LAND TREATMENT OF MUNICIPAL SEWAGE EFFLUENT AT HAYDEN, COLORADO

by

K. A. Barbarick
B. R. Sabey
N. A. Evans

October 1977

COLORADO WATER RESOURCES
RESEARCH INSTITUTE

Colorado State University
Fort Collins, Colorado

Technical Report No. 17

LAND TREATMENT OF MUNICIPAL SEWAGE EFFLUENT AT HAYDEN, COLORADO

K. A. Barbarick
B. R. Sabey
N. A. Evans

Report to

The Northwest Colorado Council of Governments

in fullfillment of

Contract No. PA-TI, EPA Grant No. P-008-096-01-0

October 1, 1977

This report covers the first year of a three-year experimental plot research project on land treatment and disposal of secondary municipal effluent at a high elevation intermountain meadow site.

COLORADO WATER RESOURCES RESEARCH INSTITUTE
Colorado State University
Fort Collins, Colorado 80523

Norman A. Evans, Director

TABLE OF CONTENTS

ACKNOWLEDGEMENTS

The authors would like to thank the Northwest Colorado Council of Governments, the Upper Yampa Water Conservancy District, and the Upper Colorado River Water Conservation District for providing the funding for this research. Appreciation is expressed to Mr. Dutch Williams and family for the use of land and irrigation water for the field study, and to Miss Carolyn Williams for operation and care of the plots. The City of Hayden and the people of the Upper Yampa area were extremely cooperative. Mr. Sam Haslem, Routt County Extension Director; Mr. John Fetcher, Manager of the Upper Yampa Water Conservancy District; and Mr. Ron Janowitz, Professional Engineer with Wright-McLaughlin Engineers, Inc., gave excellent guidance during this project. Finally, we thank Mr. John Tessadri, Miss Cindy Baker, Mr. David Fanning, Mr. Randall Mutters, and Mrs. Patti Jo Barbarick for helping with sample collection and laboratory analyses.

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICIES

I. INTRODUCTION

The waste products that our society produces will require disposal or recycling techinques that minimize contamination of our environment. Among these waste products are sewage sludges and effluents. Every municipality, regardless of size must treat and dispose of or utilize its sewage in some manner. Current alternatives range from secondary treatment involving anaerobic digestion, trickling filtration, aerobic digestion to lagooning and use of polishing ponds or combinations of these. Soil filtration is being considered in many areas as a possible final treatment for effluent before it reaches a stream. For large cities, the more elaborate treatments may be more practical for handling the large volumne of sewage; however, for small treatment plants utilized in rural areas, the possibility of soil filtration as part of the treatment process could be more practical. Bouwer (12) claims that the quality improvement obtained by soil percolation is probably comparable to that obtained by coagulation, sedimentation, carbon adsorption and disinfection.

Many studies have been conducted utilizing land treatment for disposal or recycling of municipal and industrial effluents. The study conducted in Hayden is unique for two reasons. First, only an ongoing study in Wyoming (Personal Communication) has investigated land treatment of sewage effluent in relatively high altitudesof the Rocky Mountain region. Secondly, this study involves application of waste water to mountain meadow type of vegetation (see Table 1).

TABLE 1 - Vegetation species found in the mountain meadow used for land treatment of the polishing pond effluent of Hayden, Colorado

Red Clover (*Trifolium pratense*)

Orchard Grass (*Dactylis glomerata*)

Timothy (*Phleum pratense*)

Alsike clover (*Trifolium hybridum*)

Bluegrass (*Poa pratensis*)

Smooth brome (*Bromus inermis*)

Dandelions (*Taraxcum officinale*)

White Clover (*Trifolium repens*)

Sweetclover (*Melilotus officinalis*)

Alfalfa (*Medicago sativa*)

II. OBJECTIVES

The effectiveness of land disposal will depend on the quality and application rate of the sewage effluent and the soil characteristics. Consequently, the objectives of this research are:

1. To determine if the soil can effectively filter the problematic substances from municipal effluent before the filtrate enters streams, lakes, or groundwater. The major concerns will be:
    a. Nitrogen compounds such as nitrates, ammonium, and organic nitrogen.
    b. Phosphorus, potassium, calcium, magnesium, sodium, iron, zinc, copper, manganese.
    c. Total volatile solids, total dissolved solids,
    d. Biochemical oxygen demand (BOD) and chemical oxygen demand (COD).
2. To follow the changes in soil properties created by spray irrigation with sewage effluent.
3. To compare the effectiveness of filtration at different application rates.
4. To investigate the benefits of providing drainage in a "soil filtration" system.
5. To determine if the yields and quality of hay produced by a mountain meadow irrigated with sewage effluent surpass those obtained from irrigation with typical irrigation water.
6. To determine the length of season during which sprinkler irrigation is feasible on mountain meadows.
7. To develop a set of guidelines based on the data obtained from the study and from the existing literature to assist those communities supporting the project to successfully and economically treat the lagoon effluents produced in the area. The guideline should include:
    a. Correlation of the length of irrigation season with different climatic zones in the region.
    b. Guidance on application rates with soils of the area.
    c. Indication of the degree of treatment to be expected with the proposed system.
    d. Indication of the need for drainage tile or subsurface drainage with the proposed system.

III. LITERATURE REVIEW

A. Introduction

As might be expected, land disposal systems provide advantages and disadvantages. If the soil can reduce the concentration of undesirable substances to acceptable levels over a long enough season and over enough seasons many communities will be able to treat their sewage without constructing expensive treatment facilities. Another advantage is that the land used for the disposal of the effluent will have not only a source of water for irrigation but also a source of plant nutrients, thus decreasing fertilizer needs (12,14). One disadvantage is the necessity for storage of effluent during winter months. If the storage period each year is too long, the storage reservoirs will have to be too large so as to be prohibitive. Secondly, the capacity of the soil to remove particular substances may decrease after repeated applications of sewage effluent; therefore, additional land for disposal may be required. The quantity of the land required for disposal of the effluent will depend on the size of the community, the location of the treatment facilities, the quality of the soil and effluent as well as other factors of importance. However, it is anticipated that soil filtration or land utilization of sewage effluent will be beneficial for many rural areas.

If it is found that the soil can effectively reduce the concentration of undesirable substances formed in the sewage effluent from a polishing pond, and if land is available for irrigation, many small communities could implement such a system instead of more elaborate and expensive treatment systems. The owners of the land used for the disposal will obtain a consistent source of water for irrigation and, more importantly, a readily available and inexpensive source of plant nutrients. A soil filtration system that is well designed will "cleanse" the sewage effluent while providing fertilizer for crop production for a considerable number of years.

B. Current Status

Application of sewage wastes to the land to increase crop production has occurred in a number of different areas. Land disposal has been utilized in Australia, England, Israel, Germany and various states in the U.S.A. (28,87).

A majority of the constituents found in the sewage effluent of an average polishing pond do not meet the 1982 EPA standards for surface water quality (14,58). Land application is considered by many as an effective but relatively inexpensive treatment process. The capacity of the soil to handle organic wastes may be determined by criteria discussed by Powers et. al. (59).

C. Macro Elements

Various forms of nitrogen are present in sewage effluent. Ammonium-nitrogen (NH_4^+-N) can be converted to nitrate-nitrogen (NO_3^--N) by nitrifying bacteria (4,5,69).

Soil columns that were intermittently flooded with sewage effluent over different time periods produced interesting results (46,47). A two-day flooding interval followed by five days of drying produced excellent conditions for nitrification (an aerobic process) as indicated by the high nitrate concentration in the filtrate when flooding was initiated again. A 9 to 23-day flooding period followed by five-day drying cycles produced the greatest amount of nitrogen removal from the soil(e.g. by denitrification -- an anerobic process) (46,47,48,70,86).

Another study indicated that NO_3^--N leaching predominated early while nitrogen removal occurred later in the determination in a saturated environment (76). However, flooding periods greater than two days for most irrigated crops situations are impractical. Consequently, nitrate contamination is possible if nitrogen loads are greater than plant needs and the denitrification potential.

Andrews and Troemper (1) discovered that samples from drainage tiles contained average monthly NO_3^--N levels of 14.3 mg/1 after sprinkler irrigation with liquid sewage sludge. This level is higher than the recommended standard for drinking water (80).

Water hyacinths growing in ponds of secondary sewage effluent were found to be effective in removing nitrogen and phosphorous. The nitrogen and phosphorous removal was directly correlated to the surface area of the treatment ponds (27). Sutton and Ornes (73) reported that 97% of the P in secondary sewage effluent was removed during the growth of duckweed in static waste water.

Due to precipitation, adsorption, and plant uptake, the soil is effective in removing phosphorus. A number of studies showed that 96-99% of the phosphorus in wastewater was initially removed by soil filtration (1,7,76). Kardos and Hook (44) showed that higher concentrations of phosphorus in soil water samples were found at 15,60 and 120 cm in soil irrigated with secondary sewage effluent. However, all concentrations were less than 1 mg/l, and no site had leaching losses greater than 3% of the P applied. Attempts have been made to relate the movement of P from waste water to the fraction of clay size material present at the disposal site (61) and to the sorptive capacity of the soil (34,64).

The negative sites on mineral (clay particles) and organic colloids (humus particles) commonly found in soils provide electrostatic attraction for the positive cations such as K^+, Na^+, Ca^{2+}, and Mg^{2+}. This adsorption process reduces the mobility of these cations and the soil serves for a period of time as an effective filter of these common constituents in effluents even though cations can still be found in the filtrate (41). If the exchangeable (adsorbed) sodium percentage becomes too high, the percolation rates of the soil will be greatly reduced since Na^+ disperses clay particles (36,41,50,72). This dispersion could reduce the life-time of the "soil filter".

Most effluents contain relatively high concentrations of dissolved solids (salts) (16). Laboratory studies (3,22,35) have been conducted to monitor solute movement through soils and accumulation in different horizons. Bresler (19,20) has developed mathematical models that effectively predict the behavior of salts in soils. These studies could provide the background for predicting the effective lifetime of a land disposal system.

Even though the soil does provide an excellent filter for most problematic substances in municipal effluent, reduction in chemical concentrations found in ground water samples could be the result of dilution. Purtynam et.al.(60) found that reduction in salts, hardness and various cations and anions could be attributed solely to dilution by a shallow aquifer.

D. Trace Elements and Heavy Metals

A wide range of trace element and heavy metal concentrations can be found in municipal and industrial effluents. These elements include Fe,Cu,Co, Mn, Zn, Cd, Ni, Mo, Pb, Hg, and B, most of which can be toxic to plants at high soluble concentrations. These contaminants are adsorbed by the reactive soil particles, precipitated as hydroxides, carbonates, oxides, sulfates, or phosphates or adsorbed by plants (45,50,51). The trace elements and heavy metals as a general rule are effectively removed within the top soil (49). However, most of the trace elements are relatively soluble and therefore mobile under acidic soil conditions (37,38, 50,51). Sidle et.al (67) found that no serious accumulation of heavy metals on soils irrigated with secondary sewage effluents for a period of 10 years in Pennsylvania.

E. Plant and Food Chain Effects

The toxic constituents of greatest concern in sewage effluent that could be absorbed by plants are the trace elements. Those elements that pose potential hazards to the food chain include B, Cd, Co, Cr, Cu, Hg, Ni, Pb, and Zn (14,23). Chaney (23) feels that Cd, Cu, and Zn could provide a significant hazard to the food chain while Chumbley (26) expresses the hazard of Zn, Cu, and Ni as the zinc equivalent (ZE) where

$$ZE = 1(Zn) + 2\ (Cu) + 8(Ni)$$

the concentrations are expressed in ppm. The ZE should be maintained at less than 250 ppm (26).

Chaney (23) contends that only an effort to develop perennial grasses that would exclude toxic elements appears reasonable. Past work in which honeysuckle, reed, canarygrass and sea myrtle were irrigated with food processing wastewater (53) and Bermudagrass was irrigated with secondary sewage effluent (49) indicates that grasses are relatively tolerant of the concentrations of trace elements commonly found in wastewater and that greater yields are obtained using the effluent. Utilization of sewage effluent on crops where trace metals could be concentrated in edible portions must be thoroughly scrutinized. Bean, barley, and tomato plants grown in sand culture and irrigated with aqueous sludge extracts contained excessive to toxic levels in leaf samples of B, Cu, Mo, Ni, Co, Pb, and Cd (16). Various forest species showed no increase in the Cd concentration of the foliage on sites irrigated with secondary sewage effluent for 10 years at Pennsylvania State University (66). Trace metal accumulations in soils were found to be greater on sites growing reedcanary grass than on areas growing corn (65).

Irrigation with secondary sewage effluent can often influence the yield and quality of some small grains. Wastewater was found to produce a higher moisture content in oat forage (30); higher wheat hay yields, amino acid content and total fiber (31); and higher wheat grain yields and more total protein (32). Consequently, crops irrigated with waste water may accumulate trace metals, but beneficial changes in crop quality may also occur.

F. Management of Mountain Meadows

Plant uptake of various trace metals and the quantity and quality of crops produced by irrigation with secondary sewage effluent is of major concern. Since a mountain meadow type vegetation grew on the study area, a number of hay quality parameters are of interest.

Mountain Meadows in the Rocky Mountain area are commonly harvested as a hay crop. The type of vegetation commonly found in these meadows and on our study site is listed in Table 1.

A number of management procedures can influence the yield and quality of mountain meadow hay. Sprinkler irrigation has been found by Rouse et. al. (62) to be more economical with respect to the amount of water used than various methods of flood irrigation. They also showed that intermittent irrigation with no applied nitrogen encouraged the growth of clover species with a corresponding increase in the crude protein content of the hay. Miller et. al. (54) also found that phosphorus fertilization had no effect on species composition; but, grasses were encouraged by late harvest and nitrogen fertilization. The work of Wilhite et. al. (88) indicated that 360 Kg of nitrogen per hectare increased the crude protein of the hay crop. This nitrogen application rate also resulted in elimination of most of the clover. Application rates of 45 to 90 Kg of nitrogen per hectare resulted in decreased protein content of the hay. Drainage tiles and the composition of the sewage effluent of Hayden could influence species composition on our study site.

Campbell and Dotzenko (21) and Thompson (76) found that easily determined hay quality parameters could effectively be used to predict the *in vitro* dry matter digestibility of forage samples collected in Colorado. Determination of these parameters will help determine the influence of sewage effluent on the quality of the mountain meadow hay.

G. Biological Aspects

According to Miller (55), the biological component of soils is of extreme importance in providing and maintaining the filtering aspects of soils. He states that microbes contribute significantly to the following five areas:

1. Decomposition of organic matter.
2. Detoxification of potentially hazardous organic substances (e.g., pesticides and detergents).
3. Removal of pathogenic organisms.

4. Participation in the nitrogen, phosphorus, and sulfur cycles.

5. Influence on the solubility and mobility of inorganic ions.

Most pathogenic organisms have been found to be retained by the top few cm. of soil (55). Andrews and Troemper (1) discovered that 99+% of the BOD_5, suspended solids and fecal coliform were removed before the waste water percolated into drainage tiles. Similar results were found in the Netherlands (7).

Before pasturing of alfalfa sprinkler irrigated with municipal effluent, 10 hours of bright sunlight was required to remove fecal coliforms on the plants (8). With reed canarygrass, 50 hours of bright sunlight provided the bacteriocidal effects required (9).

High wind velocities were found to carry bacterial aerosols to at least 192 m from a sprinkler (68). The authors implied that secondary sewage effluent should be chlorinated before sprinkler irrigation.

The fate of certain viruses when applied to the soil is not well understood. Bitten et.al. (11) found that waste water acts as a good desorbent of viruses held on soil particles. This phenomenon is believed to be caused by the interaction of organic material in the effluent, the viruses (Bacterial phage T_2 and poliovirus type 1 in this study) and the soil solids.

H. Physical Parameters

Continuous application of sewage effluent can alter a number of physical properties of the soil. As mentioned earlier, high Na^+ concentrations can produce infiltration problems. Effluents that contain a relatively high load of organic substances could clog soil pores and reduce aeration and infiltration. But drying helps rectify the situation. Also, Jones and Taylor (43) found that soil clogging under effluent loading occurs 3 to 10 times faster under an anaerobic than an aerobic environment. Consequently, by providing adequate drainage and proper application rates (e.g. those used for efficient crop production), the physical attributes of the soil can be maintained. These parameters are essential in developing treatment designs.

I. Treatment Designs

Bouwer (14) has described three systems for soil filtration of conventionally treated sewage. These are:

1. High rate systems with wastewater renovation as the objective.
2. Low rate systems with application rates of 2.5 to 10 cm/week as the goal (e.g. for crop irrigation).
3. Combination of the above with irrigation and renovation as the major objectives.

The following hydrologic factors should be considered in the design for land treatment systems for liquid wastes (13):

1. Infiltration rate.
2. Groundwater table fluctuation with infiltration.
3. The effect of system design and management on quality of renovated water.
4. The control of underground movement of renovated water below the water table.

The final design of a land disposal treatment system must include design application rates, quality improvement and longevity desired, the most appropriate system for application, and the groundwater management below the receiving fields (13). The recommended depth of soil that the effluent should percolate through is at least 120 cm of soil (36). Other precautions concerning pathogens and odors may be needed before a land disposal system can be acceptable to many.

J. Collection Devices

In order to monitor the quality of leachate percolating through the soil, collection devices at different soil depths are needed. The most common type of extractors utilized involve porous ceramic cups or candles (33,39,40). A number of precautions and calibrations should be completed before the cups are inserted into the soil. Hansen and Harris (39) have found NO_3^--N concentrations with up to ±30% variation from the mean in samples that were not pretreated or calibrated. These devices, however, still serve as the most acceptable method for sampling leachate at different soil depths.

IV. Site Description and Experimental Design

A. Site Description

A mountain meadow situated west of the Hayden, Colorado sewage treatment lagoons was employed for this field study. The land is owned by Mr. Dutch Williams of Hayden. The meadow is situated on a first terrace or bench along the Yampa River. The soil profile consists of a dark brown silty clay loam to a mottled grey-brown silty clay. A gravel lens is encountered at a depth of 1.5 to 2.0 meters. This soil presently has not been classified according to the Soil Conservation Service system.

The water table fluctuated between 60 and 200 cm. in the study site. The poor drainage caused the mottled soil colors observed in the soil profile.

Sewage effluent from the Hayden polishing lagoon and ditch water from the Yampa River were used to irrigate the plots. Hayden is a town with an elevation of 6375 feet (1944 m) and a population of approximately 1000. Farming, ranching and coal mining serve as the main industries of the area. Sewage originates from homes and service-oriented businesses within the city limits. No source of potentially hazardous material appears to contribute to the municipal sewage. Characteristics of the sewage effluent and ditch water are presented in Table 4.

Table 2 -- Range of values for irrigation water characteristics

Parameter	Sewage Effluent	Ditch Water
$ECx10^3$ electrical conductivity	0.51-0.91	0.13-0.39
ppm Na	42-100	15-46
ppm K	4.6-7.9	1.2-3.5
ppm Ca	54-73	24-30
ppm Mg	29-50	8-25
ppm P	2-4.4	.03-.28
NO_3^--N ppm	.1-14.0	.9-2.1
NH_4^+- N ppm	1.4-6.0	.8-3.6
BOD mg/l	9-18	1-3
COD mg/l	25-85	10-23
Fecal Coli	200-77,000	10-2600
Total Coli	8200-90,000	62-6000
Fecal Strep	0-1700	0-1000

B. Experimental Design

Nine 15m x 15m plots were constructed with the following treatments:

Plot 1: Receives one 2.5 cm application from the polishing pond and no subsurface drainage is provided.

Plot 2: Received one 2.5 cm application per week of irrigation ditch water and no subsurface drainage is provided.

Plot 3: Receives two 2.5 cm applications per week of irrigation ditch water and no subsurface drainage is provided.

Plot 4: Receives two 2.5 cm of sewage effluent per week, and no subsurface drainage is provided.

Plot 5: Control plot which receives no treatment.

Plot 6: Receives two 2.5 cm applications per week of irrigation ditch water and a subsurface drain about 75 cm deep provides drainage.

Plot 7: Receives one 2.5 cm application per week of irrigation ditch water and a subsurface drain about 75 cm deep provides drainage.

Plor 8: Receives one 2.5 cm of sewage effluent per week and a subsurface drain about 75 cm deep provides drainage.

Plot 9: Receives two 2.5 cm applications per week of sewage effluent, a subsurface drain about 75 cm deep will be used for drainage.

Plots 1, 2, 3, 5, 9 are similar to those established on a research project at Steamboat Springs in 1974 (89), while plots 4, 6, 7, 8 will be utilized so that adequate treatments are completed to give the following comparisons:

1. Drainage vs. no drainage.
2. Irrigation ditch water vs. sewage effluent.
3. One 2.5 cm irrigation vs. two 2.5 cm irrigations per week.

This will simulate the low application rate system discussed by Bouwer (12). The diagrams of the plot layout, irrigation system, and location of extractors are provided below. The general layout of the plots is shown in Figure 1 .

C. Sampling Scheme

Soil samples were collected two times. The first sampling was obtained before the treatments were initiated; the second sampling occurred in spring 1976.

Composite soil samples were taken from 3 different depths in each plot. Determinations of pH, salts, total N, NO_3-N, NH_4^+-N, P, K, Na, Ca, Mg, B, Mn, Fe, Cd, Zn, Cu, and Ni were completed. (See Section VI C. materials and methods)

Water samples were taken nine times (2 samples/month) during the irrigation season. When possible, each water sample was analyzed for total N, NH_4^+-N, NO_3^--N, P, K, total dissolved solids, total volatile solids biochemical oxygen demand, and chemical oxygen demand (see Section VI A. materials and methods)

Plant samples were harvested from each plot. Dry matter yields and determinations for total N, NO_3^--N, P, K, and Cd, Zn, Cu, and Ni were made. Also, a number of quality parameters were determined on the hay samples. (See Section VI B. materials and methods)

All of the resulting data were analyzed statistically to indicate significant differences and trends in the treatments established on the nine plots. However, since each treatment was not completely replicated (due to financial and physical limitations), the statistical tests are not reliable indicators of differences between treatments. If non-significant

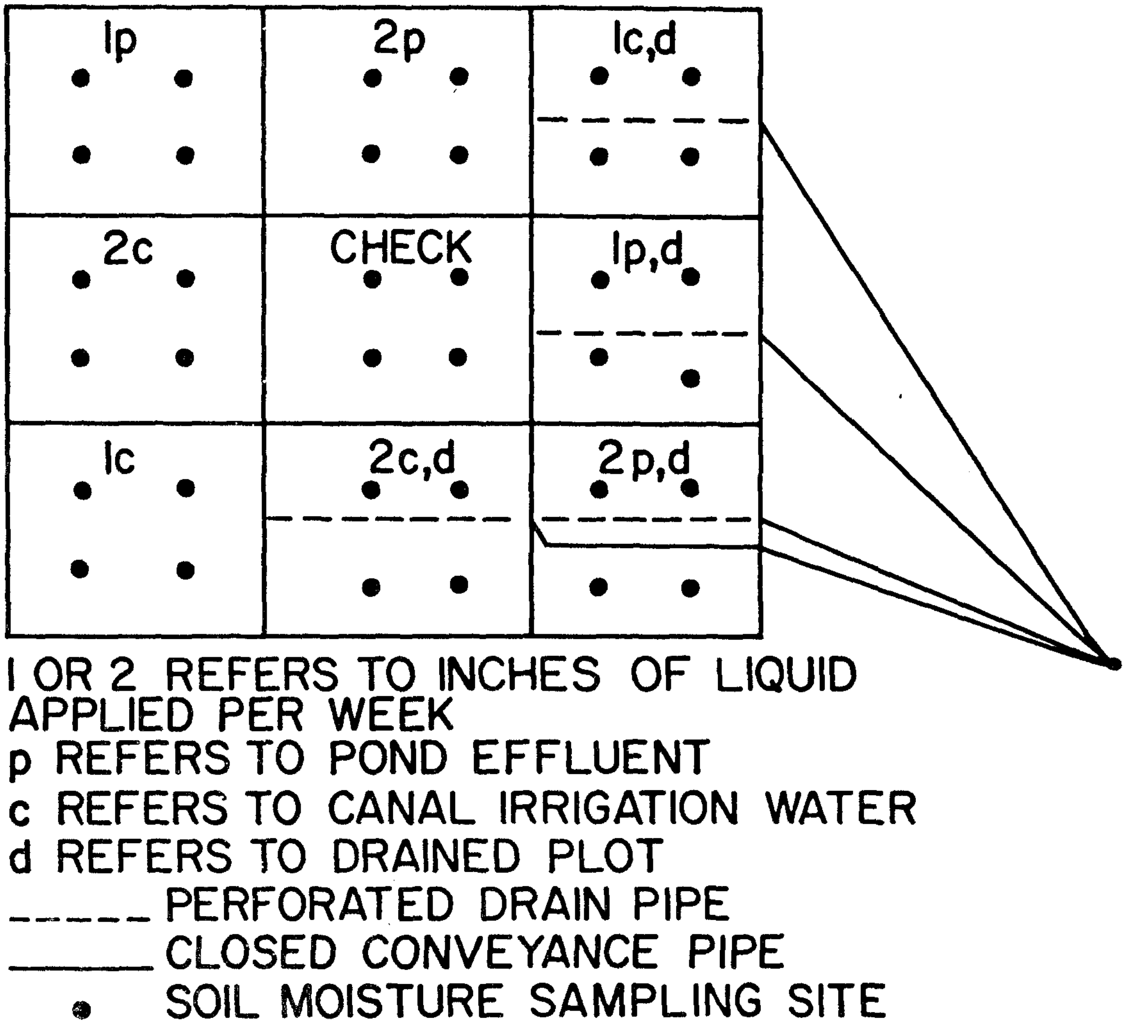


FIGURE · EXPERIMENTAL PLOT LAYOUT

Figure 1 - Experimental Plot Layout

differences are indicated by the statistical test, they would probably remain non-significant even if the treatments were replicated. Significant differences indicated by the tests would be due to both natural variation in the plots and to treatments but the tests cannot determine how much of the difference is attributable to each.

V. MATERIALS AND METHODS

A. Water Analyses

Samples were taken from the ground-water wells, drainage tiles, porus cup extractors, the sewage effluent and the ditch water.

Analyses were generally completed in the order listed below:

1. COD (Chemical oxygen demand in mg/l).
2. BOD (Biochemical oxygen demand in mg/l).
3. Electrical conductivity (mmhos/cm)
4. ppm Cl^- (Chloride)
5. ppm NO_3^--N (nitrate-nitrogen)
6. ppm NH_4^+-N (ammonium nitrogen)
7. ppm Ca^{2+} (calcium)
8. ppm Mg^{2+} (magnesium)
9. ppm K^+ (potassium)
10. ppm Na^+ (sodium)
11. ppm P (phosphorus)
12. Fecal and total coliform bacteria (number per 100 ml)

Analyses 1, 2 and 12 were completed only on ground-water, drainage tile, sewage effluent and ditch water samples. Analyses 3-10 were completed on all samples when possible.

Specific ion electrodes were utilized to measure Cl^-, NO_3^--N and NH_4^+-N (2). Total N was determined by Kjedahl determination (2). A platium electrode in conjunction with a conductivity bridge was utilized to measure the electrical conductivity (2). This determination is an indication of the total salt content of the water samples. Atomic absorption specroscopy was employed to measure Cd^{2+}, Zn^{2+}, Ca^{2+}, Mg^{2+}, K^+, Na^+, Fe, Mn, Cu, and Ni (2). The Murphy Riley colorimetric procedure was used to find the P content (2). COD was determined using the dichromate reflux method, while BOD was determined after a 5-day incubation period as described by standard methods (2). Fecal and total coliform and fecal streptococci were analyzed as described by standard methods (2). M and I incorporated of Fort Collins analyzed the water samples for COD, BOD, fecal and total coliform and fecal streptococci. All other determinations were conducted in the laboratories of the Department of Agronomy at Colorado State University. The water analysis data is listed in Appendix B.

B. Ground Water Levels

The depth from the soil surface to the water level in each ground water was recorded on a regular basis (See Appendix B). The relative elevation of various points in the study area were determined by the Steamboat Springs office of the Soil Conservation Service.

C. Plant Analyses

Five plant samples from the 7.5 x 7.5 m center section were taken from each plot on July 29, 1976. Hay samples were cut using 2-row Jari mowers. A subsample made up of random grab-samples was taken for laboratory determinations. The dry matter yield and percent moisture were calculated after over-drying the plant samples in a forced draft oven for 48 hours. The following analyses were completed on each sample:

a. Dry matter yield
b. Percent plant moisture
c. Percent crude protein
d. Percent cell contents, percent cell wall contents, percent hemicellulose, percent acid detergent fiber
e. ppm total cadmium (Cd), zinc (Zn), copper (Cu), nickel (Ni), iron (Fe), manganese (Mn), magnesium (Mg), calcium (Ca), percent total potassium (K) and percent total Phosphorus(P).

The crude protein content was found by the procedures described by Bremmer (18).

Cell contents, cell wall contents, hemicellulose, and acid detergent fiber represent parameters used to describe hay qualify. Lipids, proteins and other digestible carbohydrates, and water soluble matter comprise the cell contents (82). Acid detergent fiber includes cellulose, lignin and minerals that the plant material contains (81).

Separation of these parameters incorporates digestion of the plant material in the presence of various detergents. A neutral detergent (84) separates the cell contents, which are nutritionally available and soluble, from the cell wall constituents, which are only partially available for animal nutrition. An acid detergent (80) was employed to separate hemicellulose from the acid detergent fiber. Hemicellulose consists primarily of pentoses but also contains other material.

Hemicellulose is generally insoluble, but delignification will cause a large portion to become digestible (83). The digestibility of the acid detergent fiber varies depending upon the amount of lignification.

Total metal contents were determined after the plant samples were digested first in nitric acid and then in a perchloric - sulfuric acid mixture.

Total phosphorus was determined colorimetrically using Barton's reagent (6) while all the metals were found using standard atomic absorption techniques (57).

The data were statistically analyzed using Duncan's multiple range test at the 0.05 significance level (71). This mean separation test helps determine differences between values found for plant samples from various plots. Since each treatment was not completely replicated (due to financial and physical limitations), the statistical analyses were not sensitive enough to indicate true differences between treatments. However, the F values (Table 6-9) illustrate that a non-significant F test would probably remain non-significant with replication. Significant F values *may* indicate some differences between treatments.

D. Soil Analyses

Initial soil samples were taken from the plots on August 4, 1975. The plots were samples in 9 locations to a depth of 90 cm by use of an Oakfield probe. Five probes per plot were composited for each sample. Samples were separated into 0 to 30 cm, 30 to 60 cm and 60-90 cm samples. The soils were then air-dried and crushed to pass through a 2mm sieve.

On April 9, 1977 samples were obtained from each plot following one season of treatment. Three replicate samples were taken from each plot to a depth of 150 cm by use of a truck-mounted Giddings probe. Again, the soils were air-dried and crushed to pass through a 2mm sieve.

All samples were then analyzed for the constituents listed below:

1. pH of a saturated soil paste was measured by use of a pH meter (56).
2. Electrical conductivity (measure of total salt content) of the saturated extract obtained from the saturated soil paste was found by use of a conductivity bridge and platinum electrode (15).
3. Boron content of the saturated extract was analyzed by the colorimetric procedure of John 1975 et al (42).
4. Using atomic absorption spectrophotometry (57), levels of exchangeable sodium (Na), potassium (K), calcium (Ca) and magnesium (Mg) were determined as outlined by (24).
5. Total nitrogen was found by block digestion of samples (74) followed by micro-Kjeldahl distillation (17).
6. After extraction with potassium chloride (KCl), ammonium-nitrogen ($NH4^+$-N) in each soil was found by Kjeldahl distillation. Nitrate-nitrogen (NO_3^--N) was determined by distillation on the same extract following the addition of Devarda's alloy (18).
7. Available phosphorous (P) was measured by the colorimetric procedure developed by Watanbe and Olson (85).
8. Available zinc (n), iron (Fe), manganese (Mn) and copper (Cu) were found by atomic absorption procedures (57) after extraction with diethylenetriamine pentaacetic acid (DTPA) (52).
9. Upon digestion of each soil with 4N nitric acid (HNO_3) for 5 hours at 80°C Bradford et al (15), these soil extracts were analyzed for nickel (Ni), copper (Cu), zinc (Zn) and manganese (Mn) using atomic absorption spechtrophotometry.

After compilation of the soil data, analyses of variance and Duncan's multiple range test at the 0.05 significance level were completed Steel & Torrie, 1960 (71). As described in earlier sections, significant findings may not actually be significant since we were not able to adequately replicate each treatment. However, non-significant differences would probably remain so even if replicated plots were utilized.

VI. RESULTS AND DISCUSSION

A. Water Analysis

The regional groundwater level in the experimental area is governed by the water level in the Yampa River. By mid-July the water table was sufficiently low that adequate volumes of water samples could not be obtained from porous cup extractors at 30 cm. and 60 cm. and occasionally at 90 cm.

Ground water samples taken from all plots generally contained normal levels of the constituents measured (29). Utilizing the 1% and 5% levels to indicate very significant and significant results, respectively, analyses of variance (71) on the ground water samples yielded the following results:

1. The electrical conductivity (EC), chloride (Cl^-), magnesium (Mg^{2+}), and nitrate and ammonium-nitrogen concentrations (NO_3^--N and NH_4^+-N, respectively) showed very significant variation with the date of sampling.
2. The SE caused a significant increase in the Cl^- levels found in the ground water samples.

The ground water data generally indicated that the SE was filtered to concentrations normally found in potable subsurface waters. Samples taken from porous cup extractors generally followed the same pattern that was observed for the chemical values found in the ground water samples. The samples taken from drainage tiles in Plots 6-9 also were similar to the ground water samples.

The water analyses data for each sample is presented in Appendix A.

Figures 2 through 23 show the concentrations found in the ground-water samples and the levels found in the sewage effluent (SE) and ditch water (DW) before application. The graphs marked "undrained" refer to plots with natural drainage while those labeled "drained" indicate plots in which subsurface drainage tiles were installed. The curves marked by symbols relating to the "irrigation source" refers to the concentrations of a given constituent in the sewage effluent (SE) or ditch water (DW) before they were applied to the soil-plant system. To prevent cluttering of each figure, SE concentrations before application will always be indicated on the curves designated "undrained", and DW levels before application are on the "drained" portion of each figure. The SE and DW levels can be compared to the ground water levels on both portions of each figure. This process will allow us to place 3 rather than 4 curves on each portion of a given figure. The graphs marked "plots receiving" indicate the concentrations found in ground water samples in the plots receiving either sewage effluent (SE) or ditch water (DW). The application rates are indicated in the title of each figure. The following discussions are related only to samples obtained from the ground water in each plot.

1. Electrical Conductivity (Figures 2 and 3)

   Electrical conductivity (EC) is an indirect measure of the total salt content of the water samples. During the irrigation season, the sewage effluent (SE) had an EC range of 0.5 to 0.9 mmhos/cm whereas the ditch water ranged from 0.1 to 0.4 mmhos/cm. The ground water samples generally had a greater salt content than the original SE or DW. This indicates that the bulk of the salts in the ground water came from the soil and not from the irrigation sources. None of the ground water samples had an EC greater than 1.2 mmhos/cm. These values fall in the general range (0.03 to 2.00 mmhos/cm) reported for potable subsurface water (29).

   Note that there were no statistical differences in the EC of the ground water on plots irrigated with SE and DW even

Figure 2 - Electrical conductivity of the irrigation sources and the ground water samples from the plots receiving 2.5 cm per week.

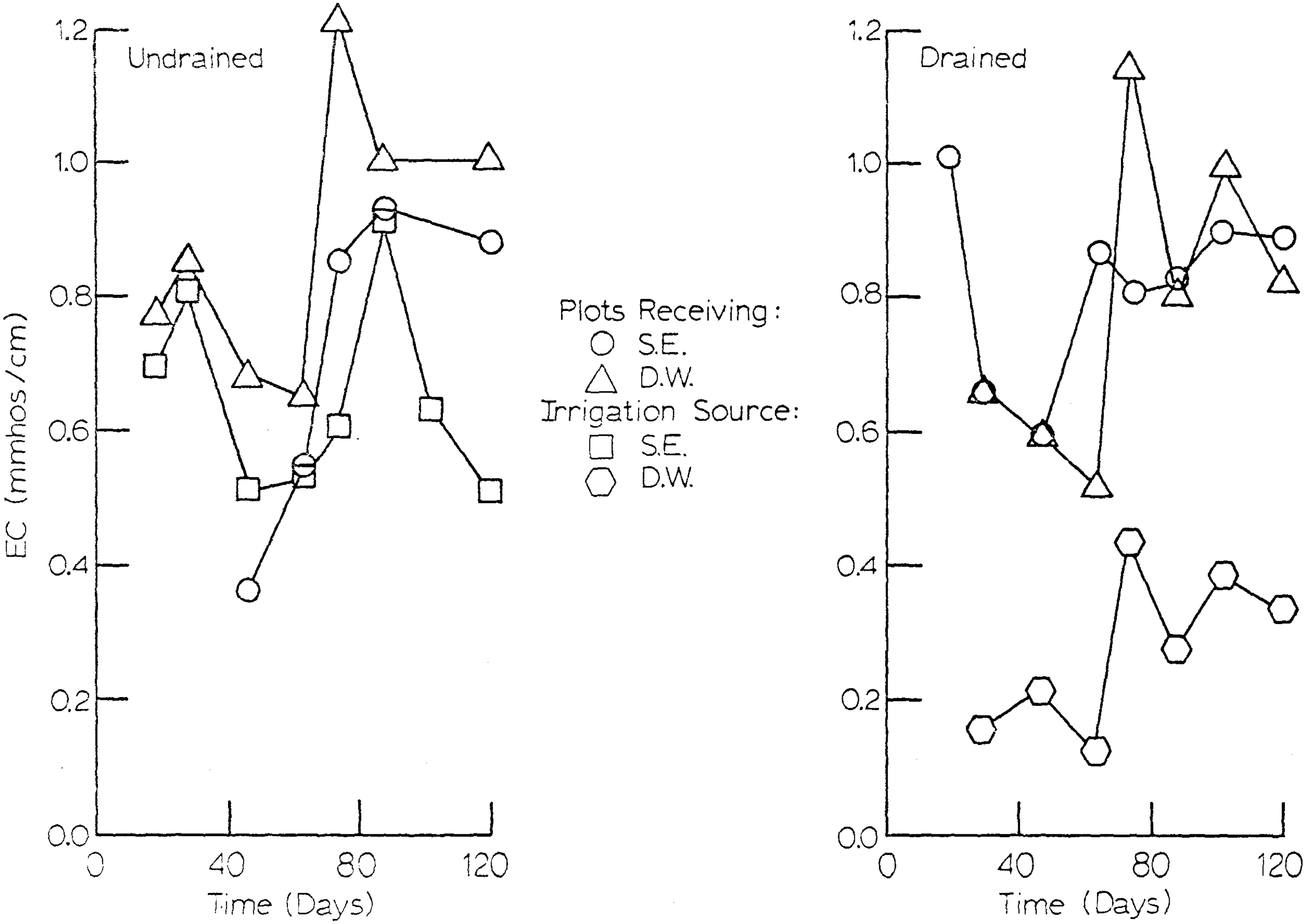
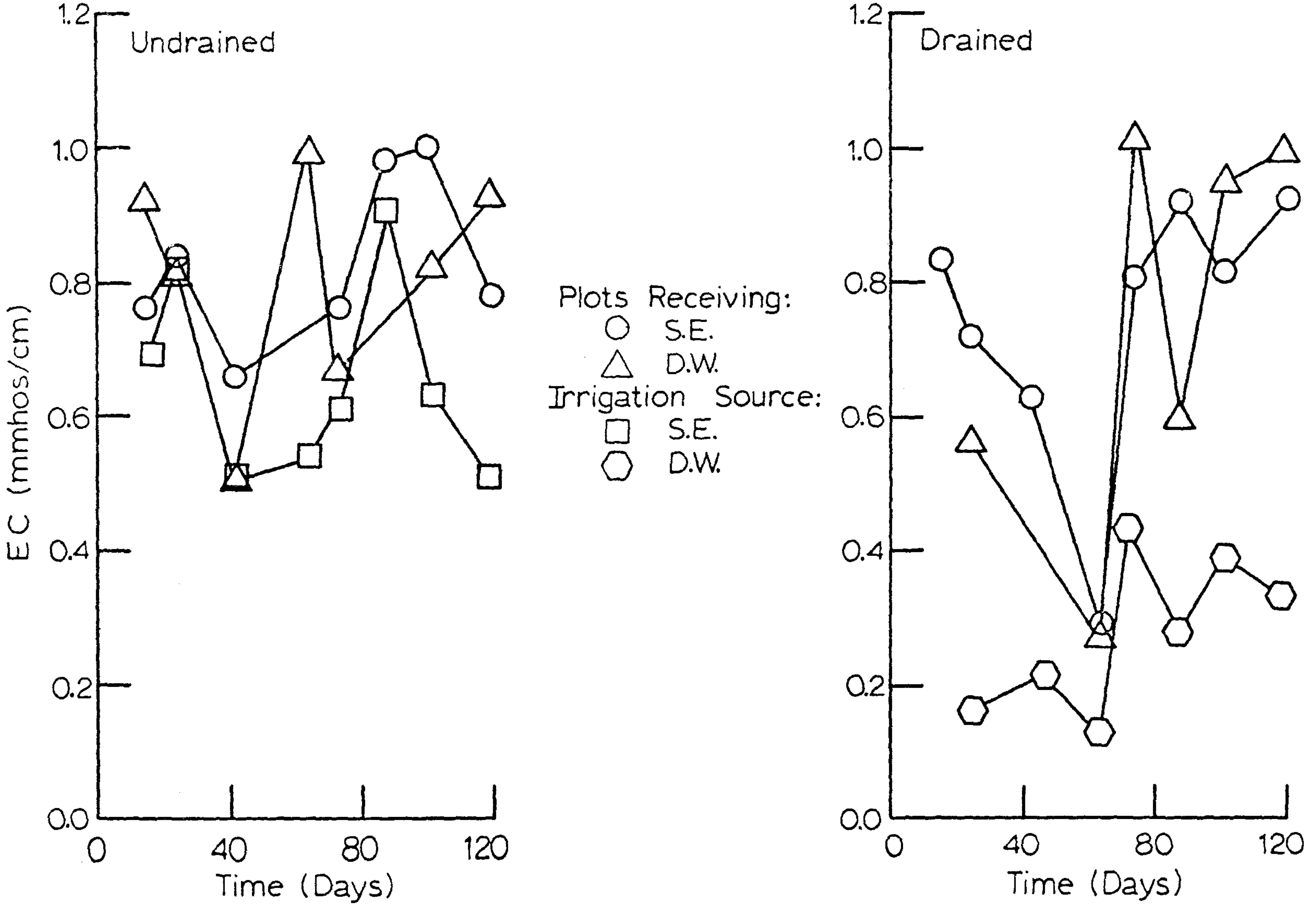


Figure 3 - Electrical conductivity of the irrigation sources and the ground water samples from the plots receiving 5.0 cm per week.



though the EC in the plots receiving DW were generally higher than the plots receiving SE. Also, no significant differences between drained and undrained plots were discovered.

2. Chloride-Cl^- (Figure 4 and 5)

The sewage effluent (SE) contained 26 to 87 ppm chloride (Cl^-) while the ditch water (DW) varied from less than 10 to 40 ppm during the season.

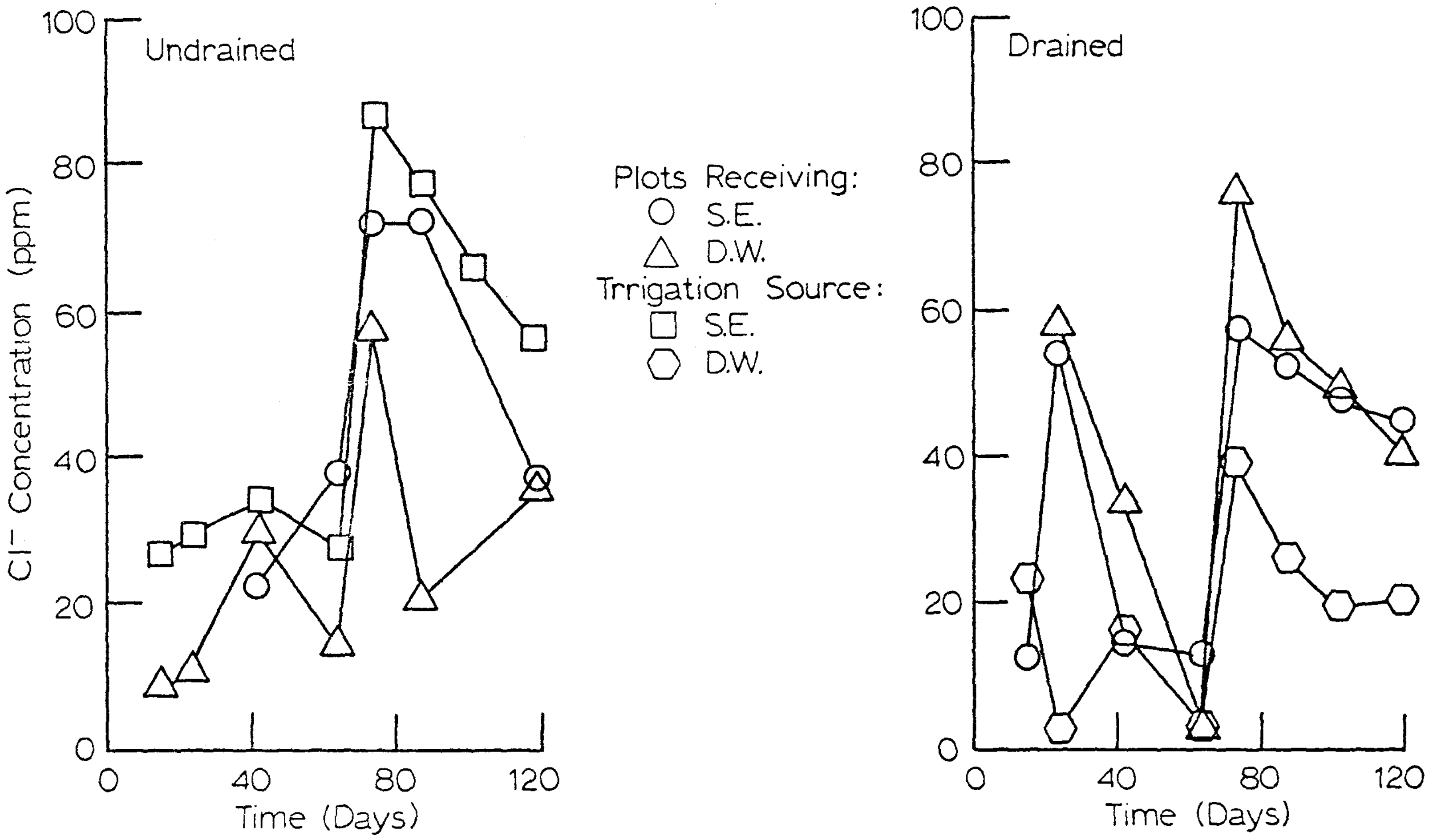
Chloride concentrations in the ground water samples taken from the plots receiving SE were at approximately the same concentration as was found in the SE before application. Cl^- is a relatively mobile anion in the soil; therefore, most of the Cl^- in the SE will migrate with the percolating water into the water table The Cl^- levels of all ground water were less than 100 ppm. These concentrations are well within the range of ground water concentrations (less than 30 to 1000 ppm) reported by Davis and De Wiest (29).

Ground water samples obtained from plots receiving DW illustrated that the Cl^- concentrations was greater than the Cl^- levels in the DW before irrigations. These results indicate that the soil serves as a source of Cl^- that is leached into the ground water. Application rate and the presence of drainage tiles had little effect on the Cl^- concentrations observed in the ground water samples.

3. Nitrate-nitrogen (Figure 6 and 7)

The nitrate-nitrogen (NO_3^--N) content of the SE, DW and ground water samples from all plots were generally less than the 10 ppm drinking-water standard (80) with the exception of the SE sample taken on the 63rd day of the irrigation season.

Figure 4 - Chloride concentrations of the irrigation sources and the ground water samples from the plots receiving 2.5 cm per week.



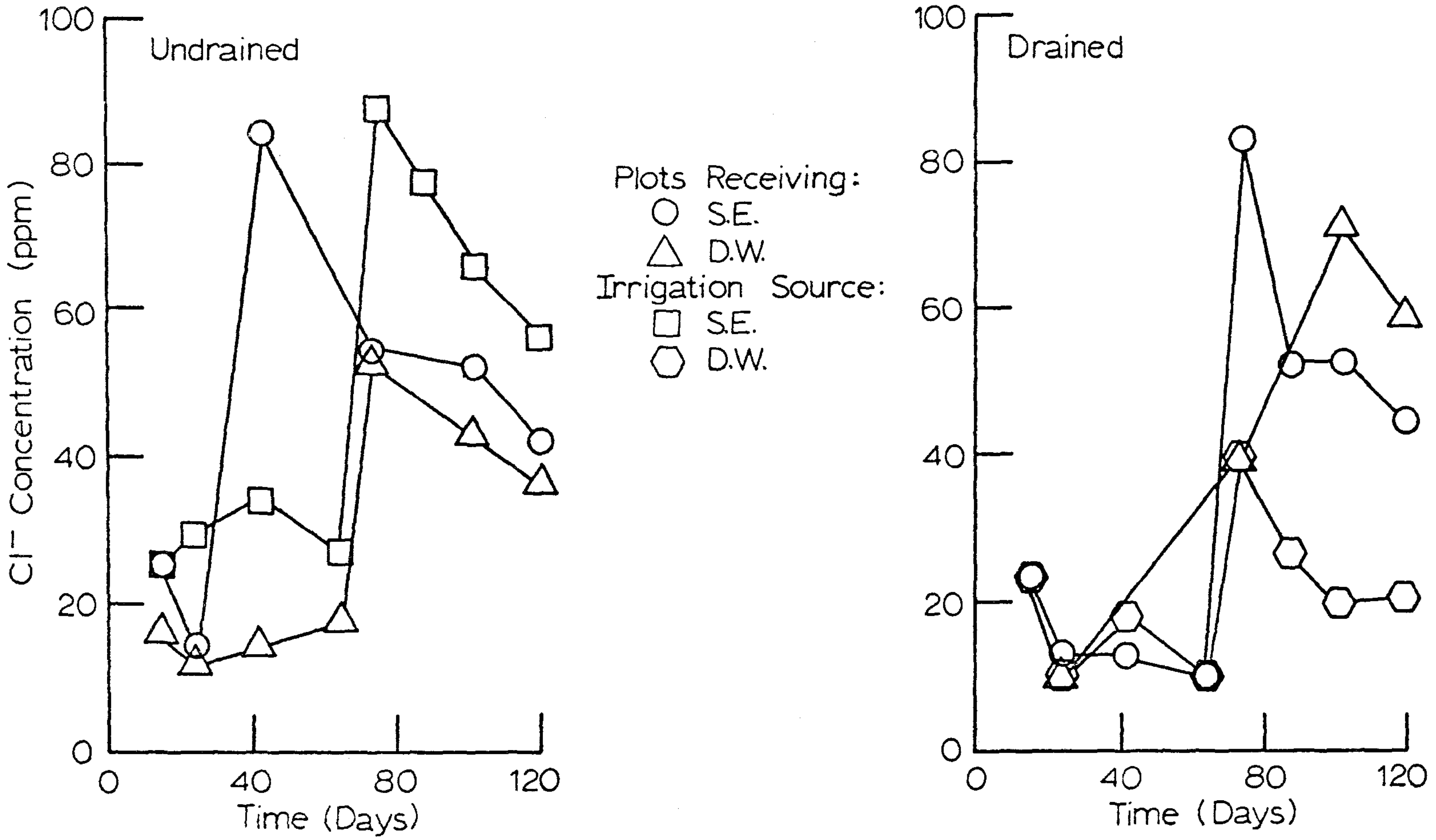


Figure 5 - Chloride concentrations of the irrigation sources and the ground water samples from the plots receiving 5.0 cm per week.

Figure 6 - Nitrate-nitrogen concentrations of the irrigation sources and the ground water samples from the plots receiving 2.5 cm per week.

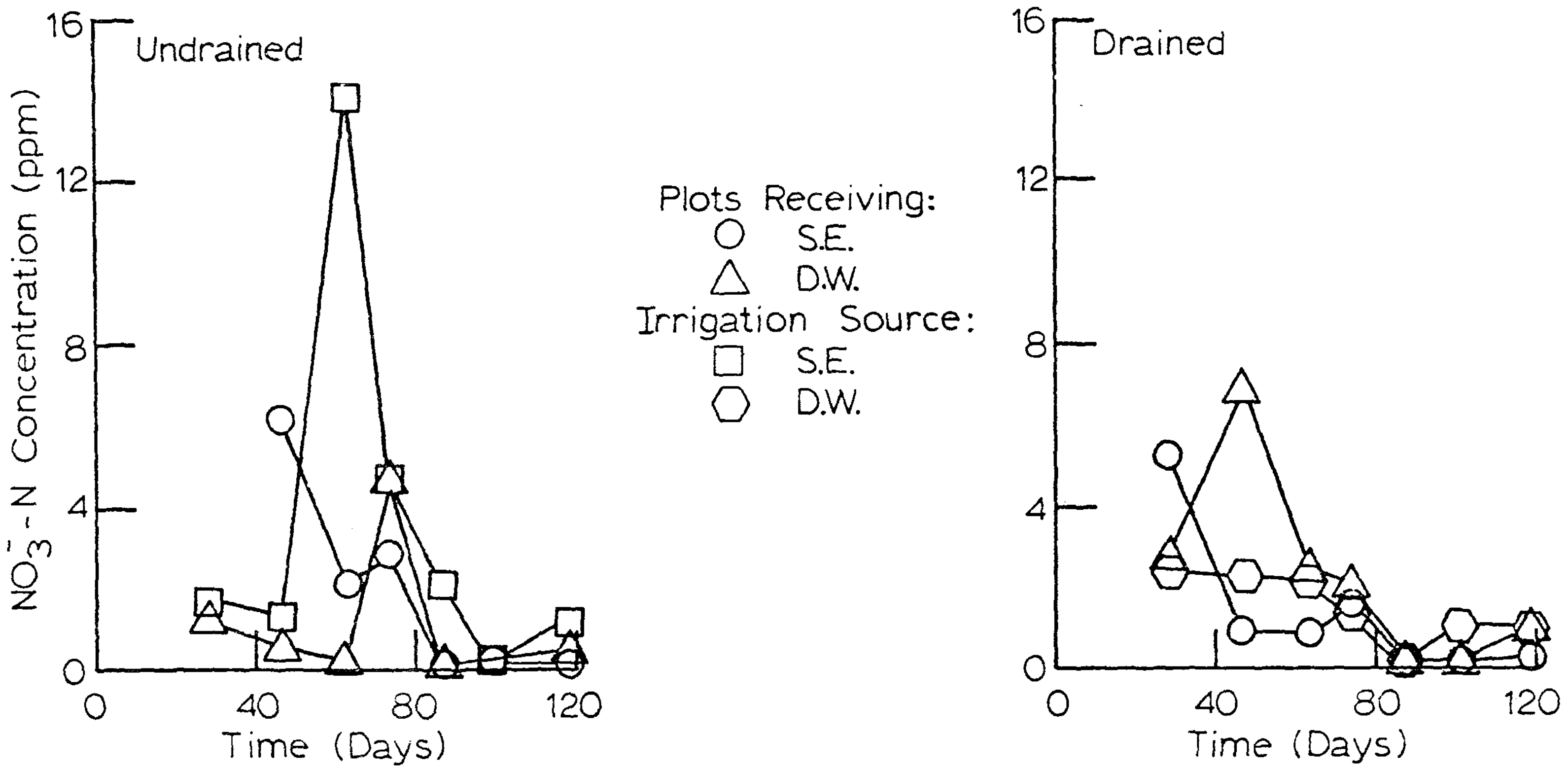
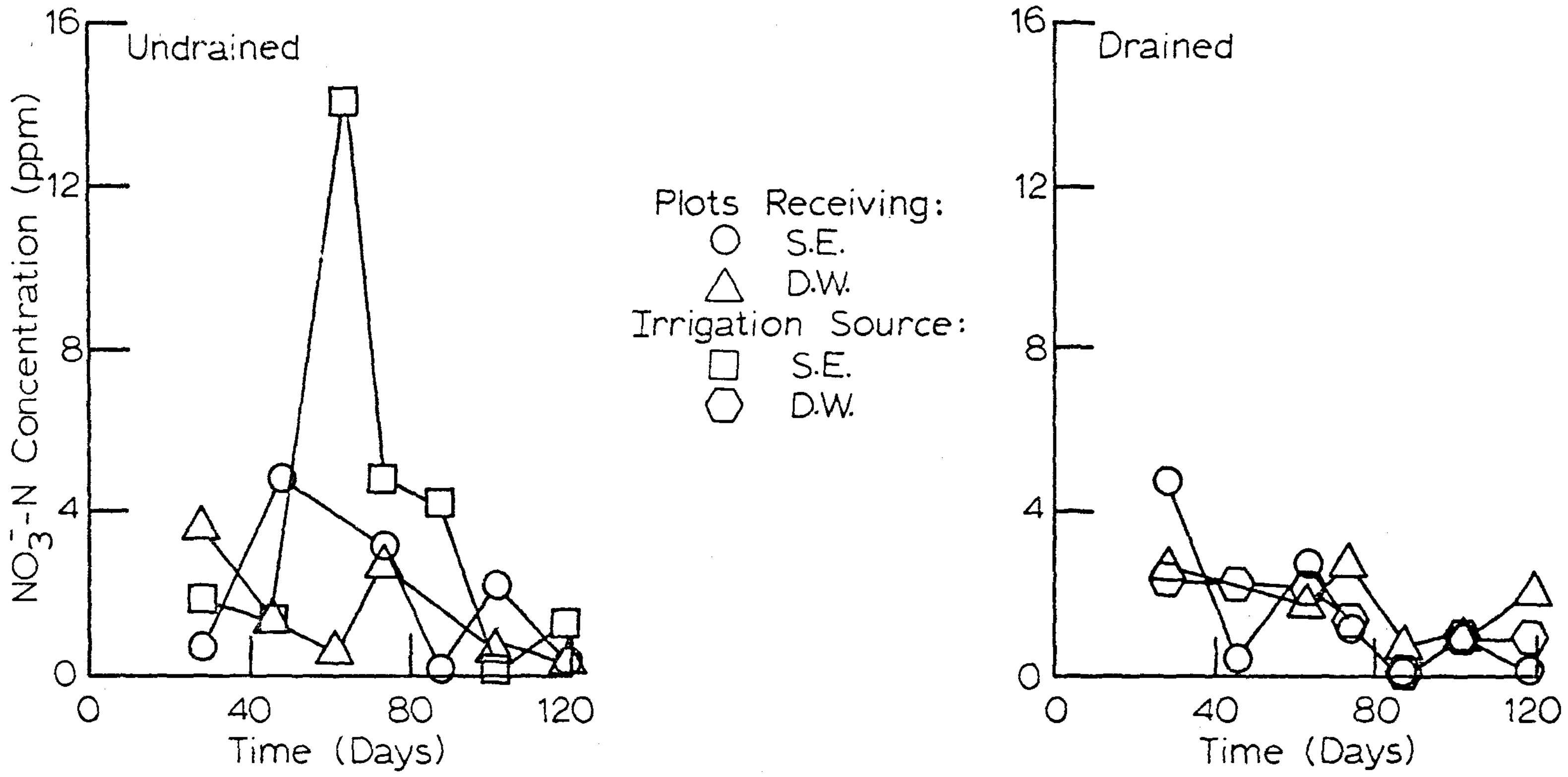


Figure 7 - Nitrate-nitrogen concentrations of the irrigation sources and the ground water samples from the plots receiving 5.0 cm per week.



The reason for this one high value is unknown. With one exception the ground water sample from the plots receiving SE contained less NO_3^--N than the SE. These water table samples generally showed less than 5 ppm NO_3^--N. Application rate, type of irrigation water and drainage did not have a significant effect on the NO_3^- -N levels of the ground water samples. Therefore, application of the SE from Hayden to mountain meadows results in no measurable NO_3^--N problem.

4. Ammonium-nitrogen (Figures 8 and 9)

The ammonium-nitrogen (NH_4^+-N) content of the SE was considerably higher than the DW, ranging up to 10 ppm NH_4^+-N. However, the ground water samples from all plots **were** generally less than 3 ppm NH_4^+-N. Land application was relatively successful in decreasing the NH_4^+-N level of the SE to the concentrations found in the typically used DW.

The possible mechanisms causing the decrease in NH_4^+-N of the SE are:

a. NH_4^+-N fixation or absorption on soil colloids.

b. Oxidation of NH_4^+-N to NO_3^--N by nitrifying bacteria.

c. Plant uptake of NH_4^+-N and/or NO_3^--N.

5. Calcium (Figure 10 and 11)

The SE contained 50 to 75 ppm calcium (Ca^{2+}) while the DW had 25 to 30 ppm. The Ca^{2+} levels in the ground water samples from all plots were higher than DW and about the same as the SE. Again, this indicates that Ca^{2+} is being leached from the soil. All ground water samples fell into the range of normal potable ground water (10 to 100 ppm) (29). Since all ground water concentrations of Ca^{2+} were comparable, land application of SE appears to be a satisfactory treatment for Ca^{2+}.

Figure 8 - Ammonium-nitrogen concentrations of the irrigation sources and the ground water samples from the plots receiving 2.5 cm per week.

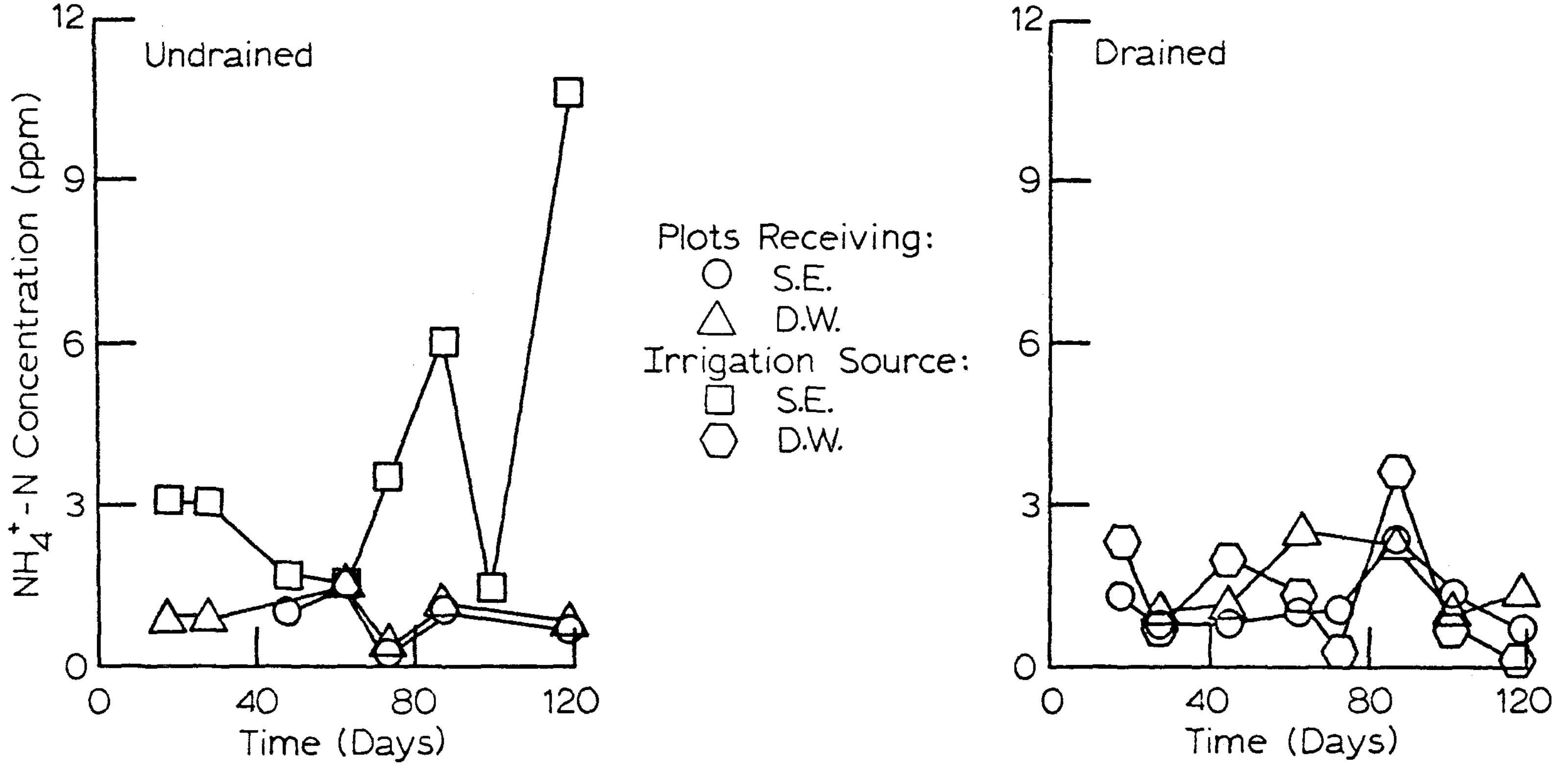
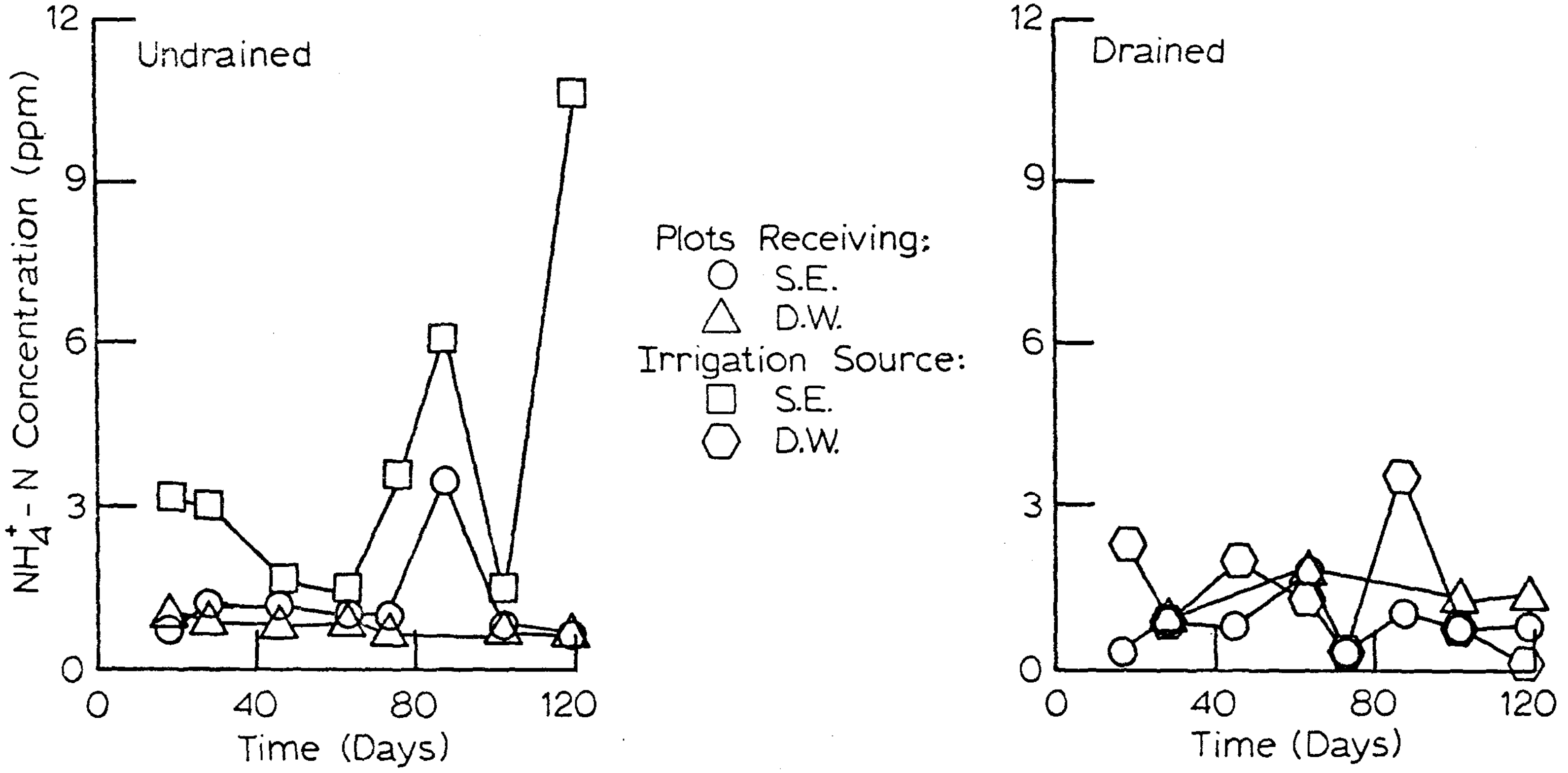


Figure 9 - Ammonium-nitrogen concentrations of the irrigation sources and the ground water samples from the plots receiving 5.0 cm per week.



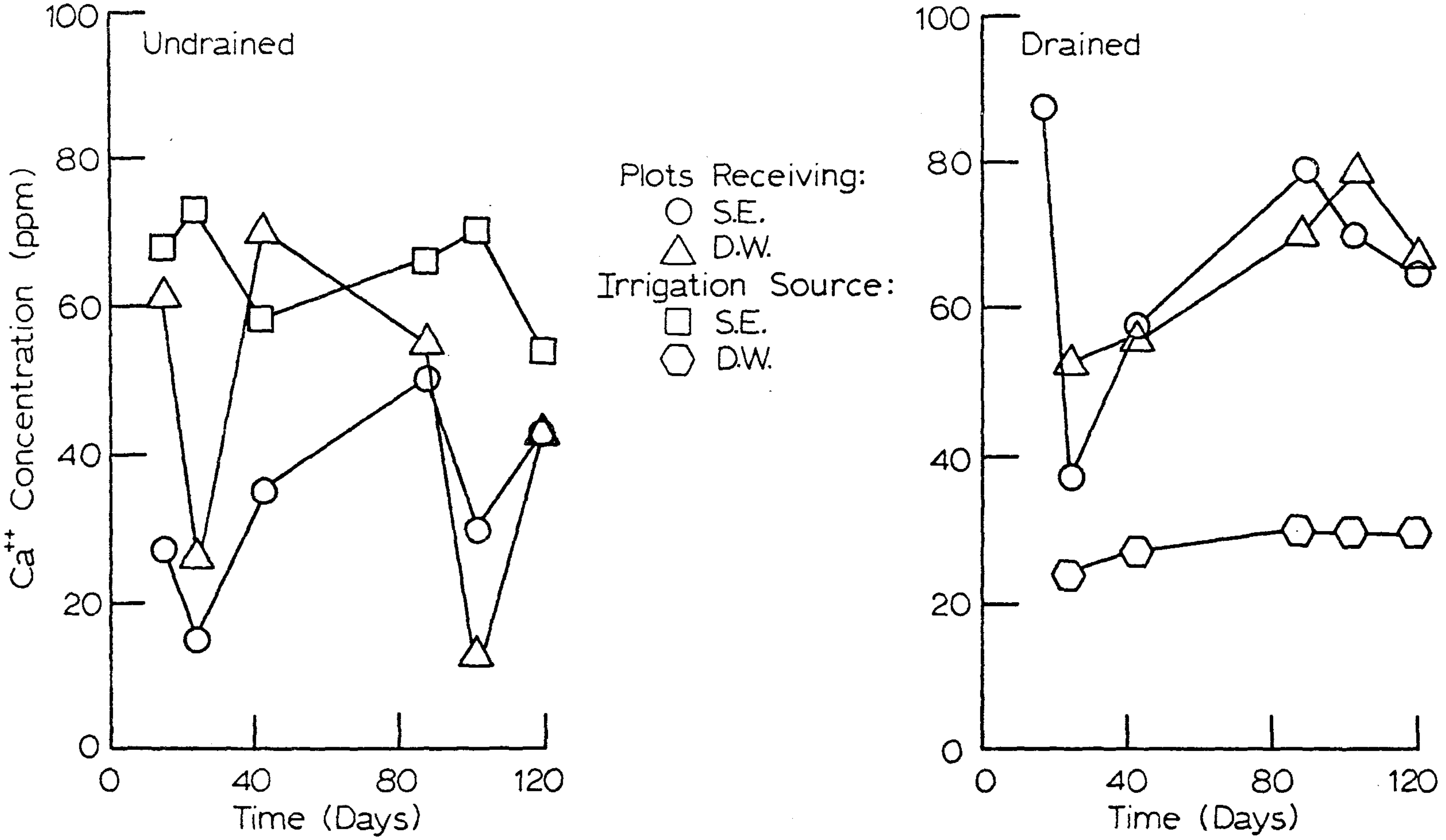
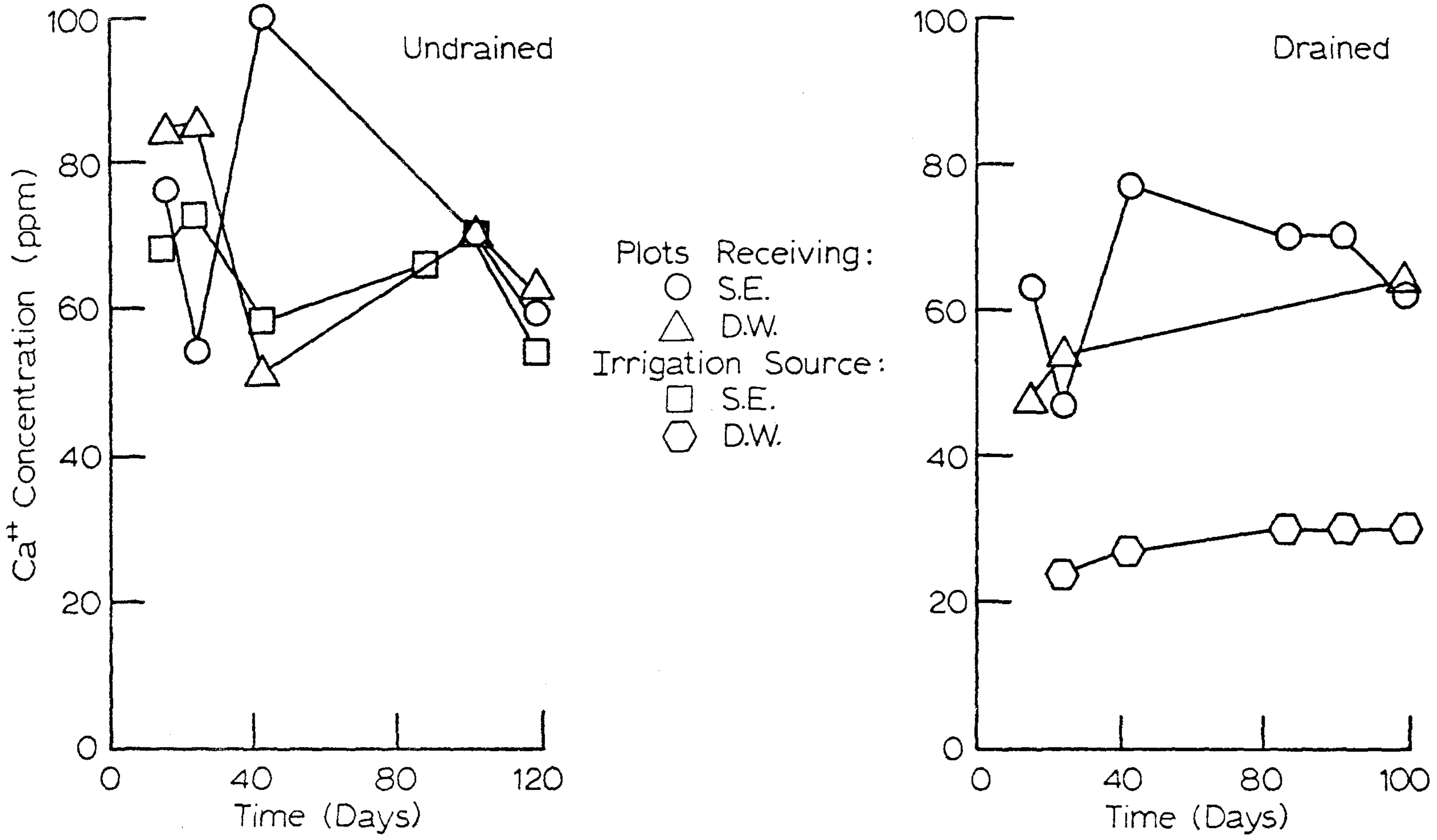


Figure 10 - Calcium concentrations of the irrigation sources and the ground water samples from the plots receiving 2.5 cm per week.

Figure 11 - Calcium concentrations of the irrigation sources and the ground water samples from the plots receiving 5.0 cm per week.



6. Magnesium (Figure 12 and 13)

The magnesium (Mg^{2+}) results are similar to those for Ca^{2+} except that the Mg^{2+} levels were generally higher. The Mg^{2+} content of the SE was somewhat higher than DW ranging from 14 to 50 ppm while the DW contained 8 to 25 ppm Mg^{2+}. All plots yielded ground water samples with higher Mg^{2+} levels than the SE. There were generally greater amounts of Mg^{2+} in the ground water from plots receiving SE than those irrigated with DW; however, these differences are not great. Davis and Dewiest (29) reported that ground water found in contact with soils rich in Mg^{2+} may have as much as 100 ppm Mg^{2+}. Therefore, the soil on these plots appears to contain minerals relatively high in Mg^{2+}. Also, Mg^{2+} will be leached from the soil to a greater extent than Ca^{2+}.

7. Potassium (Figures 14 and 15)

The soil-plant system did an effective job of lowering the potassium (K^+) of the SE from 5 to 8 ppm down to 1 to 3 ppm in the 2.5 cm/week plots and down to 1 to 4 ppm in the 5.0 cm/week plots. Most potable ground waters contain 1 to 5 ppm K^+ (29). Consequently, the K^+ found in all of the ground water samples would not pose a serious environmental problem.

8. Sodium (Figure 16 and 17)

The sodium (Na^+) level of the SE and DW ranged from about 40 to 100 ppm and about 15 to 56 ppm, respectively. The Na^+ in the SE and ground water of the drained SE plots tended to decrease during the growing season. Na^+ in the DW and all other treatments increased during the season. Seldom did the Na^+ content of the ground water samples in plots receiving SE exceed those receiving DW. Since common values for Na^+ range from 1 to 100 ppm (29), the soil is probably contributing some of the Na^+ found in all ground water samples.

9. Phosphorus (Figures 18 and 19)

The phosphorous (P) content of the SE ranged from 2 to 5 ppm.

Figure 12 - Magnesium concentrations of the irrigation sources and the ground water samples from the plots receiving 2.5 cm per week.

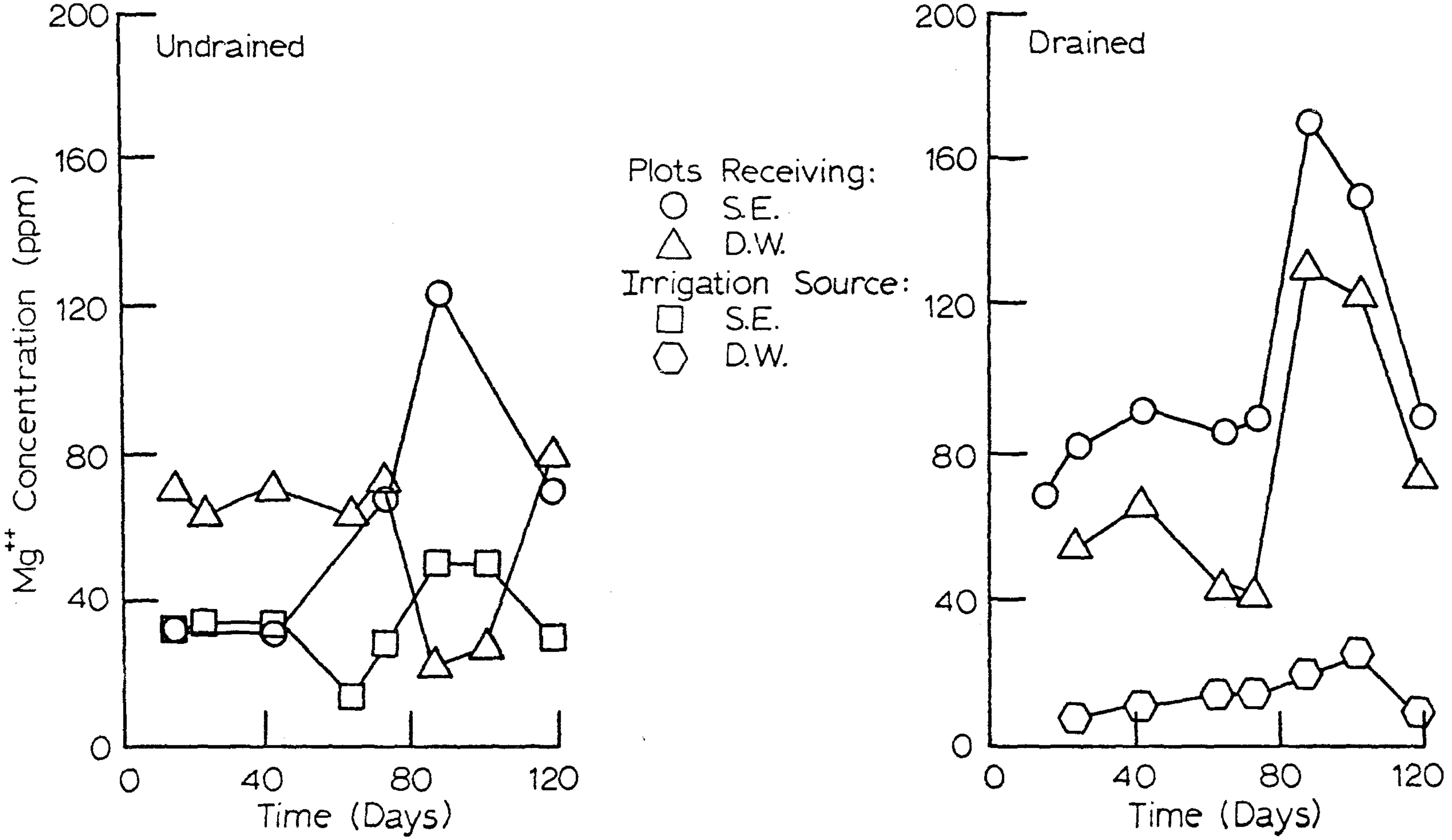


Figure 13 - Magnesium concentrations of the irrigation sources and the ground water samples from the plots receiving 5.0 cm per week.

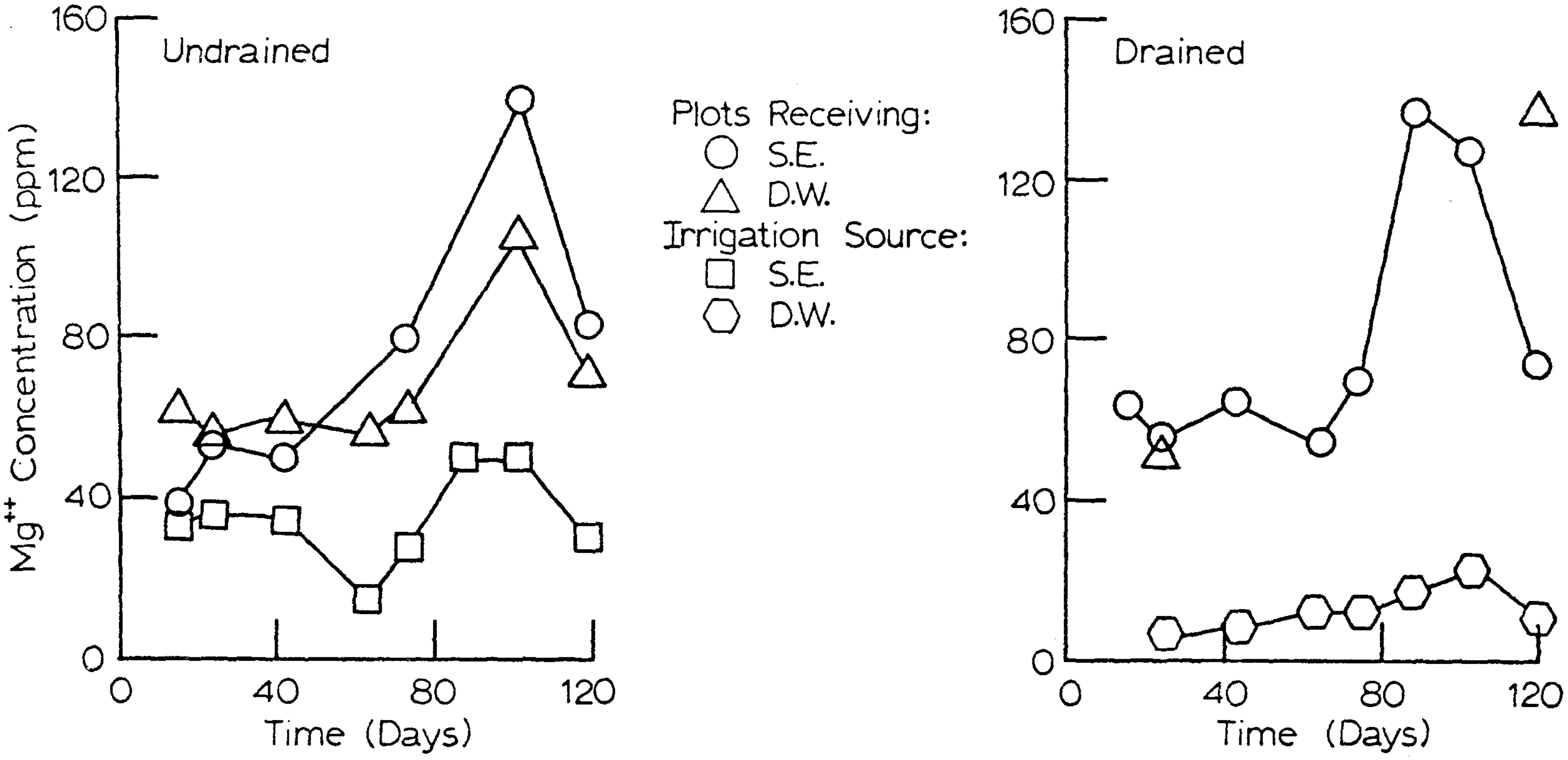


Figure 14 - Potassium concentrations of the irrigation sources and the ground water samples from the plots receiving 2.5 cm per week.

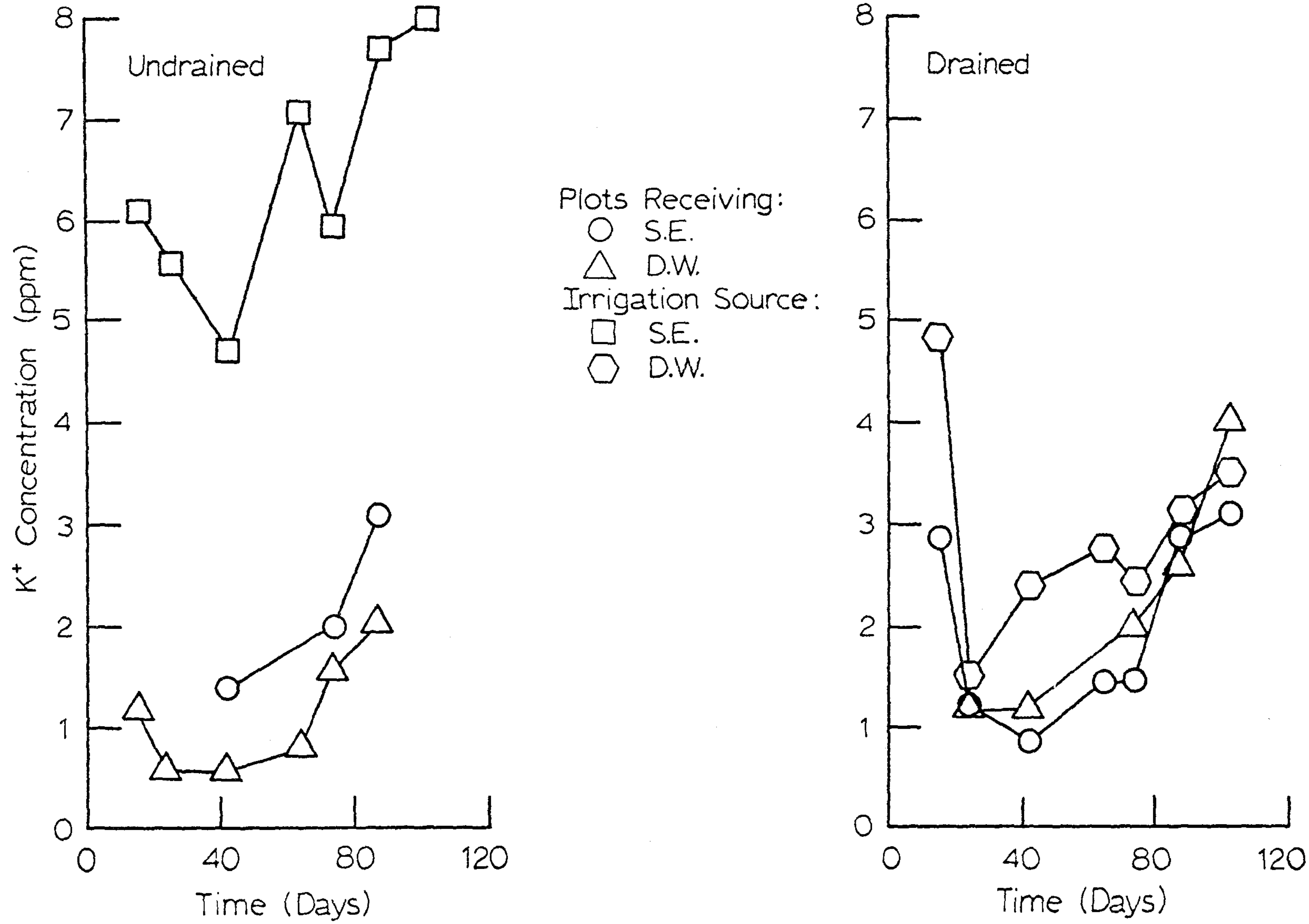


Figure 15 - Potassium concentrations of the irrigation sources and the ground water samples from the plots receiving 5.0 cm per week.

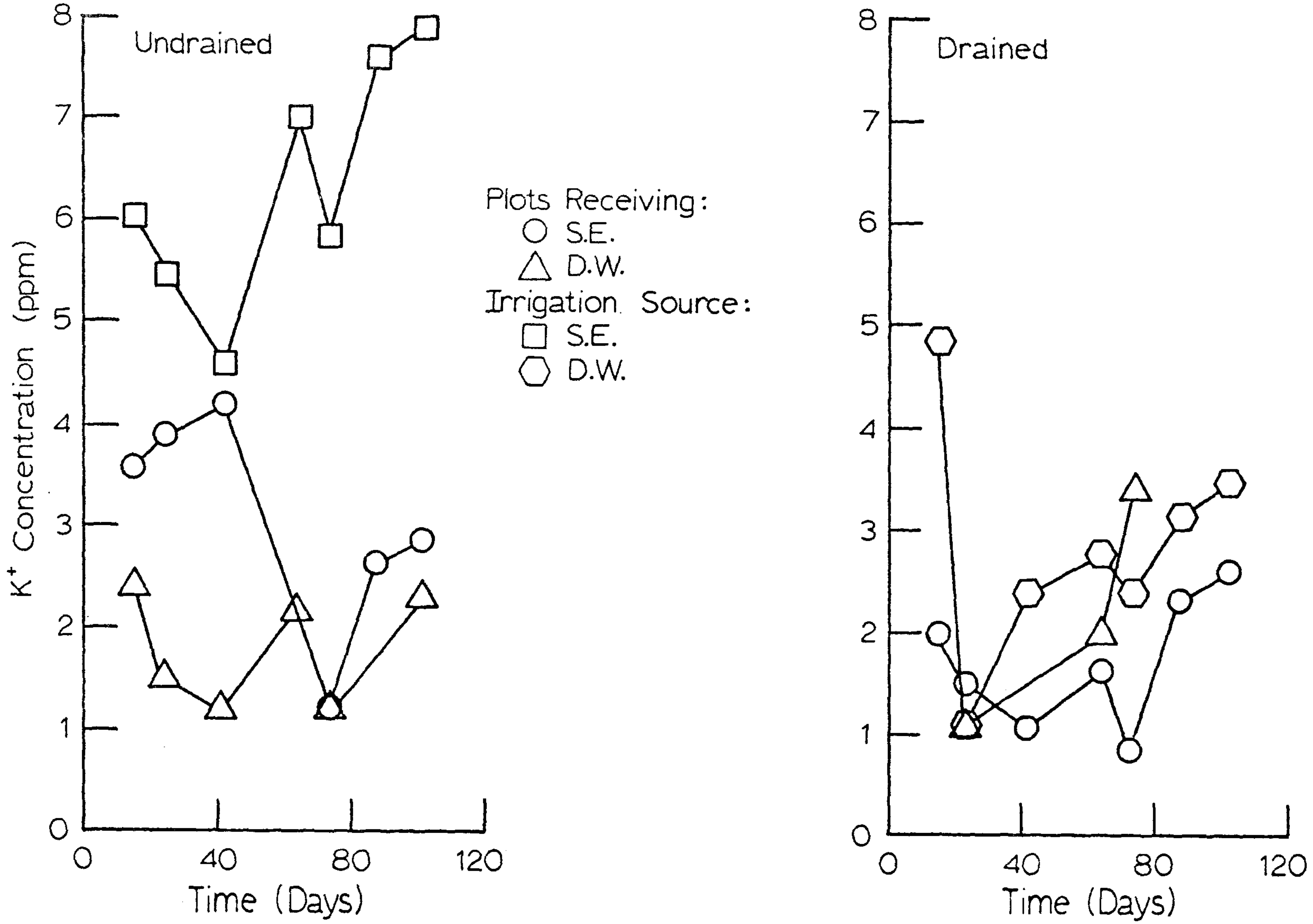


Figure 16 - Sodium concentrations of the irrigation sources and the ground water samples from the plots receiving 2.5 cm per week.

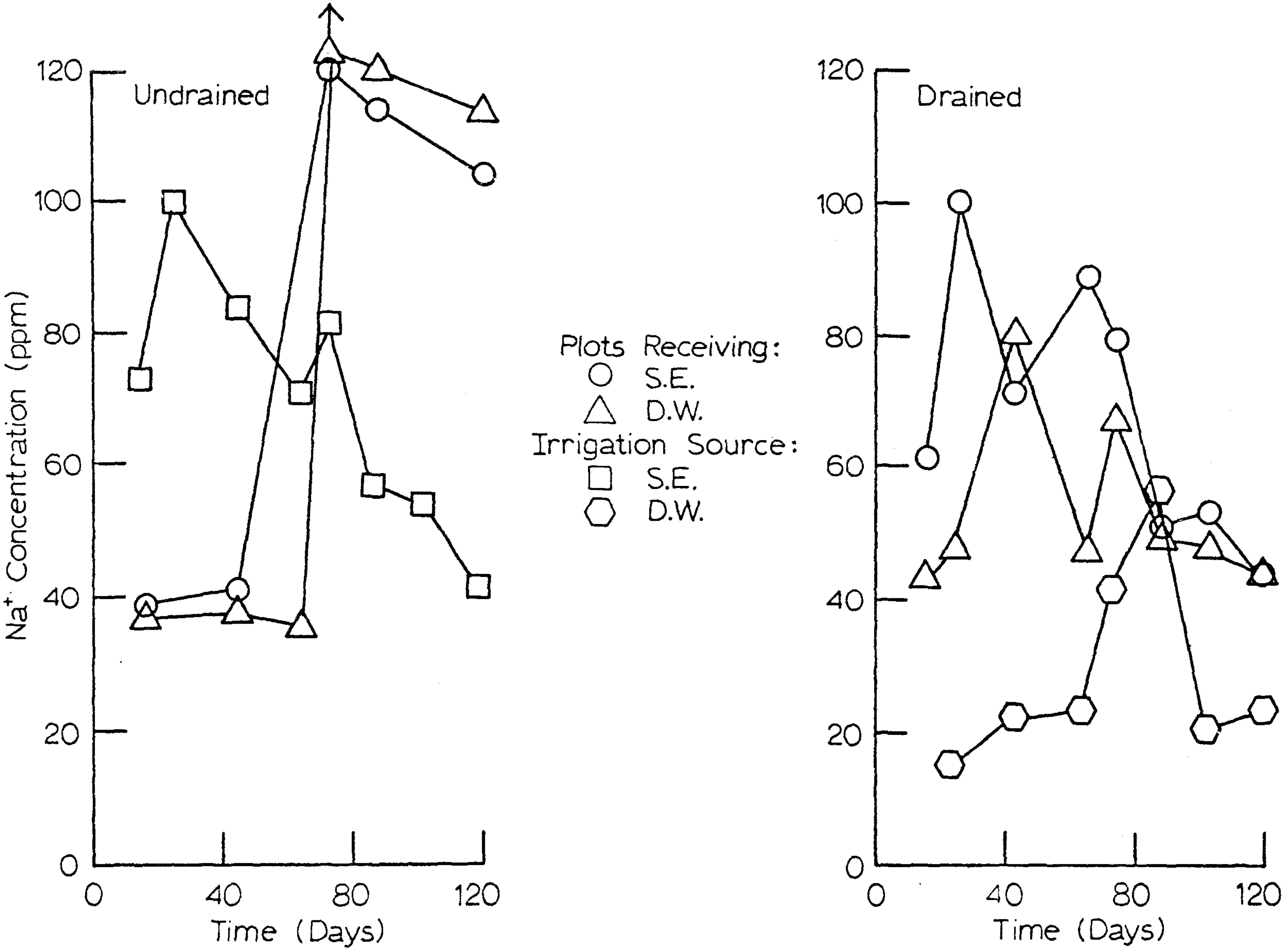
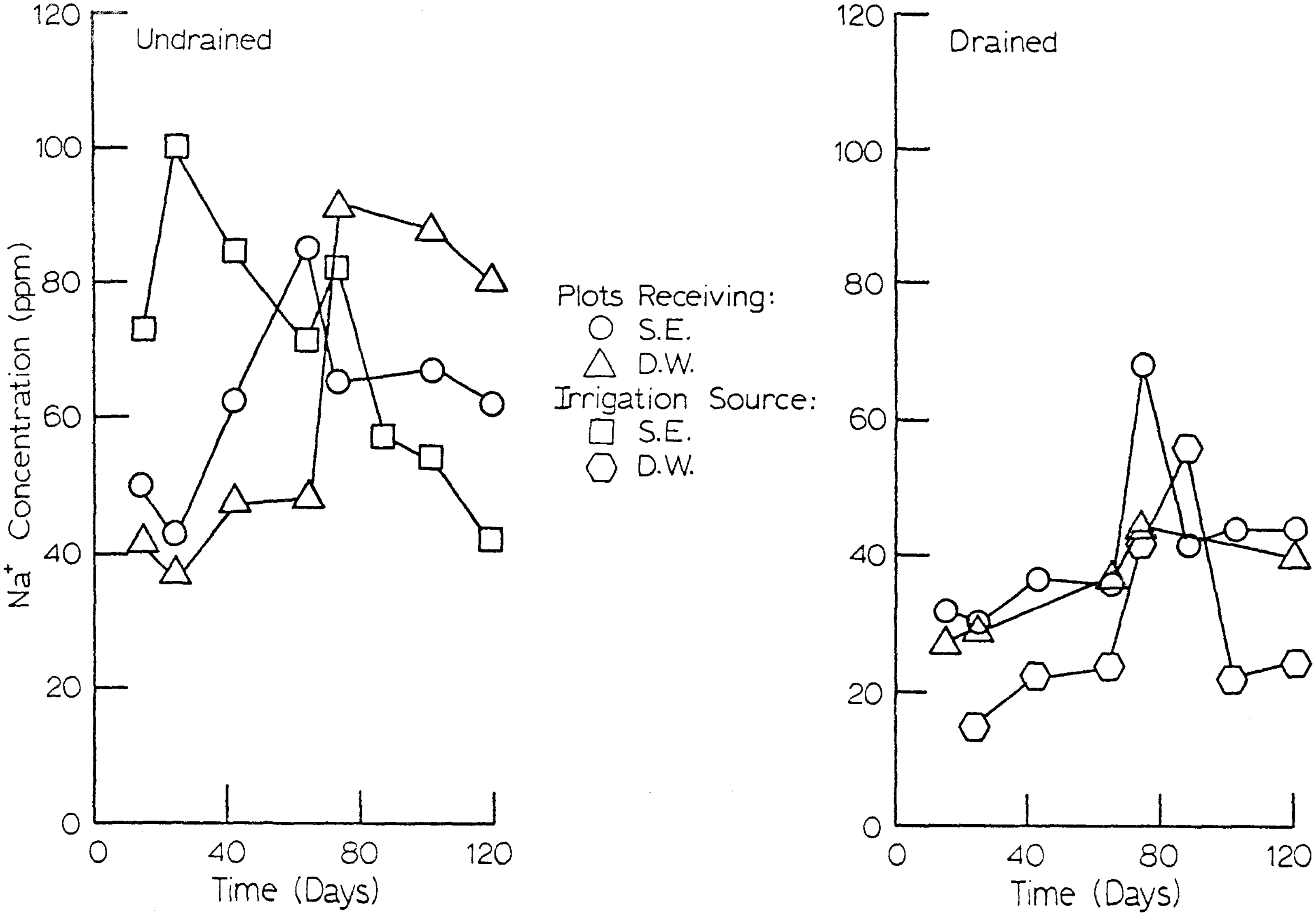


Figure 17 - Sodium concentrations of the irrigation sources and the ground water samples from the plots receiving 5.0 cm per week.



The DW contained less than 1 ppm. The soil-plant system did a very effective job of P removal in the SE. This may have resulted from precipitation or adsorption in the soil and/or plant uptake. At least 90% of the P in the SE was removed as the water leached through the soil.

10. Chemical Oxygen Demand (Figures 20 and 21)

The chemical oxygen demand (COD) ranged from 20 to 85 mg/l and 10 to 23 mg/l in the SE and DW, respectively. After application, the COD was lowered to less than 30 mg/l (generally around 20 mg/l) in the ground water of all treatments. All of these COD levels are well below those reported for a weak untreated municipal SE (approximately 250 mg/l) (58). Application rate, irrigation source or drainage had no significant effects on the COD concentrations.

11. Biochemical Oxygen Demand (Figures 22 and 23)

The SE contained 9 to 18 mg/l of biochemical oxygen demand (BOD) while the DW had 1 to 3 mg/l BOD levels. With some exceptions, BOD was generally reduced in the plots receiving SE to levels that were comparable to those of the plots receiving DW (3-8 mg/l). All of the BOD values are also well below current effluent standards (20 mg/l). Again, application rate, type of irrigation water, or the presence of subsurface drainage seemed to have little influence on the BOD values found in the ground water. The subsoil is the primary source of the organic matter which comprises the BOD found in the ground water. The organic material in the SE accumulated on the surface of the soil-plant system.

12. Fecal and Total Coliform

The sewage effluent contained from 200 to 77,000 fecal coliform per 100 ml, and 8200 to 90,000 total coliform per 100 ml.

Ground water samples from the plot receiving sewage effluent contained 0 to 10 fecal coliform per 100 ml and 0 to 510 total coliform per 100 ml.

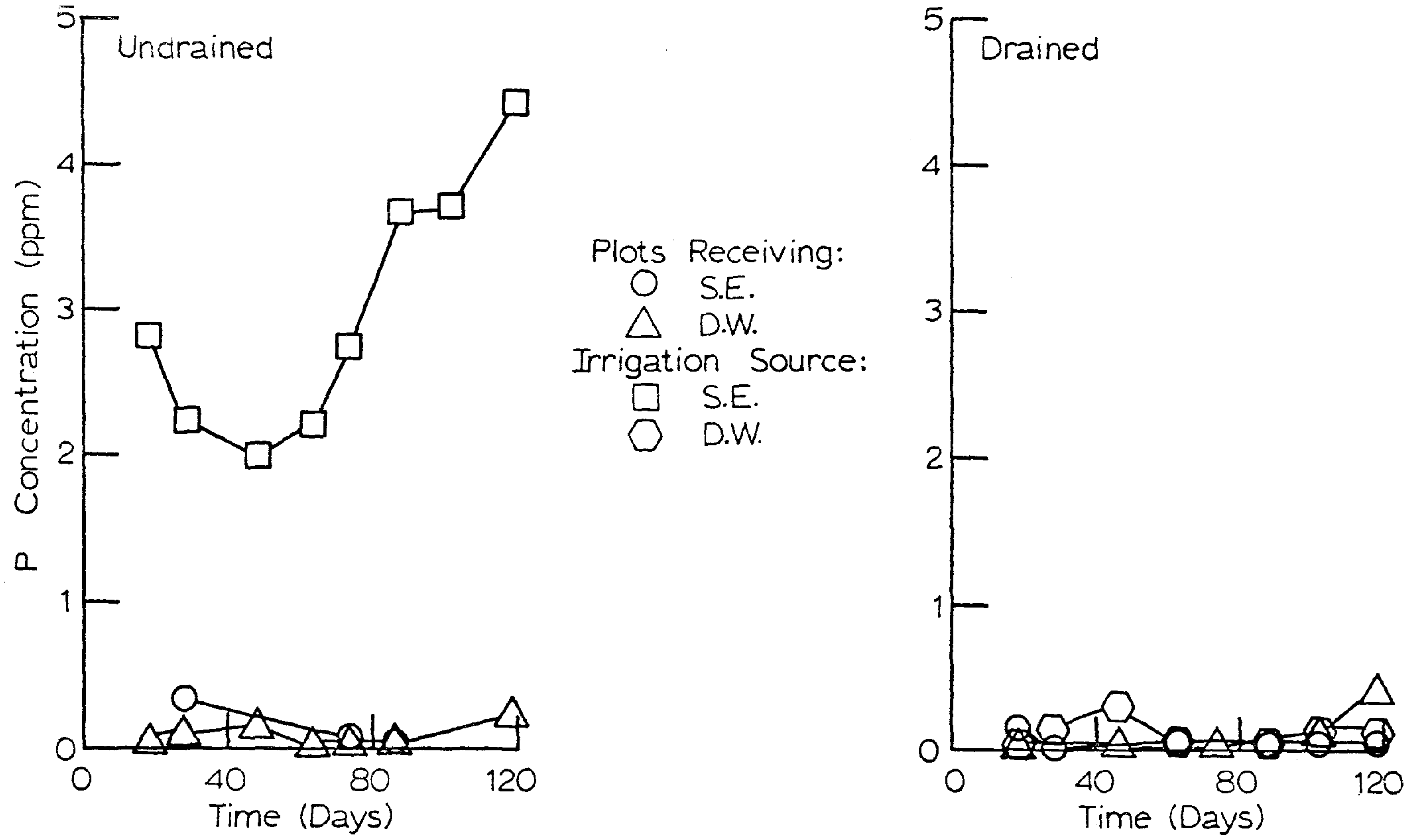


Figure 18 - Phosphorus concentrations of the irrigation sources and the ground water samples from the plots receiving 2.5 cm per week.

Figure 19 - Phosphorus concentrations of the irrigation sources and the ground water samples from the plots receiving 5.0 cm per week.

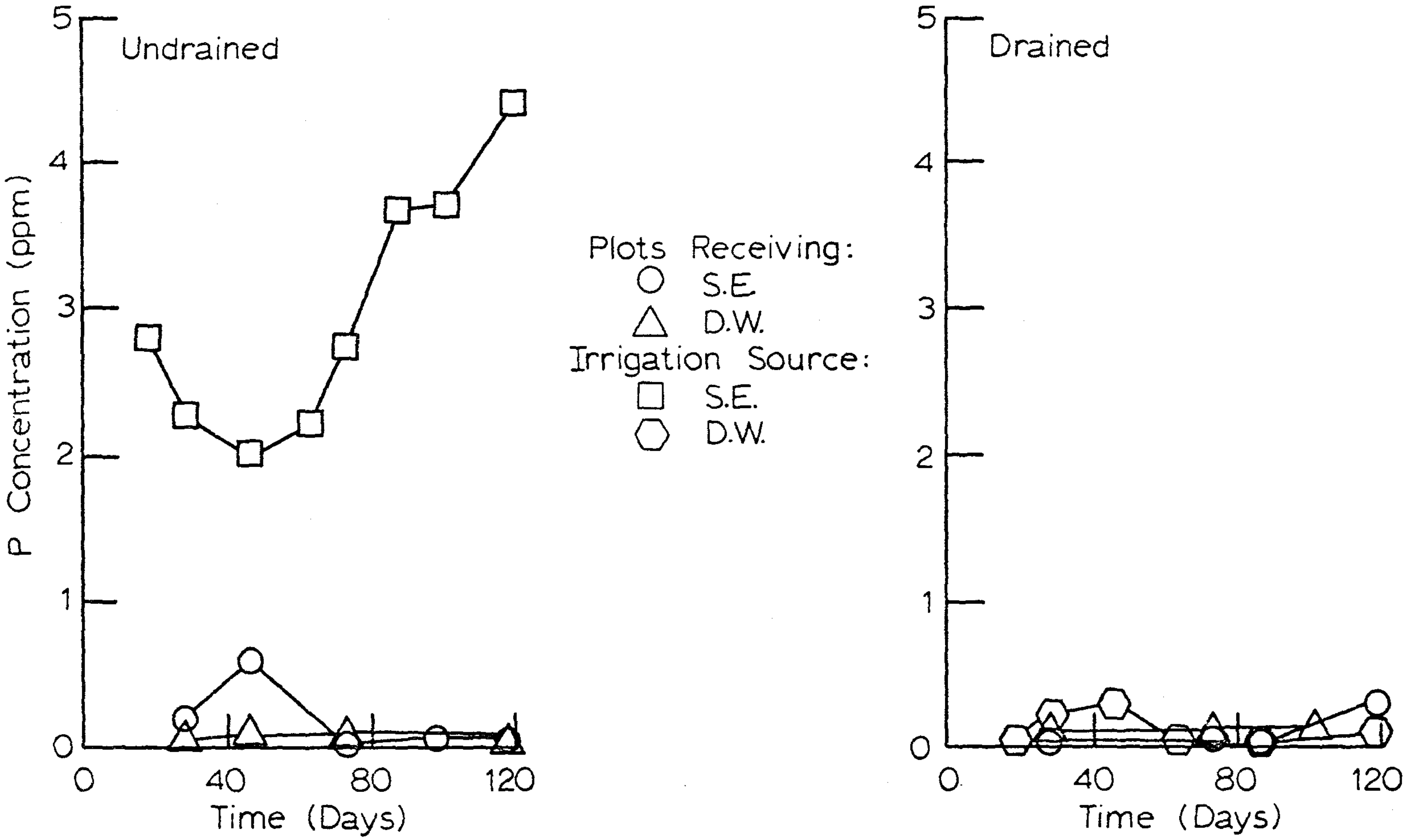


Figure 20 - Chemical oxygen demand levels for the irrigation sources and the ground water samples from the plots receiving 2.5 cm per week.

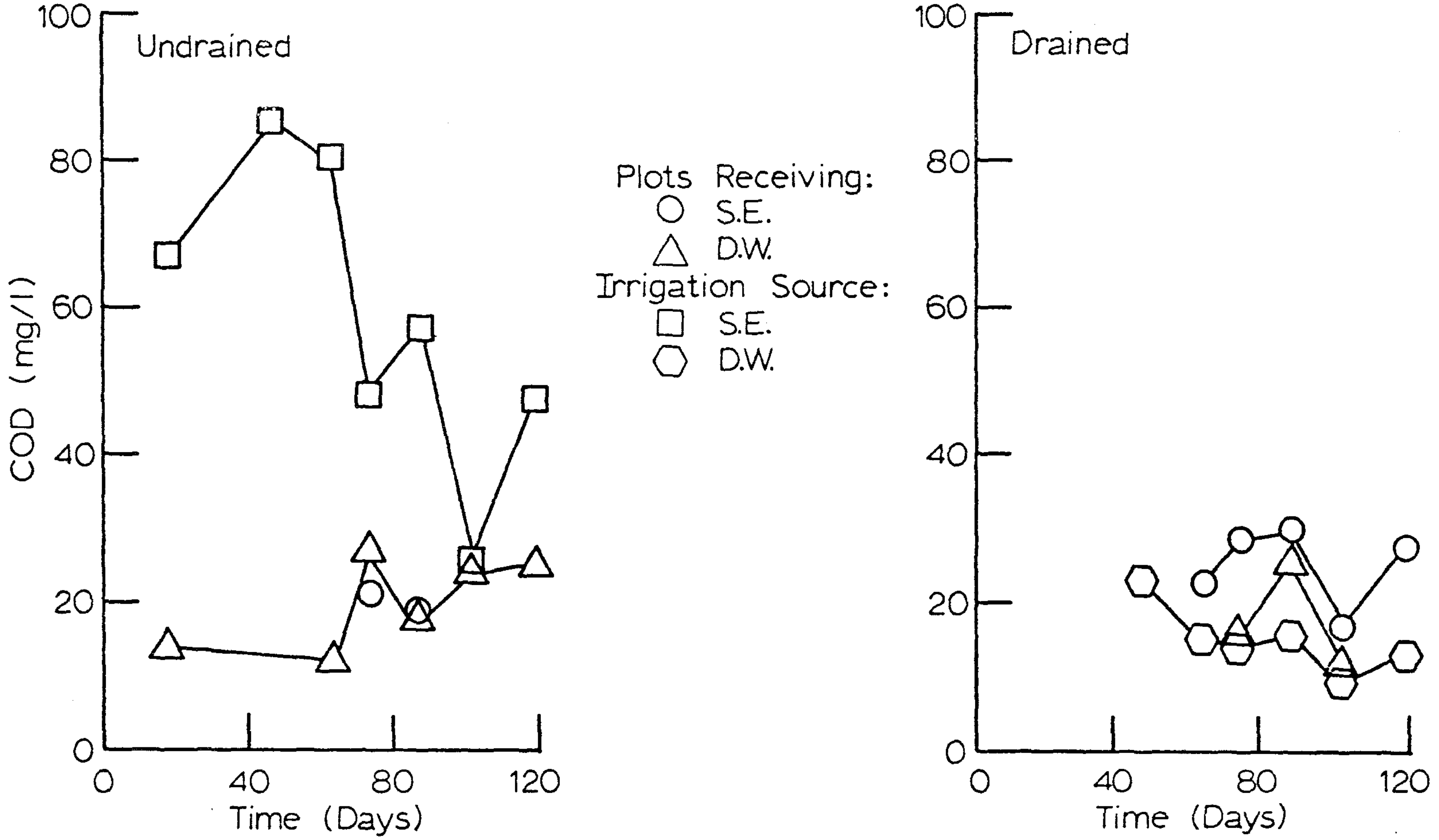


Figure 21 - Chemical oxygen demand levels for the irrigation sources and the ground water samples from the plots receiving 5.0 cm per week.

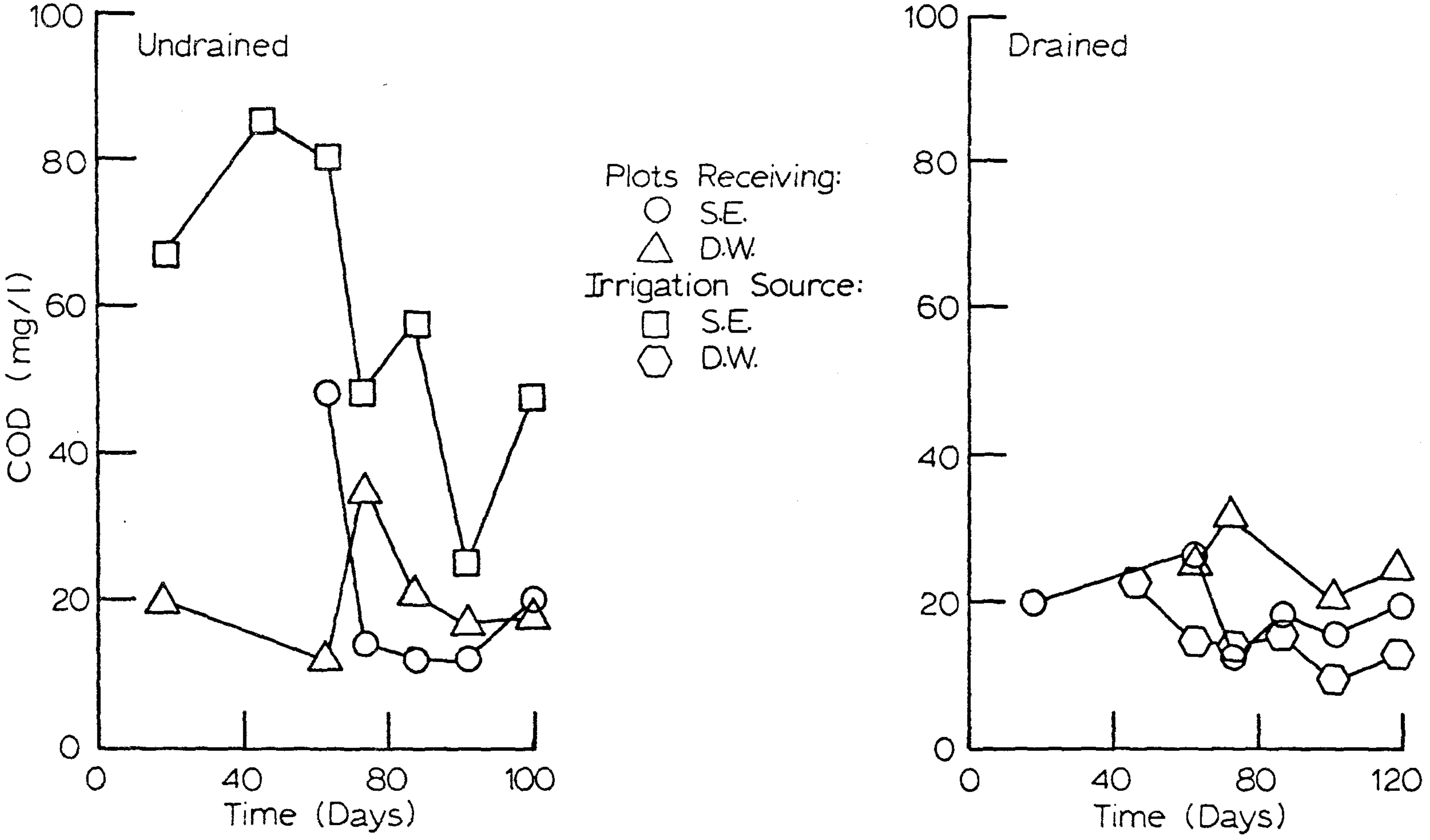


Figure 22 - Biochemical oxygen demand levels for the irrigation sources and the ground water samples from the plots receiving 2.5 cm per week.

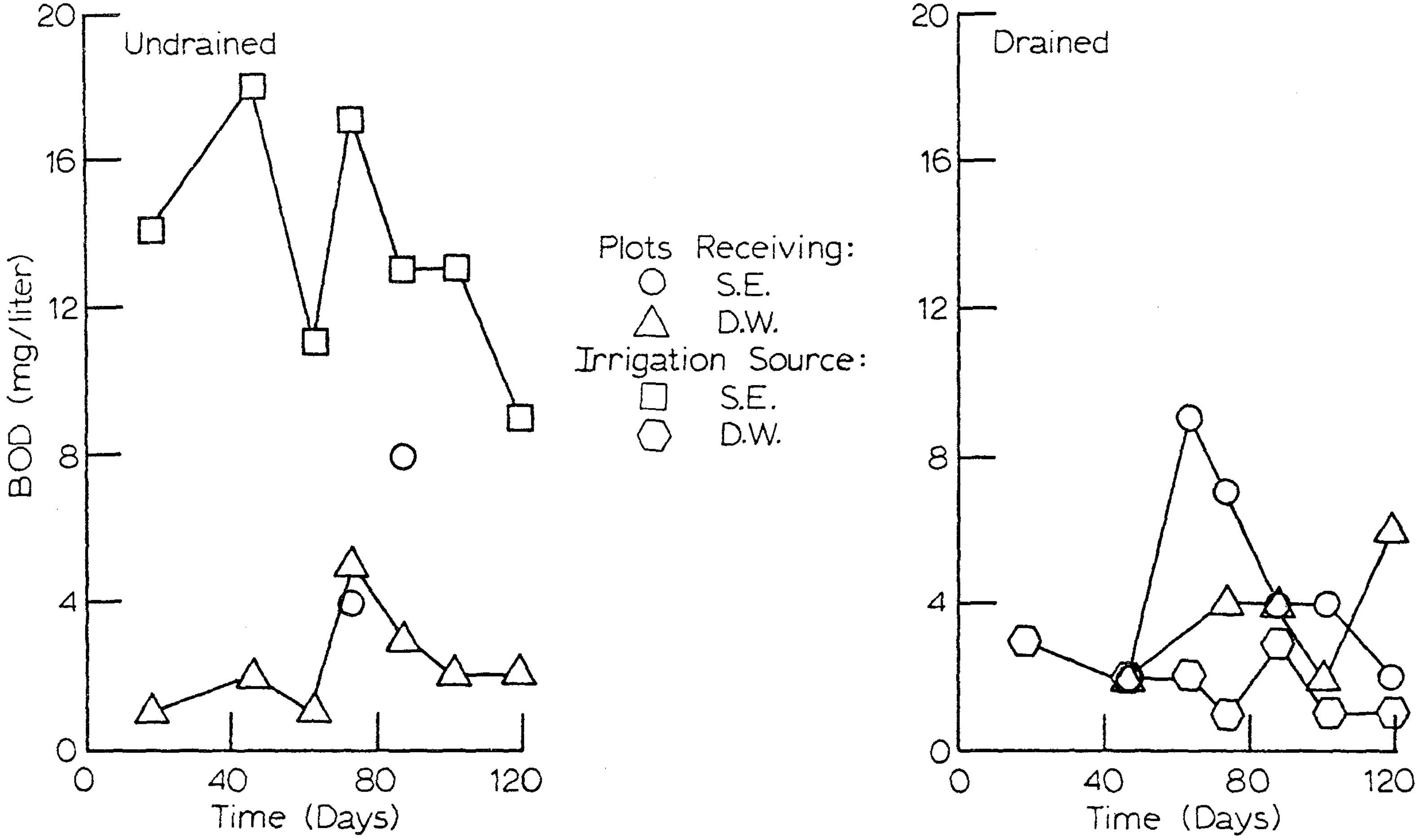
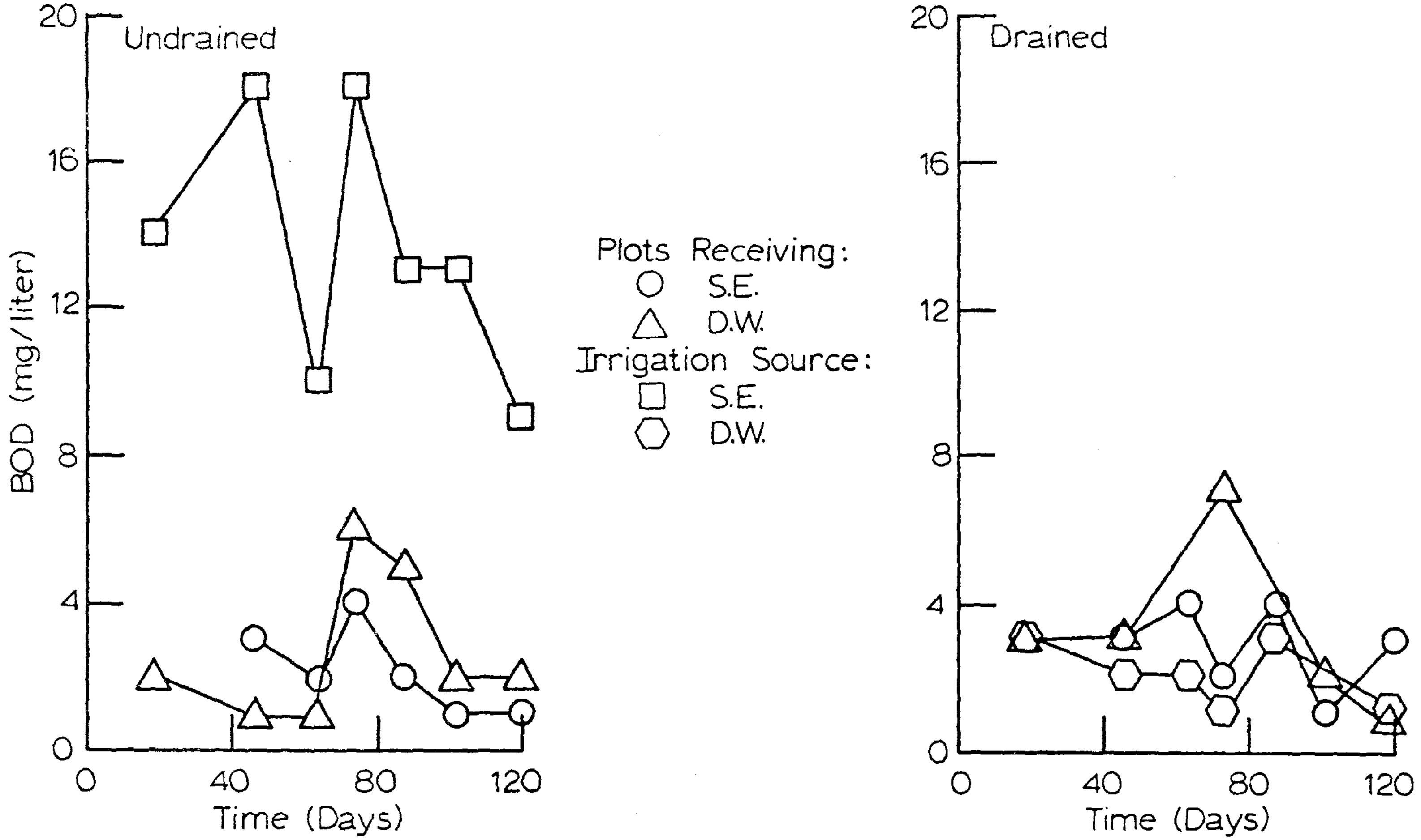


Figure 23 - Biochemical oxygen demand levels for the irrigation sources and the ground water samples from the plots receiving 5.0 cm per week.



The ditch water contained 10 to 2600 fecal coliform per 100 ml and 62 to 6000 total coliform. Ground water samples from the plots receiving the ditch water yielded 0 to 4 fecal coliform per 100 ml and 0 to 160 total coliform per 100 ml.

The soil-plant system has effectively lowered the numbers of these indicator bacteria from both sources of irrigation water. Since the ground water samples were only analyzed twice for these microorganism, graphs were not made for organism levels during the growing season.

13. Trace metals

Analyses of a few SE and DW samples indicated that the cadmium (Cd) and zinc (Zn) concentrations were less than 5 ppb. Normal atomic adsorption procedures could not accurately detect the Cd and Zn levels. These values are too low to be of concern. Iron (Fe) levels in the sewage effluent ranged from less than 0.15 to 0.57 ppm while the ditch contained less than 0.15 to 1.42 ppm. The sewage effluent contained less than 0.1 ppm to 0.7 ppm manganese (Mn) and less than 0.1 ppm to 0.2 ppm copper (Cu). In the ditch water, Mn ranged from less than 0.1 to 0.3 ppm and Cu varied from less than 0.1 to 0.3 ppm. All sewage effluent and ditch water samples contained $<.1$ ppm nickel (Ni). Fe, Mn, Cu and Ni in both irrigation sources are relatively low and pose no environmental problems. The sewage effluent contained 1.1 to 6.7 ppm total nitrogen and the ditch water values ranged from 0.1 to 1.0 ppm. The organic nitrogen could be transformed to NH_4^+ and NO_3^- which can be utilized by plants. The influence of this form of nitrogen on the hay yield and quality may not be observed for 1 to 2 years after application of sewage effluent. A 1 to 2 year period may be required to observe if NO_3^--N and NH_4^+-N formed from this organic-N are leached into the ground water.

14. Summary of Statistical Analyses

Analyses of variance (71) were completed on the data for the ground-water samples collected during the irrigation season. These calculations were utilized to determine if the concentrations of the various constituents were influenced by the date of sampling, the application rate, the type of irrigation water and the type of drainage. An F-test significance level of 1% was used to indicate very significant differences and a level of 5% to indicate significant differences. Only significant impacts will be indicated in the following discussion. The coefficient of determination (71) represents the percent or variation of the constituent or response variable that can be attributed to the treatments (e.g. date, application rate, type of irrigation water and type of drainage).

a. Electrical Conductivity (EC)

The analysis of variance (ANOVA) indicated that the fluctuations in EC were very significantly influenced by the date of sampling. The coefficient of determination was 51% in this case.

b. Chloride (Cl^-)

For Cl^- the calculations showed that date of sampling had a very significant effect while the sewage effluent resulted in a significant increase in Cl^- concentration. The coefficient of determination for this set of computations was 65%.

c. Nitrate-nitrogen (NO_3^--N)

Date of sampling was found to have a very significant effect on the NO_3^- -N concentrations found in the groundwater samples. The coefficient of determination was 45%.

d. Ammonium-nitrogen (NH_4^+-N)

As with NO_3^--N, date of sampling had a very significant effect on the NH_4^+-N concentrations found in the groundwater. The coefficient of determination for NH_4^+-N was 46% .

e. Calcium (Ca^{2+})

The analysis of variance illustrated that the changes in Ca^{2+} concentrations in the groundwater samples were significantly increased by the presence of drainage tiles. The coefficient of determination in this case was only 29%.

f. Mangesium (Mg^{2+})

Our calculations showed that Mg^{2+} in the groundwater samples was very significantly influenced by the date of sampling. For Mg^{2+} the coefficient of determination was 58%.

g. Potassium (K^+)

No significant influences on the K^+ found in the groundwater samples were discovered, and the coefficient of determination was only 11%.

h. Sodium (Na^+)

The major treatment factors had no significant effect on the Na^+ concentration found in the groundwater samples. The coefficient of determination in this case was only 19%.

i. Phosphorus (P)

As with K^+ and Na^+, no significant influences on the P concentrations found in the groundwater samples were found. The coefficient of determination was 34%.

j. Biochemical Oxygen Demand (BOD)

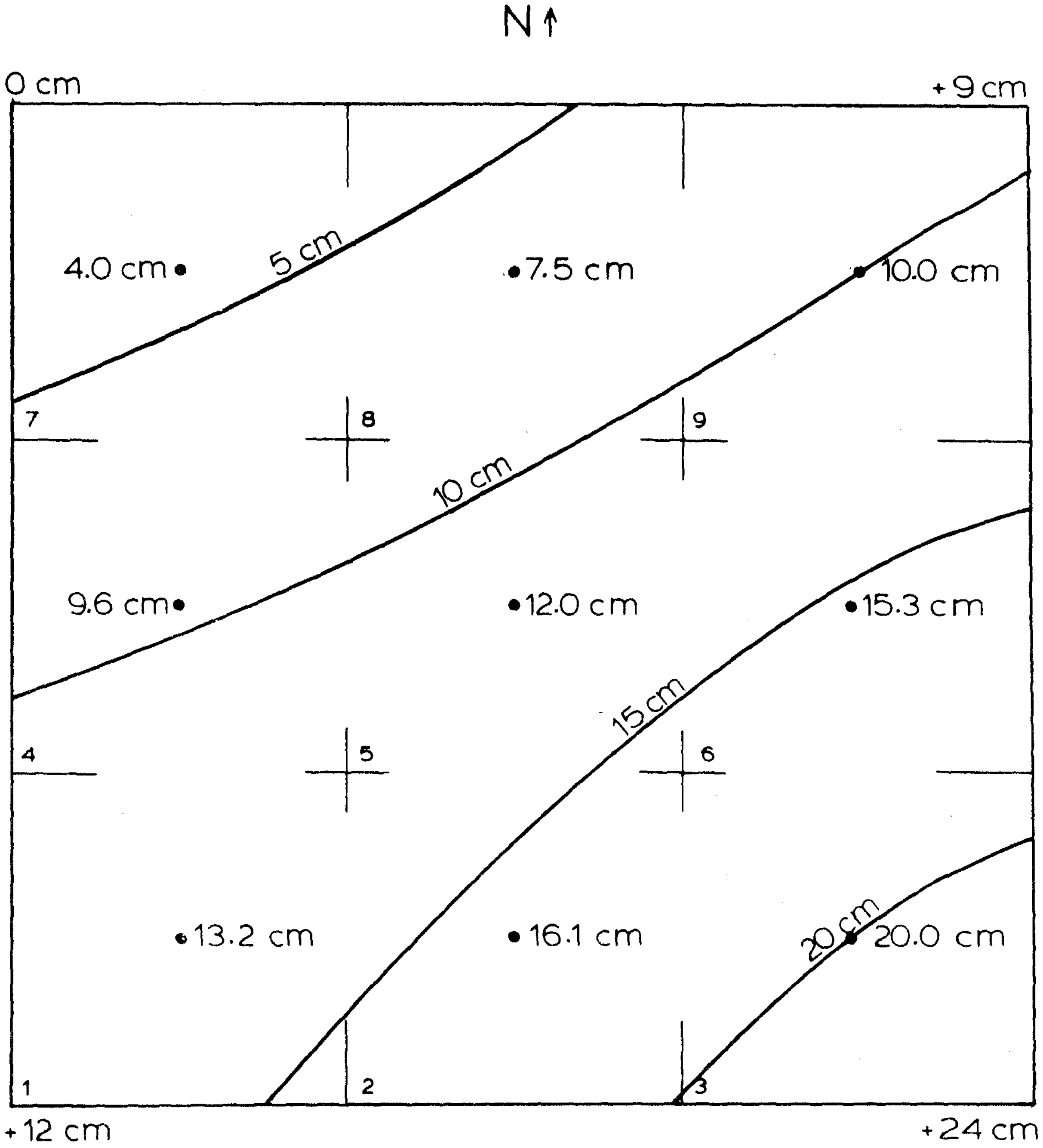
Again, no significant influences on the BOD levels in the groundwater samples were discovered. The coefficient of determination was only 17%.

B. Ground Water Levels

Ground water observation wells cased with perforated pipe in each plot were monitored regularly beginning in early June. However, by early July it became obvious that they were not functioning correctly. The wells were replaced at that time and observations were continued. No consistent pattern in water table change was observed thereafter and it was concluded that a different method of observation should be used. For the following season (to be covered in a subsequent report), piezometer tube sets were installed in each plot and at other locations outside the plot area.

While detailed water table data are not reported herein, a general observation is that the regional water table due to the Yampa river stage controls at the plot area, masking out fluccuations due to depth of water applied to individual plots or to the influence of drain tubes. For most of the season the water table was below the depth of drains (75 cm.).

Figure 24 - Surface elevations within treatment plots (relative to NE corner).



C. Plant Analyses

The following discussion will focus on the mean values for the various plant parameters. Again, if statistically significant results were obtained for a given parameter, these results may not reflect true differences and must, therefore, be viewed skeptically. However, if no significant differences were found, replication of the treatments would probably still result in non-significant differences.

Tables 6-9 represent the mean values and the statistical results for plant yield and quality.

The total concentration of a given plant component is of significance when considering hay quality. From a environmental viewpoint, the total uptake of a given component is of greater significance. Total uptake in Kg per hectare (Ha) was calculated by multiplying the plant yield (Kg/Ha) for a plant subsample by the plant concentration expressed as Kg of component, nutrient or trace metal per Kg of hay. The mean values for total uptake are presented in Table 9. The following results were obtained for the multiway analyses of variance (71):

1. Non-significant differences between hay samples from each plot were found for % moisture, total concentration of Cu, Ni and Ca and total uptake or production of protein, Zn, Cu, Ni, Fe, Mg, Ca and P.
2. Significant differences ($\alpha = 0.05$ level) were found for yield, total K and concentration and total K uptake.
3. Very significant differences ($\alpha = 0.01$ level) were discovered for percent protein, cell contents, cell wall contents, hemicellulose and acid detergent fiber, total concentration of Zn, Fe, Mn, Mg and P and total uptake of Cd and Mn.

The following results were found from Duncan's Multiple Range Test. Table 2 provides a list of plot numbers and their corresponding treatments.

---

*pp. 55, 56, 57 have been deleted from report.

No trend in yield was found due to the treatment on each plot even though some differences existed (Table 6).

Table 7 indicates that plots 8 and 9 (one inch and two inches of sewage effluent per week plus subsurface drainage tiles) contained a significantly higher percent crude protein and percent cell contents than the remaining plots. Also, plots 8 and 9 (one inch and two inches of sewage effluent per week plus subsurface drainage tiles) contained a significantly lower percent hemicellulose than all other plots except plot 5 (control plot - receives no water). For the percent acid detergent fiber, plot 9 (two inches of sewage effluent per week plus subsurface drainage) was significantly lower than plots 3,4,6, and 7. In general, plots 8 and 9 irrigated with sewage effluent, seem to have yielded a better quality crop than plots 1 through 7.

The total zinc (Zn) and iron (Fe) content of the plant material from plot 9 (two inches of sewage effluent per week plus surface drainage tiles) showed a significantly higher content than the plant material harvested in the other plots. A significantly higher total manganese (Mn) and magesium (Mg) content was found in the plant material from plots 8 and 9 (one and two inches of sewage effluent per week, respectively, plus subsurface drainage).

When total uptake of the various plant parameters was calculated and statistically analyzed, some significant differences were noted. However, no definite trends due to the treatments on each plot could be found.

Even though definite statements concerning statistical analyses cannot be made, irrigation of the mountain meadow with sewage effluent from Hayden appeared to have no deleterious effects on hay yield and quality found in this 1 year study. Total seasonal application of 30 to 70 Kg of nitrogen/ha were added to the plots receiving 5 cm per week of sewage effluent.

even though our analyses of the plant materials showed little or no significant accumulation this year. Other than total nitrogen only the phosphorus (P) concentration was much greater in the sewage effluent than the ditch water. A total of 20 to 30 Kg/ha of phosphorus (as orthophosphates) was added during the irrigation season to the plots receiving 5 cm of sewage effluent per week. Continual application of phosphorus could eventually effect the species composition and thus the yield and quality of the hay. Phosphorus tends to foster legumes at the expense of grasses.

From an agronomic standpoint, sewage effluent from Hayden may improve plant quality. From an environmental viewpoint, total uptake of plant nutrients and trace metals was within normally reported values (25) and should have little effect on environmental quality.

TABLE 3 - LIST OF PLOT NUMBERS AND CORRESPONDING TREATMENT

PLOT #	TREATMENT
1	One inch of sewage effluent per week.
2	One inch of ditch water per week.
3	Two inches of ditch water per week.
4	Two inches of sewage effluent per week.
5	No water applied (Control).
6	Two inches of ditch water per week plus subsurface drainage tiles.
7	One inch of ditch water per week plus subsurface drainage tiles.
8	One inch of sewage effluent per week plus subsurface drainage tiles.
9	Two inches of sewage effluent per week plus subsurface drainage tiles.

TABLE 4 - AVERAGE YIELD AND % MOISTURE FOR PLANT SAMPLES OF JULY 29, 1976

PLOT	YIELD (kg/Ha)	% MOISTURE
1	5054 abc	58.76 a
2	6654 c	63.44 a
3	6252 bc	64.12 a
4	5752 abc	63.54 a
5	4692 ab	60.30 a
6	5902 abc	60.56 a
7	4924 abc	62.50 a
8	4830 ab	64.64 a
9	4278 a	66.82 a
F Value (Oneway ANOVA)	2.13*	1.72

* Values followed by the same letter are not significantly different at the 0.05 significance level as determined by Duncan's Multiple Range Test.

TABLE 5 - AVERAGE QUALITY DATA FOR PLANT SAMPLES OF JULY 29, 1976

PLOT	% PROTEIN	% CELL CONTENTS	% CELL WALL CONTENTS	% HEMICELLULOSE	% ACID DETERGENT FIBER
1	5.47 a	47.03 a	52.97 b	17.17 b	35.80 bc
2	6.63 a	48.39 a	51.61 b	16.76 b	34.85 abc
3	7.43 a	43.91 a	56.09 b	18.95 b	37.14 c
4	8.00 a	43.86 a	56.14 b	19.17 b	36.97 c
5	7.86 a	48.84 a	51.16 b	15.28 ab	35.87 bc
6	6.51 a	42.84 a	57.16 b	20.40 b	36.76 c
7	7.43 a	46.52 a	53.48 b	17.00 b	36.49 c
8	10.67 b	54.58 b	45.42 a	11.83 a	33.59 ab
9	11.73 b	56.36 b	43.64 a	11.54 a	33.09 a
F Value (Oneway ANOVA)	5.49**	6.52**	6.52**	3.60 **	3.45 **

*Values followed by the same letter are not significantly different at the 0.05 significance level as determined by Duncan's Multiple Range Test.

TABLE 6 - AVERAGE TOTAL METAL CONTENT FOR PLANT SAMPLES OF JULY 29, 1976

PLOT	ppm Cd	ppm Zn	ppm Cu	ppm Ni
1	.0322 a	15.2 ab	3.48 a	3.32 ab
2	.0512 abc	15.0 ab	3.68 ab	3.30 ab
3	.0718 bc	16.4 b	4.10 abc	3.28 ab
4	.0366 ab	16.4 b	4.10 abc	3.28 ab
5	.0484 abc	16.4 b	5.14 abc	2.90 ab
6	.0240 a	15.7 b	4.14 abc	2.40 a
7	.0276 a	13.9 a	5.00 abc	2.68 ab
8	.0404 abc	16.2 b	5.84 bc	3.76 b
9	.0734 c	20.3 c	6.26 c	3.56 ab
F Value (oneway ANOVA)	2.59 *	9.74**	1.92	1.41

*Values followed by the same letter are not significantly different at the 0.05 significance level as determined by Duncan's Multiple Range Test.

TABLE 6 - CONTINUED

PLOT	ppm Fe	ppm Mn	ppm Mg	ppm Ca	% K	%P
1	87.0 ab	21.0 ab	3635 a	2250 ab	1.30 a	0.20 a
2	112.5 bc	28.5 bc	4574 a	2245 ab	1.71 bcd	0.23 bc
3	111.0 bc	17.5 a	4550 a	2420 ab	1.56 abcd	0.22 abc
4	82.0 a	34.5 c	4245 a	2480 ab	1.40 ab	0.24 c
5	92.5 ab	20.8 ab	4420 a	2565 ab	1.64 abcd	0.22 abc
6	107.5 abc	17.8 a	3872 a	1895 a	1.43 abc	0.20 ab
7	108.0 abc	26.5 abc	4340 a	2240 ab	1.51 abcd	0.20 ab
8.	119.5 c	51.8 d	6190 b	3220 b	1.75 cd	0.27 d
9	157.0 d	49.5 d	5725 b	3200 b	1.79 d	0.28 d
F Value (oneway ANOVA)	7.24**	16.14**	6.24**	2.19	2.88*	8.10**

*Values followed by the same letter are not significantly different at the 0.05 significance level as determined by Duncan's Multiple Range Test.

TABLE 6 CONTINUED

PLOT	ppm NO_3^- -N	NH_4^+ -N
1	9.2 a	27.7 a
2	36.6 a	42.0 a
3	10.2 a	33.1 a
4	19.4 a	42.9 a
5	15.0 a	34.5 a
6	16.9 a	36.9 a
7	38.1 a	45.9 a
8	47.3 a	76.4 b
9	48.2 a	89.8 b
F Value And Significance	1.35	4.85 **

TABLE 7 - AVERAGE UPTAKE OR PRODUCTION OF A NUMBER OF PLANT NUTRIENTS AND TRACE METALS

Kg/Ha

Plot	Protein	Cd	Zn	Cu	Ni
1	279 a	1.7×10^{-4}a	.077 ab	.018 a	.017 abc
2	432 ab	3.3×10^{-4}bc	.100 ab	.025 ab	.022 c
3	472 ab	4.5×10^{-4}c	.103 b	.027 ab	.020 bc
4	456 ab	2.1×10^{-4}ab	.094 ab	.022 ab	.016 abc
5	379 ab	2.4×10^{-4}ab	.078 ab	.025 ab	.014 ab
6	346 ab	1.4×10^{-4}a	.091 ab	.025 ab	.014 ab
7	378 ab	1.4×10^{-4}a	.069 a	.026 ab	.013 a
8	517 b	1.9×10^{-4}ab	.078 ab	.027 ab	.018 abc
9	488 ab	2.6×10^{-4}ab	.087 ab	.035 b	.015 ab
F value (oneway Anova)	1.23	4.28 **	1.47	0.84	2.15

Plot	Fe	Mn	Mg	Ca	K
1	.44a	.11ab	.18a	.11a	6.6×10^{-3}a
2	.73b	.19bcd	.30b	.15a	11.3×10^{-3}c
3	.70ab	.11ab	.28b	.15a	9.8×10^{-3}bc
4	.47ab	.20cd	.24ab	.14a	8.7×10^{-3}ab
5	.44a	.10a	.21ab	.13a	7.7×10^{-3}ab
6	.65ab	.11ab	.23ab	.11a	8.1×10^{-3}ab
7	.54ab	.13abc	.21ab	.11a	7.5×10^{-3}ab
8	.58ab	.25d	.30b	.16a	8.4×10^{-3}ab
9	.68ab	.22d	.24ab	.13a	7.5×10^{-3}ab
F value (Oneway Anova)	1.81	4.64 **	1.90	0.72	2.28 *

D. Soil Analyses

From the initial soil sampling (August 4, 1975), we determined that no significant soil fertility or trace metal variations existed in the treated area before implementation of the project. Consequently, all nine samples for each depth from an first sampling were grouped together for comparison with the values found from the samples of April 9, 1977. Mean values for all soil tests and the results of Duncan's multiple range test are presented in Table 10.

1. Nitrogen Species

As shown in Table 10, total soil nitrogen on the treated plots varied little from the values measured before the experiment was iniated. Both $NH4^{+}$-N and NO_3^--N were much higher in the initial samples. Differences in these values may be due to different sampling periods. The initial samples were obtained in summer while the second set was taken in early spring. Immobilization (conversion of inorganic to organic forms) may have occured during the year and half between samplings. Typically both NH^4+ and NO_3^--N do vary greatly during various periods of the year and from one year to the next. Most often the indigenons minorganisms greatly varied in numbers in early spring. Consequently, the larger population of microbe will absorb NH^4+ and NO_3^--N because of the greater nutrient demand.

2. Phosphorus

Application rate and type of drainage produced a very significant influence on soil phosphours (P). Initial P values were within the range of the levels measured on soil samples obtained after plot treatment. The plots receiving 5 cm/week with sub surface tiles contained larger concentrations of Na HCO_3 extractable P.

3. TOTAL METAL CONTENT (HOT 4N HNO_3 ACID EXTRACTABLE)

Total copper (Cu) content was significantly affected by type of drainage. Total Cu generally was higher in the plots that contained subsurface drainage. In the 0 to 30 and 30 to 60 cm sample total Cu of the initial samples was higher but not significantly different from most Cu levels found in the soil after treatment.

With higher organic matter accumulations at the surface from plant residues, depth was discovered to be a very significant factor in describing the variation of total zinc (Zn), nickel (Ni) and manganese (Mn). For some unknown reason, type of drainage exerted a very significant effect on total Ni and Mn with those plots containing tiles having the lower values for both metals.

The total Cu, Zn and Mn in the 0 to 30 cm sample taken initially were higher but not significantly different fom most Cu, Zn, and Mn concentrations found in the samples obtained after treatment. The total Ni contact in 0 to 30 cm samples was lower but not significantly different from total Ni values found in the second set of soils. Even though some variations in total metal content exist between the initial and second set of soil samples, no concentrations were extraordinarily high and no important variation were observed.

4. DTPA FOR SELECTED METALS

DTPA is a chelating agent that extracts concentrations of iron (Fe), Zn, Cu and Mn from soils that correlate well with plant needs and uptakes of these metals (52). Concentrations of the above metals when extracted with DTPA may represent their availability to plants and/or suspectibility to leaching.

For Fe it was found that type of drainage produced a very significant difference. Plots containing subsurface drainage exhibits higher Fe-DTPA values. Little difference was shown between initial levels and the concentrations found in the second set of samples.

Depth had a very significant impact on Cu-DTPA values. Initial levels of Cu-DTPA in 0 to 30 cm samples were significantly higher than those found in the

TABLE 8 MEAN SOIL VALUES AND SIGNIFICANCE (DUNCAN'S MULTIPLE RANGE TEST)

PLOT	ppm NH_4^+-N			ppm NO_3^--N		
#	0-30 cm	30-60 cm	60-90 cm	0-30 cm	30-60 cm	60-90 cm
1	1.27 a	0.10 a	2.20 a	0.45 a	0.10 a	.10 a
2	2.90 a	0.40 a	.20 a	5.20 a	0.40 a	0.90 a
3	0.60 a	0.20 a	0.90 a	0.90 a	0.10 a	2.20 a
4	0.40 a	4.40 a	.20 a	0.10 a	6.10 a	.10 a
5	0.40 a	0.20 a	3.10 a	0.10 a	0.10 a	2.20 a
6	0.20 a	6.50 a	.20 a	0.10 a	2.60 a	.10 a
7	0.20 a	0.20 a	.20 a	2.20 a	0.10 a	.10 a
8	0.75 a	0.20 a	.20 a	1.05 a	0.10 a	.10 a
9	0.70 a	4.40 a	.20 a	0.10 a	3.10 a	.10 a
Initial Sample	48.49 b	53.76 b	45.12 b	21.82 b	20.61 b	16.17 b
± S.D.	±8.84	±15.73	±7.89	±8.29	±8.48	±4.54
F Value & Sig.	30.41**	6.67**	30.80**	6.92**	3.02*	7.56**
	ppm P			% Total N		
1	15.0 a	8.7 a	5.5 a	0.20 ab	0.10 a	0.08 a
2	15.0 a	20.5 bc	16.2 abc	0.21 ab	0.10 ab	0.08 a
3	21.5 ab	36.4 d	30.6 cde	0.19 a	0.16 d	0.08 a
4	37.8 c	51.9 e	35.9 de	0.18 a	0.14 cd	0.09 a
5	48.5 cd	50.2 e	40.6 de	0.20 a	0.14 bcd	0.09 a
6	38.8 c	32.7 d	44.1 e	0.18 a	0.15 cd	0.09 a
7	42.5 cd	31.4 cd	26.6 cd	0.19 a	0.10 a	0.08 a
8	54.2 d	37.6 d	49.7 e	0.19 a	0.12 abc	0.09 a
9	46.8 ed	26.5 bcd	24.1 bcd	0.18 a	0.09 a	0.08 a
Initial	27.38 b	17.4 b	11.2 ab	0.22 b	0.16 d	0.10 a
± S.D.	±6.10	±4.7	±5.9	±0.02	±0.02	±0.03
F Value + Sig.	13.53**	16.71**	7.94**	2.68*	5.32**	1.01
	ppm Total Cu			ppm Total Zn		
1	24.4 ab	25.0 d	21.3 ab	61.5 a	54.5 abc	56.0 ab
2	22.6 a	22.5 bc	21.3 ab	73.2 cd	48.9 a	59.2 ab
3	23.2 a	23.8 bcd	22.5 ab	64.2 abc	59.2 abc	56.7 ab
4	24.4 b	23.8 bcd	25.0 b	68.5 abc	62.1 abc	57.5 ab
5	23.2 a	25.0 d	23.8 ab	66.2 abc	66.2 cd	55.8 ab
6	24.4 ab	23.8 bcd	22.5 ab	64.2 ab	81.0 e	58.8 ab
7	21.9 a	21.3 b	23.8 ab	66.3 abc	50.8 ab	56.4 ab
8	23.3 a	22.5 bc	21.3 ab	68.5 abc	54.3 abc	58.8 ab
9	22.7 a	17.5 a	20.0 a	70.2 bc	54.4 abc	50.8 a
Initial	26.7 b	25.0 d	23.1 ab	78.8 d	73.5 de	64.1 b
± S.D.	±2.2	±1.2	±2.1	±3.5	±5.4	±5.7
F Value + Sig.	3.00*	8.03 **	1.32	6.98**	9.22**	1.82

PLOT #	ppm 0-30 cm	Total 30-60 cm	Ni 60-90 cm	ppm 0-30 cm	Total 30-60 cm	Mn 60-90 cm	ppm 0-30 cm	Fe-DTPA 30-60 cm	60-90 cm
1	25.4 bc	23.6 a	26.4 b	311.3 abc	332.5 de	321.7 ab	80.0 ab	47.7 ab	49.1 ab
2	26.5 c	23.9 a	28.0 b	329.6 cd	296.7 cd	310.0 ab	62.8 a	53.4 abc	35.5 ab
3	23.3 abc	23.4 a	25.1 ab	322.6 bcd	308.3 cd	330.0 ab	64.0 a	65.6 abc	45.3 ab
4	26.3 c	21.8 a	24.2 ab	326.3 cd	297.5 cd	421.7 c	76.9 a	88.2 bc	54.7 bc
5	25.7 bc	25.2 a	26.1 ab	302.6 abc	282.5 bcd	310.8 ab	69.5 a	103.2 c	41.0 ab
6	26.2 bc	22.2 a	21.0 a	310.9 abc	306.7 cd	253.3 a	50.4 a	97.5 bc	180.0 e
7	23.1 ab	24.8 a	21.8 a	291.3 ab	260.0 bc	315.8 ab	77.5 a	64.9 abc	88.3 d
8	23.8 abc	21.8 a	22.3 a	290.4 ab	228.3 ab	354.2 bc	50.0 a	82.7 bc	77.5 ed
9	25.1 bc	22.7 a	22.3 a	280.9 a	200.0 a	269.2 ab	108.6 b	67.9 abc	58.0 bc
Initial	22.5 a	21.9 a	23.3 a	344.5 d	361.4 e	344.9 b	55.0 a	41.1 a	32.1 a
±S.D.	±1.2	±1.1	±1.2	±16.0	±23.6	±26.9	±11.0	± 3.5	±8.0
F Value & Sign	3.52**	1.48	1.87	6.21**	9.87**	3.23**	4.61**	2.71*	17.78**
	ppm	Cu-DTPA		ppm	Zn	DTPA	meg/100g	Exch. Na	
1	2.5 ab	2.3 abc	2.5 ab	2.5 a	0.7 a	1.0 ab	0.41 a	0.46 a	0.43 ab
2	2.5 ab	2.0 a	2.5 ab	2.5 a	0.9 ab	1.1 ab	0.39 a	0.42 a	0.44 ab
3	2.5 b	2.4 bc	2.6 ab	2.2a	1.8 de	1.3 ab	0.43 ab	0.43 a	0.40 ab
4	2.6b	2.6 c	2.7 ab	2.2 a	2.3 e	1.6 b	0.44 b	0.47 a	0.38 ab
5	2.3 ab	2.5 bc	2.7 ab	2.3 a	2.7 e	1.1 ab	0.42 ab	0.39 a	0.46 ab
6	2.1 a	2.4 abc	3.0 bc	2.0 a	1.7 cde	1.3 ab	0.44 ab	0.41 a	0.35 a
7	2.2 ab	2.2 ab	3.5 c	2.0 a	0.9 ab	1.1 ab	0.38 a	0.26 a	0.29 ab
8	2.3 ab	2.6 c	2.7 ab	2.3 a	1.4 bcd	1.4 b	0.39 a	0.46 a	0.49 b
9	2.3 ab	2.2 abc	2.2 a	2.2 a	1.1 abc	1.1 ab	0.36 a	0.49 a	0.36 ab
Initial	2.8 c	2.6 c	2.6 ab	2.3 a	1.5 cd	0.9 a	0.49 b	0.33 a	0.57 b
± S.D.	±0.2	±0.1	±0.2	±0.5	±0.3	±0.3	±0.05	±0.26	±0.22
F Value & Sign.	5.97**	3.64**	2.45*	0.63	6.78**	0.99	3.56**	0.66	1.53
	meg/100g	Exch. K		meg/100g	Exch. Ca		meg/100g	Exch Mg	
1	0.63 b	0.98 ab	0.55ab	23.9 cd	15.0 ab	27.8 bc	7.0 c	6.4 a	9.6 ab
2	0.65 bc	0.97 ab	0.47 a	20.2 abc	15.4 ab	24.0 bc	6.3 abc	6.2 a	10.7 b
3	0.78 bcd	0.79 ab	0.53ab	16.0 ab	18.2 b	22.1 abc	6.6 abc	6.2 a	7.1 ab
4	0.89 bcd	1.03 b	0.65 b	15.2 a	17.9 ab	15.2 a	6.5 abc	6.7 a	10.8 b
5	0.91 cd	1.05 b	0.59ab	16.1 ab	18.4 b	16.1 a	7.3 c	6.6 a	8.9 ab
6	0.95 d	0.91 ab	0.65 b	17.9 ab	19.7 b	16.1 a	6.3 abc	6.0 a	6.1 a
7	0.39 a	0.66 ab	0.55ab	26.2 d	11.3 ab	27.7 bc	7.0 bc	4.0 a	10.5 b
8	0.73 bcd	1.17 b	0.63ab	21.6 bcd	17.4 ab	24.9 bc	6.9 abc	6.7 a	10.1 b
9	0.70 bcd	1.07 b	0.50ab	19.3 abc	15.5 ab	29.1 bc	5.7 a	6.2 a	7.7 ab
Initial	0.74 bcd	0.60 a	0.50ab	15.5 a	10.7 a	18.5 ab	6.1±ab	4.6 a	7.5 ab
±S.D.	±0.11	±0.36	±0.11	±2.8	±6.4	±6.0	0.7	±2.7	±1.7
F Value	3.97**	2.23	1.94	5.00**	1.91	5.98	2.49*	0.95	2.24

p. 71 (Con'd)

PLOT #	EC mmhos/cm 30-60 cm	0-30 cm	60-90 cm	PH 30-60 cm	0-30 cm	60-90 cm	ppm Boron 30-60 cm	0-30 cm	60-90 cm
1	0.57 a	0.91 b	0.49 ab	7.6 b	7.1 a	7.6 a	0.24 a	0.25 a	0.21 a
2	0.60 a	0.97 b	0.62 b	7.3 ab	7.0 a	7.4 a	0.35 a	0.23 a	0.24 a
3	0.49 a	0.89 b	0.66 b	7.0 a	6.9 a	7.4 a	0.18 a	0.25 a	0.20 a
4	0.63 a	0.77 ab	0.49 ab	7.1 ab	6.9 a	7.3 a	0.24 a	0.28 a	0.21 a
5	0.71 a	0.69 ab	0.43 ab	7.1 ab	6.9 a	7.3 a	0.21 a	0.19 a	0.30 a
6	0.50 a	0.81 ab	0.52 ab	7.2 ab	7.0 a	7.3 a	0.29 a	0.23 a	0.30 a
7	0.57 a	0.94 b	0.49 ab	7.3 ab	6.9 a	7.6 a	0.29 a	0.23 a	0.20 a
8	0.53 a	0.96 b	0.45 ab	7.2 ab	7.1 a	7.4 a	0.38 a	0.34 a	0.26 a
9	0.50 a	0.65 ab	0.41 ab	7.6 b	6.9 a	7.5 a	0.25 a	0.21 a	0.20 a
Initial ±S.D.	0.54 a ±0.22	0.35 a ±0.10	0.37 a ±0.14	7.2 ab ±0.2	7.2 a ±0.2	7.4 a ±0.2	0.28±a 0.07	0.30 a ±0.03	0.21 a ±0.07
F Value & Sig.	0.47	2.38*	1.17	1.60	0.59	0.35	1.13	1.22	0.23

	Mn DTPA		
1	26.60 bc	12.43 ab	12.75 abc
2	29.83 c	16.20 bc	20.05 c
3	28.77 bc	19.07 c	17.53 bc
4	20.57 bc	12.07 ab	14.53 abc
5	19.77 b	12.23 ab	12.03 abc
6	18.80 ab	13.05 ab	9.23 a
7	23.60 bc	11.63 ab	17.00 abc
8	26.30 bc	10.33 a	11.30 abc
9	23.03 bc	9.07 a	11.07 ab
Initial ±S.D.	12.30 a ± 2.87	12.53 ab ±2.80	11.26 ab ±1.97
F Value & Sig.	5.80**	2.70*	2.03

second set of samples. (Table 10) However, from a practical standpoint, the differences are too small (0.2 ppm) to constitute a problem.

Zn-DTPA was very significantly affected by depth. Intial Zn-DTPA soil values were not significantly different from those found in the April 1976 soil sample.

Mn-DTPA levels decreased very significantly with depth and with the presence of subsurface drainage tiles. Plots receiving ditch water contained significantly higher concentrations of Mn-DTPA. Intial levels of Mn-DTPA (1975) in the 0 to 30 cm samples were lower but not significantly different from the values measured in the April 1976 samples obtained after one season of treatment.

5. EXCHANGEABLE CATIONS

Exchangeable sodium (Na) in soil samples was significantly affected by the type of water with most plots receiving sewage effluent containing more exchangleable Na than those irrigated with ditch water. The sodium content in the sewage effluent was generally two to three times greater than that found in the ditch water. Also, exchangleable Na levels in the intial soil samples (all depths) were higher but not significantly different from what was found in the soil samples obtained after one season of operation.

Application rate and type of water exerted significant influence on exchangeable potassium (K). Exchangeable K was greater at the surface. In plots receiving sewage effhuent, (3 to 8 ppm K), the exchangeable K was higher than in plots receiving ditch water. Lower levels of exchangeable K were found in plots receiving irrigation of 5 cm per week as opposed to those receiving 2.5 cm per week. This may result from leaching differences. Intial soil samples contained less but not significantly different exchangable K in the 0 to 30 cm depth than was measured in the sOil samples taken after the irrigation season (1976 samples).

Application rate and depth had very significant influence on the exchangeable calcium (Ca) levels found in the 1976 samples. Generally, less exchangeable Ca w found with greater depth. As reflected by pH values of the 60-90 cm samples, calcareons ($CaCO_3$) or dolomitic ($CaMg(CO_3)_2$) soil conditions probably exist. No significant differences between the initial (1975) and second set of soil samples was determined.

For exchangeable magnesium (Mg), depth exerted a very significant effect. Changes with depth indicate, as mentioned previously, that higher exchangeable Mg in the 60 to 90 cm depth samples might reflect the accumulation of free carbonates of Ca and/or Mg. No significant differences between 1975 and 1976 samples were found for exchangeable Mg.

6. IONIC SALTS, pH AND BORON

Ionic salts (electrical conductivity of saturated soil extracts) and pH varied very significantly with depth. Salts are generally higher at the soil surface; however, the salt content found in all soil samples pose no problem to plant growth or as a hazard to ground water contamination. pH of saturated soil pastes increased progressively with increasing depth. The boron content of the saturated soil extracts were not influenced by the major treatment factors or depths. No significant differences in ionic salt content, pH or boron content was found between the intial soil samples (1975) and the soil samples obtained after treatment (1976).

VII. CONCLUSIONS ON FIELD STUDY

Electrical conductivity (ionic salts) measurements on sewage effluent, ditch water, ground water, soil solution and soil samples indicated that no salt problem exists or is anticipated when irrigating the study site with the waste water from the Hayden, Colorado treatment lagoons. Salt content in the irrigation waters changed very significantly with date of sampling while the salts found in the soil samples decreased very significantly with increased soil depth.

For NO_3^--N and $NH4^+$-N, the soil-plant system effectively reduced the concentration of these chemicals as the sewage effluent and ditch water percolated into the groundwater. No significant leaching into the ground water or accumulation in plant or soil samples were found in this study.

Ground water concentrations of Ca^{+2} indicated that the soil served as the major source of this cation. At the depths of groundwater fluctuation (60 to 150 cm), the soil does contain a higher content of exchangeable Ca^{2+} . Soil samples from plots receiving 5 cm of irrigation per week contained lower exchangable Ca^{2+} than those getting 2.5 cm per week. However, differences in ground water concentrations of Ca^{2+} did <u>not</u> indicate that the higher application rate increased the leaching of Ca^{2+}. Plant concentration of Ca^{2+} was very significantly increased by irrigation with sewage effluent; but, no significant effects were found when total uptake (plant concentration X yield) was analyzed. From this investigation, Ca^{2+} appears not to be a serious problem.

Study of the Mg^{2+} situation in water, plant and soil samples implied the same results and conclusions that were reached for Ca^{2+} (Mg^{2+} poses no problem).

Potassium (K^+) in ground water samples was not influenced by any of the treatments while plant uptake of K^+ significantly decreased when the meadow was irrigated with sewage effluent. Higher exchangeable K^+ content was found in soil samples that received sewage effluent, which contained more K^+ than the ditch water. Also, higher application rates lead to lower exchangeable K^+ indicating that the higher rates may have produced more leaching; however, ground water samples did not substantiate this hypothesis. Overall, K^+ does not seem to be a major problem in using the sewage effluent of Hayden as an irrigation source.

Exchangable Na^+ increased significantly in the soils receiving sewage effluent; but,ground water samples did not show that greater leaching had occured. Presently, 2% of the cation exchange capacity consists of exchangable sodium. Exchangable sodium percentages of 15% would disperse the soil and greatly reduce infiltration of the irrigation water.

Even though the sewage effluent contained a much higher P content (2 to 5 ppm) than the ditch water (less than 1ppm), no significant differences in the P levels were found. The P in the waste water accumulated (by precipitation or absorption) at the soil surface and/or absorbed by the plants. Plant concentrations of P (percent P- Table 6) were significantly increased by application of sewage effluent and the presence of subsurface drainage tiles. Plant uptake values (Kg P absorbed per hectare - Table 7) did not follow this trend because of variations in the yield for each plant subsample. Soil level of $NaHCO_3$ extractable P were very significantly influenced by application rate and type of drainage but not by the type of irrigation water. In any event, P in the sewage effluent poses no problem to ground water contamination; but, it may provide a macronutrient required for plant growth. The continual application of sewage effluent with 2 to 5 ppm P could produce a larger percentage of clover in the mountain meadow. However, as nitrogen availability increases, grasses may crowd out the leguminous species.

BOD concentrations found in the ground water samples indicate that the organic material in the sewage effluent probably accumulates at the soil surface. BOD and COD levels found in the ground water are indications of background levels of organic material naturally resulting from soil-water interactions. BOD and COD values from the control plot and the plots receiving sewage effluent and ditch water were not significantly different.

Indications are that the soil-plant system has effectively lowered the number of fecal and total coliform from the sewage effluent before the percolate reaches the ground water.

Based on water, plant and soils data, the trace metals, Cd, Zn, Fe, Mn, Cu and Ni appear to pose no hazards during the first year. If non-agricultural industries are introduced in Hayden, the potential threat of trace metal contamination could substanially increase. Constant monitoring of the sewage effluent would be required to detect any potential problem.

Total nitrogen in the sewage effluent (1 to 7 ppm) could possibly affect protein content of plants and total soil nitrogen. The protein percentage in plants was very significantly increased by application of sewage effluent and the presence of drainage tiles; however, total production of protein (% protein X yield) was not affected by these factors. Before the organic nitrogen can be utilized by the plants, it must be transferred to NO_3^- and/or NH_4^+ . This conversion may not be detectable until after years of sewage effluent application. Organic matter accumulation, primarily from plant residues, accounts for higher surface concentration.

The quality of the hay crop (81,82,83), measured by methods of Van Soest and Van Soest and Wine (84) produced was generally better on the plots that received sewage effluent and contained subsurface drainage tiles. This factor may be attributed to shifts from grasses to clover species in the plots receiving the above treatments. Yield, on the other hand, was significantly lower on plots receiving sewage effluent and in those containing drainage tiles.

Soil pH values indicate a possible accumulation of carbonates in the subsurface (60 to 90 cm). Higher exchangeable Ca^{2+} and Mg^{2+} were found in these samples as compared to the o to 30 cm and 30 to 60 cm soil samples.

One year of field observation is insufficient to warrant far-reaching conclusions but the data herein presented strongly suggest that this land treatment and disposal site is functioning extremely well with the lagoon effluent (secondary treatment) from the town of Hayden, Colorado. The quality of effluent reaching the watertable is not significantly different from the quality of irrigation ditch water reaching the watertable. Further, the depth to watertable is relatively small at this terrace site along the Yampa river.

Future Work.

This year of field plot research, financed by the Northwest Colorado Council of Governments, the Upper Yampa Water Conservancy District and The Upper Colorado River Water Conservation District has proved to be so promising that the U. S. Environmental Protection Agency has agreed to finance its continuation for two additional seasons. The field observations will therefore be continued so that conclusions can be drawn with greater confidence. A report on the extended study should be available in late 1979 or early 1980.

VIII. LIST OF REFERENCES

1. Andrew, Roger C. and A. Paul Troemper. 1977. Underflow from sludge-irrigated cropland. Journal WPCF 49:161-168.

2. Amer. Publ. Health Assn. 1975. Standard Methods for the Examination of Water and Wastewater. 14th edition. Washington, D.C.

3. Appelt, H., K. Holtzclaw, and P.F. Pratt. 1975. Effect of anion exclusion on the movement of chloride through soils. Soil Sci. Soc. Amer. Proc. 39:264-267.

4. Ardakani, M.S., J.T. Rehbock, and A.D. McLaren. 1974. Oxidation of ammonium to nitrate in a soil column. Soil Sci. Soc. Amer. Proc. 38:96-99.

5. Ardakani, M.S., R.K. Schulz, and A.D. McLaren. 1974. A kinetic study of ammonium and nitrate oxidation in a soil field plot. Soil Sci. Soc. Amer. Proc. 38:273-277.

6. Barton, Charles J. 1948. Photometric analysis of phosphate rock. Analytical Chemistry 20:1068-1073.

7. Beck, J., F.A.M. deHaan, and L.H. Riemadylz. 1977. Phosphates in soils treated with sewage water: I. General information on sewage farm, soil and treatment results. J. Environ. Qual. 6:4-7.

8. Bell, R.G. 1976. Persistence of fecal coliform indicator bacteria on alfalfa irrigated with municipal sewage lagoon effluent. J. Environ. Qual. 5:39-42.

9. ____________ and J.B. Bole. 1976. Elimination of fecal coliform bacteria from reed canary grass irrigated with municipal sewage lagoon effluent. J. Environ. Qual. 5:417-418.

10. Benci, John F. and Thomas B. McKee. 1977. Colorado Growing Season. Colorado Climatology Report No. 77-3 Climatology Office. Colorado State University. Fort Collins.

11. Bitton, G., N. Masterson, and G. E. Gifford. 1976. Effect of secondary treated effluent on the movement of viruses through a Cypress dome soil. J. Environ. Qual. 5:370-375.

12. Bouwer, Herman. 1968. Returning wastes to the land, a new role for agriculture. J. Soil and Water Cons. 23:164-168.

13. Bouwer, Herman. 1973. Land treatment of liquid waste: The hydrologic system. In Recycling Municipal Sludges and Effluents on Land. Natl. Assoc. of State Univ. and Land Grant Colleges, Wash., D.C. pp. 103-111.

14. Bouwer, Herman, and R. L. Chaney. 1974. Land treatment of wastewater. Advan. Agron. 26:133-176.

15. Bouwer, C. A. and L.V. Wilcox. 1965. Soluble salts. In C. A. Black, D. D. Evans, J. L. White, L. E. Ensiminger, F. E. Clark (eds.) Methods of Soil Analysis. Part II. Soil Sci. Soc. Am., Madison, Wisc. pp. 933-951.

16. Bradford, G. R., A.L. Page, L.J. Lund, and W. Olmstead. 1975. Trace element concentrations of sewage treatment plant effluents and sludges; their interactions with soils and uptake by plants. J. of Environ. Qual. 4:123-127.

17. Bremmer, J. M. 1965. Total nitrogen In C. A. Black, D. D. Evans, J. L. White, L. E. Enseninger, F. E. Clark (eds) Methods of Soil Analysis, Part II. Soil Sci. Soc. Am., Madison, Wisc. PP. 1149-1178.

18. Bremmer, J. M. 1965. Inorganic forms of nitrogen. C. A. Black, D. D. Evans, J. L. White, L. E. Enseninger, F. E. Clark (eds) Methods of Soil Analysis. Part II. Soil. Sci. Soc. Am., Madison, Wisc. pp 1179-1237.

19. Bresler, Eshel. 1967. A model for tracing salt distribution in the soil profile and estimating the efficient combination of water quality and quantity under varying field conditions. Soil Sci. 104:227-233.

20. Bresler, E. 1973. Solute movement in soils. In Arid Zone Irrigation. B. Yaron, E. Danfors, and Y. Vaadia (eds.). Springer-Verlag, New York. pp. 165-175.

21. Campbell, I.S. and A.D. Dotzenko. 1975. Evaluating forage quality of postures. J. of Range Management. 28:149-151.

22. Cassel, D.K., T.H. Krueger, F.W. Schroer, and E.B. Norum. 1974. Solute movement through disturbed and undisturbed soil cores. Soil Sci. Soc. Amer. Proc. 38:36-40.

23. Chaney, Rufus L. 1973. Crop and food chain effects of toxic elements in sludges and effluents. In Recycling Municipal Sludges and Effluents on Land. Nat'l. Assoc. of State Univ. and Land Grant Colleges, Washington, D.C. pp. 129-141.

24. Chapman, H.D. 1965. Total exchangable bases. In C.A. Black, D.D. Evans, L.E. Ensminger, F.E. Clark (eds.). Methods of Soil Analysis. Part II. Soil Sci. Soc. Amer., Madison, Wisc. pp. 902-904

25. Chapman, H.D.(ed.). 1966. Diagnostic Criteria for Plants and Soils. Univ. of California, Div. of Agric. Sci., Berkley, Calif.

26. Chumbley, C.G. 1971. Permissible levels of toxic metals in sewage used on agricultural land. A.O.A.S. Advisory Paper No. 10. 12 pp.

27. Cornwell, David A., John Zoltek, Jr., C. Dean Patrinely, Thomas des Furnam and Jung I. Kim. 1977. Nutrient removal by water hyacinths. Journal WPCF. 49:57-65.

28. Dalton, Frank E., Jerome E. Stein, and Bart T. Lyman. 1968. Land reclamation- A complete solution of the sludge and solids disposal problem. Journal WPCF 40:789-804.

29. Davis, Stanley N. and Roger J.M. De Wiest. 1966. Hydrogeology. John Wiley and Sons, Inc. New York.

30. Day, A.D. and R.M. Kirkpatrick. 1973. Effects of treated municipal wastewater on oat forage and grain. J. Environs Qual. 2:282-283.

31. __________, Abdul Ralunan, F.R.H. Katterman, and Varon Jensen. 1974. Effects of treated municipal wastewater and commerical fertilizer on growth, fiber, acid-soluble nucleatides, protein and amino acid content in wheat hay. J. Envion. Qual. 3:17-19.

32. __________, F.A. Joher, and F.R.H. Kotterman, 1975. Influence of treated municipal waste water on growth, fiber, acid-soluble nucleatides, protein, and amino acid content in wheat grain. J. Environ. Qual. 4: 167-169.

33. Duke, H.R. and H.R. Haise. 1973. Vacuum extractors to assess deep percolation losses and chemical constituents of soil water. Soil Sci. Soc. Amer. Proc. 37:963-964.

34. Enfield, Carl G. 1974. Rate of phosphorus sorption by five Oklahoma soils. Soil Sci. Soc. Amer. Proc. 38:404-407.

35. Ghuman, B.S., S.M. Verna, and S.S. Prihar. 1975. Effect of application rate, initial soil wetness, and redistribution time on salt displacement by water. Soil Sci. Soc. Amer. Proc. 39: 7-10.

36. Greenberg, Arnold E. and Jerome F. Thomas. 1954. Sewage effluent reclamation for industrial and agricultural use. Sewage and Industrial Wastes 26:761-770.

37. Griffin, Robert A. and Neil F. Shimp, 1976. Effect of pH on exchange-adsorption or precipitation of lead from landfill leachates by clay minerals. Environ. Sci. Technal. 10:1256-1262.

38. __________, Neil F. Shimp, John D. Steele, Rodney R. Rush, W. Arthur White, and George M. Hughes. 1976. Attenuation of pollutants in municipal landfill leachate by passage through clay. Envion. Sci. Technal. 10:1262-1268.

39. Hansen, E.A. and A.R. Harris. 1975. Validity of woil-water samples collected with porous ceramic cups. Soil Sci. Soc. Amer. Proc. 39:528-536.

40. Harris, A. and E. Hansen. 1975. A new ceramic cup soil-water sampler. Soil Sci. Soc. Amer. Proc. 39:157-158.

41. Henry, C.D., R.E. Moldenhauer, L.E. Engelbert, and E. Truog. 1954. Sewage effluent disposal through crop irrigation. Sewage and Industrial Wastes 26:123-135.

42. John, Matt K., Hong H. Chuah, and John H. Newfield. 1975. Application of improved asomethine -H method to the determination of boron in soils and plants. Analytical Letters 8(8): 559-568.

43. Jones, Joe H. and George S. Taylor. 1965. Septic tank effluent percolation through sands under laboratory conditions. Soil Sci., 99:301-309.

44. Kardos, L. T. and J.E. Hook. 1976. Phosphorus balance in sewage effluent treated soils. J. Environ. Qual. 5:87-90.

45. Lagerwerff, J.V. 1972. Lead, mercury, and cadmium as environmental contaminants. In Micronutrients in Agriculture. J.J. Mortvedt, P.M. Giordano and W.L. Lindsay (eds.) Soil Sci. Soc. Amer., Madison, Wis. pp. 593-642.

46. Lance, J.C. and F.D. Whisler. 1972. Nitrogen balance in soil columns intermittently flooded with secondary sewage effluent. J. Environ. Qual. 1:180-186.

47. Lance, J.C., F.C. Whisler, and H. Bouwer. 1973. Oxygen utilization in soils flooded with sewage water. J. Environ. Qual. 2:345-350.

48. Larson, W.E., J.R. Gilley, and D.R. Linden. 1975. Consequences of waste disposal on land. J. Soil and Water Cons. 30:68-71.

49. Lehman, G.S. and L.G. Wilson. 1971. Trace element removal from sewage effluent by soil filtration. Water Resour. Res. 7:90-99.

50. Lindsay, W.L. 1972. Inorganic phase equilibria of micronutrients in soils. In Micronutrients in Agriculture. J.J. Mortvedt, P.M. Giordano, and W.L. Lindsay (eds.). Soil Sci. Soc. Amer., Madison, Wis. pp.41-57.

51. Lindsay, W.L. 1973. Inorganic reactions of sewage wastes with soils. In Recycling Municipal Sludges and Effluents on Land. Nat'l Assoc. of State Univ. and Land Grant Colleges, Washington, D.C. pp. 91-96.

52. Lindsay, W.L. and W.A. Norwell. 1969. Changes in DTPA extractable zinc, iron, manganese, and copper in soils following fertilization. Soil Sci. Soc. Am. Proc. 35:600-602.

53. Luley, H.G. 1963. Spray irrigation of vegetable and fruit processing wastes. Journal WPCF 35:1252-1261.

54. Miller, David E. Forest M. Willhite, and Hayden K. Rouse. 1955. High altitude meadows in Colorado: II. The effect of harvest date on yield and quality of hay. Agron. J. 47:69-72.

55. Miller, Robert H. 1973. Soil microbiological aspects of recycling sewage sludges and waste effluents on land. In Recycling Municipal Sludges and Effluents on Land. Nat'l Assoc. State Univ. and Land Grand Colleges. pp. 79-90.

56. Peech, Michael, 1965. Hydrogen-ion activity. In C.A. Black, D.D. Evans, J.L. White, L.E. Ensminger, F.E. Clark (eds.) Methods of Soil Analysis. Part II. Soil Sci. Soc. Am., Madison, Wisc. pp. 914-926.

57. Perkin-Elmer Corp. 1971. Analytical methods for atomic absorption spectrophotometry. Norwalk, Conn.

58. Pound, Charles E. and Ronald W. Crites. 1973. Characteristics of municipal effluents. In Recycling Municipal Sludges and Effluents on Land. Nat'l. Assoc. of State Univ. and Land Grant Colleges. Washington, D.C. pp. 49059.

59. Powers, W.L., G.W. Wallingford, and L.S. Murphy. 1975. Formulas for applying organic wastes to land. J. Soil and Water Cons. 286-289.

60. Purtymum, W.D., J.R. Bucholz, and T.E. Hakonson. 1977. Chemical quality of effluents and their influence on water quality in a shallow aquifer. J. Environ Qual. 7:29-32.

61. Robbins, C.W. and J.H. Smith. 1977. Phosphorus movement in calcareons soil irrigated with waste water from potato processing plants. J. Environ. Qual. 6:222-225.

62. Rouse, Hayden K., Forest M. Willhite, and David E. Miller. 1955. High altitude meadows in Colorado: I. Effect of irrigation on hay yield quality. Agron. J. 47:36-40.

63. Salvatto, Joesph A. Jr., 1972. Environmental engineering and sanitation, Wiley-Interscience, New York, N.Y.

64. Sawhney, B.L., 1977. Predicting phosphate movement through soil columns. J. Environ. Qual. 6:86-89.

65. Sidle, R.C., J.E. Hook, and L.T. Kardos, 1976. Heavy metal application and plant uptake in a land disposal system for waste water. J. Environ. Qual. 5:97-102.

66. __________ and W.E. Sopper. 1976. Cadmium distribution in forest ecosystems irrigated with treated municipal waste water and sludge. J. Environ. Qual. 5:419-422.

67. __________,J.E. Hook, and L.T. Kardos. 1977. Accumulation of heavy metals in soils from extended wastewater irrigation. Journal WPCF. 49:311-318.

68. Sorber, Charles A. Howard, T. Basum,Stephen A. Schaub, and Mitchell J. Small. 1976. A study of bacterial aerosols at a wastewater irrigation site. Journal WPCF. 48:2367-2379.

69. Stanford, G. and E. Epstein. 1974. Nitrogen mineralization-water relations in soils. Soil Sci. Soc. Amer. Proc. 38:103-107.

70. Starr, J.L., F.E. Broadbent, and D.R. Nielsen. 1974. Nitrogen transformations during continuous leaching. Soil Sci. Soc. Amer. Proc. 38:238-289.

71. Steel, R.G. and J.H. Torrie. 1960. Principles and Procedures of Statistics. McGraw-Hill, New York.

72. Stone, Ralph and John C. Merrell, Jr. 1968. Significance of minerals in wastewater. Sewage and Industrial Wastes 30:928-936.

73. Sutton, David L. and W. Harold Ornes. 1975. Phosphorus removal from static sewage effluent using duckweed. J. Environ. Qual. 4:367-370.

74. Tecator. Undated. Tecator Manual. Digestion System DS40.

75. Thompson, Larry Garth. 1976. Forage Quality Evaluation of Irrigated Pastures. Ph.D. Dissertation. Dept. of Agronomy, Colorado State University.

76. Tilstra, John R., Kenneth W. Malueg, and Winston C. Larson. 1972. Removal of phosphorus and nitrogen from wastewater effluents by induced soil percolation. Journal WPCF 44:796-805.

77. United States Department of Agriculture-Soil Conservation Service. 1971. Guide for Interpreting Engineering Uses of Soils. Washington, D.C.

78. United States Department of Agriculture. 1941. Climate and Man. Yearbook of Agriculture. Washington, D.C. pp. 798-807.

79. United States Department of Commerce. 1976. Climatological Data - Colorado. Ashville, North Carolina.

80. U.S. Public Health Service. 1962. Drinking water standards. USPHS Publ. 956-61 p.

81. Van Soest, P.J. 1963. Use of detergents in the analysis of fibrous feeds. II. A rapid method for determination of fiber and lignin. J. Assoc. Off. Anal. Chem. 46:829-835.

82. ___________, 1965. Non-nutritive residues: A system of analysis for the replacement of crude fiber. J. Assoc. Off. Anal. Chem. 49:546-551.

83. ___________, 1969. Basis for relationships between nutritive value and chemically identifiable fractions, pp. U-1---U-19. In National conference on forage quality evaluation and utilization. Nebr. Center for Cont. Ed., Lincoln, Nebr.

84. ___________, and R.H. Wine. 1967. Use of detergent in the analysis of fibrous feeds. IV. Determination of plant cell-wall constituents. J. Assoc. Off. Anal. Chem. 50:50-55.

85. Watanabe, F.S. and S.R. Olsen. 1965. Test of an ascorbic acid method for determining phosphorus in water and $NaHCO_3$ extracts from soils. Soil Sci. Soc. Am. Proc. 29:677-678.

86. Whisler, F.D., J.C. Lance, and R.S. Linebarger. 1974. Redox potentials in soil columns intermittently flooded with sewage water. J. Environ. Qual. 3:68-74.

87. Wilcox, L.V. 1948. Agricultural uses of reclaimed sewage effluent. Sewage Works Journal 20:24-35.

88. Willhite, Forrest M., Hayden K. Ronse, and David E. Miller. 1955. High Altitude Meadows in Colorado: III. The effect of nitrogen fertilization on crude protein production. Agron. J. 47:117-121.

89. Wright-McLaughlin Engineers. 1974. Report on Sewage Effluent Renovation in Mountain Meadows. Report to Board of Directors Upper Yampa Water Conservancy District. Steamboat Springs, Colorado.

Appendix A - WATER SAMPLE
DATA COLLECTED IN
1976

LOC	1976 Date	EC mmhos/cm	PPM NO_3^--N	PPM NH_4^+-N	PPM Cl^-	PPM Na+	PPM K+	Mg/l TDS	Mg/l TVS	PPm Ca2+	PPm Mg2+	PPm P	Mg/l BOD	Mg/l COD	Fecal Coli	Total Coli
Plot 1																
90cm	6-21	0.45			17.8	38.9	1.6			27	33					
90cm	7-1	1.26	0.9	2.1	43.8	14.1	1.2	190	40	15	9	33				
90cm	7-19	0.79	1.3	2.0	12.6					58	101					
Well		0.36	6.2	1.0	22.4	41.4	1.4	450	220	35	31					
Well	8-10	0.55	2.1	1.4	38.0											
90cm	8-19											<.08				
Well		0.85	2.9	0.2	72.4	120.0	2.0	720	400		68	.08	4	21		
90cm	9-2	1.01	0.2		36.3											
Well		0.93	0.1	1.1	72.4	114.0	3.1			50	123	.03	8	19		
90cm	9-16	1.08	1.5		31.6											
Well						22.0				30			18	48		
90cm	10-4	1.04	0.4	1.1	20.9	90.0				28	88					
Well		0.88	0.2	0.8	37.2	104.0		510	300	47	70	<.03				
Well	10-16	0.92	0.1	0.1	83.2											
Plot 2																
60cm	6-22	0.38		2.6	21.4	23.0	2.8	330	210	33	26					
90cm		0.77		1.0	11.0	34.6	1.6	600	420	76	60	.05				
Well		0.75		0.8	9.1	37.2	1.2	630	285	61	70	<.03	1	14		
60cm	7-1	0.71		10												
90cm		0.10	1.3	1.1	10	37.3	2.1	210	160	15	5					
Well		0.85	3.6	0.8	11.4	31.5	0.6	600	170	26	64	.07				
90cm	7-19	0.80	0.5	1.8	18.6	44.4	1.4	1330	550	22	68	<.03				
Well		0.67	0.6	1.2	30.2	38.4	0.6	770	300	70	71	.16	2	20		
Well	8-10	0.65	0.3	1.4	14.5	36.0	0.8	580	400		64	<.03	1	12	0	12
Well	8-19	1.21	4.7	0.4	57.5	120.0	1.6	1030	720		73	<.03	5	27		
90cm	9-2	1.10	0.2	6.0	95.5	34.0			26	23		<.03				
Well		1.00	0.2	1.2	20.9	120.0	2.1			55	23	<.03	3	18		
90cm	9-16	0.77	0.5	1.0	25.1	34.0										
Well										13	29		2	24		
90cm	10-4	0.76	0.1	0.8	16.2	360				38	68					
Well		1.02	0.2	0.4	35.5	114.0		630	300	44	80	.20	2	25		
90cm	10.16	0.59														
Well		1.04	0.1	0.1	51.3							.40	2	18	2	2

LOC	1976 Date	EC mmhos/cm	PPM NO_3^--N	PPM NH_4^+-N	PPM Cl^-	PPM Na+	PPM K+	Mg/l TDS	Mg/l TVS	PPm Ca2+	PPm Mg2+	PPm P	Mg/l BOD	Mg/l COD	Fecal Coli	Total Coli
Plot 3																
60cm	6-22	0.25			7.9	20.0	2.0			28	10					
90cm		0.79		1.8	8.4	33.2	3.6	530	290	57	62					
Well		0.92		0.1	16.3	41.7	2.4	480	260	84	62		2	20		
90cm	7-1	0.23	9.0	0.9	10	14.6	1.2	200	150	25	18	.05				
Well		0.81	3.6	1.0	11.3	37.3	1.5	610	110	85	56					
60cm	7-19	0.80	1.2		17.8											
90cm		0.47	10.4		19.1			560	250	61	71					
Well		0.51	1.3	0.9	14.5	47.5	1.2	650	230	51	59	.12	1	35		
90cm	8-10	0.63	0.9	1.9	13.5	48.3	3.6	620			58					
Well		0.99	0.6	0.9	17.8	45.0	2.2			57	<.03	1	12	1.2		
90cm	8-19	0.50	8.1		44.2											
Well		0.67	1.8	0.6	52.5		1.2	750	400		62	.09	6	30		
90cm	9-2	0.74	0.9		38.0											
Well													5	21		
90cm	0-16	0.55	0.6		29.5											
Well		0.82	0.6	0.6	42.7	87.5	2.3			70	106	.05	2	17		
90cm	10-4	1.06	0.1		24.0	30.0				68	68					
Well		0.93	0.1	0.5	36.3	80.0		570	290	63	71	<.03	2	18		
90cm	10-16	0.72														
Well		0.92	0.2	0.1	45.7							.08	2	18	2	2
Plot 4																
60cm	6-22	0.80			37.1											
90cm		0.30			18.6	2.4	19.3	230	210	22	21	.29				
Well	0	0.76		0.8	25.1	3.6	49.7	770	260	76	39					
60cm	7-1	0.10	6.4	2.9	10.0	3.6	8.1			12	5					
90cm		0.30		2.1	<10					30	29					
Well		0.84	0.7	1.2	14.3	3.9	43.2	750	220	54	54	.21				
Well	7-19	0.66	4.8	1.0	84.1	4.2	62.3	640	260	100	50	.61	3	38		
90cm	8-10	1.14	8.4		102.0											
Well													2	48	0	8
90cm	8-19	0.44														
Well		0.76	3.1	0.9	53.7	1.4	85.2	740	360		80	<.03	4	14		
90cm	9-2	0.21	0.1		28.2											
Well		0.98	0.2	3.5	52.5	26	65.0			70		0.03	2	12		
90cm	9-16	0.71	0.4		46.8											
Well		1.02	2.2	0.1	51.3	2.8			67.0	140	<.03	1	12			
90cm	10-4	0.81	2.8		66.1		48.0			66	59					
Well		0.78	0.3	0.6	42.7		62.0	620	340	60	84	.03	2	20		

LOC	1976 Date	EC mmhos/cm	PPM NO_3^--N	PPM NH_4^+-N	PPM Cl^-	PPM Na+	PPM K+	Mg/l TDS	Mg/l TVS	PPm Ca2+	PPm Mg2+	PPm P	Mg/l BOD	Mg/l COD	Fecal Coli	Total Coli
90cm	10-16	0.64														
Well		1.08	0.3	0.3	77.6							0.20	1	14	18	51
Plot 5																
60cm	6-22	1.17		11.0												
90cm		1.10			12.0											
Well		1.01		0.9	12.6	85.3	1.6	660	375	51	99	.03	2	23		
60cm	7-1	0.71			<10											
90cm		0.10	3.8	1.6	<10	6.8	0.9	110	100	5	2					
Well		0.10	1.7	2.2	<10	27.2	1.5	390	50	43	22					
60cm	7-19	0.60			38.9					22	94					
90cm		0.99	5.9		57.5					48	94					
Well		0.51	1.5	2.9	22.4			620	260	43	41	.11				
90cm	8-10	0.58	11.5		26.9											
Well		0.67	7.4	1.7	13.8			650	390							
90cm	8-19	0.72			39.8											
Well		0.79	2.0	0.5	53.7	97.2	1.4				63	<.03	4	21		
90cm	9-2	0.96	0.3		47.9											
Well		0.93	0.1	1.1	66.1	80.0	3.3			65	114	.03	2	21		
90cm	9-16	0.92	0.2		41.7											
Well		0.90	0.3	2.2	47.9	95.0				40	102	.15				
90cm	10-4	0.99	0.1		26.9	54.0				36	84					
Well		0.98	0.2	0.4	38.0	92.0				43	69	.80				
Well	10-16	0.42	0.3	0.3	66.1											
Plot 6																
60cm	6-22	0.14														
90cm		0.65		1.9	12.0	27.0	2.4	380	230	48	41	<.03				
Tile		0.70			17.4											
90cm	7-1	0.10	0.9	1.9	<10	8.8	0.9	140	140	11	4					
Well		0.57	2.7	1.0	<10	28.7	1.2	610	50	54	36	.11				
Tile		0.75	8.4	1.5	15.9	42.0	4.5	680	170	81	36	.16				
60cm	7-19	0.70	1.2		22.4											
90cm		0.51	1.2	2.2	20.9					56	64	.12	4	208		
Well													9	127		
90cm	8-10	0.64	2.0	5.0	32.0	55.4	3.8					.13				
Well		1.05	1.9	1.8	177.8	37.2	2.0	460	240		39	.06		26	<2	<2
Tile		0.28	1.3	4.2	25.1	46.4	4.2	740	270		52	.09				
90cm	8-19	0.54	0.8		39.8											
Well		1.11	2.8		38.9	44.4	3.4				54	.10	7	32		
Tile		0.76	1.5		87.1											
90cm	9-2	0.67	0.9	6.0	72.4		3.1									
Well		0.60	0.8	1.3	162.2											

LOC	1976 Date	EC mmhos/cm	PPM NO_3^--N	PPM NH_4^+-N	PPM Cl^-	PP Na+	PPM K+	Mg/l TD S	Mg/l TV S	PPm Ca2+	PPm Mg2+	PPm P	Mg/l BOD	Mg/l COD	Fecal Coli	Total Coli
90cm	9-16	0.80	0.2		24.6											
Well		0.95	0.8	1.4	72.4								2	21		
Tile		0.90	0.8	0.1	43.6		4.4									
90cm	10-4	0.94								78	80					
Well		1.02	2.1		58.9	40.1				140	84		1	25		
Plot 7																
90cm	6.22	1.14			16.4	42.9	10.8			77	105					
Tile		0.97		1.31	20.0	52.2	3.2	905	315	62	68	.05	1	22		
90cm	7-1	0.57			14.9											
Well		0.66	2.8	1.1	28.2	47.5	1.2	480	90	52	54	.03				
Tile		0.78	2.5	1.0	58.9	80.0	3.0	630	100	71	49	.30				
60cm	7-19	0.87	6.7		12.0											
90cm		0.78	3.8	5.2	40.7					85	125					
Well		0.37	6.8	1.1	33.9	80.0	1.2	1140	480	56	66	.13	1	17		
Tile		0.57	1.1	1.0	42.2	95.0	2.6	690	310	70	77	.13				
90cm	8-10	0.60	1.1		37.2											
Well		0.52	2.4	2.5	<10	47.6	1.8				44					
Tile		0.34	0.2	1.5	20.4	32.0	2.6	260	250		17	.37		122	2	2
90cm	8-19	1.06	1.3		89.1											
Well		1.15	2.2	0.8	75.9	67.2	2.0				41	0.6	4	16		
Tile		0.57	2.0	0.8	79.4	79.2	4.0	590	240		36	1.22	5	12		
Well	9-2	0.81	0.1	2.2	56.2	49.0	2.6			70	130	<.03	4	26		
Tile		0.88	0.2	1.1	43.7	44.0	3.5			100	121	.05	1	23		
90cm	9-16	0.78	0.8		57.5											
Well		0.90	0.2	1.1	50.1	48.0	4.0			79	123	<.03	4	17		
Tile		0.87	0.5	0.9	34.7	26.0	3.7			93	95	.25	1	23		
Well	10-4	0.83	1.0	1.4	40.7	44.0		520	270	67	74	.43	2	28		
Tile		0.67	0.8	0.6	22.9	40.0		360	170	52	43	1.20	3	27		
Well	10-16	0.85	0.5	0.1	66.1							.30	2	20	0	90
Tile		0.61	1.0	0.9	75.9							.70	1	14	4	160

LOC	1976 Date	EC mmhos/cm	PPM NO_3^--N	PPM NH_4^+-N	PPM Cl^-	PPM Na+	PPM K+	Mg/l TDS	Mg/l TVS	PPm Ca2+	PPm Mg2+	PPm P	Mg/l BOD	Mg/l COD	Fecal Coli	Total Coli
Plot 8																
60cm	6-22	0.43			9.1			10	50							
90cm		0.87		2.1	21.4	53.1	3.2			41	160					
Well		1.13		1.4	12.6	61.3	2.8	865	370	87	69	.11	3	78		
Tile								1470	320	72	52	.05	2	22		
60cm	7-1	0.10	1.7	1.5	<10	7.8	0.9	110	50	9	2	.17				
90cm		0.92		2.6	<10					20	115					
Well		0.81	5.2	0.8	53.7	100.0	1.2	790	270	37	82	.15				
Tile		0.93	3.9	1.1	17.4	80.0	1.5	620	150	58	71	.06				
60cm	7-19	0.87	7.7		21.9					32	140					
90cm		0.82	1.5	3.1	29.9					17	132					
Well		0.60	0.9	0.8	14.5	100.0	0.8	760	370	57	92	.06	2	17		
Tile		0.49	0.3	1.3	21.4	100.0	1.2	630	80	58	81		1	11		
90cm	8-10	0.78	7.4		28.8											
Well		0.87	0.9	1.1	13.0	88.6	1.4	820	510		86	.04	9	23	10	240
90cm	8-19	0.84	4.5	51.3												
Well		0.81	1.6	1.1	57.5	79.2	1.4	870	500		90	.09	7	29		
90cm	9-2	1.12	0.4	14.0	38.9											
Well		0.83	0.3	2.2	52.5	50	2.8			79	170	.03	24	32		
Tile		0.73	0.1	1.1	52.5	57	3.3		84	150	.05	2	25			
90cm	9-16	1.10	3.4		34.7											
Well		1.00	0.2	1.3	47.9	53	3.1			70	150	.10	2	12		
Tile		0.82	0.2	0.5	39.8	53	33			70	100	<.03	1	33		
90cm	10-4	1.20	0.3		58.9					22	129					
Well		0.89	0.3	0.8	50.1	44		660	340	65	90	.06	2	28		
Tile		0.70	0.1	0.8	27.2	44		410	170	53	56	.10	2	22		
Well	10-16	1.00	0.1	1.1	87.1							.05	1	14	1	<10

LOC	1976 Date	EC mmhos/cm	PPM NO_3^--N	PPM NH_4^+-N	PPM Cl^-	PPM Na+	PPM K+	Mg/l TDS	Mg/l TVS	PPm Ca2+	PPm Mg2+	PPm P	Mg/l BOD	Mg/l COD	Fecal Coli	Total Coli
Plot 9																
60cm	6-22	0.89			16.8											
90cm		0.48			63.1	27.8	2.8	460	270	41	51	.03				
Well		0.84		0.3	23.4	82.0	2.0	555	250	63	67	.03	3	20		
Tile		0.85		1.7	14.5	41.7	1.2	640	340	65	68	<.03				
60cm	7-1	0.44	3.9	2.2	14.9	28.2	2.1	360	190	47	29					
90cm		0.40		3.3	31.1	23.7	1.5									
Well		0.73	4.8	1.0	13.5	30.2	1.5	660	210	55	59	.07				
Tile		0.80	5.9	0.9	16.6	40.0	1.2	590	140	47	59	.05				
60cm	7-19	0.68	0.8		39.8			790	330	70	98					
90cm		0.72	1.3		20.0					57	71					
Well		0.63	.04	0.8	12.5	36.6	1.2			77	68	.06	3	18		
Tile		0.70	4.2	5.0	16.8	52.8	1.2	570	260	87	59	.16	1	17		
90cm	8-10	0.56	14.0		17.4											
Well		0.29	2.8	0.1	<10	36.0	1.6				58	.07	4	27	<10	40
90cm	8-19	0.57	9.5		61.7											
Well		0.81	1.2	0.4	83.2	68.4	0.8	710	340		73	.03	2	13		
90cm	9-2	0.85	0.3		52.5		4.3									
Well		0.93	0.3	1.1	52.5	42.0	2.3			70	140	<.03	4	19		
Tile		0.81	1.1	0.1	47.9		3.1			105	106	.03	1	30		
90cm	9-16	0.83	0.1		37.2											
Well		0.82	1.0	0.8	54.5	44.0	2.6			70	130	.15	1	16		
Tile		0.92	1.9	0.4	44.7	40.0	4.0			110	80	.25	1	19		
90cm	10-4	0.70				36.0				38	83					
Well		0.93	0.1	0.8	44.7	44.0		530	300	62	77	.26	3	20		
Tile		0.40	0.3	0.6	44.7	42.0		600	400	99	66	.60	1	25		
90cm	10-16	0.70														
Well		0.74	1.2	0.6	81.2							.04	2	18	0	<10

LOC	1976 Date	EC mmhos/cm	PPM NO_3^--N	PPM NH_4^+-N	PPM Cl^-	PPM Na+	PPM K+	Mg/l TDS	Mg/l TVS	PPm Ca2+	PPm Mg2+	PPm P	Mg/l BOD	Mg/l COD	Fecal Coli	Total Coli	Fecal Strep
Ditch H_2O																	
	6-22	1.25		2.3	24.0	100.0	4.8	1010	315	82	83	.05	3	67			
	7-1	0.16	1.4	0.8	10.0	15.0	1.2	90		24	8	.19					
	7-19	0.22	1.3	2.0	10.2	22.0	2.4	170	110								
	8-10	0.13	2.1	1.3	10	24.2	2.8	180	150		14	.07	2	15	≤10	62	
	8-19	0.44	1.4	0.3	42.0	2.4	39.8	270	250		15	.04	1	14			
	9-2	0.28	0.2	3.6	26.9		3.1	460		30	20	.03	3	16	75	620	0
	9-16	0.39	1.0	0.7	20.4	22.0	3.5			30	25	.10	1	10	260	600	590
	10-4	0.34	0.9	0.2	20.9	24.0		80	60	30	10	.10	1	14	200	1900	1000
	10-16	1.43	0.6	1.2	91.2							.08	2	27	110	170	790
Effluent																	
	6-22	0.69		3.1	26.3	72.8	6.0	600	273	68	34	2.4	14	67	5300	7300	
	7-1	0.82	1.7	3.1	29.2	100.0	5.4	610	110	73	34	2.4					
	7-19	0.51	1.3	1.7	33.9	83.7	4.6			58	33	2.0	18	85	3900	82,000	
	8-10	0.54	14.0	1.5	26.6	70.8	7.0	600	320		32	2.2	11	80	200	82,010	4
	8-19	0.61	4.7	3.5	87.1	81.6	5.8	530	230		29	2.7	17	48	3000	56,000	7
	9-1	0.91	2.1	6.0	77.6	57.0	7.6			66	50	3.7	13	57	3000	41,000	0
	9-16	0.63	0.2	1.4	66.1	54.0	7.9			70	50	3.7	13	25	77,000	96,000	810
	10-4	0.51	1.3	10.6	56.2	42.0				54	30	4.4	9	47	8800	52,000	170
	10-16	0.75	0.1	0.6	87.1			340	160			2.1	10	65	≤10	100	<10