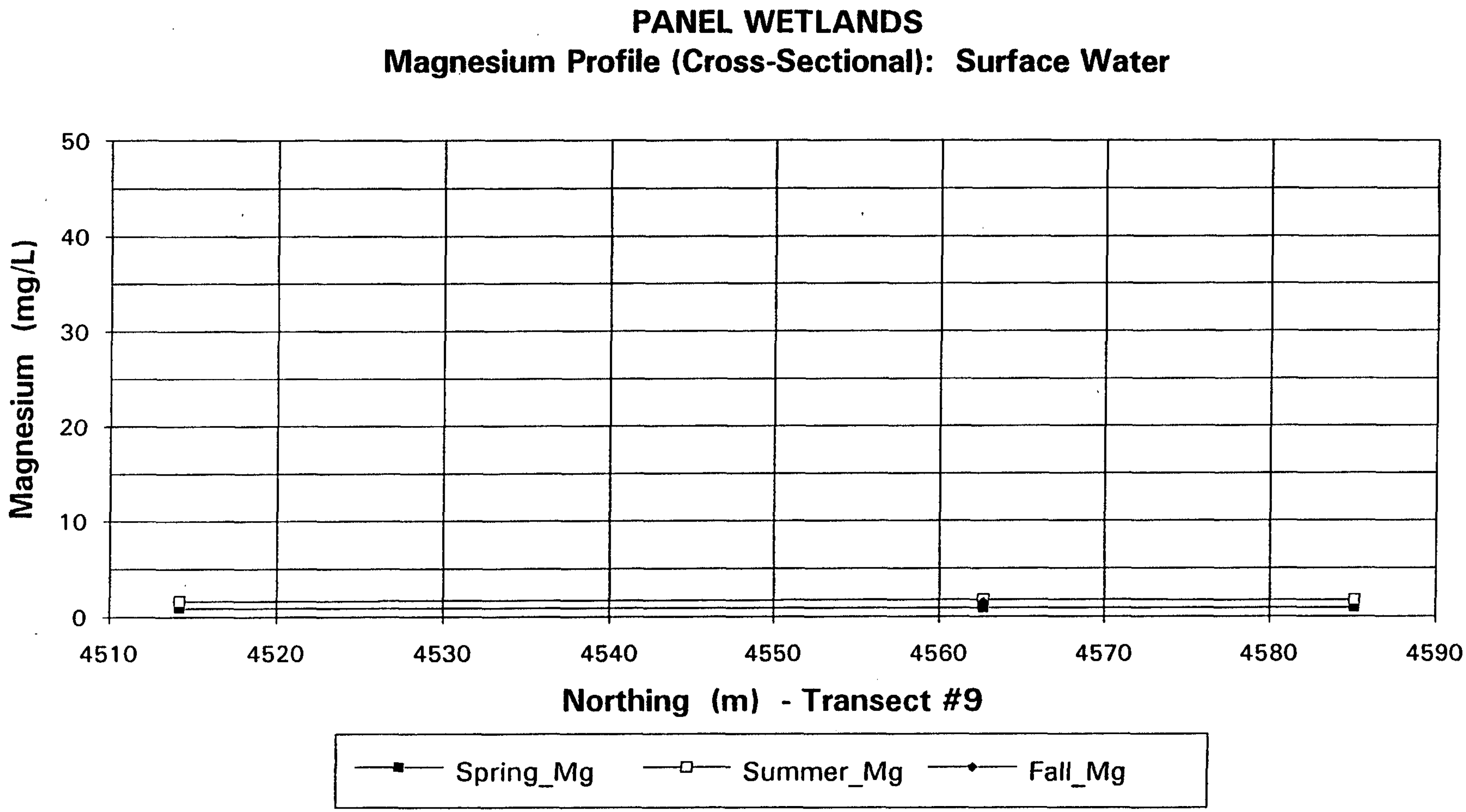


Fig. 46 b) - Surface water magnesium profile (cross-sectional transect #9).

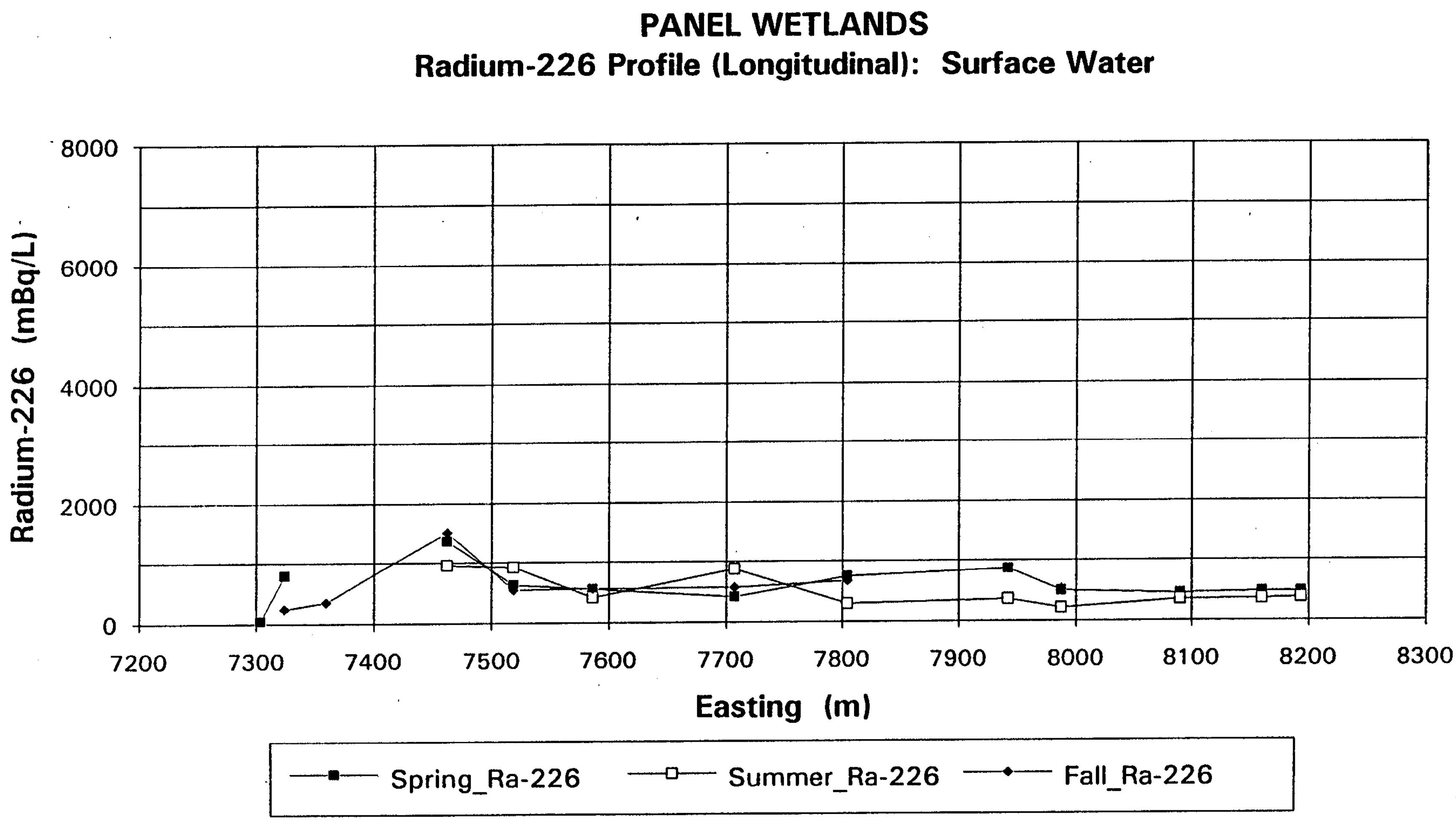


Fig. 47 - Surface water Ra-226 profile (longitudinal).

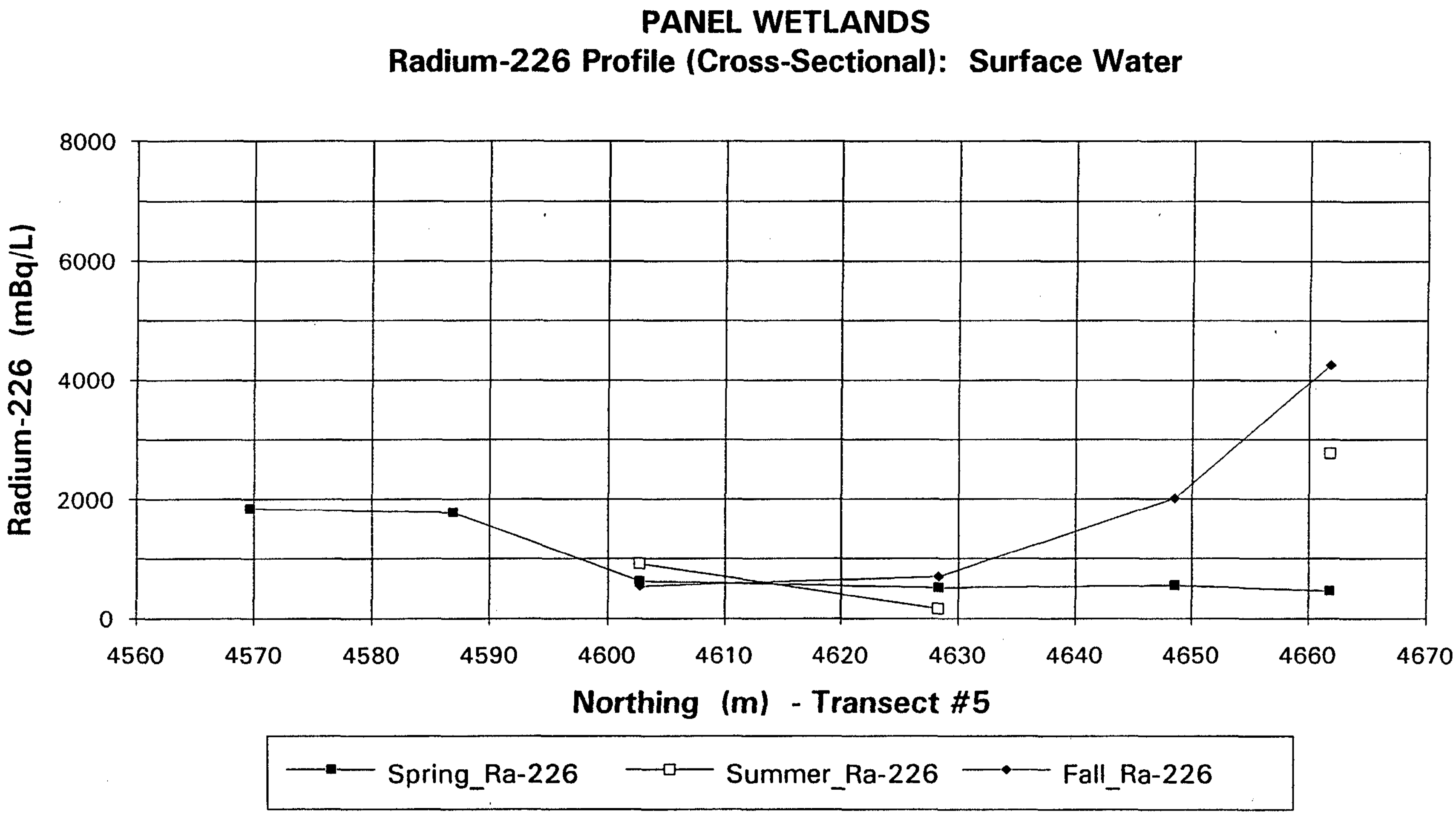


Fig. 47 a) - Surface water Ra-226 profile (cross-sectional transect #5).

165

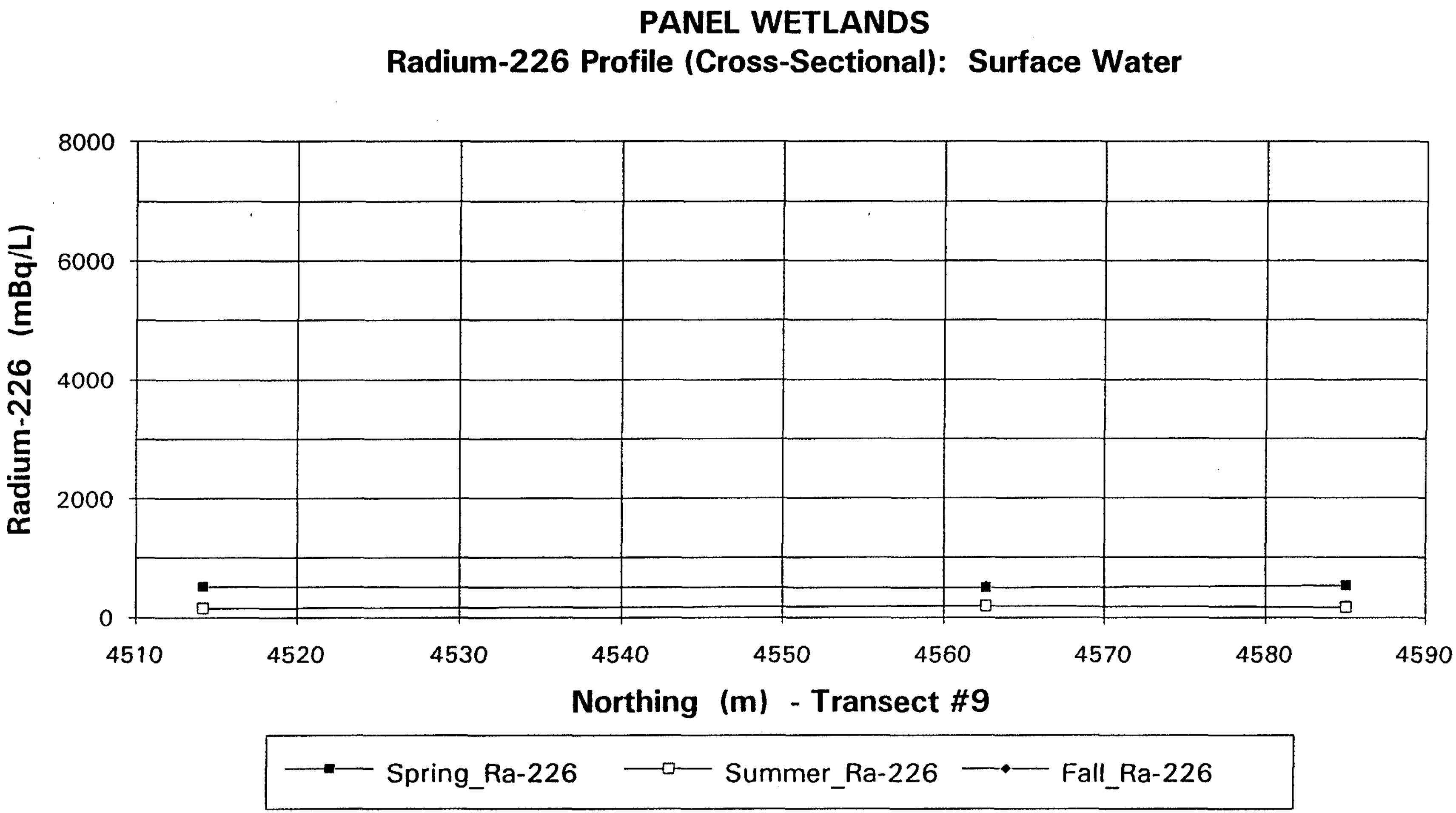


Fig. 47 b) - Surface water Ra-226 profile (cross-sectional transect #9).

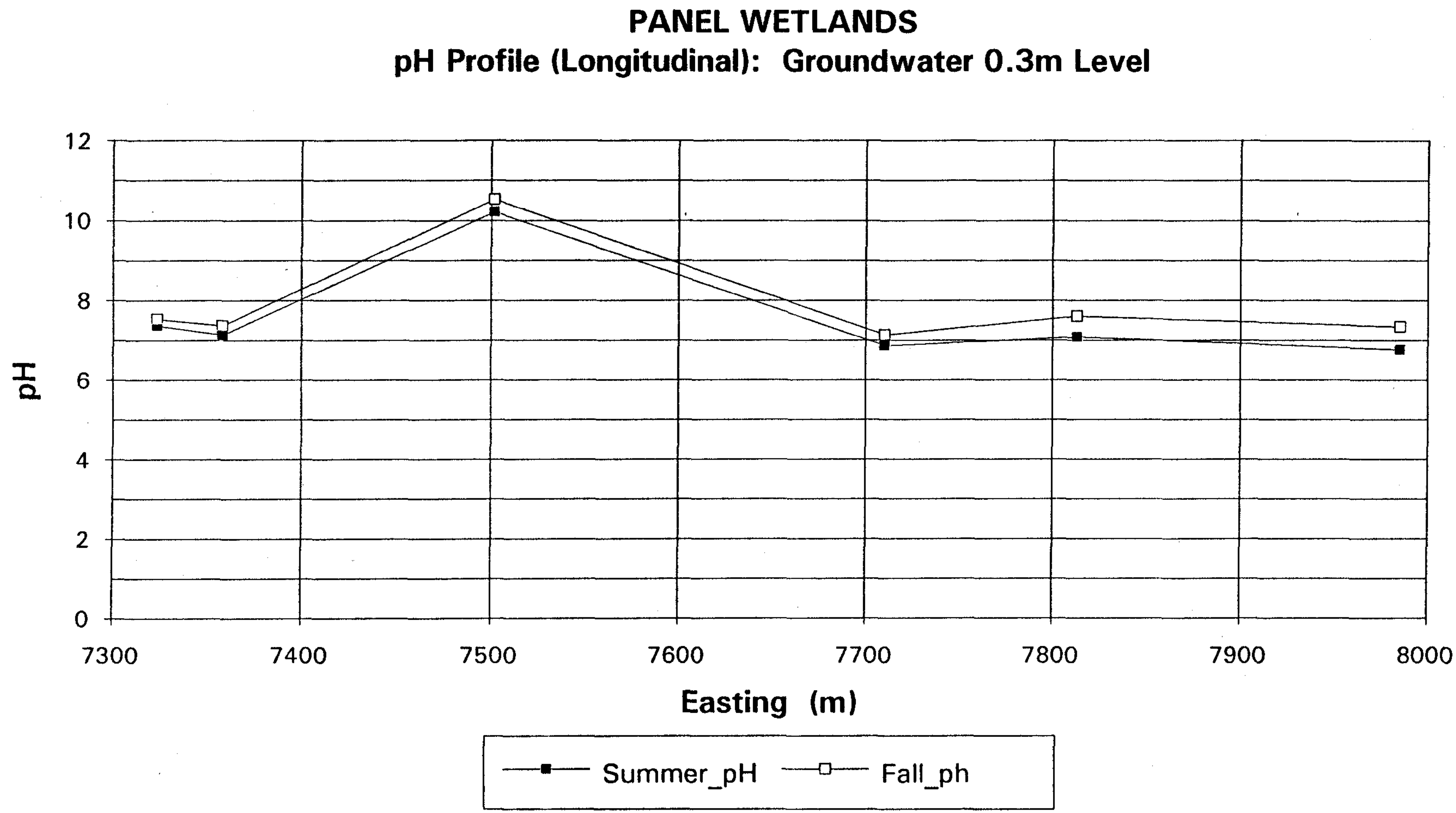


Fig. 48 - Panel wetlands: groundwater pH profiles at 0.3 m below surface.

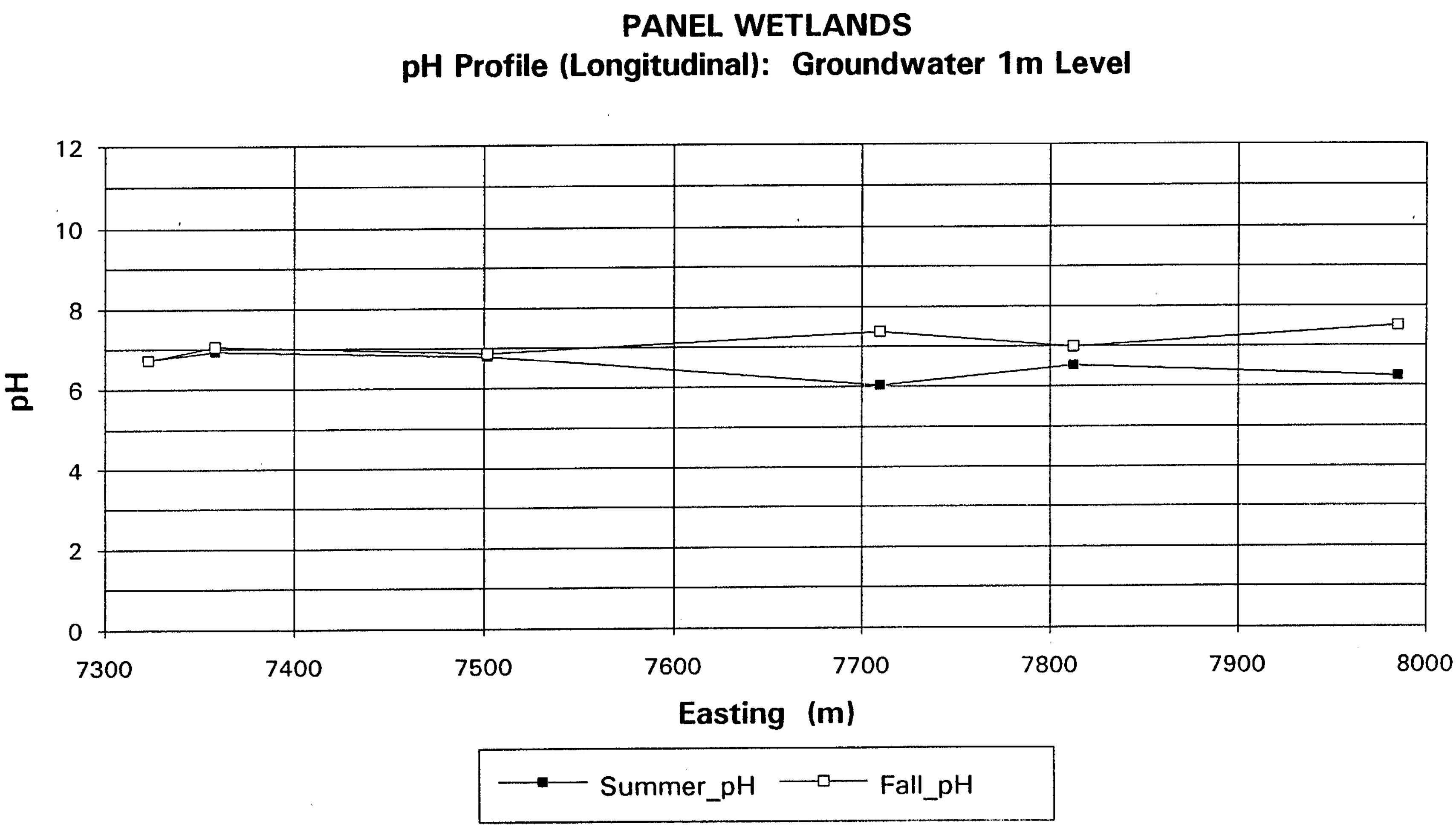


Fig. 48 a) - Panel wetlands: groundwater pH at 1 m below surface.

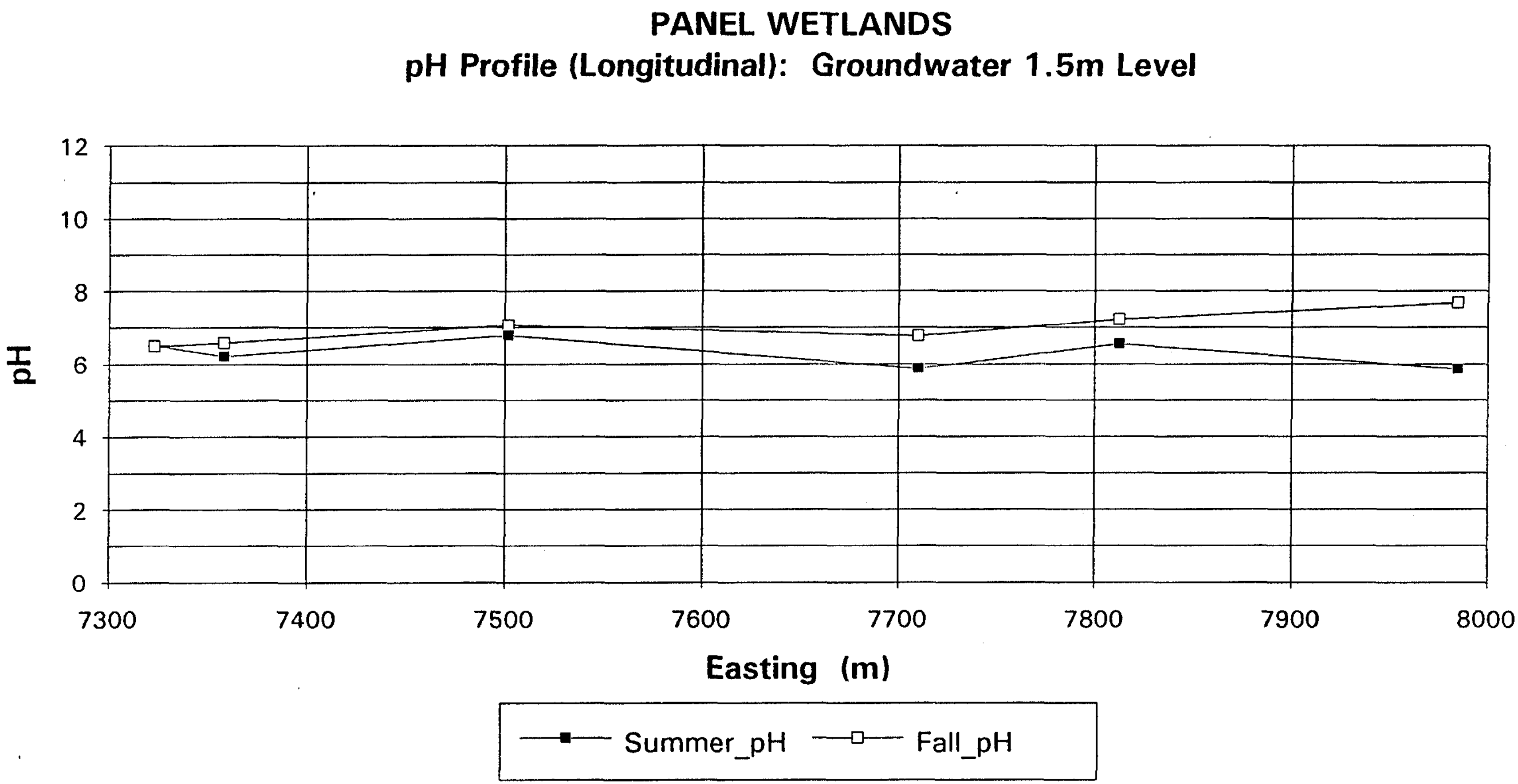


Fig. 48 b) - Panel wetlands: groundwater pH at 1.5 m below surface.

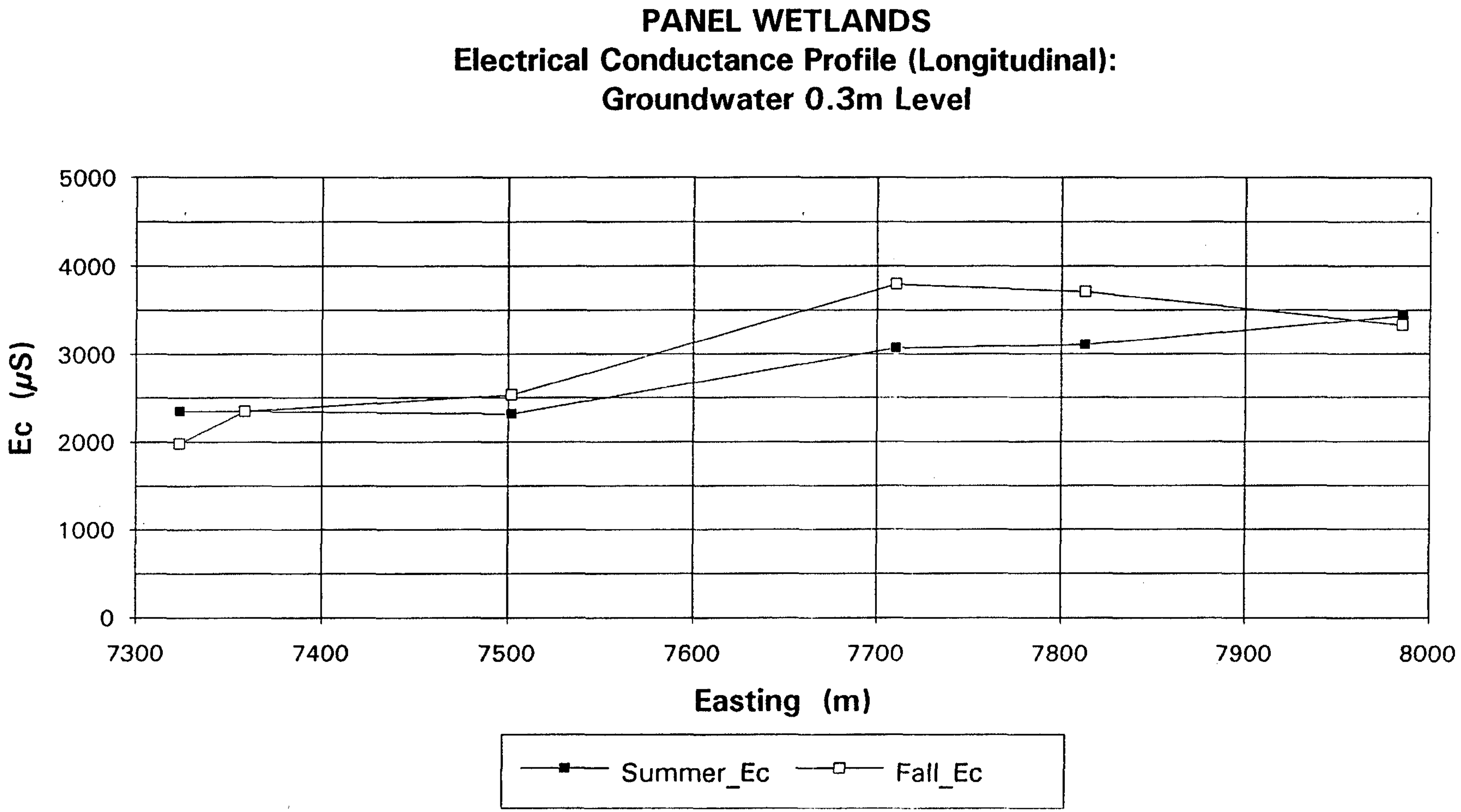


Fig. 49 - Panel wetlands: groundwater Ec at 0.3 m below surface.

PANEL WETLANDS
Electrical Conductance Profile (Longitudinal):
Groundwater 1m Level

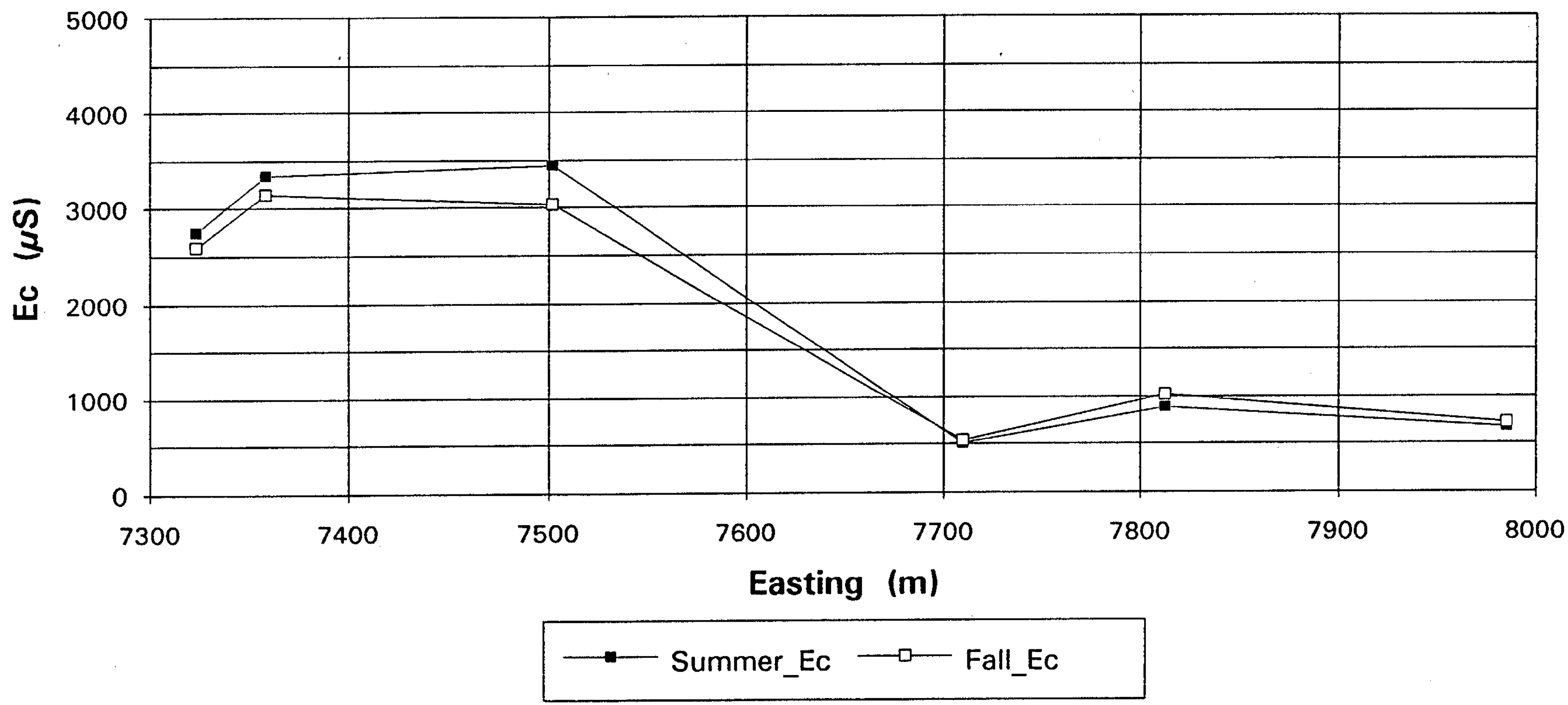


Fig. 49 a) - Panel wetlands: groundwater Ec at 1 m below surface.

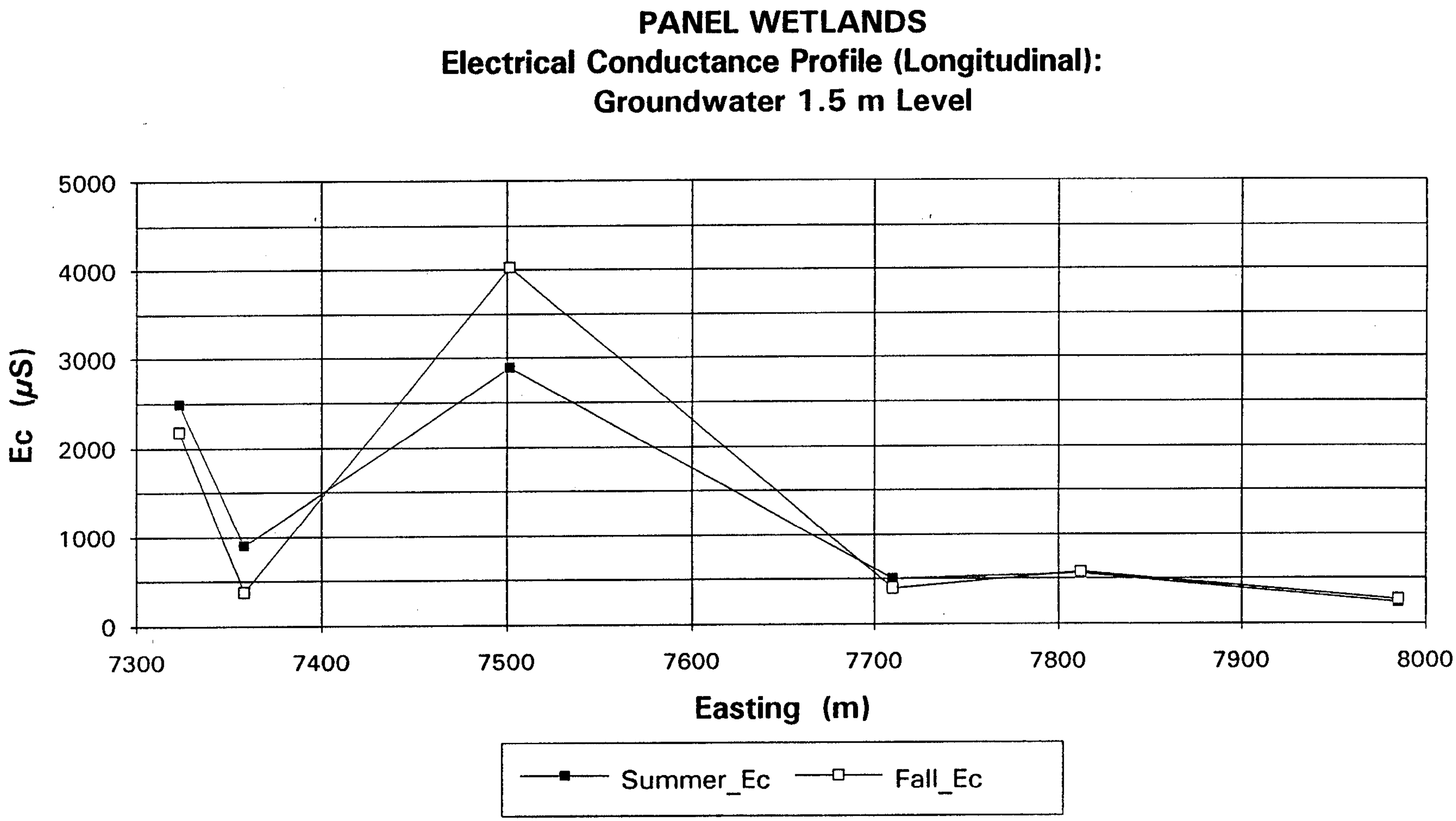


Fig. 49 b) - Panel wetlands: groundwater Ec at 1.5 m below surface.

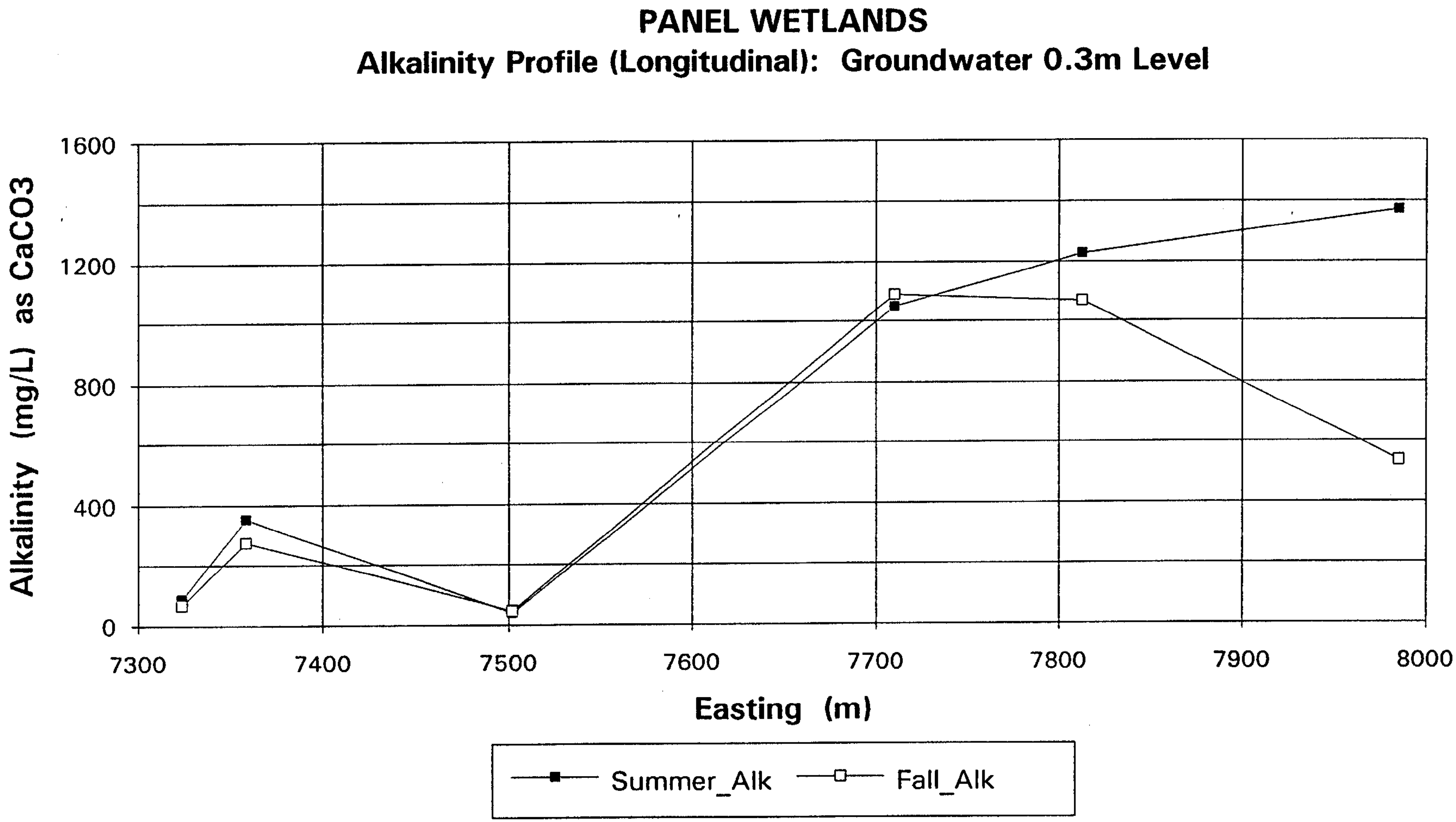


Fig. 50 - Panel wetlands: groundwater alkalinity at 0.3 m below surface.

173

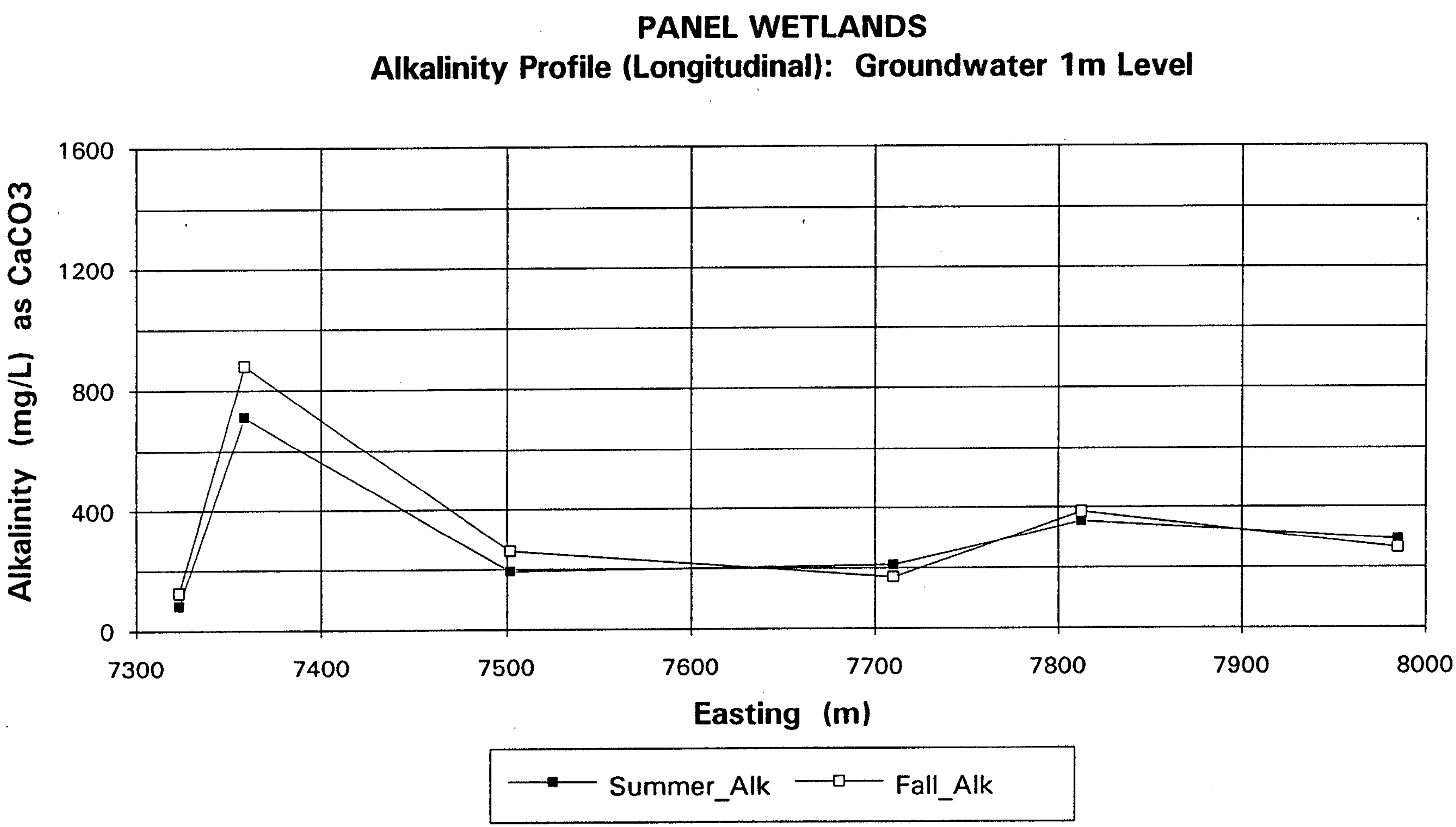


Fig. 50 a) - Panel wetlands: groundwater alkalinity at 1 m below surface.

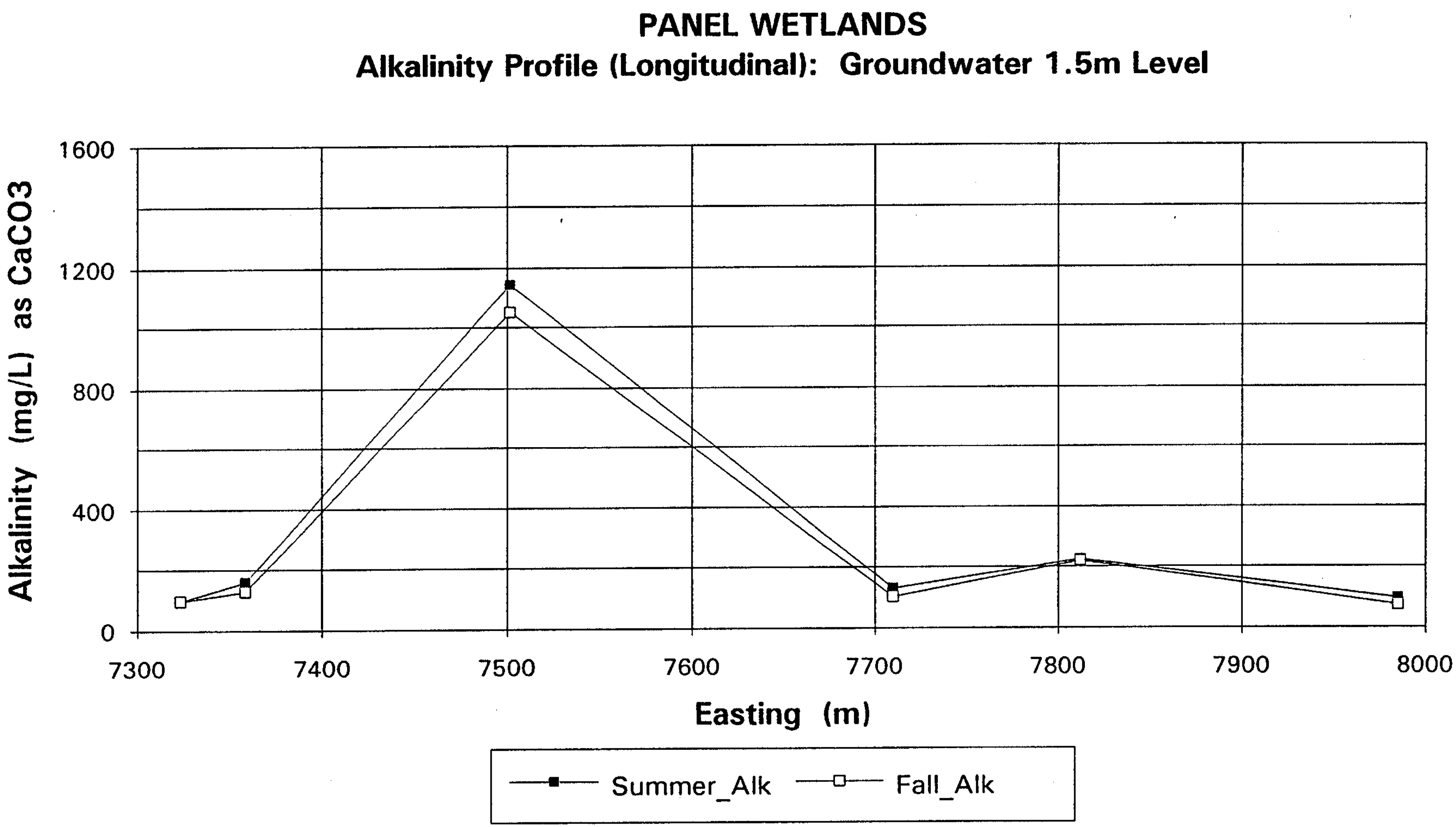


Fig. 50 b) - Panel wetlands: groundwater alkalinity at 1.5 m below surface.

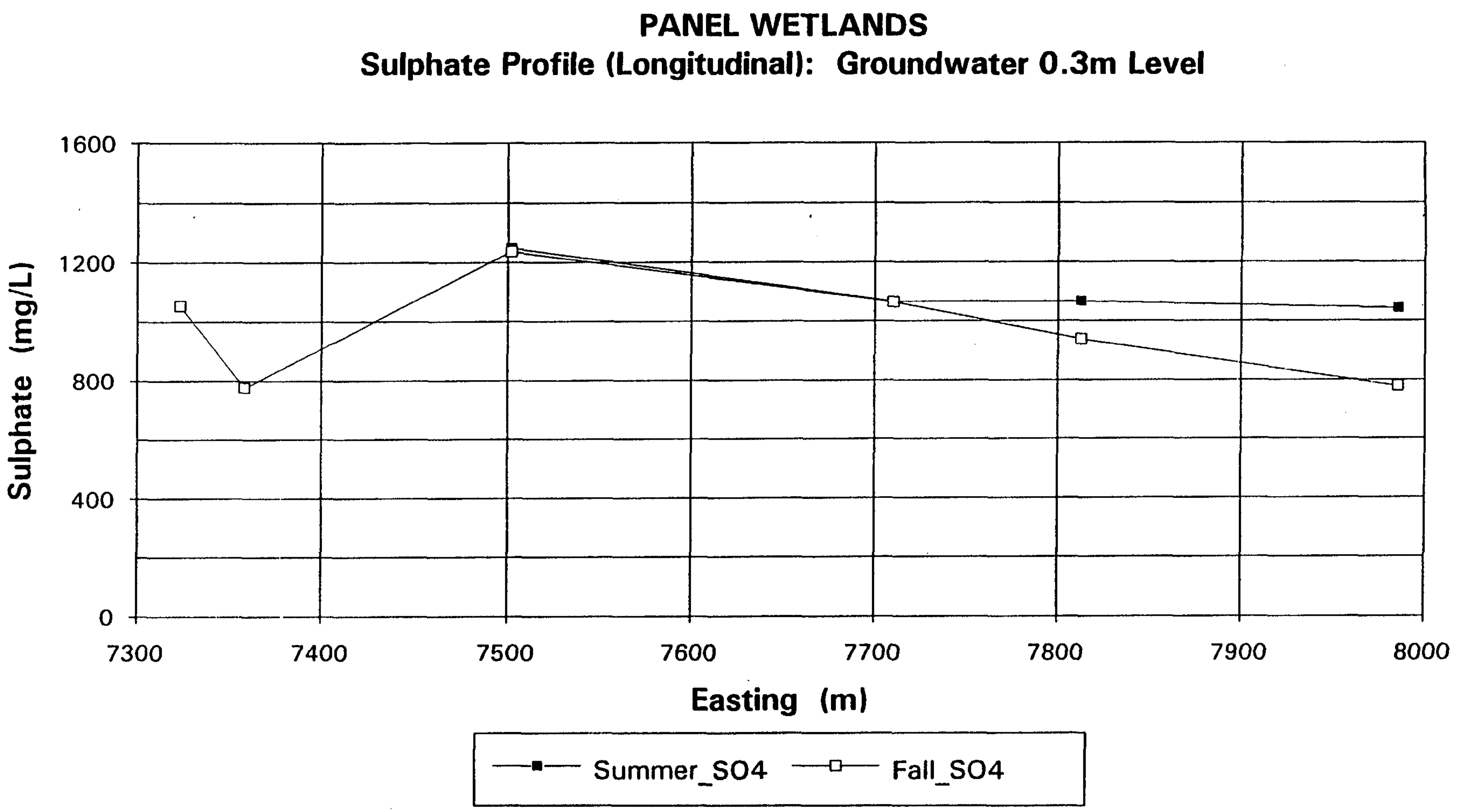


Fig. 51 - Panel wetlands: groundwater sulphate at 0.3 m below surface.

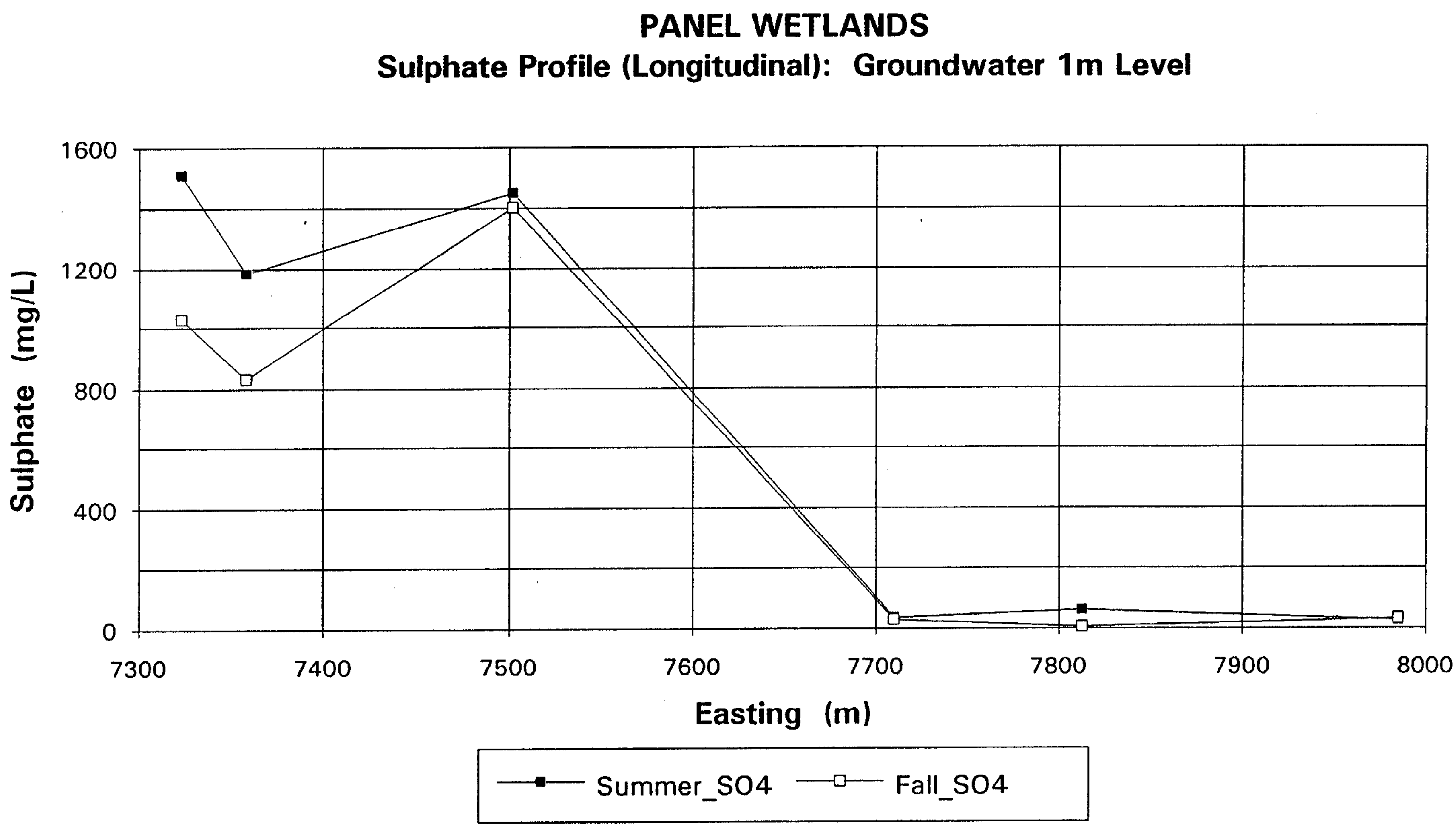


Fig. 51 a) - Panel wetlands: groundwater sulphate at 1 m below surface.

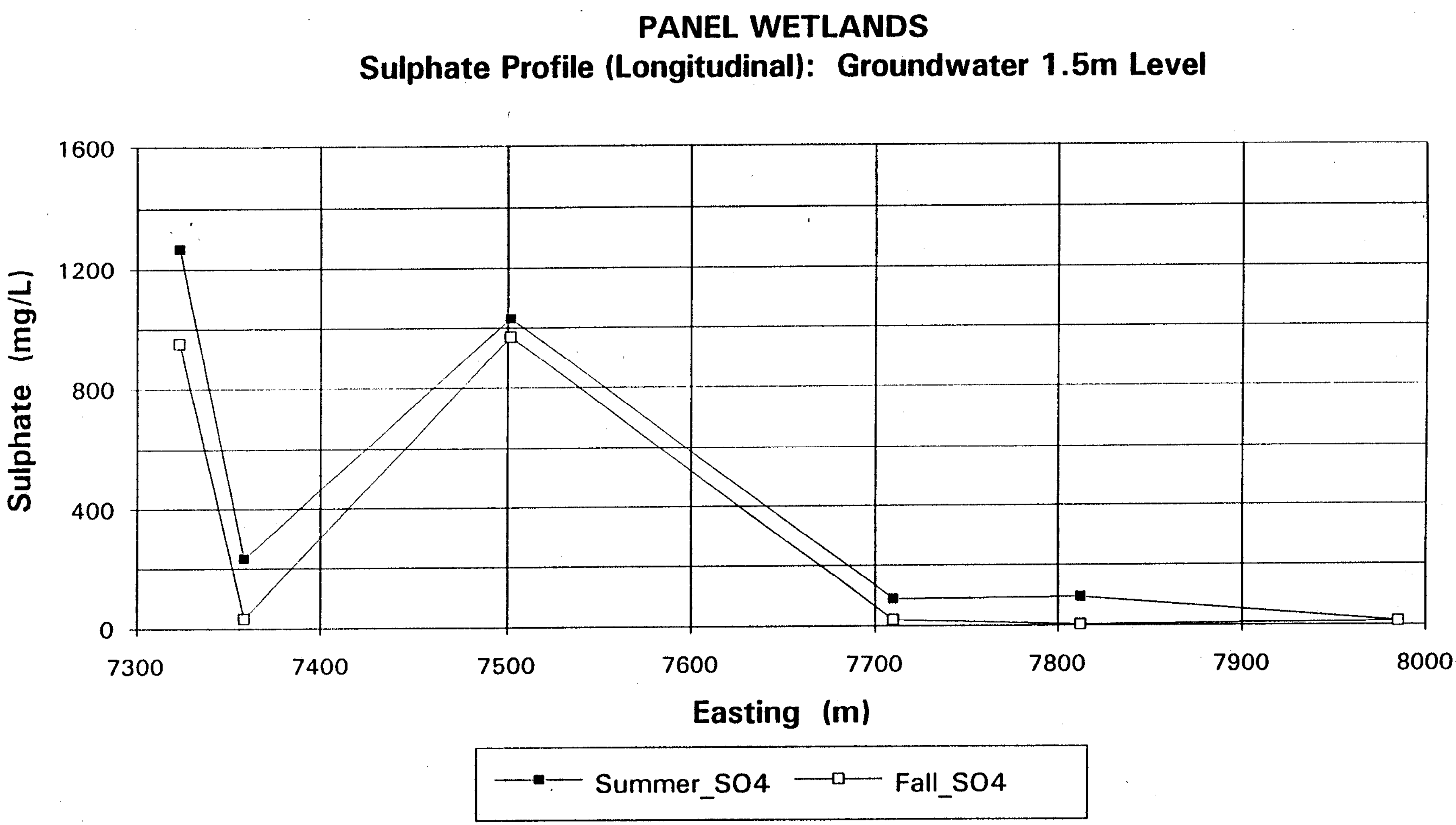


Fig. 51 b) - Panel wetlands: groundwater sulphate at 1.5 m below surface.

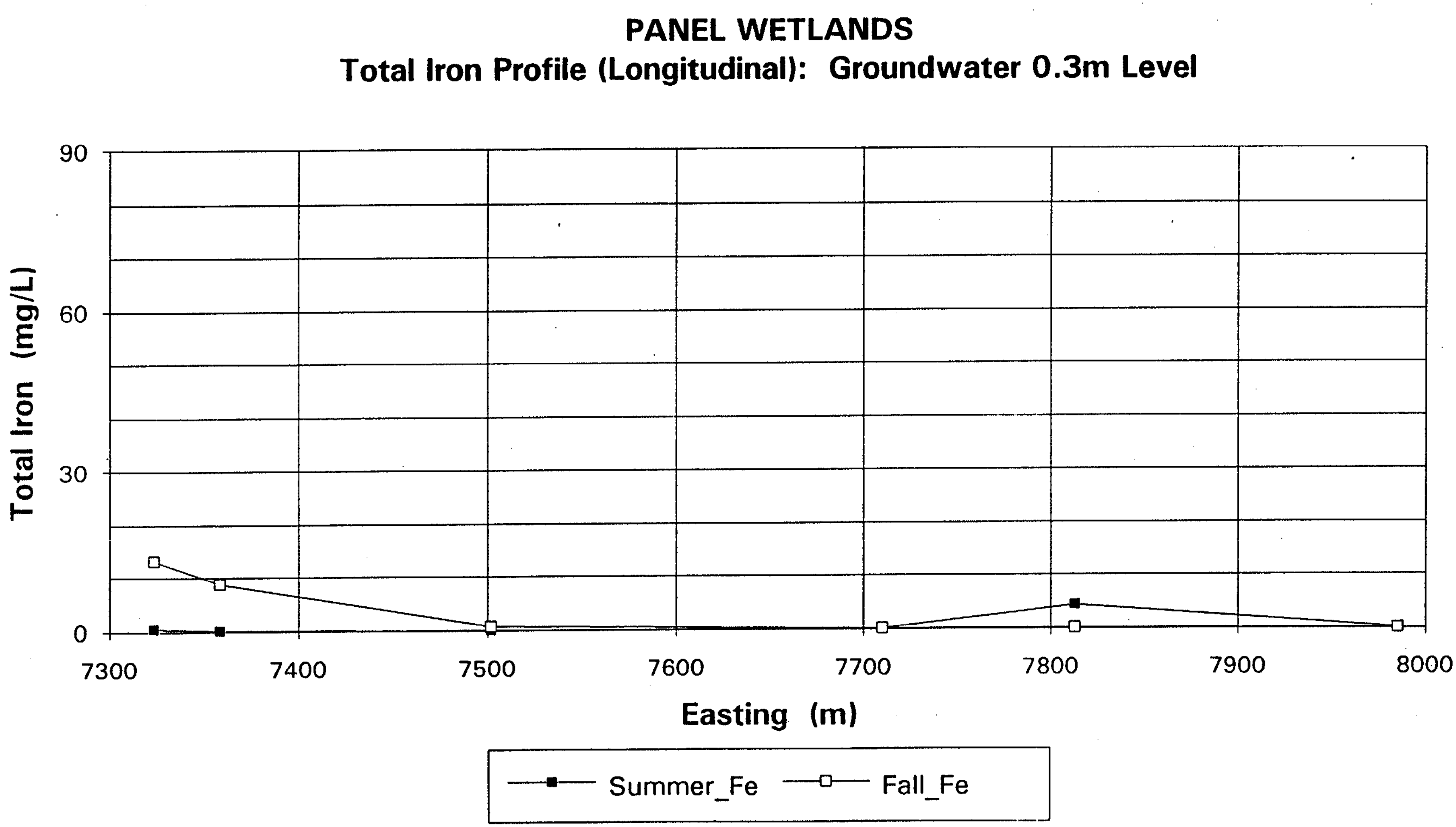


Fig. 52 - Panel wetlands: groundwater total iron at 0.3 m below surface.

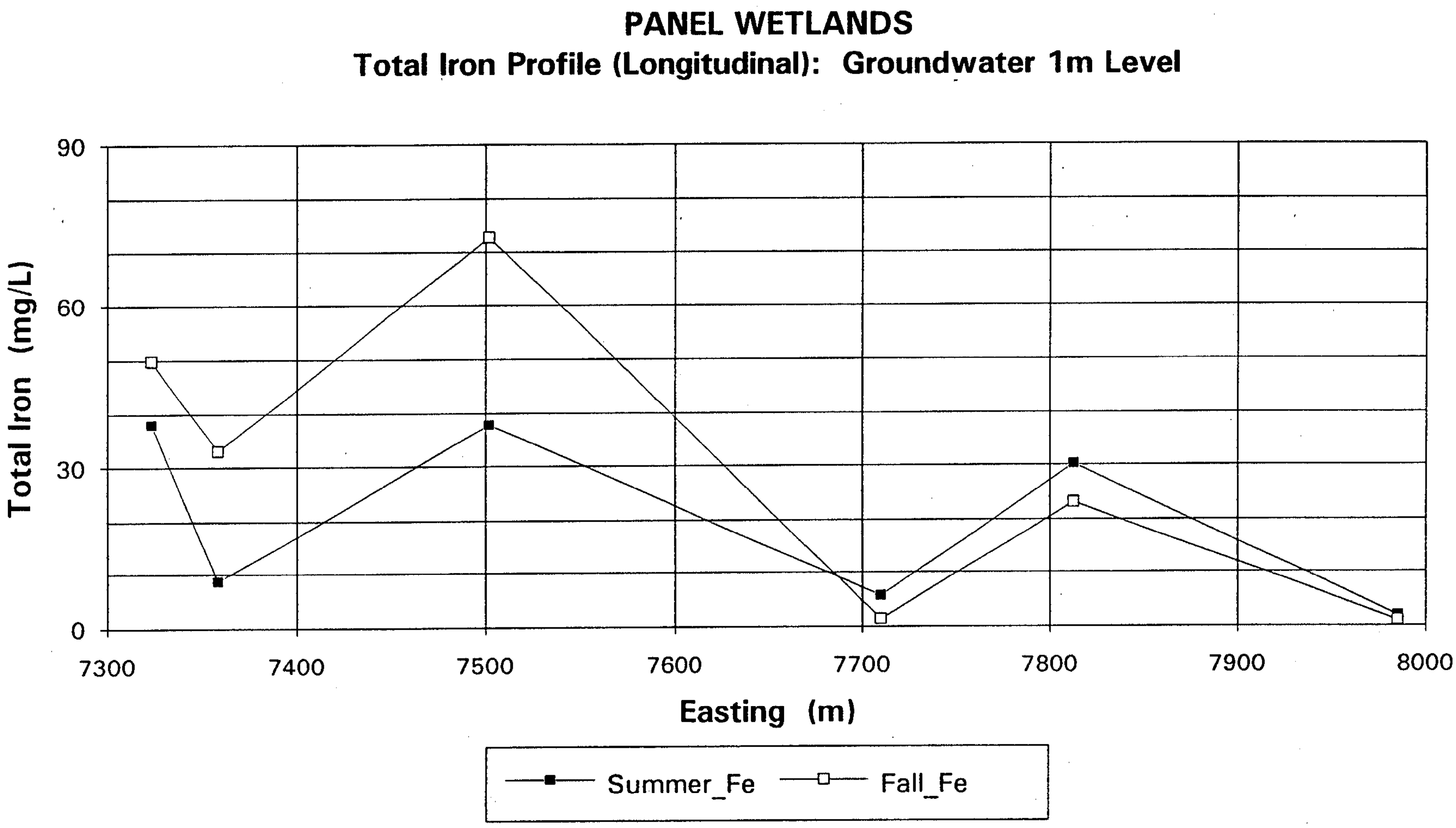


Fig. 52 a) - Panel wetlands: groundwater total iron at 1 m below surface.

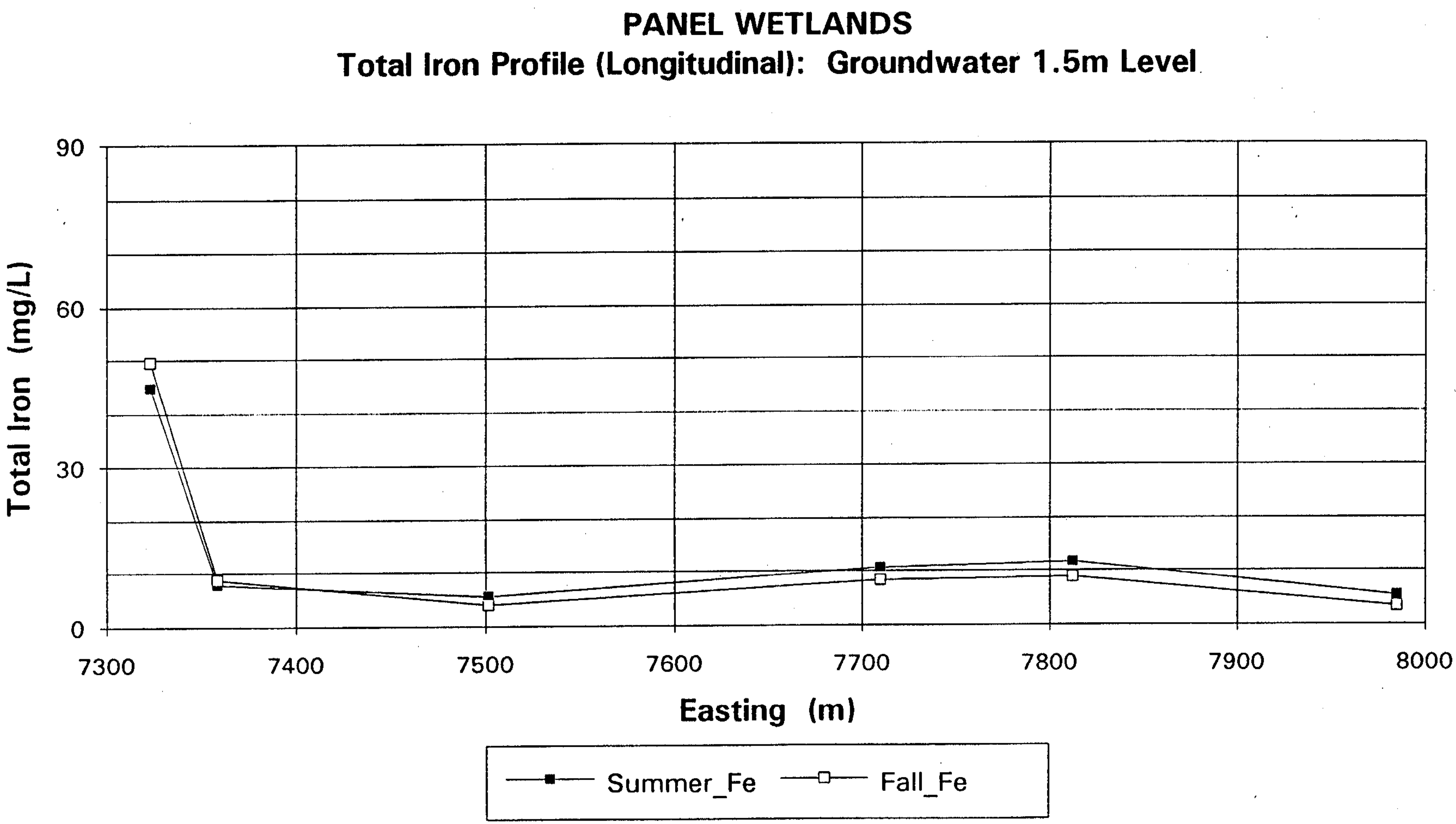


Fig. 52 b) - Panel wetlands: groundwater total iron at 1.5 m below surface.

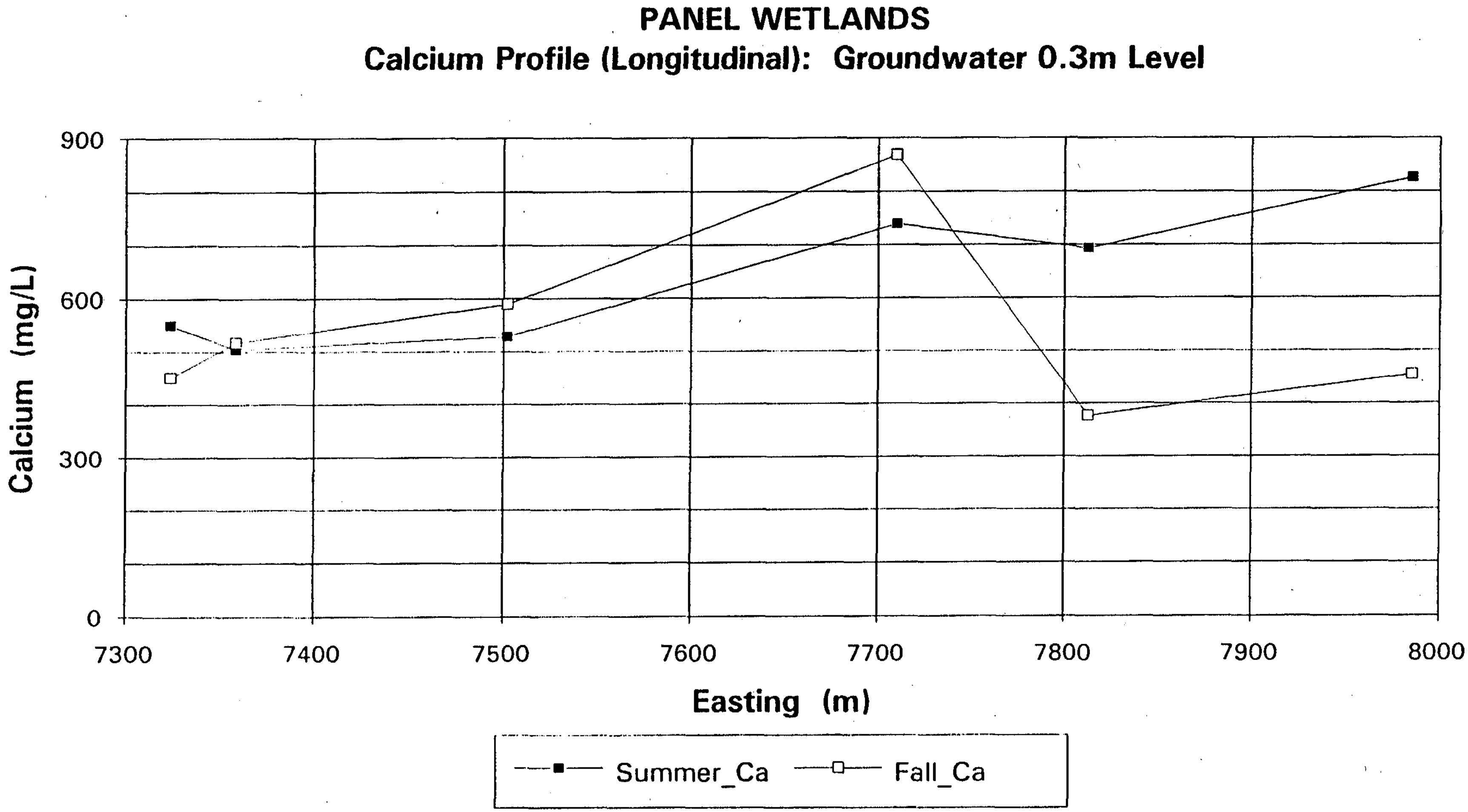


Fig. 53 - Panel wetlands: groundwater calcium at 0.3 m below surface.

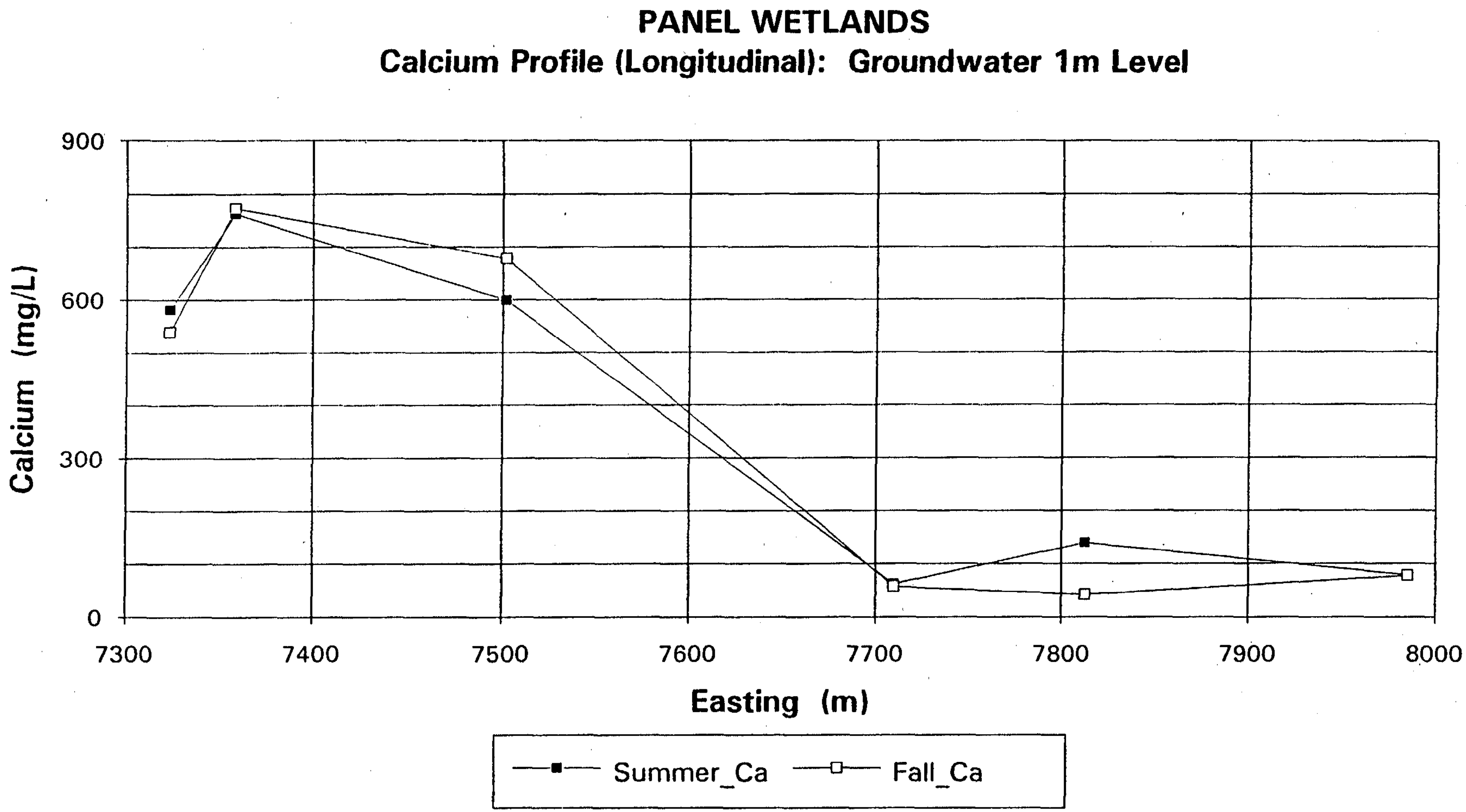


Fig. 53 a) - Panel wetlands: groundwater calcium at 1 m below surface.

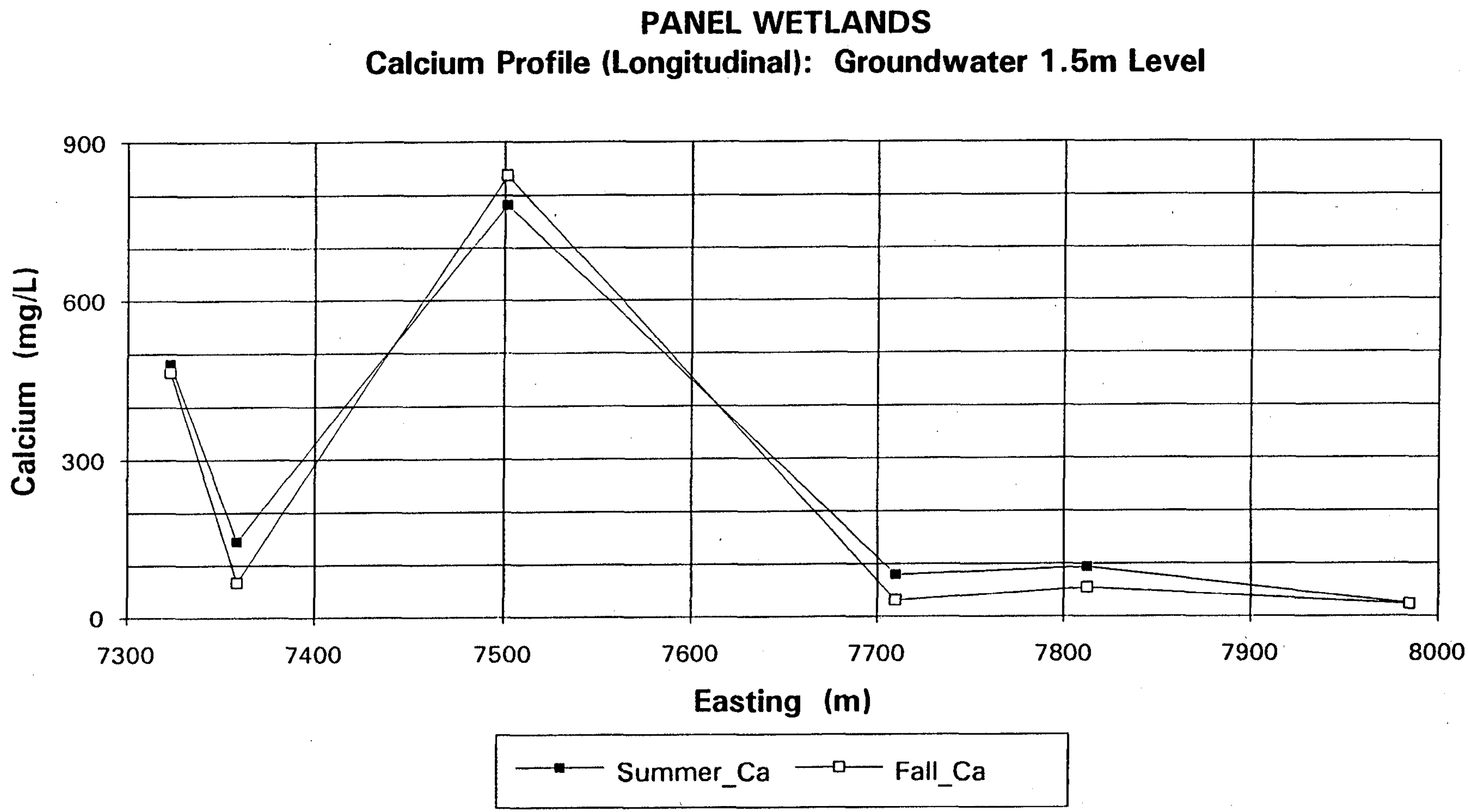


Fig. 53 b) - Panel wetlands: groundwater calcium at 1.5 m below surface.

184

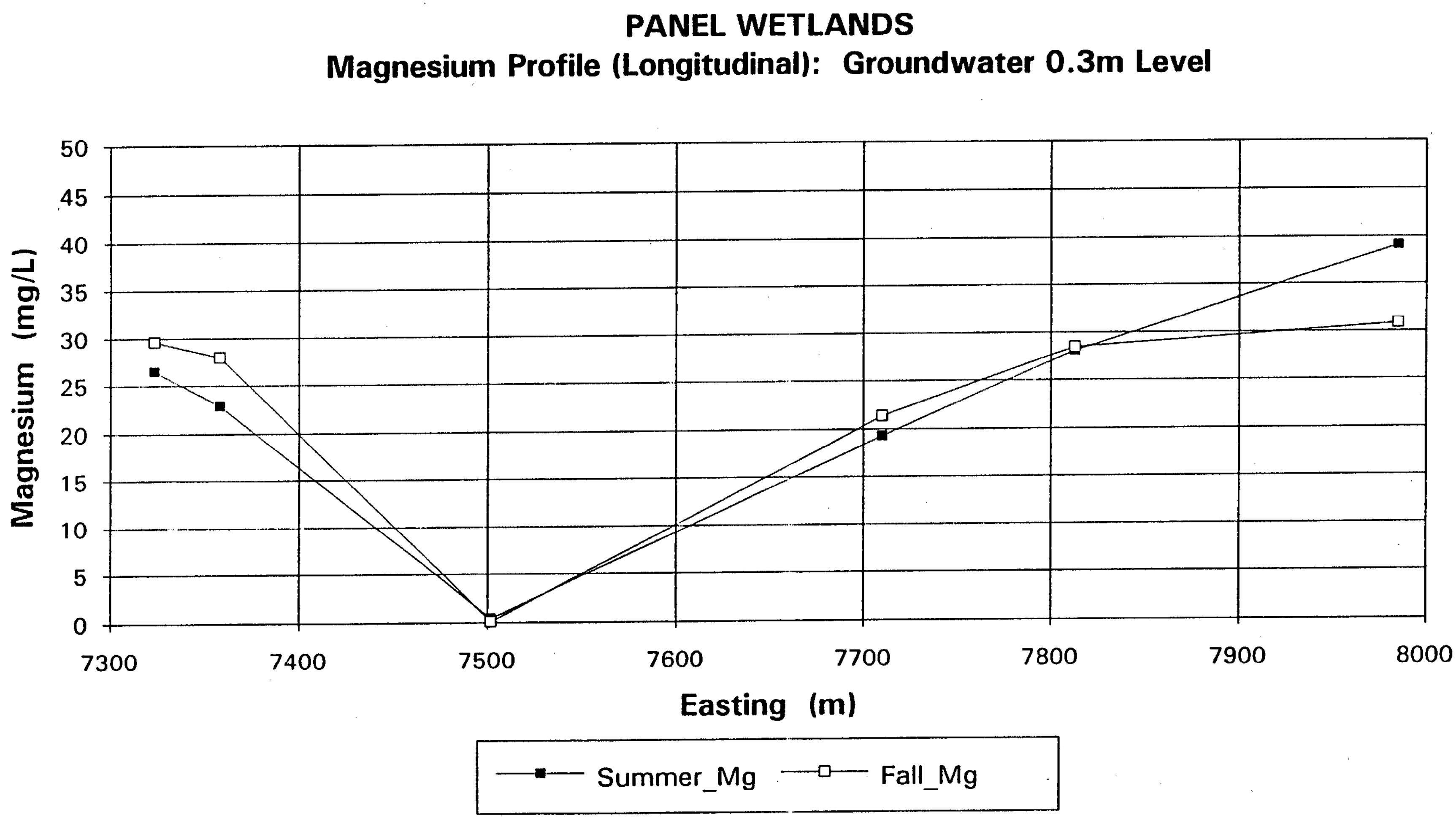


Fig. 54 - Panel wetlands: groundwater magnesium at 0.3 m below surface.

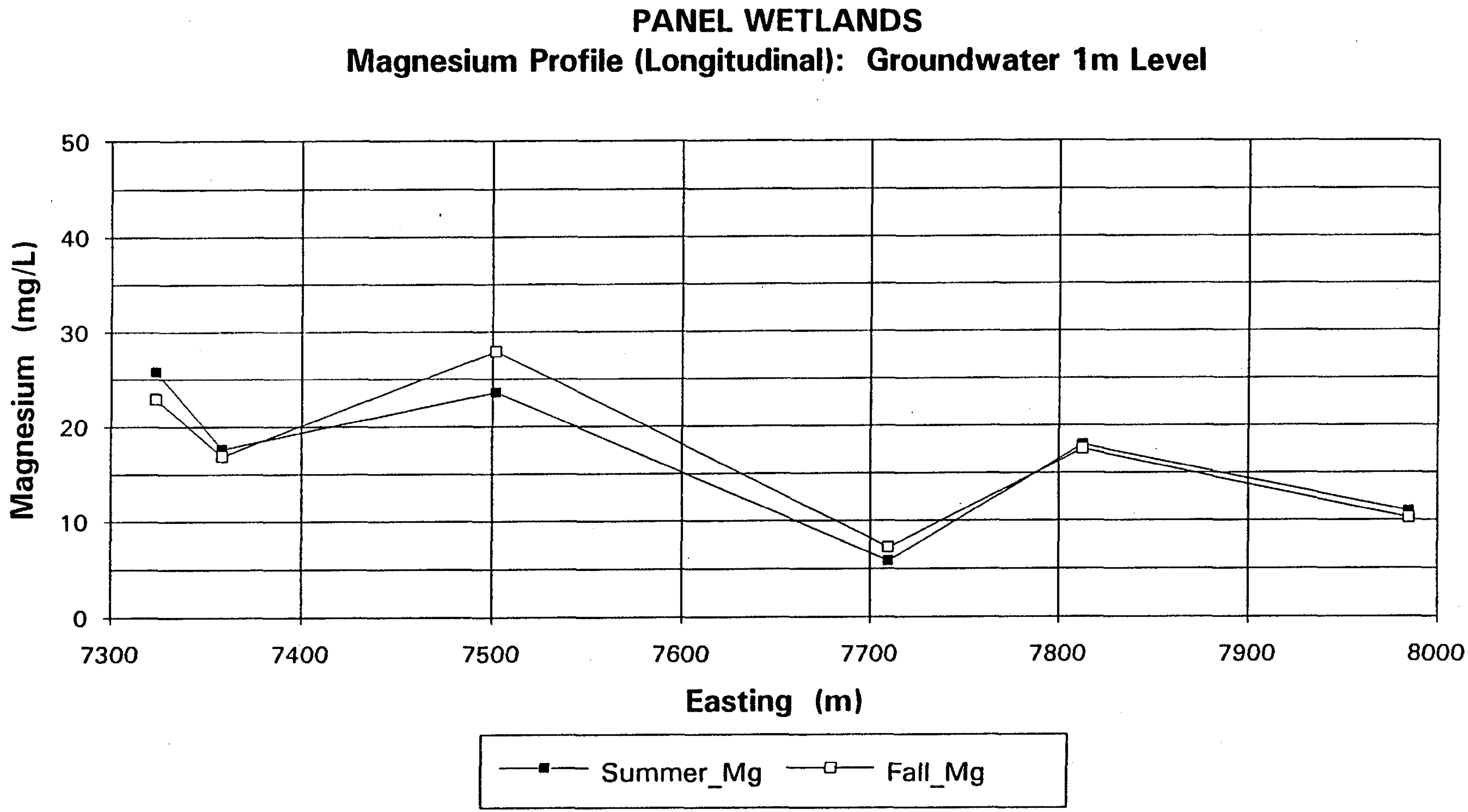


Fig. 54 a) - Panel wetlands: groundwater magnesium at 1 m below surface.

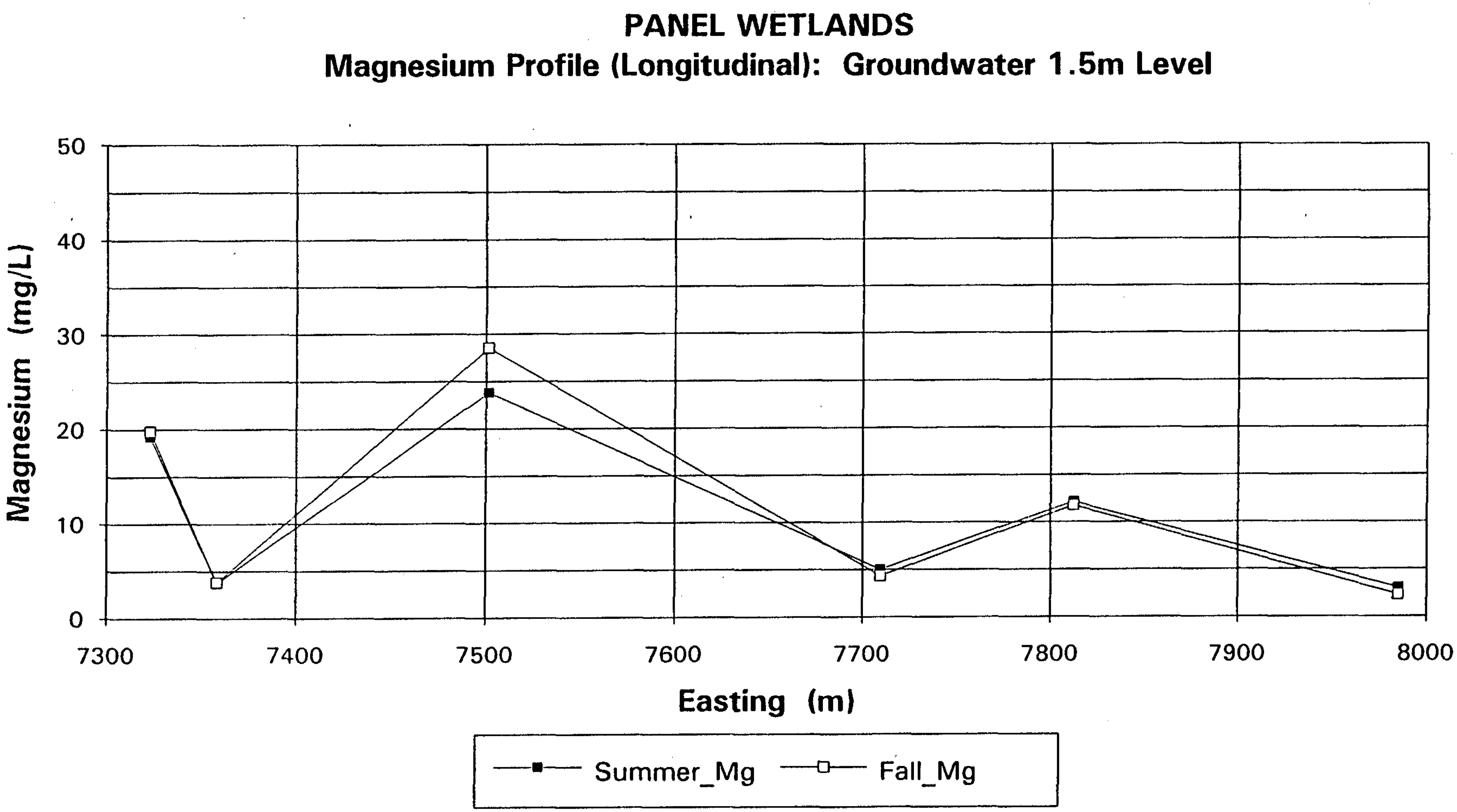


Fig. 54 b) - Panel wetlands: groundwater magnesium at 1.5 m below surface.

187

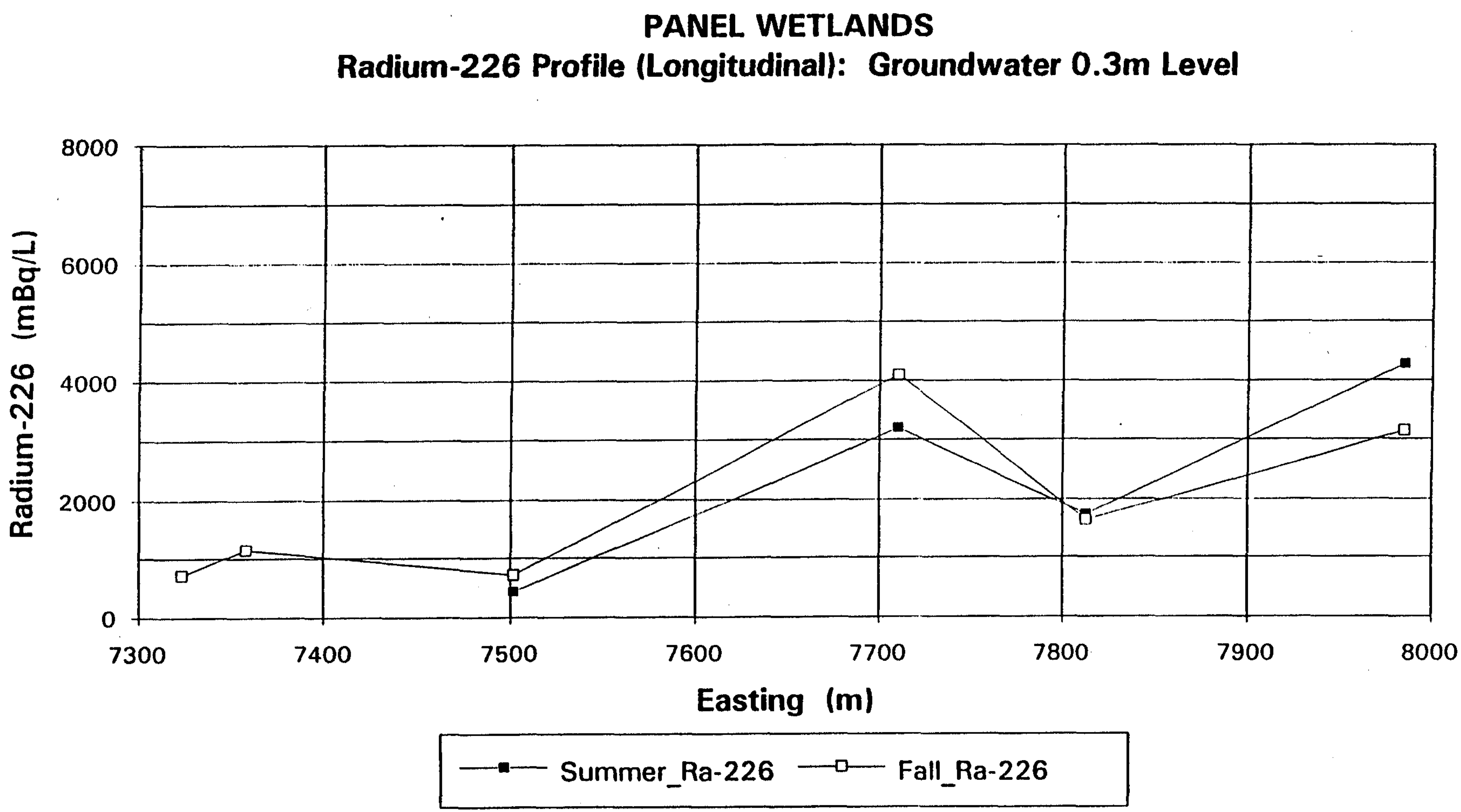


Fig. 55 - Panel wetlands: groundwater Ra-226 at 0.3 m below surface.

Welcome Screen | Search | Report List

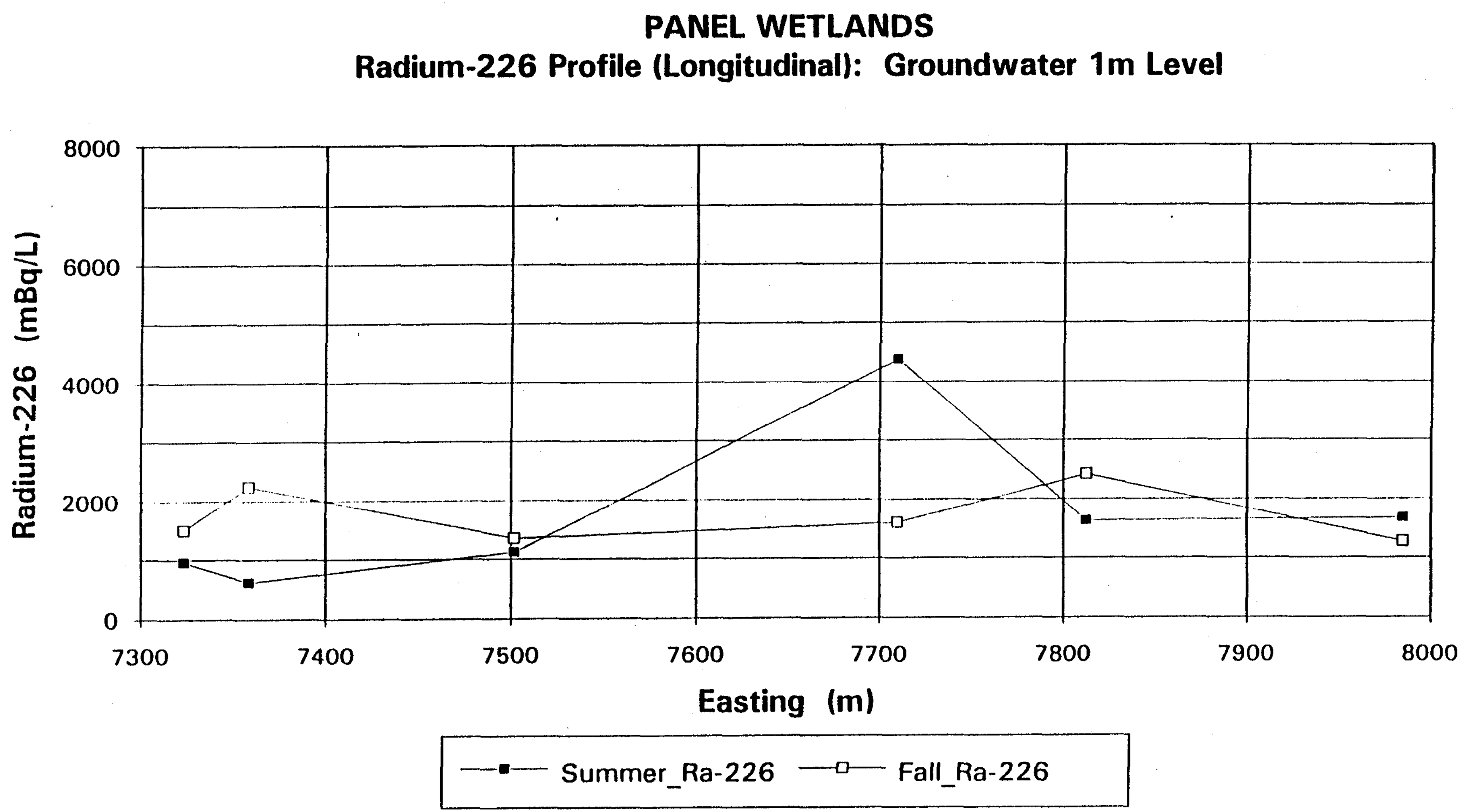


Fig. 55 a) - Panel wetlands: groundwater Ra-226 1 m below surface.

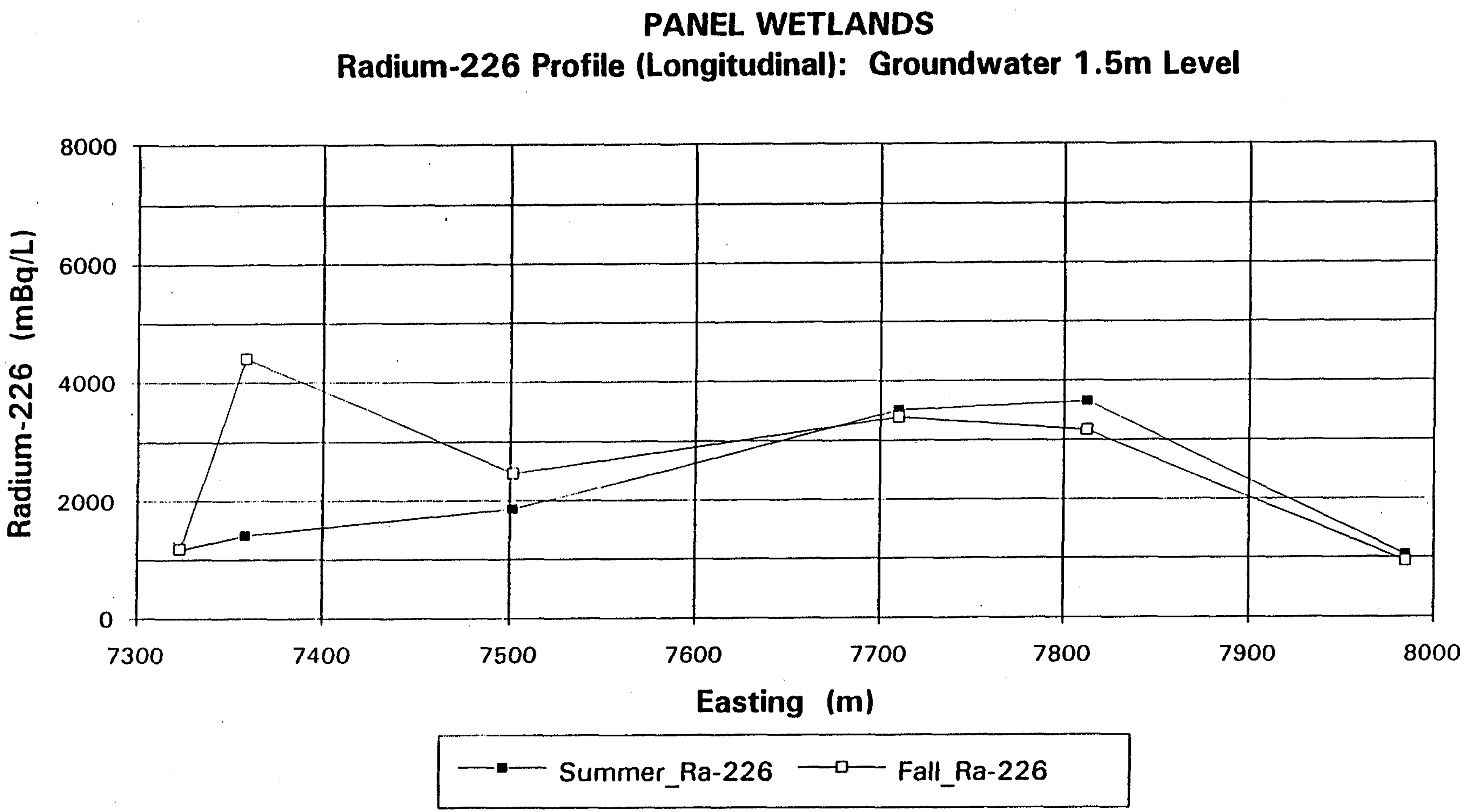


Fig. 55 b) - Panel wetlands: groundwater Ra-226 at 1.5 m below surface.

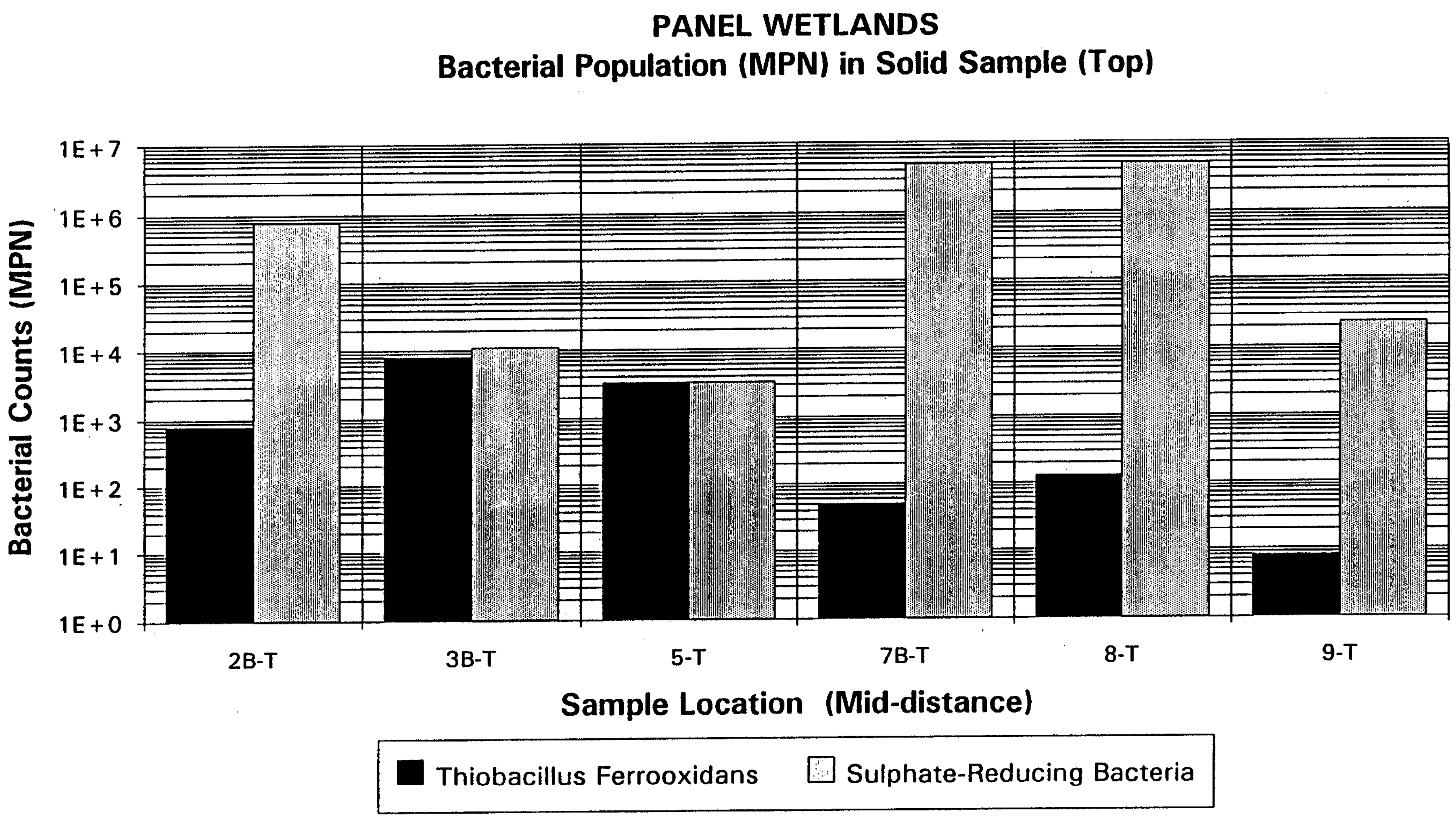


Fig. 56 a) - Panel wetlands: distribution of Thiobacillus ferro-oxidans and sulphate reducing bacteria in top 15 cm section of the substrate as a function of distance.

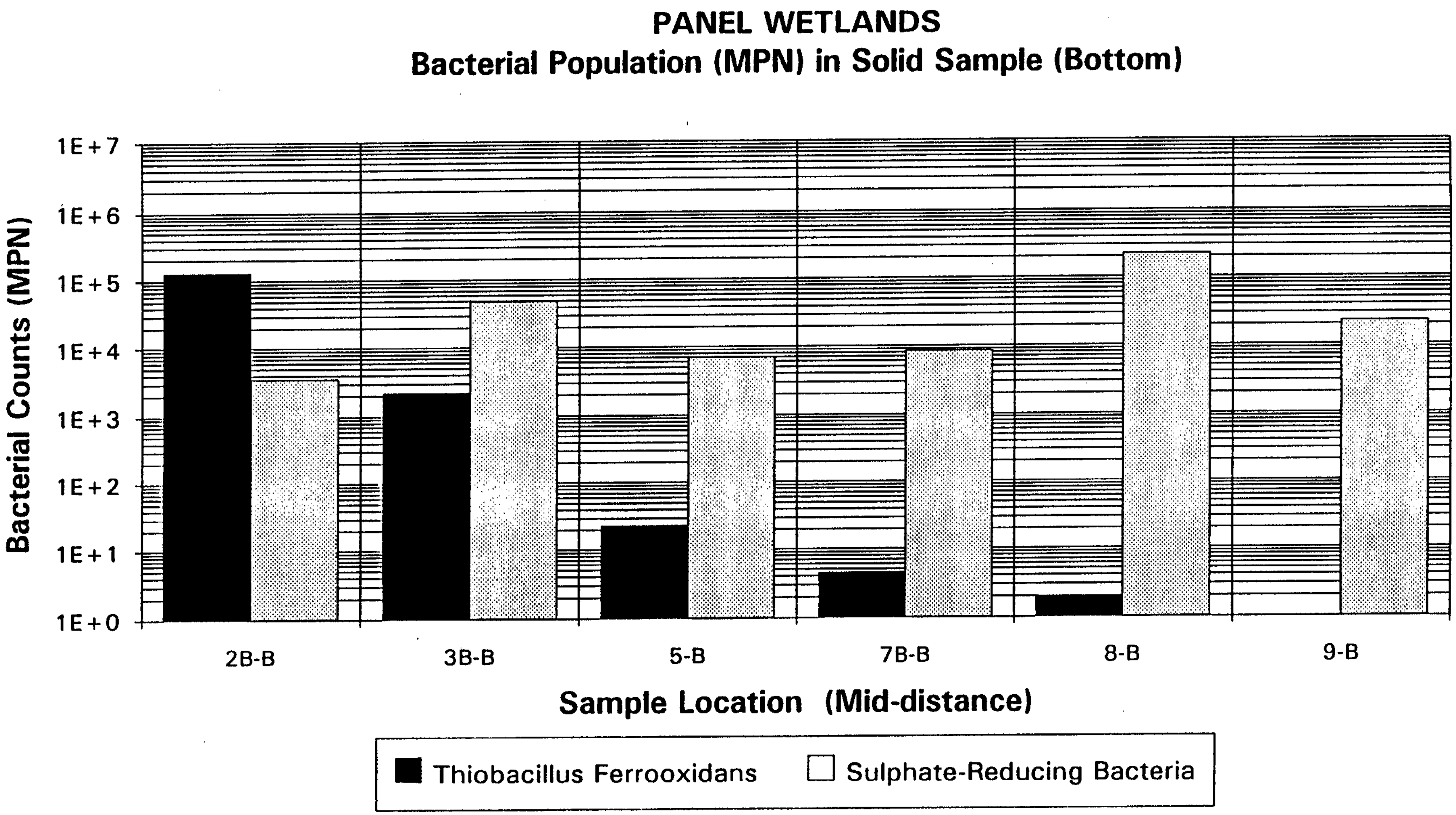


Fig. 56 b) – Panel wetlands: distribution of Thiobacillus ferro-oxidans and sulphate reducing bacteria in bottom 15 cm section of the substrate as a function of distance.

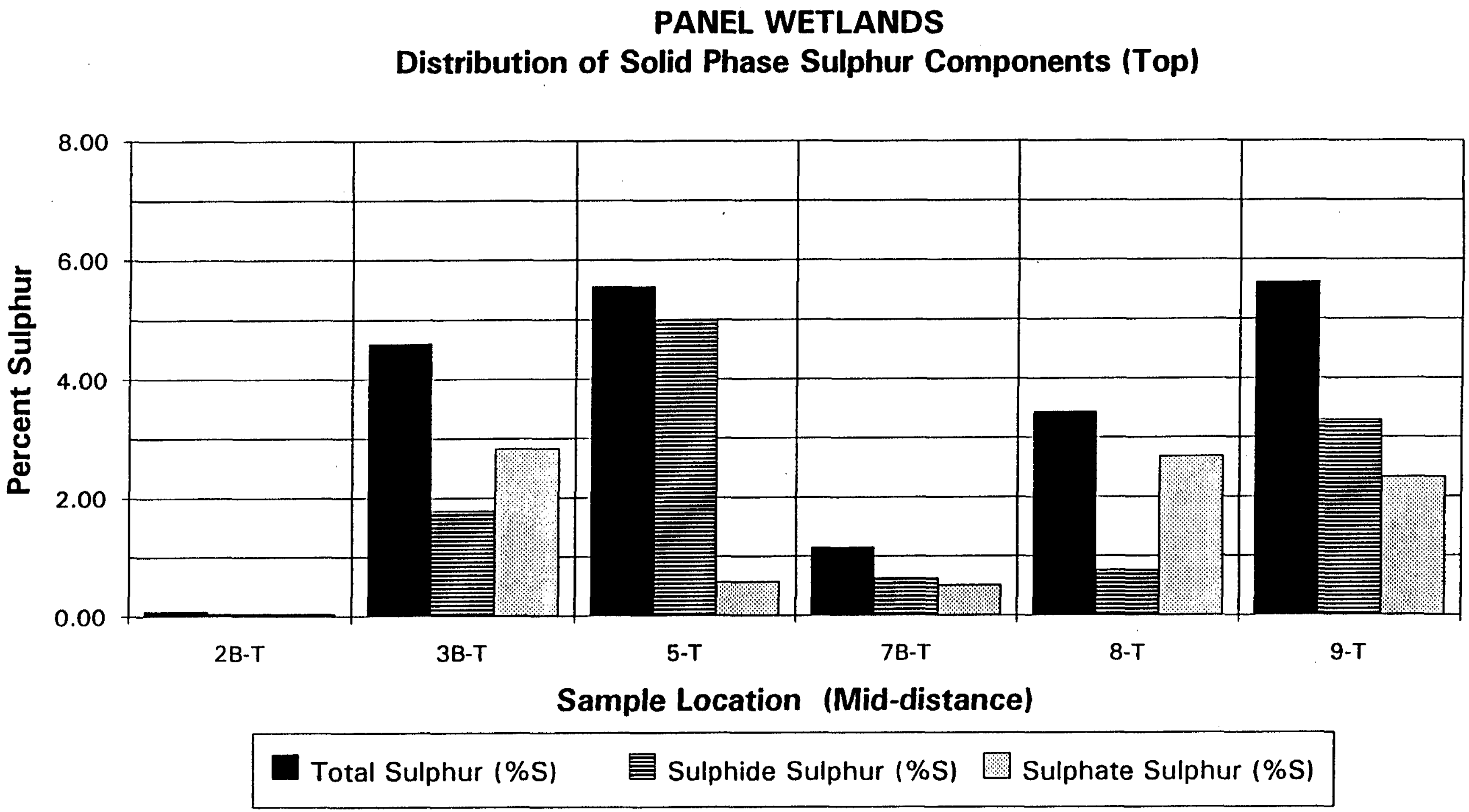


Fig. 57 a) - Panel wetlands: distribution of total sulphide and sulphate sulphurs in top 15 cm section of the substrate as a function of distance.

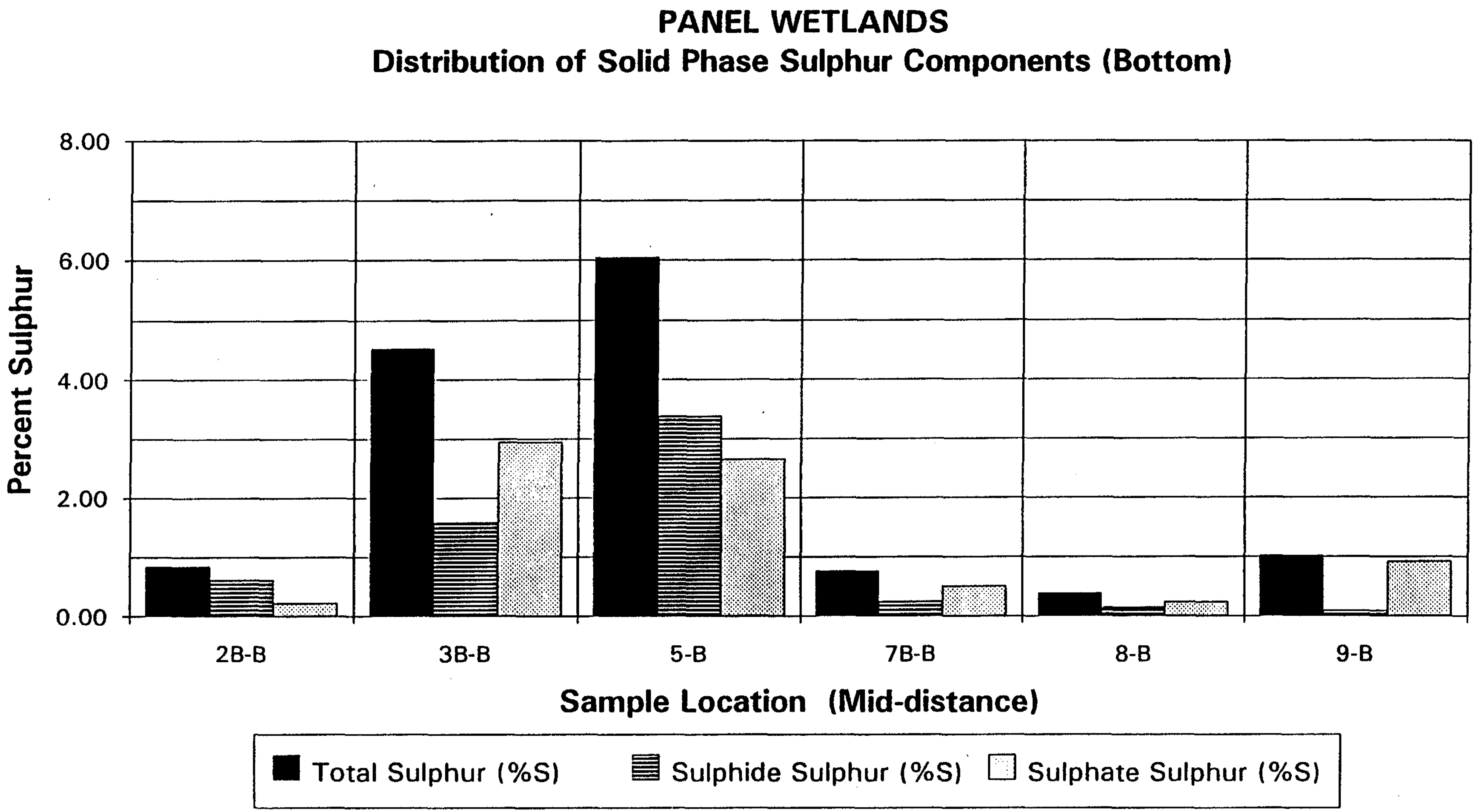


Fig. 57 b) - Panel wetlands: distribution of total sulphide and sulphate sulphurs in bottom 15 cm section of the substrate as a function of distance.

APPENDIX A

Evaluation of Wetlands at the Panel Dam "A" Site

Background:

The Panel Dam "A" Wetland site is located South East of the Panel tailings and immediately east of Dam "A". It has an area of approximately 16 ha and is located in a valley which drains towards the south-east. During the initial operation of the Panel Mine, tailings were spilled in the western part of the basin which forms part of the substrate now approximately 15-30 cms in depth with 5-10 cm oxidized layer. With the exception of some exposed tailings flats mostly in the eastern section, the whole basin consists of a lush green wetland vegetation containing cattails, sedges and moss. Cattails are dominant in the shallow water with mosses and sedges as the main species growing on saturated tailings. The whole basin is water logged and contains ponded water deeper than 30 cms in the middle where no emergent vegetation was growing. There is some water flow through the area and most of the area is water saturated.

The littoral zone is up to 20 cm thick in areas but the decayed organic layer is shallow up to 3 cm in depth. The maximum depth of the root zone is 20 cms.

A preliminary water quality survey in 1989, revealed a drastic improvement in pH from 3.6 to 6.6 and electrical conductance "Ec" from 1100 to 260 ^{e}s, as it moved from the exposed western section to the eastern water logged area. In summer and fall of 1990, the water quality parameters were respectively pH 4.4 - 8.1 and Ec 185-1272. These trends are consistent with the improvement in the water quality after the completion of Dam 'A' in 1979 (See Figs. 3 & 4).

Objective:

The objective of this study is to establish if the existing wetlands and water cover provide any treatment and control over water quality parameters associated with the oxidation of pyritic tailings and migration of contaminants. This will incorporate surface and sub-surface hydro-geochemistry and vegetation and substrate characterization for their role in various geochemical and biological interactions.

In this study, we plan to undertake the following work program:

1. A prelimnary survey of surface and groundwater hydrology and flow regimes to establish various surface and groundwater components of the total flow and its direction etc. Initial installation will consist of shallow piezometer nests at six locations with three piezometers at each site, at depths 0.3, 1, 1.5 m respectively. Estimates of total inflow and outlfow will be made by channel characterization and wier or flume installation if necessary. (See fig. 1).

2. Surface and Porewater Chemistry:

   Surface water will be sampled for in situ pH, Ec, Eh (redox potential) at various locations (see fig. 2). Both Surface and porewater samples will be collected for detailed chemical characterization at the 18 piezometer locations. Samples will be analyzed for the total dissolved metals: Fe, Al, Ca, Mn, Pb, U, Th, Mg, Cu, Ni, Zn, Sulphate (So_4^{-2}) and Ra-226.

3. Vegetation and Soil Characterizations:

At locations close to the piezometer sites vegetation and soil samples will be collected and analyzed for total metals and radionuclides as above. Soil samples will be collected from surface to 20 - 30 cm depth, sectioned in two parts, upper and lower (usually upper portion is oxidized) and then analyzed. The samples will be dried and preserved for further mineralogical analyses in the future, if required. Vegetation samples will be separated according to type i.e. cattail, moss and shrub etc. dried and analyzed for metals.

The approximate price breakdown is as follows:

i) Piezometers installation and flow measurements:

Material:	$ 2,300.	
Labour:	4,000.	
	$ 6,300.	$ 6,300.

2) Surface and groundwater sampling:

Labour:	$ 4,600.	$ 4,600.

3) Soil and vegetation sampling:

Included in above	N/C

4) Revised analytical cost

a) Surface water samples:

- 10 cross-sections and 3 locations at each section: 30 samples

- 3 seasonal samplings, spring, summer and fall

Total samples = 90
(10 x 3 x 3)

b) Pore water samples:

18 piezometers sampling, One season (summer)

Total pore water = 18 samples

Total water samples = 108

analyse for pH, Eh, Ec, Total dissolved solids, dissolved oxygen, S, So_4^{-2}, Acidity, Alkalinity & dissolved metals, Fe, Al, Ca, Mn, Mg, Cu, Ni, Zn, U, Th, & Pb.

18 parameters X $10. ea = $180 sample

Total charge = $180 X 108 (samples) = $19,440.

c) Soil samples

at 18 piezometer location, divided into upper and lower zone strata

Total samples = 36 (18 X 2)

Analyze for paste pH, S, SO_4^{-2} & 11 metals @ $10/ea. + 10 sample digestion = $150.00 ea sample.

Total cost = $150 X 36 = $ 5,400

d) Vegetation samples

Sample at '6' piezometer locations, 3 species and sub-divided into 2 parts (leaves + stem)

Total samples = 6 X 3 X 2 = 36 samples

Analyze for 11 metals + digestion charge @ $10 ea = $120/sample

Total cost = $120 X 36 = $4,320

e) Ra-226 analyses

For 18 porewater
10 surfacse water
36 soil sample
36 veg sample

Total Ra-226 samples = 100 samples, @ $50./ea

Total cost = 100 x 50 = $5,000.

Price Breakdown:

1) Piezometer installation and flow measurements

(no change) = $6,300.

2) Surface and groundwater sampling (labour sample) = $4,600.

3) Soil and vegetation sampling included above N/C

4) Chemical Analysis:

a)	Surface water and porewater	=	$19,440.
b)	Soil samples	=	5,440.
c)	Vegetation samples	=	4,320.
d)	Ra-226 analyses	=	5,000.
	TOTAL		$45,100.

CANMET will provide additional field and laboratory manpower (if required) and will prepare the report at no additional cost.

We request your authorization as early as possible in the new fiscal year so that major field work can be done by the end of August..

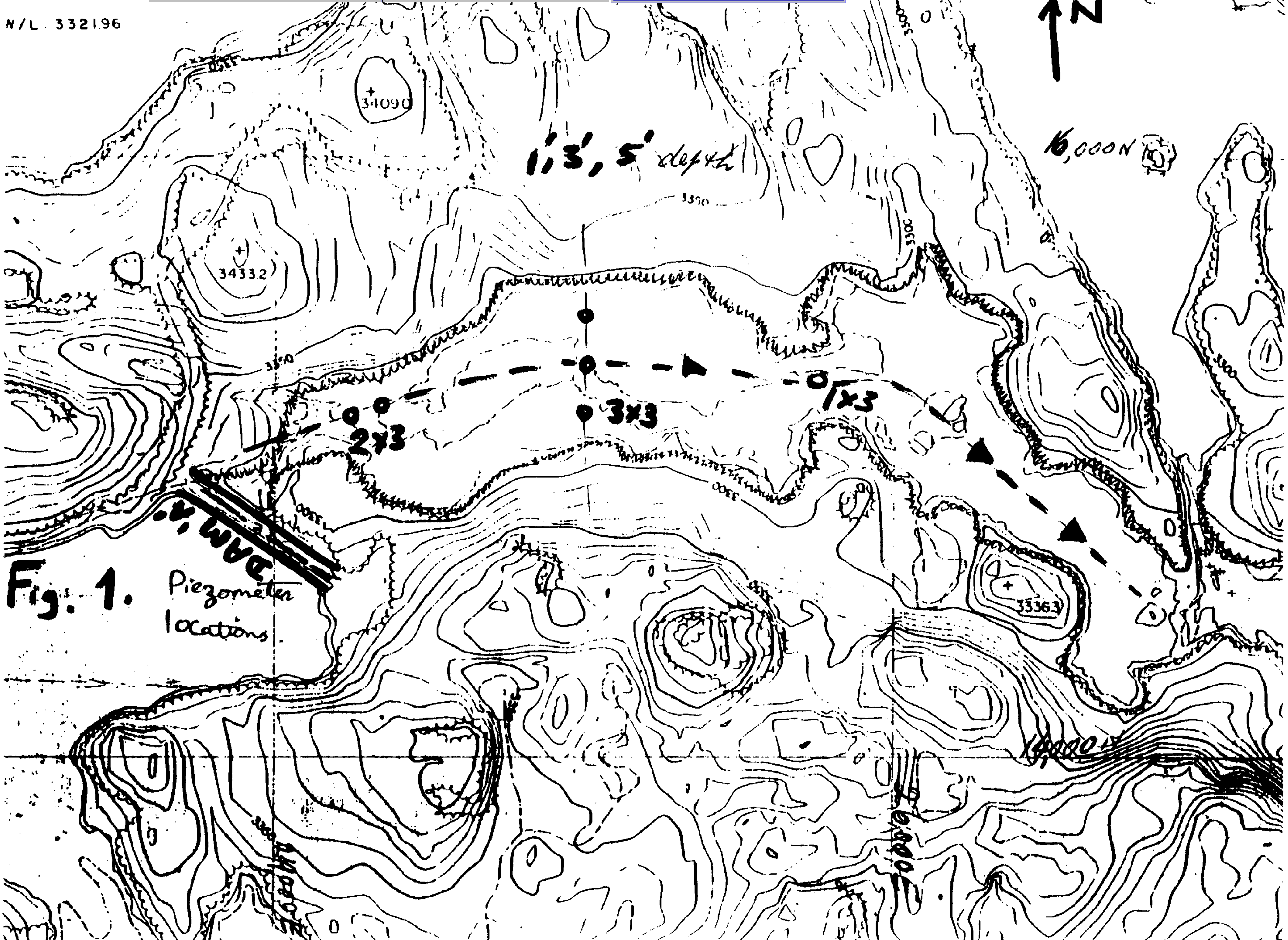


Fig. 1. Piezometer locations

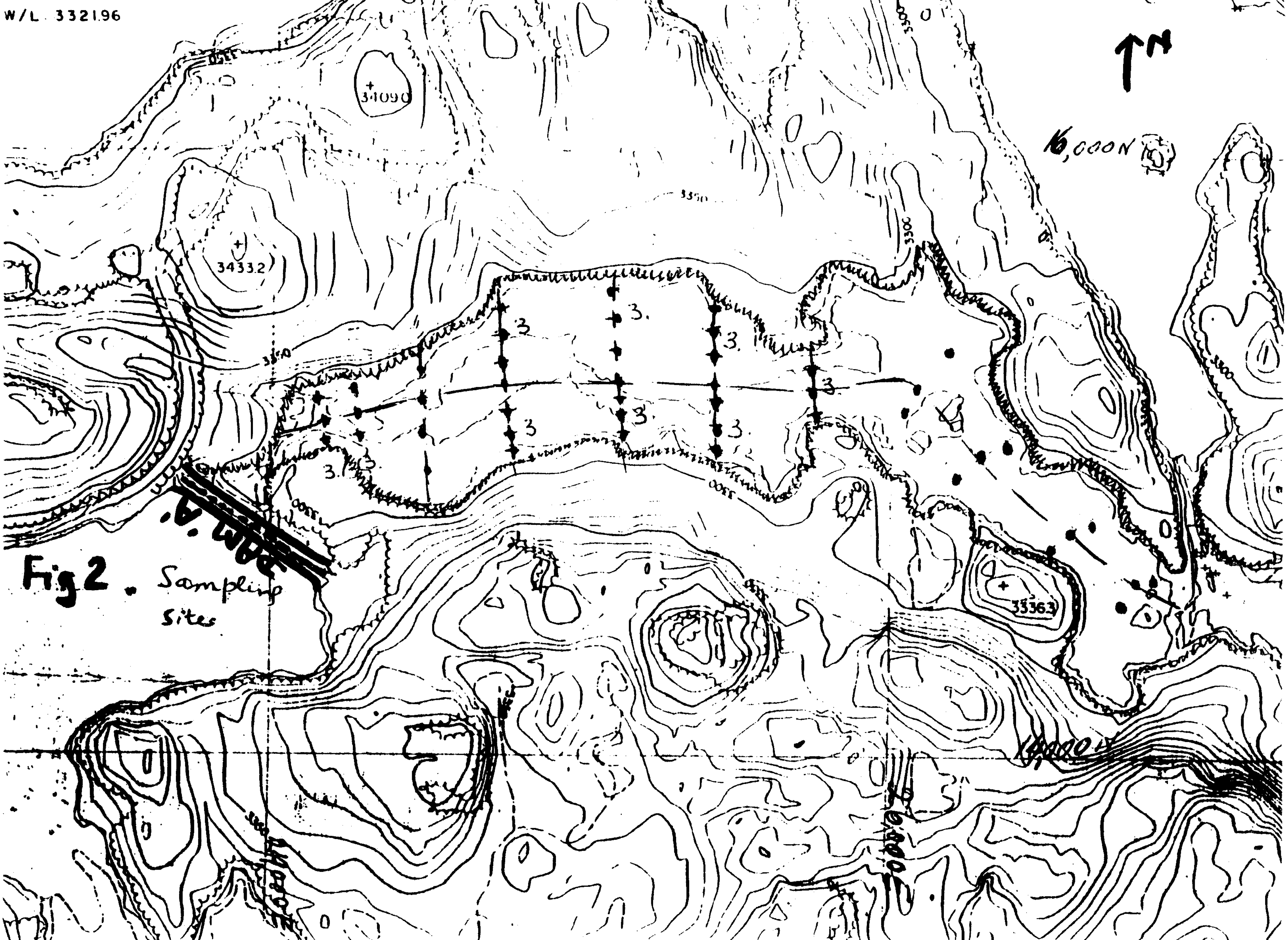
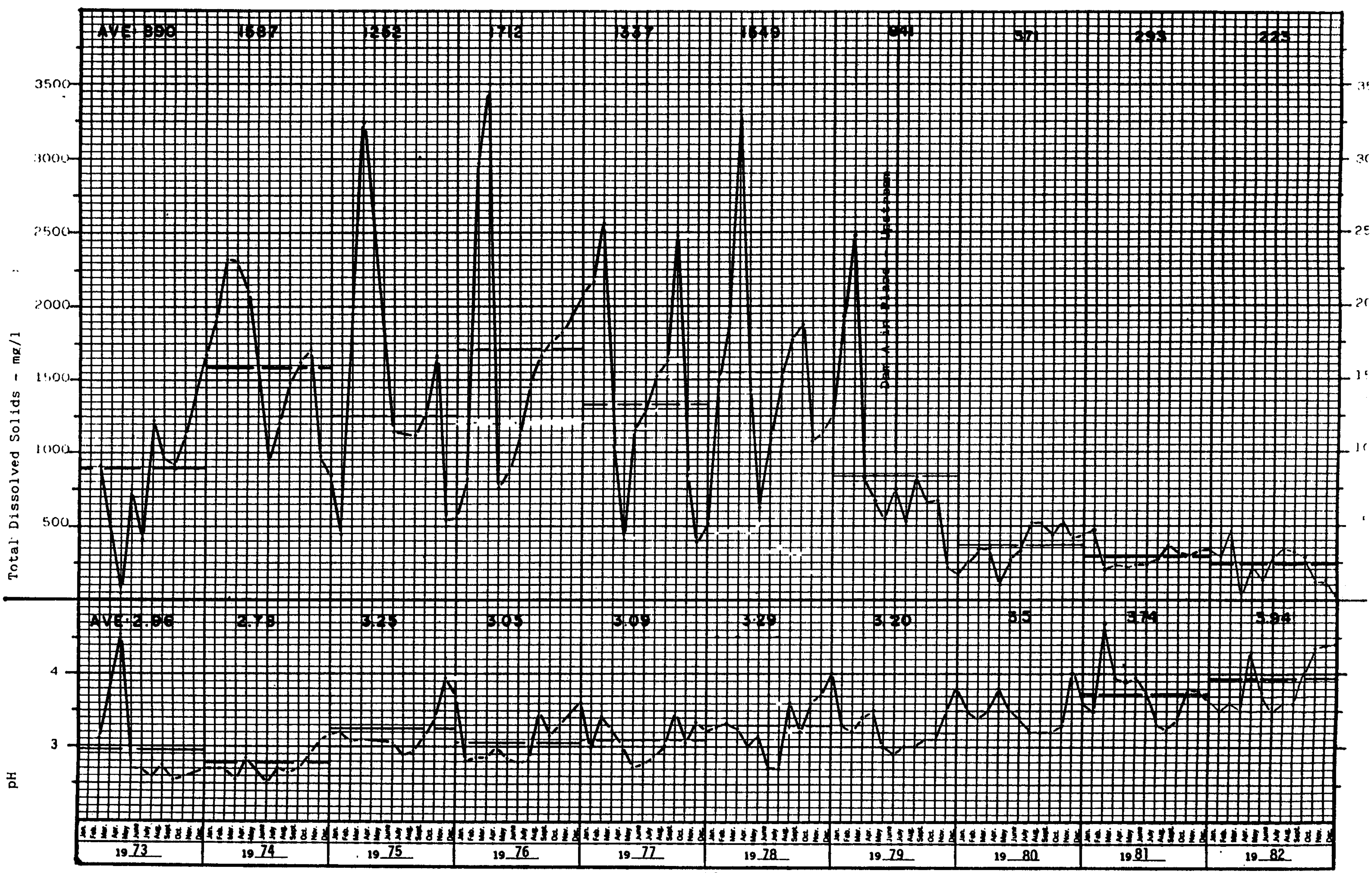
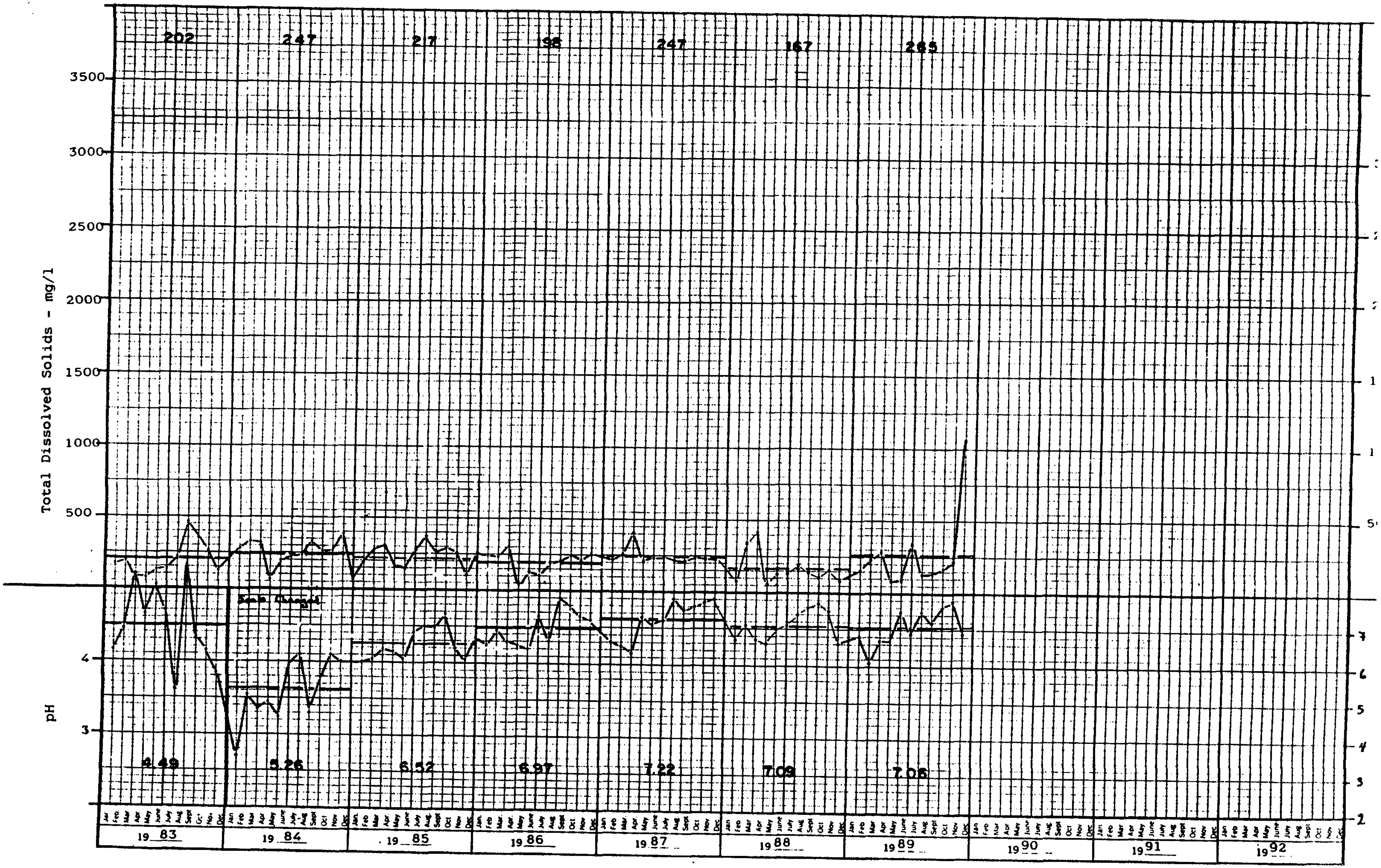


Fig 2. • Sampling sites



P-3 Parel - Beaver Pond #3 Outlet

Fig 3a.



P-3 Panel - Beaver Pond #3 Outlet

Fig 3b.

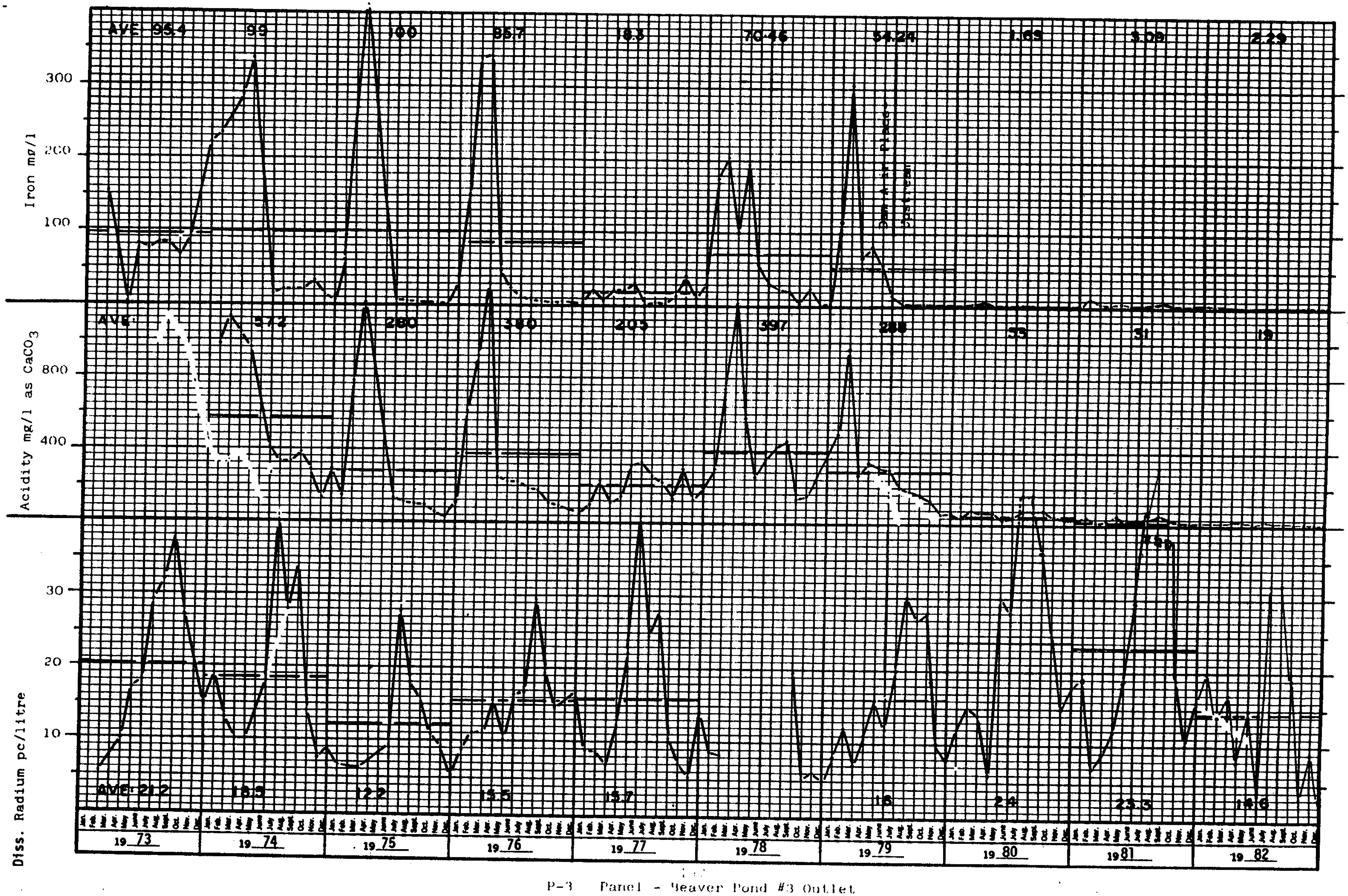
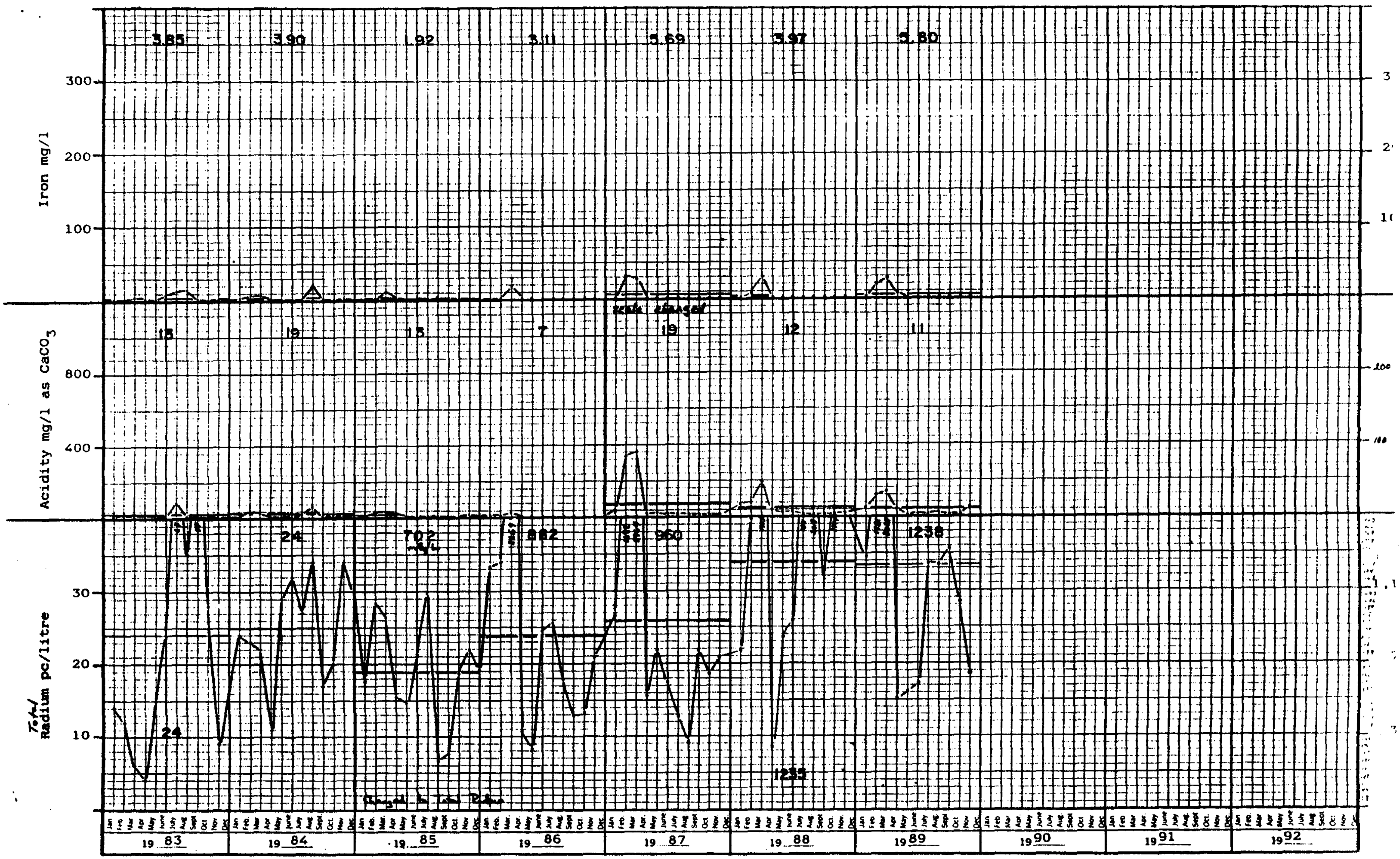

Iron mg/l
Acidity mg/l as $CaCO_3$
Diss. Radium pc/litre
AVE
P-3 Panel - Beaver Pond #3 Outlet

Fig 4a.



P-3 Panel - Beaver Pond #3 Outlet

Fig. 4b.

Ontario

APPENDIX B

Office of the Minister

Bureau du Ministre

Ministry of
Northern Development
and Mines

Ministère du
Développement du Nord
et des Mines

(705) 670-7011
Fax (705) 670-7013

159 Cedar Street
7th Floor
Sudbury, Ontario
P3E 6A5

159, rue Cedar
7e étage
Sudbury (Ontario)
P3E 6A5

Log No: X91-03701

FSB File No: ELL 224

January 3, 1992

Dr. Irwin Itzkovitch
Canadian Centre for Mineral
and Energy Technology
555 Booth Street
Ottawa, Ontario
K1A 0G1

Dear Dr. Itzkovitch:

I am pleased to inform you that the Ministry of Northern Development and Mines will provide financial assistance to the Panel Dam "A" Site Wetlands Evaluation Project on a 50/50 cost sharing basis with your organization to a maximum of Twenty-two Thousand Five Hundred and Thirty dollars ($22,530.00). These funds will be committed from the Ministry's Abandoned Mine Hazard Program for use on surface and sub-surface hydro-geochemistry assessments.

Agreements outlining the Terms and Conditions of this project are attached. Should you find these agreements to your satisfaction, please have both copies signed and returned to:

Gordon McAusland
Ministry of Northern Development and Mines
Mineral Development and Rehabilitation Branch
159 Cedar Street, 4th Floor
Sudbury, Ontario P3E 6A5.

An advance payment of $16,900.00 will be issued upon receipt by the Ministry of these signed Terms and Conditions.

Dr. Irwin Itzkovitch January 3, 1992

I would like to thank you and your organization for your continued co-operation and dedicated support in this very important project.

Yours sincerely,

Shelley Martel
Minister

THIS AGREEMENT made in duplicate as of January 9, 1992;

B E T W E E N:

HER MAJESTY THE QUEEN in right of Ontario as represented by The Minister of Northern Development and Mines (hereinafter called the "Crown")

A N D:

CANMET
Canadian Centre for Mineral and Energy Technology
555 Booth Street
Ottawa, Ontario
K1A 0G1
(hereinafter called "the Grantee")

WHEREAS the Grantee proposes to conduct a study to establish if the existing wetlands and water cover provide treatment and control of water quality parameters associated with the oxidation of pyritic tailings and migration of contaminants at the Panel Dam "A" site.

AND WHEREAS the Crown wishes to contribute towards the costs of this study.

NOW THEREFORE in consideration of mutual promises and agreements contained in this Agreement and other good and valuable consideration, the parties agree as follows:

1. <u>Definitions</u>

In this Agreement, unless there is something in the subject matter or context inconsistent therewith, the expressions following shall have the meanings below:

(a) "Project" means to carry-out the preliminary survey and gathering of information/documentation as set forth in the Project Description attached hereto as Schedule "A";

(b) "Eligible Project Costs" means the actual cost of carrying out the Project limited to the categories set out in Schedule "B"; subject to approval of the Crown prior to the actual expenditures being made. Eligible Costs are limited to those which are reasonable and which relate directly to the Project. The Grantee shall as far as practical take all trade discounts, rebates, refundable taxes and duties, credits, commissions and allowances. Such benefits lost through fault or neglect of the Grantee are excluded from Eligible Costs.

2. Project

The Grantee shall carry out and complete the Project no later than March 13, 1992, in an economical and businesslike manner.

3. Grant

3.1 The Crown shall give to the Grantee a grant of up to a maximum amount of $22,530.00, subject to the terms and conditions in this Agreement, for 50 percent (50%) of the actual expenditures on Eligible Project Costs.

3.2 The grant funds are intended for and shall be used only for the Eligible Project Costs, without written amendment to this Agreement.

3.3 In no event will the Crown be responsible for making any contribution to any cost overruns related to the Project.

3.4 The grant is intended to be in addition to the Grantee's contribution of up to $22,530.00 for 50 percent (50%) of the actual expenditures on Eligible costs.

4. Default

4.1 In the event of default of any of the terms and conditions in this Agreement by the Grantee, or if an event of default under Article 4.2 occurs, the Crown at its discretion may recover any funds advanced and refrain from making further payments.

4.2 The following constitute events of default:

(a) the Grantee becomes bankrupt or insolvent, goes into receivership, or takes the benefit of any statute from time to time in force relating to bankrupt or insolvent debtors;

(b) an order is made or resolution passed for the winding up of the Grantee, or the Grantee is dissolved;

(c) in the opinion of the Crown, the Grantee ceases to operate;

(d) the Grantee has submitted false or misleading information to the Crown, or makes a false representation in this Agreement;

(e) in the opinion of the Crown, there is a material adverse change in risk;

(f) in the opinion of the Crown, the Grantee fails to meet a term or condition of this Agreement;

(g) in the opinion of the Crown, the Grantee has failed to proceed diligently with the Project, except where such failure is due to causes which, in the opinion of the Crown, are beyond the control of the Grantee.

5. Payment

5.1 The Crown shall reimburse the Grantee for actual expenditures on the Eligible Project Costs, up to but not exceeding the maximum amount set out in Article 3.1.

5.2 Upon execution of this Agreement the Crown shall advance to the Grantee, $16,900.00. The remaining $5,630 will be advanced pending acceptance of a final report.

5.3 Upon conclusion of the Project, but no later that the 27th day of March, 1992, the Grantee shall submit to the Crown a statement of account certified by a person with signing authority for the Grantee setting out the following:

(i) the actual expenditures on Eligible Project Costs incurred;

(ii) total payments received to date;

(iii) balance due to Grantee or to the Crown

5.4 Upon acceptance by the Crown of the final statement of account required under Article 5.3, and the final report required under Article 6.3, the Crown shall pay to the Grantee the outstanding balance owing to the Grantee under this Agreement, if any.

5.5 The balance owing to the Crown if any, shall be paid by the Grantee by cheque payable to the Treasurer of Ontario and the said cheque shall accompany the final statement of account required under Article 5.3.

5.6 All statements of account required under this Agreement shall include a statement confirming all expenditures on Eligible Costs were made in accordance with this Agreement.

5.7 The Grantee shall give reasonable notice to the Crown if during the Project, funding is or is likely to be secured from other sources, or the actual amount payable is likely to be lower than the amount set out in Article 3.1.

5.8 All expenditures on Eligible Costs shall be made using the grant from the Crown on an equal (50 - 50) basis.

5.9 The provisions under this Article survive the expiration or termination of this Agreement.

6. <u>Monitoring</u>

6.1 The Grantee shall maintain financial records and books of account respecting the Project in accordance with generally-accepted accounting procedures. These financial records and books of account may be inspected by the Crown and its agents, and the Provincial Auditor, both during and following the term of this Agreement. This provision survives the expiration or termination of this Agreement for a period of four (4) years.

6.2 The Grantee shall submit to the Crown, five copies of a draft report on the project no later than February 2, 1992, satisfactory to the Crown.

6.3 Upon conclusion of the Project but no later than March 27,1992 the Grantee shall submit to the Crown eight copies of the final report on the Project, satisfactory to the Crown in scope and detail. Included in the final report will be a one page abstract highlighting the scope, results and conclusions along with two photographs with negatives representative of the project for the use of the Crown.

6.4 The Crown, its agents and employees, shall be allowed access to the Grantee's premises and to the Project site to inspect and assess the progress and results of the Project.

6.5 The Grantee shall supply, on request, such information in respect of the Project and its results as the Crown may require for the purpose of monitoring the Project.

6.6 The Grantee shall notify the Crown as soon as possible in the event that it becomes aware of actual or possible delays or inability to complete the Project.

6.7 The Grantee shall provide to the Crown all documents required in accordance with Schedule "A" to the satisfaction of the Crown.

7. Indemnity

7.1 The Grantee shall both during and following the terms of this Agreement indemnify and save harmless the Crown, from all costs, losses, damages, judgements, claims, demands, suits, actions or other proceeding in any manner based upon, occasioned by or attributed to anything done or omitted to be done by its officers, directors, partners, employees, agents or volunteers, in connection with anything purported to be required to be provided by or done be the Grantee pursuant to this Agreement or otherwise in connection with the Project.

8. Compliance with Laws and with Insurance

8.1 The Grantee and its employees and representatives, if any, shall at all times comply with any and all applicable federal, provincial and municipal laws, ordinances, statutes, rules, regulations and orders in respect of the performance of this Agreement.

8.2 The Grantee shall obtain, at its own expense, all permits from public authorities which may be required in connection with the performance of this Agreement, and to comply with all municipal, provincial, federal and other public laws, statutes, ordinances and requirements in regard to the same.

8.3 The Grantee shall comply with all provisions and requirements of any insurance policies taken out in respect of the work, and with all rules and regulations concerning safety and the proper conduct of the work.

9. Information and Acknowledgement

9.1 The grant shall be acknowledged by the Grantee on all reports, press releases, public statements, and publications pertaining to the Projects. Such statements shall not imply endorsement by the Crown of any product or process.

9.2 Subject to the Freedom of Information and Protection of Privacy Act, 1987, all information pertaining to this grant, is public information and may be released to third parties upon request.

10. Notice

10.1 Any Notices to be given, and all reports and statements of account, and correspondence, under the provisions of this Agreement, shall be in writing and shall be given by personal delivery, prepaid registered mail, or courier service, and subject to change by either party with written notice, shall be addressed as follows:

To the Crown:

Deputy Minister
Ministry of Northern Development and Mines
159 Cedar Street, 7th Floor
Sudbury, Ontario
P3E 6A5

To the Grantee:

Dr. I. Itzkovitch
Director, Mineral Sciences
CANMET, Energy, Mines and Resources Canada
555 Booth Street
Ottawa, Ontario
K1G 0G1

10.2 Notice shall be deemed to have been effectively given on the date of personal delivery or delivery by courier service, or in case of service by registered mail five (5) days after the date of mailing.

11. Ownership

The Grantee shall not alter the ownership, financing, location, cost, scope, content, objectives or timing of the Project, or permit or cause any other material change to the Project, without the prior written consent of the Crown.

12. Assignment

The Grantee shall not assign this Agreement, nor any part thereof, without the prior written approval of the Crown. Such approval may be withheld by the Crown in its sole discretion or given subject to such terms and conditions as the Crown may require.

13. Third Parties

The Grantee shall take reasonable measures to ensure that its officers, directors, partners, employees, agents and subcontractors shall be bound to observe the provisions of this Agreement. The Grantee shall include in any subcontract terms similar to and not less favourable to the Crown than the terms of this Agreement to the extent that they are applicable to the work subcontracted.

14. Grant Only

This Agreement is a contract for a grant only and nothing in it or done pursuant to it, is to be construed as constituting the Grantee as the Crown's agent, employee, or partner.

15. Entirety and Amendment

15.1 All terms and conditions of Schedule "A" and "B" are incorporated into this Agreement except where they are inconsistent with Articles 1 to 22.

15.2 This Agreement, including the attached Schedules, embodies the entire Agreement between the Grantee and the Crown with respect to its subject matter and supersedes any previous understanding or agreement, collateral, oral or otherwise, between them in the event of conflict.

15.3 This Agreement may be amended only by written agreement between the parties.

16. <u>Waiver</u>

The failure by the Crown to insist in one or more instances upon the performance by the Grantee of any of the terms or conditions of the Agreement shall not be construed as a waiver of the Crown right to require future performance of any such terms or conditions, and the obligations of the Grantee with respect to such future performance shall continue in full force and effect.

17. <u>Force Majeure</u>

A party hereto shall not be responsible for failures in performance resulting from matters beyond the reasonable control of such party, including acts of God, riots or other civil insurrection, war or strikes and lockouts.

18. <u>Invalidity of Provision</u>

The Invalidity or unenforceability of any provision of this Agreement or any covenant in it shall not affect the validity or enforceability of any other provision or covenant in it and the invalid provision or covenant shall be deemed to severable.

19. <u>Applicable Law</u>

This Agreement shall be governed by and construed in accordance with the laws of the province of Ontario.

20. <u>Interpretation</u>

20.1 Headings are not to be considered part of this Agreement, and are included solely for convenience and are not intended to be full or accurate descriptions of the content of the paragraphs.

20.2 In this Agreement, words importing the singular number include the plural and vice versa, words importing the masculine gender include the feminine and neuter genders; and words importing persons include individuals, sole proprietors, corporations, partnerships, trusts and unincorporated associations.

21. Time of Essence

Time is of the essence in the performance of the obligations under this Agreements.

22. Term

These Terms and Conditions shall be used for work commencing November 14, 1991 and terminating March 13, 1992.

Dated at Ottawa this 9th day of January, 19 92)

J.B. [signature]

Witness

[signature]

on behalf of the Grantee

Schedule "A"

Project Description

1.0 Introduction

The services to be performed by the Grantee shall adhere to these Terms of Reference, except as amended in writing by the Crown. This study is part of a comprehensive inventory and evaluation of hazards existing on active/inactive mining properties.

1.1 The Ministry

The Ministry empowered with the legislative responsibility for the Mining Act is the Ministry of Northern Development and Mines. Specifically, the Mineral Development and Rehabilitation Branch has spearheaded the drafting of the changes to the Act and the ongoing process to develop the necessary supporting regulations.

1.2 Background

The Panel "A" Wetland site is located South East of the Panel tailings and immediately east of Dam "A". It has an area of approximately 16ha and is located in a valley which drains towards the south-east. During initial operation of the Panel Mine, tailings were spilled in the western part of the basin which forms part of the substrate now approximately 15-30cm in depth with 5-10cm oxidized layer. With the exception of some exposed tailings flats, mostly in the eastern section, the whole basin consists of a lush green wetland vegetation containing cattails, sedges and moss. Cattails are dominant in the shallow water with mosses and sedges as the main species growing on saturated tailings. The whole basin is water logged and contains ponded water deeper than 30cm in the middle where no emergent vegetation was growing. There is some water flow through the area and most of the area is water saturated.

The littoral zone is up to 20cm thick in areas but the decayed organic layer is shallow up to 3cm in depth. The maximum depth of the root zone is 20cm.

A preliminary water quality survey in 1989 revealed a drastic improvement in pH from 3.6 to 6.6 and electrical conductance "Ec" from 1100 to 260 es, as it moved from the exposed western section to the eastern water logged area. In summer and fall 1990 the water quality parameters were respectively pH 4.4 - 8.1 and Ec 185-1272. These trends are consistent with the improvement in the water quality after the completion of Dam "A" in 1979.

1.3 Objectives

The objective of the study is to establish if the existing wetlands and water cover provide treatment and control over water quality parameters associated with the oxidation of pyritic tailings and migration of contaminants. This will incorporate surface and sub-surface hydro-geochemistry and vegetation and substance characterization for their role in various geochemical and biological interactions.

2.0 Confidentiality of Vendor and Ministry Information

This agreement and all information obtained from the Ministry in connection with this agreement is the property of the Crown in right of Ontario and must be treated as confidential and must not be used for any purpose other than replying to this agreement, and/or for the fulfilment of any subsequent contract.

3.0 Project Scope

The Grantee is expected to provide the following services to the Crown under this agreement:

A) Provide a preliminary survey of surface and groundwater hydrology and flow regimes to establish various surface and ground water components of the total flow and its direction etc. Initial installation to consist of shallow piezometer tests at six locations with three piezometers at each site, at depths of 0.3, 1, 1.5 metres respectively. Estimates of the total inflow and outflow are to be made by channel characterization and wier or flume installation where necessary.

B) Surface water is to be sampled for in situ pH, Eh (redox potential) at prescribed locations. Both surface and porewater samples are to be collected for detailed chemical characterization at the 18 piezometer locations. Samples are to be analyzed for the total dissolved metals: Fe, Al, Ca, Mn, Pb, U, Th, Mg, Cu, Ni, Zn, sulphate (So4-2) and Ra-226.

C) At locations close to the piezometer sites vegetation and soil samples are to be collected and analyzed for total metals and radionuclides as above. Soil samples are to be collected from the surface to 20-30cm in depth, sectioned in two parts, upper and lower, and analyzed. The samples are to be dried and preserved for further mineralogical analyses in the future, if required. Vegetation samples are to be separated according to type ie. cattail, moss and shrub etc., dried and analyzed for metals.

Schedule "B"

Eligible Project Costs

The Ministry of Northern Development and Mines will support the project on a 50/50 cost sharing basis. Eligible project costs for this agreement can be broken down into the following categories:

A) Piezometer installation and flow measurement	$ 6,300
B) Surface and ground water sampling	$ 4,600
C) Chemical Analysis	
Surface water and pore water	$19,440
Soil samples	$ 5,400
Vegetation samples	$ 4,320
Ra-226 analysis	$ 5,000
TOTAL	$45,060

TOTAL MINISTRY COMMITMENT = $22,530.00

Payment of 75% ($16,900.00) will be made upon receipt of a sign copy of this agreement.

HER MAJESTY THE QUEEN
In right of Ontario

-AND-

CANMET

****

A G R E E M E N T

Project/Evaluation of the Wetlands at the
Panel Dam "A" Site

****

Ministry of Northern
Development and Mines
159 Cedar Street
Sudbury, Ontario
P3E 6A5

Energy, Mines and Resources Canada
Énergie, Mines et Ressources Canada

CANMET
Canada Centre for Mineral and Energy Technology
Centre canadien de la technologie des minéraux et de l'énergie

APPENDIX C

REPORT ON THE BACTERIAL ENUMERATION OF TAILINGS POND SAMPLES FROM ELLIOT LAKE

L. Lortie, S. Rajan and W.D. Gould
Environmental Laboratory

Project: 30.14.01
Environmental Research at Elliot Lake

MINERAL SCIENCES LABORATORIES
DIVISION REPORT MSL 92-4 (CF)

REPORT ON THE BACTERIAL ENUMERATION OF TAILINGS POND SAMPLES FROM ELLIOT LAKE

by

L. Lortie, S. Rajan and W.D. Gould

ABSTRACT

The sulphide oxidizing (Thiobacillus ferrooxidans) and sulphate reducing bacteria from 24 Elliot Lake tailings pond samples were enumerated. No clear trends were observed between bacterial numbers and sample location except for Thiobacillus ferrooxidans which occurred in much lower numbers from samples taken below the water table.

Keywords: Acid mine drainage, thiobacillus ferrooxidans, sulphate reducing bacteria.

Environmental Laboratory, CANMET, Mineral Sciences Laboratories, Energy, Mines and Resources Canada, 555 Booth Street, Ottawa, Ontario, K1A 0G1.

ÉNUMÉRATION BACTÉRIENNE D'ÉCHANTILLONS D'UN RÉSERVOIR À RÉSIDUS D'ELLIOT LAKE

par

L. Lortie, S. Rajan et W.D. Gould

RÉSUMÉ

Une énumération du nombre de bactéries oxydant le sulfure (Thiobacillus ferrooxidans) et réductrices du sulfate a été effectuée pour 24 échantillons d'un réservoir à residus d'Elliot Lake. Il n'y a pas de tendance évidente entre le nombre de bactéries et l'endroit d'où provient l'échantillon sauf dans le cas des échantillons pris sous l'eau où le nombre de Thiobacillus ferrooxidans est très petit.

Mots clés: Drainage minier acide, Thiobacillus ferrooxidans, bactéries sulfato-réductrices.

Laboratoire de l'environnement, CANMET, Laboratoire de sciences minérales, Énergie, mines et ressources Canada, 555 Booth, Ottawa, Ontario, K1A 0G1.

OBJECTIVES

To estimate the number of Thiobacillus ferrooxidans and sulphate-reducing bacteria in 24 samples taken from different sites in an uranium tailings reservoir.

To correlate the bacterial populations with the site characteristics in the tailings reservoir.

BACKGROUND

Thiobacillus ferrooxidans (Tf) is well known to catalyze the generation of acid mine drainage into the environment. To be able to do this, this bacterium requires oxygen to be able oxidize sulphide ores such as pyrite and pyrrothite to produce H_2SO_4 and solubilize metals into the surrounding water.

On the other hand, other bacteria have the potential to counteract the effects of Thiobacillus ferrooxidans, but to be effective the absence of oxygen is necessary. These microorganisms are the sulphate-reducing bacteria (SRB), which reduce sulphate to H_2S and precipitate metals as metal sulphides.

These analyses were requested after a reduction in acid mine drainage was observed at the site, probably due to the action of SRB's.

SAMPLES

The 48 samples (24 for Tf and 24 for SRB counts) were taken at various sites in a tailings reservoir at Elliot Lake (refer to Figure 1) and at two depths, 0 to 6" (T= top sample) and between 6 to 12" (B= bottom sample), except for samples dock 5B taken at a depth between 12 to 18", dock 8B between 6 to 14", dock 9T between 0 to 10" and 9B between 10 to 12" for SRB samples and between 10 to 20" for TF samples. They were kept in the refrigerator until completion of the analyses. At the end of the microbial analyses, samples were sent to the ChemLab for total sulphide analysis.

GROWTH MEDIA AND MANIPULATIONS

The medium used to grow Thiobacillus ferrooxidans consisted of 0.0174 g/L of K_2HPO_4; 0.12 g/L of $MgSO_4.7H_2O$; 0.066 g/L of $(NH_4)_2SO_4$ sterilized by autoclaving, and ferrous sulphate 33.34 g/L filter sterilized with 100 mL of distilled water and adjusted to pH 2.5. A 9 mL volume of that medium was dispensed into sterile test tubes and 1 mL of the sample was added with a sterile syringe, then 1 mL was transferred to another test tube always with a new syringe making up 10-fold dilutions up to 10^{-9} with 5 test tubes for each dilution for a total of 45 test tubes per sample. Controls were not inoculated. The test tubes were incubated at room temperature for four weeks before recording the results. A positive result was indicated by a ring of growth of Tf at the top of the medium, by a rusty colour of the medium and by the deposition of oxidized iron. The number of Tf bacteria per gram of tailings was estimated by the most probable numbers method (MPN) for use with 10-fold dilutions and 5 tubes per dilution (Cochran, 1950). The number of positive test tubes for each dilution was counted, then P_1, which is the number of positive tubes in the least concentrated dilution in which all tubes are positive, was selected. P_2 and P_3 represent the number of positive tubes in the next two higher dilutions. According to the table of Cochran (1950), the point of intersection of the three P's correspond to the MPN of microorganisms in the original sample represented in the inoculum added in the second dilution. That number is multiplied by the appropriate dilution factor to obtain the MPN for the original sample.

The medium used to grow the sulphate reducing bacteria is an adaptation of Postgate Medium B (MacLeod *et al.*, 1992). It contains per litre of distilled water: 0.5 g of KH_2PO_4; 1 g of NH_4Cl; 1.0 g of $CaSO_4$; 2 g $MgSO_4.7H_2O$; 2.92 g of sodium lactate (60%); 1.28 g of sodium acetate; 1.0 of yeast extract; 1 mL of resazurin (0.1%). The pH of the medium is adjusted to 7.2 with NaOH (5N).

The medium is then heated and reduced by addition of nitrogen by the Hungate technique (Hungate, 1969) for gassing culture vessels. Once the medium is completely reduced, as indicated by the colour change of the resazurin, 0.5 mL of a reducing agent $Na_2S.9H_20$ (2.5% w/v) per litre of medium is added before its transfer into the anaerobic glove box and 0.5 mL/L is added before dispensing into serum bottles. A 9 mL volume of medium is dispensed into serum bottles containing a nail acting as a reducing agent which are then capped with a rubber stopper before being autoclaved. Five series of 10-fold dilutions, or 45 bottles per sample, were inoculated. When the sample was too thick or too dry to use a syringe, 1 mL of distilled water was added to 1 g of tailings. All the bottles including controls without bacteria were incubated at room temperature in the dark for 4 weeks. A positive result was indicated by the blackening of the medium due to the presence of H_2S produced by the SRB.

RESULTS AND DISCUSSION

From Table 1, no clear trends are obvious with respect to the number of Thiobacillus ferrooxidans in the tailings pond with the exception of the dock samples which have a very low number of Tf's. The section of the tailings pond where the dock samples were taken is under 1-1.5 meters (5 feet) of water which could probably be anaerobic and unfavourable for the growth of Thiobacillus ferrooxidans. The number of Tf's in the other sample locations vary considerably and in some cases, samples from greater depths have a higher number of Tf. The number of sulphate reducing bacteria is always higher than the number of Tf for the dock samples because of the lower oxygen contents of those samples. For all the other samples no correlation exists between the number of SRB and the depth where they were taken. Table 2 represents the amount of sulphate in the 24 samples. Where the amount of sulphate is higher, the number of SRB or Tf is not necessarily higher and the reverse is also true.

CONCLUSION

It appears from the results that SRB are present in all the samples taken at different locations on the site but the number of TF was very low in the samples taken under water. It is obviously useful to maintain the tailings constantly under water to minimize the growth of Thiobacillus ferrooxidans and thus reduce the oxidation of the metal sulphides in the tailings.

REFERENCES

1. Cochran, W.G. (1950), Estimation of bacterial densities by means of the most probable number, Biometrics 6, 105-116.

2. Hungate, R.E. (1969), A roll tube method for cultivation of strict anaerobes, In J.R. Norris and D.W. Ribbons (ed.), Methods in microbiology, Vol. 2. Academic Press, Inc. New York, p. 117-132.

3. Postgate, J.R. (1984), The sulfate-reducing bacteria, 2nd Edition, Cambridge, University Press, Cambridge UK.

4. MacLeod, F.A., Kiff, D.R. and Vosikovsky, O. (1992), Microbially influenced corrosion under disbonded coatings on a line pipe, p. VII-3-1-VII-3-11, In R.W. Revie and K.C. Wang (ed.), Proceedings of the International Conference on Pipeline Reliability, June 2-5, 1992, Calgary, Alberta, Canada.

Table 1. Estimation of bacterial numbers by the most probable number technique

Tailings samples #	Most probable number of Thiobacillus ferrooxidans	Most probable number of sulphate-reducing bacteria
2AT	1.4×10^8	7.0×10^3
2AB	2.3×10^5	2.8×10^3
2BT	7.9×10^2	7.9×10^5
2BB	1.3×10^5	3.5×10^3
2CT	1.3×10^5	3.5×10^5
2CB	1.3×10^5	7.9×10^6
3AT	1.7×10^7	2.8×10^3
3AB	2.3×10^5	7.0×10^3
3BT	7.9×10^3	1.1×10^4
3BB	2.2×10^3	4.9×10^4
3CT	7.9×10^5	2.3×10^3
3CB	2.8×10^5	9.5×10^2
5BT	5.4×10^5	1.1×10^6
5BB	4.9×10^3	3.5×10^2
5FT	7.9×10^3	2.8×10^5
5FB	2.3×10^2	3.3×10^5
5T*	3.3×10^3	3.3×10^3
5B*	2.3×10^1	7.0×10^3
7BT*	4.9×10^1	4.9×10^6
7BB*	4.5	8.4×10^3
8T*	1.3×10^2	4.9×10^6
8B*	2.0	2.2×10^5
9T*	7.8	2.3×10^4
9B*	0	2.2×10^4

* Dock samples

Table 2. Amount of sulphate in the 24 tailings samples

Tailings samples #	SO_4 (%)	Total S (%)	% SO_4-S
2AT	4.61	4.49	34
2AB	7.72	6.61	39
2BT	0.15	0.09	55
2BB	1.86	0.84	75
2CT	0.17	1.46	4
2CB	0.14	2.47	2
3AT	4.28	4.34	33
3AB	3.54	4.06	30
3BT	5.32	4.60	39
3BB	4.75	4.53	36
3CT	11.87	4.79	84
3CB	5.48	5.53	33
5BT	4.65	5.20	30
5BB	8.19	6.68	42
5FT	4.80	5.33	30
5FB	8.00	4.72	57
5T*	14.94	5.55	90
5B*	10.18	6.05	57
7BT*	1.90	1.15	56
7BB*	0.76	0.76	34
8T*	2.29	3.44	22
8B*	0.44	0.39	38
9T*	9.87	5.62	59
9B*	0.30	1.02	10

* Dock samples