EIDGENÖSSISCHE ANSTALT
FÜR DAS FORSTLICHE VERSUCHSWESEN

INSTITUT FÉDÉRAL
DE RECHERCHES FORESTIÈRES

ISTITUTO FEDERALE
DI RICERCHE FORESTALI

SWISS FOREST RESEARCH INSTITUTE

CH - 8903 BIRMENSDORF ZH
Schweiz / Suisse / Svizzera / Switzerland

THE ESTABLISHMENT, DATA AND OBSERVATIONS FROM A STUDY OF GROUNDWATER IN VOGELBACH CATCHMENT, ALPTHAL

C.M.H. Clarke, Oct. 1969

The Establishment, Data and Observations from a Study of Groundwater in Vogelbach Catchment, Alpthal

C.M.H. Clarke, Oct. 1969

INTRODUCTION

Detailed hydrological investigations have been made by Ing. H. Keller since 1964 in Vogelbach catchment, Alpthal, Canton Schwyz, Switzerland. As a facet of this research a study was made between May and September 1969 to investigate relations between water table level, weather conditions, stream discharge, and the influence of different sites upon some qualities of groundwater and fluctuations of the water table. The data, observations, recording procedures and details of establishment of groundwater stations are presented. This study constitutes only preliminary investigations for later more intensive research. The short-term nature of the investigation does not allow wide interpretation of these data, however, it is anticipated that the observations will provide insight for future work.

On the 7th May, I visited Vogelbach catchment with Ing. H. Keller but was not able to commence fieldwork until the 14th May because of considerable snowcover. The siting of groundwater stations was then initiated in lower regions of the catchment and progressed to higher elevations as the snowcover dimimished. By the 30th May all stations were established and during the following three months, until the end of August, 16 series of observations were made at 2-9 day intervals.

ESTABLISHMENT

Twenty groundwater stations were established, each consisting of two piezometers of 130 cms length, 5 cm diameter, perforated plastic tubing. These were fitted with removable plastic caps to prevent ingress of precipitation. The individual piezometers of each pair were positioned 20 metres apart, one upslope of the other. The function of the additional piezometer was to provide a second set of data which presented a means of testing the overall uniformity of the site.

Site selection

Groundwater stations were located exclusively in the wetter soil types '2' and '3', previously mapped and defined by E.A.F.V. staff. Soil type '2' was typified to a depth of 110 cms by thick humus, particularly Sphagnum material, a boggy texture and was confined to poorly drained terraces or slopes not exceeding a 5 degree angle. On most steeper, better drained slopes, apart from forested and ridge top regions, soil type '3' occurred. This was typified by shallow, well stratified soils overlying thick impermeable clay

strata and often, coarse aggregate material. Typical sites with apparent uniform drainage and slope were selected for establishment of groundwater stations. The distribution of soil types '2' and '3' and location of groundwater stations are shown in Figure I. Altitude of stations range from 1145 metres to 1465 metres (mean 1375 metres) and aspect is generally E - SE.

Installation

In normal sites, groundwater observation wells were bored to a depth of 110 cms, so that once the piezometer was installed, a 20 cm length protruded above groundsurface. When inpenetrable material obstructed boring, a depth of 80 cms was considered the minimum acceptable. Prior to installation loose mud was evacuated from the hole and once installed a collar of clay was placed around the neck of the piezometer to prevent ingress of surface runoff. During the initial siting of each station details of soil profile, depth to impermeable clay horizon, slope, aspect, altitude and vegetation cover were noted.

RECORDING PROCEDURES

Standard measurements were made during each visit between the 30th May and the 31st August, except when malfunction and breakage of instruments or bad weather prevented complete observation.

Measurement of water table depth below groundsurface

The level of the water table was obtained by measuring the reciprocal depth of water from the top of the piezometer and substracting the length of piezometer protruding above groundsurface.

Electrical conductance of groundwater

Groundwater conductivity was measured in the upper zone of groundwater initially in its unmixed state, but in all measurements made after the 11th June the groundwater column was mixed prior to recording. Accordingly, a factor was calculated to standardise earlier records.

Temperature of groundwater

This was determined by immersing the bulb and lower stem section of a standard Centigrade thermometer in the upper zone of groundwater. Initially temperature was measured without premixing of groundwater, but latterly the column of groundwater was mixed prior to recording. Similarly, a factor was calculated to standardise earlier records.

Measurement of P.H.

Groundwater P.H. was measured in the upper zone of groundwater after mixing the water column.

Additional records

Daily precipitation

Daily totals of precipitation, recorded at a raingauge situated at 1500 metres altitude in Vogelbach catchment, were derived from weekly period charts held at the E.A.F.V.

Precipitation during 1, 3 and 7 days prior to groundwater observation

Totals of precipitation for 1, 3 and 7 day periods prior to each series of groundwater observation were calculated from Vogelbach raingauge charts. In most cases these figures are accurate for each station to within a two hour period.

Mean daily stage height Vogelbach stream

Daily means of stream flow level were calculated from continuous stage height recordings made at a gauging station situated on Vogelbach stream approximately 400 metres from its confluence with the Alp River.

OBSERVATIONS

The establishment of groundwater stations presented several difficulties. The initial inability to obtain good correlation of groundwater level between pairs of piezometers at certain sites, was of particular concern. This lack of correlation generally resulted from variations of water source due to differing drainage patterns. Differences of permeability of soils were perhaps the most important factor. These differences were seldom evident from ground-surface appraisal and correction necessitated much trial and error relocation, or on occasions, abandonment of the site.

Inpenetrable obstructions encountered while boring also posed considerable problems. Obstructions were of two main types; logs in soil type '2' compartments and sandstone or aggregate strata in soil type '3' compartments.

A site near to the present station 4 was abandoned when penetration of the thin impermeable layer resulted in drainage of local soil water to underlying strata. Paradoxically, artesian pressure forced the abandonment of another site.

During initial recordings, considerable variations of electrical conductance and temperature of groundwater at different levels, were noted. This was attributed to layering of dissimilar groundwater zones. When two or more shallow layers of dissimilar water occurred within the measuring zone variations were of critical importance to measurement. Premixing of the groundwater column substantially reduced the scope for error, through averaging properties of the different layers. The variation of electrical conductance between the uppermost zone of groundwater, base zone

(generally 110 cms below groundsurface) and mixed column of groundwater was the object of particular observation at Station 3A. These observations are recorded in Figure 2. The relations between upper and mixed groundwater are evident from similar fluctuations occurring in both. Differences of electrical conductance between the three measurements are, however, clearly defined.

Data

All data are presented in the appendices. Sections A and B of appendices are observations from the lower and upper piezometers, respectively, of each pair constituting a groundwater station. Summaries by observation dates of average mean $(\frac{\text{mean of A + mean of B}}{2})$ depths to water table, average mean electrical conductance, temperature and PH, are in Table 1. The mean precipitation at all stations for 1, 3 and 7 day periods prior to time and date of recording, are also given. The seasonal patterns of daily precipitation, daily mean stream stage height, average mean water table depth and average mean electrical conductance, temperature and PH of groundwater are shown in Figure 3. The relationships between three and also seven day precipitation and average mean depth to water table are presented in Figure 4.

Discussion

The relation between amount of precipitation and average mean fluctuations of the water table is clearly established (Fig. 3). During periods of high precipitation the average mean depth to water table occurred close to groundsurface, but in prolonged periods with little precipitation, levels declined progressively to depths of up to 30 cms. Intense precipitation during unstable weather conditions (when mean water table levels fluctuated between shallow and intermediate depths) resulted in rapid rises of the average mean water table level. For example on the 13th August, following precipitation of 1.80 cms from a thunderstorm between 1315 and 1345 hours, average mean water table level rose from 14.3 (12 station mean) to 3.1 cms (11 station mean) below groundsurface. The effect of occasional intense precipitation from thunderstorms during the predominantly dry period from 13th July to 11 August was not nearly so marked (Fig. 3).

The seasonal pattern of average mean electrical conductance closely reflected that of precipitation and average mean water table level. Fluctuations of electrical conductance were clearly related to the extent of dilution of groundwater by recent precipitation of lower electrical conductance. During a period with little precipitation between 11th and 25th July average mean electrical conductance increased progressively, then decreased following high precipitation on 29th July and declined steadily with onset of wetter conditions in mid-August (Fig. 3). Increases of electrical conductance during periods with little precipitation probably result not only from lack of precipitation but also from replacement of usual water sources by alternative water from deeper

or more distant origins. This phenomenum may well be characteristic of such drainage areas where the impermeable layer is discontinuous and occurs at different depths. The impression of replacement of usual water by alternative sources is supported by the rising trend of electrical conductance of base level groundwater, between 18th June and July 31st, at Station 3 A (Fig. 2).

Despite seasonal simularities between patterns of precipitation, -stream discharge and water table depth, high precipitation result-ing in increased flow to stream was not consistently reflected by corresponding peaks of mean daily stream discharge (Fig. 3). This results from the calculation of daily means of stream discharge having a diminishing effect upon short-lived peaks of precipitation.

The data shows that precipitation over both 3 and 7 day periods, prior to groundwater observation, substantially influences the position of the water table (Fig. 4). Additional data are required -in order to determine the precise period of influence. Supplement-ary analysis of present data suggests however, that precipitation of more than five day origin has little influence upon water table level.

The performance of groundwater stations differ greatly in detail. Despite an overall pattern of complexity within individual stations, several stations were characterised by consistent behaviour. On the basis of amplitude of water table fluctuations stations may be grouped into three categories: those with consist--ently shallow water tables, numbers 4 A, 10 A, 16 and 19; those with widely fluctuating levels, including numbers 2, 9 and 11; and stations with consistently deep water tables, numbers 6 A, 12 and 20.

The effects of precipitation at the different sites were simi--larly quite diverse. Stations having characteristically constant groundwater supply displayed the greatest measure of stability of both water table level and groundwater properties. Upwelling of groundwater at station 16 rapidly displaced precipitation falling -on the site, rendering its effect negligible. Conversely, pre-cipitation strongly influenced both level of water table and measure of electrical conductance at stations with irregular ground--water supply. Two exceptions were stations 13 B and 18 B, situated in gulley sites where rapid drainage removed recent precipitation, suppressing large rises of water table level.

Although differences are evident in quality of groundwater from soils types '2' and '3', these are not discussed. Further re--search, particularly concerning permeability of soils at the different sites would do much to complement this study. All notes and original data have been retained and are filed on a folder labelled "Groundwater Study, Alpthal, 1969". It is regretted that I did not have time enough to produce a second draft of this report - it would presumably have led to many improvements.

ACKNOWLEDGMENTS

Working at the E.A.F.V. has been a most beneficial and pleasant experience and I thank the staff for making it so. For assistance with the preparation of this report I need thank Fräulein D. Mauss and Herren A. Huber, A. Mahler and P. Scherrer. Special thanks are due to Ing. H. Keller for providing the work opportunity and for frequent discussions and suggestions upon procedures. Dr. N. Kuhn kindly identified vegetation growing at the station sites.

Addendum

A limited number of copies of this report are held at the E.A.F.V. Photographs have been included with the first three copies only, one of which is held by E.A.F.V., F.R.E.S. Rangiora, New Zealand, and myself.

C.M.H. Clarke,

12 Oct 1969

C.M.H. Clarke
Forest & Range Experiment Station
P.O. Box 106, Rangiora
New Zealand

TABLE 1

Summary of Data

Date	Average Mean Depth to Water Table (cms)	Total Precipitation 1 day (cms)	3 days (cms)	7 days (cms)	Average Mean Temperature (OC)	Average Mean Electrical Conductance (Micromhos)	Av/Mean PH
30/5	9.35	0.41	1.14	3.16	8.65	95.0	6.49
9/6	6.55	0.10	2.20	9.65	7.30	76.1	5.95
11/6	18.05	0	0.10	4.46	8.80	-	-
13/6	12.90	0.21	0.41	2.61	10.40	97.4	5.78
18/6	9.27	0.21	2.56	3.48	10.50	90.0	5.84
24/6	0.90	3.96	3.96	10.23	9.40	79.8	6.40
3/7	19.85	0	0	2.20	11.00	103.6	6.27
11/7	6.70	0.87	4.17	9.90	9.05	82.5	6.24
17/7	26.10	0	0	1.80	11.00	116.2	6.20
25/7	30.10	0	0.65	0.65	12.50	126.2	6.10
31/7	12.10	0	2.75	4.00	13.35	90.0	6.02
7/8	21.45	0	0	4.45	13.65	110.0	6.28
13/8[1]	16.70	1.40	1.40	1.40	13.70	98.25	-
13/8[2]	4.50	1.94	1.94	1.94	15.40	94.65	-
22/8	9.17	0	5.25	14.29	12.10	80.8	6.22
29/8	6.50	0.82	5.51	10.04	9.30	77.1	6.42

1 before thunderstorm

2 after thunderstorm

Appendix 1 A

Depth of Water Table Below Groundsurface

(in cms)

Station Number	Date of Observation															
	30/5	9/6	11/6	13/6	18/6	24/6	3/7	11/7	17/7	25/7	31/7	7/8	13/8[1]	13/8[2]	22/8	29/8
1	0	1	19	10	0	0	9	0	22	29	3	9.5	4	2	0	0
2	0	2	23	18	4	0	34	0	40	52	5.5	27.5	50.5	0	2.50	0
3	1	1	-	7	3	0	16	4.5	20	22	7.5	11	5.5	3	6.5	3
4	8	7	-	9	7	-	7	4	5	10.5	6.5	14	7	-	3	2
5	37	3	-	37	9	-	33	2.5	35	38.5	16	20	6.5	-	5	3
6	35	14	26	25	24	-	30.5	27	35	34	25	23.5	24.5	-	23.5	23.5
7	-	6	4.5	13	8	-	23	9.5	27.5	29	11.5	20.5	15.5	-	9	8
8	5	3	11	7	4	-	18	2.5	27	33	10.5	24	8	-	6.5	5.5
9	1	1	-	6	1	-	12	4	24	26	9.5	21	9	-	6.5	4
10	6	4	-	8	6	-	9	3	16	11.5	6	12.5	4.5	-	0	0
11	16	0	-	25	15	-	27	9	35	31	15.5	24.5	9	-	9	7
12	18	12	-	27	22	-	33	14	26	34.5	22.5	28.5	28	-	16.5	13.5
13	8	9	-	15	10	-	24	6	39	47.5	11	23	-	0	6	1.5
14	6	3	-	9	7	-	17.5	3	31.5	28.5	12	19	-	0	3.5	2.5
15	5	6	10	10	4	-	18	6.5	24.5	39	18.5	20.5	-	3	8	5
16	3	7	8	9	8	-	7	12	10	10	10	10	-	4.5	3	4.5
17	15	8	26	11	2	-	4.5	0	26	45.5	11.5	33.5	-	1.5	2	0
18	10	4	18	15	12	-	21	5	32	35	12	19	-	3	23	9
19	2	4	10	2	8	0	8.5	3.5	12	13	8	16	-	5	3.5	2.5
20	18	20	30	27	23	1	30	19	35	30.5	26	32.5	-	12	21	19

1 before thunderstorm 2 after thunderstorm

Appendix 1 B

Depth of Water Table Below Groundsurface

(in cms)

Station Number	Date of Observation															
	30/5	9/6	11/6	13/6	18/6	24/6	3/7	11/7	17/7	25/7	31/7	7/8	13/8[1]	13/8[2]	22/8	29/8
1	9	7	25	22	5	1	22	5	27.5	30	11.5	21	25	8	4.5	6.5
2	0	6	20.5	16	6	0	26	1	31.5	44	6.5	22	29	0	1	0
3	3	2	-	5	3	0	16	2	17.5	18.5	6.5	14.5	6	5	6	2.5
4	10	12	-	13	11	-	21	11	31.5	36.5	10	23	35.5	-	12	9.5
5	12	4	-	19	8	-	23	3	26	32.5	15.5	27	24	-	7.5	5.5
6	0	0	12.5	13	0	-	13	0	13.5	17	4	13.5	3	-	0	0
7	-	23	40	40	25	-	31	15.5	42.5	35.5	20	24	31.5	-	15.5	14.5
8	8	4	7	10	7	-	17	9.5	27.5	27	12	28	10	-	14.5	3
9	5	2	-	6	2	-	13.5	2	23	26	6.5	18	14	-	4.5	3.5
10	11	9	-	19	15	-	20	11	23	19	11	16	9.5	-	14	12
11	16	1	-	17	12	-	19	9	22	22	14	20	7.5	-	8.5	5.5
12	12	10	-	12	14	-	26.5	13	26	29	18.5	24.5	35	-	15.5	13.5
13	8	8	-	23	8		33	5	35	48.5	6.5	28.5	-	15	8	3.5
14	4	5	-	9	6	-	12	4.5	17	16	7	17.5	-	9	9	8
15	11	16	34	32	18	-	37.5	12	40	47.5	22	37	-	2.5	6	5
16	2	3	3	3	3	-	1	0.5	4	5.5	4	4.5	-	1.5	0	0
17	10	5	8.5	6	4	-	6.5	1.5	26	54	11.5	35	-	1	3	1
18	26	10	37	41	22	-	47	8.5	53	63	20.5	37.5	-	2	68	36
19	2	1	4	1	4	0	6	1	9	8.5	7.5	9	-	6.5	2.5	1.5
20	13	19	21	18	21	7	20.5	18	26	26.5	21	28.5	-	14	17	15.5

1 before thunderstorm 2 after thunderstorm

Appendix 2 A

Conductivity of Groundwater

(in micromhos, corrected for 20 degrees Centigrade)

Station Number	Date of Observation															
	30/5	9/6	11/6	13/6	18/6	24/6	3/7	11/7	17/7	25/7	31/7	7/8	13/8[1]	13/8[2]	22/8	29/8
1	24.5	16.6	-	19.9	58.3	23.7	15.2	15.0	17.0	19.7	22.3	37.3	28.8	-	14.9	17.5
2	63.8	64.4	-	69.2	53.8	40.5	200.1	155.4	156.0	133.5	38.7	49.0	104.0	-	36.7	46.8
3	127.3	135.0	-	128.6	189.5	240.5	310.6	159.6	325.0	359.0	223.8	326.5	235.8	-	193.2	169.8
4	112.0	98.2	-	111.9	109.0	-	116.7	135.2	127.2	165.0	189.5	182.6	164.0	-	116.5	138.4
5	33.9	18.6	-	23.0	18.4	-	16.1	17.6	18.2	20.9	23.4	21.5	22.9	-	22.5	20.5
6	28.1	23.1	-	43.5	20.4	-	43.3	59.1	74.8	76.5	84.6	47.5	126.5	-	48.4	54.3
7	-	18.0	-	-	13.7	-	13.1	14.6	14.9	14.9	17.6	16.6	15.8	-	16.3	13.5
8	209.2	162.1	-	227.5	168.1	-	206.4	133.5	244.0	241.0	200.0	283.4	157.3	-	128.4	100.6
9	158.5	128.0	-	129.6	150.6	-	87.5	96.3	178.6	263.0	124.0	177.5	206.7	-	32.8	120.8
10	165.0	153.8	-	162.0	141.7	-	136.5	108.6	137.3	135.9	123.7	128.0	131.5	-	64.2	58.6
11	39.7	13.3	-	15.6	22.3	-	13.2	15.2	18.7	17.7	16.6	16.7	16.2	-	17.8	13.1
12	68.4	61.3	-	76.5	39.9	-	61.0	108.0	38.4	76.2	40.7	76.7	50.3	-	41.0	16.1
13	150.0	53.1	-	78.4	156.9	-	109.1	59.7	133.0	214.8	54.8	141.6	-	42.6	43.6	35.0
14	57.0	21.8	-	43.2	32.7	-	26.2	22.9	45.5	40.2	26.1	25.3	-	17.6	18.0	14.5
15	87.8	232.6	-	246.5	251.3	-	253.2	180.0	250.5	258.1	72.2	90.8	-	130.6	223.0	234.7
16	243.6	204.3	-	243.6	230.0	-	216.2	226.0	225.0	232.6	242.0	247.0	-	227.0	258.9	213.8
17	23.9	-	-	26.9	30.6	-	35.4	22.3	38.5	47.8	38.2	145.4	-	31.3	29.4	29.8
18	82.5	90.6	-	125.1	78.4	-	147.7	50.8	162.1	176.6	127.3	170.0	-	123.0	48.2	52.7
19	-	-	-	49.8	51.4	33.7	47.7	23.7	58.7	66.8	49.9	65.4	-	48.0	126.8	35.3
20	-	-	-	90.8	107.8	77.1	97.2	108.6	111.6	107.7	97.3	98.3	-	101.4	97.8	106.6

1 before thunderstorm 2 after thunderstorm

Appendix 2 B

Conductivity of Groundwater

(in micromhos, corrected for 20 degrees Centigrade)

Station Number	Date of Observation															
	30/5	9/6	11/6	13/6	18/6	24/6	3/7	11/7	17/7	25/7	31/7	7/8	13/8[1]	13/8[2]	22/8	29/8
1	58.4	46.9	-	41.3	35.2	32.3	40.7	138.0	92.1	50.4	32.5	55.3	54.1	-	26.8	20.1
2	106.5	92.0	-	64.6	113.6	25.6	153.6	155.4	127.7	174.0	61.7	118.6	111.6	-	64.2	46.8
3	192.0	167.4	-	208.0	191.0	190.6	254.4	171.0	230.0	250.8	230.0	230.0	230.0	-	139.7	134.9
4	50.2	45.7	-	42.2	39.9	-	49.0	38.2	200.6	63.8	46.9	40.9	83.0	-	39.1	73.7
5	24.5	18.0	-	21.5	18.1	-	17.0	32.4	19.0	25.1	22.1	21.4	21.7	-	20.5	20.0
6	-	43.6	-	37.3	24.7	-	40.3	16.7	38.0	42.8	22.3	31.6	21.8	-	32.9	15.7
7	-	24.5	-	33.7	14.8	-	13.5	16.4	20.9	22.3	34.8	21.4	24.2	-	20.1	19.2
8	132.5	95.0	-	122.1	104.0	-	127.7	87.0	127.1	166.5	123.2	158.9	127.5	-	81.5	80.1
9	133.0	81.0	-	94.9	134.5	-	59.9	55.8	92.5	59.7	114.0	50.2	67.3	-	22.6	61.6
10	56.0	51.4	-	59.2	70.2	-	75.1	66.2	100.8	110.0	105.5	116.5	113.1	-	106.4	117.4
11	60.8	34.6	-	36.4	53.2	-	31.5	21.8	24.6	48.1	21.6	24.3	18.9	-	21.3	18.0
12	48.9	40.3	-	41.6	74.8	-	82.9	36.8	76.8	84.6	43.5	67.1	83.5	-	36.1	43.3
13	57.4	42.9	-	56.7	66.5	-	67.9	46.0	53.8	86.8	53.5	67.8	-	53.8	43.8	36.8
14	54.6	51.6	-	40.7	48.5	-	41.2	35.2	46.8	78.6	51.9	54.7	-	42.8	55.1	58.0
15	132.8	134.9	-	292.9	132.0	-	320.0	90.3	316.0	324.1	146.6	227.0	-	96.5	257.8	221.8
16	232.9	-	-	233.0	201.2	-	225.8	216.1	240.5	252.5	246.0	250.3	-	237.0	218.3	213.3
17	89.8	76.3	-	71.0	45.1	-	74.2	56.1	86.6	93.1	38.0	84.6	-	31.7	57.7	51.9
18	33.7	47.3	-	51.1	43.5	-	49.5	46.0	65.3	64.6	46.2	57.4	-	43.8	89.4	64.3
19	-	-	-	82.5	71.8	58.4	59.0	56.2	72.2	100.6	94.1	98.3	-	100.5	55.3	54.6
20	-	-	-	256.8	193.5	-	209.1	206.5	240.1	283.0	251.1	280.2	-	213.8	266.8	240.9

1 before thunderstorm 2 after thunderstorm

Appendix 3 A

Groundwater Temperature

(in degrees C.)

Station Number	Date of Observation															
	30/5	9/6	11/6	13/6	18/6	24/6	3/7	11/7	17/7	25/7	31/7	7/8	13/8[1]	13/8[2]	22/8	29/8
1	13.0	-	12.4	15.4	14.7	12.3	14.6	11.8	15.4	16.0	17.1	18.2	17.7	-	15.5	11.6
2	10.6	-	8.9	12.7	13.8	9.9	10.2	9.4	10.9	12.1	14.8	14.1	13.4	-	17.6	9.7
3	10.7	10.6	-	11.4	11.1	9.3	10.6	9.3	11.9	14.7	14.4	14.6	14.7	-	12.8	9.6
4	10.4	7.7	-	12.6	10.8	-	12.1	8.9	13.4	14.4	13.4	13.9	14.1	-	12.2	8.4
5	6.9	6.1	-	8.2	10.9	-	11.3	9.9	9.8	10.8	14.0	13.2	14.9	-	12.4	9.1
6	10.2	-	6.8	9.2	11.9	-	9.4	9.0	10.3	12.0	13.9	13.9	13.6	-	12.5	8.8
7	-	8.4	6.4	9.9	9.0	-	9.0	7.3	9.1	10.5	11.4	11.3	11.9	-	10.4	8.0
8	9.6	11.5	8.4	10.8	11.8	-	11.8	9.1	10.8	12.7	13.5	13.5	14.0	-	12.2	9.9
9	9.6	8.2	-	10.7	11.0	-	11.9	9.1	10.8	13.9	13.7	13.8	13.7	-	12.1	9.0
10	7.7	4.3	-	7.5	8.9	-	9.3	7.9	9.1	10.7	11.8	11.6	12.0	-	9.9	8.5
11	4.9	2.8	-	9.6	8.3	-	8.5	8.0	8.4	9.0	12.6	12.1	13.4	-	10.8	8.2
12	6.6	4.0	-	9.3	9.0	-	9.5	8.6	11.8	11.5	13.1	13.1	12.9	-	11.6	8.9
13	7.7	8.7	-	9.7	10.0	-	9.6	8.7	10.4	10.7	13.0	13.2	-	14.8	11.5	8.7
14	6.9	6.8	-	9.5	10.7	-	11.2	9.4	11.4	13.6	13.9	15.5	-	16.3	12.3	9.4
15	7.7	9.7	9.2	9.7	11.1	-	11.4	9.6	10.8	11.8	9.0	14.2	-	16.5	12.7	10.0
16	8.3	9.8	11.0	13.2	11.4	-	11.8	9.9	12.8	14.2	13.5	14.2	-	16.6	12.6	9.9
17	7.7	-	8.8	11.1	11.1	-	12.5	9.4	11.8	12.0	14.0	13.1	-	16.5	12.6	9.5
18	8.3	8.2	8.7	9.7	11.0	-	11.8	9.5	11.5	14.0	14.2	14.3	-	15.3	12.6	10.0
19	-	-	10.0	12.3	12.0	8.7	14.2	10.2	13.6	15.8	15.3	16.0	-	16.0	12.7	9.8
20	-	-	7.0	6.7	9.6	8.4	9.8	8.8	9.6	12.4	12.8	12.4	-	14.1	11.2	9.0

1 before thunderstorm 2 after thunderstorm

Appendix 3 B

Groundwater Temperature

(in degrees C.)

Station Number	Date of Observation															
	30/5	9/6	11/6	13/6	18/6	24/6	3/7	11/7	17/7	25/7	31/7	7/8	13/8[1]	13/8[2]	22/8	29/8
1	12.1	-	11.8	16.2	14.2	12.0	14.4	12.2	14.7	16.7	17.7	17.9	18.0	-	15.7	12.4
2	9.6	-	8.2	12.7	10.8	9.2	10.2	9.4	10.1	11.0	13.9	13.5	13.1	-	12.2	9.7
3	10.0	-	-	12.8	10.8	9.2	11.3	9.6	11.9	14.1	14.4	14.7	14.8	-	12.7	9.8
4	10.9	7.3	-	12.7	11.5	-	12.0	10.1	12.2	14.1	15.0	15.4	14.7	-	13.6	10.2
5	10.0	6.3	-	8.4	9.1	-	8.7	7.4	8.3	9.2	12.0	9.6	11.7	-	10.4	8.2
6	10.4	-	8.0	10.6	11.9	-	10.5	9.0	11.0	13.4	13.9	14.4	14.8	-	12.7	9.0
7	-	7.8	4.6	8.3	6.9	-	7.9	7.0	8.0	9.4	10.4	11.0	11.5	-	9.9	7.9
8	9.4	11.2	11.0	10.7	11.3	-	10.5	9.2	9.9	12.2	13.1	13.3	13.3	-	11.9	8.8
9	10.4	8.4	-	11.8	11.1	-	12.7	9.6	12.3	13.7	14.5	15.0	14.7	-	13.1	9.9
10	6.7	4.9	-	9.0	8.5	-	9.4	7.9	8.8	11.5	11.9	12.6	11.8	-	10.1	7.6
11	5.3	2.1	-	8.5	7.7	-	9.8	7.2	8.7	10.7	11.9	11.5	12.4	-	10.1	7.7
12	5.8	3.9	-	8.6	8.9	-	9.4	8.2	9.9	11.6	12.7	12.6	12.1	-	11.0	8.8
13	9.3	8.6	-	10.7	10.2	-	10.7	9.3	11.1	12.2	14.1	14.4	-	14.8	12.4	9.5
14	7.2	6.4	-	9.4	10.4	-	11.4	8.5	11.3	14.1	13.5	14.0	-	14.6	11.9	8.9
15	7.0	9.0	6.8	9.2	9.5	-	9.2	8.9	8.9	10.3	12.7	12.0	-	15.2	11.1	10.3
16	9.4	-	13.0	12.8	12.8	-	14.0	9.7	15.0	17.5	13.7	16.0	-	16.3	11.4	10.0
17	8.0	6.8	9.4	8.8	10.7	-	11.3	9.4	11.8	11.0	14.2	13.3	-	15.9	12.6	9.6
18	7.2	8.2	7.2	8.3	9.8	-	10.1	9.3	10.0	11.2	13.7	12.8	-	15.8	12.1	10.6
19	-	-	8.2	9.5	7.7	6.3	10.9	7.5	11.7	12.4	10.6	12.4	-	13.9	9.9	8.6
20	-	-	7.3	7.9	8.8	8.8	9.6	7.9	9.9	12.5	12.4	13.1	-	13.4	11.4	8.5

1 before thunderstorm 2 after thunderstorm

Appendix 4 A

P.H. of Groundwater

Station Number	Date of Observation															
	30/5	9/6	11/6	13/6	18/6	24/6	3/7	11/7	17/7	25/7	31/7	7/8	13/8[1]	13/8[2]	22/8	29/8
1	5.6	5.8	-	5.4	5.6	5.8	5.6	6.4	5.9	5.3	5.6	5.2	-	-	6.1	5.9
2	6.8	6.1	-	6.1	5.8	6.3	6.3	6.4	6.4	6.2	6.3	6.2	-	-	6.7	5.6
3	7.1	6.8	-	6.4	6.2	6.8	7.0	6.6	6.9	6.8	6.7	6.9	-	-	6.7	6.8
4	6.4	6.3	-	6.1	6.1	-	6.7	7.3	6.8	6.2	6.6	6.8	-	-	6.8	-
5	6.2	4.7	-	4.9	4.2	-	4.9	5.1	4.7	4.8	4.5	4.9	-	-	4.9	-
6	-	5.0	-	5.4	5.5	-	6.1	6.4	6.2	5.9	6.1	6.1	-	-	6.3	-
7	-	4.7	-	4.6	4.5	-	5.0	5.1	5.1	5.0	5.0	5.3	-	-	5.4	-
8	-	7.2	-	6.6	6.2	-	6.3	7.2	7.3	6.9	6.8	7.1	-	-	6.7	-
9	-	6.1	-	6.0	5.9	-	6.2	6.7	6.5	6.3	6.2	6.7	-	-	6.1	-
10	-	6.2	-	5.8	6.4	-	6.6	6.4	6.5	6.0	6.0	6.6	-	-	6.4	-
11	-	5.8	-	5.4	5.1	-	5.5	5.9	5.7	5.4	5.1	5.5	-	-	5.9	-
12	-	5.1	-	6.3	5.6	-	6.3	5.4	5.7	6.2	5.8	6.3	-	-	5.9	-
13	-	6.3	-	5.7	6.2	-	6.6	5.6	6.3	6.9	6.9	7.1	-	-	6.3	-
14	-	5.8	-	5.8	5.6	-	6.1	6.3	6.1	6.2	5.6	6.1	-	-	6.0	6.3
15	-	6.1	-	5.9	6.2	-	6.6	-	6.4	6.3	6.2	6.1	-	-	6.4	6.3
16	-	7.0	-	6.4	6.6	-	6.8	-	6.7	6.4	6.3	6.7	-	-	6.9	6.6
17	-	5.8	-	5.8	5.7	-	5.9	-	5.7	5.9	5.6	6.0	-	-	6.4	6.0
18	-	6.0	-	5.7	6.1	-	6.6	-	6.2	7.0	6.3	7.0	-	-	-	6.2
19	-	6.1	-	5.1	5.7	5.9	6.0	-	5.9	5.7	5.8	6.0	-	-	-	6.0
20	-	6.3	-	6.4	6.4	6.7	6.9	-	6.3	6.6	6.6	6.6	-	-	-	6.6

1 before thunderstorm 2 after thunderstorm

Appendix 4 B

P.H. of Groundwater

Station Number	Date of Observation															
	30/5	9/6	11/6	13/6	18/6	24/6	3/7	11/7	17/7	25/7	31/7	7/8	13/8[1]	13/8[2]	22/8	29/8
1	6.3	5.4	-	5.0	5.6	6.0	6.0	6.4	6.0	5.8	5.8	5.9	-	-	6.4	5.8
2	6.8	6.3	-	6.1	5.9	6.3	6.3	6.4	6.3	6.2	6.5	6.4	-	-	7.1	6.8
3	7.1	6.5	-	6.5	6.1	6.7	7.0	7.2	6.9	6.8	6.8	6.9	-	-	6.7	6.8
4	6.5	5.7	-	5.5	6.0	-	6.2	6.6	6.0	5.8	5.8	6.0	-	-	6.4	-
5	6.2	4.7	-	4.7	4.5	-	5.4	5.7	5.5	5.3	5.3	5.2	-	-	5.6	-
6	-	4.8	-	4.5	5.4	-	5.5	5.5	5.3	5.0	5.2	5.4	-	-	5.6	-
7	-	4.7	-	5.1	5.4	-	5.3	5.3	5.4	5.2	5.8	5.5	-	-	5.7	-
8	-	6.9	-	6.4	6.6	-	7.0	7.2	6.7	6.6	6.3	6.8	-	-	6.9	-
9	-	5.9	-	5.9	6.3	-	6.4	7.0	6.4	5.8	5.9	6.4	-	-	6.0	-
10	-	6.1	-	5.8	6.5	-	6.7	6.9	6.6	6.0	6.1	6.4	-	-	6.4	-
11	-	5.8	-	5.9	5.6	-	6.0	5.5	6.1	5.7	5.5	5.9	-	-	6.1	-
12	-	5.6	-	5.8	5.8	-	6.3	6.0	5.7	6.5	5.9	6.6	-	-	6.1	-
13	-	6.3	-	5.7	5.5	-	6.4	6.1	6.5	6.4	6.2	6.6	-	-	6.2	-
14	-	5.8	-	5.5	5.6	-	6.1	6.2	6.1	6.1	5.7	6.1	-	-	6.0	6.5
15	-	6.3	-	6.3	6.4	-	6.7	-	7.1	6.6	6.0	6.5	-	-	6.7	6.7
16	-	7.3	-	7.1	7.2	-	7.5	-	7.1	7.1	7.2	7.1	-	-	7.5	7.8
17	-	5.5	-	5.5	5.5	-	6.1	-	5.8	5.9	5.7	6.1	-	-	6.1	5.7
18	-	5.9	-	6.2	5.9	-	6.2	-	6.1	6.3	5.9	6.1	-	-	-	6.2
19	-	6.8	-	5.9	6.5	6.9	6.8	-	6.6	6.5	6.6	7.1	-	-	-	6.9
20	-	6.8	-	6.3	6.4	6.6	7.2	-	6.7	6.6	6.7	7.2	-	-	-	6.9

1 before thunderstorm 2 after thunderstorm

Appendix 5

Daily Precipitation at Vogelbach

(in cms)

Month	Date	Amount	Comments
May	20	0	approximately 90 % snow cover above 1300 metres altitude
	21	0	
	22	0	
	23	0	
	24	0	
	25	0.30	
	26	1.70	
	27	0	Remnant patches of snow confined to true right headbasin
	28	0.85	
	29	0.20	
	30	0.60	Fresh snow above 1500 metres altitude
	31	0	
June	1	1.40	
	2	0	
	3	3.25	
	4	2.95	Fresh snow above 1300 metres altitude
	5	1.25	Fresh snow to 1000 metres altitude
	6	1.55	
	7	0.55	
	8	0.10	
	9	0	
	10	0	
	11	0.25	
	12	0.10	
	13	0.65	Thunderstorm with heavy rain late afternoon
	14	0.20	
	15	0.30	
	16	2.15	
	17	0.10	
	18	3.60	Remnant snow completely thawed
	19	2.25	

Appendix 5 (contd.)

Month	Date	Amount	Comments
June	20	0.40	
	21	0	
	22	0	
	23	1.70	
	24	4.05	Fresh snow to 1300 metres altitude
	25	3.55	Considerable flooding
	26	1.20	
	27	0.75	
	28	1.45	
	29	0	
	30	0	
July	1	0	
	2	0	
	3	0	
	4	0	
	5	2.55	
	6	1.00	
	7	1.90	
	8	1.10	
	9	2.40	
	10	0.95	
	11	1.80	
	12	0	
	13	0	
	14	0	
	15	0	
	16	0	
	17	0	
	18	1.60	
	19	0	
	20	0	
	21	0	
	22	0	
	23	0.65	

Appendix 5 (contd.)

Month	Date	Amount	Comments
July	24	0	Generally fine period, but intermittent thunderstorms with heavy rain
	25	1.25	
	26	0	
	27	0	
	28	0.10	
	29	2.65	
	30	0	
	31	0	
August	1	2.70	
	2	0	
	3	1.75	
	4	0	
	5	0	
	6	0	
	7	0	
	8	0	
	9	0	
	10	0	
	11	0	
	12	1.40	
	13	1.80	Brief intense thunderstorm 1315-1345 hrs.
	14	1.70	Frequent thunderstorms 12/8 - 22/8
	15	3.90	Severe flooding
	16	5.00	
	17	4.60	Frequent flooding 15/8-23/8
	18	0.50	
	19	0.20	
	20	4.50	
	21	0.55	
	22	0.85	
	23	2.60	Steady rain 23/8-28/8
	24	1.30	
	25	1.10	

Appendix 5 (contd.)

Month	Date	Amount	Comments
August	26	3.85	
	27	0.70	
	28	1.10	
	29	0	
	30	0	
	31	0	

Appendix 6

Precipitation at Groundwater Observation Stations During 24 Hours Preceeding Recording (in cms)

Station Number	Date of Observation														
	30/5	9/6	11/6	13/6	18/6	24/6	3/7	11/7	17/7	25/7	31/7	7/8	13/8	22/8	29/8
1	0.20	0.10	0	0.10	0.10	3.10	0	1.00	0	0	0	0	1.40	0	1.00
2	0.20	0.10	0	0.10	0.10	3.60	0	1.00	0	0	0	0	1.40	0	1.00
3	0.20	0.10	0	0.10	0.10	4.20	0	1.00	0	0	0	0	1.40	0	1.00
4	0.20	0.10	0	0.10	0.10	-*	0	0.95	0	0	0	0	1.40	0	1.00
5	0.20	0.10	0	0.10	0.10	-	0	0.95	0	0	0	0	1.40	0	1.00
6	0.20	0.10	0	0.10	0.10	-	0	0.90	0	0	0	0	1.40	0	1.00
7	0.20	0.10	0	0.10	0.10	-	0	0.90	0	0	0	0	1.40	0	1.00
8	0.20	0.10	0	0.10	0.10	-	0	0.90	0	0	0	0	1.40	0	1.00
9	0.20	0.10	0	0.10	0.10	-	0	0.90	0	0	0	0	1.40	0	0.90
10	0.20	0.10	0	0	0.10	-	0	0.90	0	0	0	0	1.40	0	0.90
11	0.55	0.10	0	0	0.10	-	0	0.90	0	0	0	0	1.40	0	0.90
12	0.55	0.10	0	0	0.10	-	0	0.90	0	0	0	0	1.40	0	0.90
13	0.55	0.10	0	0	0.10	-	0	0.90	0	0	0	0	2.15	0	0.60
14	0.55	0.10	0	0	0.10	-	0	0.85	0	0	0	0	2.15	0	0.60
15	0.55	0.10	0	0	0.10	-	0	0.85	0	0	0	0	2.15	0	0.60
16	0.55	0.10	0	0	0.10	-	0	0.85	0	0	0	0	2.15	0	0.60
17	0.55	0.10	0	0	0.10	-	0	0.70	0	0	0	0	2.15	0	0.60
18	0.80	0.10	0	0	0.10	-	0	0.70	0	0	0	0	2.15	0	0.60
19	0.80	0.10	0	0.65	0.20	4.40	0	0.70	0	0	0	0	2.15	0	0.60
20	0.80	0.10	0	0.65	0.20	4.50	0	0.70	0	0	0	0	2.15	0	0.60

* No groundwater observations

Appendix 7

Precipitation at Groundwater Observation Stations During 3 Days Preceeding Recording

(in cms)

Station Number	Date of Observation														
	30/5	9/6	11/6	13/6	18/6	24/6	3/7	11/7	17/7	25/7	31/7	7/8	13/8	22/8	29/8
1	1.05	2.20	0.10	0.35	2.55	3.10	0	4.35	0	0.65	2.75	0	1.40	5.25	5.65
2	1.05	2.20	0.10	0.35	2.55	3.60	0	4.35	0	0.65	2.75	0	1.40	5.25	5.65
3	1.05	2.20	-	0.35	2.55	4.20	0	4.35	0	0.65	2.75	0	1.40	5.25	5.65
4	1.05	2.20	-	0.35	2.55	-*	0	4.35	0	0.65	2.75	0	1.40	5.25	5.65
5	1.05	2.20	-	0.35	2.55	-	0	4.35	0	0.65	2.75	0	1.40	5.25	5.65
6	1.05	2.20	0.10	0.35	2.55	-	0	4.35	0	0.65	2.75	0	1.40	5.25	5.65
7	1.05	2.20	0.10	0.35	2.55	-	0	4.35	0	0.65	2.75	0	1.40	5.25	5.65
8	1.05	2.20	0.10	0.35	2.55	-	0	4.35	0	0.65	2.75	0	1.40	5.25	5.65
9	1.05	2.20	-	0.35	2.55	-	0	4.25	0	0.65	2.75	0	1.40	5.25	5.55
10	1.05	2.20	-	0.35	2.55	-	0	4.25	0	0.65	2.75	0	1.40	5.25	5.55
11	1.40	2.20	-	0.35	2.55	-	0	4.25	0	0.65	2.75	0	1.40	5.25	5.55
12	1.40	2.20	-	0.35	2.55	-	0	4.25	0	0.65	2.75	0	1.40	5.25	5.55
13	1.40	2.20	-	0.35	2.55	-	0	3.95	0	0.65	2.75	0	2.15	5.25	5.35
14	1.40	2.20	-	0.35	2.55	-	0	3.95	0	0.65	2.75	0	2.15	5.25	5.35
15	1.40	2.20	0.10	0.35	2.55	-	0	3.95	0	0.65	2.75	0	2.15	5.25	5.35
16	1.40	2.20	0.10	0.35	2.55	-	0	3.95	0	0.65	2.75	0	2.15	5.25	5.35
17	1.40	2.20	0.10	0.35	2.55	-	0	3.95	0	0.65	2.75	0	2.15	5.25	5.35
18	1.65	2.20	0.10	0.35	2.55	-	0	3.95	0	0.65	2.75	0	2.15	5.25	5.35
19	1.65	2.20	0.10	1.00	2.65	4.40	0	3.95	0	0.65	2.75	0	2.15	5.25	5.35
20	1.65	2.20	0.10	1.00	2.65	4.50	0	3.95	0	0.65	2.75	0	2.15	5.25	5.35

* No groundwater observations

Appendix 8

Precipitation at Groundwater Observation Stations During 7 Days Preceeding Recording

(in cms)

Station Number	Date of Observation														
	30/5	9/6	11/6	13/6	18/6	24/6	3/7	11/7	17/7	25/7	31/7	7/8	13/8	22/8	29/8
1	3.05	9.65	4.25	2.55	3.50	9.35	2.20	9.90	1.80	0.65	4.00	4.45	1.40	14.55	10.10
2	3.05	9.65	4.25	2.55	3.50	9.85	2.20	9.90	1.80	0.65	4.00	4.45	1.40	14.55	10.10
3	3.05	9.65	-	2.55	3.50	10.45	2.20	9.90	1.80	0.65	4.00	4.45	1.40	14.55	10.10
4	3.05	9.65	-	2.55	3.50	-*	2.20	9.90	1.80	0.65	4.00	4.45	1.40	14.35	10.10
5	3.05	9.65	-	2.55	3.50	-	2.20	9.90	1.80	0.65	4.00	4.45	1.40	14.35	10.10
6	3.05	9.65	4.80	2.55	3.50	-	2.20	9.90	1.80	0.65	4.00	4.45	1.40	14.35	10.10
7	3.05	9.65	4.80	2.55	3.50	-	2.20	9.90	1.80	0.65	4.00	4.45	1.40	14.35	10.10
8	3.05	9.65	5.10	2.55	3.50	-	2.20	9.90	1.80	0.65	4.00	4.45	1.40	14.35	10.10
9	3.05	9.65	-	2.55	3.50	-	2.20	9.90	1.80	0.65	4.00	4.45	1.40	14.20	10.10
10	3.05	9.65	-	2.55	3.50	-	2.20	9.90	1.80	0.65	4.00	4.45	1.40	14.20	10.00
11	3.20	9.65	-	2.55	3.50	-	2.20	9.90	1.80	0.65	4.00	4.45	1.40	14.20	10.00
12	3.20	9.65	-	2.55	3.50	-	2.20	9.90	1.80	0.65	4.00	4.45	1.40	14.20	10.00
13	3.20	9.65	-	2.55	3.50	-	2.20	9.90	1.80	0.65	4.00	4.45	2.15	14.20	10.00
14	3.20	9.65	-	2.55	3.50	-	2.20	9.90	1.80	0.65	4.00	4.45	2.15	14.20	10.00
15	3.20	9.65	4.60	2.55	3.40	-	2.20	9.90	1.80	0.65	4.00	4.45	2.15	14.20	10.00
16	3.20	9.65	4.25	2.55	3.40	-	2.20	9.90	1.80	0.65	4.00	4.45	2.15	14.20	10.00
17	3.20	9.65	4.25	2.55	3.40	-	2.20	9.90	1.80	0.65	4.00	4.45	2.15	14.20	10.00
18	3.40	9.65	4.25	2.55	3.40	-	2.20	9.90	1.80	0.65	4.00	4.45	2.15	14.20	10.00
19	3.50	9.65	4.25	3.20	3.50	10.75	2.20	9.90	1.80	0.65	4.00	4.45	2.15	14.20	9.95
20	3.50	9.65	4.25	3.20	3.50	10.75	2.20	9.90	1.80	0.65	4.00	4.45	2.15	14.20	9.95

* No groundwater observations

Fig. 1 VOGELBACH CATCHMENT Showing Distribution of Soil Types 2 and 3 and Location of GROUNDWATER STATIONS.

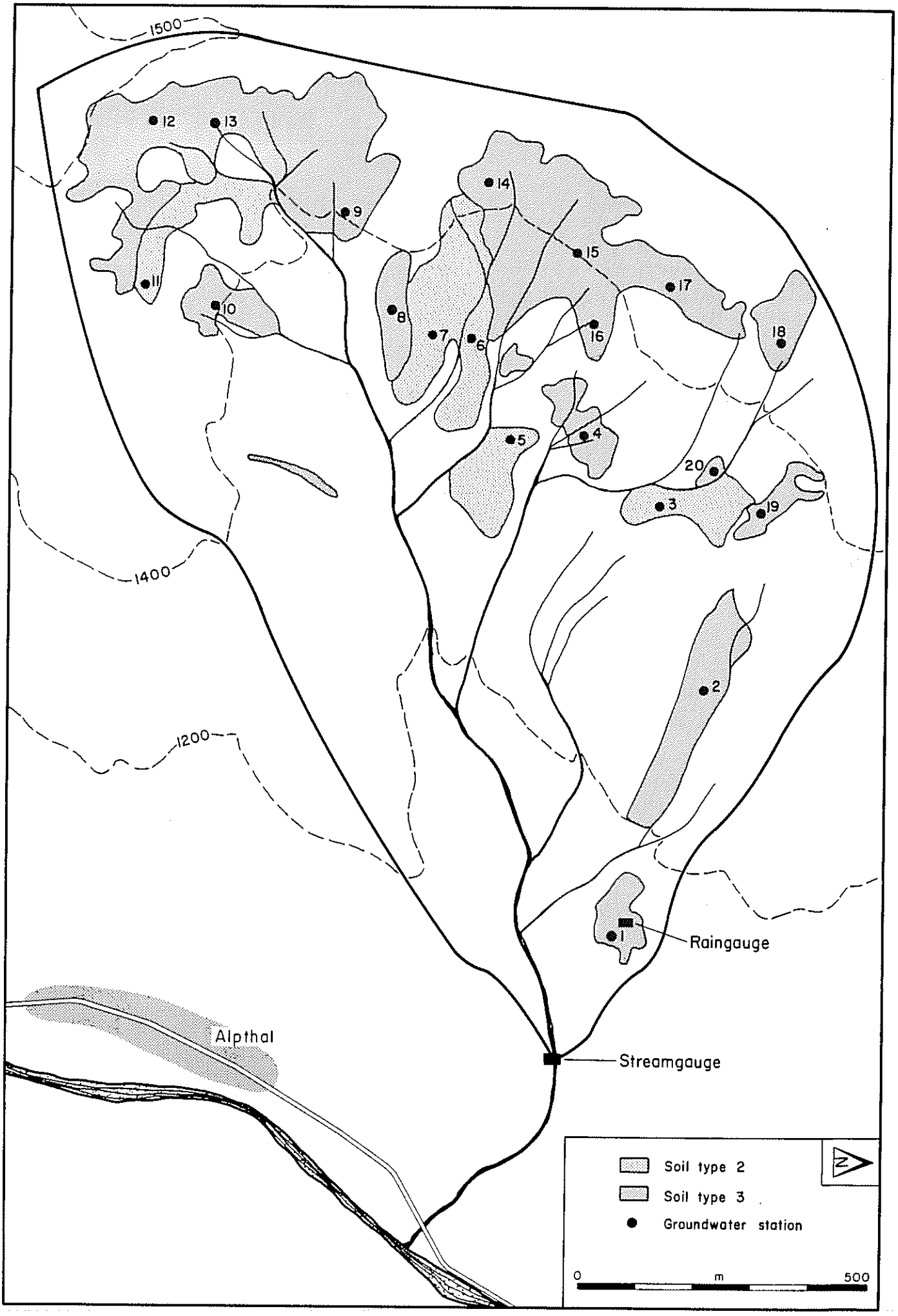
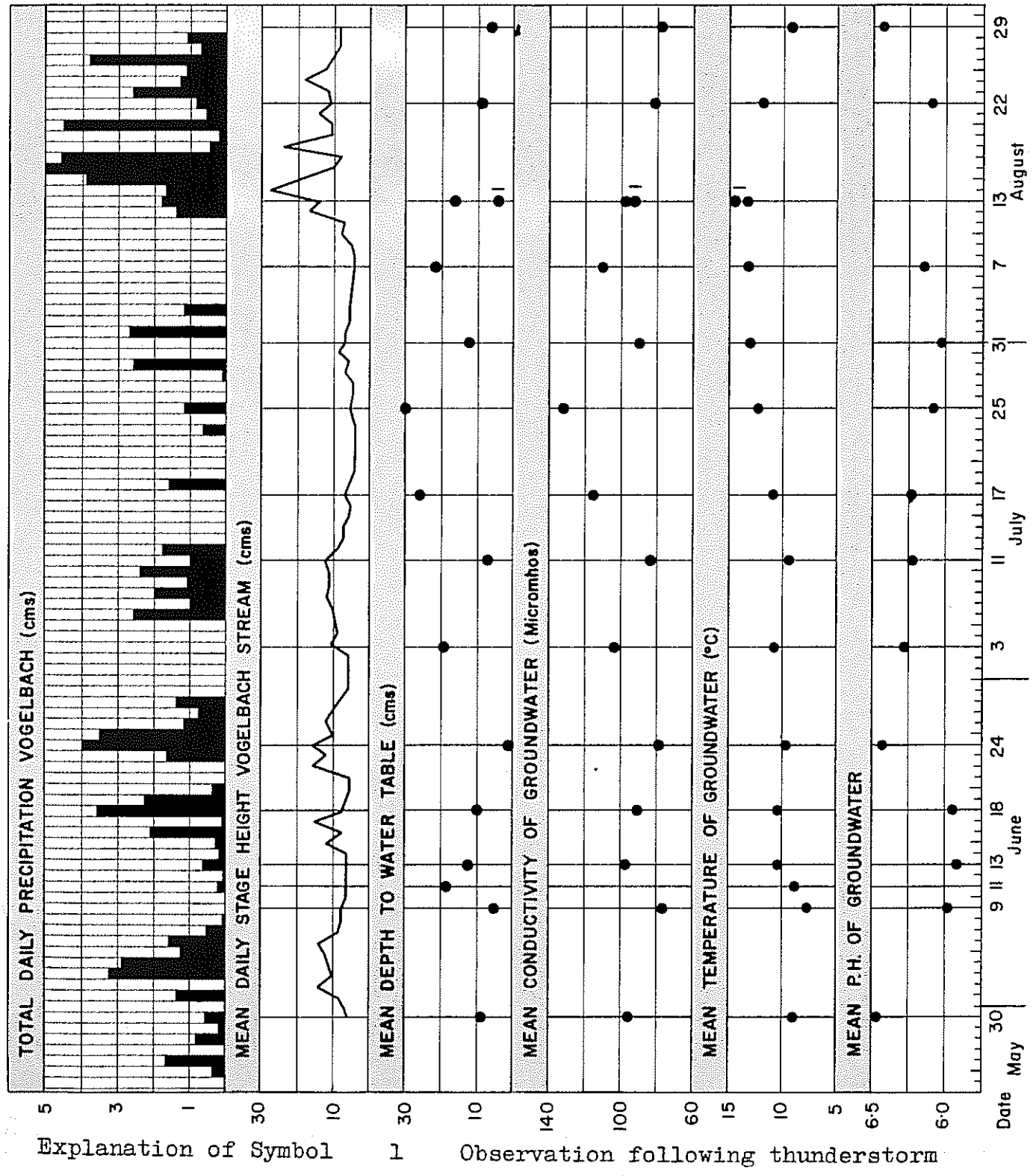


Fig. 3 Seasonal Patterns of DAILY PRECIPITATION, DAILY MEAN STREAM DISCHARGE, AVERAGE MEAN WATER TABLE DEPTH AND AVERAGE MEAN, ELECTRICAL CONDUCTANCE, TEMPERATURE AND P.H. OF GROUNDWATER.



Special Note due to omission. Apart from daily stream stage height all other means are in effect, average means.

Explanation of Symbol 1 This observation is not comparable to others since it occurred immediately following a thunderstorm when the water table may have been only temporarily shallow.

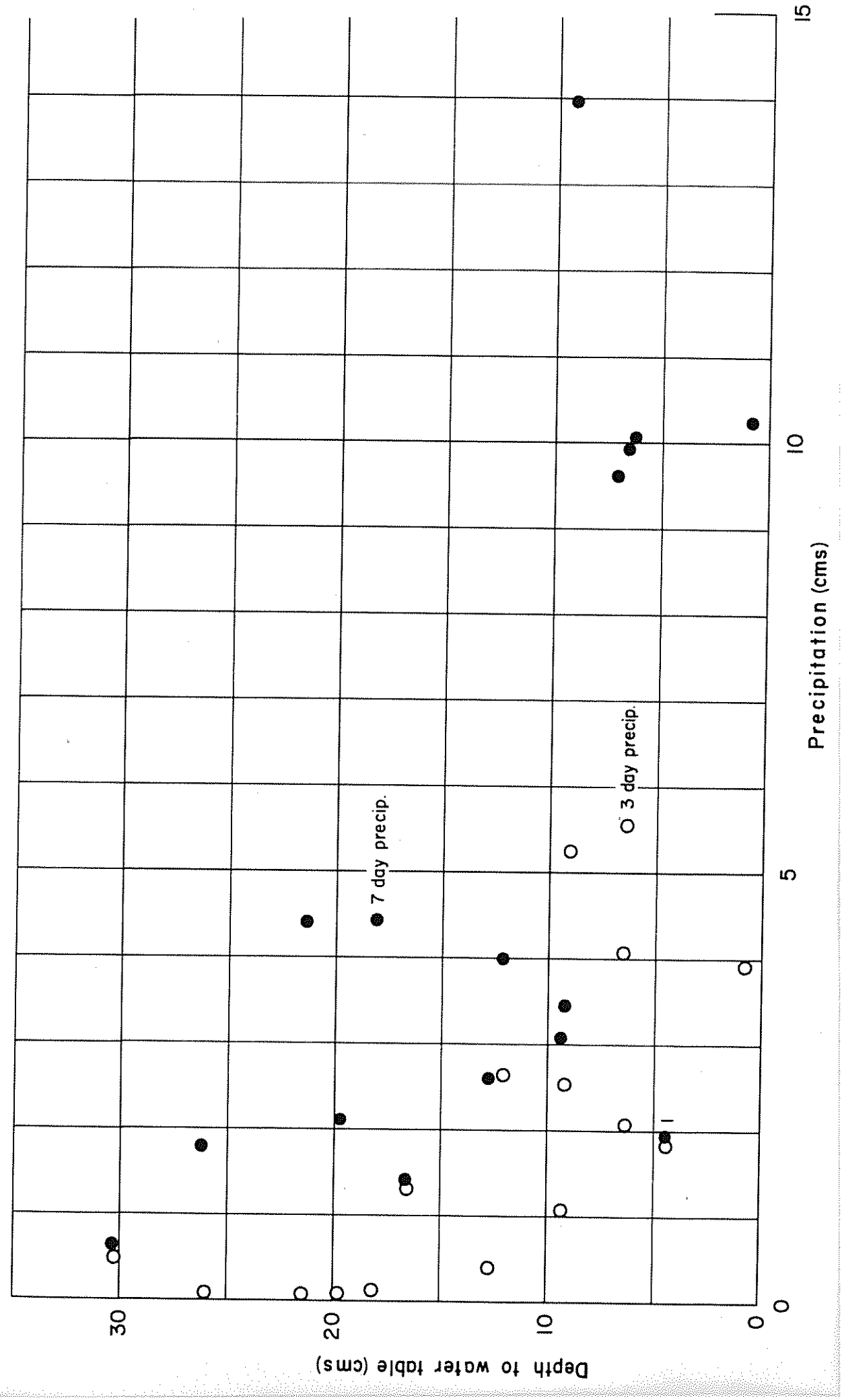


Fig. 4 RELATIONSHIP OF THREE AND SEVEN DAY PRECIPITATION TO WATER TABLE DEPTH