PAPER No. 391

Technical Appraisal of Salinity Control and Reclamation Project-1 with Reference to Decline of Water Level

By

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Synopsis

Salinity Control and Reclamation Project-1, covering an area of 1.2 million acres, went into operation in early 1961. The average pumpage from over 2,000 project wells, Rasul wells and private wells is on the order of 2.40 feet per year. Since the operation of the project, water level data were being collected by WASID to determine the average decline of water levels as a result of ground water withdrawal. Enough water level data are now available to attempt an approximate water balance for the area to compare the observed behaviour of the project with the anticipations made in the project report and its feasibility review.

In the project report an operational yield of 2 feet per year has been calculated assuming, 10 per cent storage coefficient, one foot lowering rate per year, and that the component of the recharge and discharge would balance at 15 feet below the natural surface. The average depth before reclamation operation was approximately 9 feet below the land surface. According to this estimated lowering rate the water level in SCARP-1, was forecast to stabilise after 6 years of pumping.

In the feasibility review of the project report it was concluded that the recharge from the canal leakage was over estimated, while the availability of ground water from storage was under estimated because of low assumed value of storage coefficient. According to this review, assuming 30 per cent storage coefficient and abstraction rate of 1.25 feet per year, the water level in SCARP-1 would lower to pre-irrigation level in a matter of 40 years, provided there is no development in contiguous areas.

Analysis of the observed data indicate that the average water level decline in the SCARP-1 since June 1960 to June 1966 is 7.6 feet, while the predicted lowering under the abstraction rate of 1.25 feet per year is 19 feet. Further analysis of the observed decline rate indicate that under the present operational conditions and environment, the water level in the SCARP-1 would not lower to more than 20 feet after 40 years of pumping.

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The water balance study for July 1965 to June 1966 show that the effective average recharge to the ground water reservoir is approximately 2.38 feet per year while the contribution from the ground water storage is 0.6 feet per year. The approximate future operational yield of the project under present condition will be on the order of 2.4 feet per year as compared to the predicted value of 2 feet per year in project report and 1.25 feet per year in feasibility review. The contribution from ground water storage would decrease as the outflow decrement increase and at the end of 40 years would be zero.

If the feasibility review decline is to be achieved by 2,000 A.D. the approximate pumpage required is 3 feet per year. The analysis of the tubewell operation indicate that 0.7 feet per year of pumpage is being lost through lack of distribution work and no demand. If this pumpage can be saved by providing additional uses of the water during the year, the ground water withdrawal can be raised to 3.1 feet per year thus increasing the present lowering rate without additional tubewells. In addition wherever necessary private tubewell development within the SCARP-1 can be considered if the water level to pre-irrigation level by 2,000 A.D. may be desirable.

INTRODUCTION

General

Pakistan is an agricultural country and 85 per cent of its population earns its livelihood from the land. To boost up the agricultural production, a huge network of canal system was planned and subsequently executed since early twentieth century. At present hundreds of miles of main canals, branches, and smaller distribution channels traverse the alluvium plain Indus and supply water to the far-flung areas. Most of these channels are unlined and constantly add huge quantity of water to the ground water reservoir.

This man made source of recharge, imposed upon the existing balanced hydrologic system, resulted in a rapid rise of the water level. The rising water level exposed the land to the menace of water-logging and salinity. According to the salinity survey of Punjab plain during 1955-56, approximately 70,000 acres of land were going out of production each year and the danger of thousands of acres turning into desolate waste with every passing year was becoming increasingly serious.

To deal with this increasing threat a meagre attempt was made towards reclaiming the land by tubewell schemes. Consequently, with the help of F.A.O. of United Nations five schemes namely Churkana, Pindi Bhattian, Chichoki Mallian, Shadman-II and Jaranwala having 195 tubewells were formulated and constructed during 1954-1960.

For the detailed investigation of the problem and collection of basic data for planning of large reclamation projects, Water and Soil Investigation Division (Ex-G.W.D.O.) was established in 1954 with the help of U.S. AID. In 1959, when the organization had collected sufficient field data, the first reclamation project named "Salinity Control and Reclamation Project-1" was formulated. This project covers an area of approximately 1.2 million acres in the Central Rechna Doab (Fig. 1) and consists of twelve schemes (including the old five schemes) ranging in size from about 8,300 acres (Pindi-Bhattian scheme) to about 247,000 acres (Shahkot scheme). The remaining schemes were completed between 1960 to 1962 and the total number of tubewells in all the twelve schemes at present are 2043.

The primary objective of SCARP-1 is to lower the general water table and provide additional supply for the purpose reclaiming saline land. In addition, it was also intended to augment the existing canal supply of about 2 million acre feet per year for increasing the delta more near to the optimum water requirement.

Aquifer Characteristics

For the quantitative analysis of any hydrologic system, the accurate knowledge of the two basic characteristics of an aquifer namely : transmissibility and storage coefficient, cannot be over emphasized. On account of their importance in various analyses, their values are subject to discussion. The aquifer test analyses indicate a magnitude of 0.72 ft.²/sec. for transmissibility and 14 per cent for storage coefficient (Bennett *et al.* 1964). Yet another detailed analysis of a few long-range pumping tests (Chaudhri, 1966) indicate an average permeability of 7.54×10^{-4} ft.²/sec and storage coefficient of 20 per cent. These are the results as determined from comparatively short-duration tests on partially penetrating pump wells and probably are not representative of the regional values.

C. E. Jacob (1959) in his review on Project report of SCARP-1 has made a regional evaluation of coefficients of transmissibility and storage. His conclusions indicate that the effective average transmissibility for the purpose of estimating regional decline due to pumping is 3.0 ft.²/sec. and storage coefficient is 30 per cent. The value of transmissibility for inflow and outflow determinations is 1.0 ft.²/sec. at the northern end and 10 ft.²/sec. at the southern end. The difference in the value of transmissibility at the two ends of the project is probably on account of the partial obstruction of buried ridge to the regional flow. In area above the ridge the regional flow may be effective in the upper few hundred feet, while the sediments downstream of the ridge are a few thousand feet thick. In the analysis presented in this paper the values of various coefficients used are those recommended by C. E. Jacob.

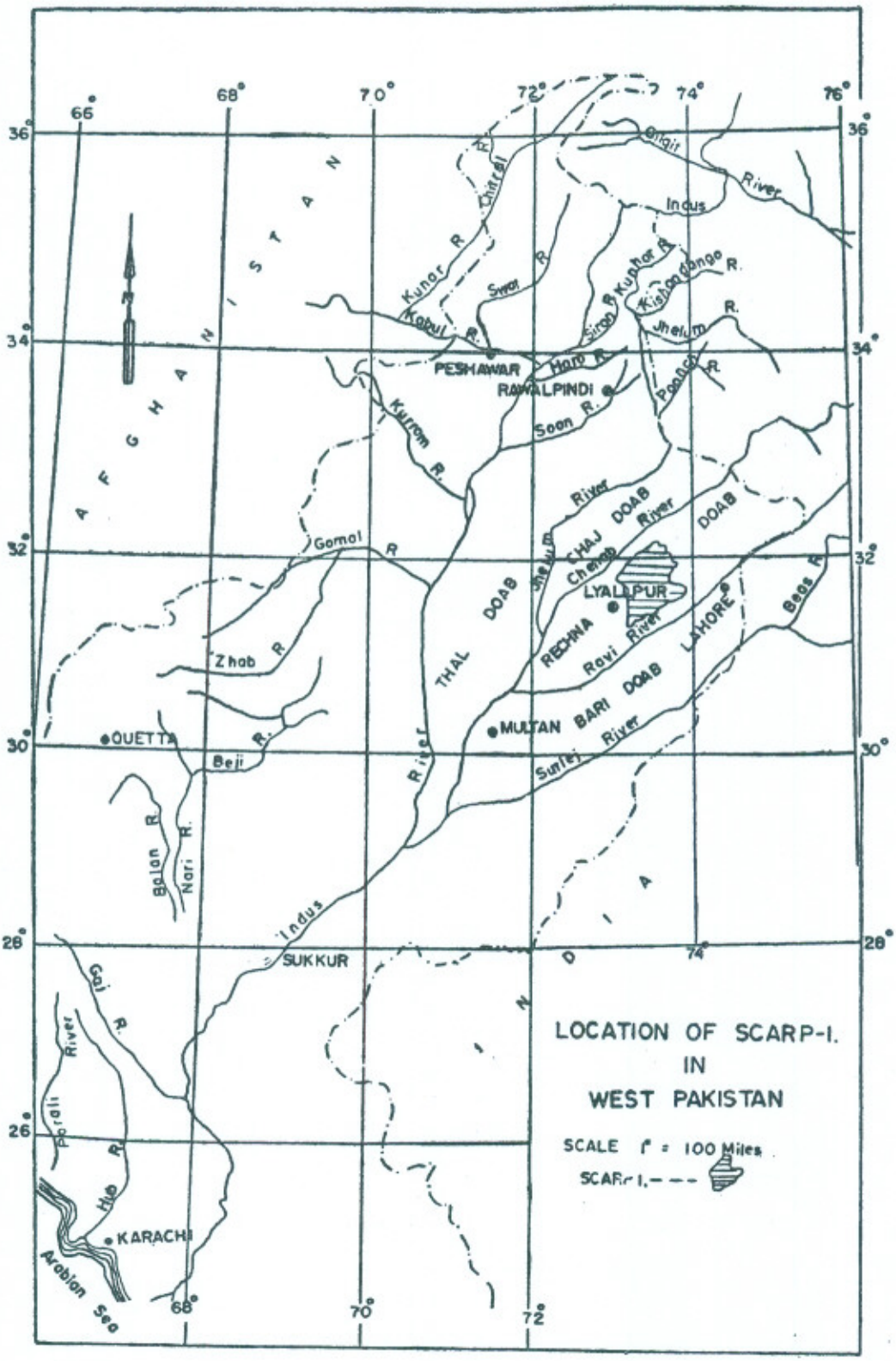


Figure: I INDEX MAP OF WEST PAKISTAN SHOWING SCARP-I.

PREVIOUS ESTIMATES OF WATER LEVEL DECLINE, WATER BALANCE AND OPERATIONAL YIELD OF SCARP-1

The operational yield in SCARP-1 Project report has been defined as the water that can be pumped from ground water reservoir without lowering it beyond economical depth. Assuming the lowering rate of one foot per year, 10 per cent storage coefficient and that the components of recharge and discharge would balance at 15 feet below the land surface, the probable operational yield determined in Project report is 2.5 million acre feet per year (SCARP-1, 1959, pp. 72-77).

In this operational yield the withdrawal from ground water storage within SCARP-1 boundary is only 0.12 million acre feet and the remaining 2.38 million acre feet or 2 feet per year is supplied by various components of recharge.

C. E. Jacob (1959) in review of the project report analysed the available data and made estimates of the present and future water balances and operational yields and also made predictions of the water level decline rate under assumed operational conditions. A brief account of his conclusions (for detail refer to the original report) is:

1. Recharge due to rain based on the analysis of water table profile of 1882 is 0.2 ft./yr.

2. During the period 1920—45 of relatively stabilized irrigation the canal seepage reaching the water table at 30 per cent coefficient is 0.24 ft./yr.; infiltration from farm supply and water courses at 10 per cent of supply reaching the fields is on the order of 0.1 ft./yr. the longitudinal inflow to the area is 0.11 ft./yr. and the outflow is 0.36 ft./yr. The net recharge to the ground water storage during the period 1920 to 1945 is therefore 0.28 ft./yr.

3. If all the initial withdrawal is from ground water reservoir, the water level in the SCARP-1 would decline to pre-irrigation level after 40 years of pumping with the net abstraction rate of 1.25 ft./yr. provided there is no development in the contiguous areas and the doab is hydraulically isolable.

4. Based on the above decline rate, the recharge from canals would probably increase to 0.4 ft./yr. due to lowering of water table, and the infiltration from farm supply (including canals and project wells) would increase to 0.4 ft./yr. The average removal from the storage over the period of 40 years will be 0.4 ft./yr. The future operational yield would therefore be 1.25 ft./yr.

WATER LEVEL OBSERVATION

General

Prior to canal irrigation the only record of water levels available is in the form of spot water levels marked on the maps. This record is traceable in the files of Hydrology Directorate of the Irrigation Department and was probably obtained from the Land Records Office. These spot measurements are scattered over the period of 1872 to 1900 for different areas of Rechna doab. An average water level contour and depth map for the pre-canal period have been made from these measurements and gives the general condition of the ground water reservoir (Figs. 2, 3). The approximate average water level for SCARP-1 area in the pre-canal period was 586.60 feet and the depth below land surface varied from 50 feet in the north eastern part to 100 feet at the southern end.

With the opening of Lower Chenab canal system, a network of open wells was selected for the purpose of making regular water level measurements in the months of June and October each year. These wells were numbered and their measuring points fixed with respect to the mean sea level. The bi-annual measurements of these wells are compiled in the Hydrology Directorate of the Irrigation Department. This water level data prior to 1960 has already been processed and published by the Water and Soil Investigation Division (Shakur *et al.*, 1960).

The water levels in the SCARP-1 area began to rise after the construction of canals. The average water level in the post canal period has been determined from the water level contour maps for the month of June for the years 1910, 1920, 1930, 1940 and 1959. A smooth curve which depicts the rise in the average water level since canal irrigation is drawn through these points (Fig. 4).

Before the operation of SCARP-1 (1960) the water table existed in 9700 acres (0.7 per cent) at surface, in 1,33,600 acres (9.8 per cent) between 0 to 3 feet, and on 4,65,900 acres (34.9 per cent) between 3 to 6 feet. In the rest of 54.6 per cent area the water table was deeper than 6 feet (Dr. Nazir, 1966, p. 15*a*). The average depth of water table below land surface was 9.0 feet (L.W.D.B. 1965).

Khanqah Dogran and Sangla Hill schemes partially started functioning since early 1961, and to follow up the effects of ground water withdrawal on the average water level of the area, monthly observations were started by WASID in approximately 13 open wells. With the completion of the remaining schemes the observation points have been continually expanding and by June 1966 there were 26 automatic stage recorders, 108 observation pipes and 44 open wells. Following is a brief account of the decline of average water level in the SCARP-1 area since the start of tubewell pumpage.

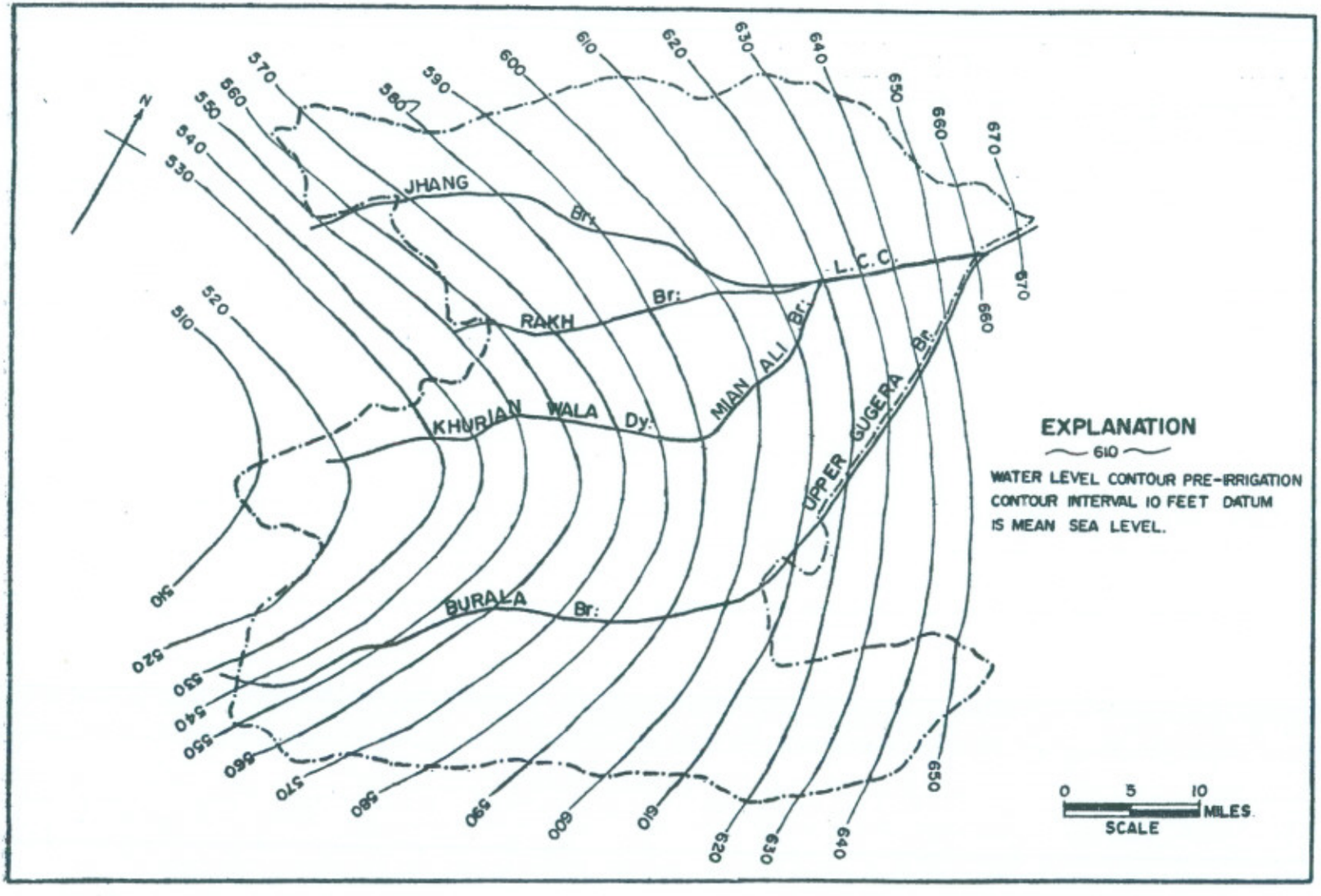


FIGURE: 2 MAP OF SCARP-I SHOWING THE APPROXIMATE ALTITUDE OF WATER LEVEL IN PRE-IRRIGATION PERIOD (1872-1900)

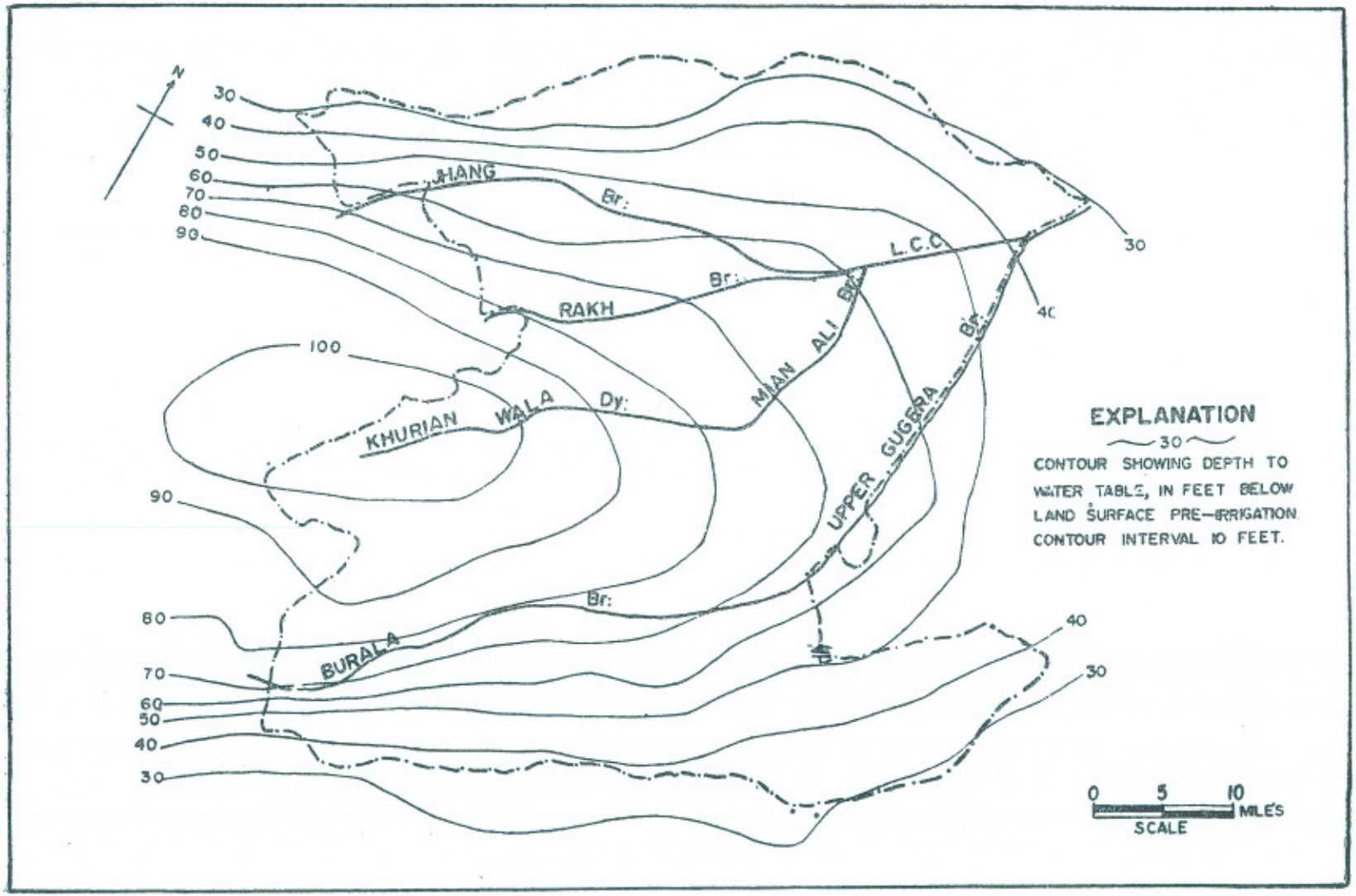


FIGURE: 3 MAP OF SCARP-I. SHOWING APPROXIMATE DEPTH TO WATER LEVEL BELOW LAND SURFACE IN PRE-IRRIGATION PERIOD (1872-1900)

Decline of Average Water Level

Five tubewell schemes, which were later incorporated into the SCARP-1, started functioning before June 1960. These schemes are small as compared to the SCARP-1 and as such their effect was mostly local and did not cause any large scale lowering. The tubewells of Khanqah Dogran and Sangla Hill schemes started pumping in early 1961, while those of the remaining schemes were in operation by 1962. Under these circumstances the average water level, which may be taken as reference for estimating the effects of ground water withdrawal on the hydrologic system, becomes uncertain. To facilitate the comparison with feasibility review, for the purpose of analysing water table decline rate, June 1960 level has been taken as the bench mark; for all other purposes such as change maps, June 1961 water level has been taken as the reference (as has already been done in previous WASID reports).

The decline in the average water level of SCARP-1 started simultaneously with the operation of tubewell schemes. The average water level for any particular year has been estimated from the water level contour maps and change maps of the respective years. Based on maps for the years 1961 to 1966, the average fall in water level has been calculated and is given in the following table (Table 1).

TABLE No. 1.—*Average Decline of Water in SCARP-1 since June* 1960

Year	Average decline of water level
June 1961 ..	2.24
June 1962 ..	3.30
June 1963 ..	5.10
June 1964 ..	7.78
June 1965 ..	5.60
June 1966 ..	7.60

The decline rate is not uniform because of the changes in the magnitude of recharge due to rain and fluctuation in the annual pumpage. The pre-reclamation water level (June 1960) has been determined from the extrapolation of the average rising water level curve (Fig. 4) and is approximately 642.50.

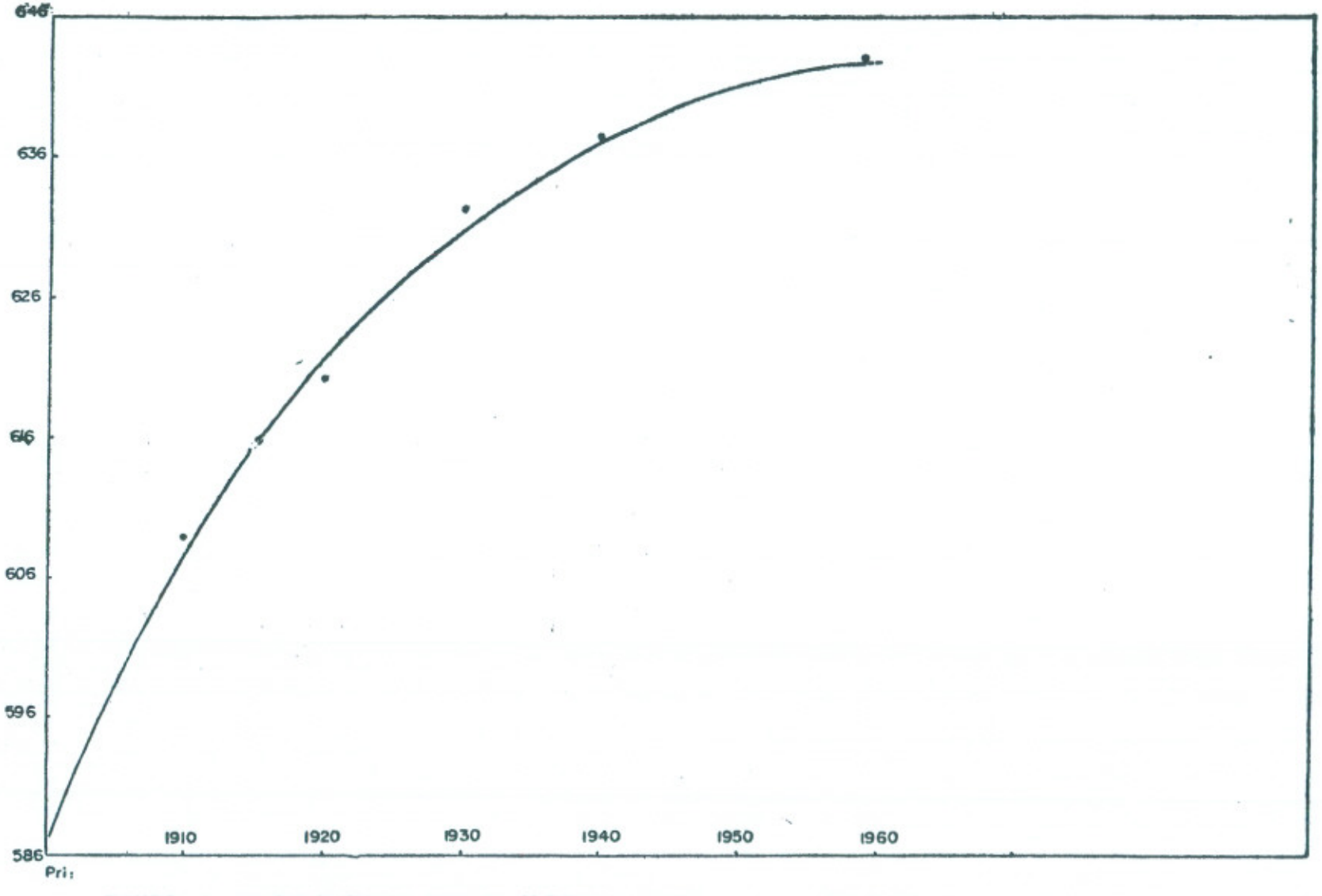


FIGURE: 4 CHART SHOWING RISE OF AVERAGE WATER LEVEL (ABOVE MEAN SEA LEVEL) IN SCARP-I. (1900-1960)

Figures 5 and 6 are the maps of water table contour and depth below N.S.L. in June 1966, and Fig. 7 is the change map of 1961 to 1966 and depicts the condition after five years of reclamation operation. The cone of influence by June 1966 has extended to 1.86 million acre.

WATER BALANCE FOR JULY 1965 to JUNE 1966

The detailed water budget analysis for the year 1965-66 with 15 per cent storage coefficient has been presented in WASID Technical paper 16 (Malmberg *et al.*, 1966). A brief resume of the water budget in this paper is considered necessary on account of the different value of storage coefficient used here. Most of the figures have been taken from report of Malmberg *et al.*, 1966, and adjusted to the new values of storage coefficient and transmissibility without making any fresh calculations.

Tubewell Pumpage

The withdrawal from the ground water reservoir during the period July, 1965 to June, 1966 is 2.86 million acre feet. This includes 0.3 million acre feet of the estimated pumpage from Rasul and private wells in addition to that of the project wells.

Depletion of Ground Water Storage

The effect of pumpage has extended beyond the limit of SCARP-1 and from July 1965 to June 1966 it covered an area of 1.86 million acres. Based on contour maps of June 1965 and June 1966 and change map of July 1965 to June 1966, (Fig. 8) the average lowering in the area of influence is 1.7 feet and within the scheme boundary the average lowering is approximately 2.0 feet. The net depletion of ground water storage within the SCARP-1 at 30 per cent storage coefficient is 0.6 feet.

Inflow

The surface inflow to the area is from Upper and Lower Chenab canals and is evaluated largely from the daily staff gauge readings. The principal stations from which inflow from Lower Chenab canal to SCARP-1 is estimated are the measuring sites at the Saghar Rest House at bifurcation of the Lower Chenab canal and Upper Gugera canal and the head gates of Muradian and Kot Nikka distributaries. The inflow to the area from Upper Chenab canal is through Chichoki Mallian distributary. The total inflow past all these sites from July, 1965 to June 1966 is 6.42 million acre feet.

The regional subsurface inflow from updoab to the area is computed from Darcy's Law. Based on transmissibility value of 1 ft.^{2}/sec. the regional

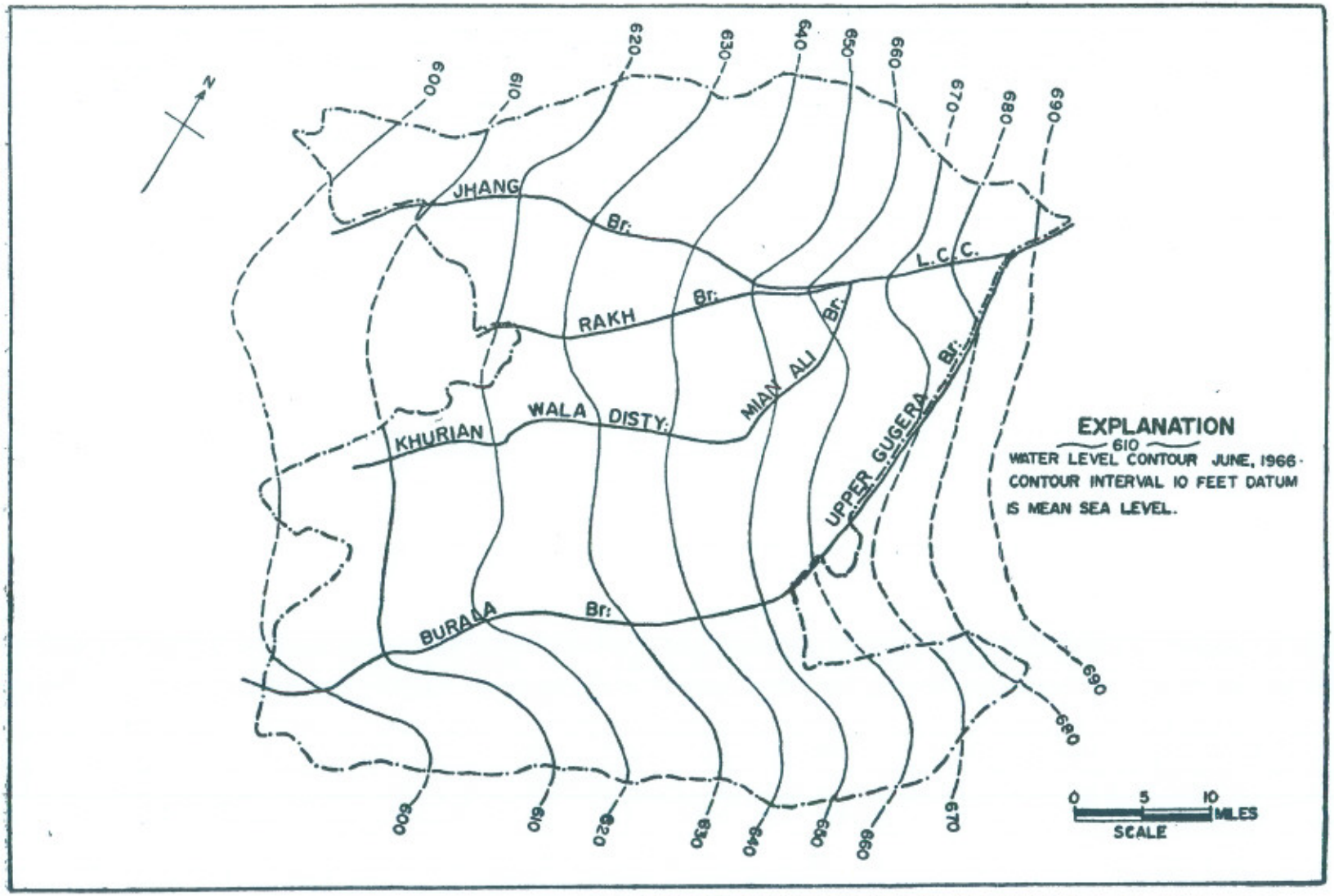


FIGURE: 5 MAP OF SCARP-I. SHOWING THE APPROXIMATE ALTITUDE OF THE WATER LEVEL IN JUNE 1966.

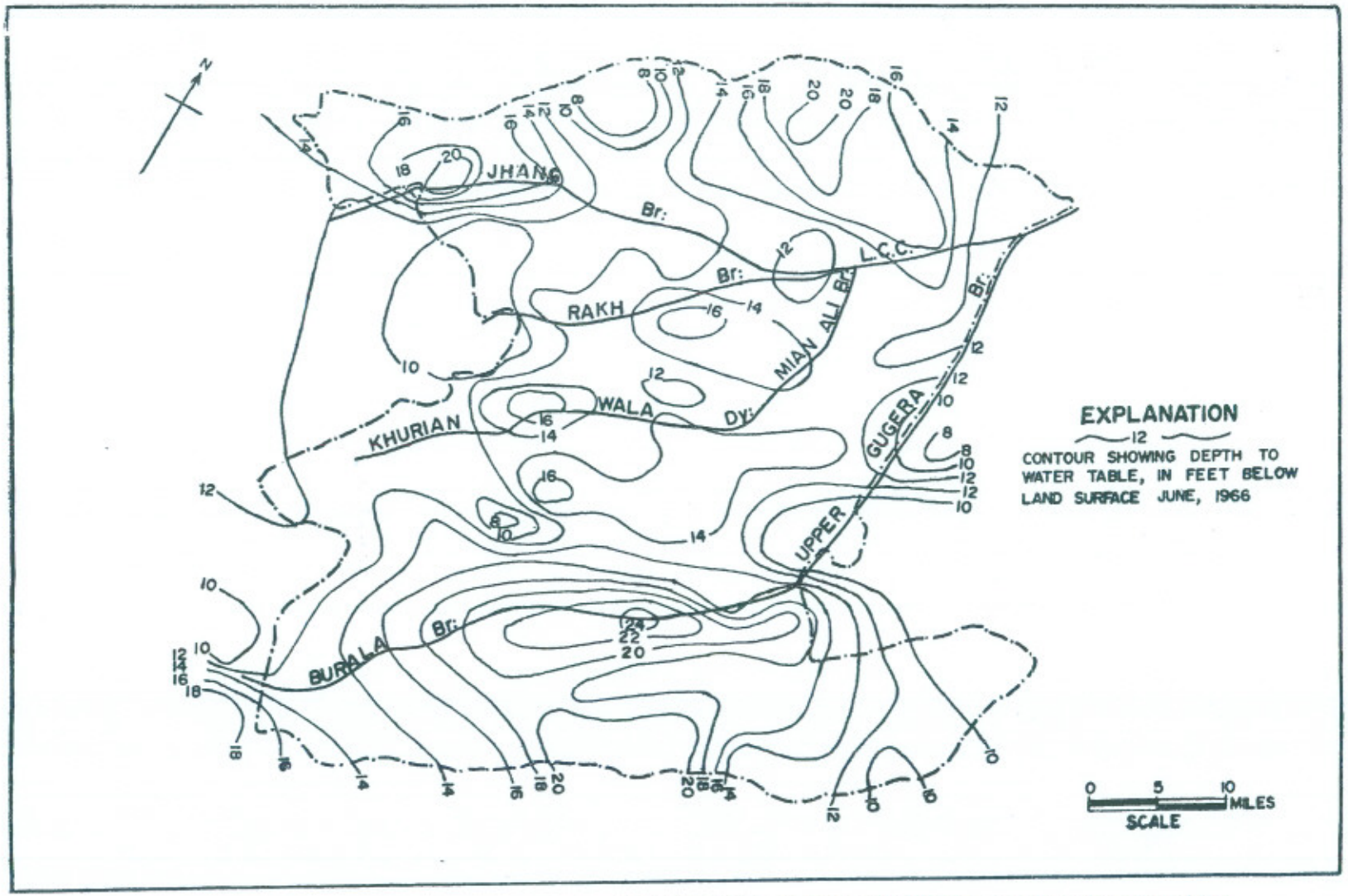


FIGURE: 6 MAP OF SCARP-I. SHOWING THE APPROXIMATE DEPTH TO WATER LEVEL BELOW LAND SURFACE IN JUNE 1966.

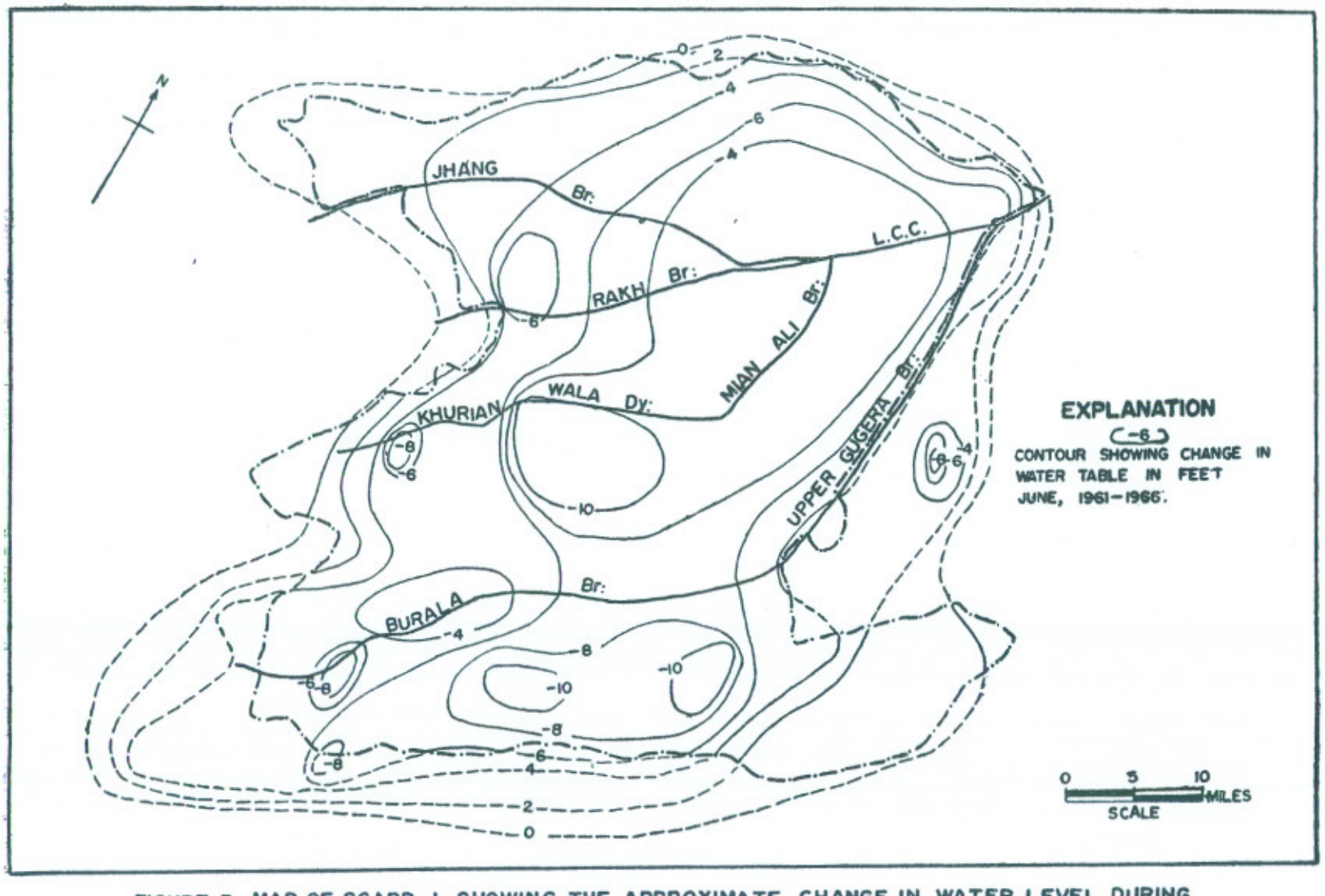


FIGURE: 7 MAP OF SCARP-I. SHOWING THE APPROXIMATE CHANGE IN WATER LEVEL DURING THE PERIOD JUNE 1961-JUNE 1966.

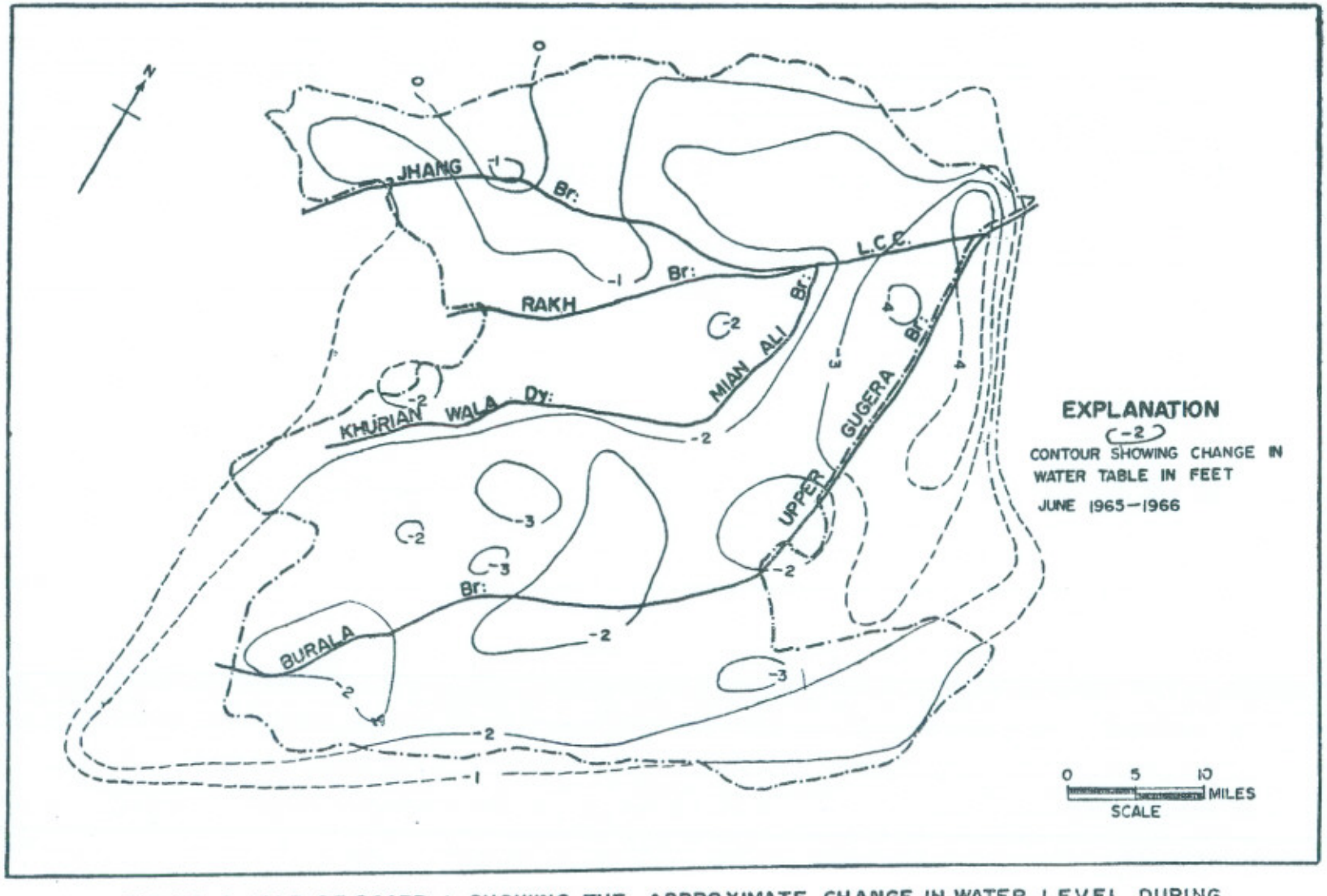


FIGURE: 8 MAP OF SCARP-I. SHOWING THE APPROXIMATE CHANGE IN WATER LEVEL DURING THE PERIOD JUNE 1965- JUNE 1966.

inflow is 0.08 feet per year. The contribution from ground water storage of the area in the cone of influence but outside SCARP-1 boundary is 0.2 feet. The total subsurface inflow thus approximates to 0.28 feet.

Outflow

Surface water is discharged from SCARP-1 by canals, drains and 'nalas'. Discharge by canals occurs principally along the south western margin of the area through the Jhang and Rakh branches and a few small distributaries. The principal measuring site on the Jhang Branch is near RD 277,500 about 5 miles beyond the boundary of SCARP-1. Diversions between the measuring site and the boundary of the study area are added to the calculated discharge in the main canal to obtain the total canal outflow through this canal network.

Outflow from the Rakh Branch is calculated from daily staff-gauge readings at RD 114,000, at Sangla Hill about 5 miles east of the boundary of SCARP-1. Diversions into the study area by the Sangla Minor and Aruri Distributary are subtracted from the total flow past Sangla Hill to obtain the total outflow. Discharge from the Lower Gugera canal is calculated as the sum between the total flow past the measuring site at RD 27,000 on the Lower Gugera canal and the flow crossing the boundary in Paulani , Awagat, Kheowala and Jasuana distributaries. The total outflow through canals, approximates to 4.3 million acre feet.

The subsurface regional outflow from the southern end of the SCARP-1 based on transmissibility value of 10 ft.^{2}/sec. is approximately 0.6 feet.

Precipitation

The average annual precipitation in the area computed from the isohyetal map of Rechna doab for the period 1956-57 (Sheikh, 1963) is about 17 inches or about 1.7 million acre feet. Distribution of precipitation on the area is uneven ranging from a minimum of about 12 inches in southwest, progressively increasing to a maximum of about 18 inches in the north-east. The area lies near the western extremity of the Indian ocean monsoon belt and the amount of precipitation during the monsoon may vary from year to year depending on the prevailing wind and so do the ground water recharge and run off. Based on precipitation data obtained by the Meteorological Department and Irrigation Branch for many stations in and adjacent to SCARP-1, the approximate rainfall on the area from July, 1965 to June 1966 is 1.2 feet which is about 12 per cent below the long term average.

Estimated Canal Seepage

The net amount of water to the area by canals and Rasul wells (as these wells discharge into canals) is approximately 2.13 million acre feet. The canal

water reaching the field as calculated from the water delta and irrigated acreage for the Kharif 1965 and Rabi 1966 is approximately 1.08 million acre feet. The difference between the net canal inflow and the actual amount reaching the fields or about 1.05 million acre feet is the conveyance loss resulting from infiltration and evaporation. The surface area of the canals in SCARP-1 is approxitely 9,000 acres and assuming average annual lake evaporation of about 60 inches (Harza Engineering Co. Int., 1965) the total evaporation from free surface is 45,000 acre feet. Thus the infiltration from canals approximates to 1.0 million acre feet or about 0.83 feet.

Infiltration from Irrigation and Precipitation

No direct means are available to determine this quantity. Here an effort is made to determine its magnitude indirectly by solving the water budget equation;

$$I = 0 \pm \triangle S$$

where 1 is the inflow, 0 is the outflow and $\triangle S$ is the change in storage. Assuming 20 feet as the average depth of the ground water, the loss from water table is 0.02 cm/day (2.9 inches/yr. Gardner and Firman, 1958) or about 0.12 ft./yr. Applying the water balance equation to the ground water reservoir only the recirculation is estimated :

Inflow

Canal seepage	= 0.83 feet
Subsurface inflow	= 0.28 feet
Infiltration from irrigation and precipitation	= ?
Total (1)	= 1.11+ ? feet

Outflow

Pumpage	= 2.38 feet
Subsurface outflow	= 0.60 feet
Evaporation	= 0.12 feet
Total (2)	= 3.10 feet
Change in storage (3)	= 0.60 feet
Infiltration from irrigation and precipitation (2-1-3)	= 3.10—1.11—0.60 = 1.39 feet

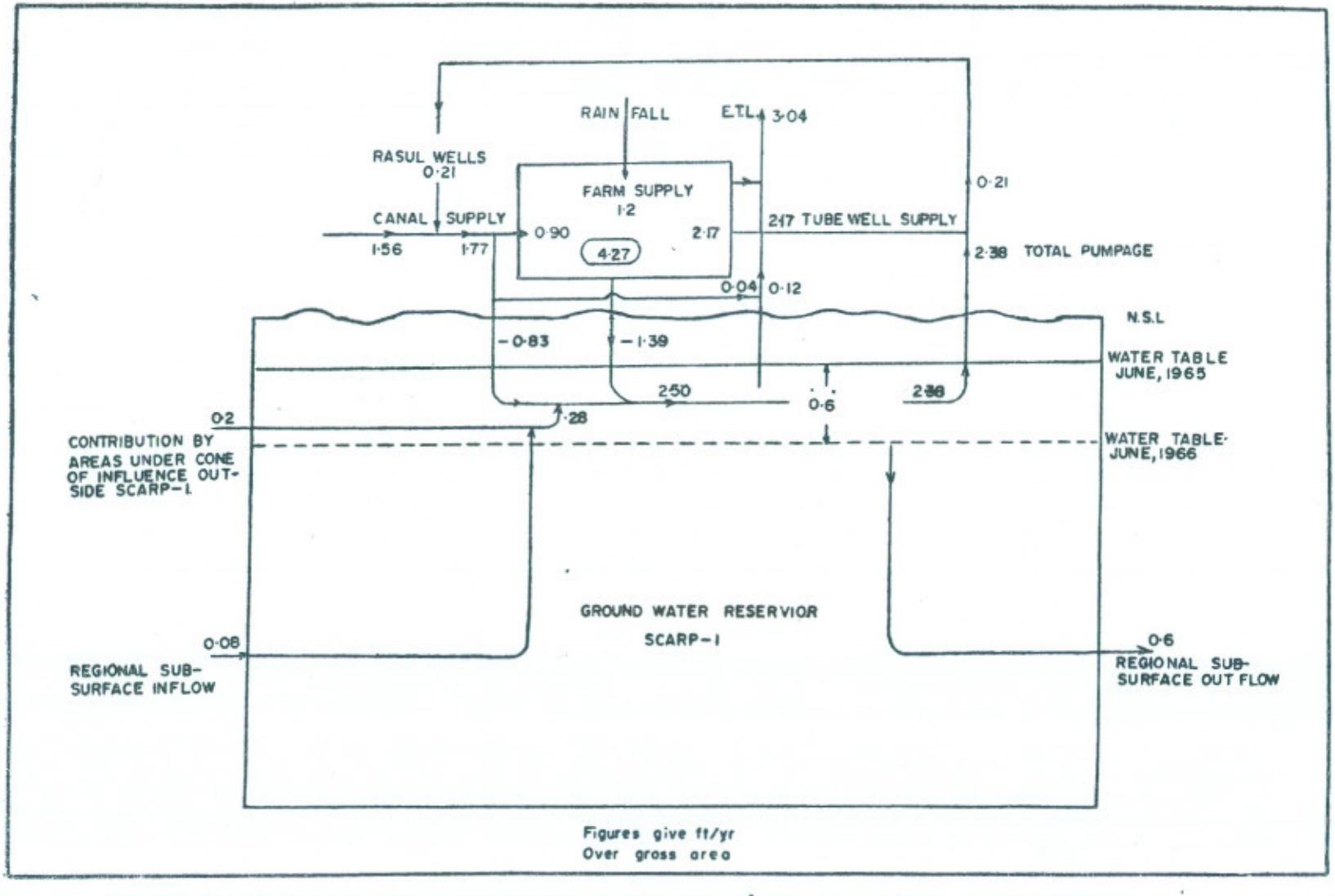


FIGURE: 9- SCHEMATIC FLOW CHART FOR WATER BALANCE OF SCARP-I JULY, 1965 TO JUNE 1966 (ASSUMING 30% STORAGE COEFF:)

The total farm supply inclusive of precipitation is 4.27 feet and 32 per cent of this $(1.39/4.27)^{100}$ infiltrates into the ground. If 0.2 feet is considered the infiltration from rain (Jacob, 1959) the infiltration from farm supply of canal and tubewells exclusive of precipitation is 38 per cent $\left(\frac{1.39—0.2}{4.27}\times 100\right)$.

Evapotranspiration

The evapotranspiration from the project area has been calculated indirectly as no detailed data is available. The total farm supply including rainfall is 4.27 feet. Out of this the infiltration is 1.39 feet. Thus the loss from surface supply is 2.88 feet and to this is added 0.16 feet from the ground water reservoir The total loss is, therefore, approximately 3.04 feet. A schematic flow chart for the water balance of the SCARP-1 is given in Fig. 9.

ANALYSIS OF OBSERVED RATE OF WATER LEVEL DECLINE

Analysis of the observed drawdown is based on the approximate theory developed by C. E. Jacob (1959) for the prediction of average drawdown in SCARP-1. A brief account of the theory is given below and for details the reader is referred to the original report (Review of SCARP-1 Appendix D, 1959).

Theory

Consider a strip of unconfined aquifer of uniform width "2*a*" bounded by parallel streams (such as Chenab and Ravi Rivers). Assume a uniform rate of accretion w_o to the water table. If the flow in the direction parallel to the streams is neglected the problem reduces to a unidirectional flow. Consider now a small strip perpendicular to the streams and one foot wide (Fig. 10).

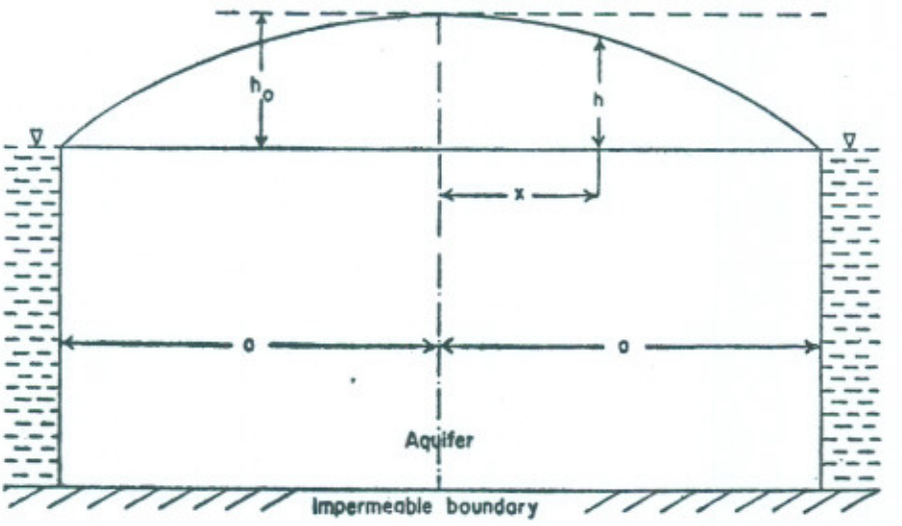


FIG: 10

The uniform accretion would produce the steady state water table profile between the streams which is given by the equation:

$$h = \frac{w_o}{2T}(a^2 - x^2) \qquad .. \quad (1)$$

where

w_o = Uniform vertical recharge
$2a$ = distance between the parallel streams
x = distance of point on the profile from the centre.

This is a parabolic profile and the average head over the strip in steady state condition will be $\frac{w_o}{3}\frac{a^2}{T}$. If the recharge is now suddenly stopped the profile would decay and at any time "t" after the cessation of the recharge the head "h" is given by the equation;

$$h = \frac{32\, a^2\, w_o}{2\pi^3\, T} \sum \pm \left(\frac{1}{n^3}\right) \cos\left(\frac{n\,\pi\, x}{2a}\right) e^{-\frac{n^2 \pi^2 T t}{4 a^2 S}} \qquad ..(2)$$

where

T = Transmissibility of the aquifer and is uniform in space and time

S = Storage Coefficient

Integrating (2) over "x" from "0" to "a" and approximating by one term, the average head over the strip at any time after the cessation of recharge is given by the equation;

$$h_d = \frac{a^2\, w_o}{3T} \cdot e^{-\frac{3 T t}{a^2 S}} \qquad ..(3)$$

If the final steady state head $\left(h_o = \frac{a^2\, w_o}{3\, T}\right)$ is considered as the reference plane, the magnitude of decay $\triangle h$ is given by;

$$\triangle h = h_o - h_d = \frac{a^2\, w_o}{3\, T}\left(1 - e^{-\frac{3 T t}{a^2 S}}\right) \qquad ..(4)$$

The build up of head from position of rest at uniform zero head is similar in nature as the decay of head from final steady state position given by equation (4). If instead of the recharge a uniform draft "W" is applied, the drawdown from position of rest at uniform zero is also given by the equation (4) which in appropriate terms can now be written as;

$$s = s_o\left(1 - e^{-\frac{3 T t}{a^2 S}}\right) \qquad ..(5)$$

where

s = average drawdown at any time "t" after application of uniform draft

s_o = final drawdown under steady state condition

Equation (5) is developed on the assumption that the accretion of water to the aquifer and subsequent draft on the water table are both uniform over the entire area. It is now desired to develop an approximate equation which can be used for prediction of drawdown in a roughly circular area surrounded by unexploited area (as is the case of SCARP-1). Consider now the SCARP-1 area which is roughly square in shape and can be approximately assumed as circular. As the contiguous area is not exploited the area can be considered as a circular island because this condition will be finally created due to areal recharge.

In order to derive the similarity in results of the two areas, consider a well pumping at rate Q and situated at the centre of each area. The maximum drawdown at the centre in case of area bounded by parallel infinite streams "$2a$" apart is given by :

$$s_w = \frac{Q}{2\pi T} \ln \frac{4a}{r_w \pi} \qquad ..(6)$$

In case of circular island of radius "r_e" the drawdown is

$$s_w = \frac{Q}{2\pi T} \ln \frac{r_e}{r_w} \qquad ..(7)$$

For two areas to give similar result at the centre the following relationship should hold;

$$r_e = 4a/\pi \qquad ..(8)$$

Assume a uniform draft "W" over an area roughly "r_e" in radius. The effect of such draft would be to drawdown the water table in accordance with $s = W(r_e^2 - r^2)/ 4T$. The average drawdown over the entire area will be $W. r_e^2/8 T$. Inserting the appropriate values in equation (5) the approximate average drawdown over the circular area is given by;

$$s = \left(\frac{2a^2 W}{\pi^2 T}\right)\left[1 - \exp.\left(-\frac{\pi^2 T t}{2a^2 S}\right)\right] \qquad ..(9)$$

Assuming $2/\pi^2$ approximately equal to 1/5, the above equation reduces to

$$s = \frac{W^3 a^2}{5T}\left(1 - e^{-\frac{5Tt}{a^2 S}}\right) \qquad ..(10)$$

Equation (10) therefore gives the average drawdown over the SCARP-1 area under the uniform draft of "W" from the ground water storage, with no development of contiguous areas.

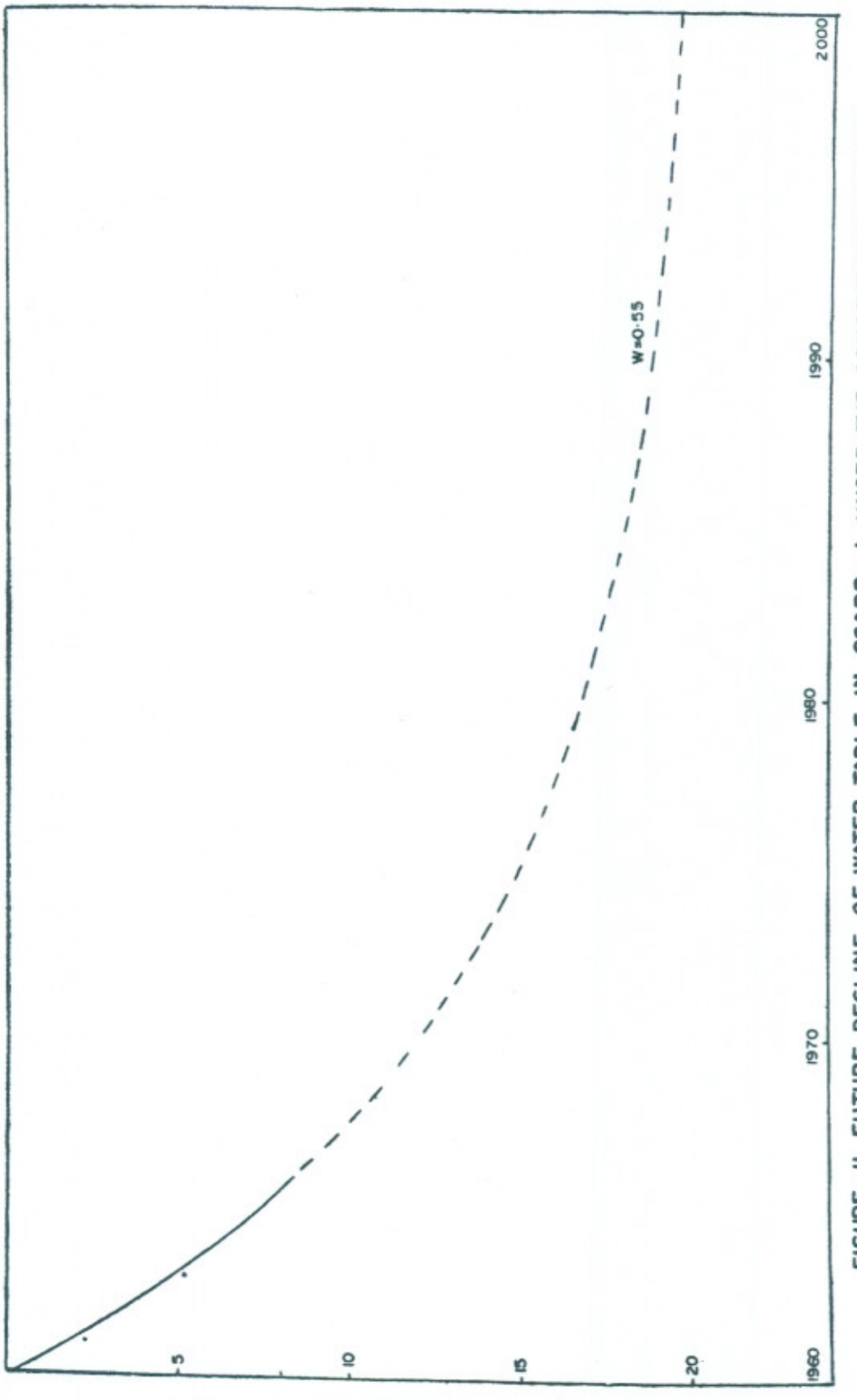


FIGURE: II FUTURE DECLINE OF WATER TABLE IN SCARP – I. UNDER THE PRESENT OPERATIONAL CONDITIONS AND ENVIRONMENTS.

Analysis

The average water level in the months of June for different years is given in Table 1. Fig. 11 is a plot of average drawdown and time since 1960. A family of time drawdown curves based on equation (10) for different abstraction rates and T = 3 ft.^{2}/sec. and S=0.3 have been prepared. By means of matching technique the best fit curve has been fitted to the observed drawdown. The firm line indicate the portion fitted to the observed drawdown and dotted line is the continuation of the curve beyond 1966.

This analysis indicate that the average net abstraction rate which would approximately give this pattern of drawdown curve is 0.55 ft. yr. Also the probable decline of average water level by 2000 A.D. under the existing operational conditions and environments will not be more than 20 feet.

Future Ground Water Yield

Based on the future decline rate of average water level in SCARP-1 (Fig. 11) and net abstraction rate of 0.55 ft. yr. Fig. 12 gives the curve for future

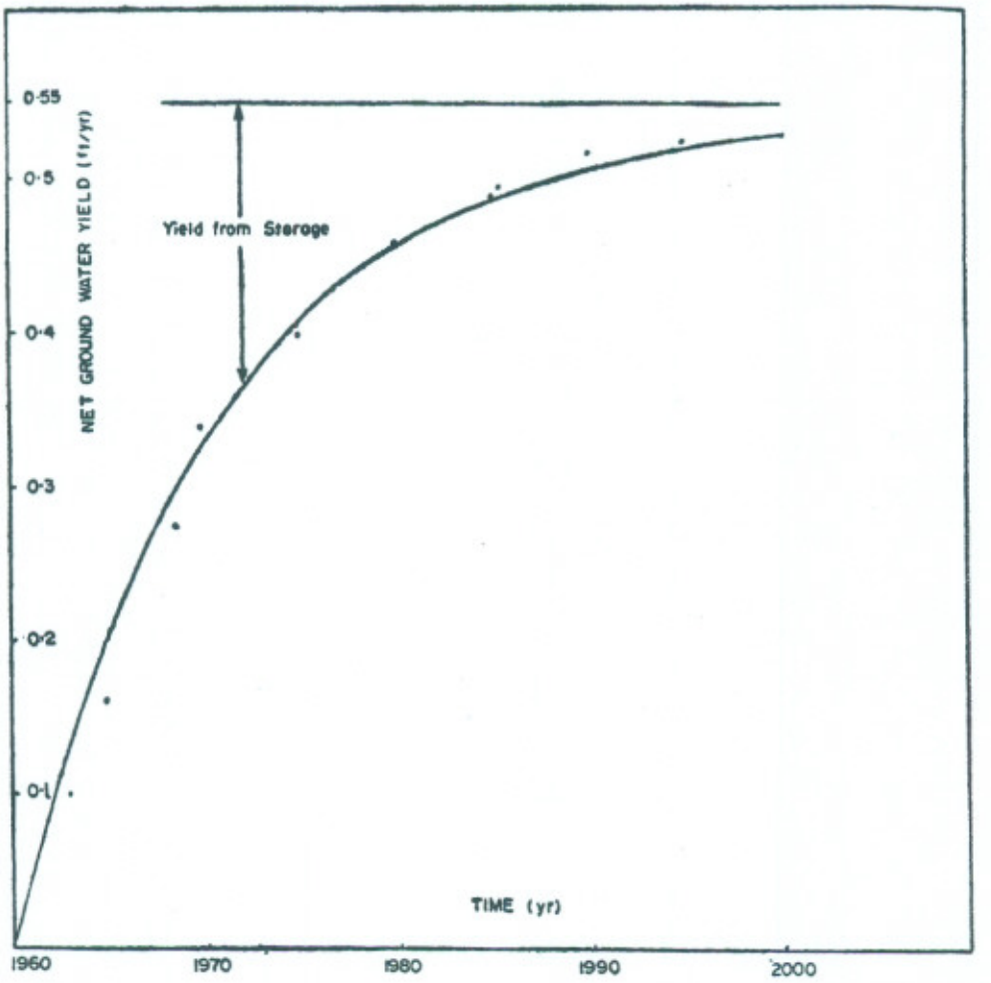


FIGURE: 12 FUTURE GROUND WATER YIELD OF SCARP-I.
(ASSUMING 30% STORAGE COEFFICIENT)

ground water yield. This curve is based on the assumption that the existing operational conditions will continue with no change in the environments. It is estimated that with time the outflow decrement will increase and by 2000 A.D. the contribution from ground water storage will be approximately zero. Based on this ground water yield curve, the contribution of ground water during 1965-66 is to be of the order of 0.38 ft./yr. as compared to the observed value of 0.6 ft.

If the present irrigation intensities in the area are to be increased then the additional water to the tune of 0.7 feet (1.25 – 0.55) is available from the ground water reservoir, this will lower the water table to nearly pre-irrigation conditions.

ANALYSIS OF TUBEWELL OPERATION

In SCARP-1 2043 tubewells were proposed but so far 2018 have been installed. The total annual pumping capacity is on the order of 3.9 million acre-feet. The average annual pumpage since 1962-63 is on the order of 2.5 million acre feet, giving an average utilization factor of about 62 per cent (Table 2). The break up of the unutilization which is 38 per cent of the total pumpage capacity is as follows (Table 3).

Electrical faults	..	7.53
Mechanical faults	..	6.32
Lack of distribution and no demand	..	19.67

The supply lost through no demand and lack of distribution work is on the order of 0.8 million acre feet per year.

Summary 1961-66

Electrical fault :	7.53	Lack of distribution work:	6.38
Mechanical fault :	6.32	No demand	.. 13.29

Total lost hours : 33.52

DISCUSSION AND CONCLUSIONS

The main object of this apprisal was to evaluate the present operating conditions of the project to permit a comparison with the predictions made in the feasibility review.

According to the feasibility review the decline in SCARP-1 by June 1966 would have been 19.0 feet, while the actual lowering is only about 8 feet. This indicates that some of the assumption or operational conditions visualized in

TABLE 2 :—*Summary of Pumpage and Utilization Tubewells in SCARP-1.*

Year	Installed Cap.			Actual Pumpage			Utilization		
	Rabi	Kharif	Ann.	Rabi	Kharif	Ann.	Rabi	Kharif	Ann.
	Million			Acre Feet			Per cent		
1961-62 ..	1.21	1.43	2.64	0.65	1.07	1.72	52	73	63
1962-63 ..	1.83	2.03	3.86	1.20	1.34	2.54	65	73	69
1963-64 ..	1.94	1.95	3.89	1.11	1.37	2.48	58	66	62
1964-65 ..	1.96	1.95	3.91	1.06	1.30	2.36	53	64	58
1965-66 ..	1.96	1.95	3.91	1.19	1.19	2.38	58	56	57

TABLE 3 :—*Analysis of Tubewell Operation*

YEAR	RABI					KHARIF				
	Electrical faults	Mechanical faults	Lack of Distribution works	No demand	Total lost hours	Electrical faults	Mechanical faults	Lack of Distribution works	No demand	Total lost hours
	(*Percent of time*)									
1961-62 ..	9.8	7.4	6.25	14.04	38.00	8.47	8.03	6.56	3.76	26.82
1962-63 ..	4.73	5.14	10.75	12.82	33.44	8.11	8.16	5.25	4.22	25.74
1963-64 ..	2.77	3.92	8.42	24.99	40.10	4.84	4.92	7.22	8.34	26.32
1964-65 ..	4.61	6.05	6.54	27.22	44.43	9.09	6.47	5.11	10.98	31.65
1965-66 ..	6.82	6.10	4.34	18.07	35.33	16.10	7.08	3.36	8.46	35.00
Av. 1961-66	5.74	5.72	7.22	19.43	38.15	9.93	6.93	5.50	7.15	28.90

that report did not actually exist in the field. The major departure is probably in the assumption that to start with all the pumpage would be from storage. It appears that even to start with the net abstraction from the ground water reservoir was not more than 0.55 feet as compared to assumed value of 1.25 feet. The remaining pumpage was being supplied by areal recharge and canal leakage already taking place at that time.

The operational yield of 1.2 feet estimated in feasibility review is based on the various estimates of recharge and storage depletion of 0.4 ft./yr. The average pumpage since 1962-63 is on the order of 2.4 feet. This indicate that the operational yield is under-estimated probably because of the under-estimation of recharge from the canals and infiltration from farms and water courses. It is, however, observed that the projected lowering in the original project report is closer to the actual field condition.

A summary of principal conclusions are as follows:

1. The total decline within SCARP-1 since June 1960 to June 1966 is on the order of 7.60 feet.
2. The decline of average water table in SCARP-1 by 2000 A.D. to 50 feet predicted in feasibility review is an exaggerated value.
3. The decline of average water level by 2000 A.D. will be less than 20 feet under the existing operational conditions and environments.
4. The effective recharge to SCARP-1 area through surface and subsurface sources is approximately 2.30 feet per year.
5. Subsurface outflow is 0.6 feet per year, while inflow is 0.08 feet per year.
6. Inflow to SCARP-1 due to depletion of ground water reservoir from outside SCARP-1 and within cone of influence is 0.2 ft./yr.
7. The average annual pumpage from SCARP-1 (including private and Rasul wells) since 1962-63 is on the order of 2.4 feet.
8. The net withdrawal from the reservoir in the beginning is on the order of 0.55 ft./yr. and by 2000 A.D. the contribution from storage will reduce to zero on account of increase in outflow decrement.
9. The pumpage lost through no demand and lack of distribution work is approximately 0.8 million acre feet per year.
10. The ground water approximately 0.7 feet is available for further development if the irrigation intensities are to be increased in

this area. As a result of this further development of the ground water under the present environments, the water level will not go beyond pre-irrigation level. This additional supply can be obtained by saving the hours lost as a result of no demand and lack of distribution work.

11. If 0.2 feet is assumed as the recharge due to rainfall, then from farm supply of 3.1 ft./yr. (excluding the precipitation), 1.10 ft./yr. is the recirculation and is 38 per cent of farm supply.

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