Observation points are selected at the nod nearest to the water level recorders and other places in order to check the variations in groundwater level.

Fig 5.3.9 shows the initial groundwater table in 1972 simulated under steady state and the variation in the groundwater level at the observation points for 20 years. The water level in the Study Area was almost recovered for a few meters.

From this initial head, the non-steady state mentioned above was used to form the Simulated groundwater table in 1992 shown in Fig 5.3.10.

Annual pumping discharge in 1991 calculated in each mesh, is shown in Fig. 5.3.11. Rainfalls in 1972 - 1990 are attached in Data Book. Annual rainfalls in 1972 - 1991 are shown in Fig. 5.3.12.
As discussed in Section 4.4, the average of the decrease in static groundwater level was around 3 m in Carlos Fonseca and Sabana Grande well fields and around 5 m in the center of Managua City.

On the other hand, simulation results show a 2-5 m draw down in Carlos Fonseca and Sabana Grande, and 7-8 m in the other points. As this simulation results involve a dynamic pumping stage, the parameters used, therefore, nearly satisfy the present field condition.

Fig. 5.3.13 shows the water level variation at Lake Asososca from 1972-1992. Although the simulated level and measurements differ, the increasing and decreasing tendencies of the water correspond to that observed. When the recharge condition in the upper area and other aquifer parameters will be modified with additional hydrogeological studies, more adaptable results can be expected.

### 5.3.6 Future Case Study

Future prediction of groundwater table was conducted on the model with the aquifer parameters determined by calibration work. Year 2000 is given as target, i.e., simulation was conducted for a span of 8 years from 1992 to 2000.

Assumed annual rainfall and pumping discharge values were used to grasp the results - as in the form of case studies.

(1) Future factors

(a) Rainfall

Annual rainfall was applied 50% non-exceedance probability as mentioned on Section 3.2. This value almost corresponds average rainfall.

(b) Pumping discharge

(i) Pumping Discharge at Lake Asososca

The extraction at Lake Asososca was reduced from 1992, and this amount will be kept in some years.

| Well Location | Extraction in 1991 | Extraction 1992 |
|---|---|---|
| Lake Asososca | 17.3 MGD (657643 $m^3/d$) | 10 MGD (37854 $m^3/d$) |

(ii) Well rehabilitation program in 1992-1993

A rehabilitation project funded by BID was conducted from 1992, and the construction works are presently ongoing. The well replacement program is expected to effect a new pumping discharge which will be simulated from 1993. The discharge value assumed in the program is as shown in the following table.

| Well | Location | Existing Condition in Apr,'92 | Pumping Discharge of wells to be rehabilitated |
|---|---|---|---|
| 40 | Nicarao No.2 | Abandoned | 5458 ($m^3/d$) |
| 57 | km 8 C. Masaya | 997 $m^3/d$ | 3274 |
| 94 | Ciudad Sandino | Abandoned | 4366 |
| 95 | Ciudad Sandino | Abandoned | 4366 |
| 42 | San Cristbal No.2 | 2551 $m^3/d$ with No.1 | 5458 |
| 32 | Altamira | Abandoned | 3820 |
| 36 | Centro America No.1 | Abandoned | 3820 |
| 37 | Centro America No.2 | 3726 $m^3/d$ with No.3 | 3820 |
| 60 | km 14.5 C.Sur | 1321 $m^3/d$ | 3274 |
| 96 | Cristian Pelez | Abandoned | 5458 |
| 73 | Sn Isidro de la C.Verde | Abandoned | 3274 |

(iii) Well Rehabilitation Program in 1993-1995

According to the INAA's rehabilitation plan, following surplus water will be expected from 1995.

| Well Location | Extraction in 1991 | Plan |
|---|---|---|
| Carlos Fonseca | 15.91 MGD ($60238\ m^3/d$) | 25.26 MGD ($95619\ m^3/d$) |
| Veracruz (incl. JICA wells) | 2.8 MGD ($10599\ m^3/d$) | 8.88 MGD ($33614\ m^3/d$) |

(iv) New groundwater development

High groundwater development potential is expected in the middle part of Sabana Grande-Cofradia and Veracruz-Ticuantepe Areas.

In consideration of the development scale mentioned in Chapter 6, Groundwater Development Project, the following is applied:

| Development Area | 1995 | 2000 |
|---|---|---|
| Sabana Grande - Cofradia Area | - MGD | 31.34 MGD (118634 $m^3$/day) (= 1.45 $m^3$/sec) |
| Veracruz - Ticuantepe Area | 18.74 MGD (70938 $m^3$/day) (=0.82 $m^3$/sec) | - MGD |

The pumping discharge map employed for the prediction is shown in Fig. 5.3.14(1)-(3).

(2) Allowable Water Level Limitation

(a) Center of Managua City

The setting up of an allowable draw-down of the groundwater table is aimed to maintain a water level higher than the level of Lake Managua with some additional heads to produce a northward flow.

(b) Sabana Grande - Cofradia and Veracruz - Ticuantepe Area

An allowable draw-down value should be set at a range that would not adversely affect the production of the wells in Carlos Fonseca and Sabana Grande and the spring zones of Mocuana.

Draw down, by the new development in the upper area, in the Carlos Fonseca well field will reduce the dynamic water level thus creating a sharp depression cone. As discussed in Section 4.8, the dynamic water level is lower than the top area of the position of the screen in most of the wells at the Carlos Fonseca well field because of intersecting well cones.

This condition will be improved by thinning out some inefficient wells, however, it is necessary to appropriately limit draw down by the development of the upper area. The screen length of one well in this field is from 19.81-96.31 m, showing an average of about 44 m. 5% of this average length, that is 2.2 m, was then determined as the allowable draw down. Consequently, the total yield can be maintained with the installation of the suction pipes at a deeper level.

(3) Cases Applied in the Simulation

Future prediction is provided by the combination of above mentioned cases.

| | Condition |
|---|---|
| Case 1: | Pumping Condition in 1991 |
| Case 2: | Case 1 and Well Rehabilitation 1992-1993 |
| Case 3: | Case 2 and 80% of pumping discharge at Lake Asososca |
| Case 4: | Case 2 and 60% of pumping discharge at Lake Asososca |
| Case 5: | Case 1 and 60% of pumping discharge at Lake Asososca |
| Case 6: | No Pumping |
| Case 7: | Case 2, Well Rehabilitation Program 1993-1995, 10 MGD extraction from Lake Asososca and 1995 stage Development in Veracruz-Tecuantepe |
| Case 8: | Case 7 and 2000 stage development in Sabana Grande-Cofradia Area |
| Case 9: | Case 1, 10 MGD of extraction from Asososca and 1995 stage Development in Veracruz-Tecuantepe |
| Case 10: | Case 9 and 2000 stage development in Sabana Grande-Cofradia Area |

Results of the simulated groundwater level are given in the groundwater table map, elevation above sea level and levels at checking points. The selected checking points were those installed with the automatic water level recorders and other points in Sabana Grande area and center of the City.
Fig. 5.3.15(1)-(10) show the calculated water levels in these cases.

- Case 1

This indicates that the 1991 pumping amount will be maintained until 2000, in order to check existing pumping discharge.

The results indicated a continuous decrease in the groundwater table, 0.6 m in Lake Asososca and 2-5 m in the center of Managua City. As mentioned in Section 3.5, the water level is still considered largely accurate, however, large drawddown tendencies should be evident in some places. No serious draw down is observed in Carlos Fonseca and Sabana Grande Area.

The pumping discharge of the No.7 (El Stadia), No.8 (San Antonio), No. 9 (banco de America) and No.10 (Mercado Oriental) INAA production wells is very high, producing large draw down.

- Case 2

This case used an additional pumping discharge estimated from the Case I rehabilitation program conducted by BID. Furthermore, large extractions were used in the center, and a large draw-down will be a serious problem around the area from Tiscapa lake to JICA 4.

- Case 3, Case 4 and Case 5

Case 3 & 4 indicate conditions when the pumping discharge of Lake Asososca is 80% and 60% in 1991, while that of other wells is similar to Case 2. These reduction can help the recovery of the lake's original water level. A reduction of more than 40% of the 1991 level discharge is recommended in order to provide 40 m in m.s.n.m. Survey on rainfall condition and monitoring of the water level in industrial area should be conducted also to ascertain the depth of recovery.
Case 5 is performed according to the Case 1- condition, the pumping discharge in 1991, and the 60% discharge of Asososca in the 1991 level.

- Case 6

Case 6 refers to conditions in the Study Area when there is no pumping discharge. It refers to the raising up of all groundwater level, and the recovery of the water level of Asososca up to 43.7m within 8 years time.

- Case 7, Case 8

The new groundwater development project in Veracruz-Tecuantepe area will start the production of drinking water in 1995 and Sabana Grande-Cofradia area will produce from 2000. These cases are simulated with both rehabilitation project in 1992-'92 and 1993-'95. The water level at Lake Asososca is almost stable because arrived to secondary balance. The water level in the city area is contineously decreased around 5-10 m. The water level movements from 2000 in both cases show with and without the project in Sabana Grande-Cofradia area very cleary. The groundwawter around Sabana Grande Area is go down about 10 m and will take time to get balance.

- Case 9, 10

These cases are considered if rehabilitation in the central area will not be done. Results of calculation show that the groundwater level in the city center is almost stabled. The results in the eastern area is almost same to case 7 and 8.

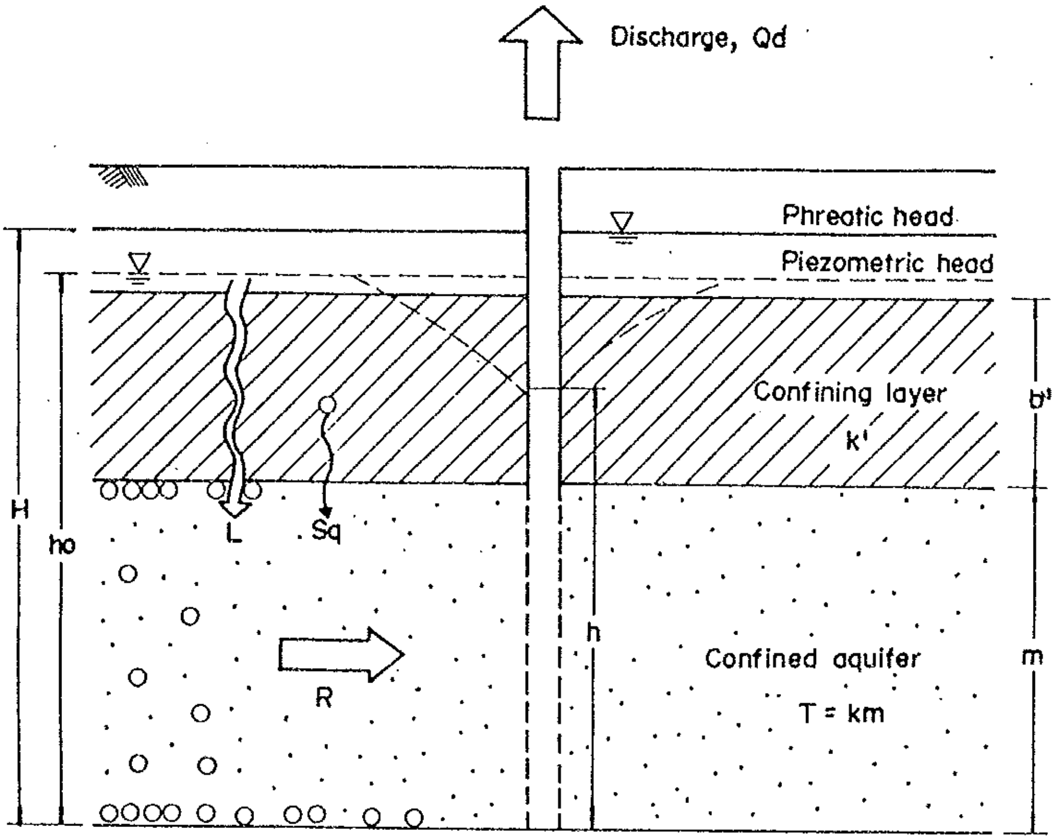



Fig. 5.3.1 Schematic Cross-Section of the Q3P 3-Dimension Model

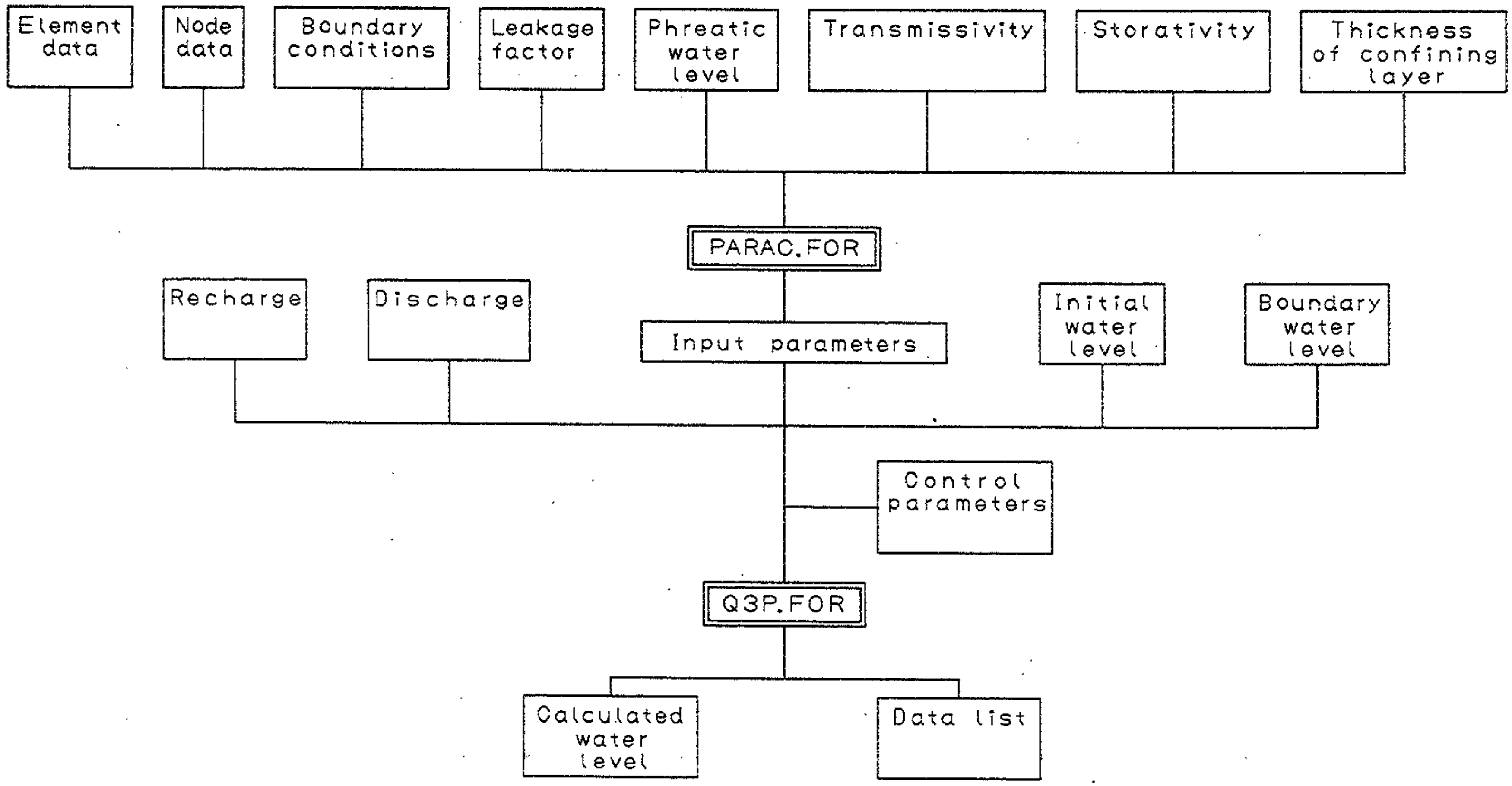



Fig. 5.3.2 Conventional Procedure of Q3P Model

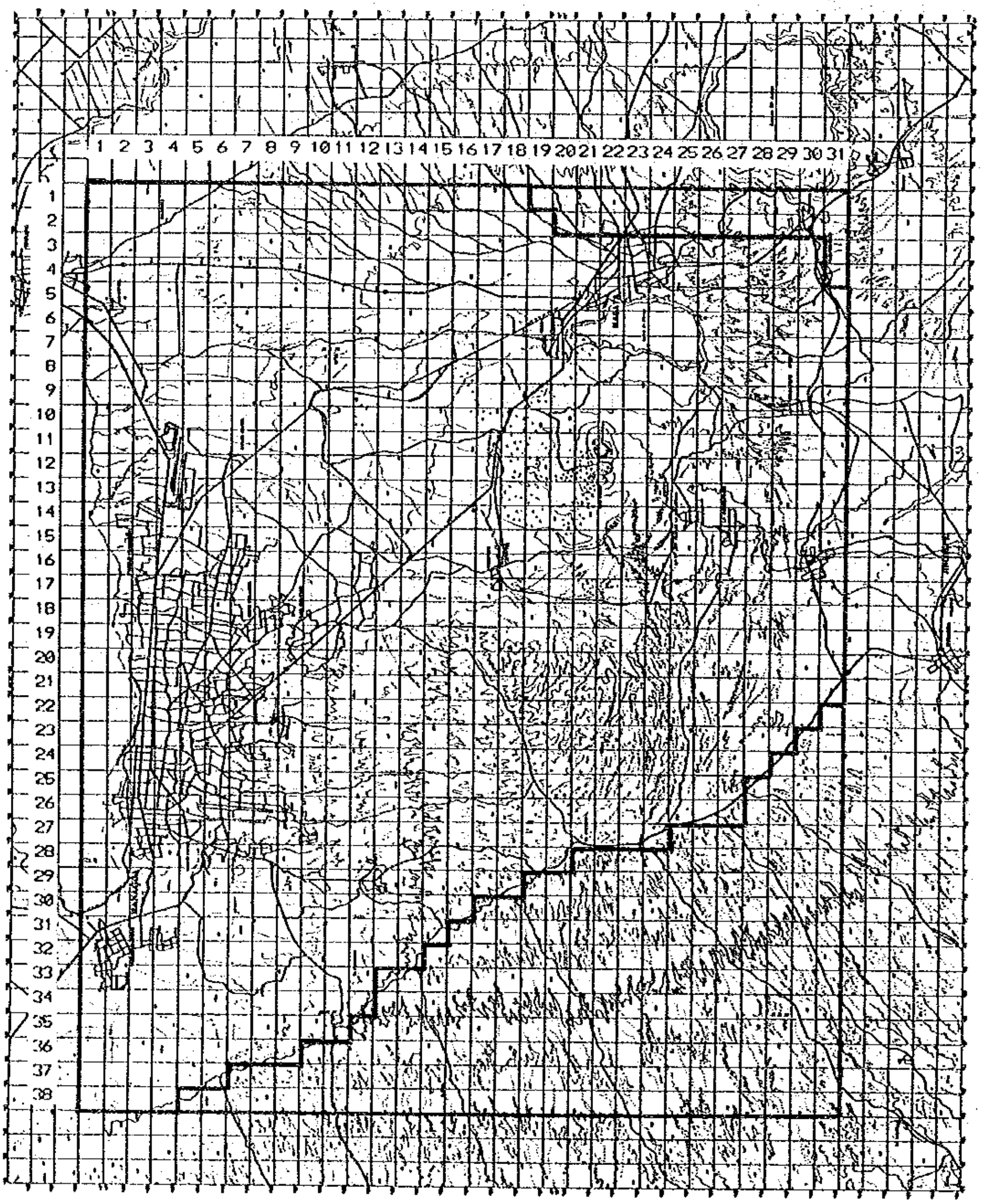
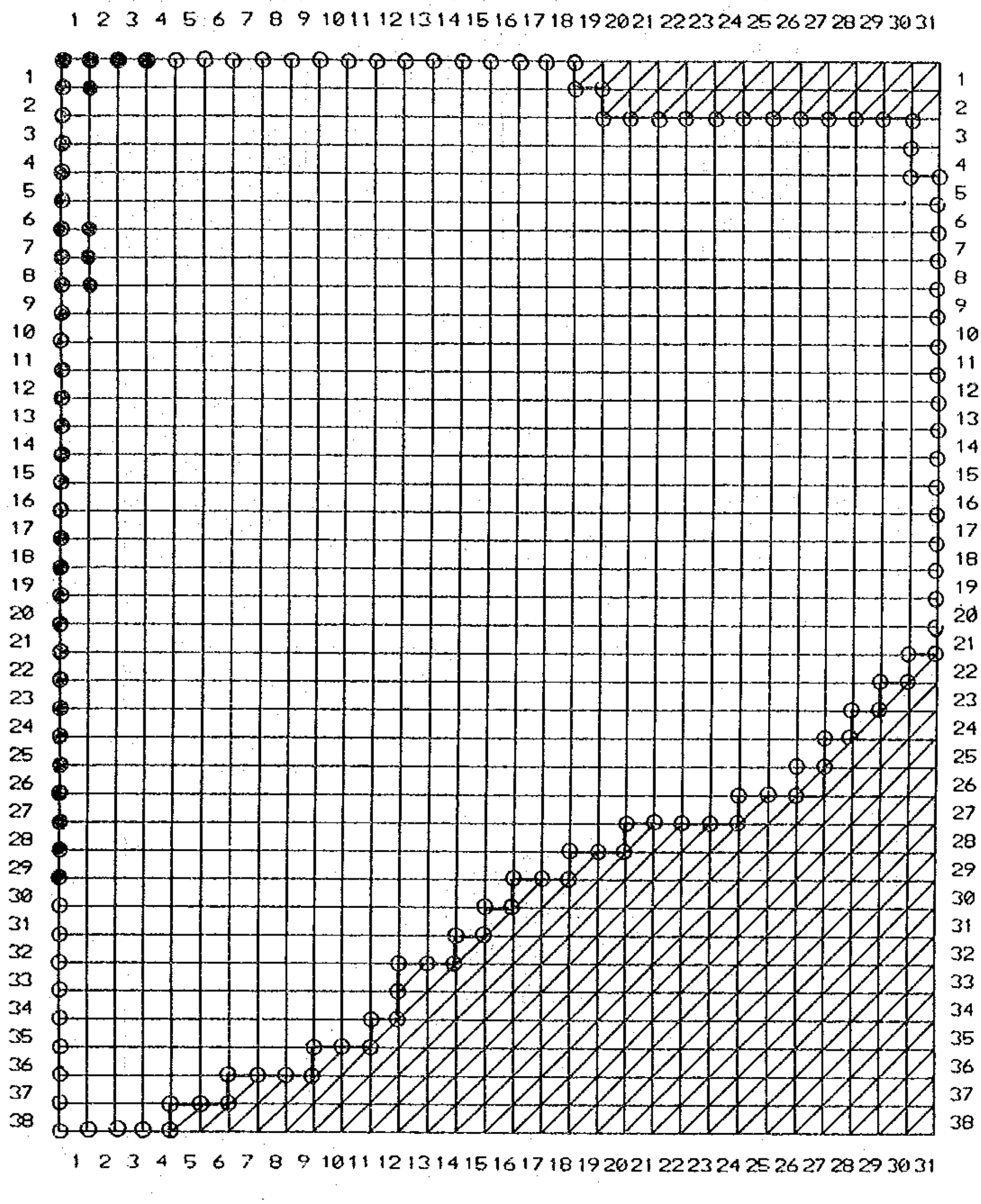



**Fig. 5.3.3 Finite-element of the Model**

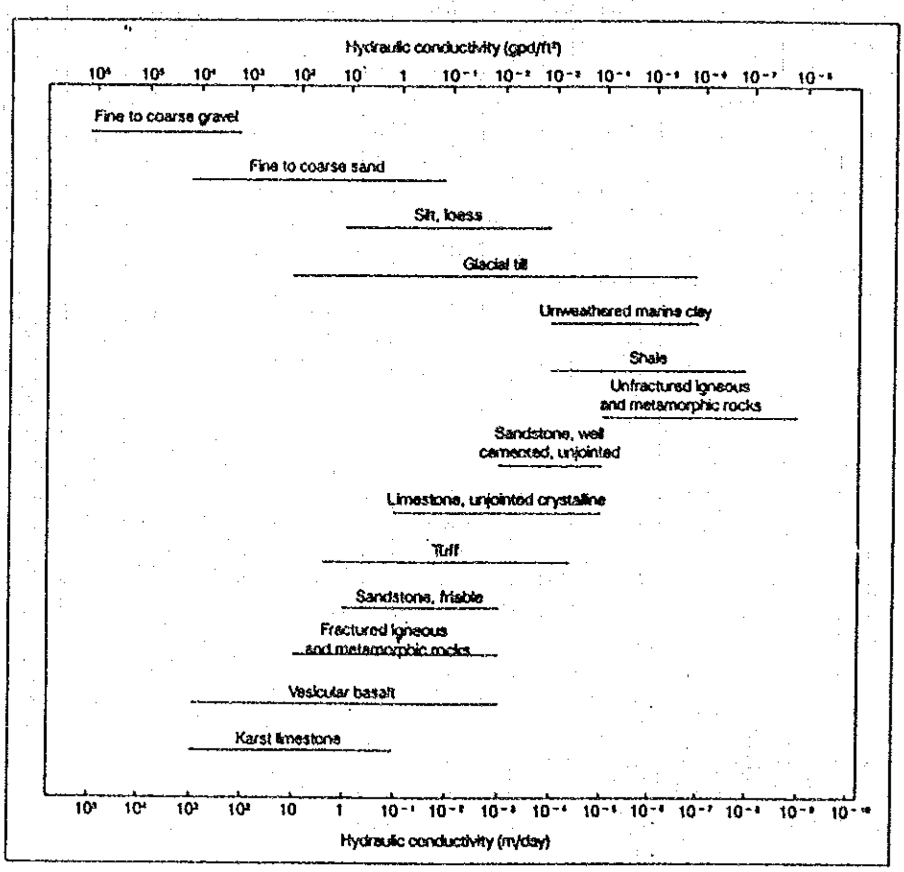



o No Flow
● Constant Head

**Fig. 5.3.4 Boundary Condition**

| Sediment | Specific Yield, % |
|---|---|
| Clay | 1–10. |
| Sand | 10–30 |
| Gravel | 15–30 |
| Sand and Gravel | 15–25 |
| Sandstone | 5–15 |
| Shale | 0.5– 5 |
| Limestone | 0.5– 5 |

*(Walton, 1970)*




**Typical *K* values for consolidated and unconsolidated aquifers.** *(After Davis, 1969; Dunn and Leopold, 1978; Freeze and Cherry, 1979).*

Fig. 5.3.5 **General Range of Specific Yield & Hydraulic Conductivity**

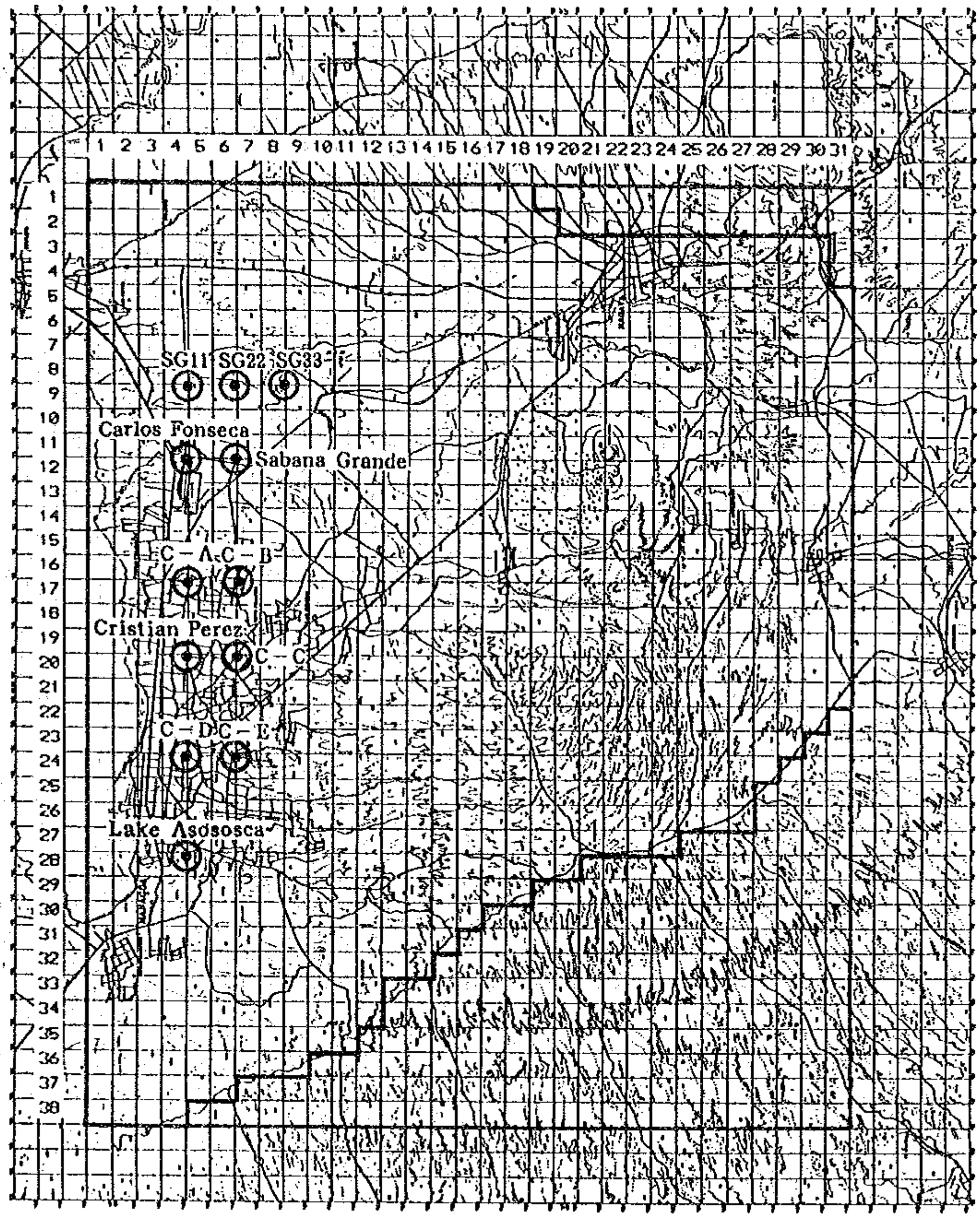


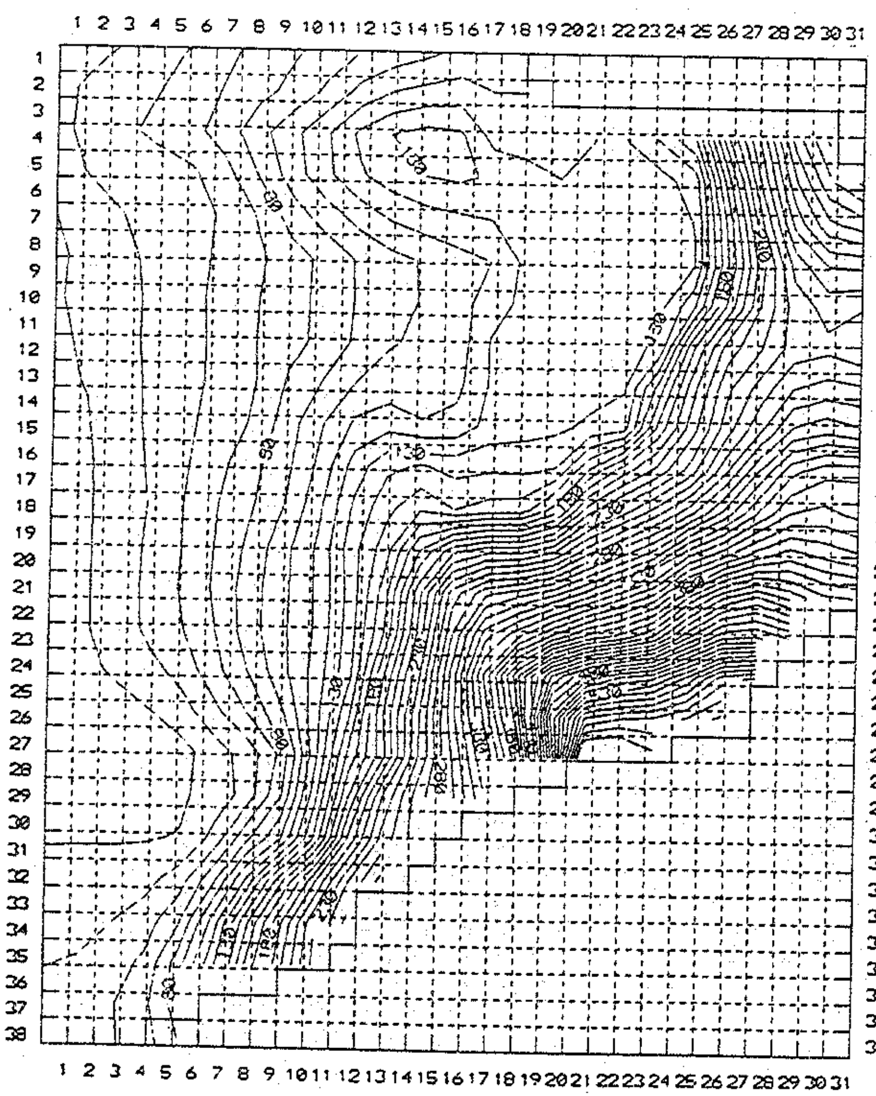

Fig. 5.3.6 Observation Points

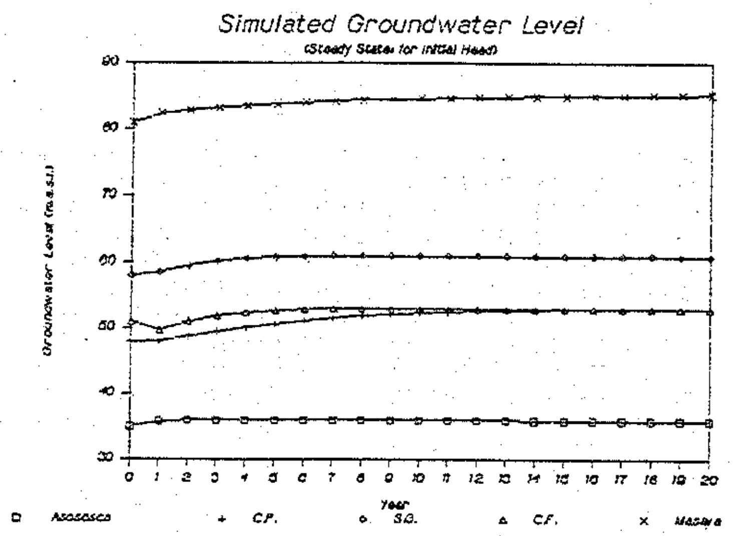
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 |
| 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 |
| 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 9999 |
| 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 1 | 9999 |
| 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 1 | 1 |
| 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 7 | 7 | 7 | 1 | 1 | 1 | 1 | 1 | 10 | 10 | 10 | 10 | 10 | 1 |
| 0 | 0 | 0 | 0 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 2 | 1 | 1 | 1 | 1 | 10 | 10 | 10 | 10 | 10 | 1 |
| 0 | 0 | 0 | 0 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 2 | 2 | 2 | 2 | 2 | 2 | 10 | 10 | 10 | 10 | 10 | 1 |
| 0 | 0 | 0 | 0 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 10 | 10 | 10 | 10 | 10 | 1 |
| 0 | 0 | 0 | 0 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 10 | 10 | 10 | 10 | 10 | 1 |
| 0 | 0 | 0 | 0 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 2 | 2 | 2 | 2 | 2 | 2 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 1 |
| 0 | 0 | 0 | 0 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 7 | 7 | 7 | 7 | 7 | 2 | 2 | 2 | 2 | 2 | 2 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 1 |
| 0 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 7 | 7 | 7 | 7 | 2 | 2 | 2 | 2 | 2 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 1 |
| 0 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 7 | 7 | 7 | 2 | 2 | 2 | 2 | 2 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 1 |
| 0 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 7 | 7 | 7 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 1 |
| 0 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 7 | 7 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 20 | 20 | 20 | 20 |
| 0 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 20 | 20 | 20 | 20 |
| 0 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 1 |
| 0 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 1 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 1 |
| 0 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 1 | 1 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 1 |
| 0 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 1 | 1 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 1 | 1 |
| 0 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 1 | 1 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 1 | 1 | 9999 |
| 0 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 1 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 1 | 1 | 9999 | 9999 |
| 0 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 1 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 1 | 1 | 9999 | 9999 | 9999 |
| 0 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 1 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 1 | 9999 | 9999 | 9999 | 9999 |
| 0 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 1 | 10 | 10 | 10 | 10 | 1 | 1 | 1 | 1 | 9999 | 9999 | 9999 | 9999 |
| 0 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 1 | 1 | 1 | 1 | 1 | 1 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 |
| 0 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 1 | 1 | 1 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 |
| 0 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 1 | 1 | 1 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 |
| 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 10 | 10 | 10 | 10 | 10 | 10 | 1 | 1 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 |
| 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 10 | 10 | 10 | 10 | 10 | 1 | 1 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 |
| 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 1 | 1 | 1 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 |
| 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 1 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 |
| 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 1 | 1 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 |
| 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 1 | 1 | 1 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 |
| 10 | 10 | 10 | 10 | 10 | 1 | 1 | 1 | 3 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 |
| 10 | 10 | 10 | 1 | 1 | 1 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 |
| 1 | 1 | 1 | 1 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 |

**Fig. 5.3.7 Storage Coefficient**

| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 15000 | 15000 | 15000 | 15000 | 15000 | 15000 | 15000 | 15000 | 15000 | 15000 | 15000 | 15000 | 15000 | 15000 | 15000 | 15000 | 15000 | 15000 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 |
| 100 | 100 | 100 | 100 | 100 | 100 | 100 | 300 | 300 | 300 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 8000 | 8000 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 |
| 100 | 100 | 100 | 100 | 100 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 5000 | 5000 | 5000 | 100 | 100 | 100 | 100 | 100 | 20 | 20 | 20 | 20 | 30 | 9999 |
| 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 5000 | 5000 | 5000 | 100 | 100 | 100 | 100 | 20 | 30 | 20 | 20 | 30 | 9999 |
| 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 5000 | 5000 | 200 | 400 | 400 | 200 | 20 | 20 | 20 | 20 | 30 | 30 |
| 12000 | 12000 | 12000 | 1000 | 1000 | 400 | 450 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 200 | 5000 | 12000 | 12000 | 12000 | 12000 | 20 | 20 | 20 | 20 | 30 | 30 |
| 12000 | 12000 | 12000 | 12000 | 12000 | 12000 | 12000 | 200 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 200 | 200 | 200 | 5000 | 12000 | 12000 | 12000 | 12000 | 20 | 20 | 20 | 20 | 30 | 30 |
| 12000 | 12000 | 12000 | 12000 | 9500 | 12000 | 12000 | 12000 | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 | 9500 | 9500 | 200 | 200 | 12000 | 12000 | 12000 | 12000 | 12000 | 12000 | 20 | 20 | 20 | 20 | 30 | 30 |
| 12000 | 12000 | 12000 | 12000 | 9000 | 9000 | 12000 | 12000 | 12000 | 9000 | 9000 | 9000 | 9000 | 9000 | 9000 | 12000 | 5000 | 1000 | 12000 | 12000 | 12000 | 12000 | 12000 | 12000 | 12000 | 20 | 20 | 20 | 20 | 30 | 30 |
| 12000 | 12000 | 5000 | 5000 | 5000 | 5000 | 9000 | 12000 | 12000 | 12000 | 12000 | 12000 | 12000 | 12000 | 12000 | 12000 | 1000 | 12000 | 12000 | 12000 | 12000 | 12000 | 12000 | 12000 | 20 | 20 | 20 | 20 | 20 | 30 | 30 |
| 10000 | 10000 | 5000 | 5000 | 5500 | 6000 | 7000 | 5000 | 5000 | 5000 | 5000 | 7000 | 7000 | 9500 | 9000 | 9000 | 200 | 12000 | 12000 | 12000 | 12000 | 12000 | 12000 | 20 | 20 | 20 | 20 | 20 | 20 | 30 | 30 |
| 10000 | 10000 | 5000 | 5000 | 5500 | 6000 | 4000 | 1000 | 1000 | 1000 | 1000 | 200 | 200 | 9500 | 9000 | 200 | 200 | 12000 | 12000 | 12000 | 12000 | 12000 | 12000 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 30 |
| 4000 | 4000 | 500 | 500 | 500 | 6000 | 4000 | 100 | 100 | 100 | 100 | 100 | 100 | 9000 | 9000 | 9000 | 12000 | 12000 | 12000 | 12000 | 12000 | 12000 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 30 | 30 |
| 5000 | 5000 | 500 | 500 | 500 | 6000 | 4000 | 200 | 100 | 100 | 50 | 50 | 50 | 100 | 12000 | 12000 | 12000 | 12000 | 12000 | 12000 | 12000 | 12000 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 30 | 30 |
| 6000 | 6000 | 400 | 300 | 800 | 900 | 800 | 200 | 100 | 100 | 100 | 100 | 50 | 50 | 12000 | 12000 | 12000 | 600 | 600 | 600 | 20 | 20 | 20 | 30 | 20 | 20 | 20 | 20 | 20 | 30 | 30 |
| 6000 | 6000 | 600 | 300 | 500 | 400 | 600 | 400 | 300 | 200 | 100 | 100 | 50 | 50 | 12000 | 12000 | 500 | 600 | 600 | 600 | 30 | 30 | 20 | 30 | 20 | 20 | 20 | 25 | 25 | 35 | 35 |
| 6000 | 6000 | 1000 | 300 | 500 | 400 | 600 | 500 | 300 | 200 | 100 | 100 | 100 | 50 | 50 | 600 | 600 | 600 | 600 | 600 | 25 | 20 | 20 | 20 | 20 | 25 | 25 | 25 | 25 | 35 | 35 |
| 6000 | 6000 | 1000 | 300 | 300 | 300 | 400 | 500 | 300 | 200 | 100 | 100 | 100 | 50 | 50 | 600 | 600 | 600 | 600 | 30 | 25 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 30 | 30 |
| 6000 | 4000 | 1000 | 400 | 400 | 300 | 300 | 300 | 100 | 100 | 100 | 100 | 100 | 30 | 30 | 30 | 20 | 20 | 20 | 20 | 25 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 30 | 30 |
| 6000 | 4000 | 400 | 300 | 400 | 400 | 400 | 300 | 200 | 200 | 200 | 100 | 100 | 30 | 30 | 30 | 20 | 20 | 20 | 20 | 25 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 30 | 30 |
| 6000 | 4000 | 500 | 300 | 400 | 400 | 400 | 500 | 500 | 500 | 200 | 200 | 100 | 30 | 30 | 30 | 20 | 20 | 20 | 20 | 25 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 30 | 30 |
| 6000 | 4000 | 400 | 600 | 600 | 900 | 400 | 500 | 500 | 500 | 200 | 200 | 100 | 50 | 30 | 30 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 30 | 9999 |
| 5000 | 4000 | 400 | 300 | 600 | 800 | 300 | 500 | 300 | 400 | 500 | 200 | 100 | 50 | 50 | 30 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 9999 | 9999 |
| 6000 | 4000 | 1000 | 300 | 300 | 400 | 400 | 600 | 400 | 400 | 500 | 200 | 50 | 50 | 30 | 30 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 9999 | 9999 | 9999 |
| 6000 | 4000 | 1000 | 400 | 400 | 400 | 400 | 300 | 100 | 100 | 100 | 100 | 30 | 30 | 30 | 30 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 9999 | 9999 | 9999 | 9999 |
| 6000 | 4000 | 3000 | 3000 | 400 | 400 | 200 | 300 | 200 | 100 | 100 | 100 | 30 | 30 | 30 | 30 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 9999 | 9999 | 9999 | 9999 |
| 8000 | 8000 | 8000 | 8000 | 3000 | 1000 | 200 | 200 | 200 | 100 | 100 | 100 | 30 | 30 | 30 | 30 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 |
| 10000 | 9500 | 9500 | 6000 | 7000 | 3000 | 2000 | 400 | 200 | 100 | 100 | 100 | 30 | 30 | 30 | 30 | 20 | 20 | 20 | 20 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 |
| 10000 | 10000 | 11000 | 6000 | 7000 | 3000 | 2000 | 400 | 200 | 100 | 100 | 100 | 30 | 30 | 30 | 20 | 20 | 20 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 |
| 9500 | 9000 | 9000 | 5000 | 4000 | 2000 | 200 | 100 | 100 | 100 | 100 | 30 | 30 | 30 | 20 | 20 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 |
| 800 | 500 | 500 | 700 | 700 | 200 | 100 | 100 | 100 | 30 | 30 | 30 | 20 | 20 | 20 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 |
| 1000 | 1000 | 400 | 400 | 200 | 100 | 100 | 50 | 30 | 30 | 30 | 20 | 20 | 20 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 |
| 1000 | 1000 | 200 | 200 | 100 | 50 | 50 | 30 | 30 | 30 | 30 | 20 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 |
| 900 | 400 | 200 | 200 | 30 | 30 | 30 | 30 | 30 | 20 | 20 | 20 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 |
| 900 | 400 | 200 | 200 | 30 | 30 | 20 | 20 | 20 | 20 | 20 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 |
| 100 | 100 | 30 | 30 | 20 | 20 | 20 | 20 | 20 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 |
| 20 | 20 | 20 | 20 | 20 | 20 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 |
| 20 | 20 | 20 | 20 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 | 9999 |

Fig. 5.3.8 Transmissivity





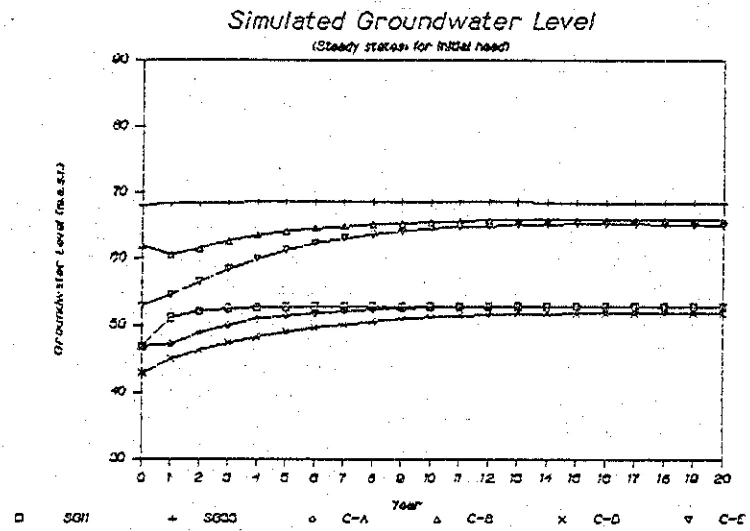




Fig. 5.3.9 Simulated Groundwater Level (under Steady State)

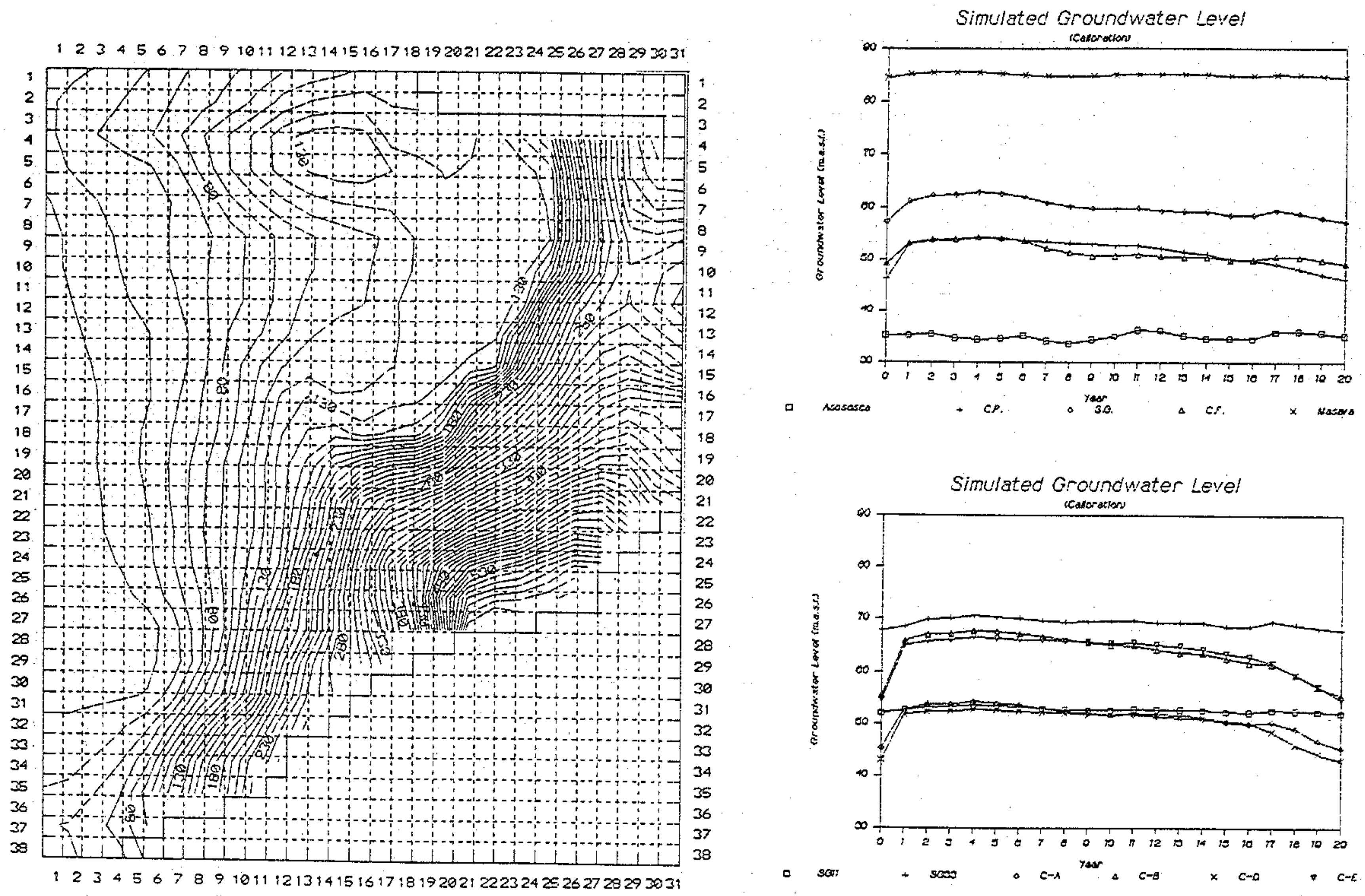



Fig. 5.3.10 Simulated Groundwater Level (Calibration)

| ** | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. |
| 2 | 0. | 0. | 0. | 138. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. |
| 3 | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 9999. |
| 4 | 0. | 0. | 84. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 6034. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 9999. |
| 5 | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 6 | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 7 | 0. | 0. | 0. | 0. | 0. | 355. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 1305. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 238. | 0. | 0. | 604. |
| 8 | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 9 | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 1320. | 0. |
| 10 | 0. | 0. | 0. | 0. | 1200. | 700. | 2400. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 11 | 0. | 0. | 0. | 0. | 0. | 0. | 1200. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 12 | 0. | 0. | 0. | 0. | 13253. | 190. | 597. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 13 | 0. | 0. | 1200. | 0. | 43373. | 6564. | 0. | 0. | 0. | 0. | 1664. | 3623. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 14 | 0. | 0. | 0. | 0. | 3614. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 3798. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 329. | 0. | 0. | 0. | 0. | 0. | 0. |
| 15 | 0. | 2085. | 0. | 758. | 0. | 5520. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 1571. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 874. |
| 16 | 0. | 0. | 190. | 1895. | 2244. | 2854. | 3119. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 874. | 0. | 874. | 0. |
| 17 | 0. | 0. | 0. | 535. | 498. | 1072. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 2106. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 18 | 0. | 0. | 45. | 2843. | 0. | 0. | 245. | 4516. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 19 | 0. | 0. | 2047. | 0. | 0. | 1517. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 20 | 0. | 0. | 76. | 0. | 0. | 0. | 0. | 0. | 633. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 21 | 0. | 0. | 234. | 5264. | 3679. | 0. | 0. | 2123. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 22 | 0. | 0. | 2224. | 0. | 0. | 0. | 5308. | 0. | 1763. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 9999. |
| 23 | 0. | 0. | 3916. | 0. | 1896. | 6103. | 0. | 0. | 2001. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 9999. | 9999. |
| 24 | 0. | 0. | 10757. | 0. | 2926. | 2349. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 9999. | 9999. | 9999. |
| 25 | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 8079. | 10. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 465. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 9999. | 9999. | 9999. | 9999. |
| 26 | 0. | 0. | 0. | 7056. | 0. | 0. | 0. | 0. | 1369. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 9999. | 9999. | 9999. | 9999. |
| 27 | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. |
| 28 | 0. | 0. | 405. | 95. | 65764. | 78. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 1321. | 0. | 0. | 0. | 0. | 0. | 0. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. |
| 29 | 0. | 0. | 4578. | 569. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. |
| 30 | 0. | 0. | 0. | 3880. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. |
| 31 | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. |
| 32 | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. |
| 33 | 0. | 8502. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 3097. | 0. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. |
| 34 | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. |
| 35 | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. |
| 36 | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. |
| 37 | 0. | 0. | 0. | 0. | 0. | 0. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. |
| 38 | 0. | 0. | 0. | 0. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. |

Fig. 5.3.11 Pumping Dsicharge Map (20) Year 1991

Annual Rainfall for the Calibration

UNIT : mm

| Block | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| Station | 50 | 45 | 46 | 47 | 27 | Av. | 115 | 49 |
| 1972 | 540 | 805 | 726 | 798 | 694 | 910 | 1126 | 1198 |
| 1973 | 1544 | 1654 | 1770 | 1698 | 1743 | 1805 | 1867 | 1986 |
| 1974 | 1005 | 978 | 1046 | 1164 | 856 | 1134 | 1412 | 1502 |
| 1975 | 1534 | 1186 | 1269 | 1411 | 1365 | 1372 | 1378 | 1466 |
| 1976 | 646 | 504 | 860 | 600 | 744 | 761 | 777 | 827 |
| 1977 | 675 | 667 | 870 | 815 | 816 | 838 | 860 | 915 |
| 1978 | 844 | 809 | 1248 | 1095 | 1008 | 1059 | 1110 | 1093 |
| 1979 | 1311 | 1494 | 1658 | 2795 | 1059 | 1159 | 1260 | 1822 |
| 1980 | 1253 | 1341 | 1442 | 1563 | 1448 | 1586 | 1723 | 1586 |
| 1981 | 1136 | 1445 | 1554 | 1828 | 1286 | 1504 | 1721 | 1541 |
| 1982 | 1524 | 1490 | 1602 | 2072 | 1353 | 1442 | 1532 | 1688 |
| 1983 | 771 | 1180 | 1269 | 1011 | 807 | 1005 | 1204 | 1289 |
| 1984 | 1042 | 1187 | 1317 | 1320 | 1151 | 1249 | 1346 | 1448 |
| 1985 | 817 | 757 | 814 | 1523 | 1261 | 1199 | 1138 | 1200 |
| 1986 | 639 | 1214 | 1305 | 1993 | 774 | 838 | 902 | 1235 |
| 1987 | 1219 | 1431 | 1539 | 1462 | 1103 | 1281 | 1458 | 1693 |
| 1988 | 1821 | 2047 | 2190 | 2437 | 2185 | 2075 | 1964 | 2082 |
| 1989 | 796 | 874 | 960 | 1529 | 781 | 855 | 929 | 1106 |
| 1990 | 762 | 836 | 918 | 1097 | 747 | 818 | 888 | 1059 |
| 1991 | 954 | 1048 | 1151 | 1375 | 936 | 1024 | 1113 | 1326 |
| Av. | 1041. | 1147. | 1275. | 1479. | 1105. | 1195. | 1285. | 1403. |

Fig. 5.3.12 Annual Rainfall used for the Calibration

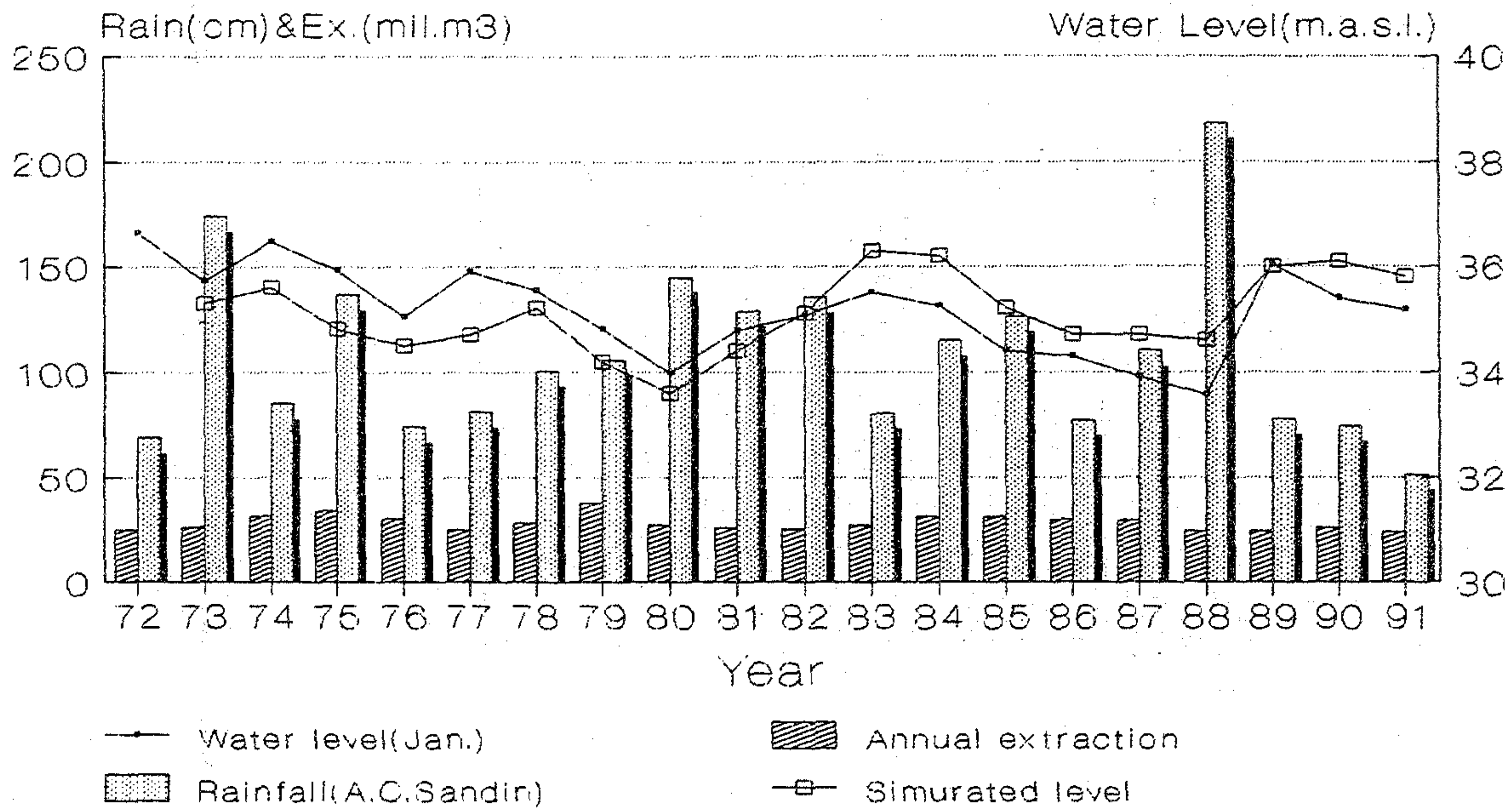



**Fig. 5.3.13 Observed and simulated Water Level of Lake Asososca**

## Pumping Discharge in 1991

| ## | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 2 | 0. | 0. | 0. | 138. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 3 | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 4 | 0. | 0. | 84. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 5 | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 6 | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 7 | 0. | 0. | 0. | 0. | 0. | 355. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 8 | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 9 | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 10 | 0. | 0. | 0. | 0. | 1200. | 700. | 2400. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 11 | 0. | 0. | 0. | 0. | 0. | 0. | 1200. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 12 | 0. | 0. | 0. | 0. | 13253. | 190. | 597. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 13 | 0. | 0. | 1200. | 0. | 43373. | 6564. | 0. | 0. | 0. | 0. | 1664. | 3623. | 0. | 0. | 0. | 0. |
| 14 | 0. | 0. | 0. | 0. | 3614. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 3198. | 0. | 0. | 0. |
| 15 | 0. | 2085. | 0. | 158. | 0. | 5520. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 1571. | 0. | 0. |
| 16 | 0. | 0. | 190. | 1895. | 2244. | 2854. | 3119. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 17 | 0. | 0. | 0. | 535. | 498. | 1072. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 18 | 0. | 0. | 45. | 2843. | 0. | 0. | 245. | 4516. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 19 | 0. | 0. | 2047. | 0. | 0. | 1517. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 20 | 0. | 0. | 76. | 0. | 0. | 0. | 0. | 0. | 633. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 21 | 0. | 0. | 234. | 5261. | 3679. | 0. | 0. | 2123. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 22 | 0. | 0. | 2224. | 0. | 0. | 0. | 5308. | 0. | 1163. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 23 | 0. | 0. | 3916. | 0. | 1896. | 6103. | 0. | 0. | 2001. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 24 | 0. | 0. | 10157. | 0. | 2926. | 2349. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 25 | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 8079. | 10. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 26 | 0. | 0. | 0. | 7056. | 0. | 0. | 0. | 0. | 1359. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 27 | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 28 | 0. | 0. | 405. | 95. | 65764. | 78. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 1321. | 0. | 0. |
| 29 | 0. | 0. | 4578. | 569. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 30 | 0. | 0. | 0. | 3880. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 31 | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 9999. |
| 32 | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 9999. | 9999. |
| 33 | 0. | 8502. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 3097. | 0. | 9999. | 9999. | 9999. | 9999. |
| 34 | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 9999. | 9999. | 9999. | 9999. |
| 35 | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 9999. | 9999. | 9999. | 9999. | 9999. |
| 36 | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. |
| 37 | 0. | 0. | 0. | 0. | 0. | 0. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. |
| 38 | 0. | 0. | 0. | 0. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. |

## Pumping Discharge with Rehabilitation Program

| ## | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 2 | 0. | 0. | 0. | 138. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 3 | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 4 | 0. | 0. | 84. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 5 | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 6 | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 7 | 0. | 0. | 0. | 0. | 0. | 355. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 8 | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 9 | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 10 | 0. | 0. | 0. | 0. | 1200. | 700. | 2400. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 11 | 0. | 0. | 0. | 0. | 0. | 0. | 1200. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 12 | 0. | 0. | 0. | 0. | 13253. | 190. | 597. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 13 | 0. | 0. | 1200. | 0. | 43373. | 6564. | 0. | 0. | 0. | 0. | 1664. | 3623. | 0. | 0. | 0. | 0. |
| 14 | 0. | 0. | 0. | 0. | 3614. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 3198. | 0. | 0. | 0. |
| 15 | 0. | 2085. | 0. | 158. | 0. | 5520. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 1571. | 0. | 0. |
| 16 | 0. | 0. | 190. | 1895. | 2244. | 2854. | 3119. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 17 | 0. | 0. | 0. | 535. | 498. | 1072. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 18 | 0. | 0. | 45. | 2843. | 0. | 0. | 245. | 4516. | 0. | 0. | 0. | 4212. | 0. | 0. | 0. | 0. |
| 19 | 0. | 0. | 2047. | 0. | 5458. | 7893. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 20 | 0. | 0. | 76. | 0. | 0. | 0. | 0. | 0. | 633. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 21 | 0. | 0. | 234. | 5254. | 7450. | 0. | 0. | 15281. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 22 | 0. | 0. | 2224. | 0. | 0. | 0. | 13512. | 0. | 1763. | 0. | 3275. | 0. | 0. | 0. | 0. | 0. |
| 23 | 0. | 0. | 3916. | 0. | 1896. | 6103. | 0. | 0. | 2001. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 24 | 0. | 0. | 10157. | 0. | 2926. | 2349. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 25 | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 8079. | 10. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 26 | 0. | 0. | 0. | 7056. | 0. | 0. | 0. | 0. | 1359. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 27 | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 28 | 0. | 0. | 405. | 95. | 65764. | 78. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 3275. | 0. | 0. |
| 29 | 0. | 0. | 4578. | 569. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 30 | 0. | 0. | 0. | 8345. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 31 | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 9999. |
| 32 | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 9999. | 9999. |
| 33 | 0. | 12068. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 3097. | 0. | 9999. | 9999. | 9999. | 9999. |
| 34 | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 9999. | 9999. | 9999. | 9999. |
| 35 | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 9999. | 9999. | 9999. | 9999. | 9999. |
| 36 | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. |
| 37 | 0. | 0. | 0. | 0. | 0. | 0. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. |
| 38 | 0. | 0. | 0. | 0. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. |

Fig. 5.3.14 Pumping Discharge Map for Future Prediction (1)

## Pumping Discharge with New Development North Tecuantepe (1995)

| ## | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 2 | 0. | 0. | 0. | 130. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 3 | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 4 | 0. | 0. | 81. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 5 | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 6 | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 7 | 0. | 0. | 0. | 0. | 0. | 355. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 8 | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 9 | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 10 | 0. | 0. | 0. | 0. | 1200. | 700. | 2400. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 11 | 0. | 0. | 0. | 0. | 0. | 0. | 1203. | 0. | 0. | 0. | 2000. | 0. | 0. | 0. | 0. | 0. |
| 12 | 0. | 0. | 0. | 0. | 32000. | 150. | 597. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 13 | 0. | 0. | 1200. | 0. | 30000. | 4556. | 0. | 0. | 0. | 0. | 5200. | 3300. | 0. | 0. | 0. | 0. |
| 14 | 0. | 0. | 0. | 0. | 20095. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 2100. | 0. | 14200. | 14200. |
| 15 | 0. | 2015. | 0. | 758. | 0. | 5520. | 0. | 0. | 0. | 0. | 0. | 0. | 1900. | 2450. | 9900. | 14200. |
| 16 | 0. | 0. | 150. | 1035. | 2240. | 2854. | 3119. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 14200. | 14200. |
| 17 | 0. | 0. | 0. | 5328. | 458. | 1072. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 18 | 0. | 0. | 45. | 2843. | 0. | 0. | 165. | 4516. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 19 | 0. | 0. | 2047. | 5370. | 0. | 1517. | 513. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 20 | 0. | 0. | 76. | 0. | 0. | 0. | 4290. | 0. | 633. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 21 | 0. | 0. | 236. | 5254. | 3675. | 0. | 0. | 2123. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 22 | 0. | 0. | 2224. | 0. | 0. | 0. | 5302. | 0. | 1761. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 23 | 0. | 0. | 3916. | 0. | 1895. | 6103. | 0. | 0. | 2801. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 24 | 0. | 0. | 10157. | 0. | 2926. | 2349. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 25 | 0. | 0. | 0. | 0. | 0. | 2045. | 0. | 1075. | 10. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 26 | 0. | 0. | 0. | 7056. | 0. | 1650. | 0. | 0. | 1369. | 2250. | 0. | 0. | 0. | 0. | 0. | 0. |
| 27 | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 28 | 0. | 0. | 405. | 95. | 37834. | 78. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 1321. | 0. | 0. |
| 29 | 0. | 0. | 4578. | 563. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 30 | 0. | 0. | 0. | 3200. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 31 | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 9999. |
| 32 | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 9999. | 9999. |
| 33 | 0. | 6502. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 3097. | 0. | 9999. | 9999. | 9999. | 9999. |
| 34 | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 9999. | 9999. | 9999. | 9999. |
| 35 | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 9999. | 9999. | 9999. | 9999. | 9999. |
| 36 | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. |
| 37 | 0. | 0. | 0. | 0. | 0. | 0. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. |
| 38 | 0. | 0. | 0. | 0. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. |

## Pumping Discharge with New Development in Sabana Grande - Cofradia - Tecuantepe (2000)

| ## | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 2 | 0. | 0. | 0. | 133. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 3 | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 4 | 0. | 0. | 81. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 5 | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 6 | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 7 | 0. | 0. | 0. | 0. | 0. | 355. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 8 | 0. | 0. | 0. | 0. | 0. | 0. | 7500. | 7500. | 7500. | 7500. | 0. | 0. | 0. | 0. | 0. | 0. |
| 9 | 0. | 0. | 0. | 0. | 0. | 0. | 7560. | 7500. | 7500. | 7500. | 0. | 0. | 0. | 0. | 0. | 0. |
| 10 | 0. | 0. | 0. | 0. | 1200. | 700. | 7100. | 7500. | 7500. | 7500. | 0. | 0. | 0. | 0. | 0. | 0. |
| 11 | 0. | 0. | 0. | 0. | 0. | 0. | 7200. | 7200. | 7200. | 7200. | 2000. | 0. | 0. | 0. | 0. | 0. |
| 12 | 0. | 0. | 0. | 0. | 35000. | 150. | 597. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 13 | 0. | 0. | 1200. | 0. | 30000. | 4501. | 0. | 0. | 0. | 0. | 5200. | 1000. | 0. | 0. | 0. | 0. |
| 14 | 0. | 0. | 0. | 0. | 20000. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 2100. | 0. | 14200. | 14200. |
| 15 | 0. | 2045. | 0. | 758. | 0. | 5520. | 0. | 0. | 0. | 0. | 0. | 0. | 1900. | 2450. | 9900. | 14200. |
| 16 | 0. | 0. | 150. | 1035. | 2244. | 2854. | 3115. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 14200. | 14200. |
| 17 | 0. | 0. | 0. | 5328. | 498. | 1072. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 18 | 0. | 0. | 45. | 2843. | 0. | 0. | 245. | 4516. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 19 | 0. | 0. | 2047. | 5370. | 0. | 1517. | 511. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 20 | 0. | 0. | 76. | 0. | 0. | 0. | 4290. | 0. | 633. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 21 | 0. | 0. | 236. | 5254. | 3675. | 0. | 0. | 2123. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 22 | 0. | 0. | 2224. | 0. | 0. | 0. | 5300. | 0. | 1763. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 23 | 0. | 0. | 3916. | 0. | 1895. | 6103. | 0. | 0. | 2801. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 24 | 0. | 0. | 10157. | 0. | 2926. | 2349. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 25 | 0. | 0. | 0. | 0. | 0. | 0. | 2045. | 4075. | 10. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 26 | 0. | 0. | 0. | 7056. | 0. | 1650. | 0. | 0. | 1369. | 2250. | 0. | 0. | 0. | 0. | 0. | 0. |
| 27 | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 28 | 0. | 0. | 405. | 95. | 37854. | 78. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 1321. | 0. | 0. |
| 29 | 0. | 0. | 4578. | 563. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 30 | 0. | 0. | 0. | 3289. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. |
| 31 | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 9999. |
| 32 | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 9999. | 9999. |
| 33 | 0. | 6502. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 3097. | 0. | 9999. | 9999. | 9999. | 9999. |
| 34 | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 9999. | 9999. | 9999. | 9999. |
| 35 | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 9999. | 9999. | 9999. | 9999. | 9999. |
| 36 | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. |
| 37 | 0. | 0. | 0. | 0. | 0. | 0. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. |
| 38 | 0. | 0. | 0. | 0. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. | 9999. |

Fig. 5.3.14 Pumping Discharge Map for Future Prediction (2)

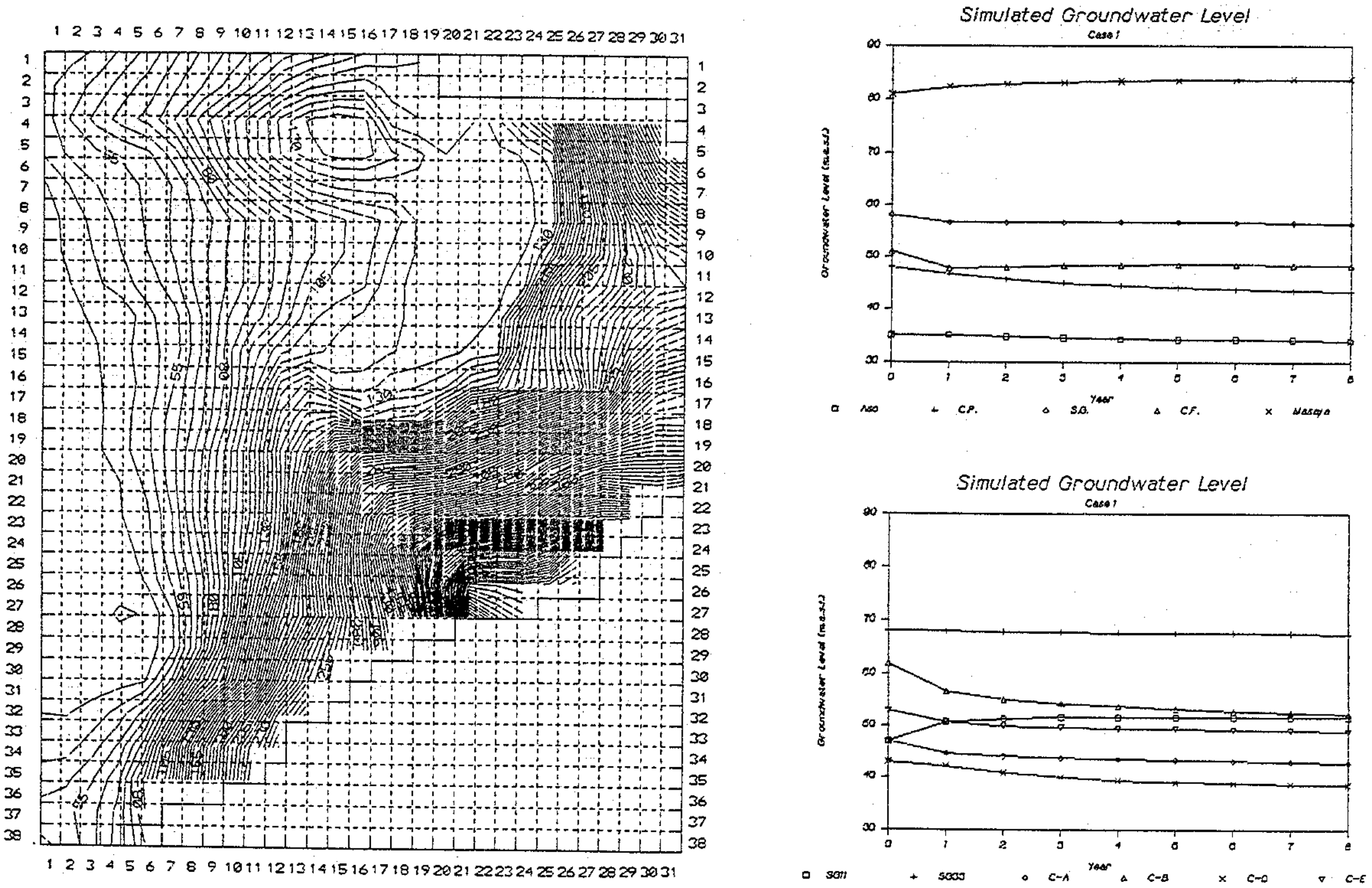
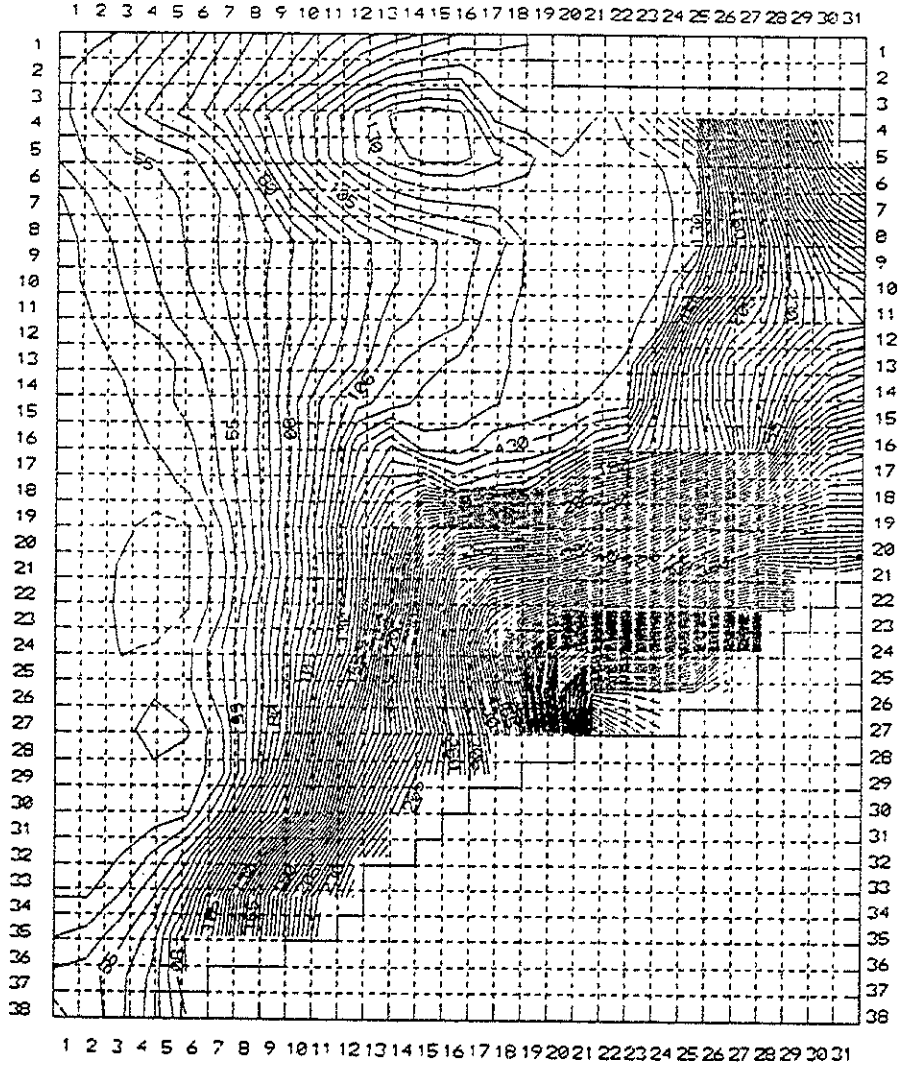



Fig. 5.3.15 Simulated Results (1)
- Case 1 -



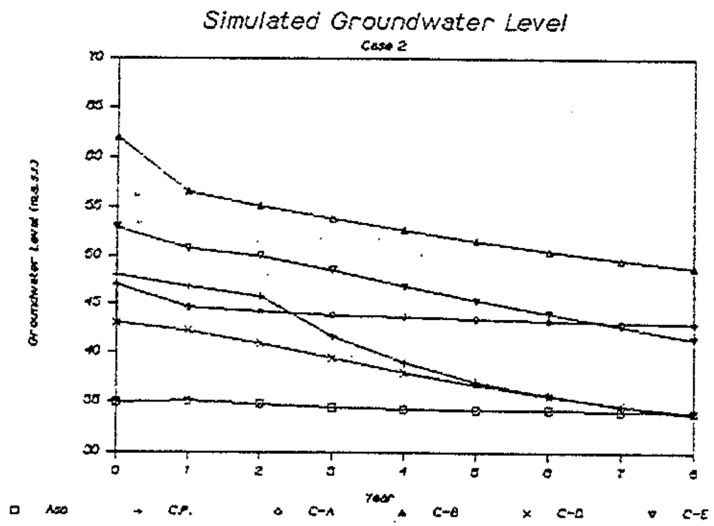
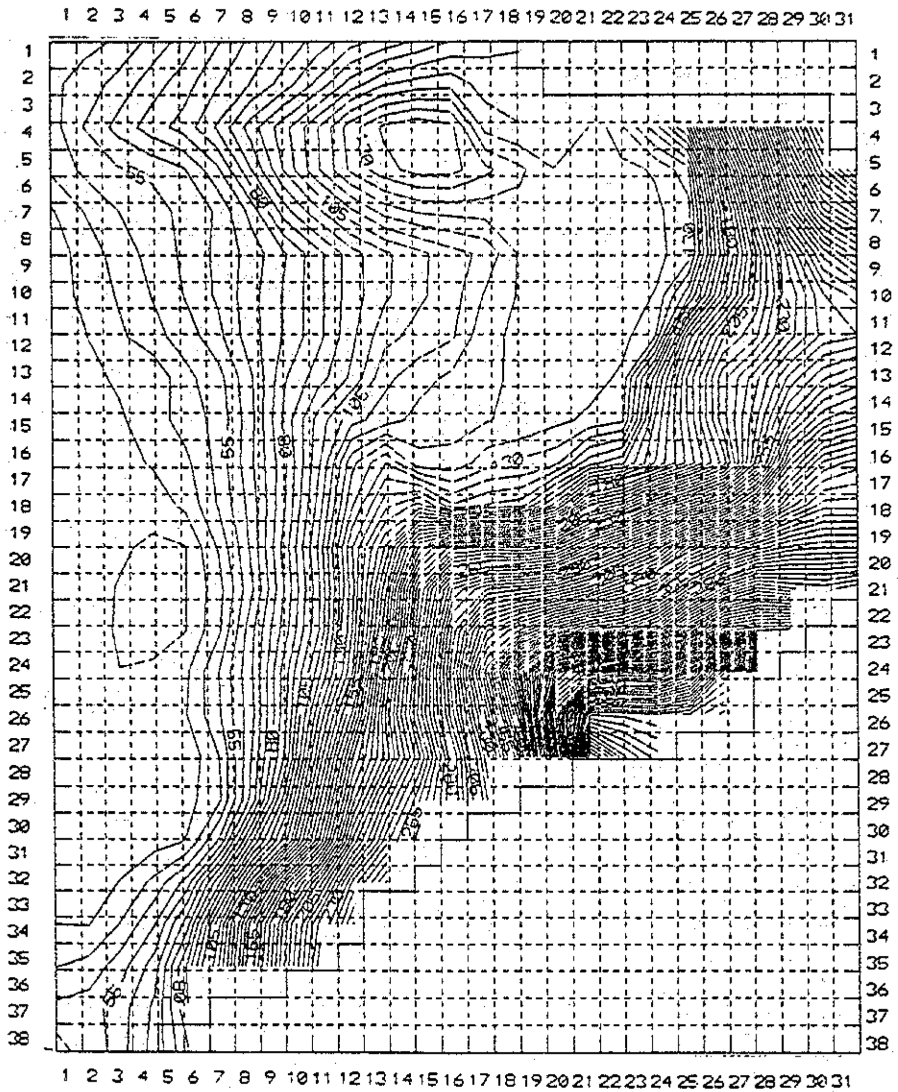



Fig. 5.3.15 Simulated Results (2)
- Case 2 -



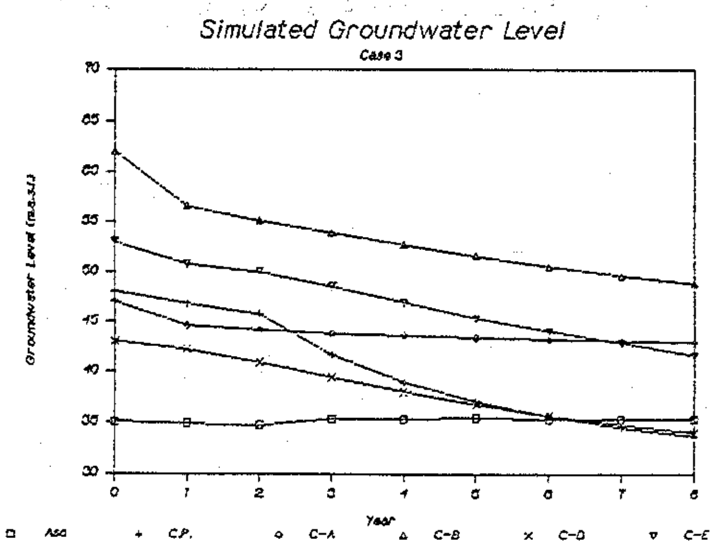
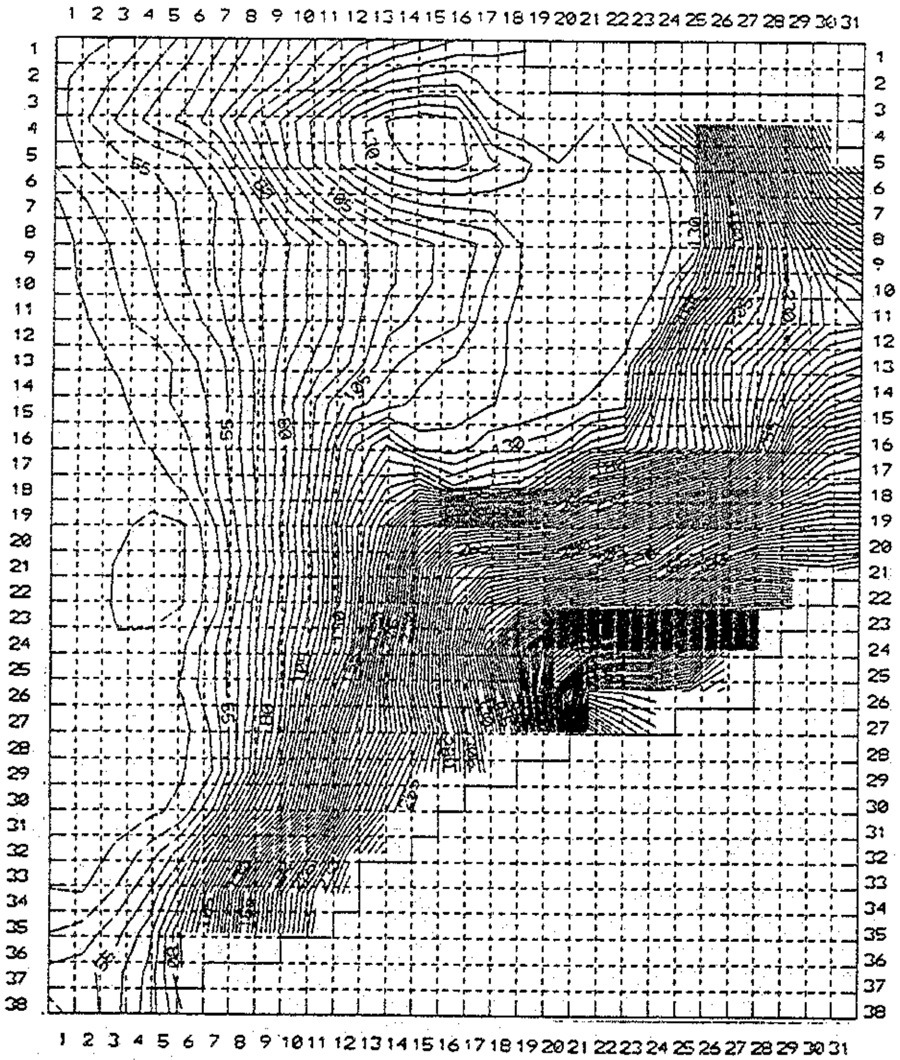



Fig. 5.3.15 Simulated Results (3)
- Case 3 -



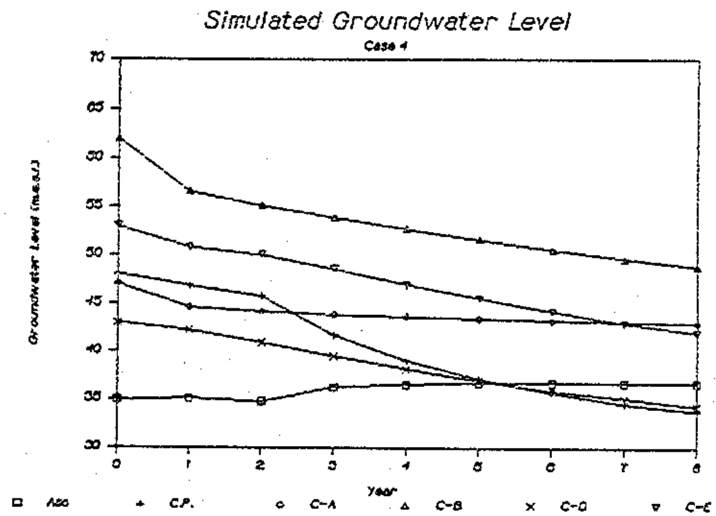
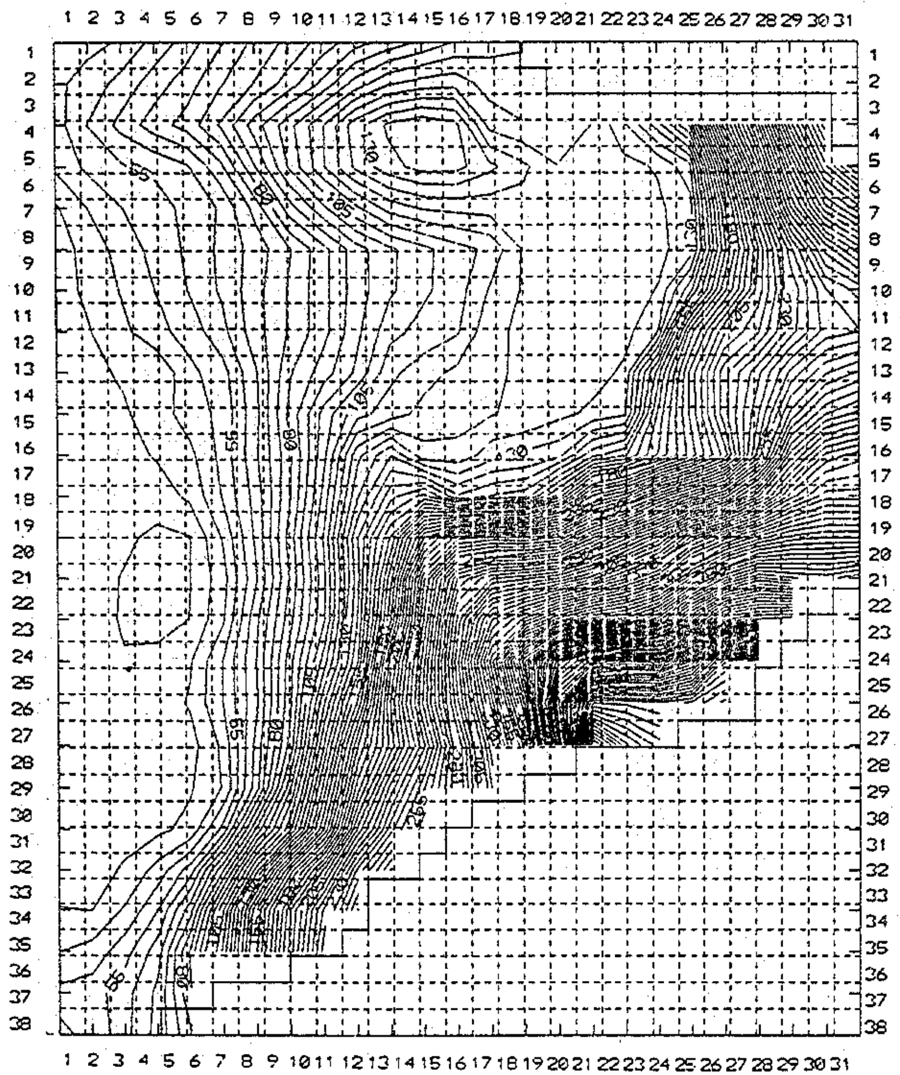



Fig. 5.3.15 Simulated Results (4)
- Case 4 -



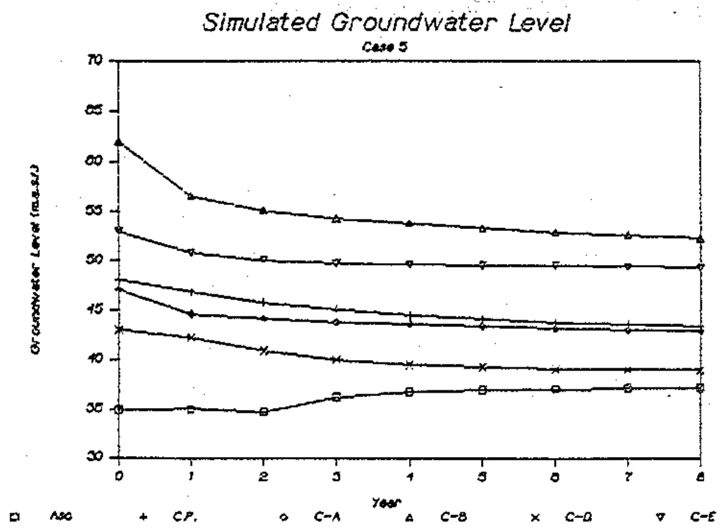
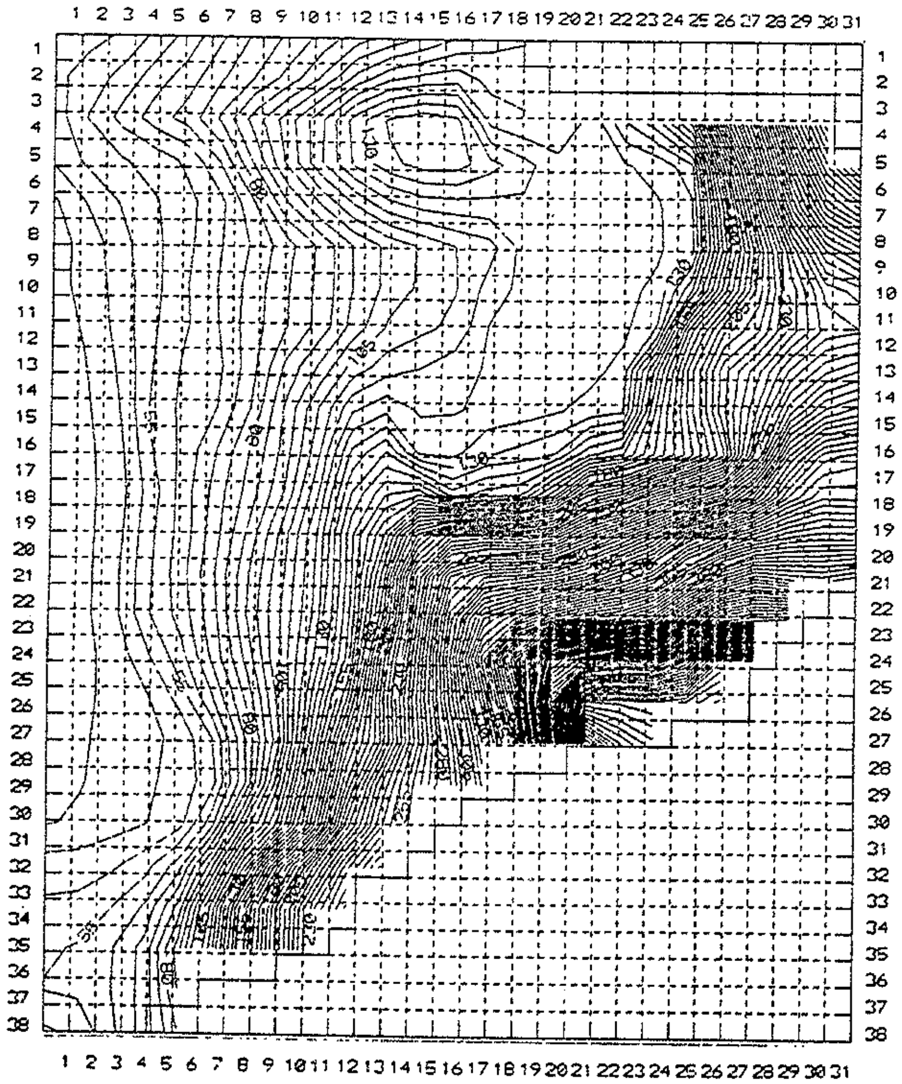



Fig. 5.3.15 Simulated Results (5)
- Case 5 -



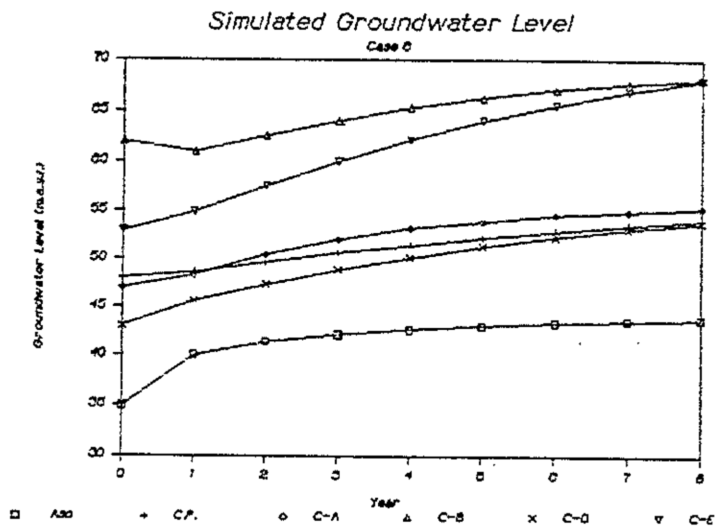
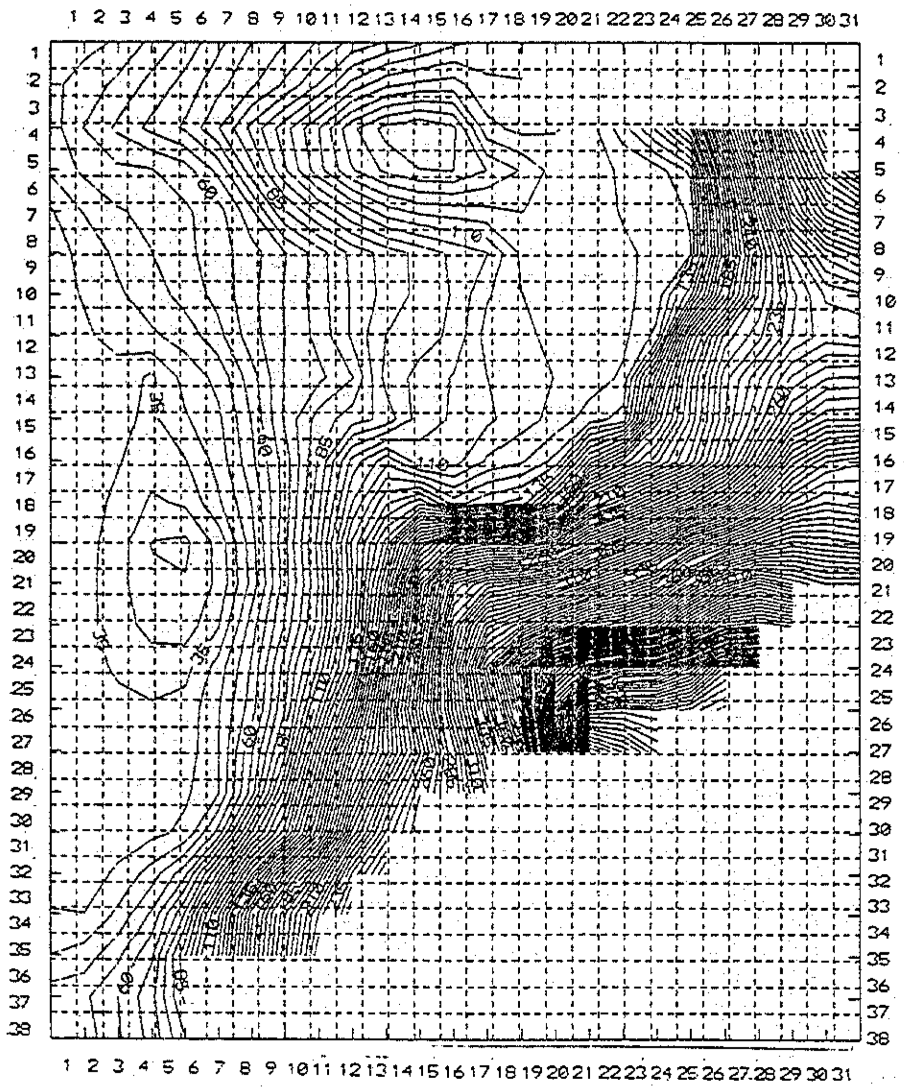
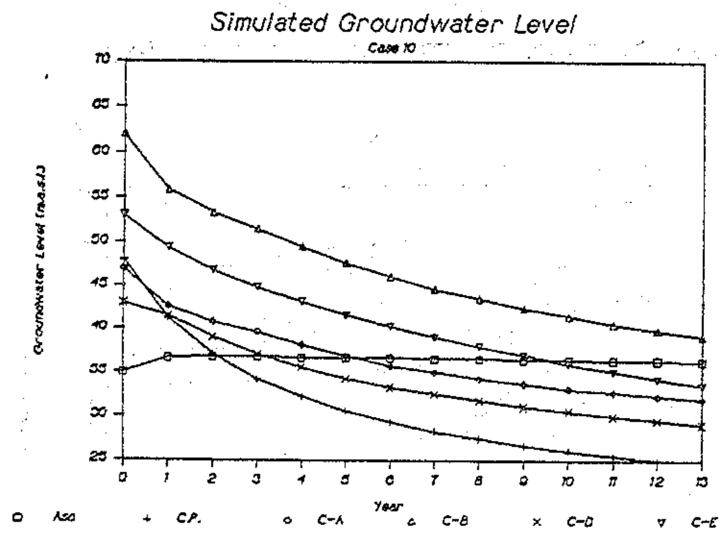



Fig. 5.3.15 Simulated Results (6)
- Case 6 -





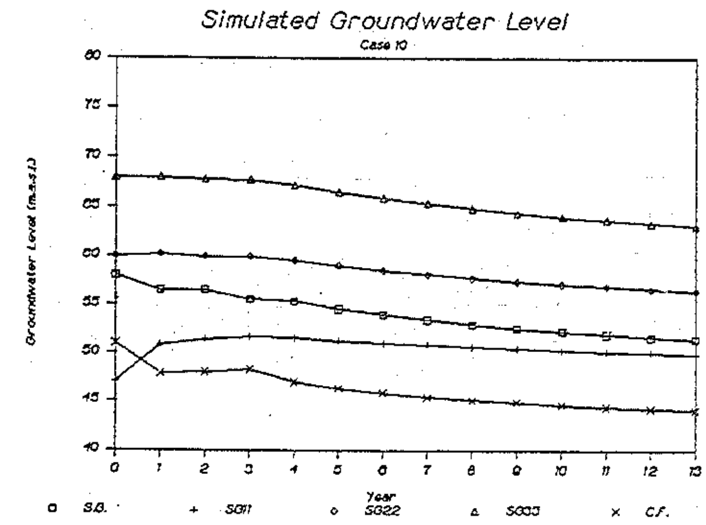
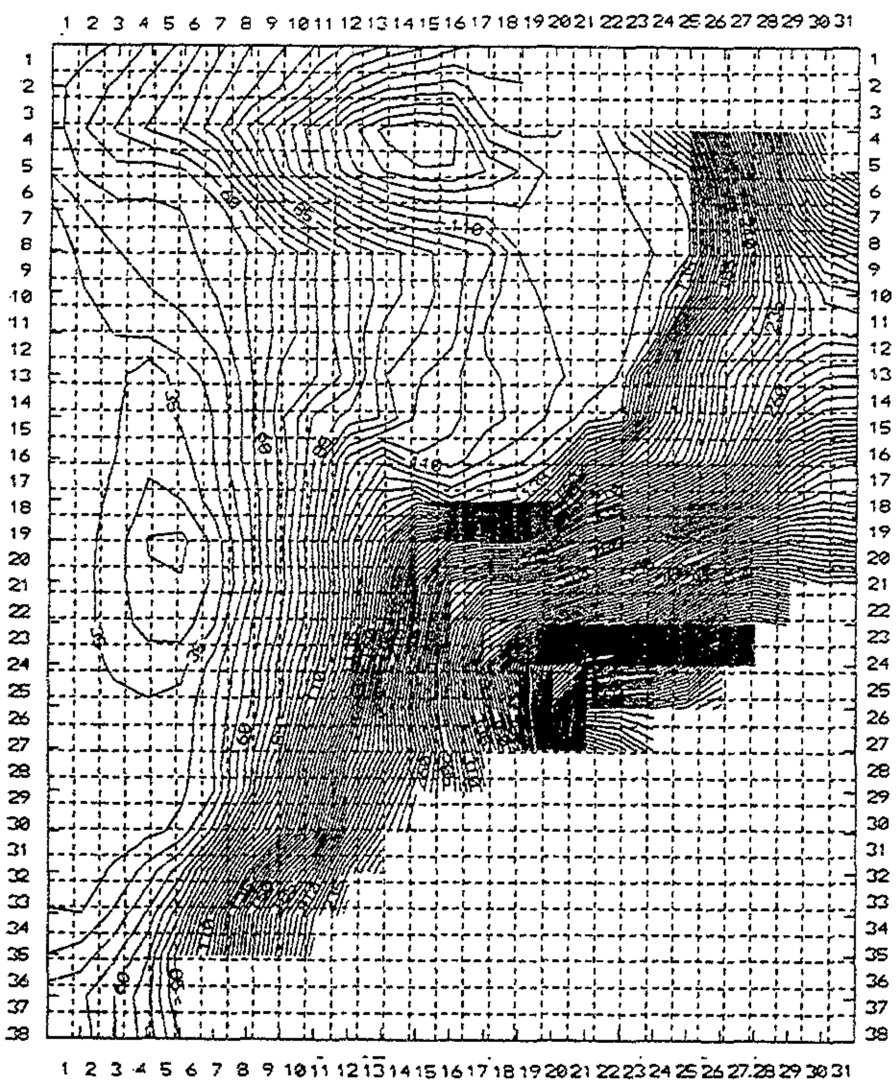
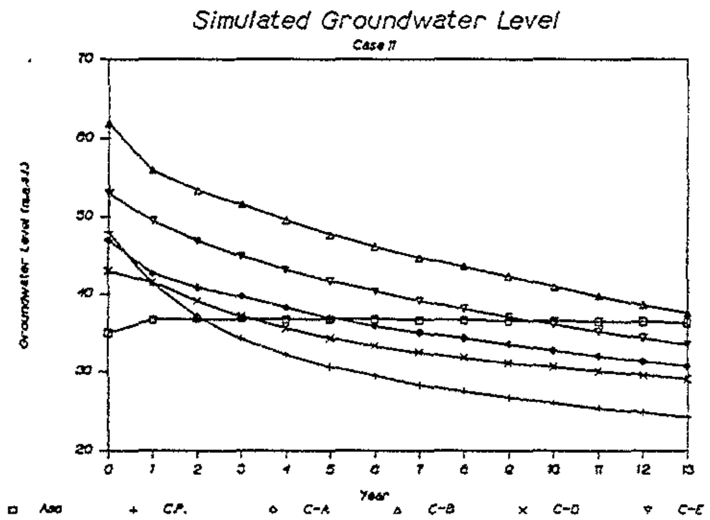




Fig. 5.3.15 Simulated Results (7)





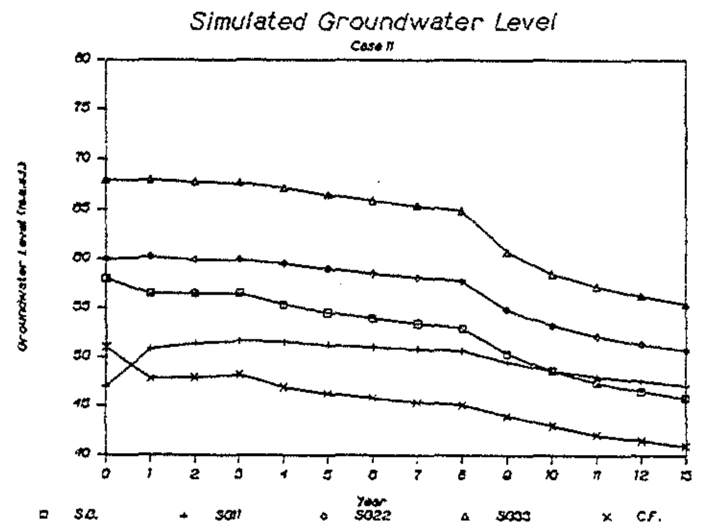
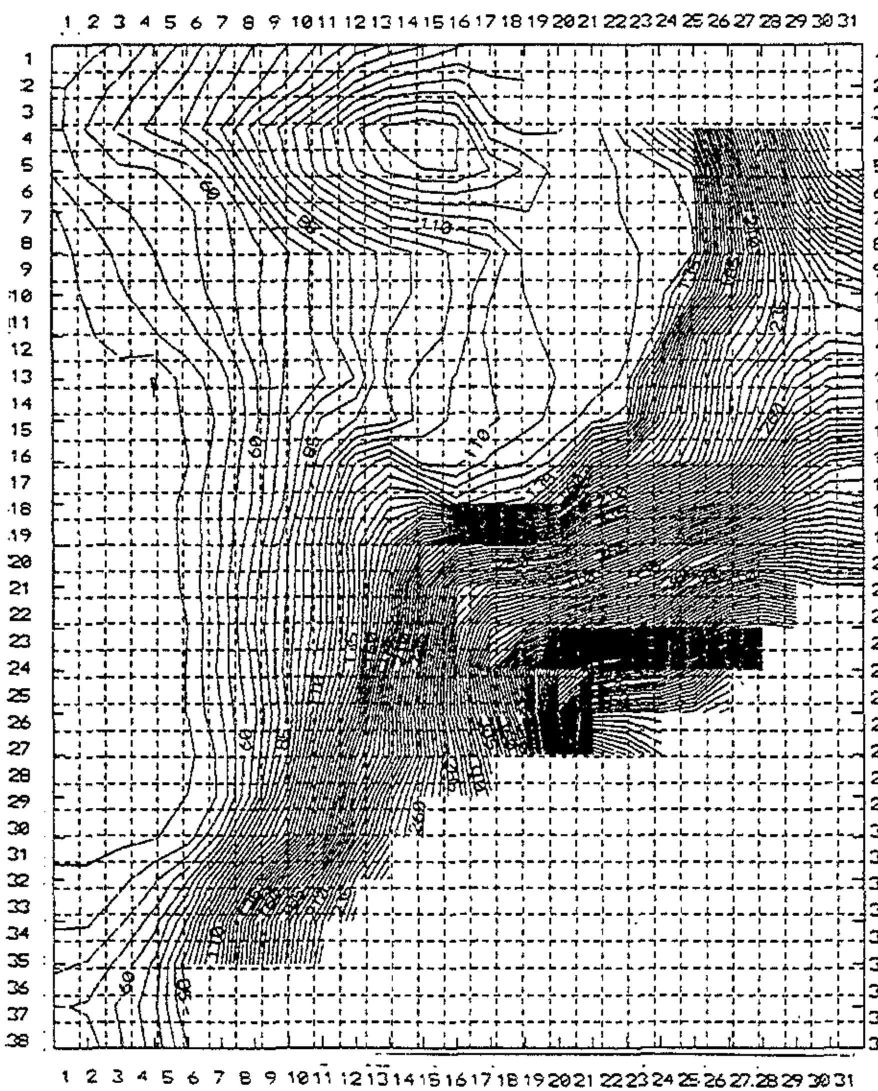
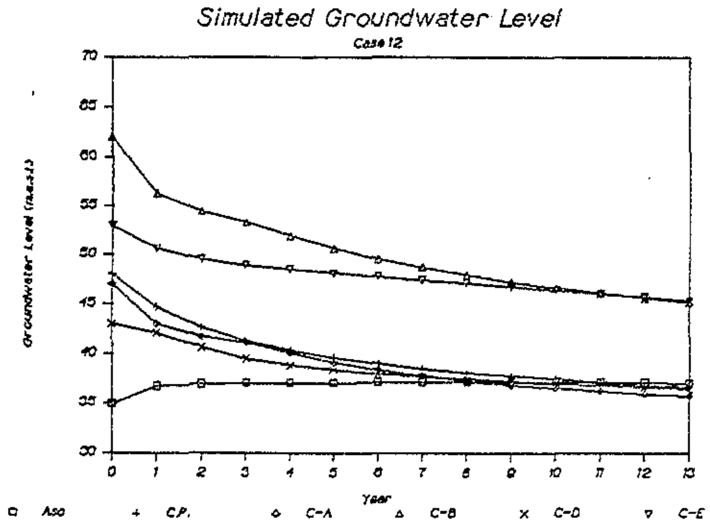




Fig. 5.3.15 Simulated Results (8)





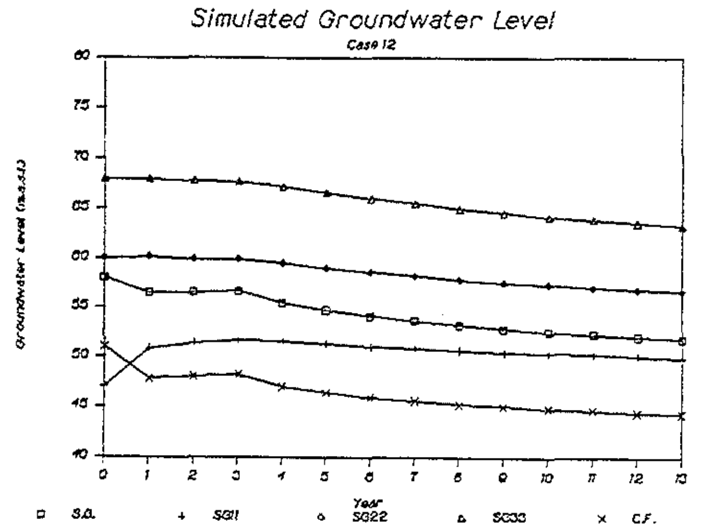
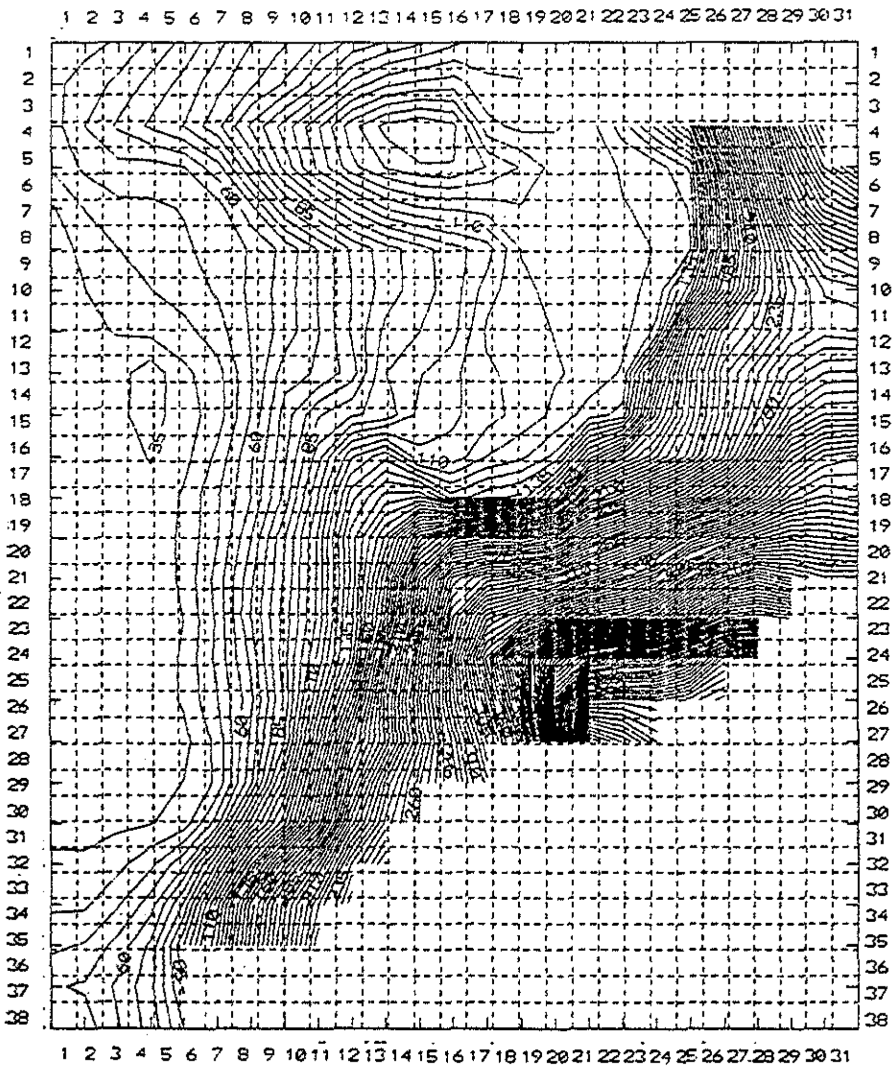




**Fig. 5.3.15 Simulated Results (9)**



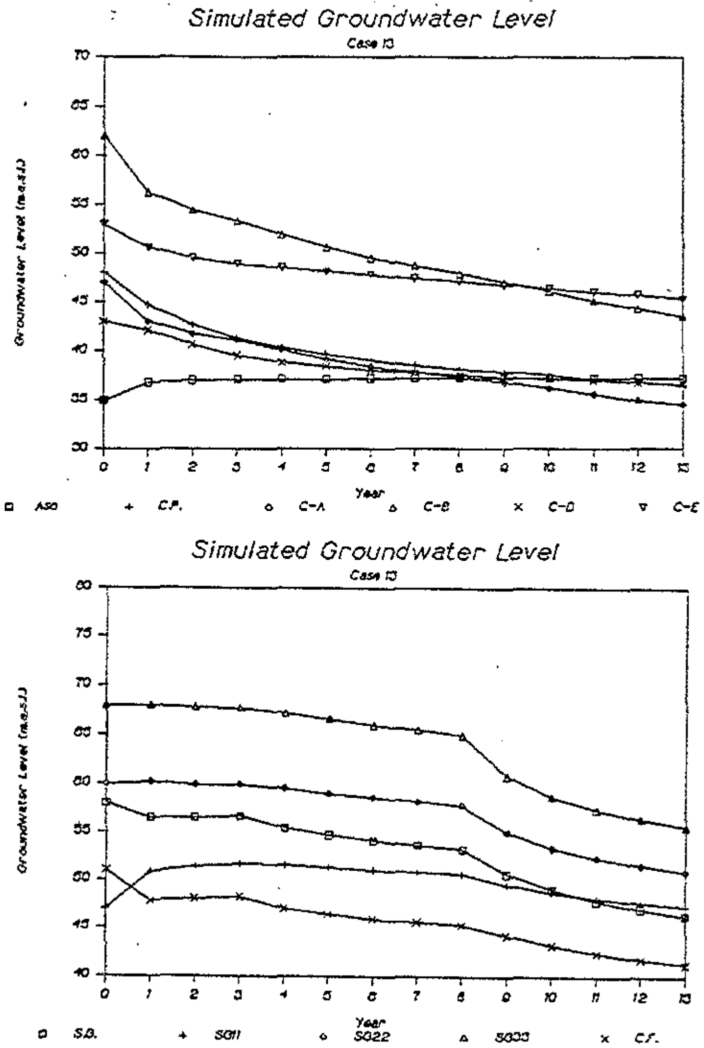



Fig. 5.3.15 Simulated Results (10)

## 5.4 Recommendation

As mentioned in the previous section, this model simulation analysis is based on the calibration of available groundwater records in limited points and periods.

In order to practically use this simulated results for future prediction, groundwater monitoring must be continued with the aid of the facilities installed by the Study, and must be conducted at additional points in order to check the exact behavior of groundwater. It will be expected that the model parameters will be modified simultaneously.

In consideration of the described water balance and simulation studies, the following approaches are recommended:

(1) According to the values calculated according to the water balance, additional groundwater developments will be conducted at the western and eastern hydrogeological basins. However, pumping discharge must be reduced in the central basin.
Calculated values are still rough estimates, and re-evaluation will be conducted along with the monitoring results of the groundwater level in the future.

(2) The groundwater level in the center of Managua City will be drawn down even with the existing extraction rate. INAA production wells No.7 (El Stadia), No.8 (San Antonio), No.9 (banco de America) and No.10 (Mercado Oriental) are located around 1 km from the lake coast with a high pumping yield.

Monitoring wells are to be installed between Lake Managua and these production wells. Reduction of pumping discharge have to be considered with the monitoring results of the level of Lake Managua. Other pumping discharge, especially by the rehabilitation program, will also effect large draw down in the extraction area. Discharge control must be done with groundwater monitoring.

(3) Recovery of the water level upto 40 m.a.s.l. at Lake Asososca will be achieved by reducing the pumping discharge of the 1991 yield to more than 40%. Detailed regulations shall be considered for the water level of the industrial area between Asososca and Managua lakes. This reduction should be made urgent because all pumpage must be stopped once industrial waste water permeates the water of Asososca.

(4) New groundwater development in Sabana Grande - Cofradia and Veracruz - Tecuantepe area will produce draw down in lower areas like Carlos Fonseca. Well interference in the Carlos Fonseca well field is discussed in Chapter 3, and a water level recovery averaging 7 m is expected from the effective coordination and control of the pumping discharge. The development scale of the 1995 stage which is considered to affect the draw down of the existing wells like in Carlos Fonseca will still be acceptable.

However, the next development in 2000 stage is necessary to consider the results of the monitoring works which will be conducted in these areas.

Therefore, to implement the required reduction of the pumping discharge of Lake Asososca and other wells in the center of Managua City, studies for the development of other areas as potential water resources should commence as soon as possible.

# CHAPTER 6 THE PROJECT

Based on the study on Managua's water supply discussed in Chapter 3 and the groundwater development potential within the catchment area of 880km$^2$ discussed in Chapter 5, a plan to develop groundwater as Managua's water supply source has been established as one part of the Study.

## 6.1 Basic Concept

The groundwater development plan is made under the following basic concepts:

a) The target year is the year 2000.

b) The water supply service area is the entire City of Managua comprising seven Districts, but, the Project shall cover Districts 2 to 6 excluding the independent supply area of District 1, and the service level shall not be uniform. Rural service level is applied to District 7, while Districts 2 to 6 are designated as areas with the urban service level.

c) The population served in 2000 shall be the estimated total population of District 2 to 6 in 2000.

d) The water demand in 2000 is estimated to exceed the expected total production in the Study area. However, the planned supply service level is not to be lowered expecting benefits from the additional groundwater development at outside of the Study area.

e) The project shall be implemented in three phases. Phase 1 shall focus on the urgent supply plan at least to minimize the present severe inconveniences such as periodical water suspension and very limited supply to highly elevated area. Phase 2 shall focus on a full-scale groundwater development by means of safe pumpage from the high potential area within the Study area in order to catch up with the demand in 2000 as much as possible. The development of a supplementary water source to meet the demand in 2000 from outside the Study area shall be dealt with in phase 3 of the Project.

f) The scope of the Project comprises groundwater development and construction of conveyance facilities to the existing eservoir. The improvement of the distribution facilities hould be covered by other projects.

## 6.2 Service Area

The existing water supply service area is the seven Districts of Managua as shown in Fig. 3.1.1. The characteristics of the Districts in view of the supply system or service level are summarized below:

1) District 1

District 1 is situated in the western end of Managua City. Since this area is topographically separated from other major areas of Managua by a mountain ridge, the water supply system in this area is independent from other areas. This area occupies most of the Western sub-area of the studied catchment area, and is separated from the Central and Eastern sub-areas of the hydrogeological basin. Therefore, the supply system in District 1 shall remain independent, because the water supply source is limited to the developed groundwater from the Western sub-area and its extended area to the north. Since the Project concerns on the Central and Eastern sub-areas and their east side, this District is excluded from the service area of the Project.

2) Districts 2 to 6

Districts 2 to 6 consist of the major urban areas of Managua. Districts 2, 4 and 6 extend from the low zone along the south shore of the Managua Lake to the high zone (35-135m in elevation). Districts 3 and 5 are situated in the higher zone which is elevated from 50 to 300m.

Except for the eastern parts of Districts 5 and 6, which are in the Eastern sub-area, most parts of the above Districts are included in the Central sub-area of the hydrogeological basin. The water demand projection and the water consumption rate per capita per day are planned in all these Districts in compliance with the service level of the urban water supply.

3) District 7

District 7 is situated in the highest area in the southern end of Managua (more than 300m in elevation).

Although this District is administratively included in the city area, the service level of this water supply system is not within the same level as those in other Districts. The plan for the year 2000 is kept within the present rural water supply service level, and the population or demand growth rate is to be kept at nearly half of other Districts, because drastic social and industrial development is not expected in this District affected by an unfavorable topography.

## 6.3 Water Demand Projection

The water demand in the concerned year, that is the planned water supply quantity, is determined by the following equation:

$$\text{Average daily supply quantity} = \frac{\text{population served} \times \text{Average daily supply quantity per head}}{\text{Effectivity factor}} \quad \ldots(1)$$

$$\text{Daily maximum supply quantity} = \text{Average daily supply quantity} \times \text{Coefficient of Daily maximum} \quad \ldots(2)$$

1) Projection of population served

The total population of Managua, 1,164,103 as of 1991, has been estimated based on the CSE data described in Chapter 3. The population growth rates are different depending on District and future time span, and the projected population in 1995 and 2000 is shown in Table 6.3.1(1).

| Growth rate | Period | Districts |
|---|---|---|
| 5.2 % | 1991 - 1995 | 1 - 6 |
| 5.0 % | 1995 - 2000 | |
| 2.5 % | 1991 - 2000 | 7 |

The population served is 100 percent of the population, as stated the basic concept of the plan.

2) Planned average daily consumption per head

Since the domestic water consumption quantity per head, "174 l/c/d (45.9 g/c/d)", was obtained from the sampling survey (and this value seems to represent the probable consumption rate of domestic water as described in 3.2.4-2), this value can be the basis for determining the planned daily consumption. Meanwhile, the ratio between the domestic water consumption and the total consumption, including other categorized water uses in Managua, is 1:1.2, as described in 3.2.5. Therefore, the planned daily average consumption per head comes to 208.8 l/c/d (55 g/c/d).

3) Planned daily maximum consumption per head

Daily consumption is variable, being particularly big between seasons. The design value for consumption rate should be estimated from the past consumption statistics. However, recent data are not useful, because seasonal variation was considered ineffective due to the periodical water suspension policy. Therefore, determination of maximum rate is to be based on INAA's criteria, 1.2 times the average consumption.

Thus, planned daily maximum consumption per head is:

208.8 l/c/d/ x 1.2 = 250 l/c/d (66.0 g/c/d)

4) Planned affectivity factor

The affectivity factor designates the ratio of the effectively used water. (Non-effectively used water refers to leakage).

The affectivity factor as of 1991 was estimated at 0.733 as described in 3.2.4. However, this value is not used as it is because of the fear of excessive design of water demand.

The planned affectivity factor is to be fixed at 0.80, a value commonly used in the planning of water supply, with an expectation that the effort of reducing the loss is to be continued. Using the values of various factors, the water demand in 2000 is calculated in accordance with equations (1) and (2).

The above demand projection is applied to the urban service areas of District 2 to 6. With regard to District 7, a fixed value of 10 gal/c/d (about 38/liter c/d) is used for the daily maximum consumption per head. Therefore, the demand is simply calculated by multiplying 10 g/c/d by the projected population of the concerned year. Thus, the total water demand in 2000 amounts to 138.88 MGD (525,700 $m^3$/day). The projected demand in 1995 and 2000 are shown in Table 6.3.1 (2).

Table 6.3.1 (1) Estimated population in 1991, 1995 and 2000

| | Low Zone | | | High Zone | | | Highest Zone | | | High Highest Zone | | | District 1 | | | Total | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| District | 1991 | 1995 | 2000 | 1991 | 1995 | 2000 | 1991 | 1995 | 2000 | 1991 | 1995 | 2000 | 1991 | 1995 | 2000 | 1991 | 1995 | 2000 |
| 1 | - | - | - | - | - | - | - | - | - | - | - | - | 70.986 | 86.943 | 110.964 | 70.986 | 86.943 | 110.964 |
| 2 | 105.678 | 129.434 | 165.194 | 45.348 | 55.542 | 70.887 | - | - | - | - | - | - | - | - | - | 151.026 | 184.976 | 236.081 |
| 3 | - | - | - | 60.916 | 74.610 | 95.223 | 54.859 | 67.191 | 85.755 | 53.651 | 65.711 | 83.866 | - | - | - | 169.426 | 207.512 | 264.844 |
| 4 | 158.303 | 193.889 | 247.457 | 70.704 | 86.598 | 110.523 | - | - | - | - | - | - | - | - | - | 229.007 | 280.487 | 357.980 |
| 5 | - | - | - | 42.916 | 52.563 | 67.085 | 143.134 | 175.310 | 223.745 | 14.800 | 18.127 | 23.135 | - | - | - | 200.850 | 246.000 | 313.965 |
| 6 | 94.933 | 116.273 | 148.397 | 147.156 | 180.236 | 230.032 | 4.131 | 5.060 | 6.458 | - | - | - | - | - | - | 246.220 | 301.569 | 384.887 |
| 7 | - | - | - | - | - | - | - | - | - | 96.588 | 106.615 | 120.625 | - | - | - | 96.588 | 106.615 | 120.625 |
| Total | 358.914 | 439.596 | 561.048 | 367.040 | 449.549 | 573.750 | 202.124 | 247.561 | 315.958 | 165.039 | 190.453 | 227.626 | 70.986 | 86.943 | 110.964 | 1.164.103 | 1.414.102 | 1.789.346 |
| | | | | | | | | | | | | | | | | Total of District 2-7 | | |
| | | | | | | | | | | | | | | | | 1.093.117 | 1.327.159 | 1.678.382 |

Table 6.3.1 (2) Estimated water demand in 1991, 1995 and 2000

Unite:MGD

| | Low Zone | | | High Zone | | | Highest Zone | | | High Highest Zone | | | District 1 | | | Total | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1991 | 1995 | 2000 | 1991 | 1995 | 2000 | 1991 | 1995 | 2000 | 1991 | 1995 | 2000 | 1991 | 1995 | 2000 | 1991 | 1995 | 2000 |
| 1 | - | - | - | - | - | - | - | - | - | - | - | - | 5.86 | 7.17 | 9.15 | 5.86 | 7.17 | 9.15 |
| 2 | 8.72 | 10.68 | 13.63 | 3.74 | 4.58 | 5.85 | - | - | - | - | - | - | - | - | - | 12.46 | 15.26 | 19.48 |
| 3 | - | - | - | 5.03 | 6.16 | 7.86 | 4.52 | 5.54 | 7.07 | 4.43 | 5.42 | 6.92 | - | - | - | 13.98 | 17.12 | 21.85 |
| 4 | 13.06 | 16.00 | 20.42 | 5.83 | 7.14 | 9.12 | - | - | - | - | - | - | - | - | - | 18.89 | 23.14 | 29.54 |
| 5 | - | - | - | 3.54 | 4.34 | 5.53 | 11.81 | 14.46 | 18.46 | 1.22 | 1.50 | 1.91 | - | - | - | 16.57 | 20.30 | 25.90 |
| 6 | 7.83 | 9.59 | 12.24 | 12.14 | 14.87 | 18.98 | - | - | - | 0.34 | 0.42 | 0.53 | - | - | - | 20.31 | 24.88 | 31.75 |
| 7 | - | - | - | - | - | - | - | - | - | 0.97 | 1.07 | 1.21 | - | - | - | 0.97 | 1.07 | 1.21 |
| Total | 29.61 | 36.27 | 46.29 | 30.28 | 37.09 | 47.34 | 16.33 | 20.00 | 25.53 | 6.96 | 8.41 | 10.57 | 5.86 | 7.17 | 9.15 | 89.04 | 108.94 | 138.88 |
| | | | | | | | | | | | | | | | | Total of Distrcit 2-7 | | |
| | | | | | | | | | | | | | | | | 83.18 | 101.77 | 129.73 |

## 6.4 Groundwater Development Plan

### 6.4.1. Groundwater development potential by area

The groundwater development potential in the Study area discussed in Chapter 5 totals 158.5 million $m^3$/year (114.72 MGD), with the following capacity in each of the three sub-area.

| | | |
|---|---|---|
| Western sub-area | 8.9 million $m^3$/year | ( 6.44 MGD) |
| Central sub-area | 41.6 million $m^3$/year | (30.11 MGD) |
| Eastern sub-area | 108.0 million $m^3$/year | (78.17 MGD) |

On the other hand, the total production of water (pumpage of groundwater including pumpage from Asososca Lake) from the Study area as of 1991 was 100.6 million $m^3$/year (72.981 MGD), with the following production from each of the three sub-areas.

| | | |
|---|---|---|
| Western sub-area | 3.10 million $m^3$/year | ( 2.24 MGD) |
| Central sub-area | 63.57 million $m^3$/year | (46.01 MGD) |
| Eastern sub-area | 31.33 million $m^3$/year | (22.68 MGD) |

Therefore, the remaining groundwater development potential in the total Study area after 1991 is 46.73 million $m^3$/year (33.82 MGD), Conclusively, additional groundwater can be safely developed from the Study area up to 46.73 million $m^3$/year (33.82 MGD) after 1991. However, the remaining potential is very different in each of the hydrogeological sub-areas concerned, as shown below.

| | | |
|---|---|---|
| Western sub-area | + 5.80 million $m^3$/year | (+ 4.20 MGD) |
| Central sub-area | - 27.85 million $m^3$/year | (-20.16 MGD) |
| Eastern sub-area | + 68.78 million $m^3$/year | (+49.78 MGD) |

The Western sub-area, which includes District 1, is capable of an additional groundwater development of 4.20 MGD. This amount,however, cannot cover the demand in 2000 if the daily supply quantity per head is increased to the planned amount of 82.5 gl/c/d from the existing service level of about 31.6 gl/c/d.

However, the studied Western sub-area, which includes District 1 does not cover the entire hydrogeological basin since it is bounded by the line of North latitude of 12 14'. The North side of the Study area is expected to have some more capacity for groundwater development. A further study covering the entire catchment area is required in the near future.

The Central sub-area is devoid of any remaining capacity for additional groundwater development. On the contrary, the total pumpage from this area as of 1991 exceeded the capacity of this sub-area which has been overpumped up to 20.16 MGD. The total pumpage from this area should be gradually reduced in order to recover the water balance.

The Eastern sub-area, on the other hand, has a considerable remaining capacity of 49.78 MGD. Therefore, the plan on a new groundwater development should be focused on this sub-area. Since District 1 in the Western sub-area shall remain as an independent supply area, further discussion on the balance of water demand and groundwater development potential will be focused on both the Central and Eastern sub-areas. The balance in the two sub-areas is shown below:

| | |
|---|---|
| Total development potential of Central and Eastern sub-areas | 149.60 million $m^3$/year(108.28MGD) |
| Total pumpage as of 1991 from the two sub-areas | 108.67 million $m^3$/year (78.66MGD) |
| The balance (remaining potential of the two sub-areas) | 40.93 million $m^3$/year (29.63MGD) |

6.4.2. Allocation of developed groundwater

The groundwater developed from the Central and Eastern sub-areas is used for the following purposes as of 1991:

- Source of Managua water supply — 94.90 million $m^3$/year (68.69 MGD)
- Source of water supply for rural areas — 6.65 million $m^3$/year ( 4.81 MGD)
- Industrial use — 5.88 million $m^3$/year ( 4.26 MGD)
- Agricultural use — 1.24 million $m^3$/year ( 0.90 MGD)

Assuming that no increase in industrial and agricultural uses is to take place in the near future, and applying a 2.5% increase ratio to the rural (municipal) water supply, the allocation of the developed groundwater other than Managua water supply is estimated to reach the following quantities in 1995 and 2000:

| | 1995 | 2000 |
|---|---|---|
| Agricultural use | 0.90 MGD | 0.90 MGD |
| Industrial use | 4.26 MGD | 4.26 MGD |
| Rural water supply | 5.31 MGD | 6.01 MGD |
| Sub total | 10.47 MGD | 11.17 MGD |

By adding the estimated water requirements of Managua water supply, the water demand in the Central and Eastern sub-areas in 1995 and 2000 totals 112.24 MGD and 140.90 MGD, respectively, as shown in the following table.

Table 6.4.1 Allocation of developed groundwater in the Central and Eastern sub-area

unit: MGD & ($m^3$/day)

| Allocation | 1995 | 2000 |
|---|---|---|
| Managua water supply (District 2-7) | 101.77 (385,200) | 129.73 (491,100) |
| Rural/municipal water supply | 5.31 (20,100) | 6.01 (22,800) |
| Industrial use | 4.26 (16,100) | 4.26 (16,100) |
| Agricultural use | 0.90 (3,400) | 0.90 (3,400) |
| Total demand | 112.24 (424,900) | 140.90 (533,400) |

## 6.4.3. Balance of groundwater potential and water demand

As described in 6.4.1., the total pumpage from the Central sub-area has exceeded the groundwater development potential by 1991, resulting in a excessive lowering of groundwater level and the level of Asososca Lake. However, since the potential of the Eastern sub-area is big enough to compensate the minus potential of the Central sub-area, the development potential amount is still maintained when the total potential is compared with the

Table 6.4.2 Balance of groundwater potential and total demand in Central and Eastern sub-area

unit:MGD

| | | 1991 | | 1995 | | 2,000 | |
|---|---|---|---|---|---|---|---|
| | | Central Sub-area | Eastern Sub-area | Central Sub-area | Eastern Sub-area | Central Sub-area | Eastern Sub-area |
| Groundwater Development potential | | 30.11 (41.60) | 78.17 (108.0) | 30.11 (41.6) | 78.17 (108.0) | 30.11 (41.6) | 78.17 (108.0) |
| Sub total | | 108.28MGD (149.6M m³/year) | | 108.28MGD (149.6M m³/year) | | 108.28MGD (149.6M m³/year) | |
| Water Production as of 1991 | Management water supply (District 2-7) | 46.01 | 22.68 | | | | |
| | Rural (Municipal) water supply | -- | 4.81 | | | | |
| | Industrial use | 4.26 | -- | | | | |
| | Agricultural use | -- | 0.90 | | | | |
| | Sub total | 50.27 | 28.39 | | | | |
| | | 78.66MGD (108.67M m³/year) | | | | | |
| | Managua water supply (District 2-7) | 83.18 | | 101.77 | | 129.73 | |
| | Rural (Municipal) water supply | -- | 4.81 | -- | 5.31 | -- | 6.01 |
| | Industrial use | 4.26 | -- | 4.26 | -- | 4.26 | -- |
| | Agricultural use | -- | 0.90 | -- | 0.90 | -- | 0.90 |
| | Sub total | 93.16 MGD (128.70M m³/year) | | 112.24 MGD (155.0M m³/year) | | 140.90 MGD (194.68M m³/year) | |
| Balance of Production-Potential (1991) | | -20.16 | +49.78 | | | | |
| | | +29.62 MGD (+40.93 M m³/year) | | | | | |
| Balance of Demand-potential | | +15.13 MGD (+20.90 M³/year) | | -3.96 MGD (-5.47 M³/year) | | -32.62 MGD (-45.07 M³/year) | |

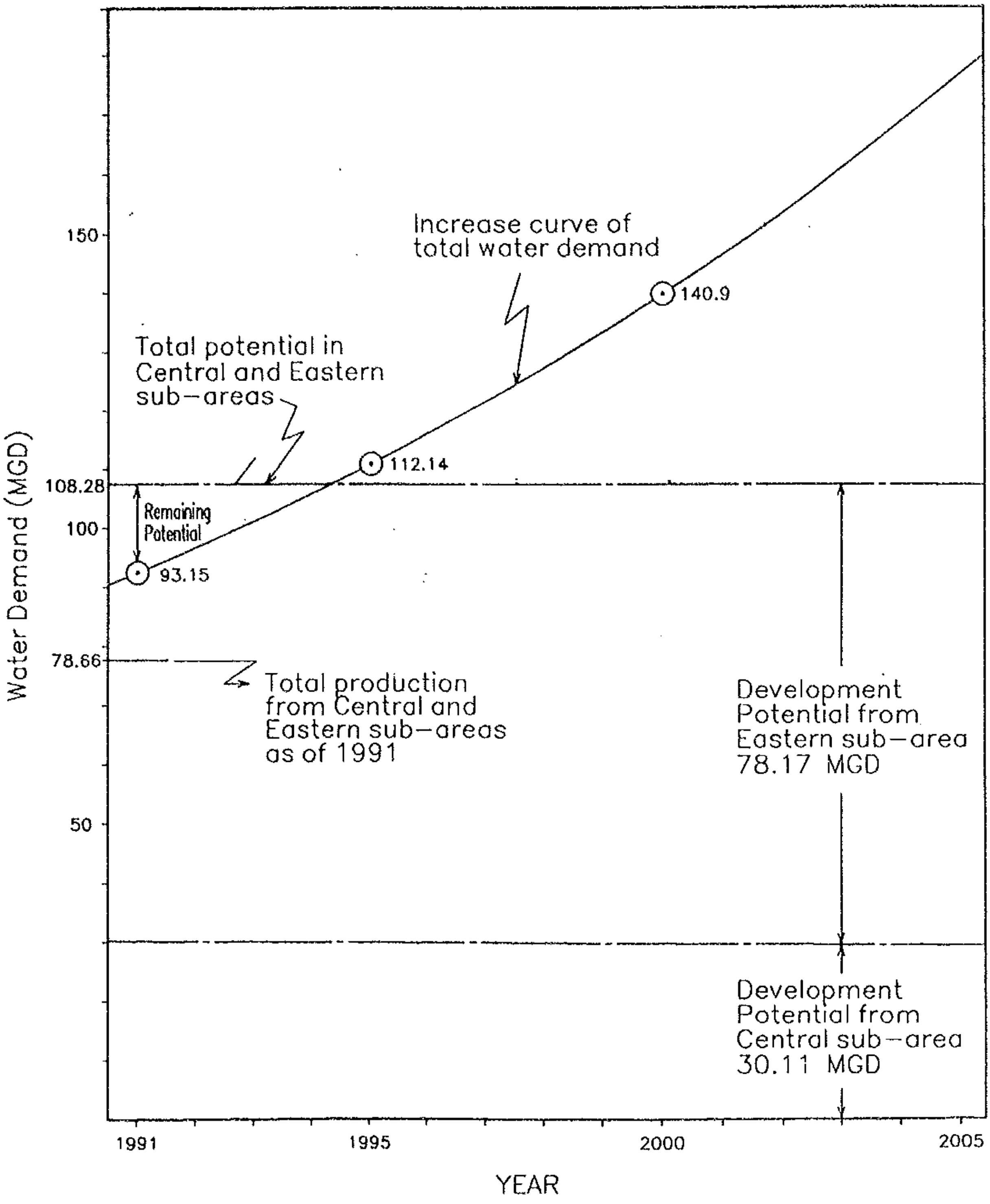



Fig. 6.4.1 Relation between water demand and development potential in the Central and Eastern sub-areas

total demands of the two sub-areas as of 1991, with a remaining potential of 15.13 MGD. But, the increasing demand will exceed the development potential, before 1995, as shown in Table 6.4.3 and Fig. 6.4.2.

When the balance between the potential and the demand in Managua water supply is concerned, the Table 6.4.2 and Fig. 6.4.1 are replaced by Table 6.4.3 and Fig. 6.4.2 by putting aside the other demands than Managua water supply.

Table 6.4.3 Balance of groundwater potential and water demand for Managua water supply in Central and Eastern sub-area

unit: MGD, (million $m^3$/year)

| | 1991 | 1995 | 2000 |
|---|---|---|---|
| Groundwater development potential allocated to Managua water supply | 98.31 (135.83) | 97.81 (135.14) | 97.11 (134.17) |
| Water demand in Managua water supply (Disrict 2-7) | 83.18 (114.93) | 101.77 (140.61) | 129.73 (179.24) |
| Balance of Demand-Potential | 15.13 (20.90) | -3.96 (-5.47) | -32.62 (-45.07) |

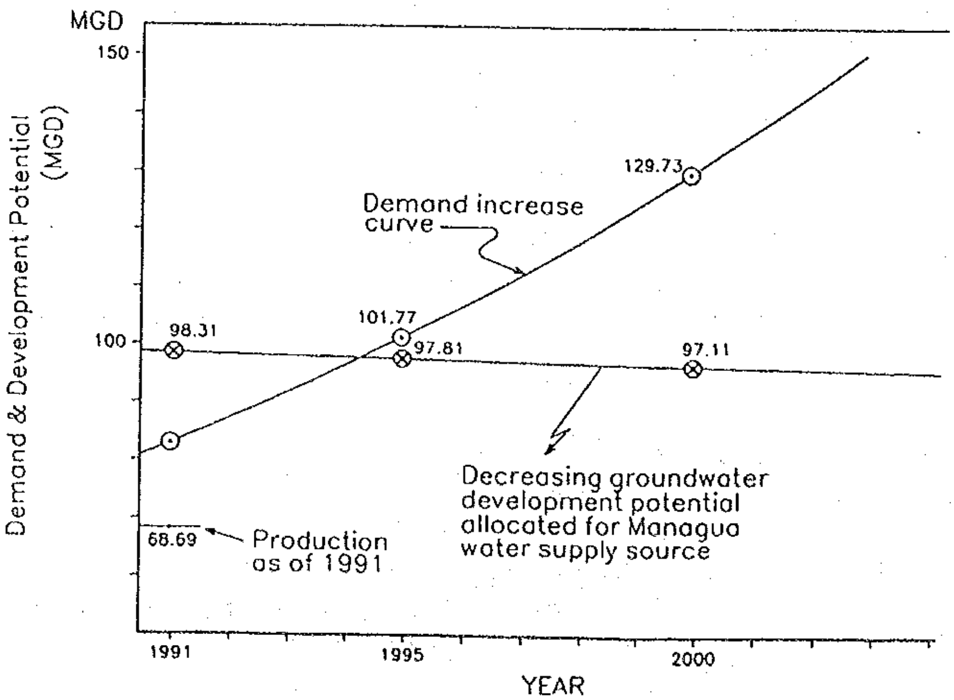



Fig. 6.4.2 Relation between demand and development potential for Managua water supply

### 6.4.4 Groundwater development from Eastern sub-area

In order to meet the demand of 129.73 MGD in 2000, the additional source is necessary to be developed from outside of the Study area after full development from the Eastern sub-area, because the total development potential of the Central and Eastern sub-area is limited to an amount of 108.28 MGD, of which the potential to be allocated to the Managua water supply is 97.11 MGD (11.17 MGD is for other demands like rural water supply and industrial/agricultural use).

The development potential of the Eastern sub-area is an amount up to 78.17 MGD, of which 71.26 MGD can be used as the source of Managua water supply.

The groundwater development from the Eastern sub-area will be attained in the following two phases:

Phase 1: It is planned as an urgent supply plan to solve the present severe problems of supply shortage such as periodical water suspention in the entire service area and too short supply especially to the highest zone. An amount of 18.74 MGD is to be developed by 1996.

Phase 2: The amount within the remaining potential of the Eastern sub-area (29.84 MGD out of 71.26 MGD) is planned to be fully developed in order to meet the water demand of 2000 as much as possible. If the remaining potential of the Eastern sub-area at an amount of 29.84 MGD will be fully developed, the total production from the Central and Eastern sub-area will come to 117.27 MGD, which is 12.46 MGD shorter than the demand (129.73MGD) in 2000. However, the use of the developed water from the Eastern sub-area depends on how the over-pumpage problem in the Centrarl sub-area is dealt with. The development plan will be, therefore, selected from the following three alternatives in connection with the over-pumpage in the Central sub-area.

Alternative 1: The over-pumpage condition is to be eliminated by 2000, that is, the over-pumped water in the Central sub-area is to be replaced by the developed water from the Eastern sub-area at an amount of 20.16 MGD. In this case, only 9.68 MGD can be used for the additional supply source, and the water source which should be supplemented from outside of the Study area in order to meet the demand in 2000 amounts to 32.62 MGD.

Alternative 2: About half of the over-pumped water (10.16 MGD out of 20.16 MGD) is to be substituted by the developed water from the Eastern sub-area, resulting that an amount of 19.68 MGD can be used for additional supply source. In this case, the supplementary water source required from outside of the Study area will amount also to 32.62 MGD, of which 10 MGD will be used for replacement of over-pumped water.

Alternative 3: The over-pumping in the Central sub-area shall be dealt with after 2000, that is, the all of the developed water from the Eastern sub-area (29.84 MGD) will be used for the additional supply source, and an amount of 20.16 MGD out of 32.62 MGD developed from outside of the Study area shall be used for the substitution of the over-pumped water.

In this development plan, the Alternative 3 is to be selected from viewpoint that the sooner achievement of the supply plan is put priority rather than the mitigation of the over-pumping condition.

### 6.4.5 Mitigation of over-pumping in Central sub-area

The over-pumpage condition in the Central sub-area should be counteracted sooner or later in order to avoid the fear of contaminated water intrusion from the Lake Managua by reverse groundwater flow. However, since some safety factor is involved in the water balance analysis such as no counting of recharge by leakage water from the distribution pipes, the elimination of over-pumpage is not very urgent, so long as groundwater development in this Central sub-area is kept at the same amount (46.01 MGD) as of 1991. That is why the use of developed water is planned fully as a supplement of the supply source and not as a replacement for the over-pumped amount of water in the Central sub-area.

A detailed study on pumpage reduction at the Central subarea is necessary. The over-pumped volume shall be replaced by the supply from the source developed outside of the Study area. The analysis of the monitoring data on groundwater level may be great help to determine how and when over pumping should be mitigated.

The natural decrease in pumping from the aged wells located in the Central sub-area is suggested as one of the methods to solve the problem. In this connection, it is recommended that the wells located in the Central sub-area are excluded from the well rehabilitation program.

## 6.5 Selected Well Fields in the Study Area

The two sites of good hydrogeological condition in the Eastern sub-area have been selected as the group well construction fields in order to effectively develop groundwater from the area.

One is the area around Sabana Grande-Veracruz, and another is the area between north of Ticuantepe and Veracrruz as shown in Fig. 6.6.3.

Characteristics of both sites are tabulated below:

Table 6.5.1 Characteristics of the selected well fields

| | Sabana Grande | North Ticuantepe |
|---|---|---|
| Aquifer geology | Masaya Group volcanic in Middle Las Sierras Group | Various volcanic materials in Middle las Sierras Group |
| Static water level | 15 - 45 m BGS | 95 - 100 m BGS |
| Specific capacity | 600 - 1000 $m^3$/day/m | More than 10,000 $m^3$/day/m (Negligible drawdown at a pumping rate of 1500 $m^3$/day) |
| Water quality | good | excellent |
| Well depth to be drilled | 150 - 200 m | 200 - 250 m |
| Ground elevation | 80 - 130 m | 150 - 270 m |
| Appropriate supply area | Low and high zones (to Las America No. 4 reservoir) | Highest zone (To Altamira reservoir) |
| Potential of further development for Urban water supply | 80,000 - 120,000 $m^3$/d | 70,000 - 100,000 $m^3$/d |
| | Total 184,000 $m^3$/d (48.58 MGD) | |

In consideration of the urgent supply to the highly elevated area, the North Ticuantepe area is preferable to be developed earlier than the Sabana Grande area, because water transmission to the reservoir Km 8 from Ticuantepe area is more cost-effective than from Sabana Grande area as shown in Fig. 6.5.1

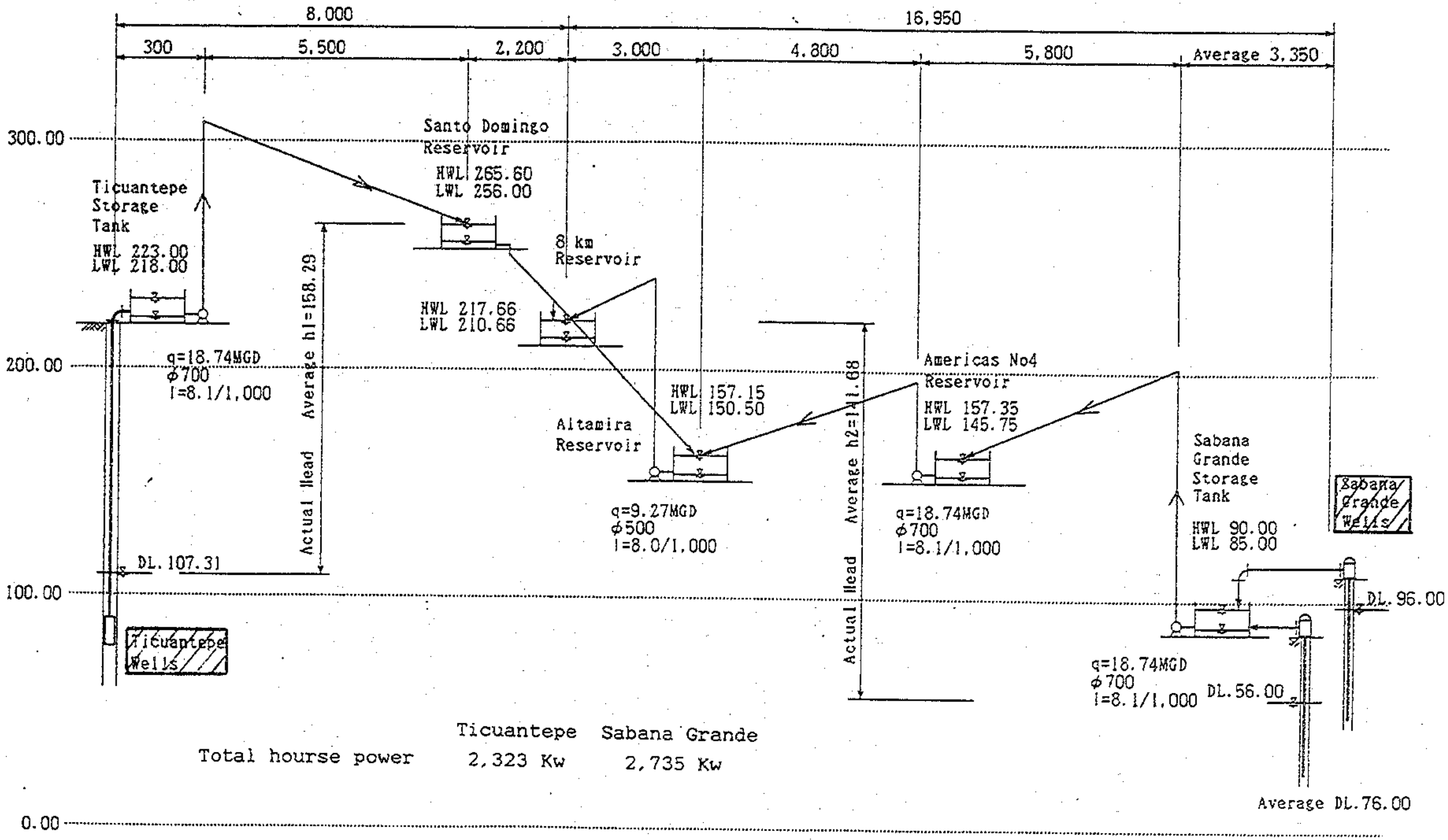



Fig. 6.5.1 Comparison of cost-effectiveness between Ticuantepe and Sabana Grande for transmission to Km 8 reservoir

## 6.6 Implementation Plan

### 6.6.1 Outline and Implementation Schedule of the Project

The Project of groundwater development is to be divided into three phases, as shown in Fig. 6.6.1, to meet the demand in 2000.

Phase 1 of the Project is focused on the urgent improvement of the insufficient service level of the present water supply. A condition that would produce an amount of 18.74 MGD is to be developed in one of the two promising areas in the Eastern sub-area (North Ticuantepe area), at least to mitigate the inconveniences of the periodical water suspension and unfair (too short) supply to highly elevated areas.

Phase 2 of the Project is focused on a full-scale groundwater development in the other promising area in the Eastern sub-area (Sabana Grande-Verasquez area), to produce the remaining development potential of the Eastern sub-area which is a maximum of 29.84 MGD, in order to catch up with the demand in the year 2000 as much as possible.

The remaining required amount of water will be produced by developing water supply sources outside the Study area in the 3rd project phase. The required additional amount of water to be produced to meet the demand in 2000 falls within the range of 12.46 and 32.62 MGD, depending on how the over pumpage condition in the Central sub-area is treated. Since the groundwater development potential in the area outside of the Study area is unknown, the 3rd phase of the Project is divided into two stages, namely the study stage and construction stage. The following two items should be studied prior to the construction stage:

(1) Groundwater development potential of the area

(2) Determination of when and how to replace the over pumped amount of water from the Central sub-area with the water from newly developed sources by analyzing the results of groundwater monitoring undertaken since 1992.

The relation between water demand, production and groundwater potential is schematically shown in Fig. 6.6.1 and Fig. 6.6.2.

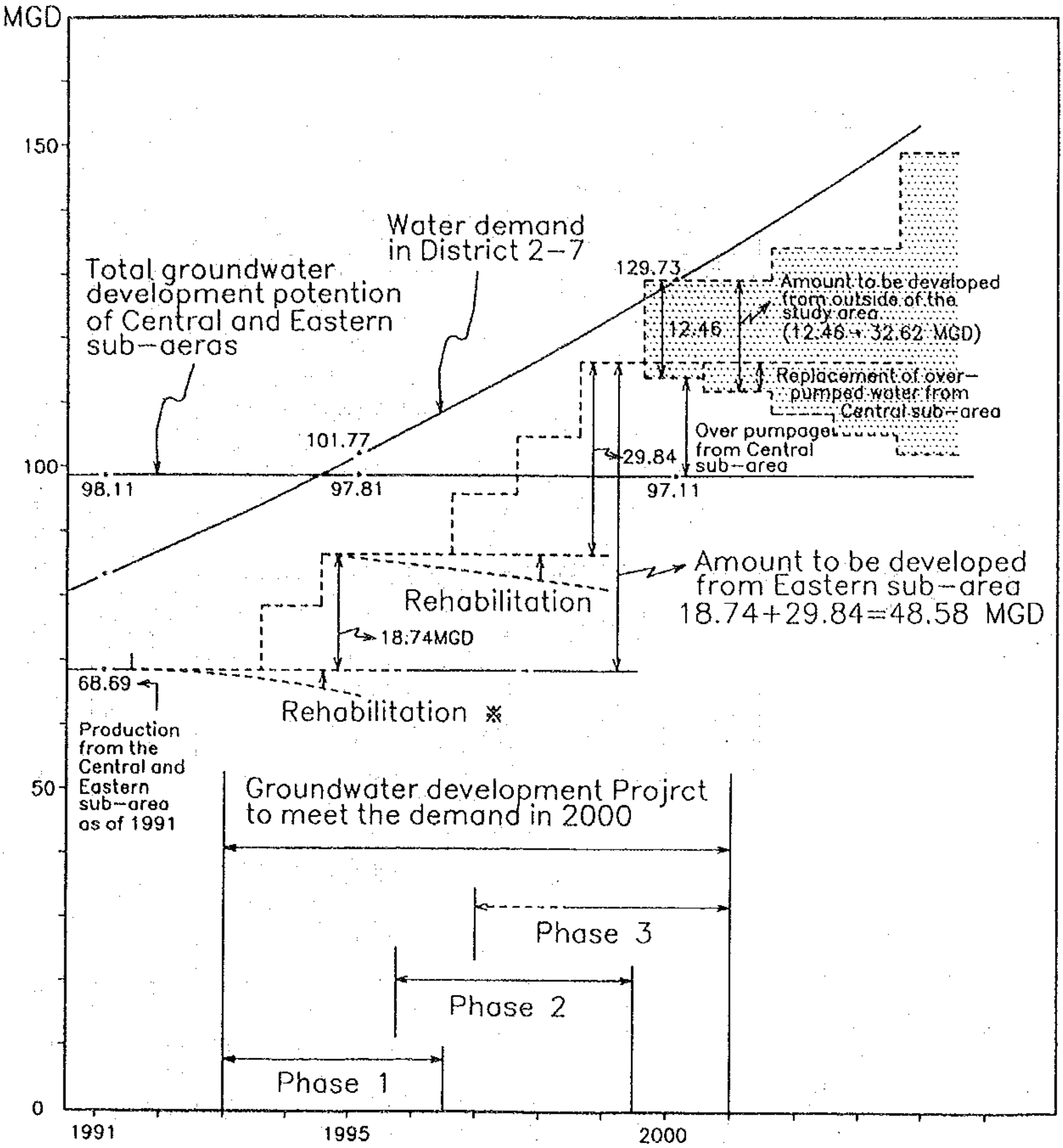



Fig.6.6.1 Project Implementation Phases and Relation between Demand and Production

※ Well rehabilitation is recommended to limit to recovering the original capacity of the(aged)wells,especially those in the Central Sub−area,so as not to exacerbate the over−pumping of 20.16 MGD

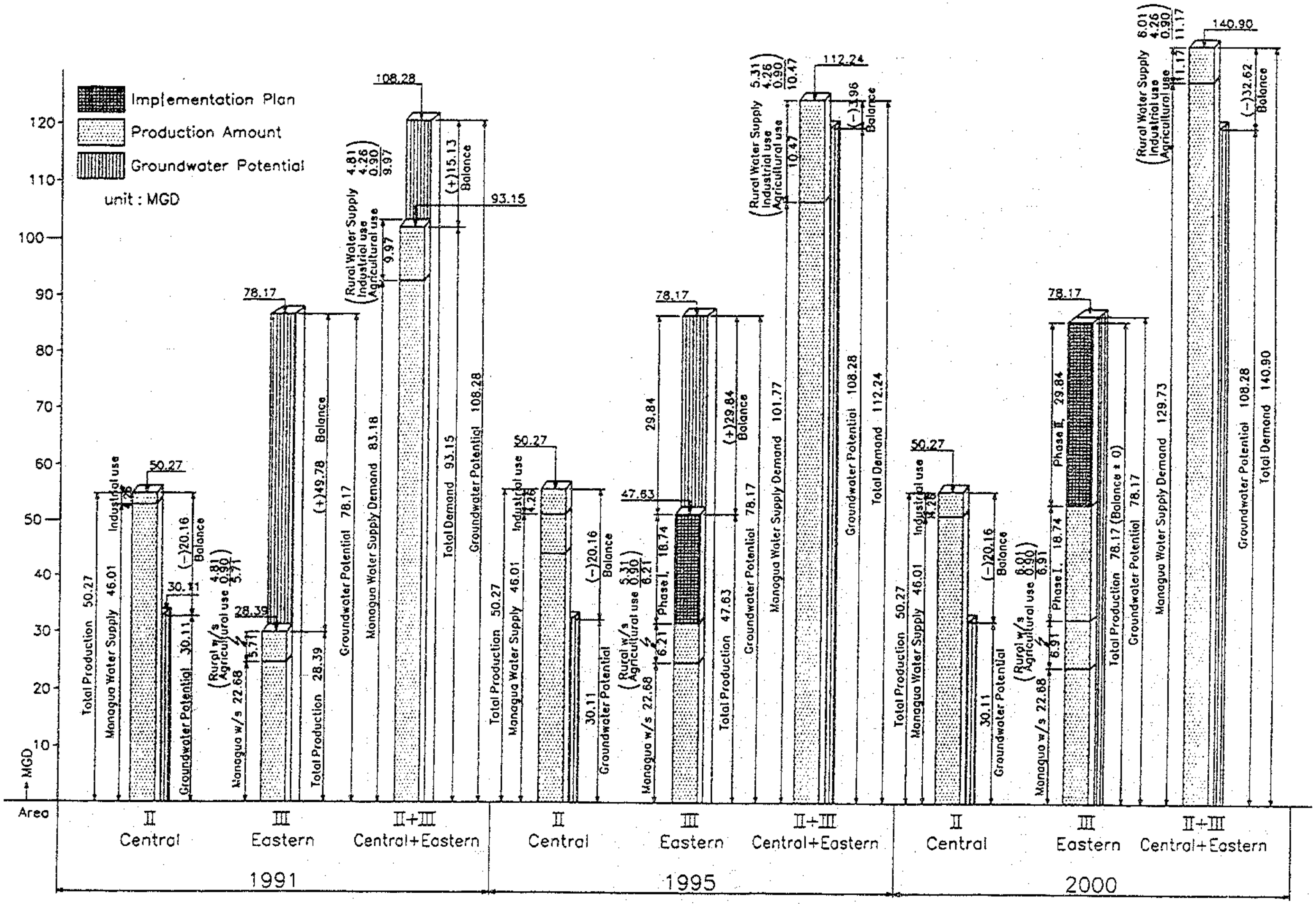



Fig.6.6.2 Relation between groundwater potential, water demands and production

The scope of the Project, through all phases, is limited to increase in water production by well construction and the construction of conveyance facilities from the wells to the existing major reservoir tanks. The expansion of rehabilitation of the distribution facilities should be covered by other different projects.

In phase 1, since one of the major purposes of this urgent program s to eliminate the unfair supply of water to highly elevated areas, the water developed from a comparatively higher area in North Ticuantepe is to be transmitted to the Altamira reservoir where water is presently pumped up to the highly elevated areas.

The area supplied with water from the distribution tank of Altamira reservoir will be expanded to the west and south, thus also covering parts of the area served by the Asososca water supply as illustrated in Fig. 6.6.5(3). Also increase in the inflow of Altamia reservoir will lighten the burden of the distribution reservoirs of San Cristobal and las Americas No. 4, resulting in the increase in distribution amount in the Low and High zone. The variations from Fig. 6.6.5(1) to 6.6.5(3) indicate not only variations in service area but also increase in the supply amount in almost the entire service area, thus eliminating periodical water suspension.

In the 2nd phase of the Project, the developed groundwater from the lower area of Sabana Grande-Veracruz area is to be transmitted to Las Americas No. 4 reservoir.

By increasing the quantity of water coming into Las Americas No. 4 distribution tank, the supply area from this reservoir will be expanded to the west resulting in a considerable increase in the supply amount for the entire service area. The comparison of Fig. 6.6.5(3) and Fig. 6.6.5(2) indicates the above variation.

However, the capacity of the existing major reservoirs, especially Las Americas No. 4, does not seem to be enough to receive all of the newly developed water. Therefore, the new reservoir installation near Las Americans No. 4 or the direct connection of Las Americas No. 4 with Altamira reservoir is believed necessary; this should be covered also by a different project beforehand or in parallel with the phase 3 of the Project.

In consideration of the presumed shortage in the capacity of Las Americas No. 4 reservoir, a big capacity reservoir tank is to be designed in phase 2 of the Project at least to supplement the capacity of Las Americas No. 4 reservoir to receive an amount of 29.84 MGD.

### 6.6.2 Facility plan for the 1st and 2nd phase of the Project

Fig. 6.6.4 represents the total facilities to be constructed in the phase 1 and phase 2 of the Project, and the outline of the facility plan for each of the phase is as follows:

1) Facility plan for phase 1 of the Project

The new water supply sources producing an amount of 18.74 MGD are the fourteen (14) borehole wells to be drilled in the area of North Ticuantepe is once transmitted to the two sets of newly constructed tanks on the hill (Santo Domingo reservoirs).

The reserved water in the hill top reservoir (Santo Domingo) is then transmitted by natural flow down to the existing Altamira reservoir. On the way to the Altamira reservoir, the transmission line can be branched to the reservoir of Km 8 also through natural flow.

The number, dimension/capacity and general specification designed for each of the facility are as follows:

a. Well:

| | | |
|---|---|---|
| Casing diameter | : | 12 inches or more |
| Drilling depth | : | 200 - 250 (dynamic water level 100 - 110m) |
| Pumping discharge | : | 3.79 $m^3/min$ at total head of 117m |
| Pump type | : | Submersible motor pump |
| Number of wells | : | 14 wells |
| Location arrangement | : | Grouped wells within $1km^2$ |

b. Storage tanks beside the well group:

| | | |
|---|---|---|
| Material | : | Concrete made |
| Capacity | : | 1,500 $m^3$ (Retention time: 0.5 hours) |
| Ground elevation | : | 217 m |
| Number | : | 2 sets |

c. Pump station with chlorinator and electricity controller

| | | |
|---|---|---|
| Transmission pump | : | 12.5 $m^3$/min. with total head of 82 m |
| Number of pump | : | 5 sets (one is for spare) |
| Chlorination facility | : | 1 set |
| Pump house with electricity control panel | : | 1 set |

d. Santo Domingo reservoir tank:

| | | |
|---|---|---|
| Material | : | Prestressed Concrete or Iron reinforced concrete |
| Capacity | : | 11,000 $m^3$ 7.5-hour retention by two tanks |
| Number of tanks | : | 2 sets |
| Ground elevation | : | 255 m |

e. Transmission pipe line:

| | | |
|---|---|---|
| Well to storage tank | : | 250 mm L=1300m |
| Pump station to reservoir tank | : | 700mm L=5500m |
| S. Domingo to Altamira | : | 500 - 600mm, L=5200m |
| Material | : | Steel, and ductile iron with cement lining |

2) Facility plan for phase 2 of the Project

The new water supply source is to be developed from the other promising area of Sabana Grande-Veracrus in the Eastern sub-area to produce an amount of 29.84 MGD by drilling nineteen (19) boreholes. The produced amount will be transmitted to the existing reservoir of Las Americas No. 4.

The details of the facilities are as follows:

a. Wells:

| | | |
|---|---|---|
| Casing diameter | : | 12 inches or more |
| Drilling depth | : | 150-200m (dynamic water level 20 - 60m BGS) |
| Pumping discharge | : | 4.1 $m^3$/min |
| Pump type | : | Top driven vertical pump |
| Number of wells | : | 19 wells |
| Location arrangement | : | Grid arrangement with a space of 500m or more. |

b. Reservoir tank:

| | | |
|---|---|---|
| Material | : | Pre-stressed concrete or iron reinforced concrete |
| Capacity | : | 15,000 $m^3$ |
| Number of tanks | : | 2 sets |
| Ground elevation | : | 84 m |

C. Pump station with chlorinator and electricity controller

| | | |
|---|---|---|
| Transmission pump | : | 19.6 $m^3$/min, with total head of 90 m |
| Number | : | 5 units |
| Chlorination facility | : | 1 set |
| Pump house with electricity control panel | : | 1 set |

d. Transmission pipe lines

| | | |
|---|---|---|
| Wells to tank | : | 300 - 800mm, L=12900m |
| New reservoir to Las Americas No.4 | : | 1000 mm, L=5800m |

### 6.6.3 Facility plan for the 3rd phase of the Project

The necessary amount to be produced from outside of the Study area, most probably at the east side of the Study area, falls within the range of 12.46 and 32.62 MGD. The amount that would least satisfy the water demand in 2000 is 12.46 MGD, and some of the water of additionally developed sources up to 20.16 MGD is used to replace the over-pumped amount of water in the Central sub-area.

The groundwater development potential of the eastside of the Study area may not be as high as the Eastern sub-area and moreover, the transportation distance to Managua becomes farther. Therefore, the unit cost of the groundwater development in this area may be 30 to 40 % higher than that in the Eastern sub-area.

The details of the above matters shall be studied in the first stage of the 3rd phase of the Project, however, the facility plan in the implementation of phase 3 may be basically similar to that in phase 2. The followings are the assumed facilities for the 3rd phase of the Project:

| | |
|---|---|
| Wells | : 13 - 34 wells<br>(Discharge of 2.3 $m^3$/min per well) |
| Storage tank | : 2 to 4 sets of 1500 $m^3$ concrete tanks |
| Reservoir tank | : 1 to 2 sets of 11000 $m^3$ concrete tanks |
| Pump station | : 1 main and sub-pump station |
| Transmission pipes | : 250 - 1000 mm<br>L = 20000 - 25000 m |

### 6.6.4 Project cost estimation

#### 1) General

The costs estimated in this Project includes the following items:

(1) Direct construction expenses
(2) Land acquisition expense
(3) Consultation services and administration expenses
(4) Physical contingencies
(5) Price contingencies

Cost estimation was made in every phase of the Project, however, the estimation for phase 3 was conducted differently. Since the 3rd phase of the Project involves a lot of unknown factors concerning both groundwater development potential and the necessary amount to be developed, cost estimation was simply conducted on the basis of the unit price of water developed from Sabana Grande area in the 2nd phase of the Project, and by the assumption that the unit development cost of water from outside of the Study area is 30% higher than that from Sabana Grande area including the expenses for the study in the 1st stage of phase 3.

The construction cost estimation of the 1st and 2nd phases of the Project was performed based on the following conditions:

a. Cost estimation is based on the price rate as of April, 1993.

b. Construction cost is divided into portions of foreign and local currency. Majority of the construction cost falls under foreign portion, and the local portion comprises mainly of land acquisition expenses, the cost of locally available constructing materials and manpower.

c. In conversion of foreign and local currency, the following rate is used:
1 US Dollar = 6.0 Nicaraguan Cordoba = 115 Japanese Yen.

d. The physical contingencies is estimated at 10% of the total of the above (1) to (3) items.

e. The price contingencies is estimated at 8 to 5% in the foreign portion and 20 to 10 % in the local portion of the total of the above (1) to (4) items.

2) Project cost estimated

The estimated costs of the 1st and 2nd phases of the Project are summarized in Table 6.7 and 6.8, and the independent total cost of phase 1 and phase 2 in relation with the unit price of developed water per cubic meter is as follows:

| | Total cost estimated | Amount of water to be developed | Project cost per 1 cubic meter |
|---|---|---|---|
| Phase 1 | C$ 213,187,000 | 71,000 $m^3$/day (18.74 MGD) | C$ 3,003 /(day/$m^3$) |
| Phase 2 | C$ 349,004,000 | 113,000 $m^3$/day (29.84 MGD) | C$ 3,088 /(day/$m^3$) |

By applying the assumption that the water development cost per cubic meter in phase 3 in 30% higher than that in phase 2, the unit price of the development water is assumed as C$ 4,014 day/$m^3$ (C$3,088 day/$m^3$ x 1.3).

Since the amount of water to be developed in the 3rd phase of the Project may fall within the range of 47,000 $m^3$/day (12.46 MGD) and 123,000 $m^3$/day (32.62 MGD), the project cost for phase 3 is considered to range between C$ 188,658,000 and C$ 403,722,000.

Thus, the estimated cost for the groundwater development project to meet the water demand in the year 200 totals a minimum of C$ 747,697,000 (no elimination of over-pumpage from the Central sub-area),and a maximum of C$ 1,052,761,000 (over-pumpage problem is entirely eliminated by this Project).

The expenses for the study, which is necessary prior to the implementation of the 3rd phase of the Project is involved in the above mentioned total project cost.

## Table 6.6.1 Cost estimated for phase 1 and 2 of the Project

PROYECTO DE TICUANTEPE

(Unit: Cordoba)

| Item | 1994 Foreign | 1994 Local | 1994 Total | 1995 Foreign | 1995 Local | 1995 Total | 1996 Foreign | 1996 Local | 1996 Total | 1997 Foreign | 1997 Local | 1997 Total | Total Foreign | Total Local | Total Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A. North Tecuantepe | | | | | | | | | | | | | | | |
| 1. Water Production System | - | - | 0 | 9.937.000 | 1.617.000 | 11.554.000 | 29.810.000 | 4.852.000 | 34.662.000 | 29.810.000 | 4.852.000 | 34.662.000 | 69.557.000 | 11.321.000 | 80.878.000 |
| 2. Transportation System | - | - | 0 | 10.698.000 | 158.000 | 10.856.000 | 42.136.000 | 554.000 | 42.690.000 | 29.561.000 | 396.000 | 29.957.000 | 82.395.000 | 1.108.000 | 83.503.000 |
| 3. Preparation | - | - | 0 | 541.320 | 34.680 | 575.000 | - | - | 0 | - | - | 0 | 518.000 | 58.000 | 576.000 |
| 4. Land Acquisition | - | 1.205.400 | 1.205.400 | - | 1.205.400 | 1.205.400 | - | - | 0 | - | - | 0 | - | 2.410.000 | 2.410.000 |
| 5. Engineering/Administration | 4.367.000 | 238.000 | 4.605.000 | 3.130.000 | 285.600 | 3.415.600 | 3.130.000 | 285.600 | 3.415.600 | 3.130.000 | 285.600 | 3.415.600 | 13.757.000 | 1.094.800 | 14.851.800 |
| Sub Total | 4.367.000 | 1.443.400 | 5.810.400 | 24.306.320 | 3.300.680 | 27.607.000 | 75.076.000 | 5.691.600 | 80.767.600 | 62.501.000 | 5.533.600 | 68.034.600 | 166.227.000 | 15.991.800 | 182.218.800 |
| 6. Physical Contingencies | 436.700 | 144.340 | 581.040 | 2.430.632 | 330.068 | 2.760.700 | 7.507.600 | 569.160 | 8.076.760 | 6.250.100 | 553.360 | 6.803.460 | 16.622.700 | 1.599.180 | 18.221.880 |
| Total | 4.803.700 | 1.587.740 | 6.391.440 | 26.736.952 | 3.630.748 | 30.367.700 | 82.583.600 | 6.260.760 | 88.844.360 | 68.751.100 | 6.086.960 | 74.838.060 | 182.875.352 | 17.566.208 | 200.441.560 |
| 7. Price Contingencies Ratio | 8% | 20% | | 7% | 15% | | 6% | 10% | | 5% | 10% | | | | |
| Grand Total | 5.187.996 | 1.905.288 | 7.093.284 | 28.608.539 | 4.175.360 | 32.783.899 | 87.538.616 | 6.886.836 | 94.425.452 | 72.188.555 | 5.695.656 | 78.884.311 | 193.523.806 | 19.663.140 | 213.186.946 |

PROYECTO DE SABANA GRANDE

(Unit: Cordoba)

| Item | 1998 Foreign | 1998 Local | 1998 Total | 1999 Foreign | 1999 Local | 1999 Total | 2000 Foreign | 2000 Local | 2000 Total | Total Foreign | Total Local | Total Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| B. Sabana Grande | | | | | | | | | | | | |
| 1. Water Production System | 25.128.000 | 3.566.000 | 28.694.000 | 79.141.000 | 10.698.000 | 89.839.000 | 79.141.000 | 10.698.000 | 89.839.000 | 183.410.000 | 24.962.000 | 208.372.000 |
| 2. Transportation System | 10.163.000 | 101.000 | 10.264.000 | 25.407.000 | 84.000 | 25.491.000 | 35.570.000 | 151.500 | 35.721.500 | 71.140.000 | 303.000 | 71.443.000 |
| 3. Preparation | 388.000 | 44.000 | 432.000 | - | - | - | - | - | 0 | 388.000 | 44.000 | 432.000 |
| 4. Land Acquisition | - | 2.324.700 | 2.324.700 | | 2.324.700 | 2.324.700 | | | | - | 4.649.000 | 4.649.000 |
| 5. Engineering/Administration | 3.130.000 | 285.600 | 3.415.600 | 3.130.000 | 285.600 | 3.415.600 | 3.130.000 | 285.600 | 3.415.600 | 9.390.000 | 856.800 | 10.246.800 |
| Sub Total | 38.809.000 | 6.321.300 | 45.130.300 | 107.678.000 | 13.392.300 | 121.070.300 | 117.841.000 | 11.135.100 | 128.976.100 | 264.328.000 | 30.814.800 | 295.142.800 |
| 6. Physical Contingencies | 3.880.900 | 632.130 | 4.513.030 | 10.767.800 | 1.339.230 | 12.107.030 | 11.784.100 | 1.113.510 | 12.897.610 | 26.432.800 | 3.081.480 | 29.514.280 |
| Total | 42.689.900 | 6.953.430 | 49.643.330 | 118.445.800 | 14.731.530 | 133.177.330 | 129.625.100 | 12.248.610 | 141.873.710 | 290.760.800 | 33.933.570 | 324.694.370 |
| 7. Price Contingencies Ratio | 8% | 20% | | 7% | 15% | | 6% | 10% | | | | |
| Grand Total | 46.105.092 | 8.344.116 | 54.449.208 | 126.737.006 | 16.941.260 | 143.678.266 | 137.402.606 | 13.473.471 | 150.876.077 | 310.244.704 | 38.758.847 | 349.003.551 |

Table 6.6.2 Construction cost for phase 1 of the Project

North Tecuantepe (Unit:1000xCordoba)

| Item | | Foreign | Local | Total |
|---|---|---|---|---|
| 1. Water Production System | | | | |
| (1) Well Drilling<br>Casing pipe, Strainer pipe, Transportation, Pumping test, etc. | 14 Nos. | 11,408 | 520 | 11,928 |
| (2) Installation of Pump/Motor<br>accesary, cable, etc.<br>control panel | 14 Nos. | 13,671 | 76 | 13,747 |
| (3) Connecting Pipe Line 300mmφ | 1300 m | 1,754 | 96 | 1,850 |
| (4) Storage Tanke 1500 m3 | 2 Nos. | 6,696 | 504 | 7,200 |
| (5) Field Expenses | | 9,785 | 3,449 | 13,234 |
| (6) Packing & Transportation | | 15,377 | 6,566 | 21,943 |
| (7) Temporary Work | | 1,473 | 111 | 1,584 |
| (8) Overhead Expenses | | 9,392 | 0 | 9,392 |
| Sub Total | | 69,557 | 11,321 | 80,878 |
| 2. Transportation System | | | | |
| (1) Pump/Installation<br>valve, pipe, crane 3ton, etc. | 5 Nos | 9,047 | 21 | 9,068 |
| (2) Electric Facilities | 1 unit | 19,167 | 23 | 19,190 |
| (3) Pump House 240 m2 | 1 unit | 900 | 8 | 908 |
| (4) Chlorinator | 2 Nos | 340 | 1 | 341 |
| (5) Transportation Pipe Line | 10,700m | 16,622 | 112 | 16,734 |
| (6) Reservoir 11000 m3 | 2 Nos. | 36,319 | 943 | 37,262 |
| Sub Total | | 82,395 | 1,108 | 83,503 |
| 3. Preparation<br>Preparation<br>Land preparation, etc. | 16,000 m3 | 518 | 58 | 576 |
| 4. Land Acquisition | 70,000 m2 | 0 | 2,410 | 2,410 |
| Grand Total | | | | 167,367 |

Table 6.6.3 Construction cost for phase 2 of the Project

Sabana Grande (Unit: 1000 Cordoba)

| Item | No. | Foreign | Local | Total |
|---|---|---|---|---|
| 1. Water Production System | | | | |
| (1) Well Drilling<br>Casing pipe, Strainer pipe, Transportation, Pumping test, etc. | 19 Nos. | 14,073 | 480 | 14,553 |
| (2) Installation of Pump/Motor<br>accesary, cable, etc.<br>control panel<br>Power Supply Facilities<br>Transmission line, etc. | 19 Nos.<br><br><br>19,900 m | 51,694 | 286 | 51,980 |
| (3) Connecting Pipe Line 300mmφ | 19,900m | 18,636 | 1,022 | 19,658 |
| (4) Pump House | 19 Nos. | 794 | 42 | 836 |
| (5) Storage Tanke 15,000 m3<br>Water gauge, etc. | 2 Nos. | 47,798 | 4,021 | 51,819 |
| (6) Field Expenses | | 9,785 | 4,046 | 13,831 |
| (7) Packing & Transportation | | 25,417 | 14,941 | 40,358 |
| (8) Temporary Work | | 1,647 | 124 | 1,771 |
| (9) Overhead Eexpenses | | 13,566 | 0 | 13,566 |
| Sub Total | | 183,410 | 24,962 | 208,372 |
| 2. Transportation System | | | | |
| (1) Pump/Installation<br>valve, pipe, crane 3ton, etc. | 5 unit | 13,029 | 31 | 13,060 |
| (2) Electric Facilities | 1 unit | 34,040 | 41 | 34,081 |
| (3) Pump House 495 m2 | 1 unit | 1,767 | 15 | 1,782 |
| (4) Chlorinator | 2 set | 340 | 1 | 341 |
| (5) Transportation Pipe Line | 5800m | 21,963 | 148 | 22,111 |
| Sub Total | | 71,140 | 303 | 71,443 |
| 3. Preparation<br>Preparation<br>Land preparation, etc. | 12,000 m2 | 388 | 44 | 432 |
| 4. Land Acquisition | 270,000 m2 | | 4,649 | 4,649 |
| Grand Total | | | | 284,896 |

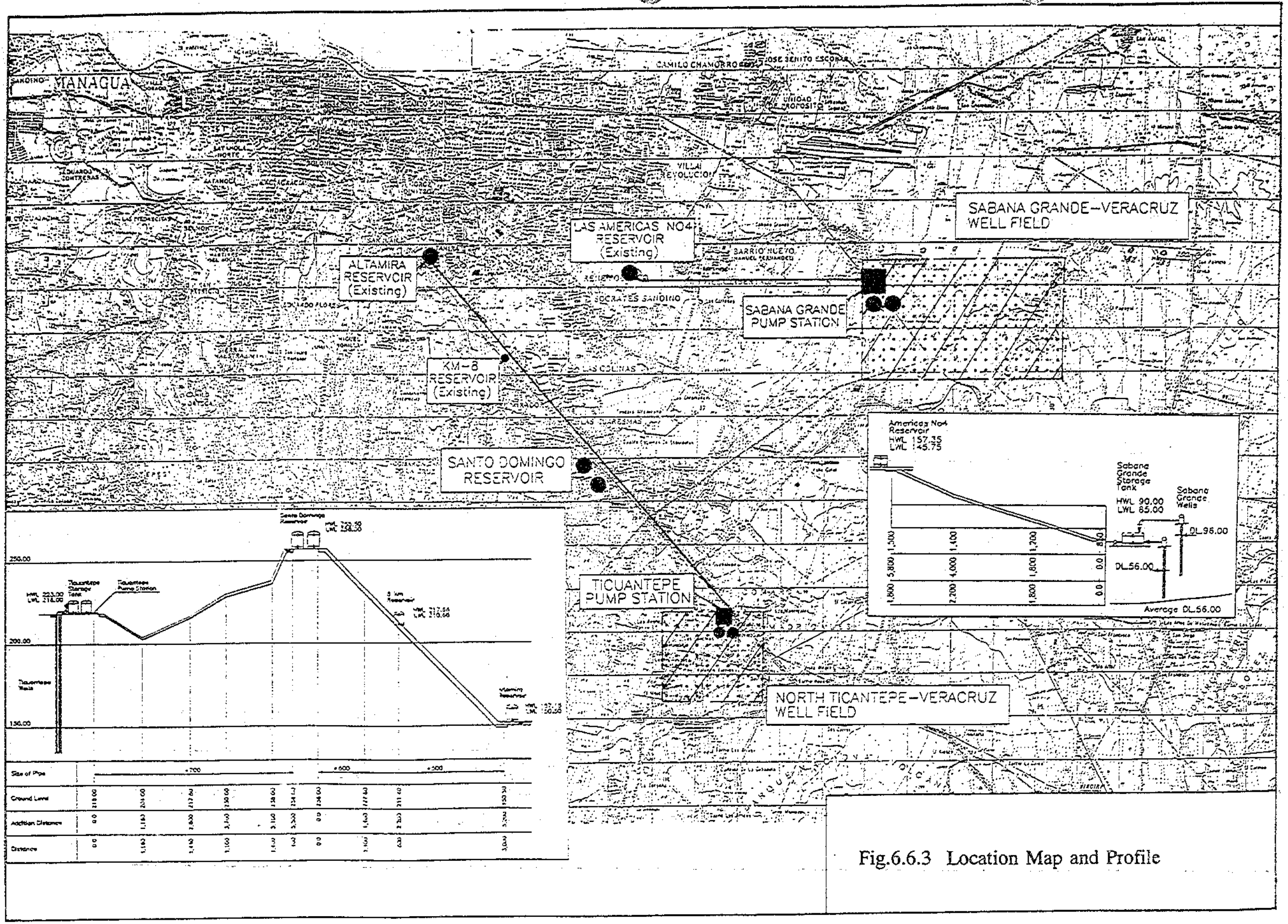
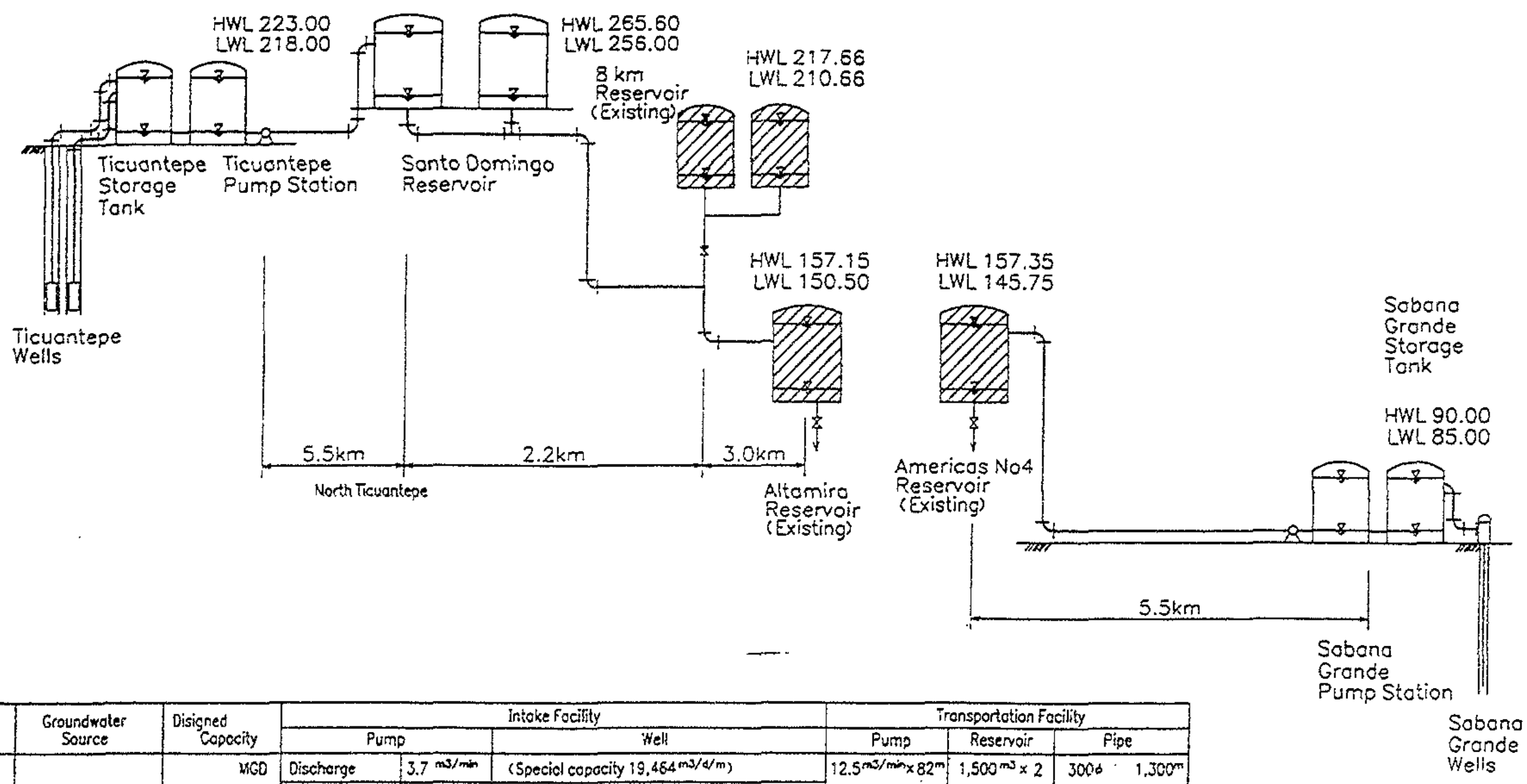


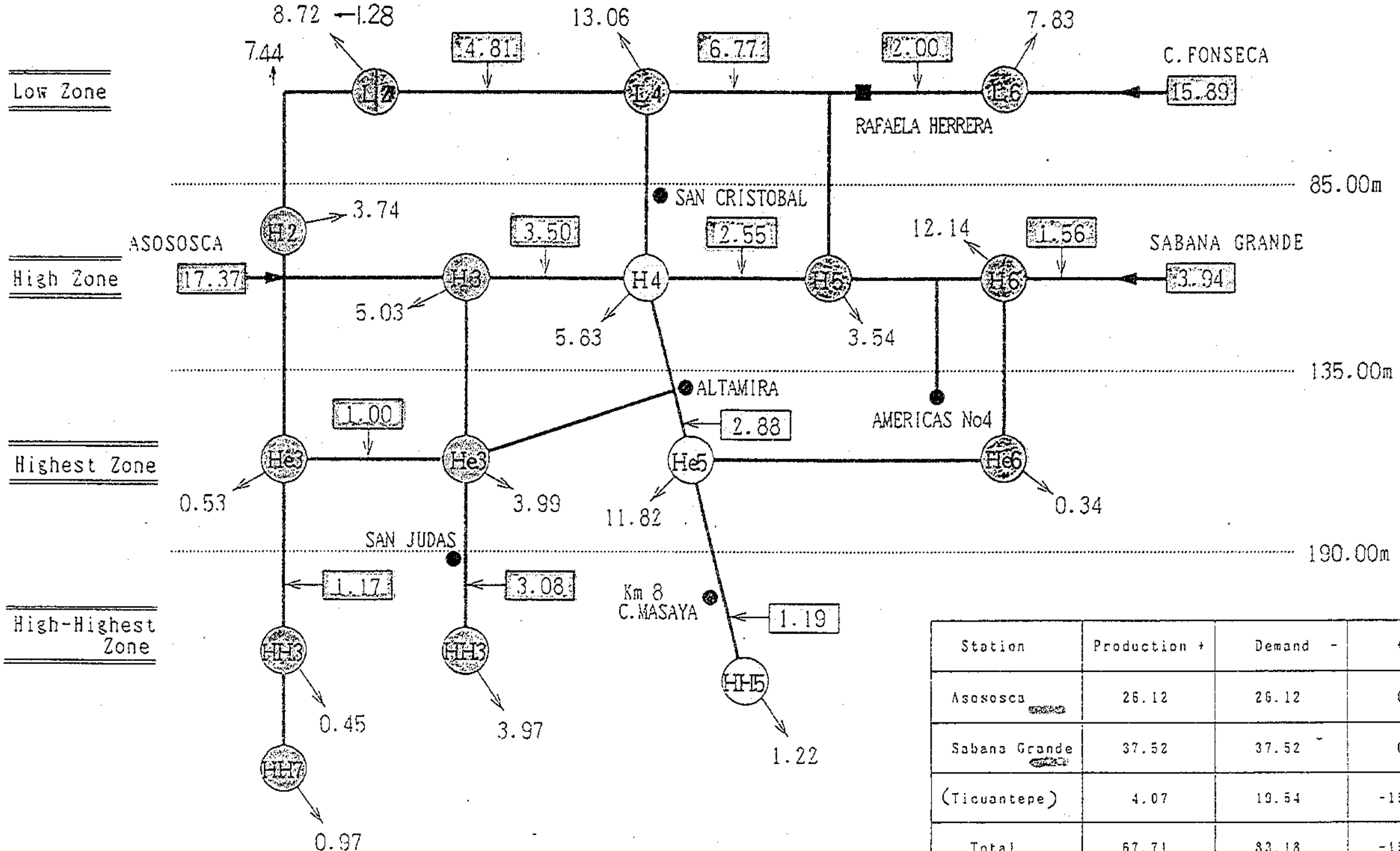

Fig.6.6.3 Location Map and Profile




| Phase | Groundwater Source | Disigned Capacity | Intake Facility: Pump | | Intake Facility: Well | Transportation Facility: Pump | Transportation Facility: Reservoir | Transportation Facility: Pipe |
|---|---|---|---|---|---|---|---|---|
| I | North Ticuantepe – Veracug | MGD 18.74 | Discharge | 3.7 m3/min | (Special capacity 19,464 m3/d/m) | 12.5 m3/min x 82m | 1,500 m3 x 2 | 300φ 1,300m<br>500φ 3,800m<br>600φ 1,400m<br>700φ 5,500m<br>total 12,000m |
| | | | Head | 117.0 m | (Dynamic water level EL.107m) | 1800 rpm x 250 kw | 11,000 m3 x 2 | |
| | | | Pump diameter | 8 inch | Well diamiter 14"~12 3/4" | Pump House | | |
| | | | Horse Power | 132 kw | Well location arrengiment | 240 m2 x 1 | | |
| | | | Rotation | 3600 rpm | group wells, 250m depth | 40 m2 x 14 | | |
| | | | Number of Unit | 14 unit | Number of well 14 unit | 5 unit | | |
| II | Sabana Grande – Veracug | 29.84 | Discharge | 4.1 m3/min | (Special capacity 687 m3/d/m) | 19.6 m3/min x 90m | 15,000 m3 x 2 | 300φ 700m<br>400φ 3,700m<br>450φ 2,000m<br>500φ 1,000m<br>600φ 1,500m<br>700φ 2,000m<br>800φ 1,000m<br>1000φ 5,800m<br>total 17,700m |
| | | | Head | 45.0 m | (Dynamic water level EL.56-96m) | 1800 rpm x 400 kw | | |
| | | | Pump diameter | 8 inch | Well diamiter 14"~12 3/4" | Pump House | | |
| | | | Horse Power | 55 kw | Well location arrengiment | 490 m2 x 1 | | |
| | | | Rotation | 1800 rpm | 500 interval, 200m depth | 40 m2 x 19 | | |
| | | | Number of Unit | 19 unit | Number of well 19 unit | 5 unit | | |

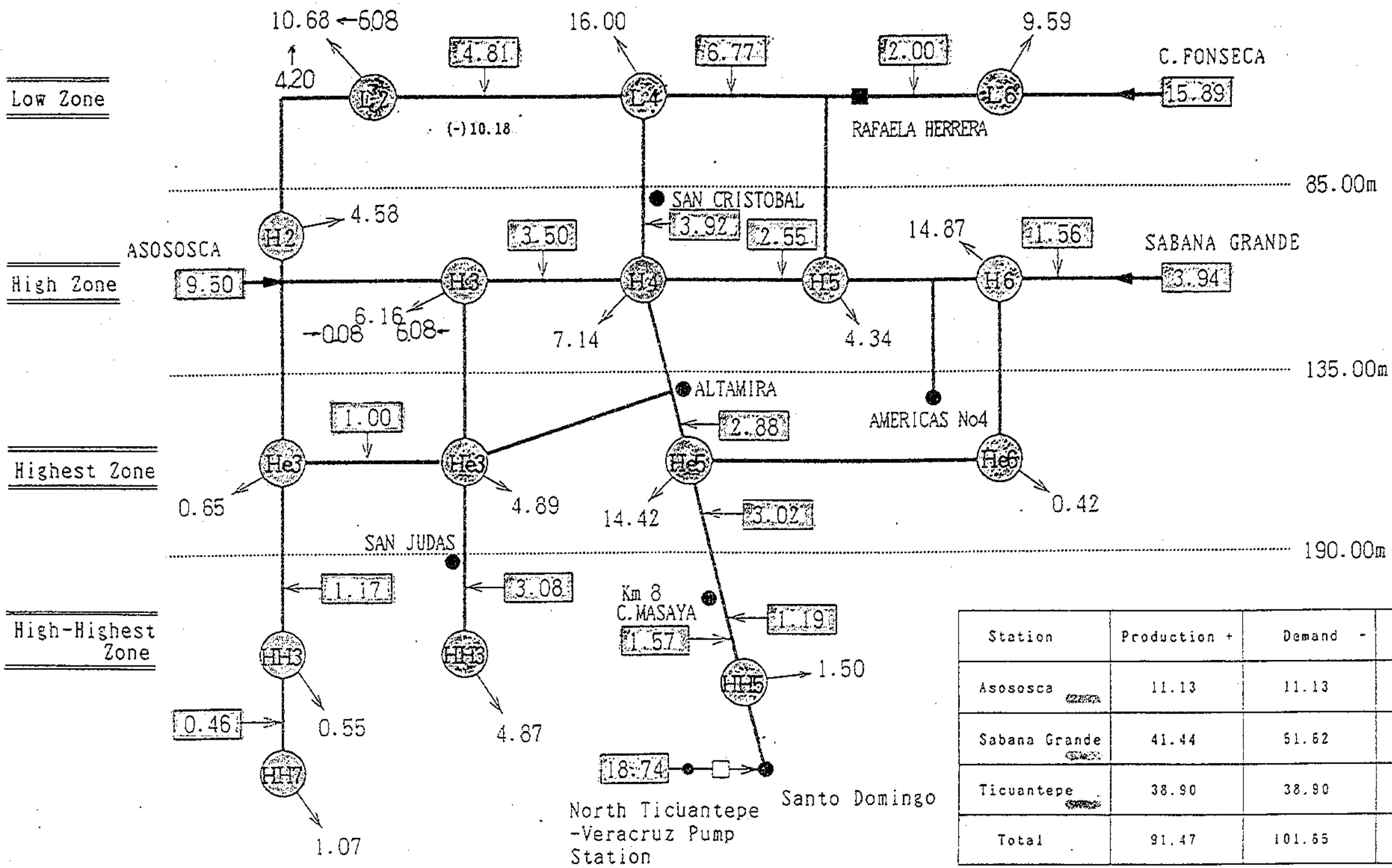
Fig. 6.6.4

Total facility plan for phase 1 and 2 of the Project




| Station | Production + | Demand - | + - |
|---|---|---|---|
| Asososca | 26.12 | 26.12 | 0.00 |
| Sabana Grande | 37.52 | 37.52 | 0.00 |
| (Ticuantepe) | 4.07 | 19.54 | -15.47 |
| Total | 67.71 | 83.18 | -15.47 |

Fig.6.6.5.(1) **General distribution system as of 1991**




| Station | Production + | Demand - | + - |
|---|---|---|---|
| Asososca | 11.13 | 11.13 | 0.00 |
| Sabana Grande | 41.44 | 51.62 | -10.18 |
| Ticuantepe | 38.90 | 38.90 | 0.00 |
| Total | 91.47 | 101.65 | - 10.18 |

Fig.6.6.5.(2) **General distribution system after phase 1 of the Project**

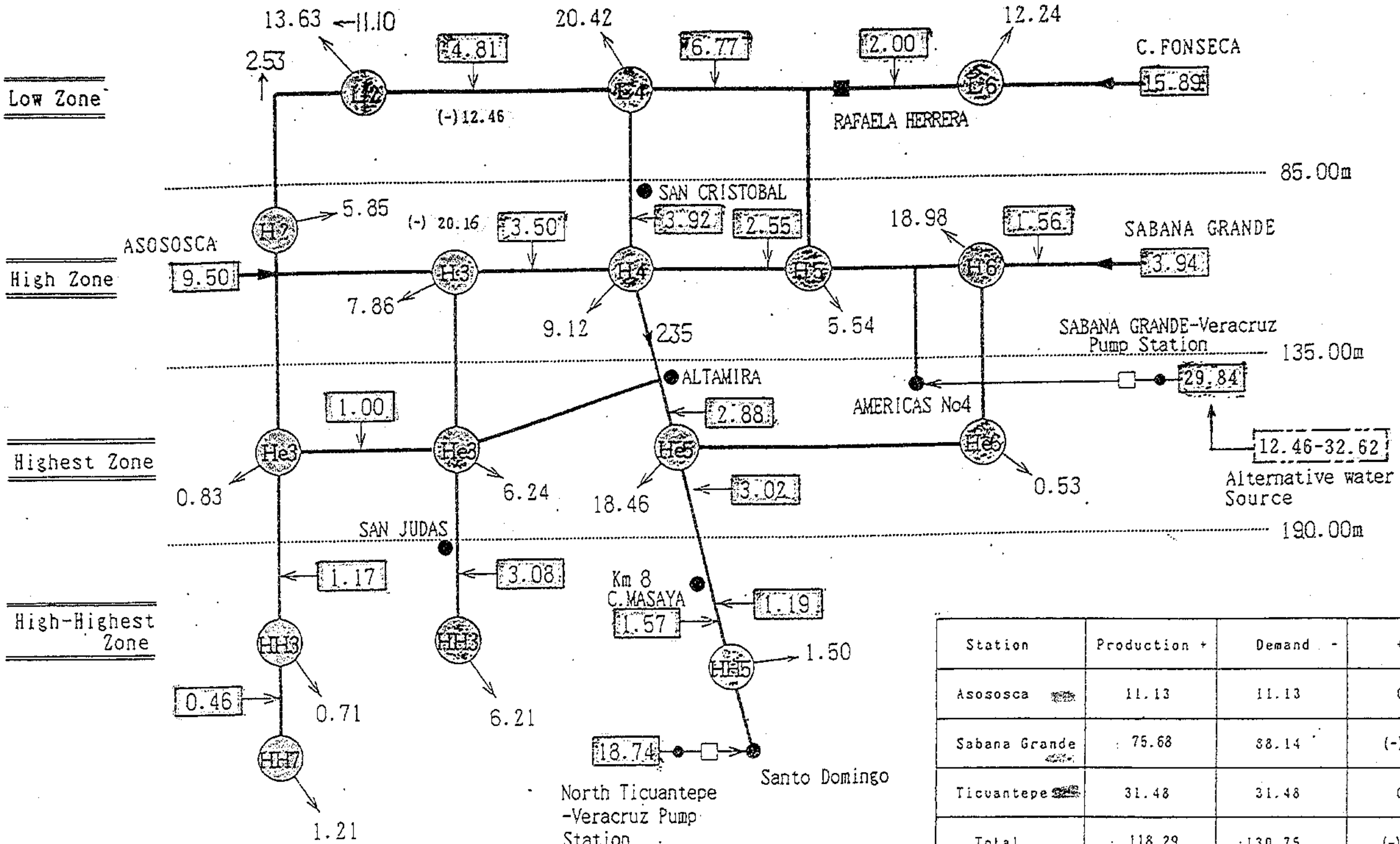



Fig.6.6.5.(3) **General distribution system after phase 2 of the Project**

| Station | Production + | Demand - | + - |
|---|---|---|---|
| Asososca | 11.13 | 11.13 | 0.00 |
| Sabana Grande | 75.68 | 88.14 | (-)12.46 |
| Ticuantepe | 31.48 | 31.48 | 0.00 |
| Total | 118.29 | 130.75 | (-)12.46 |

## 6.7 Operation and Maintenance Plan

1) Operation of pumpage and conveyance system

A semi-automatic operation system, which comprises on automatic water level indication of the reservoir linked with automatic operation of electric valve (Altamira) and enables information exchange between the reservoir and pump station through radiophone and manual operation of the transportation pumps is to be introduced in this Project. An automatic level indication and alarm system of for the intake facility is also included in this semi-automatic operation system.

A sub-operation center is to be opened in the Ticuantepe area in the 1st phase of the Project and will consists of the offices, the pump station, Santo Domingo reservoir station and Altamira station. Another sub-operation center is planned for the Sabana Grande area in the 2nd phase of the Project and shall be composed of the Las Americas reservoir station and Sabana Grande pump station. A sub-operation center similar to the one in Sabana Grande will also be installed in the 3rd phase of the Project.

The overall supervision of the above 3 sub-operation center will be undertaken by the Centralized operation Center in the INAA headquarters by radio communication system.

Fig. 6-9 represents the general plan of the semi-automatic operation system for the 1st and 2nd of the Project along with the personnel arrangement plan for each sub-operation center.

2) Estimation of the operation and maintenance cost

The total cost of the operation and maintenance of the constructed facilities in phase 1 and 2 is estimated at C$ 14,318,000 per year. The unit production cost per cubic meter per day will become C$ 0.21, divided by the total production quantity of 183,900 $m^3$/day (48.58 MGD).

The followings are the major component in estimation of the operation and maintenance cost. (The cost increase with the lapse of time is not taken into account)

a. Electric power cost (for well pumps and transportation pumps)

Phase 1 (Ticuantepe): 53184 Kwh/day
Phase 2 (Sabana Grande): 44280 Kwh/day

C$ 0.282 /Kwh x 97,464 Kwh/day = C$ 27,500/day

b. Personnel expenses (For O/M staff in sub-stations)

Ticuantepe sub-station: C$ __________/month
Sabana Grande sub-station: C$ __________/month

C$ ______________/month x 12 months = C$ 626,400/year

c. Chlorination expenses

Ticuantepe : 71,000 $m^3$/d x 0.0067 g/l/$m^3$
= 473 g/l/$m^3$/d
Sabana Grande : 113.000 $m^3$/d x 0.0067 g/l/$m^3$
= 753 g/l/$m^3$/d

C$ 2.5/g/l/$m^3$ x (473+753) g/l/$m^3$/d = C$ 3,065/day

d. Repair expenses (for pumping and transmission facilities)

With a ____ % of pumping equipment cost and ____ % of transmission pipe lines and tanks,

Ticuantepe : C$ 641,000/year
Sabana Grande : C$ 1,880,000/year

The above estimated annual operation and maintenance cost is shown in the Table 6.6.4 in comparison with the O/M cost of facilities existing as of 1992.

Table 6.6.4 Comparison of the O/M cost between existing condition as of 1992 and for the new facilities of the Project

| Item of Expenses | Annual operation and maintenance cost and unit O/M cost per cubic meter | | | |
|---|---|---|---|---|
| | For total water supply system of Managua as of 1992. (Production; 97,909,000 $m^3$/year) | | For facilities to be constructed in phase 1&2 of the Project (Planned production; 67,122,000 $m^3$/year) | |
| | Unit Cost | | Unit Cost | |
| | O/M Cost | per $m^3$ | O/M Cost | per $m^3$ |
| a) Electric power | 21,600,000 | 0.221 | 10,052,000 | 0.150 |
| b) Personnel | 4,949,000 | 0.051 | 626,400 | 0.009 |
| c) Chlorination | 508,000 | 0.005 | 1,119,000 | 0.017 |
| d) Repair | 11,238,000 | 0.115 | 2,521,000 | 0.028 |
| e) Others | --- | -- | -- | -- |
| Total | 38,771,000 | 0.396 | 14,318,000 | 0.232 |

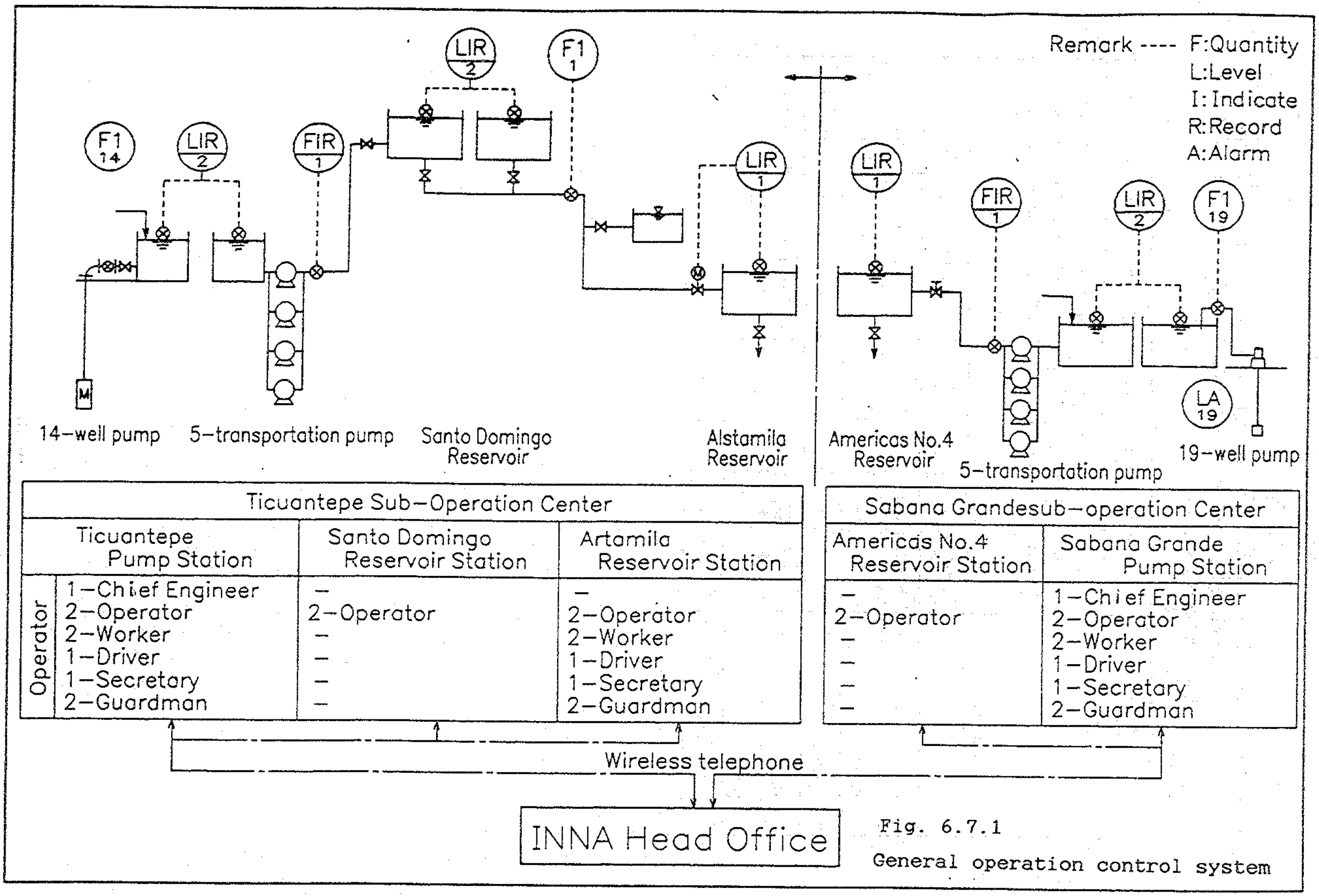



Fig. 6.7.1

General operation control system

## 6.8 Project Evaluation

Water supply projects are generally regarded as having large social benefits, such as health improvements and appreciation of the value of the land where water supply is provided. Health improvements refer to a particular type stemming from the lower incidence of infant mortality and adult morbidity, which are recognized to be caused by the low quality of the drinking water. These social benefits, however, will not be explicitly quantified in this project, due to the difficulties in obtaining relevant and reliable data. Suffice it to say that these beneficial effects do exist and are generally large.

Consequently, evaluation of this Project will be based on the financial viability of the investment required for the implementation of the Project. This criterion is of the utmost importance for INAA, as it defines the ability of the implementing agency to carry out the investment for the Project. A financially viable project has the above mentioned social benefits as additional elements to justify the feasibility of the Project.

The financial evaluation of the Project will follow the procedure indicated below.

- Definition of assumptions for revenue estimation
- Estimation of income
- Calculation of financial viability index
- Interpretation of results

### 6.8.1 Definition of Assumptions for Revenue Estimation

The relevant assumptions are the following.

(1) The project life is assumed to be 30 years.

(2) Year 1 of the Project is to be devoted to the formulation of the detailed design and preparation works for the construction of wells and associated facilities.

(3) Construction works for new wells are to begin in year 2.