No.

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

EMPRESA NICARAGÜENSE DE ACUEDUCTOS Y ALCANTARILLADOS SANITARIOS (ENACAL)

THE STUDY ON IMPROVEMENT OF WATER SUPPLY SYSTEM IN MANAGUA IN THE REPUBLIC OF NICARAGUA

FINAL REPORT

Volume IV : Supporting Report - Part 2

DECEMBER 2005

NIHON SUIDO CONSULTANTS CO., LTD.
ASIA AIR SURVEY CO., LTD.

GE
JR
06-002

Currency Conversion Rates used in this Study:

US$ 1.00 = C$ 16.2834 = JPY 106.0900
= EUR 0.7583

Date of Application: December 10, 2004
Rates Quoted from: The Central Bank of Nicaragua

FINAL REPORT

Volume I : Executive Summary (English Version)
Volume II : Main Report (English Version)
Volume III : Supporting Report – Part 1 (English Version)
Volume IV : Supporting Report – Part 2 (English Version)
Volume V : Executive Summary (Spanish Version)
Volume VI : Main Report (Spanish Version)

Volume IV : Supporting Report - Part 2 (English Version)

Supporting Report No.5	Measurement of Flows and Pressures
Supporting Report No.6	Water Consumption and Awareness Surveys
Supporting Report No.7	Improvement of Water Transmission and Distribution Systems
Supporting Report No.8	Strengthening of ENACAL's Institutional Capacity
Supporting Report No.9	Strengthening of ENACAL's Financial Capacity
Supporting Report No.10	Supports on Environmental and Social Considerations
Supporting Report No.11	Economic and Financial Evaluation of Long-term Improvement Plan and Priority Project

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

EMPRESA NICARAGÜENSE DE ACUEDUCTOS Y ALCANTARILLADOS SANITARIOS (ENACAL)

THE STUDY ON IMPROVEMENT OF WATER SUPPLY SYSTEM IN MANAGUA IN THE REPUBLIC OF NICARAGUA

FINAL REPORT

Supporting Report No.5
Measurement of Flows and Pressures

DECEMBER 2005

NIHON SUIDO CONSULTANTS CO., LTD.
ASIA AIR SURVEY CO., LTD.

THE STUDY ON IMPROVEMENT OF WATER SUPPLY SYSTEM IN MANAGUA IN THE REPUBLIC OF NICARAGUA

FINAL REPORT

Supporting Report No.5
Measurement of Flows and Pressures

Table of Contents

ANNEXES

5.1 OBJECTIVES OF MEASUREMENT

The existing records on the volume of water produced from each existing source as well as the volume of water distributed from each service reservoir/tank were reviewed. Further, in collaboration with ENACAL, the measurement of flows and pressures at various strategic points within the existing transmission and distribution system is being carried out. This is done to have a better understanding on the geographic distribution of water and disparity in supply conditions between various parts of the service area as well as on the volume of water actually received by each service reservoir/tank included in the Managua I and Managua II schemes. The locations for flows and pressures measurement were selected based on the proposal from the Study Team and the opinion of ENACAL through several meetings with ENACAL. The following organizations cooperate with the Study Team in doing the measurement. Mainly the measurement works are carried out by staff organized from these organizations.

a. Dpto. de Explotacion, Gerencia de Operasiones
b. Dpto. de Agua Potable, Gerencia de Operasiones
c. Dpto. de ANC, Gerencia de Comercial

Before the commencement of actual measurement with ENACAL, the demonstrations of instruments which are used for the measurement of flows and pressures and also for the leakage surveys as listed below have been conducted for ENACAL staff on 9th and 10th of September 2004 (see **Photo 5.1.1** and **Photo 5.1.2**).

Photo 5.1.1 Demonstration of Instruments

Photo 5.1.2 Demonstration of Instruments

The instruments were brought into Nicaragua from Japan by the Study Team. The demonstrations were executed for the explanation of instruments and the training for the usage of instruments as the one of technology transfer by this Study. Also during the measurement, the technology transfer of the manipulation of the instruments to the counterpart has been done partly.

a. ultrasonic flow meter, 3 units
b. pressure recorder, 5 units
c. leakage detector, 1 unit
d. metal detector, 1 unit
e. listening stick, 4 units

The objectives of the flow and pressure measurement are outlined as follows:

- to understand the geographic distribution of water and the disparity in supply conditions between various parts of the service area

- to have opportunities to execute technology transfer for the explanation of instruments and the training for the usage of instruments for the measurement

It is noted that the results of flow and pressure measurement at the selected locations are only for reference in order to understand present flow pattern in the Study Area and water supply condition, and do not represent present water supply system.

5.2 SUMMARY OF MEASUREMENT

5.2.1 Flow Measurement

Flow measurement has been conducted at 20 locations such as pumping stations, tanks and wells in the Study Area (refer to **Photo 5.2.1** and **Photo 5.2.2**). The results of the measurement are detailed in the following chapter. Based on the flow measurement, in summary, the following issues have been identified principally.

a. It could be confirmed that most existing flow meters were almost accurate.
b. At Asososca flow rate to Zona Baja by gravity changes depending on the number of pump operation for Zona Alta.
c. Enough water planned by Managua I Project is not supplied to San Judas, Schick and Altamira Tanks.
d. At Altamira water more than half of transmitting water from Santo Domingo Tank by gravity is pumping up to upper area in the direction of Santo Domingo Tank.
e. Transmission facilities of Managua I and II have not been used enough for their capacities and well production amounts of Managua I and II were not reached to the planned capacities.
f. Flow rates from wells of Zona Baja were fluctuated according to the water pressure, because water pumped up from well is directly flowed into distribution pipeline.

Photo 5.2.1 Asososca

Photo 5.2.2 Managua I Pumping Station

5.2.2 Pressure Measurement

Pressure measurement has been conducted at 38 location in the Study Area (refer to **Photo 5.2.3** and **Photo 5.2.4**). The results of the measurement are detailed in the following chapter. Based on the pressure measurement, in summary, most area in the Study Area has no serious problem in water supply condition. However the following areas as shown in **Figure 5.2.1**) are faced in the bad water supply condition.

a. Area supplied from San Judas Tank (eastern part of Zona Alta Superior Oeste and part of higher area of Zona Alta Oeste)
b. Area supplied from Schick Tank (lower area of Zona Alta Superior Este)
c. Area supplied by Sabana Grande Well Field (eastern part of Zona Alta Este)

Photo 5.2.3 Zona Baja Oeste

Photo 5.2.4 Zona Alta Oeste

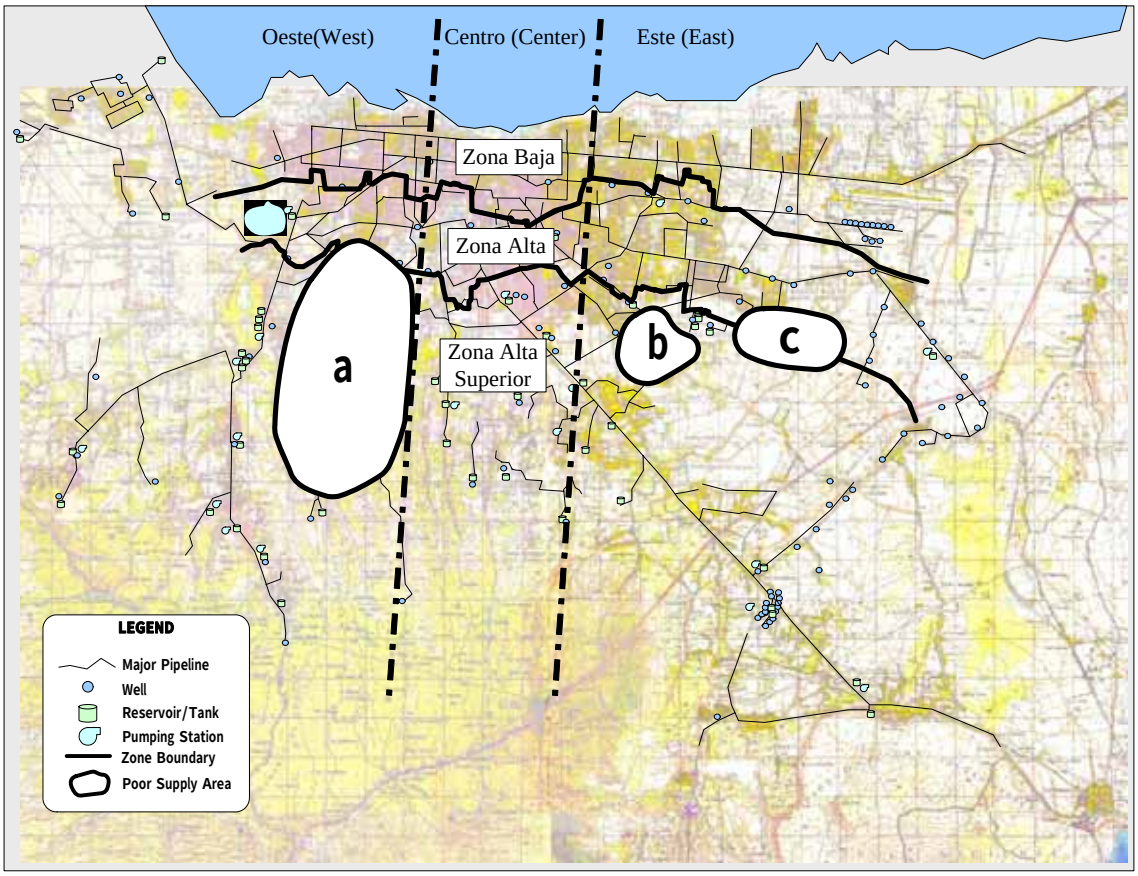


Figure 5.2.1 Poor Water Supply Area

5.3 SELECTION OF MEASUREMENT LOCATION

5.3.1 Flow Measurement

To achieve the objectives mentioned above, flow rates were measured at 20 locations shown in **Table 5.3.1** and **Figure 5.3.1**. Originally some junctions were nominated for measuring flows in order to understand the flow directions in the distribution network, but could not be carried out due to difficulties of traffic control and road safety. Before the measurement each measurement location site was surveyed together with ENACAL in order to check the site conditions and decide the exact flow measurement points. Excavation works including

backfill and restoration, if necessary, were done by ENACAL.

Table 5.3.1 Location of Flow Measurement

No.	Name of Location	Number of Measuring Points				
		Inlet Flow	Outlet Flow		Other Flow	Total
			by Gravity	by Pump		
1	Asososca	2	1	2	0	5
2	Km8.5 Carretera Sur	0	0	1	0	1
3	San Judas	4	0	3	0	7
4	Unan	2	1	1	0	4
5	Altamira	2	0	1	0	3
6	San Cristobal	2	0	0	0	2
7	Las Mercedes	0	0	0	1	1
8	Km8 Carretera Masaya	2	1	2	0	5
9	Santo Domingo	0	1	0	0	1
10	Schick	2	0	0	0	2
11	Managua I Well Field	0	0	1	0	1
12	Managua II Well Field	0	0	1	0	1
13	Las Americas	1	0	0	0	1
14	Km9.2 Carretera Sur	1	0	2	0	3
15	Km14.5 Carretera Masaya	0	0	2	0	2
16	Km18.5 Carretera Masaya	0	0	1	0	1
17	Km16 Carretera Sur	1	0	0	0	1
18	Altos de Santo Domingo	1	0	0	0	1
19	Olof Palme Well	0	0	1	0	1
20	Rafaela Herrera Well	0	0	1	0	1
Total		20	4	19	1	44

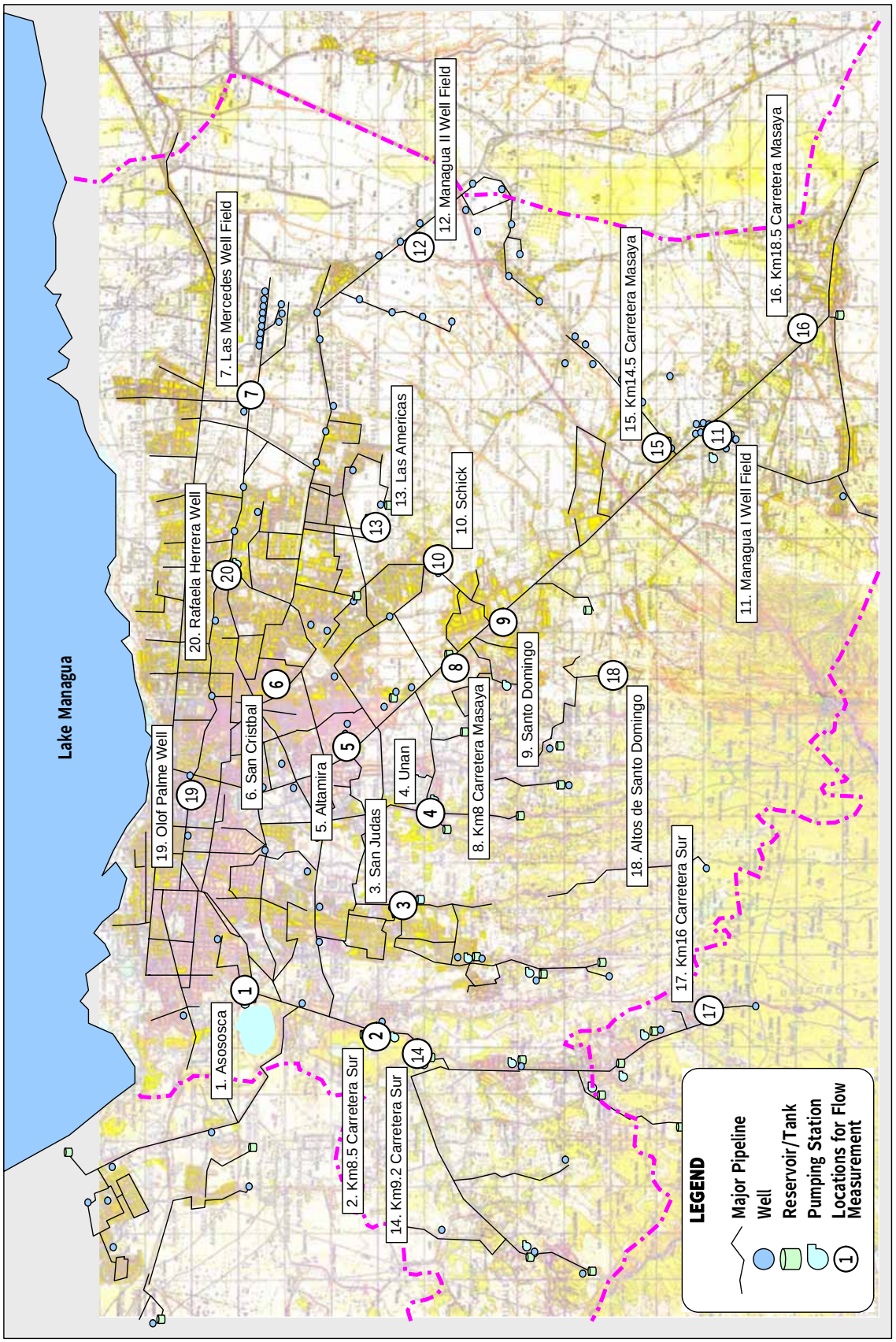


Figure 5.3.1 Location of Flow Measurement

5.3.2 Pressure Measurement

Pressures were also measured at various locations spreading across the existing service area. For this purpose, each elevation zone in Managua was divided into three districts, namely Western District (Oeste), Central District (Centro) and Eastern District (Este), and at least three locations were selected in each district as shown in **Table 5.3.2**. The exact locations of measurement were determined after reviewing pipe network drawings and in consultation with ENACAL as shown in **Figure 5.3.2**, and finally total 38 locations consisting of 33 locations in Managua and 5 locations outside Managua were selected.

Table 5.3.2 Location List for Pressure Measurement

Elevation Zone	Western District (Oeste)	Central District (Centro)	Eastern District (Este)	Total
Baja	3	3	3	9
Alta	3	3	5	11
Alta Superior	6	3	4	13
Total in Managua	12	9	12	33
Outside Managua	5 Locations (2 in Ticuantepe and 3 in Nindiri)			

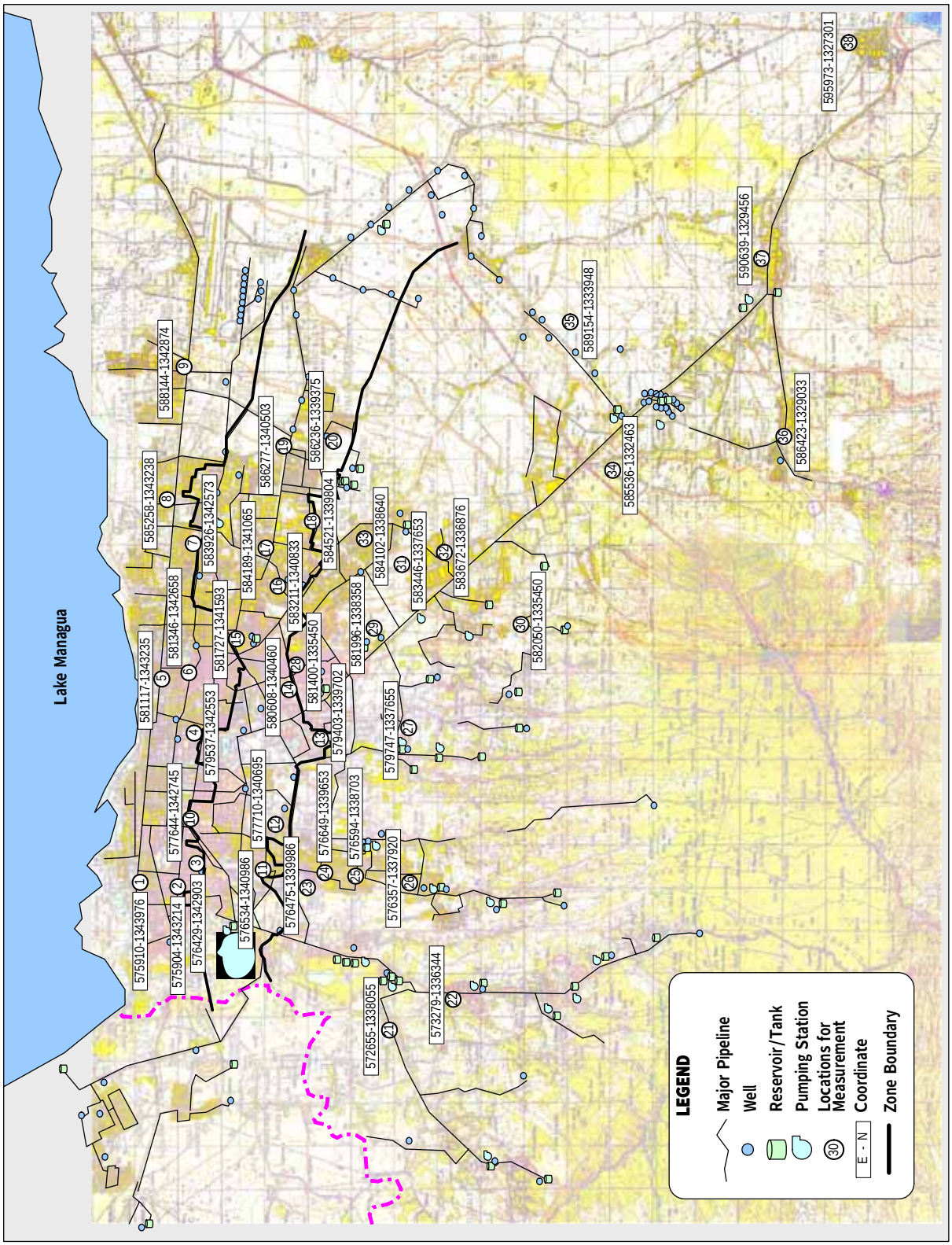
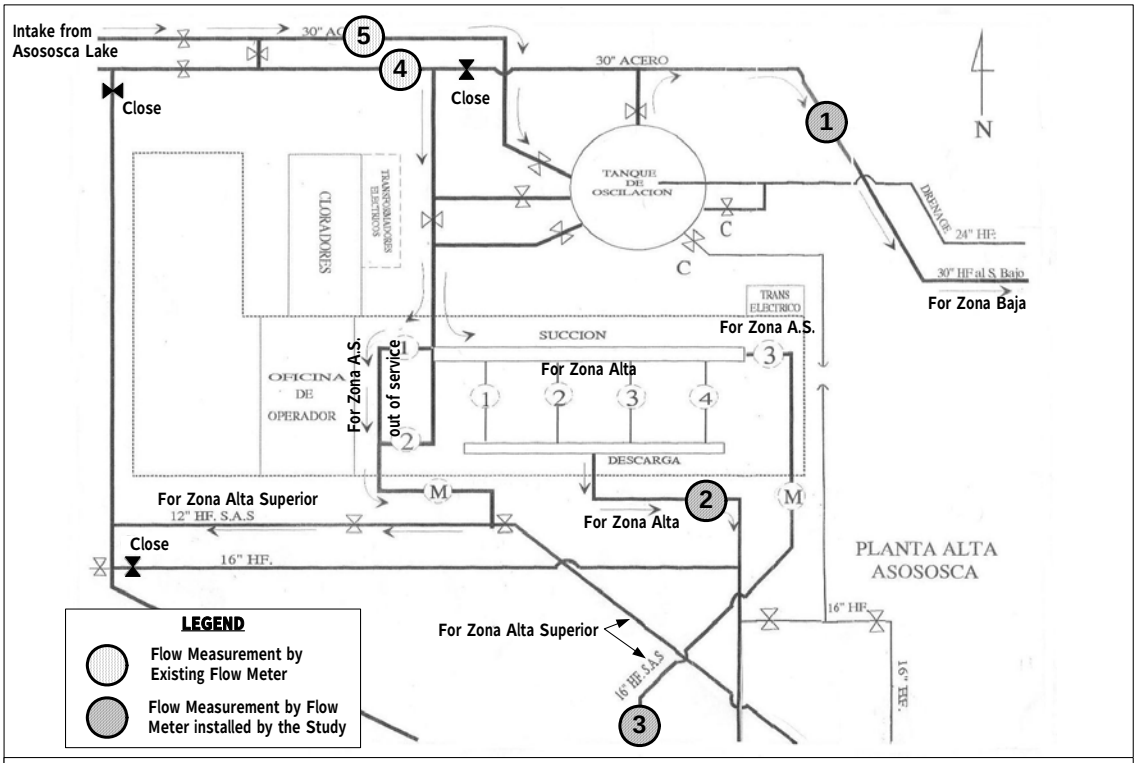


Figure 5.3.2 Location of Pressure Measurement

5.4 RESULTS OF FLOW MEASUREMENT

5.4.1 Asososca

In Asososca flow rates were measured at 5 points as shown in **Figure 5.4.1** for 24 hours from 9 September to 10 September 2004. Three of them were measured by installing ultrasonic flow meters and other two were measured by the existing flow meters.



Flow Measurement Survey at Asososca

Figure 5.4.1 Points of Flow Measurement at Asososca

The existing flow meters were checked with the ultrasonic flow meter through the comparison between readings of the existing flow meter and the ultrasonic flow meter (hereinafter referred to as "JICA flow meter") installed at near the existing one, Point No.4. As the results, the flow rate measured by the existing flow meter (difference between readings at 11:00 and at 12:00 on 9 September 2004) and flow measured by JICA flow meter as shown in **Figure 5.4.2** were 2,170 m3/hour and 2,075 m3/hour respectively. Therefore, it is concluded that the existing flow

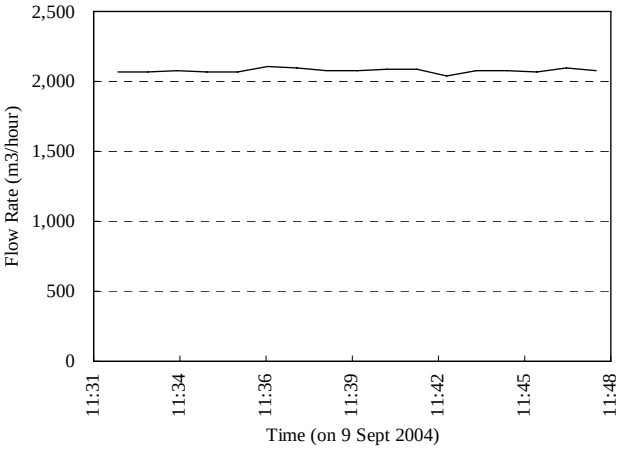


Figure 5.4.2 Record of Ultrasonic Flow Meter installed at Point No.4

meter is almost accurate and can be used for the Study. Results of flow measurement of three points measured by JICA flow meters are shown in **Figure 5.4.3**. During measurement time, two pumps for High Zone (Zone Alta Superior), No.1 and No.2, were not operated, so the sum of these three flows equals total outlet flow of Asososca.

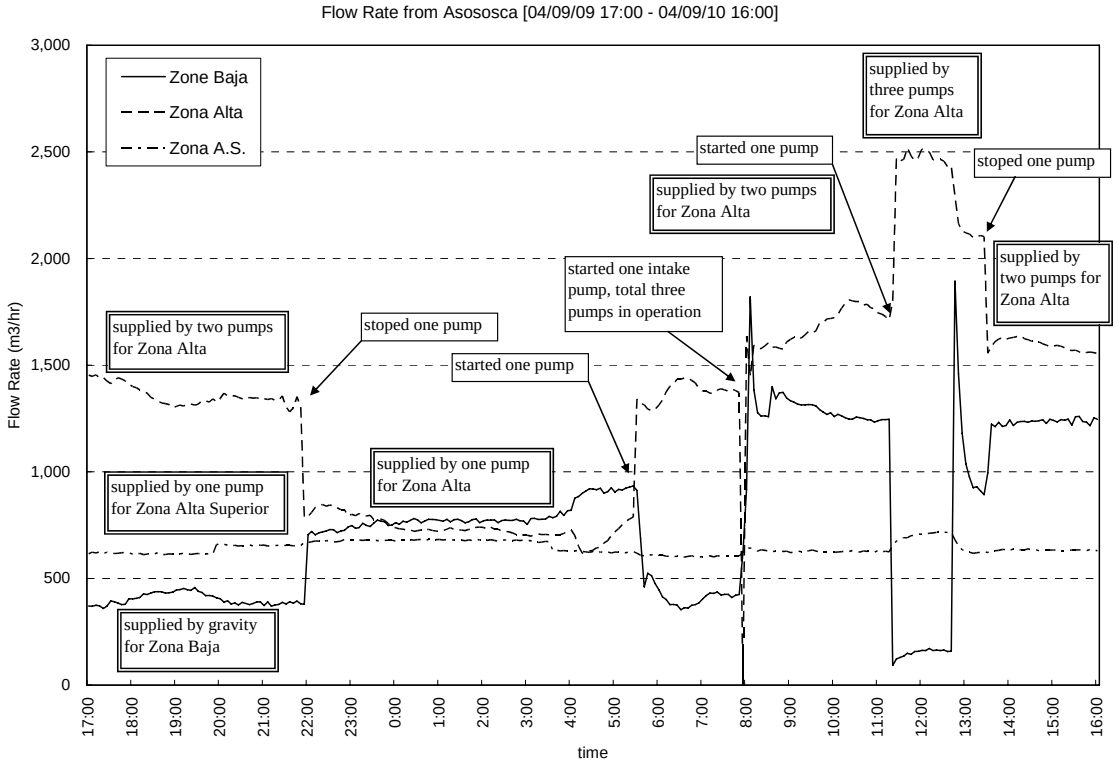


Figure 5.4.3 Results of Flow Measurement

Flow rate to Low Zone (Zona Baja) by gravity changes depending on the number of pump operation for Medium Zone (Zona Alta). However, flow rate of High Zone is almost constant even if the number of pump operation for Medium Zone changes. Total flow rate supplied to each zone for 24 hours is summarized as shown in **Table 5.4.1** and **Figure 5.4.4**.

Table 5.4.1 Flow Rate for Each Zone

Elevation Zone	Flow rate per day (m3/day)
Low (Zona Baja)	18,172
Medium (Zona Alta)	31,610
High (Zona Alta Superior)	15,443
Total	65,225

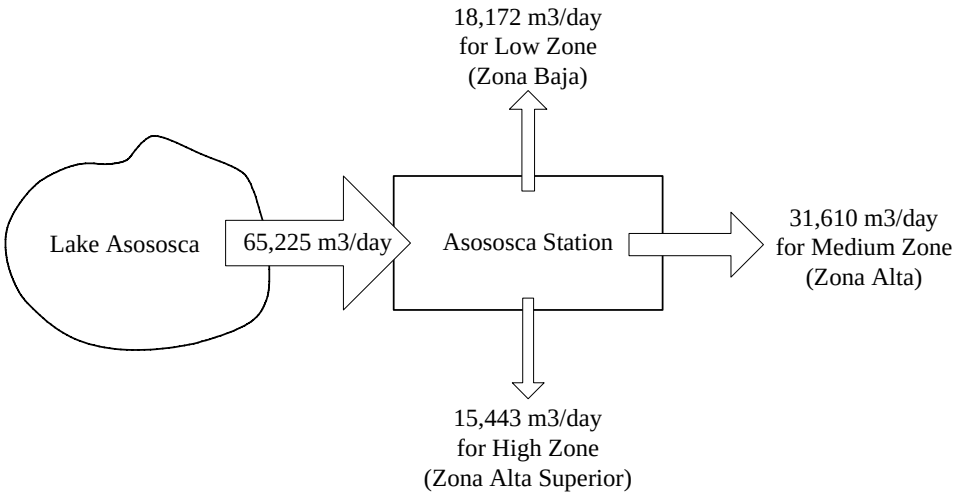


Figure 5.4.4 Flow Rate for Each Zone

According to the record of ENACAL, intake flow rate from 16:00 on 9 September to 16:00 on 10 September 2004 was 68,526 m3/day. Almost the same results between intake flow by the existing flow meter and outlet flow measured by JICA flow meter were obtained though there is a difference of 5 %. **Figure 5.4.5** shows the comparison between intake flow rates and total outlet flow.

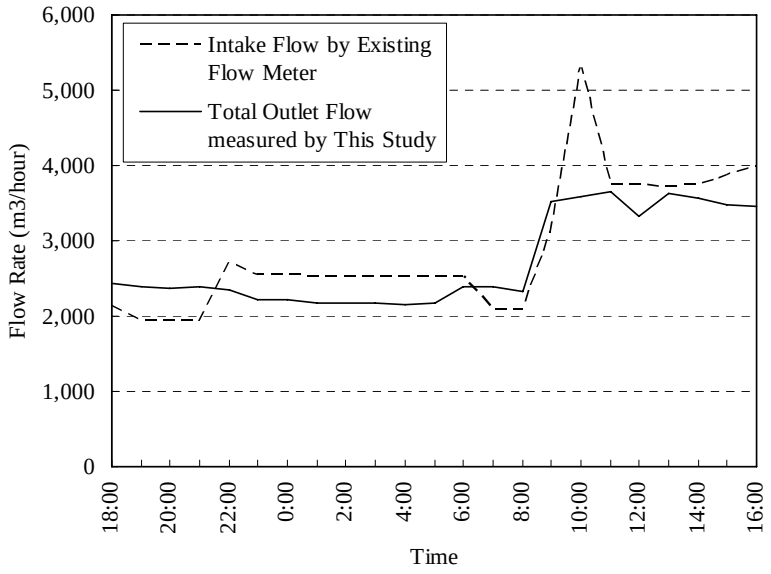


Figure 5.4.5 Intake Flow by Existing Flow Meter and Outlet Flow by JICA Flow Meter

According to records of ENACAL administrated by Statistic Section, Departamento de Explotacion, ENACAL, flow rates for three zones on 9 and 10 September 2004 were as shown in **Table 5.4.2**.

Table 5.4.2 Flow Rate for Each Zone by ENACAL records

	9 Sept 2004	10 Sept 2004
Low Zone	36,688 m3/day	35,452 m3/day
Medium Zone	14,935 m3/day	18,153 m3/day
High Zone	13,626 m3/day	13,626 m3/day
Total	65,249 m3/day	67,231 m3/day

Data Source: Statistic Section, Dept. de Explotacion, ENACAL

ENACAL calculates the flow rates of medium and high zones by pump operation hours. Total flow rate is obtained from the readings of intake flow meters. Flow rate of low zone is calculated by difference flow rate between the intake flow and sum of flows for medium and high zones. Based on such estimation method by ENACAL, therefore, 24-hour flow rate from 16:00 on 9 September which is the same length as JICA measurement can be estimated as shown in **Table 5.4.3**.

Table 5.4.3 Flow Rate for Each Zone by ENACAL records

		Dischage*[1] (m3/h)	Operation*[2] (hours)	Flow (m3/day)
Intake Flow (measured by the existing flow meters)				68,526
Outlet Flow for Low Zone (difference between intake and other outlet flows)				36,399
Outlet Flow for Medium Zone				18,501
	Pump No.1	530.28	5.5	2,917
	Pump No.2	480.77	16.5	7,933
	Pump No.3	355.91	21.5	7,652
	Pump No.4	(not working)	-	-
Outlet Flow for High Zone				13,626
	Pump No.1	499.62	0.0	0
	Pump No.2	499.62	0.0	0
	Pump No.3	567.75	24.0	13,626

*1: Statistic Data, Dept. de Explotacion, ENACAL

*2: from 16:00 on 9 Sept to 16:00 on 10 Sept

As the results, there is a big difference between flow rate measured by the JICA flow meter and flow rate estimated by ENACAL for Low Zone and Medium Zone. For the confirmation, the flow rates for Low Zone and Intake were measured again from 18 to 20 October 2004. Flow rate for Low Zone was 21,516 m3/day as shown in **Figure 5.4.6**.

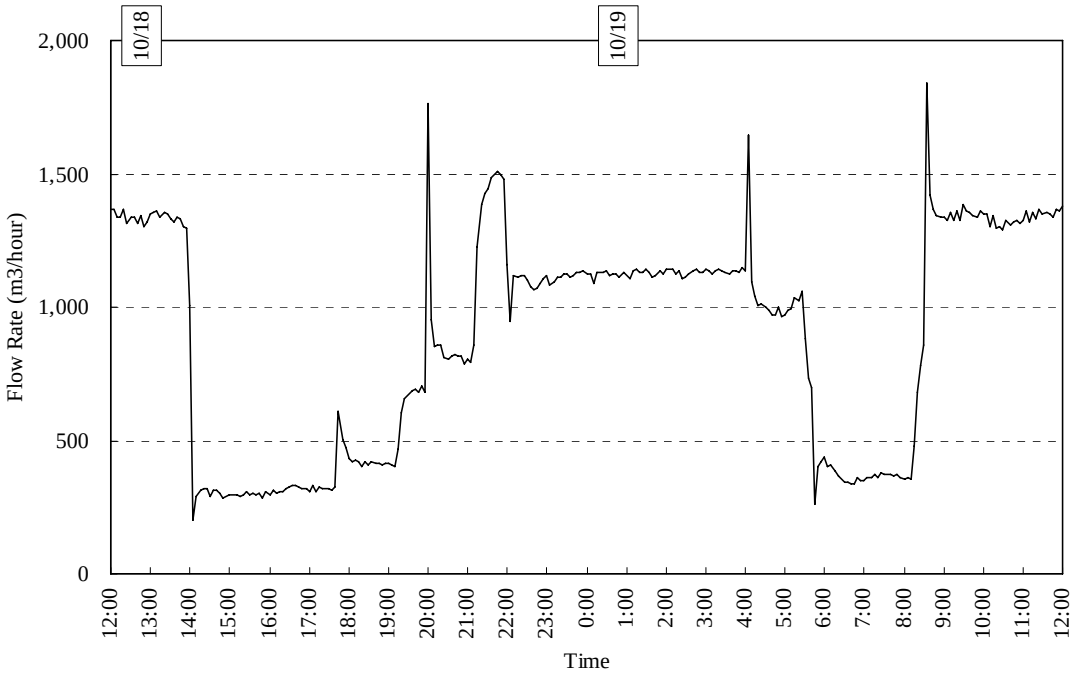


Figure 5.4.6 Result of Flow Measurement for Low Zone from 18th to 19th October

According to records of ENACAL intake flow and flow rates for three zones on 18 and 19 October 2004 were as shown in **Table 5.4.4**.

Table 5.4.4 Flow Rate for Each Zone by ENACAL records

	18th Oct. 2004	19th Oct. 2004
Low Zone	26,626	27,018
Medium Zone	15,671	15,332
High Zone	8,232	10,220
Intake	50,530	52,569

Data Source: Statistic Section, Dept. de Explotacion, ENACAL

There is a difference of about 5,000 m3/day between flow rate measured by the JICA flow meter and flow rate estimated by ENACAL for Low Zone. **Figure 5.4.7** shows the comparison between intake flow rate by the existing flow meters and flow rate measured by JICA flow meters.

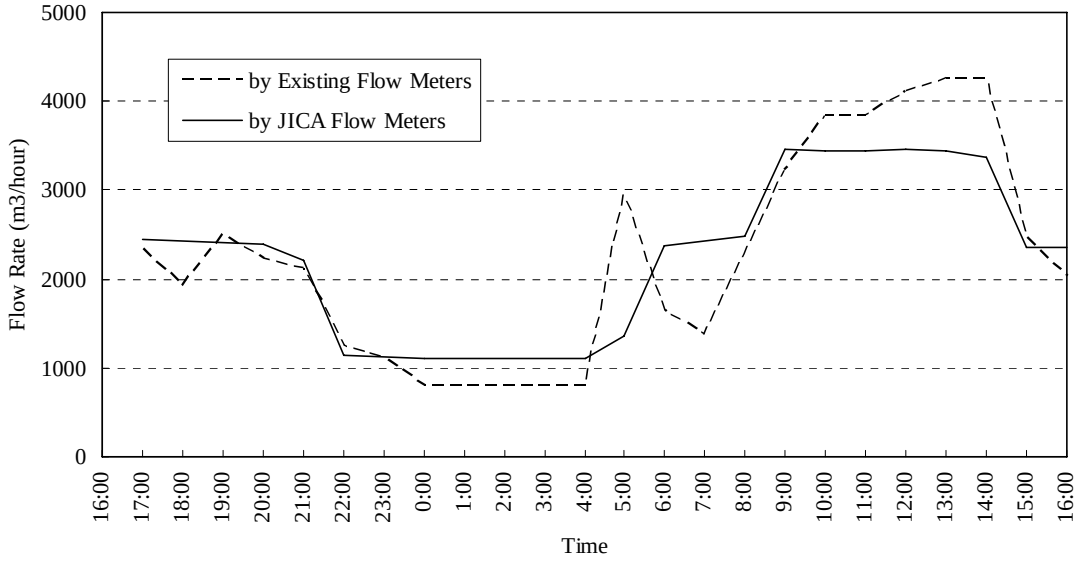


Figure 5.4.7 Results of Flow Measurement for Intake from 19th to 20th October 2004

Intake flow rates measured by the JICA flow meter and the existing flow meter from 16:00 on 19th October to 16:00 on 20th October were almost same, which were 53,624 m3/day and 53,704 m3/day respectively.

For the reference, the flow rate for each zone in 2004 based on the records of ENACAL is shown in **Figure 5.4.8**.

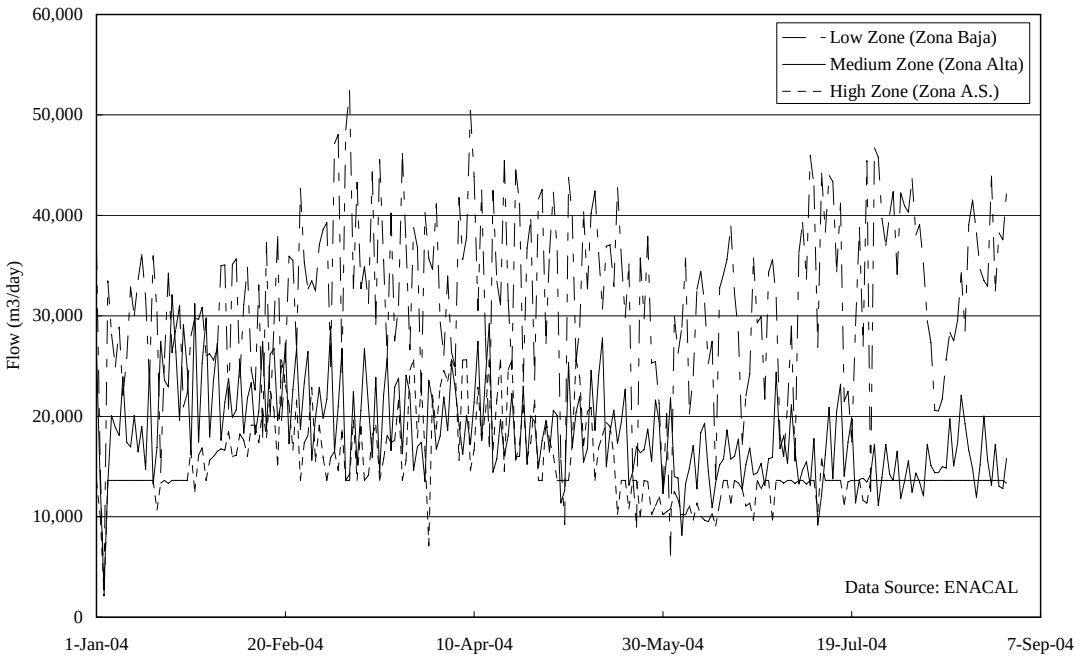
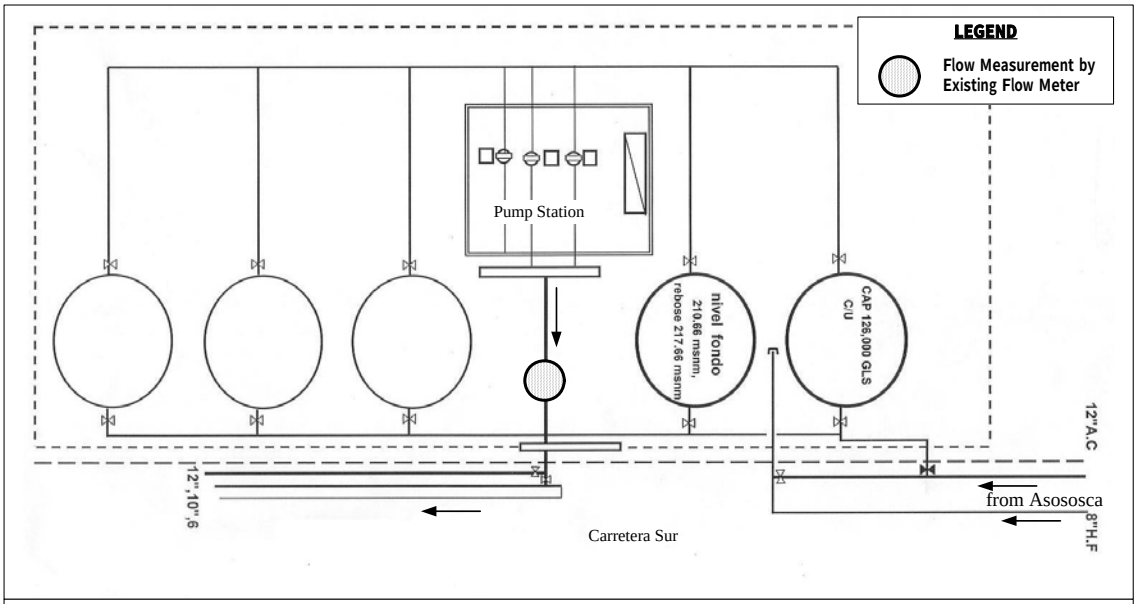


Figure 5.4.8 Flow Rate for Each Zone

5.4.2 Km 8.5 Carretera Sur

Flow measurement at Km8.5 Carretera Sur was conducted by the existing flow meter installed at outlet pipe from the pumping station as shown in **Figure 5.4.9** from 5:00 am on 2nd Nov. to 6:00 am on 3rd Nov. 2004. As the result as shown in **Figure 5.4.10**, about 3,000 m^3/day was pumping up to higher area from Km8.5 Carretera Sur Pumping Station. According to ENACAL records, Asososca Pumping Station transmitted water of about 7,000 m^3/day for Super-High Zone on 2nd Nov. 2004, which means that more than a half water transmitted from Asososca for Super-High Zone was consumed at area below Km8.5 Carretera Sur Pumping Station.



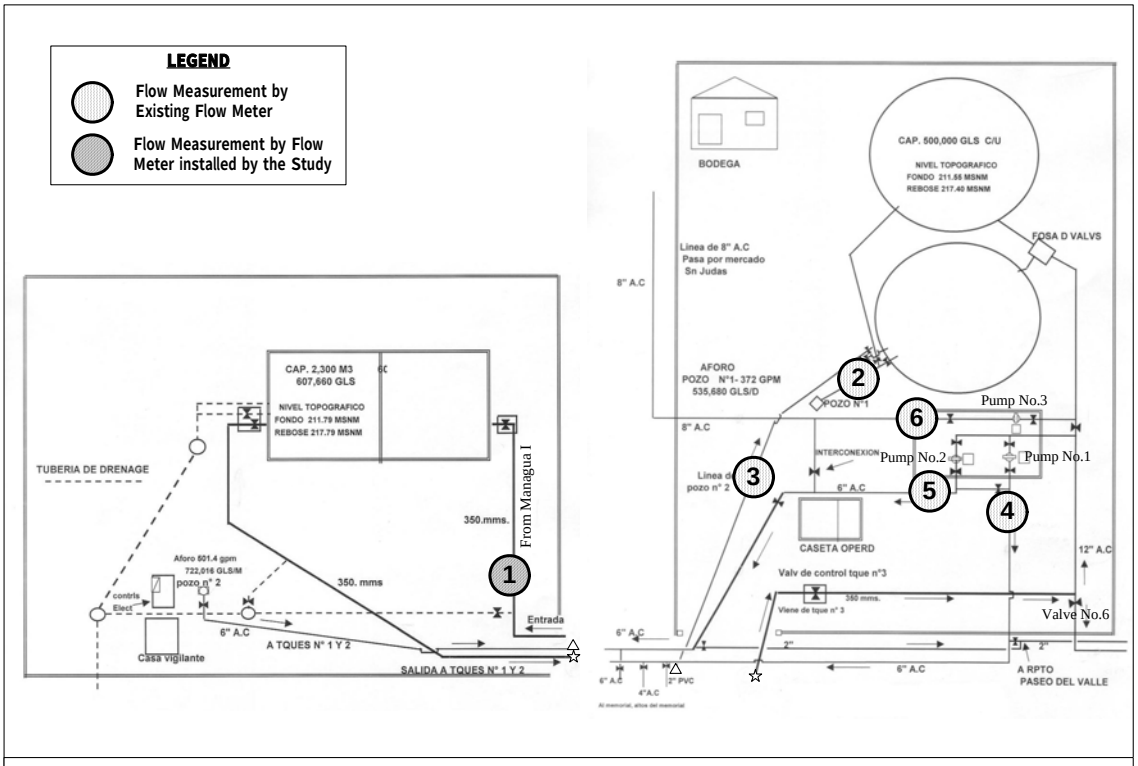
Flow Measurement Survey at Km8.5 Carretera Sur

Figure 5.4.9 Point of Flow Measurement at Km 8.5 Carretera Sur

Figure 5.4.10 Result of Flow Measurement at Km 8.5 Carretera Sur Pumping Station

5.4.3 San Judas

In San Judas flow rates were measured at 6 points as shown in **Figure 5.4.11** for 24 hours from 9 September to 10 September 2004. Point No.1 was measured by installing ultrasonic flow meters (JICA flow meter) and others were measured by the existing flow meters. The existing flow meters were checked with JICA flow meter. **Table 5.4.5** shows the results of the comparison between JICA and existing flow meters.



Flow Measurement Survey at San Judas

Figure 5.4.11 Points of Flow Measurement at San Judas

Table 5.4.5 Results of Existing Flow Meters

Measurement Point		Flow Rate (m3/hour)		Ratio (%)	Flow Rate (m3/day) based on the existing flow meter
		by JICA Flow Meter	by Existing Flow Meter		
Point No.2	Well No.1	78.5	79.7	102%	1,884
Point No.3	Well No.2	98.6	111.4	113%	2,366
Point No.4	Pump No.1	109.7	110	100%	0
Point No.5	Pump No.2	148.9	155	104%	2366*
Point No.6	Pump No.3	190.1	197	104%	2640*

*: 24 hours from 14:00 on 27th September 2004

As the results, it is concluded that the existing flow meters are almost accurate. Results of meter readings of the existing flow meters for three distribution pumps, Pumps No.1, No.2 and No.3, are shown in **Figure 5.4.12**. During measurement, however, Pump No.1 was not operated. **Figure 5.4.13** shows a result of flow measurement at Point No.1 measured by JICA flow meter. During measurement period at Point No.1, flow was control by tank inlet valve. Total inlet flow from Managua I System was 4,421 m^3/day.

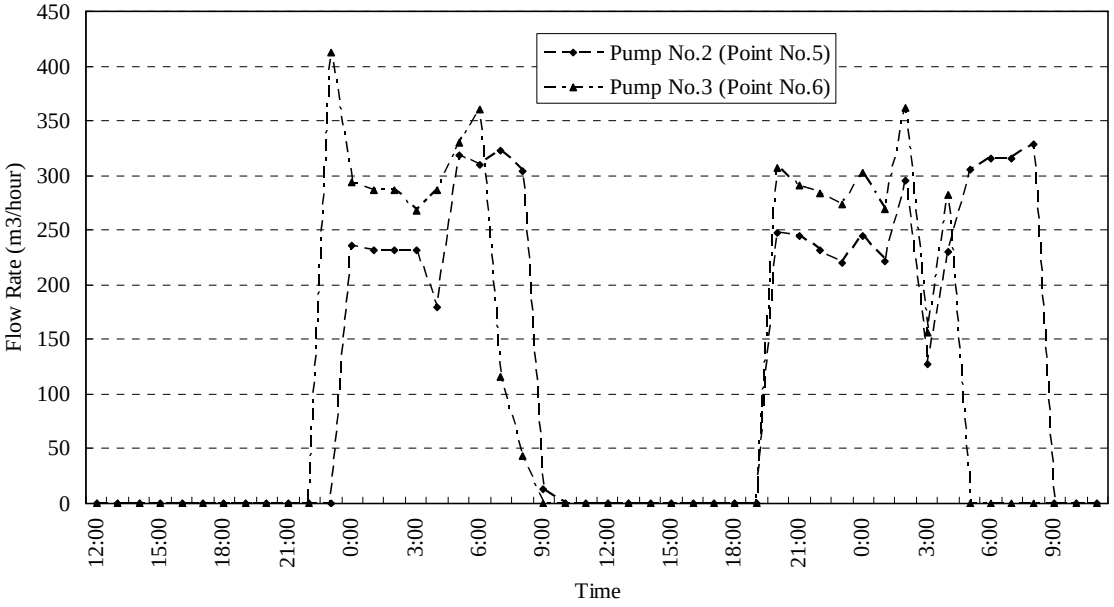


Figure 5.4.12 Results of Flow Measurement at Points No.4, No.5 and No.6

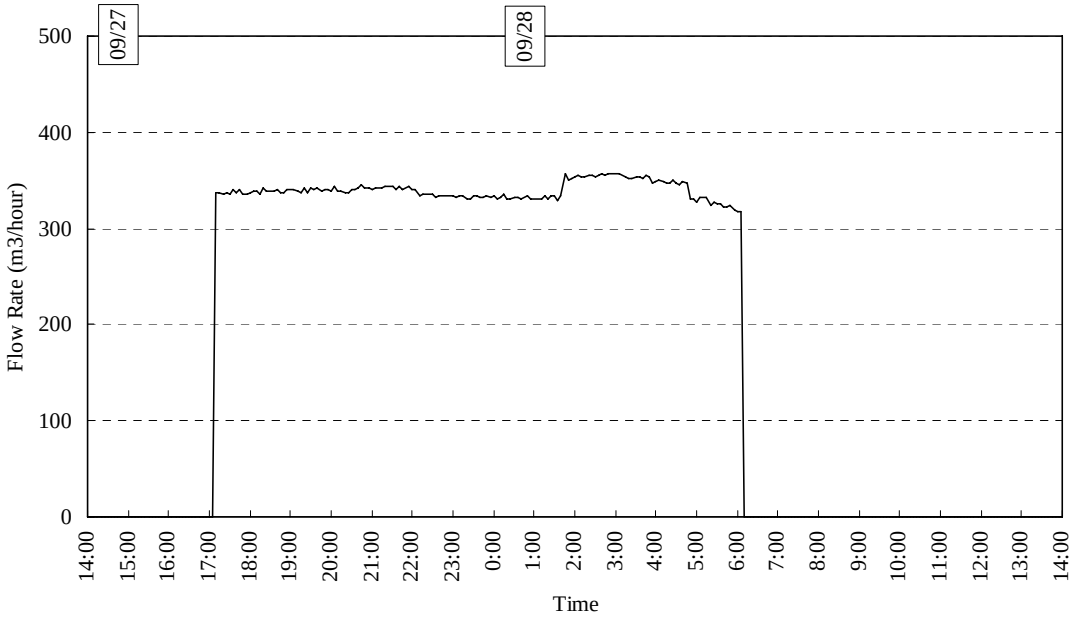


Figure 5.4.13 Result of Flow Measurement at Point No.1

Productions from wells can be estimated at multiplying the flow rate per hour and pump operation hours. The production amount is almost constant regardless of time, because the pumping head is also constant. Therefore, production amount of wells are calculated as follows;

Pump No.1: 78.5 m^3/hour x 24 hours = 1,884 m^3/day
Pump No.2: 98.6 m^3/hour x 24 hours = 2,366 m^3/day

The flow balance at San Judas Tank is summarized as **Figure 5.4.14**. Outlet flow of 3,465 m^3/day from San Judas Tank by gravity is calculated from the balance of other flow rates.

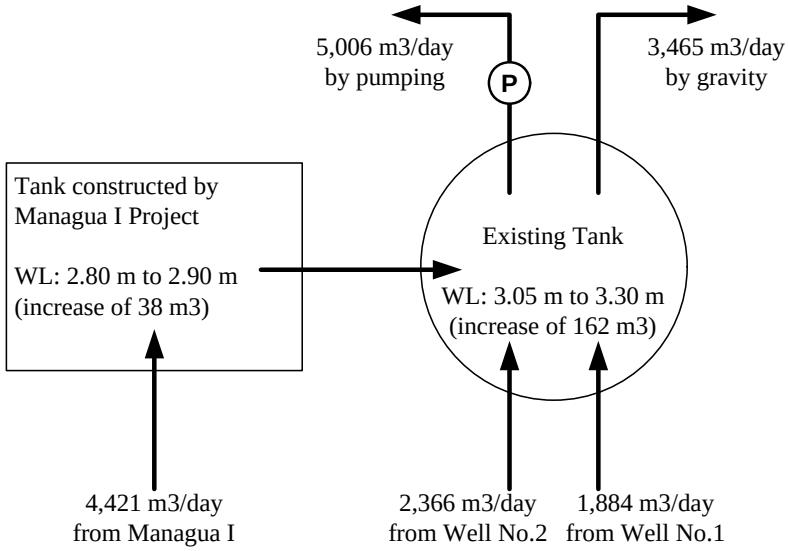


Figure 5.4.14 Flow Balance at San Judas Tank

According to the basic design report of Managua I Project, water of 6,983 m^3/day is transmitted from Santo Domingo Tank by gravity. The result of the flow measurement shows that the expected enough water is not supplied to San Judas Tank, which is only 63 % of planning flow rate. During measurement period the tank inlet control valve was opened 20 % only for 13 hours.

For the confirmation, the flow rate from Managua I System was measured again for 7 days from 5th to 12th November 2004. As the results the average flow rate from Managua I System is about 5,000 m^3/day which is about 70 % of the planning flow rate of 6,983 m^3/day. It is concluded that the expected enough water is not supplied to San Judas Tank. **Figure 5.4.15** shows a record of measurement. It is noted that the measurement point was not Point No.1, but was Point No.7 located at valve chamber of outlet pipeline from the tank constructed by Managua I Project (refer to **Figure 5.4.16**). During this measurement the existing 6 flow meters, Point No.2 to No.6, were also read and **Table 5.4.6** shows the summary of 7-day measurement.

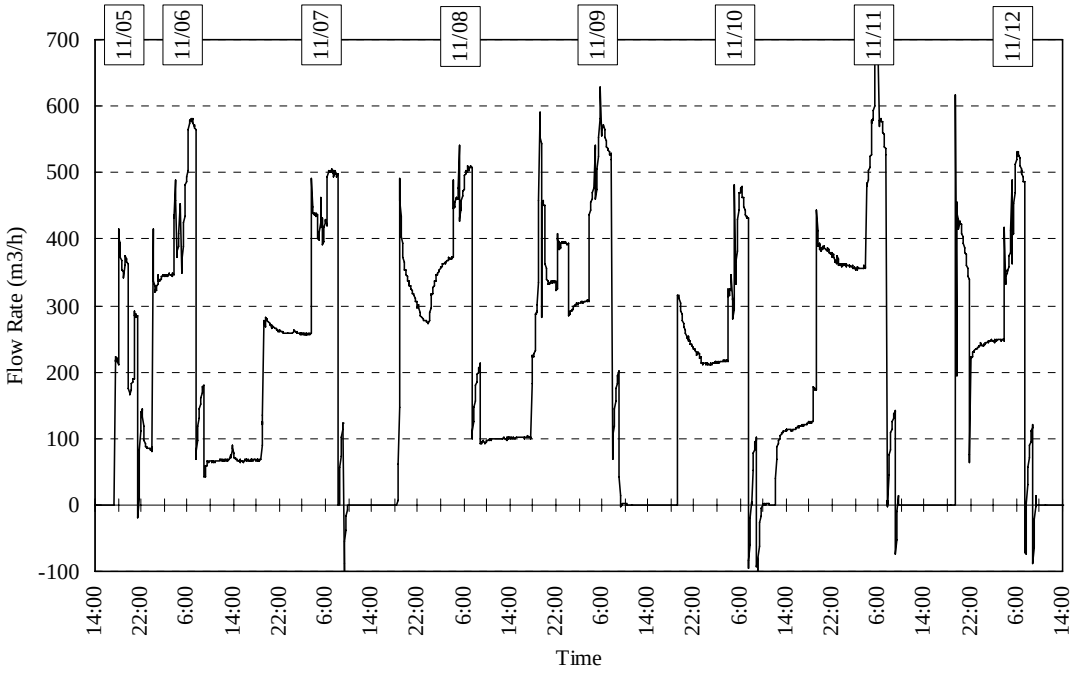
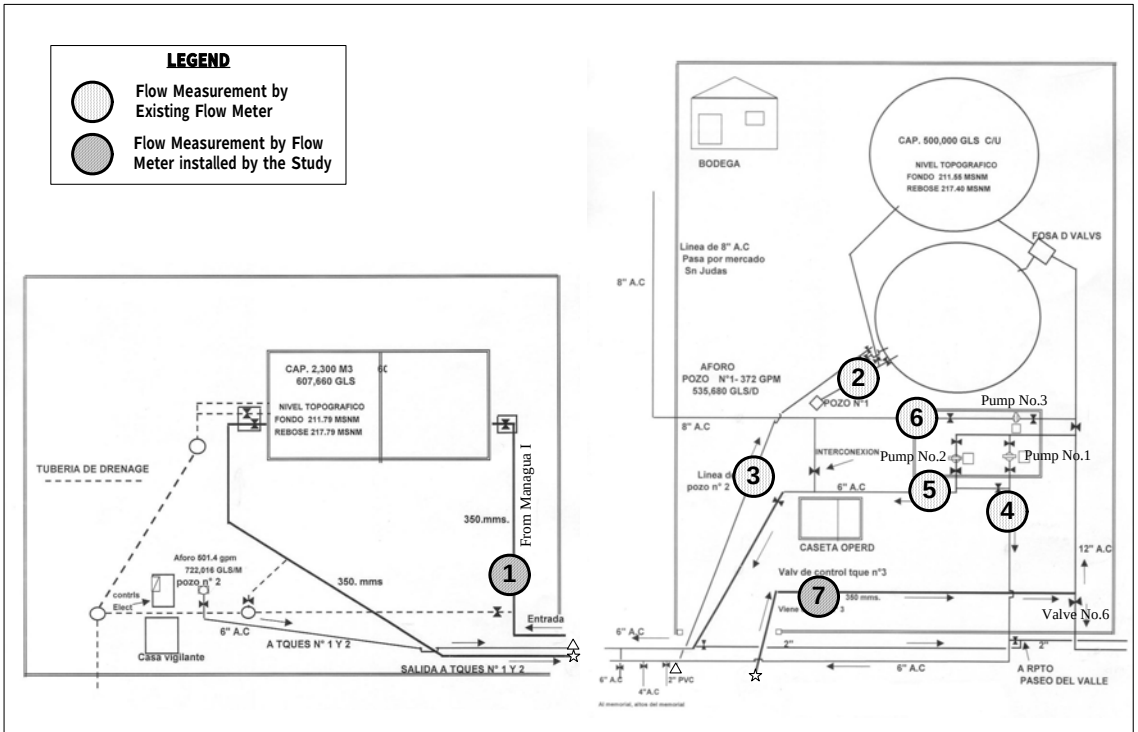


Figure 5.4.15 Result of Flow Measurement from Managua I System from 5th to 12th November 2004



Flow Measurement Survey at San Judas

Figure 5.4.16 Point of Additional Flow Measurement (Point No.7)

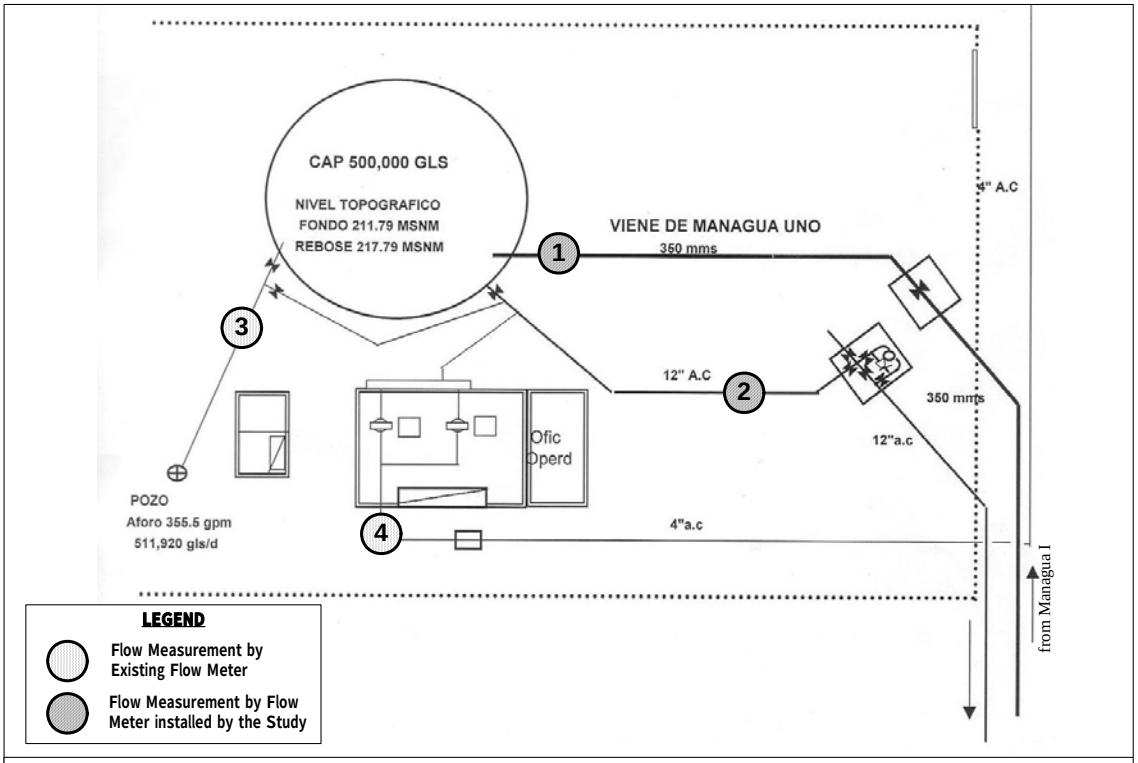
Table 5.4.6 Summary of 7-day Measurement

		Survay Point	5th Nov. 14:00 Friday	6th Nov. 14:00 Saturday	7th Nov. 14:00 Sunday	8th Nov. 14:00 Monday	9th Nov. 14:00 Tuesday	10th Nov. 14:00 Wednesday	11th Nov. 14:00 Thursday	12th Nov. 14:00 Friday	Average Flow Rate (m3/day)
Inlet	Managua I	No.7	4,962	4,730	5,462	6,078	3,586	6,013	4,038		4,981
	Well No.1	No.2	1,197	1,942	1,958	1,944	1,938	1,946	1,947		1,839
	Well No.2	No.3	2,376	2,676	2,696	2,661	2,706	2,609	2,738		2,637
Outlet	Pump No.1	No.4	15	1	1	0	1	1	0		3
	Pump No.2	No.5	2,507	1,204	3,555	2,767	1,214	3,510	2,872		2,518
	Pump No.3	No.6	2,599	3,662	2,966	3,369	3,615	3,119	3,131		3,209
	Gravity*	-	3,414	4,481	3,594	4,547	3,400	3,938	2,720		3,728

Note : Flow rate by gravity is calculated by balance between inlet and outlet.

5.4.4 Unan

Flow rates for 24 hours from 28 September to 29 September 2004 were measured at 3 points except Point No.1 in Unan as shown in **Figure 5.4.17**. One of them, Point No.2, was measured by installing JICA flow meter and others, Point No.3 and No.4, were referred to the existing flow meters.



Flow Measurement Survey at Unan

Figure 5.4.17 Points of Flow Measurement at Unan

The existing flow meter which measures the production amount of well was compared with JICA flow meter. As the results, average flow based on the records of the existing flow meter from 14:00 on 28 September to 14:00 on 30 September 2004 and the result of 2-hour measurement by JICA flow meter were 25.07 m^3/hour and 26.34 m^3/hour respectively. **Figure 5.4.18** shows the result of flow measurement by JICA flow meter. Therefore, it is concluded that the existing flow meter is accurate and can be used for the Study. Result of flow measurement of Point No.2 measured by JICA flow meter is shown in **Figure 5.4.19**.

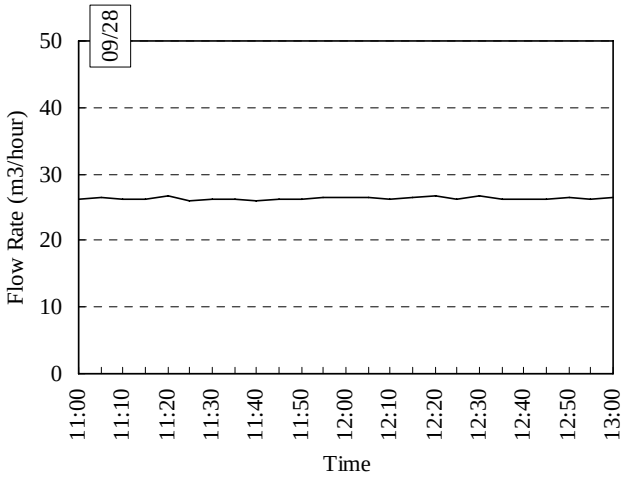


Figure 5.4.18 Record of Ultrasonic Flow Meter Installed at Point No.3

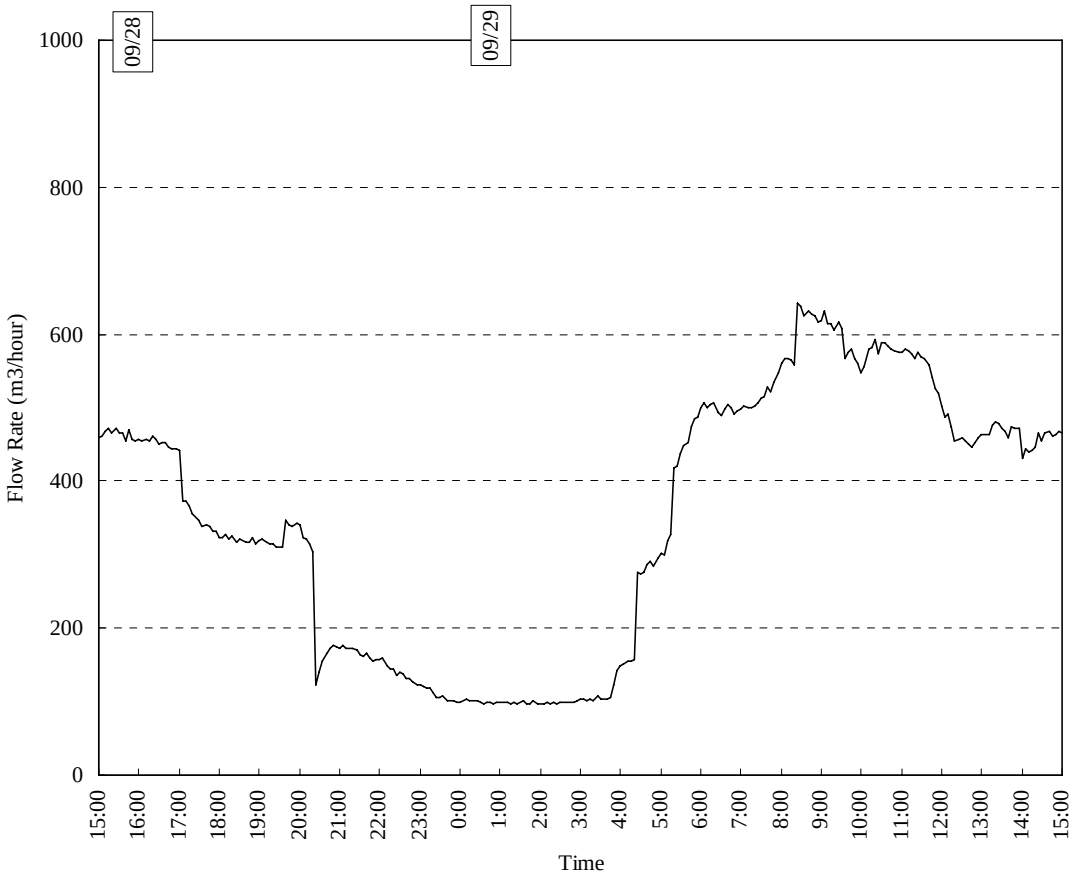


Figure 5.4.19 Results of Flow Measurement at Point No.2

The flow measurement is summarized as **Figure 5.4.20**. Flow rate of Point No.1 is calculated from the flow rates of other three points.

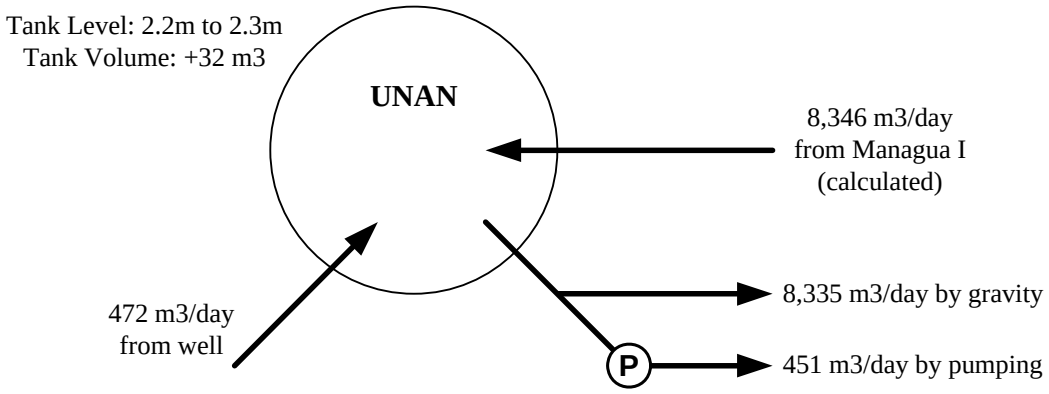


Figure 5.4.20 Balance of Flow Rate at Unan Tank

According to the basic design report of Managua I Project, water of 8,346 m^3/day is transmitted from Santo Domingo Tank to Unan Tank by gravity. The result of the flow measurement shows that the expected enough water is supplied to Unan Tank. For the confirmation the flow measurement of inlet flow from Managua I System (Point No.1) was measured from 26 to 27 October 2004 and its result was 9,103 m^3/day as shown in **Figure 5.4.21**.

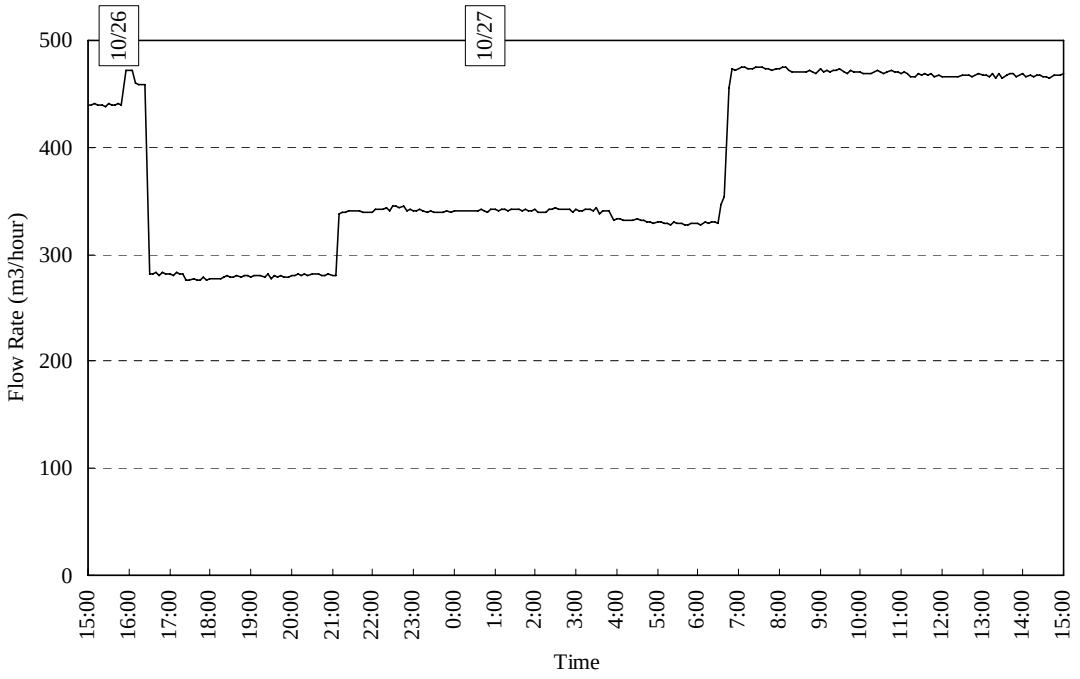
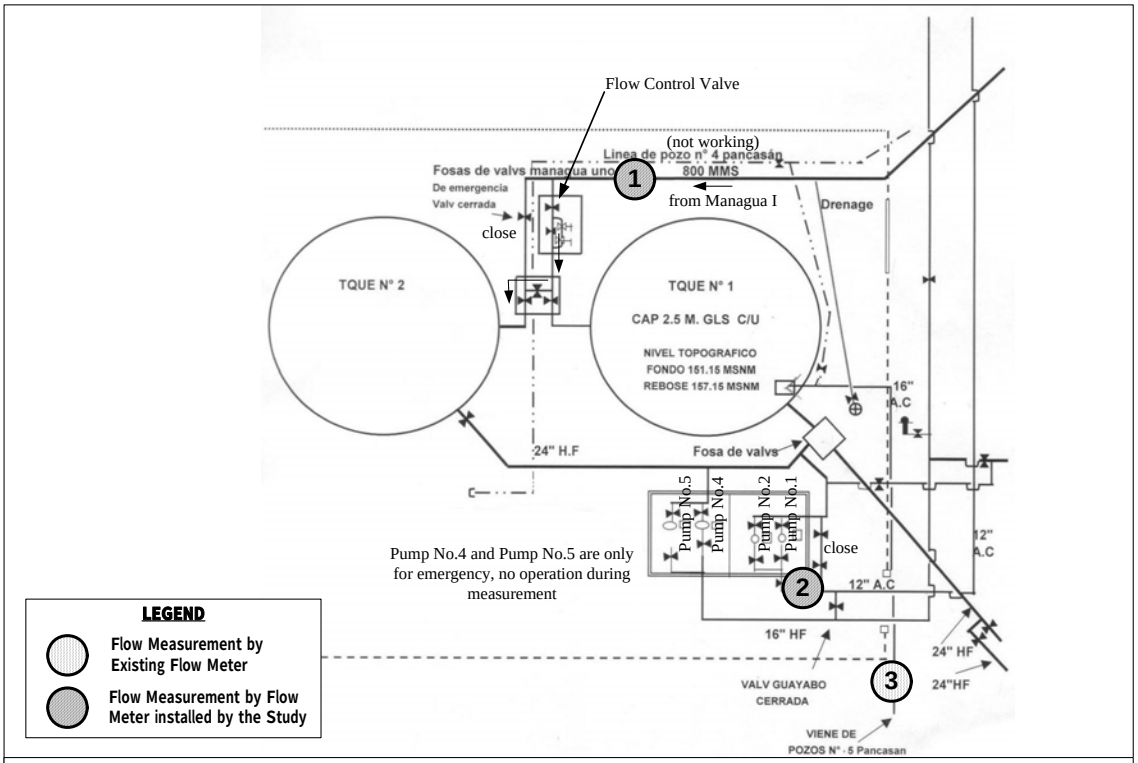


Figure 5.4.21 Results of Flow Measurement at Point No.1

5.4.5 Altamira

Flow rates were measured at 3 points in Altamira as shown in **Figure 5.4.22** for 24 hours from 7 October to 8 October 2004. One of them, Point No.1, was also measured from 30 September to 1 October 2004. Measuring points No.1 and No.2 were measured by installing ultrasonic flow meter (JICA flow meter) and another location, Point No.3, was estimated from pumping amount checked by the JICA flow meter and pump operation hours.



Flow Measurement Survey at Altamira

Figure 5.4.22 Points of Flow Measurement at Altamira

The result of flow measurement of well production which is measured at Point No.3 is shown in **Figure 5.4.23**. The well produced water of 72.7 m^3/hour (1,745 m^3/day). At that time the reading of existing flow meter was 71.7 m^3/hour which was almost the same as the flow measurement result.

Results of flow measurement of Points No.1 (inlet from Managua I System) and No.2 (outlet by pumping) measured by JICA flow meter are shown in **Figures 5.4.24** and **5.4.25** respectively.

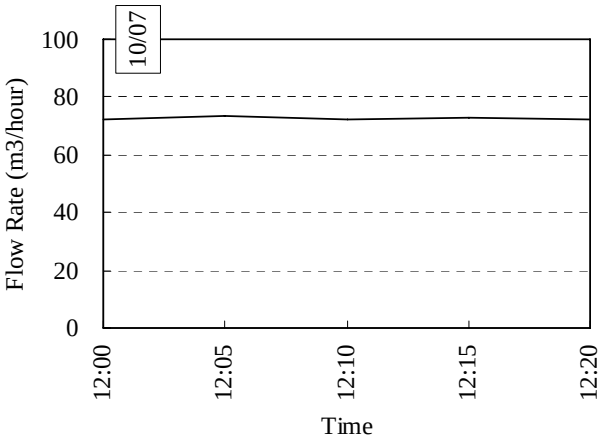


Figure 5.4.23 Result of Flow Measurement at Point No.3

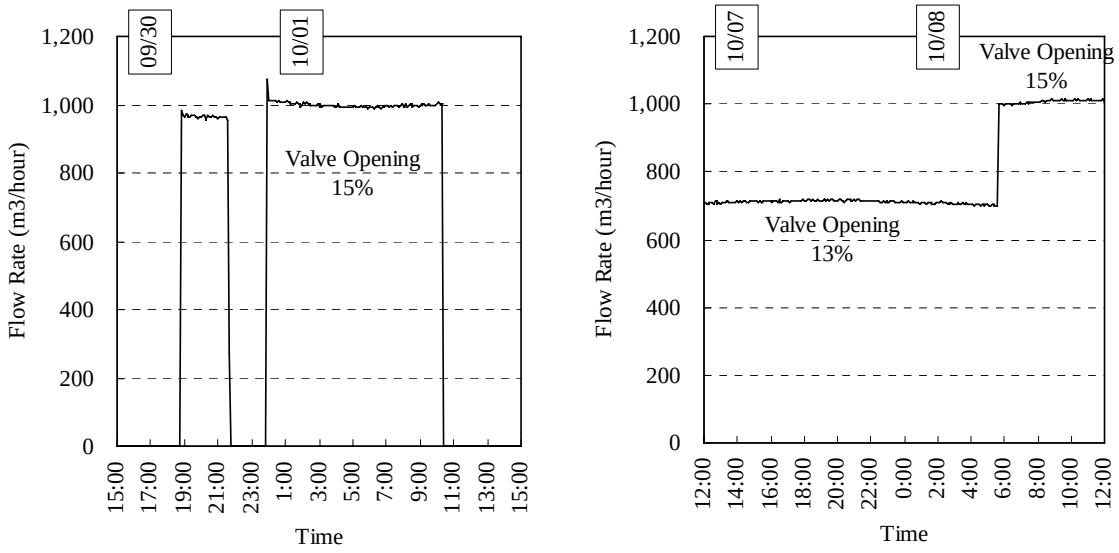


Figure 5.4.24 Results of Flow Measurement at Point No.1

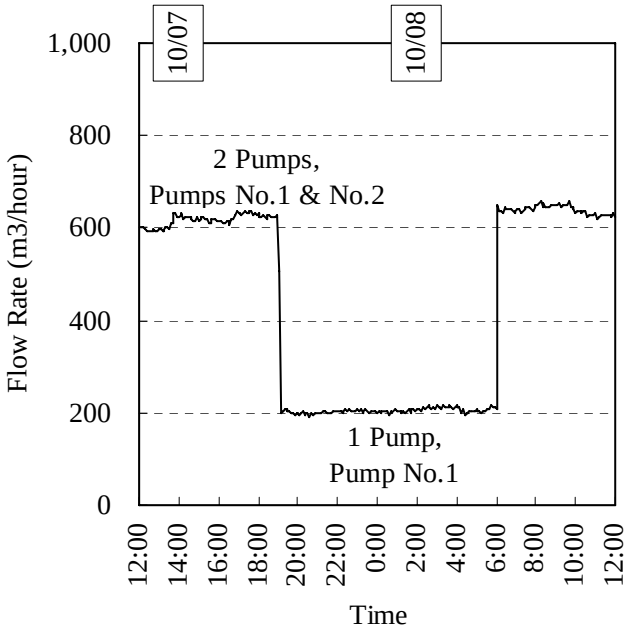


Figure 5.4.25 Result of Flow Measurement at Point No.2

The results of 24-hour flow measurement from 7 October to 8 October are summarized as shown in **Figure 5.4.26**. Outlet flow rate from Altamira Tank by gravity of 10,275 m^3/day is calculated from measured flow rates of three points. Water levels at 12:00 on 7th Oct. and 12:00 on 8th Oct. 2004 were same level of 3.85m.

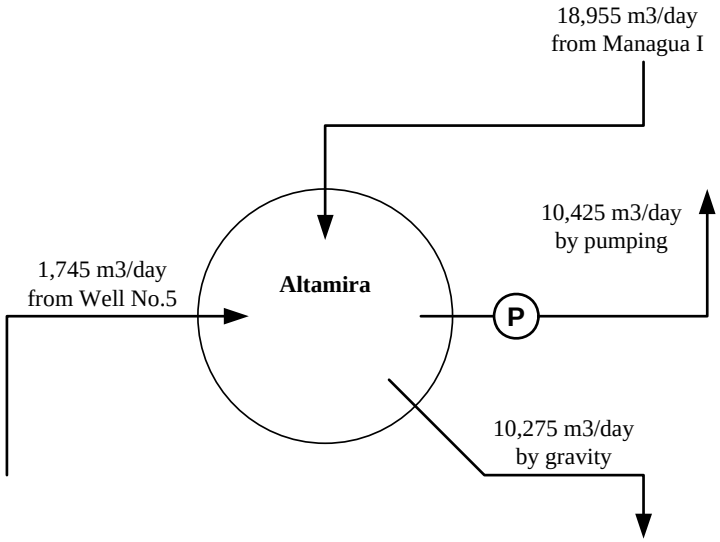


Figure 5.4.26 Balance of Flow at Altamira Tank

According to the basic design report of Managua I Project, water of 22,898 m^3/day is transmitted from Santo Domingo Tank to Altamira Tank by gravity. The results of the flow measurement were 13,241 m^3/day from 30th September to 1st October and 18,955 m^3/day from 7th to 8th October, which shows that enough water is not necessarily transmitted to Altamira Tank from Managua I System.

In addition, water more than half of transmitting water from Santo Domingo Tank by gravity is pumping up to upper area in the direction of Santo Domingo Tank.

5.4.6 San Cristobal

Flow rates were measured at 2 points in San Cristobal as shown in **Figure 5.4.27** for 24 hours from 4 October to 5 October 2004. One of them, Point No.1, was measured by installing ultrasonic flow meter (JICA flow meter) and another location, Point No.2, was measured by the existing flow meter.

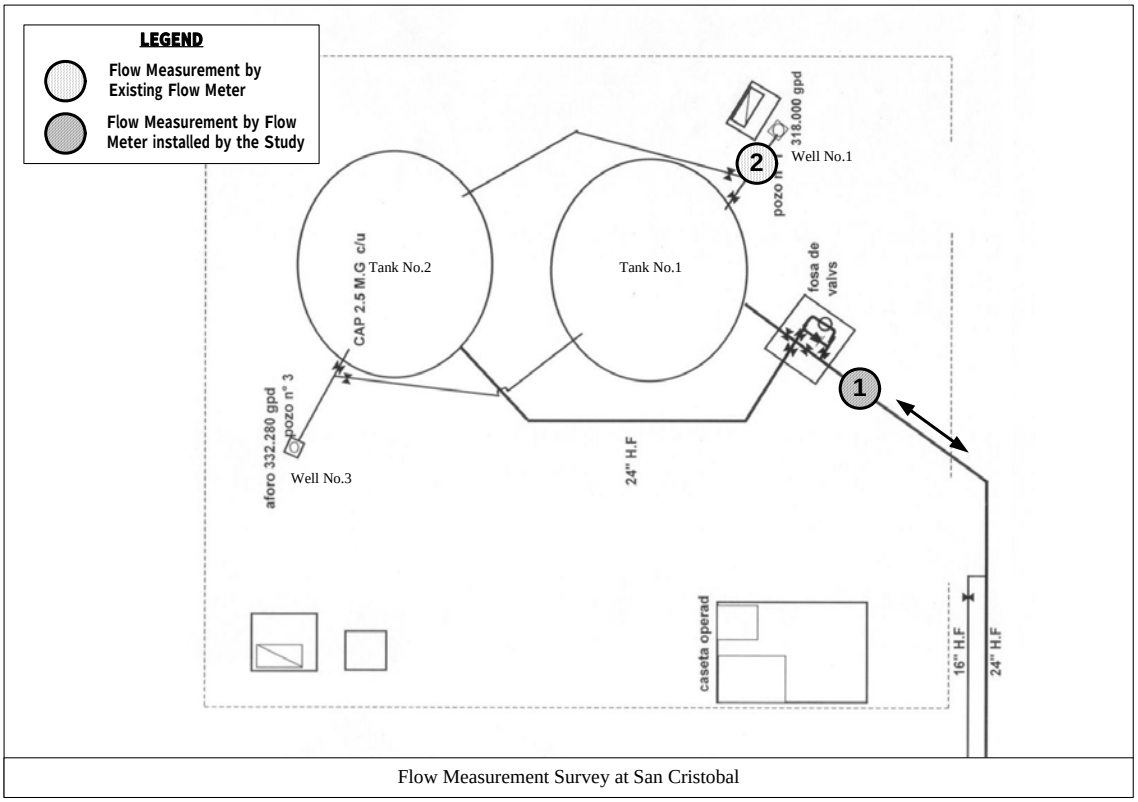


Figure 5.4.27 Points of Flow Measurement at San Cristobal

The existing flow meter which measures the production amount of Well No.1 was checked with JICA flow meter. As the results of 1 hour measurement, readings of the existing flow meter and JICA flow meter were 45.59 m^3/hour and 44.90 m^3/hour respectively. **Figure 5.4.28** shows the result of flow measurement by JICA flow meter. Therefore, it is concluded that the existing flow meter is accurate and can be used for the Study.

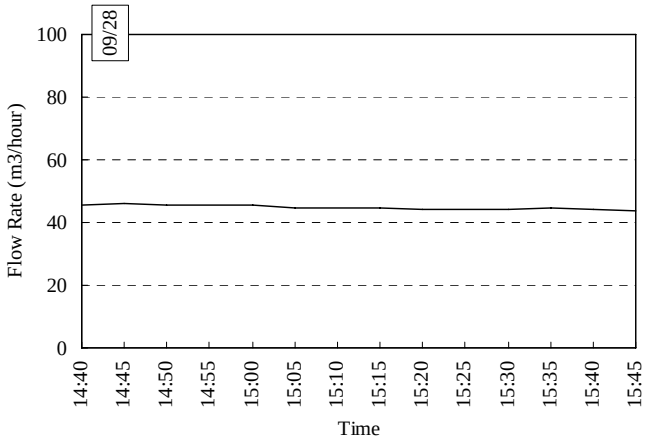


Figure 5.4.28 Record of Ultrasonic Flow Meter installed at Point No.2

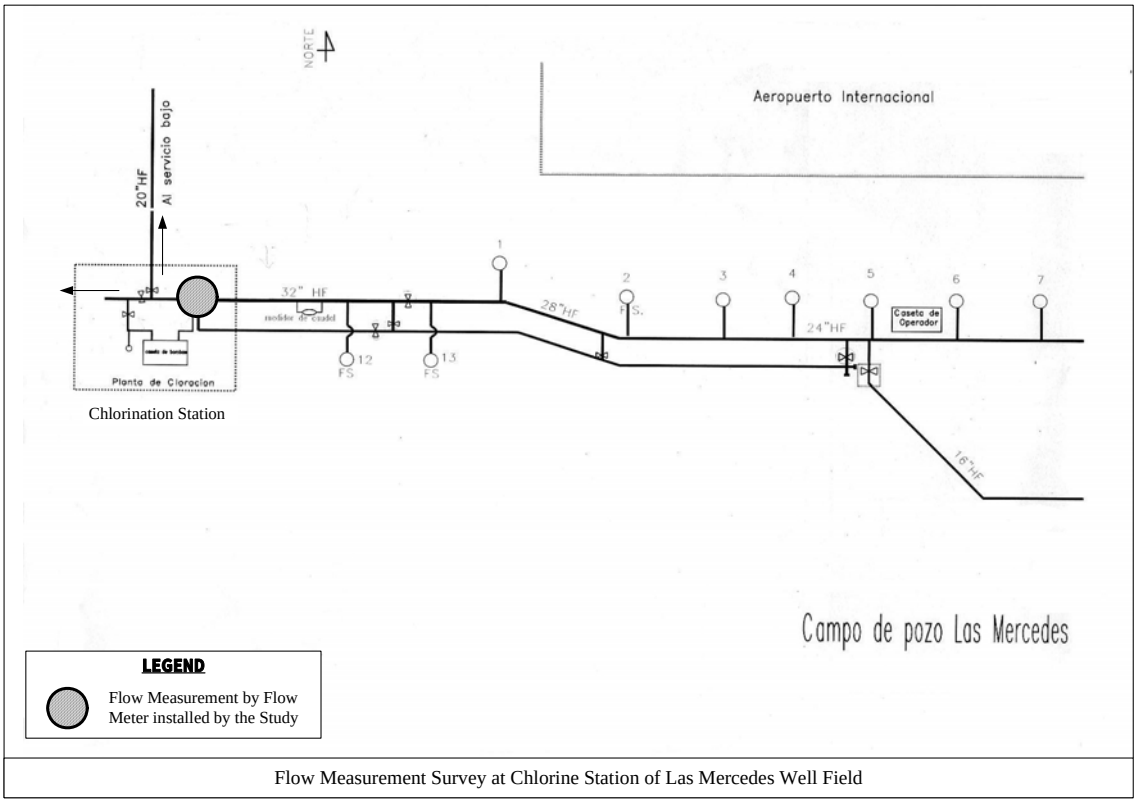
Result of flow measurement of Point No.1 measured by JICA flow meter is shown in **Figure 5.4.29**.

Figure 5.4.29 Results of Flow Measurement

San Cristobal Tank has only one pipeline which is connected with the distribution network system. Therefore, its pipeline has two functions as inlet pipe and outlet pipe. As shown in **Figure 5.4.29** at night time the reverse flow which means inlet to the tank occurred. Difference between outlet (plus flow) and inlet (minus flow) is calculated at + 89.6 m^3, which means that the amount of outlet flow through this pipeline was more than that of inlet flow for 24-four measurement. Considering the well water of 1,078 m^3/day (44.9 m^3/hour X 24 hours; inlet), inlet flow to the tank was more than outlet flow, but it can be said that inlet and outlet flows are almost balanced. As the record of ENACAL water levels of the tank at 16:00 on 4 October and at 16:00 on 5 October 2004 were almost same. About the water of 9,000 m^3 a day goes in and out from San Cristobal Tank.

5.4.7 Las Mercedes

Flow rate from the Las Mercedes Well Field which has 13 wells was measured at Chlorination Injection Station as shown in **Figure 5.4.30** for 24 hours from 23 September to 24 September 2004. **Figure 5.4.31** shows the result of flow measurement.



Flow Measurement Survey at Chlorine Station of Las Mercedes Well Field

Figure 5.4.30 Point of Flow Measurement at Las Mercedes

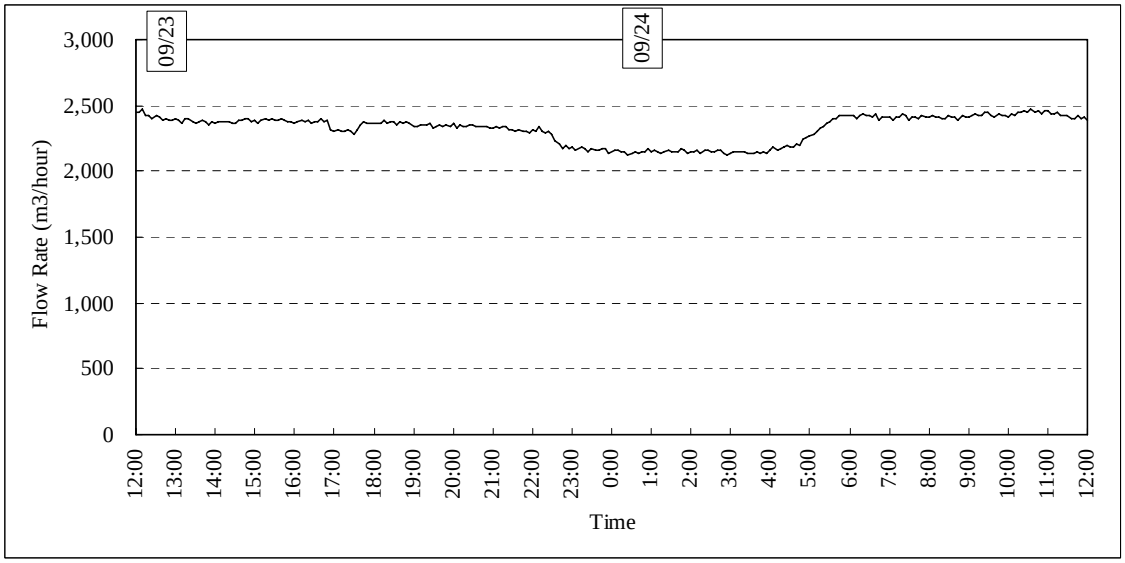


Figure 5.4.31 Result of Flow Measurement

Actually the water flowed through the measurement point is produced from 12 wells, because one well is located at the downstream of the measurement point. As the result water of 55,735 m^3/day was supplied to Low Zone from 12 wells of Las Mercedes Well Field. According to the statistic records of ENACAL, production amount of remaining one well, Well No.9, is estimated at 2,387 m^3/day. Therefore water of about 58,000 m^3/day was supplied from Las Mercedes Well Field. ENACAL recorded total flow rates on 23rd and 24th September 2004 from Las Mercedes Well Field as follows;

23rd September 2004: 53,071 m^3/day (51,015 m^3/day excluding Well No.9)
24th September 2004: 64,417 m^3/day (62,030 m^3/day excluding Well No.9)

Average flow excluding Well No.9 of these two days is 56,523 m^3/day, which is almost same as the results of flow measurement by the Study, 55,735 m^3/day.

For the reference, production amount of Las Mercedes Well Field in 2004 based on the records of ENACAL is shown in **Figure 5.4.32**.

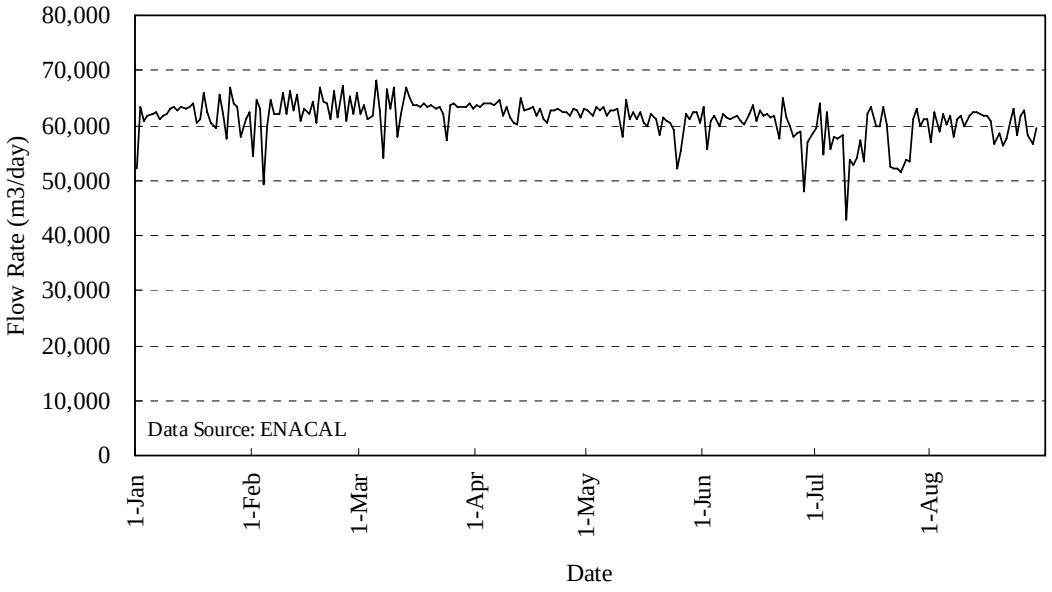
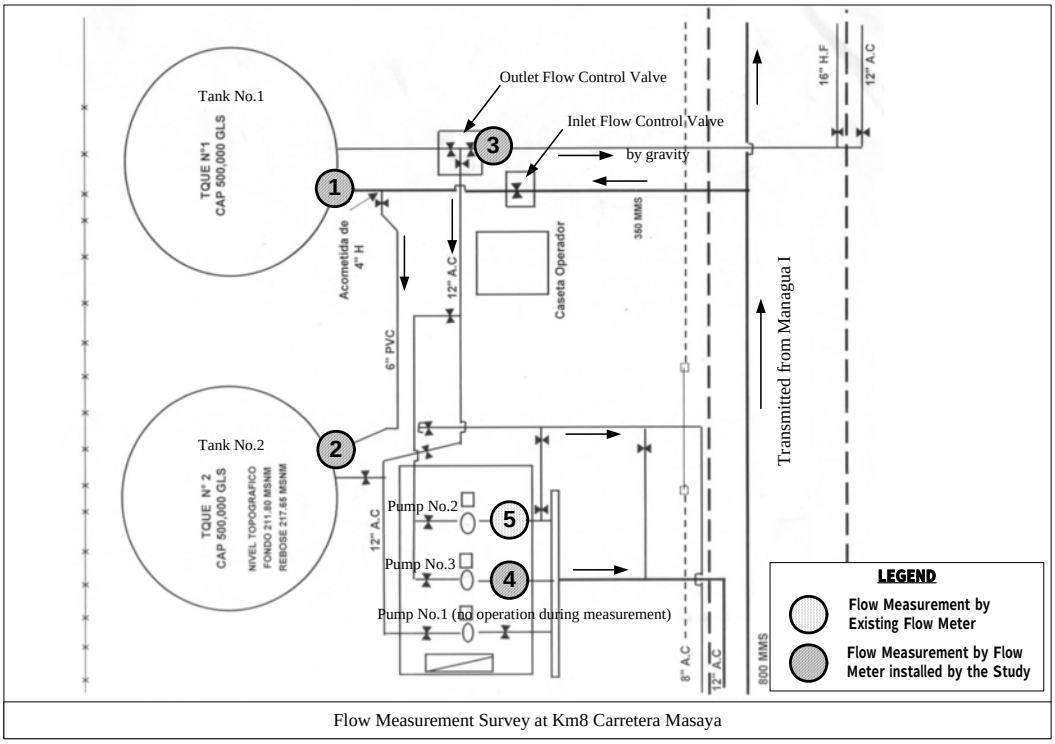


Figure 5.4.32 Flow Rate from Las Mercedes Well Field in 2004

Average flow rate from Las Mercedes Well Field in 2004 (until the end of August) is calculated at 61,136 m^3/day.

5.4.8 Km 8 Carretera Masaya

In Km8 Carretera Masaya flow rates were measured at 5 points as shown in **Figure 5.4.33** from 20 September to 22 September 2004. Results of flow measurement of Points No.1, No.2 and No.3 measured by JICA flow meters are shown in **Figures 5.4.34** and **5.4.35**.



Flow Measurement Survey at Km8 Carretera Masaya

Figure 5.4.33 Points of Flow Measurement at Km8 Carretera Masaya

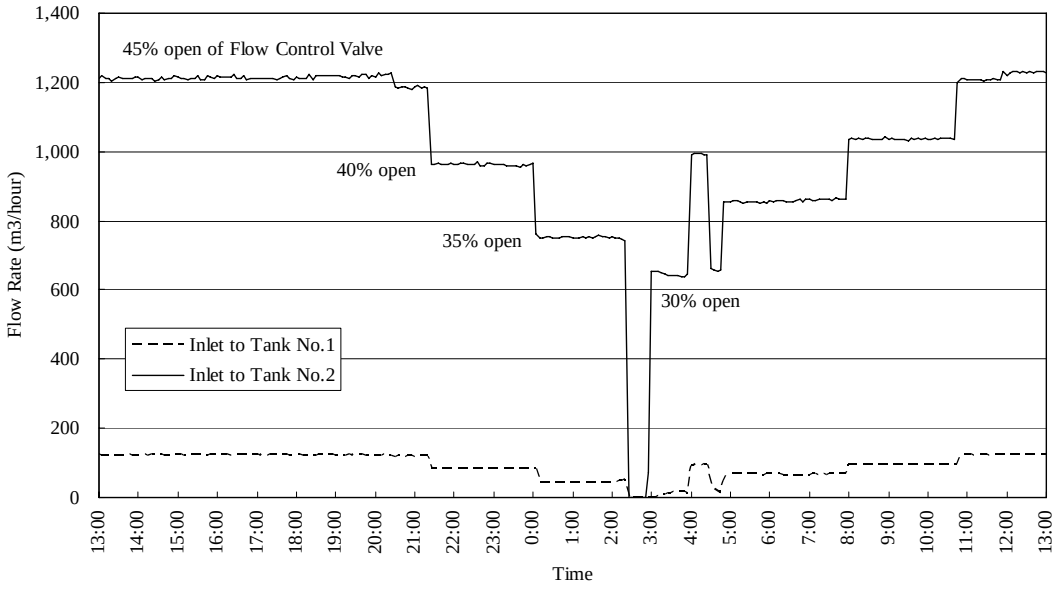


Figure 5.4.34 Results of Flow Measurement at Points No.1 and No.2

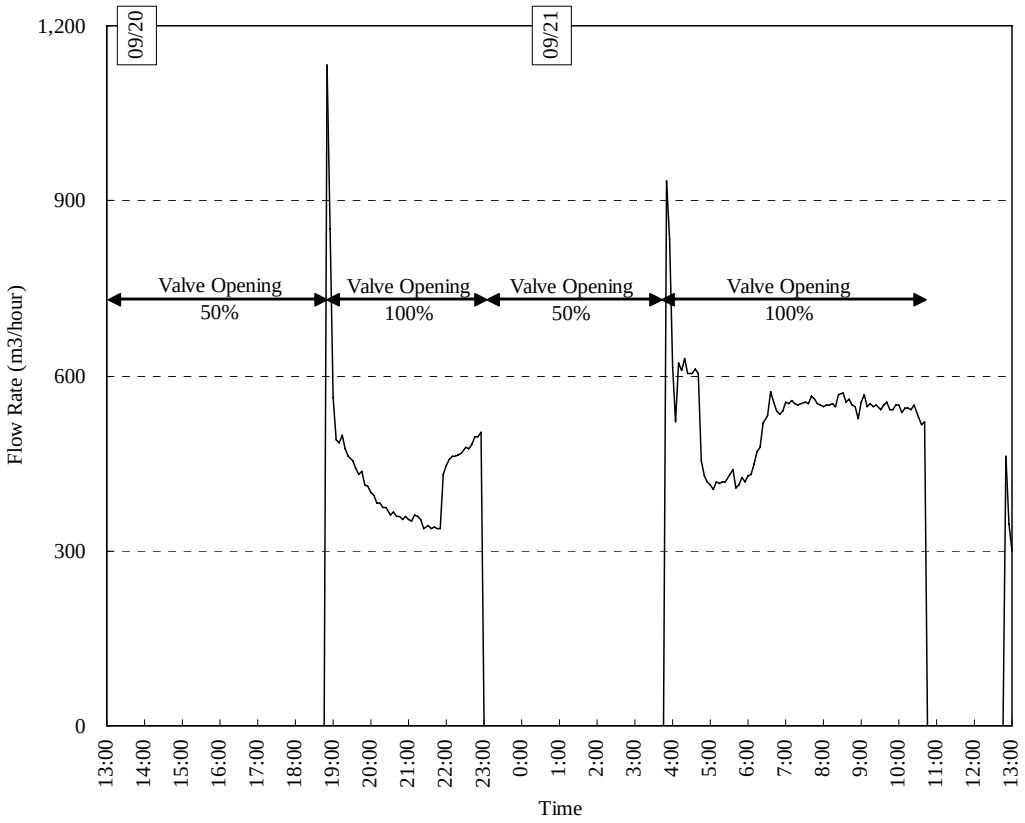


Figure 5.4.35 Result of Flow Measurement at Points No.3

Inlet flows to tanks were control by the inlet flow control valve and also outlet flow by gravity was controlled. As shown in **Figure 5.4.34** the inlet flows to tanks reflected opening of the inlet flow control valve. Gravitated outlet flow from tank could not be measured during 50 % opening of the outlet flow control valve because of turbulence flow. This outlet flow by gravity can be, however, calculated from the balance between inlet flow and the outlet flow by pumping and considering tank water levels at 13:00 on 20th and 21st September 2004, which is estimated as below;

Inlet flow from Managua I System : 26,415 m^3/day (total flow of Points No 1 & 2)
Tank Volume Fluctuation : - 268 m^3
(Tank No.1: 3.40 m to 4.70 m, Tank No.2: 3.55 m to 1.40 m, from 13:00 on 20th September to 13:00 on 21st September 2004)
Outlet Flow by Pumping : 16,275 m^3/day
Pump No.1: no operation during measurement
Pump No.2: 11,654 m^3/day (measured by the existing flow meter)
Pump No.3: 4,621 m^3/day (measured by JICA flow meter)
Outlet Flow by Gravity : 10,408 m^3/day.

On the other hand, the outlet flow control valve is a standard butterfly valve, so it can be assumed that about 80 % of water flows even only at the 50 % opening. From such assumption the outlet flow by gravity is calculated at 10,462 m^3/day. As the results the flow balance at Km8 Carretera Masaya is summarized as **Figure 5.4.36**. According to the basic design report of Managua I Project, water of 16,074 m^3/day is transmitted from Santo Domingo Tank by gravity. The results of flow measurement show that water more than the plan, 26,415 m^3/day, is supplied to Km8 Carretera Masaya and distributed. Almost half water of Managua I System transmitted from Santo Domingo is consumed at Km8 Carretera Masaya. According

to the inlet valve operation records, the daily opening percentage of inlet valve is almost 35 % to 40 %. This means that water of 21,000 m^3/day to 26,000 m^3/day is transmitted from Managua I System.

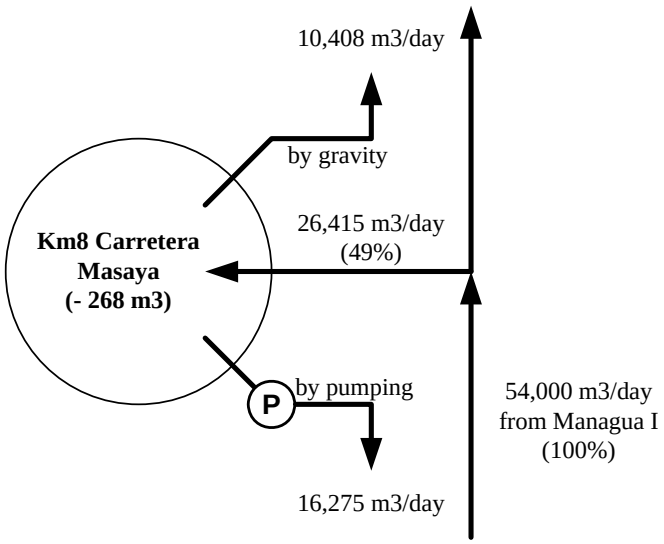


Figure 5.4.36 Flow Balance at Km8 Carretera Masaya

5.4.9 Santo Domingo

In Santo Domingo flow rate was measured at Point No.1 as shown in **Figure 5.4.37** by JICA flow meter from 21st September to 22nd September 2004. As the result during measurement period no water flowed through Point No.1. Flow measurement was carried out another day from 5th October to 6th October 2004, but same result as no water flow was also obtained.

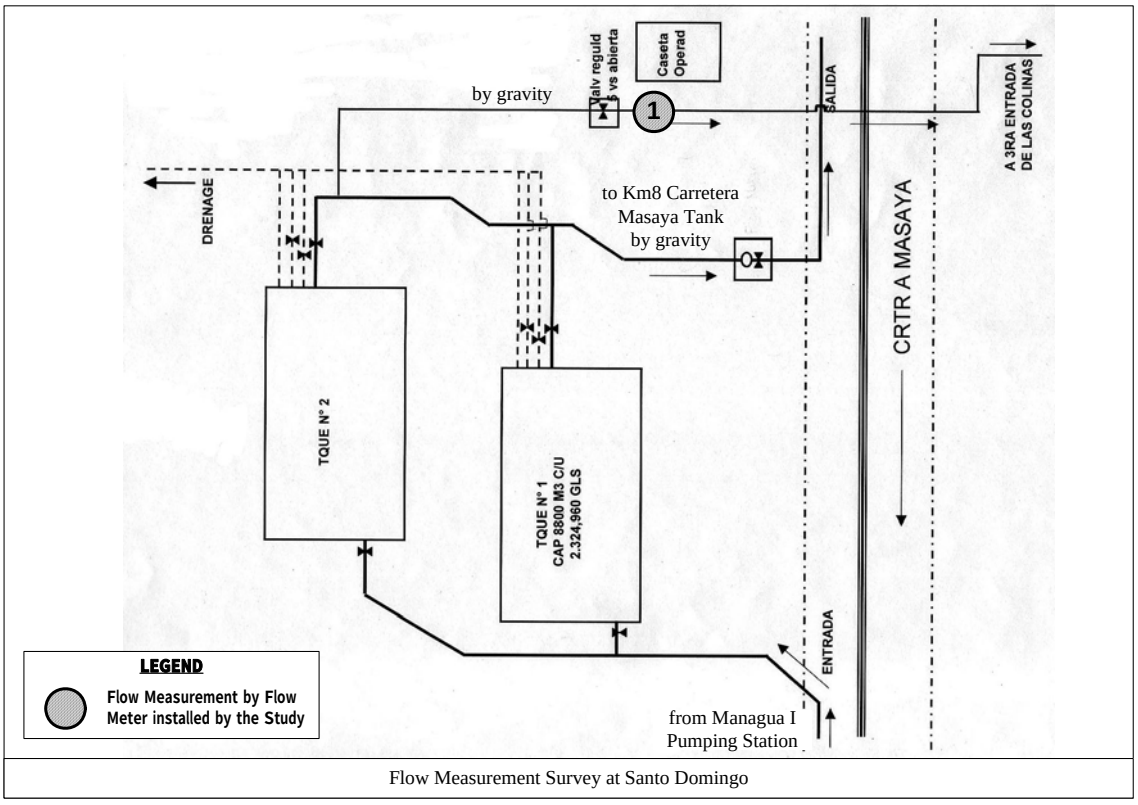


Figure 5.4.37 Point of Flow Measurement at Santo Domingo

5.4.10 Schick

In Schick flow rate was measured at Point No.1 as shown in **Figure 5.4.38** by JICA flow meter from 11th October to 13th October 2004. Result of flow measurement at Points No.1 is shown in **Figures 5.4.39**.

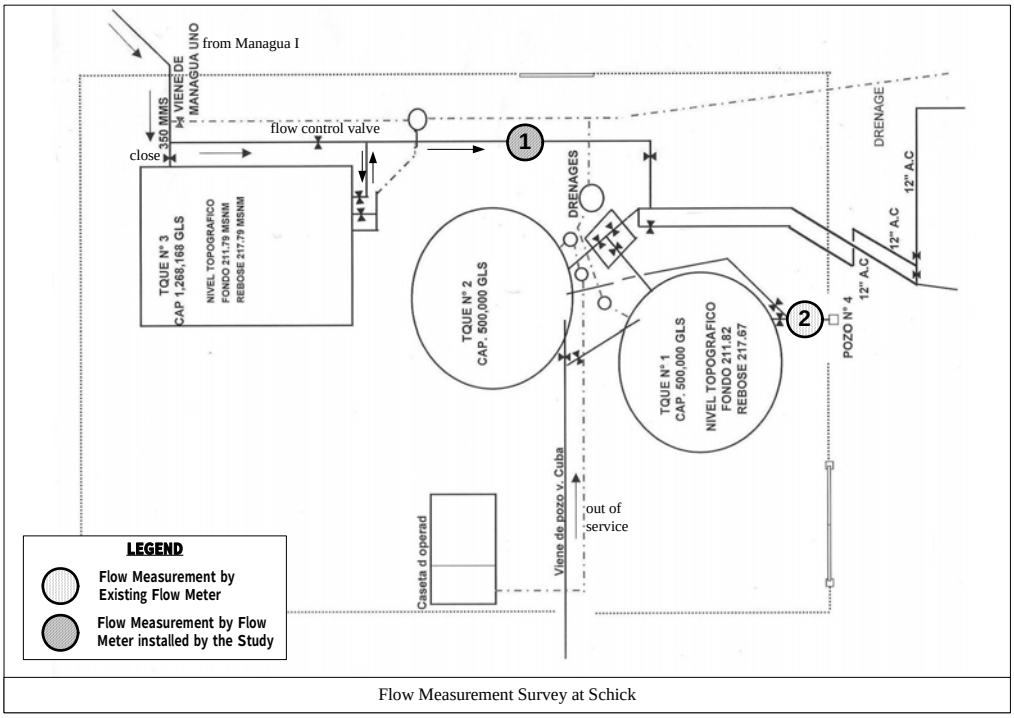


Figure 5.4.38 Points of Flow Measurement at Schick

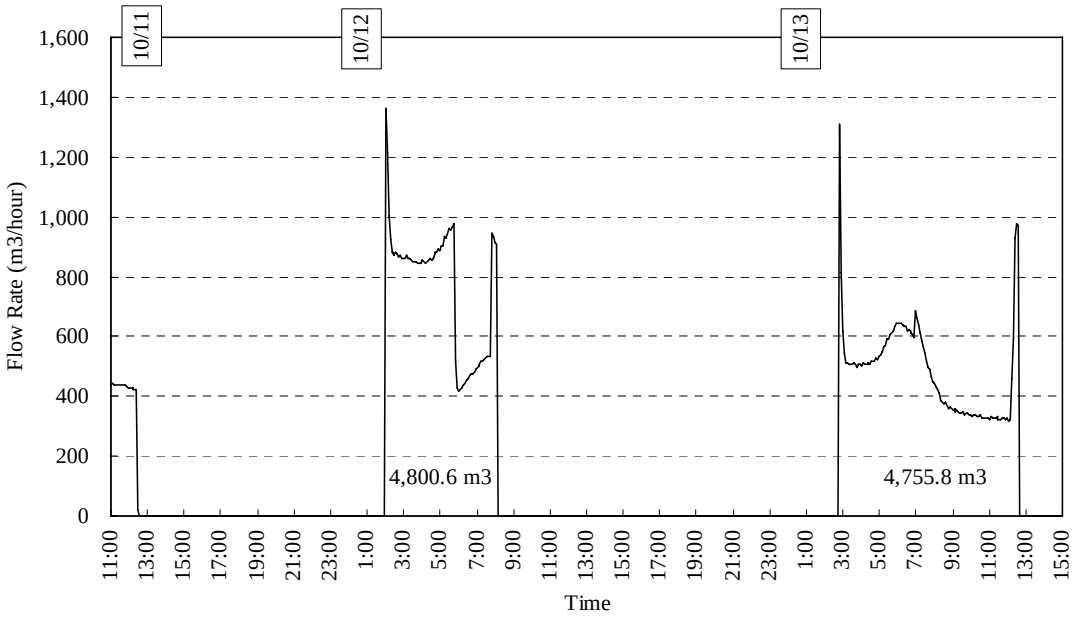


Figure 5.4.39 Result of Flow Measurement at Point No.1

Schick Tank received water of 4,800 m^3/day from Santo Domingo Tank by gravity. According to the basic design report of Managua I Project, water of 14,315 m^3/day is transmitted from Santo

Domingo Tank by gravity. The result of the flow measurement shows that the expected enough water is not supplied to Schick Tank, which is only 34 % of planning flow rate.

At Point No.2 the existing flow meter was checked with the JICA flow meter as shown in **Figure 5.4.40** and the result was that the readings of JICA flow meter and the existing flow meter are nearly the same. Therefore well at Schick Tank produces water of about 800 m^3/day.

Data No.	
Schick Point No.2	
Max.	
2004/10/11	10:50:00
33.6	CU M/HR
Min.	
2004/10/11	11:05:00
32.7	CU M/HR
Average.	
33.1	CU M/HR
Total (for 30 minutes)	
16.5	CU M

Pipe data	[inch]
Pipe OD	4.5116
Pipe Material	Cast Iron
Wall Thickness	0.2558
Liner Material	None
Liner Thickness	0

Existing Meter Reading	
10:50	10932.92
11:20	10949.55
total	16.63
	=16.63×2
	=33.26/Hr

Comparison	
Existing	33.26
JICA	33.00
	99.22%

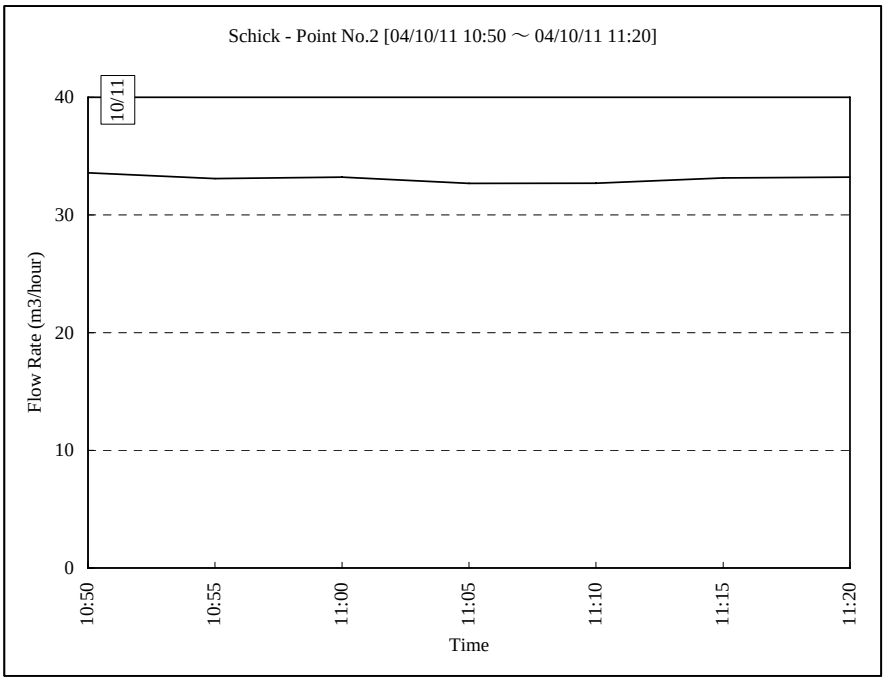


Figure 5.4.40 Result of Flow Measurement at Point No.2

5.4.11 Managua I

In Managua I flow rate was measured at the outlet flow from the transmission pumping station as shown in **Figure 5.4.41** for 24 hours from 16:00 on 16 September to 16:00 on 17 September 2004. At that time three transmission pumps, Pump No.1, No.2 and No.3, were being operated. Results of flow measurement by JICA flow meter is shown in **Figure 5.4.42**.

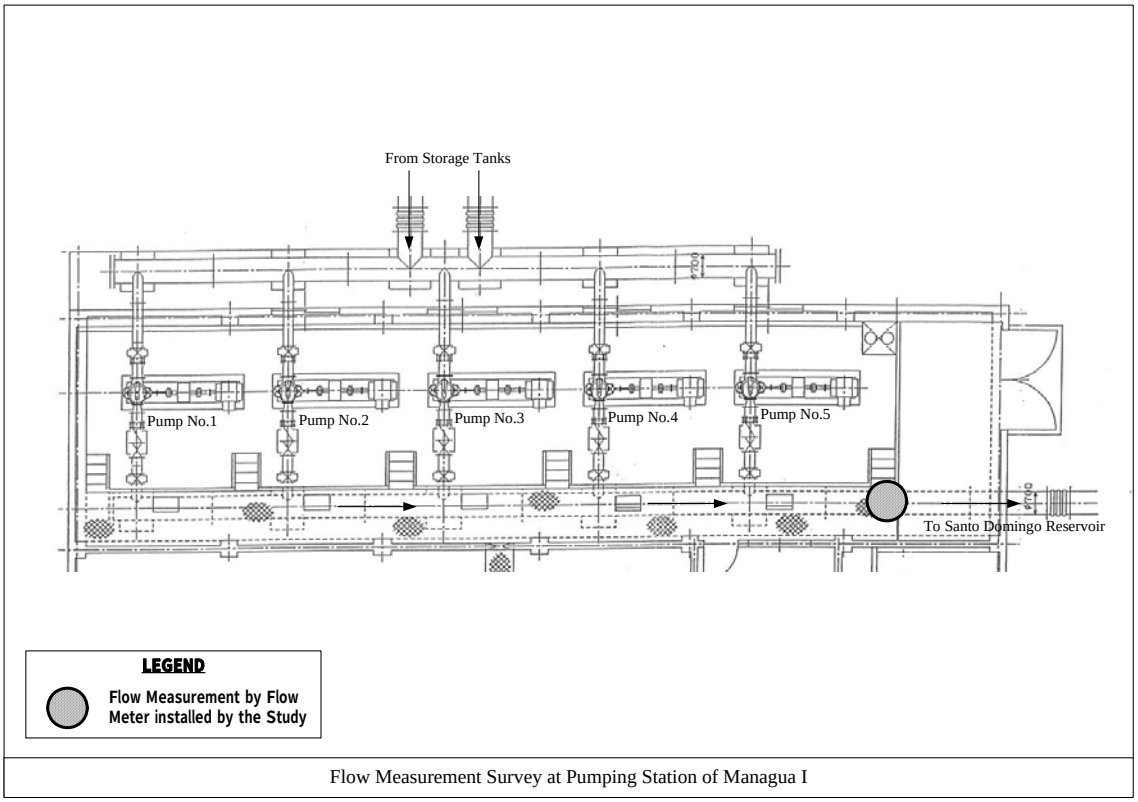


Figure 5.4.41 Points of Flow Measurement at Managua I

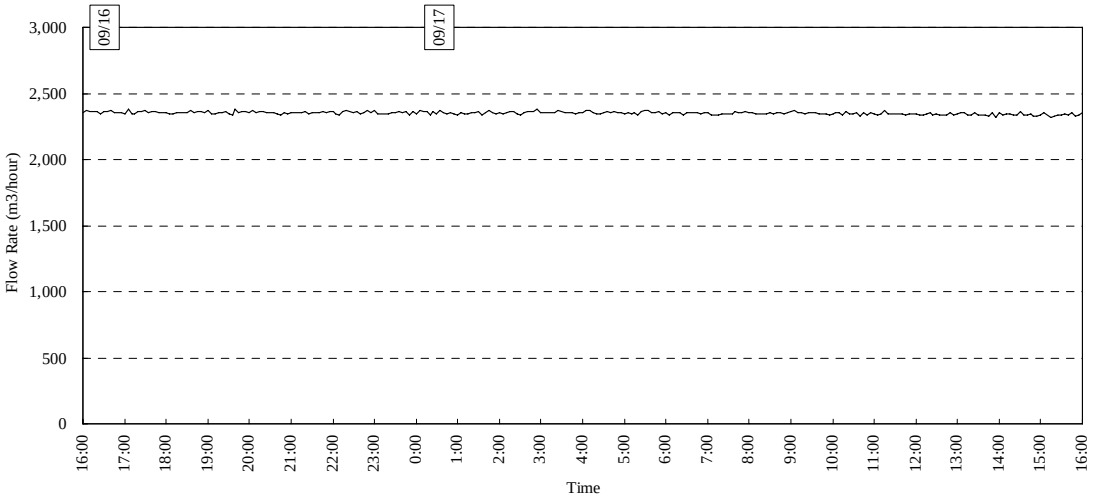


Figure 5.4.42 Results of Flow Measurement

As the results, water of 56,400 m^3/day was pumped to Santo Domingo Tank from Managua I Transmission Pumping Station. Design capacity of the station is, however, 71,000 m^3/day.

According to ENACAL Statistic Data during the same period water of 54,864 m^3/day was produced from Managua I Well Field as shown in **Table 5.4.7**. **Figure 5.4.43** shows the production record of Managua I Well Field for one year from September 2003 to August 2004. Average production is calculated at 50,111 m^3/day.

Table 5.4.7 Production of Managua I Wells

East Wells				West Wells			
No.	Capacity (m3/min)	Operation (hours)	Production (m3/day)	No.	Capacity (m3/min)	Operation (hours)	Production (m3/day)
E1	3.8	24.0	5,472	W1	2.4	24.0	3,456
E2	3.7	24.0	5,328	W2	2.7	24.0	3,888
E3	3.1	24.0	4,464	W3	3.0	24.0	4,320
E4	2.0	0.0	0	W4	2.1	24.0	3,024
E5	3.1	24.0	4,464	W5	3.6	24.0	5,184
E6	2.7	0.0	0	W6	2.8	24.0	4,032
E7	2.7	24.0	3,888	W7	2.7	24.0	3,888
				W8	2.4	24.0	3,456
Total of East Well			23,616	Total of West Well			31,248
Total Production of Managua I for 24 hours from 16:00 on 16 Sept 2004							54,864

source: Daily Resords of Managua I Well Pumps, ENACAL

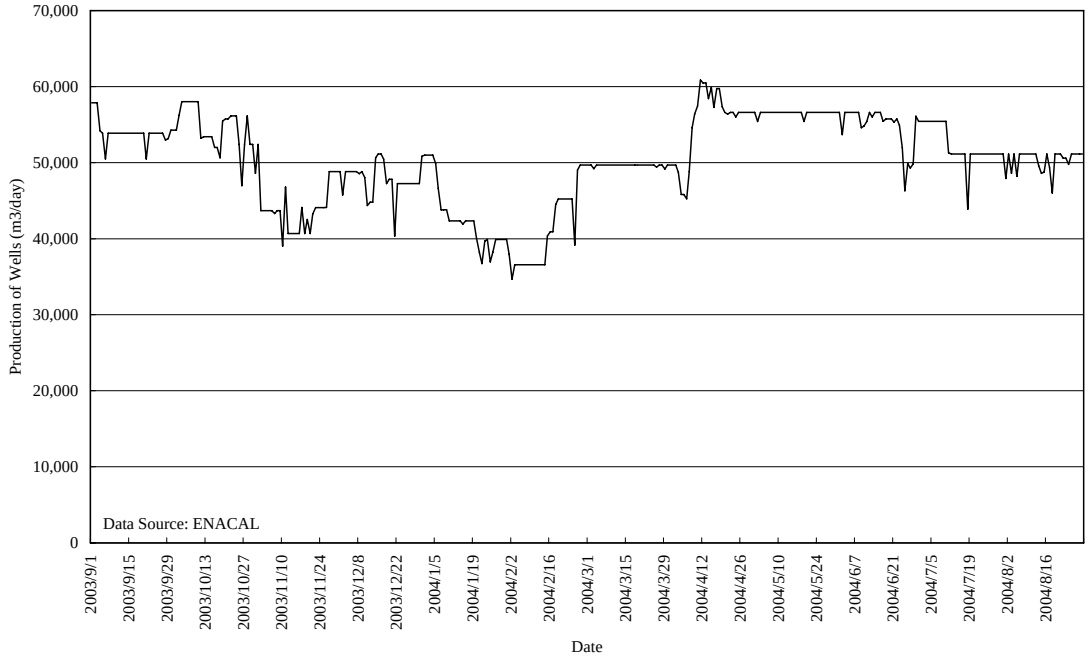
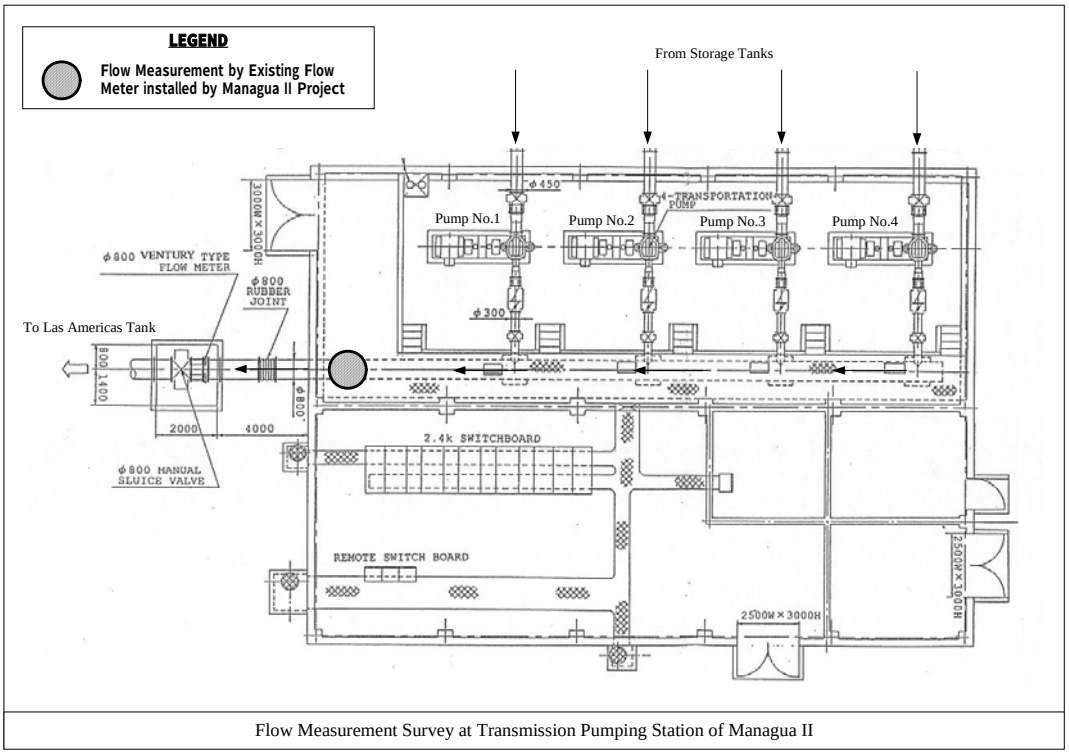


Figure 5.4.43 Production of Managua I Wells in 2003/2004

5.4.12 Managua II

In Managua II flow rate was measured at the outlet flow from the transmission pumping station as shown in **Figure 5.4.44** for 48 hours from 8:00 on 21st October to 8:00 on 23rd October 2004. This measurement was done by reading the existing flow meter every hour.



Flow Measurement Survey at Transmission Pumping Station of Managua II

Figure 5.4.44 Point of Flow Measurement at Managua II

The result of the measurement is shown in **Figure 5.4.45**. As the result of flow measurement the transmission flow from the pumping station of Managua II to Las Americas Tank is 44,783 m^3/day on average during 2 days measurement. Capacity of transmission pumping station of Managua II is 39 m^3/min (56,160 m^3/day) by 3 pumps. At this time, therefore, the pumping station was not operating full.

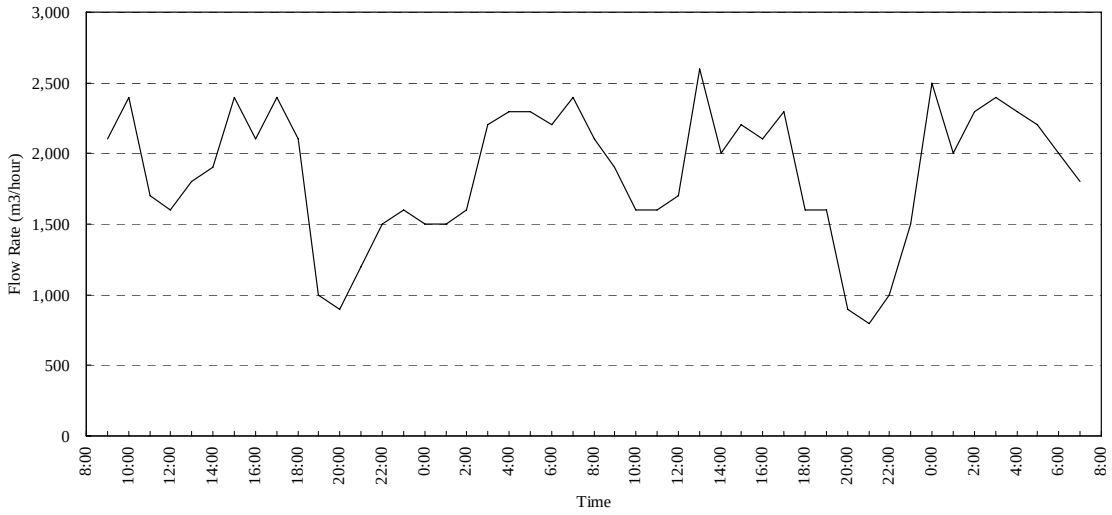


Figure 5.4.45 Result of Flow Measurement

Figure 5.4.46 shows the records of transmission flow in the last one year from August 2003 to July 2004.

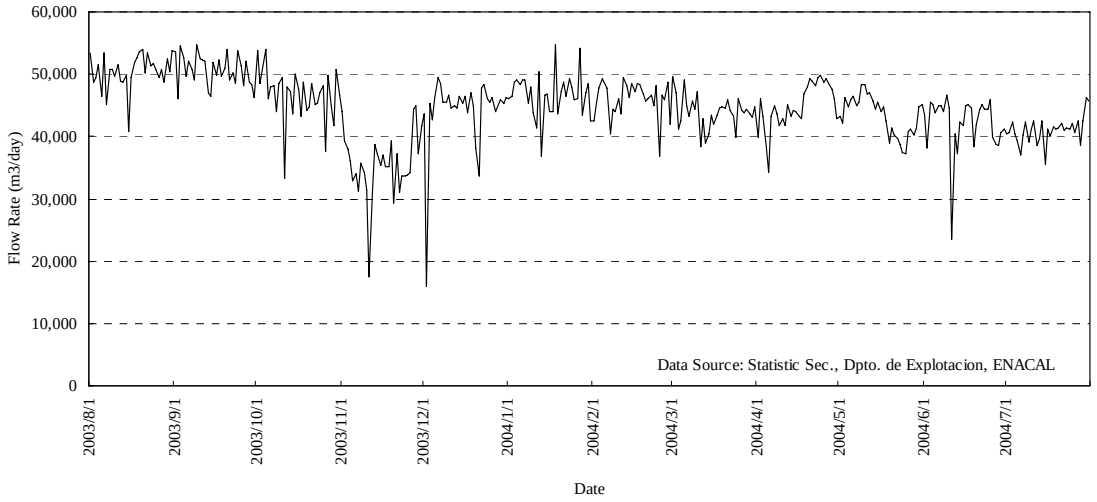


Figure 5.4.46 Transmission Flow in the Last Year

Average transmission flow in the last one year from the pumping station is calculated at 44,514 m^3/day. According to the pump operation records an average number of transmission pump operation a day was about 2.3. In addition **Figure 5.4.47** shows the production records of wells for reference.

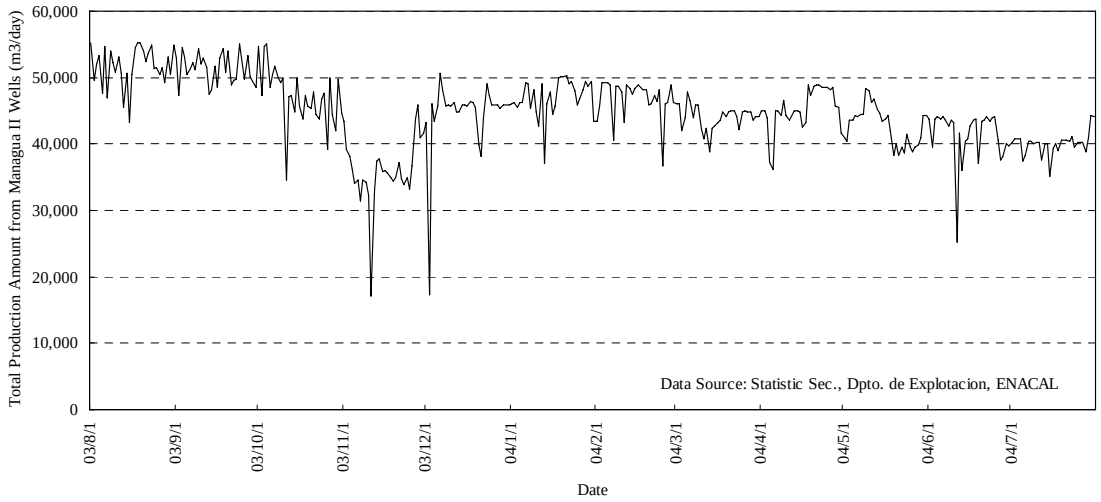


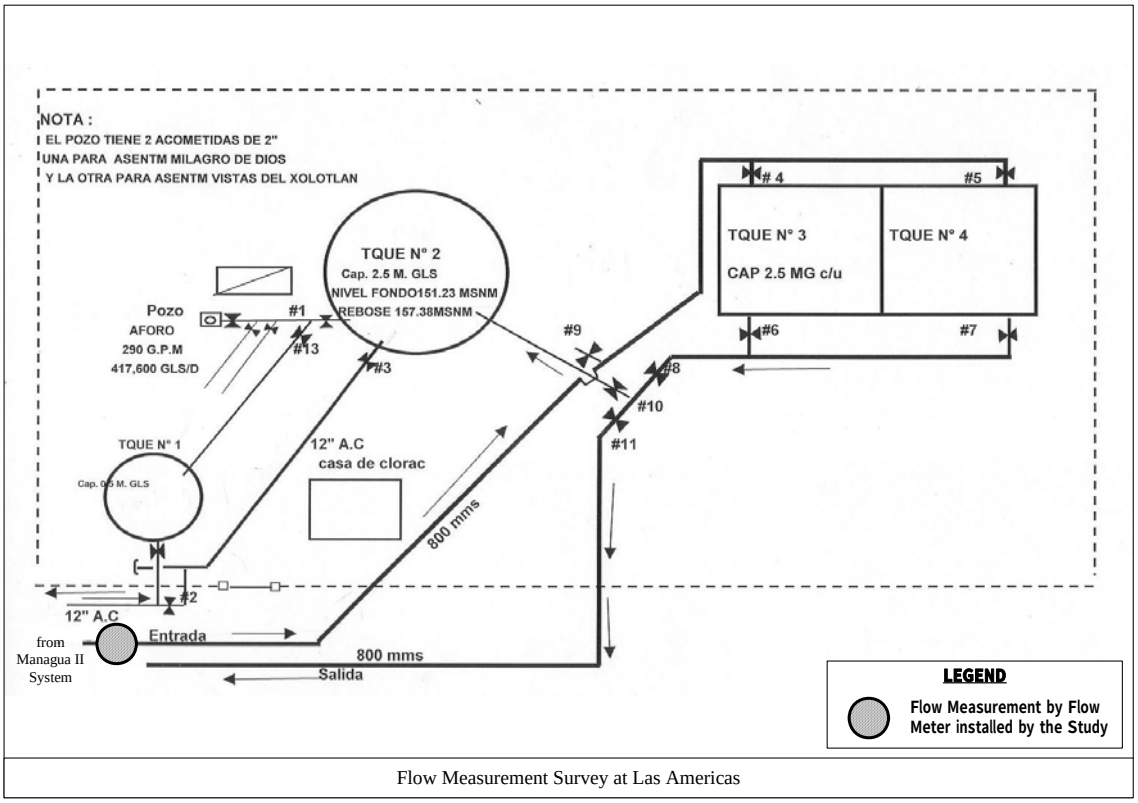
Figure 5.4.47 Total Production of Wells

According to the records of ENACAL from August 2003 to July 2004, it is concluded as follows;

Average transmission amount : 44,783 m^3/day (designed as 56,160 m^3/day)
Average production of wells : 44,726 m^3/day (designed as 56,160 m^3/day)
Average number of well operation: 11.82 wells a day (total 16 wells)
Production amount per well : 2.63 m^3/min/well (designed as 2.6 m^3/min/well)

5.4.13 Las Americas

In Las Americas flow rate was measured at the inlet flow from the transmission pumping station of Managua II System as shown in **Figure 5.4.48** for 24 hours from 13:00 on 21st October to 13:00 on 22nd October 2004. The result of the measurement is shown in **Figure 5.4.49**.



Flow Measurement Survey at Las Americas

Figure 5.4.48 Point of Flow Measurement at Las Americas

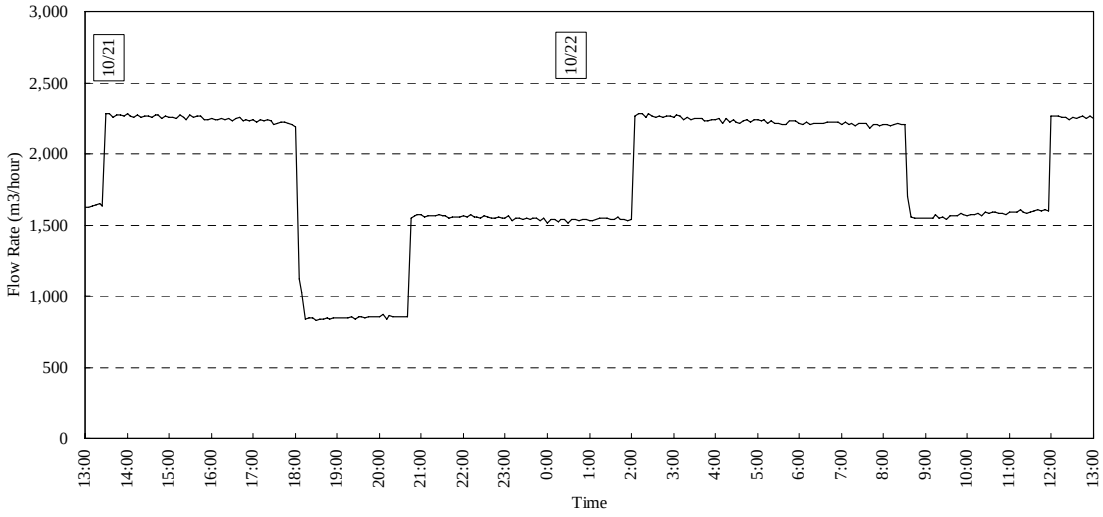


Figure 5.4.49 Result of Flow Measurement

As the result water of 43,892 m^3/day was flowed into Las Americas Tanks. At the same time water of 44,600 m^3/day was transmitted from Managua II Pumping Station. **Figure 5.4.49** shows the difference of flow rate level according to the number of transmission pump operated

at Managua II Pumping Station.

Comparison between flow rates of inlet to Las Americas Tanks and outlet from Managua II Pumping Station is shown in **Figure 5.4.50**. Patterns of both flow rate show the same tendency.

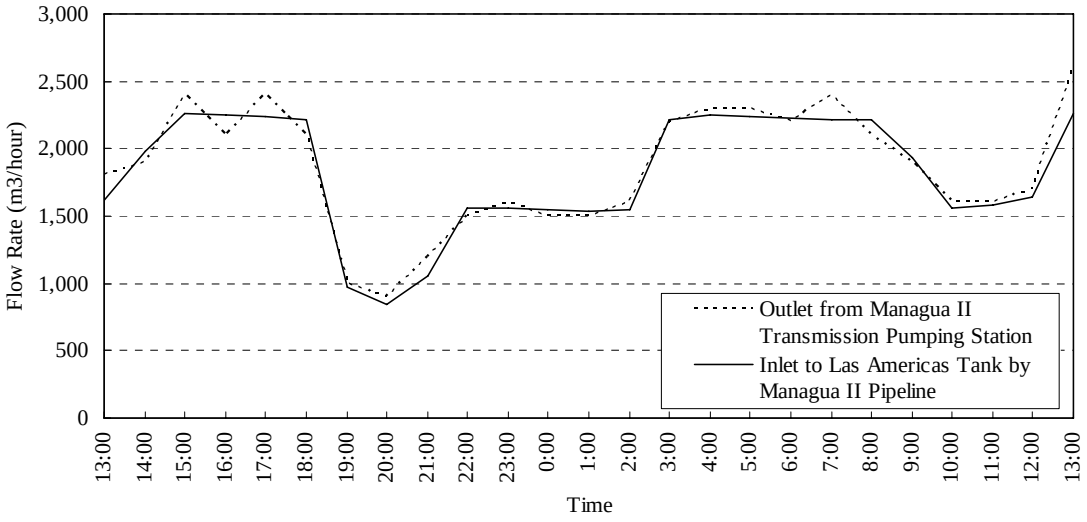
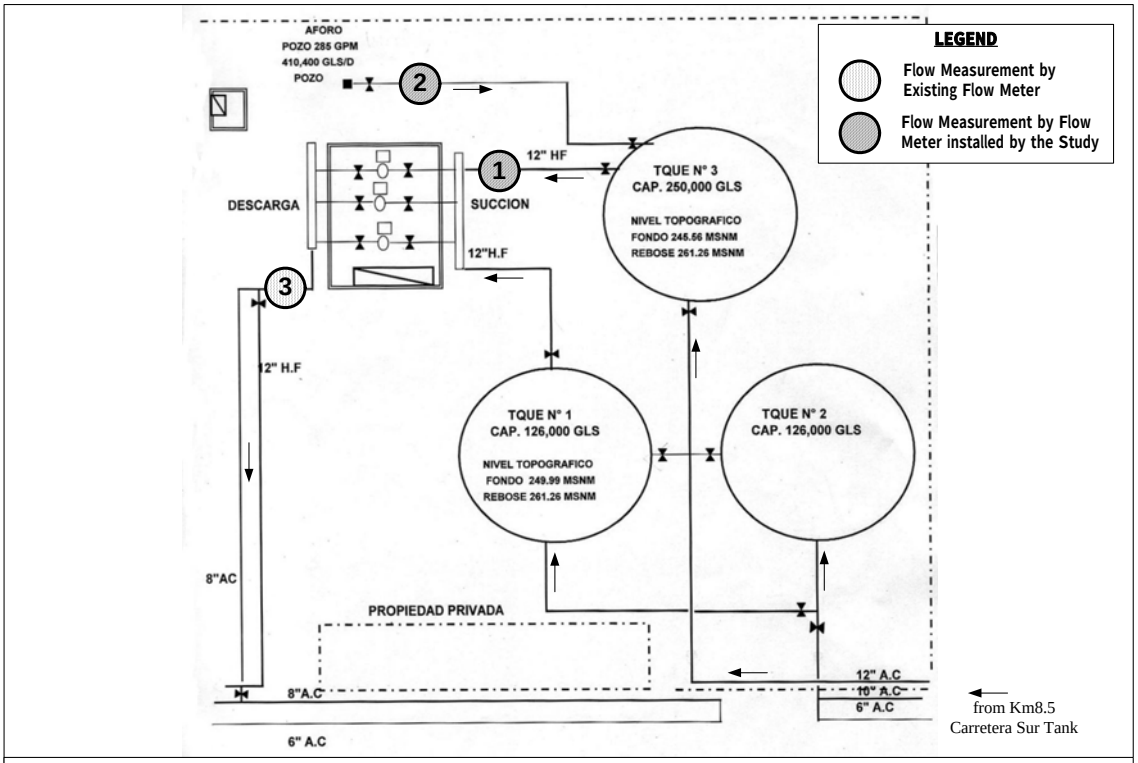


Figure 5.4.50 Flow Comparison between Outlet from Managua II Pumping Station and Inlet to Las Americas Tank

5.4.14 Km 9.2 Carretera Sur

In Km9.2 Carretera Sur flow rates were measured at two points first as shown in **Figure 5.4.51** for 24 hours from 15:00 on 4th November to 12th November 2004.



Flow Measurement Survey at Km9.2 Carretera Sur

Figure 5.4.51 Point of Flow Measurement at Km 9.2 Carretera Sur

The existing flow meter which measures the production amount of Well was checked with JICA flow meter. As the results of 40 minutes measurement, readings of the existing flow meter and JICA flow meter were 39.8 m^3 and 41.0 m^3 respectively. **Figure 5.4.52** shows the result of flow measurement by JICA flow meter. Therefore, it is concluded that the existing flow meter is accurate and can be used for flow measurement.

Result of flow measurement of Point No.1 measured by JICA flow meter is shown in **Figure 5.4.53**.

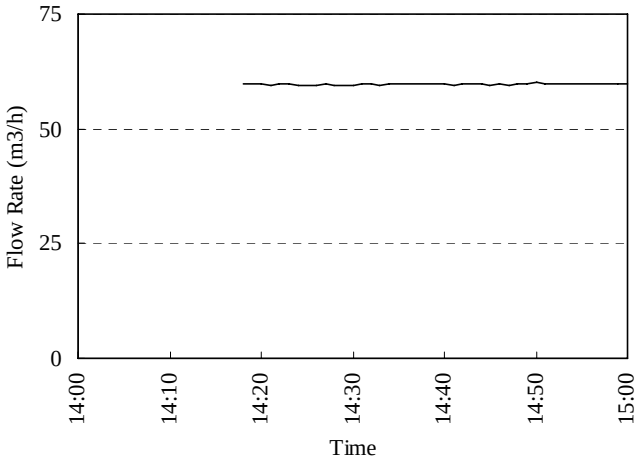


Figure 5.4.52 Record of JICA Flow Meter installed at Point No.2

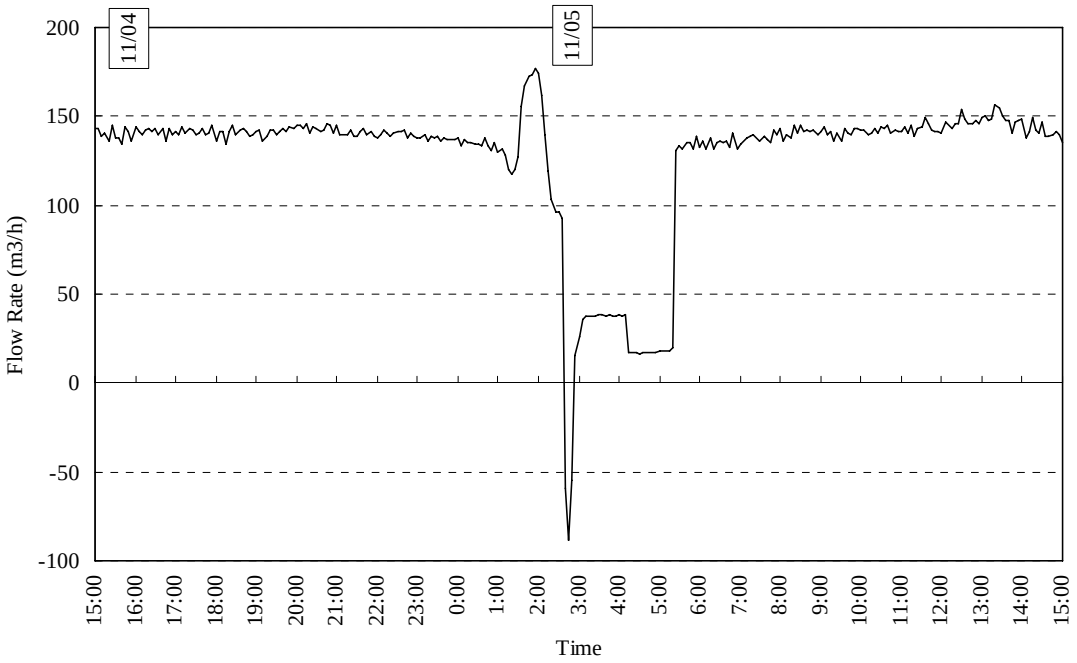


Figure 5.4.53 Results of Flow Measurement

Next the flow rate at Point No.3 was measured by reading the existing flow meter, and its results are as follows;

at 15:00 on 5th Nov. 2004	: 6218715
at 15:00 on 12th Nov.2004	: 6239321

The flow rate at Point No.3 was 20,606 m^3 for 7 days and 2,944 m^3/day on average. For reference, based on ENACAL Statistic Data the flow rates from Km9.2 Carretera Sur Pumping Station in 2004 are shown in **Figure 5.4.54**.

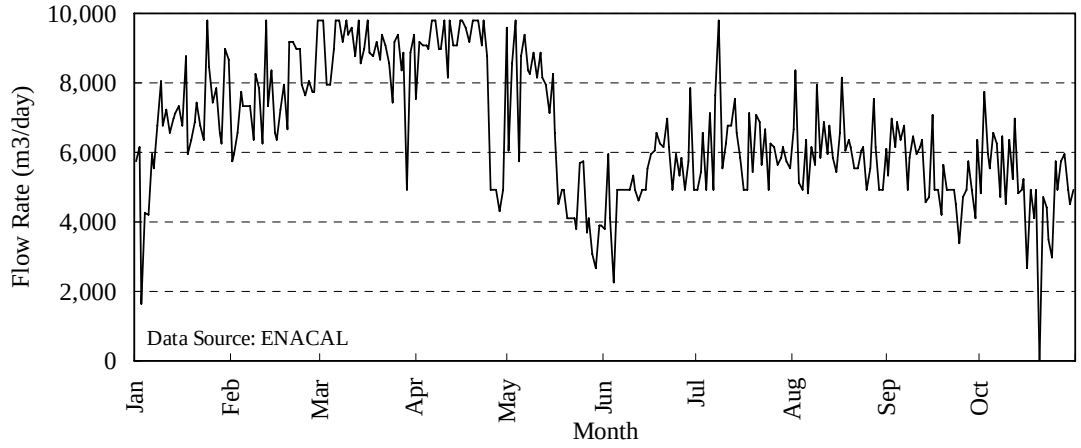
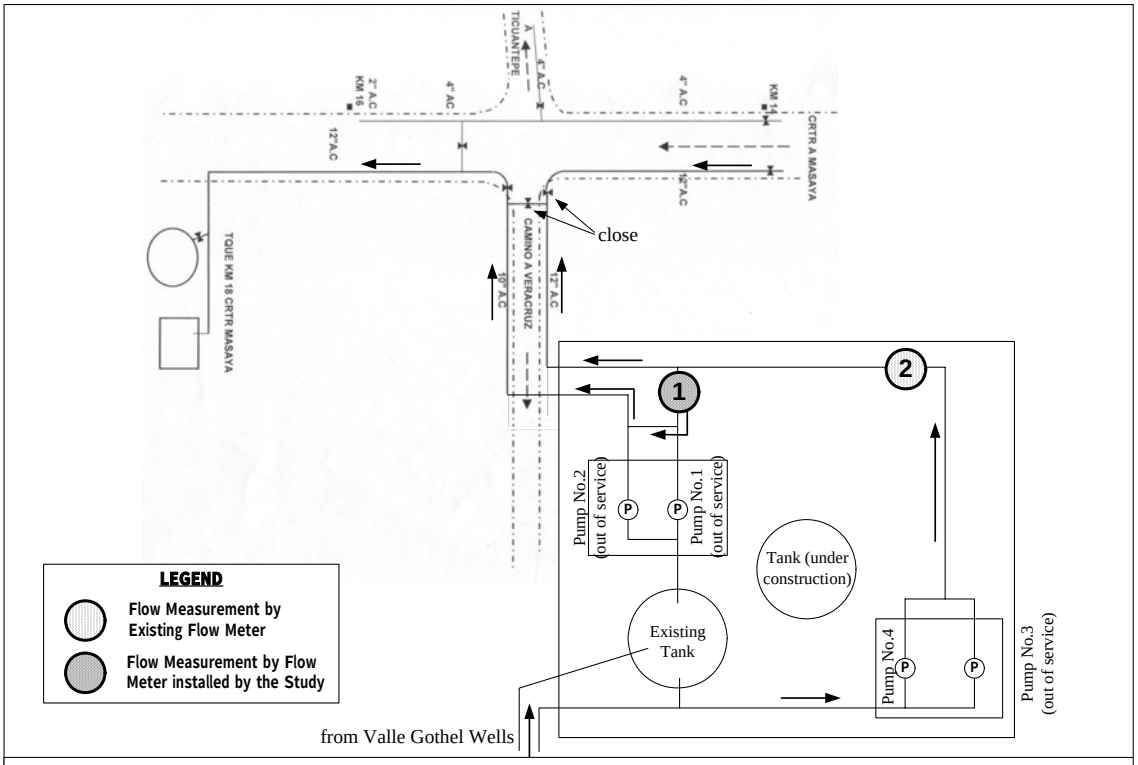


Figure 5.4.54 Records of Flow Rates from Km 9.2 Carretera Sur in 2004

5.4.15 Km 14.5 Carretera Masaya

In Km14.5 Carretera Masaya Pumping Station flow rates were measured at two points as shown in **Figure 5.4.55** for 24 hours from 12:00 am on 28th October 2004.



Flow Measurement Survey at Km14.5 Carretera Masaya

Figure 5.4.55 Point of Flow Measurement at Km14.5 Carretera Masaya

Flow rate at Point No.1 was measured by the JICA flow meter and flow rate at Point No.2 was measured by the existing flow meter. Since during the measurement only Pump No.4 was operated and other three pumps were out of service, the flow rate through Point No.2 is equal to total outlet from Km14.5 Carretera Masaya Pumping Station. The flow rate at Point No.1 means the flow rate in the direction to Km18.5 Carretera Masaya Pumping Station. The results of measurement at two measuring points are shown in **Figure 5.4.56** and summarizes below;

Total Flow from Km14.5 Carretera Masaya : 7,887 m^3/day
Flow Rate in the direction to Km18.5 Carretera Masaya : 6,291 m^3/day

About 80% of pumped water from Km14.5 Carretera Masaya Pumping Station is distributed and transmitted in the direction to Km18.5 Carretera Masaya Pumping Station.

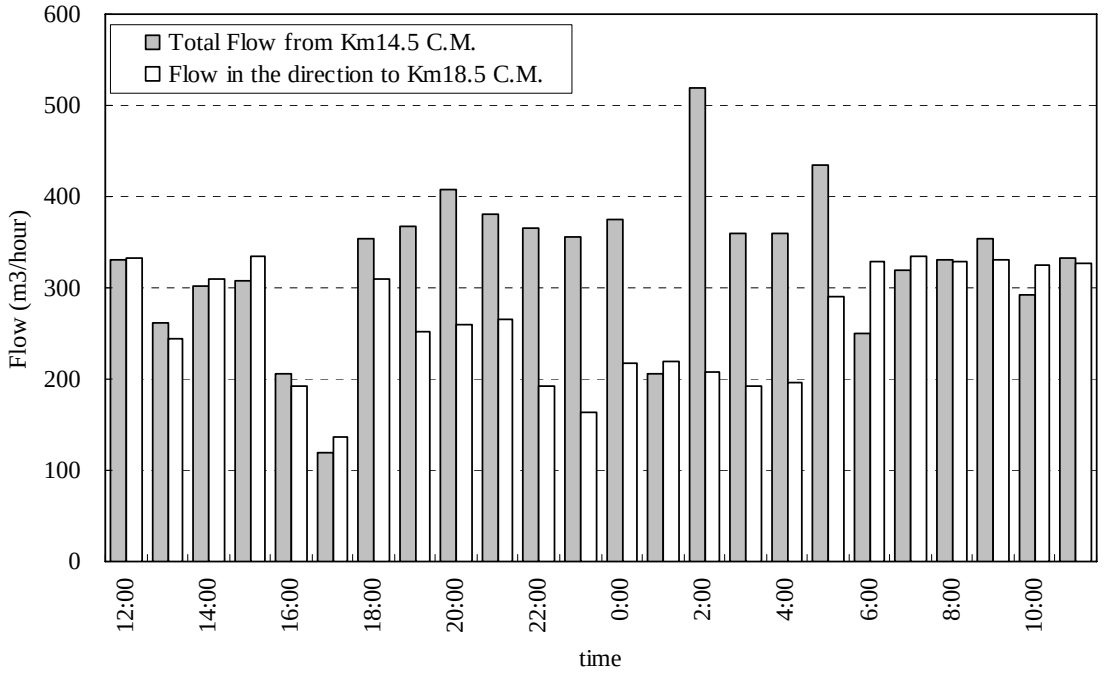


Figure 5.4.56 Results of Flow Measurement

Based on ENACAL Statistic Data, the average total flow rate from Km14.5 Carretera Masaya in 2004 (up to October) is calculated at 7,287 m^3/day, and average flow rate in 2004 pumped from Km18.5 Carretera Masaya is 4,1,47 m^3/day. This means that about 60% of water pumped from Km14.5 Carretera Masaya is transmitted up to Km18.5 Carretera Masaya. **Figure 5.4.57** shows the records of daily flow rates pumped from Km14.5 and Km18.5 Carretera Masaya Pumping Stations.

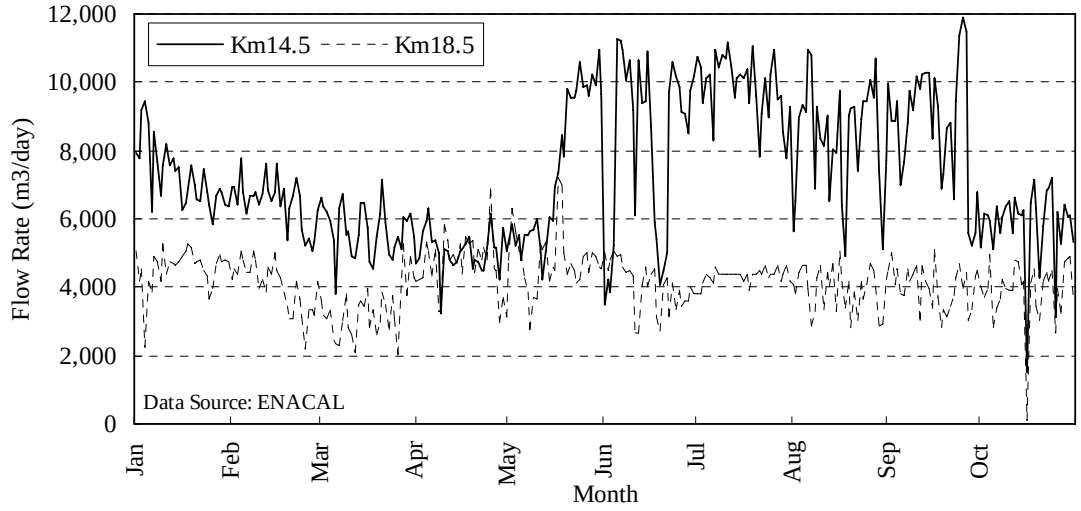
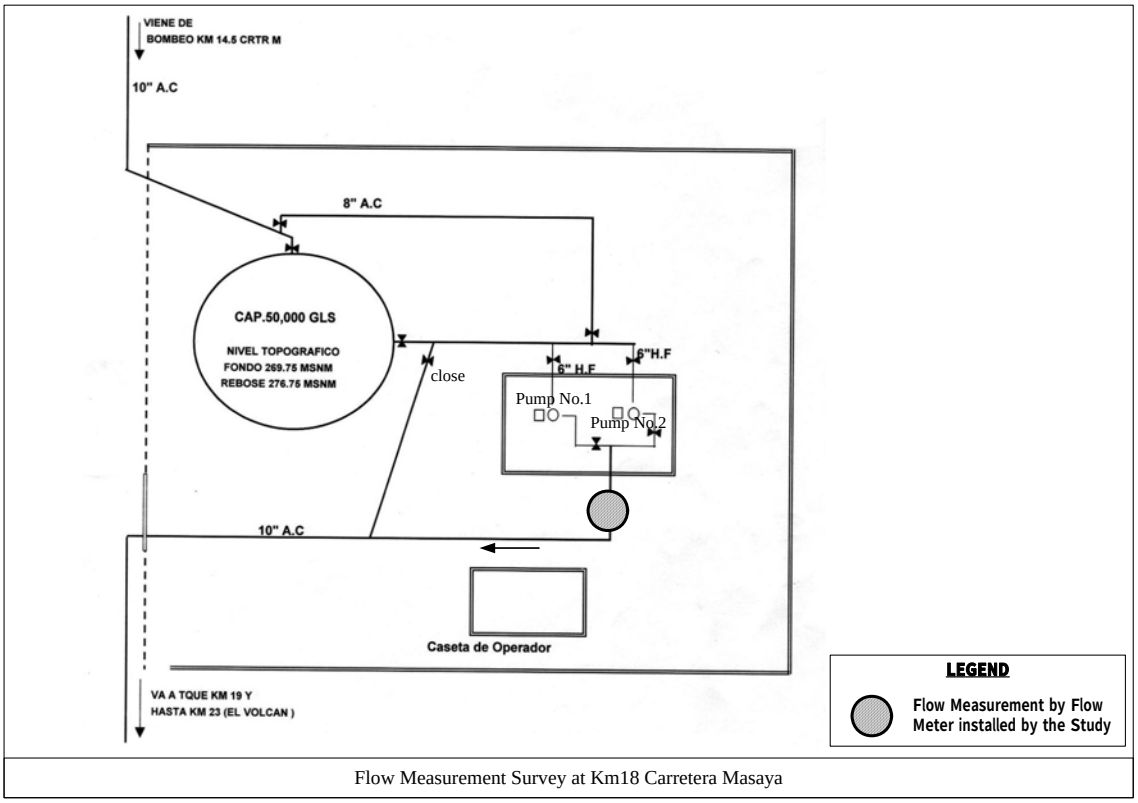


Figure 5.4.57 Records of Flow Rates from Km14.5 and Km18.5 Carretera Masaya in 2004

5.4.16 Km 18.5 Carretera Masaya

In Km18.5 Carretera Masaya Pumping Station flow rate was measured at the outlet flow from the transmission pumps as shown in **Figure 5.4.58** for 24 hours from 15:00 on 12 October to 15:00 on 13 October 2004.



Flow Measurement Survey at Km18 Carretera Masaya

Figure 5.4.58 Point of Flow Measurement at Km18.5 Carretera Masaya

Result of flow measurement is shown in **Figure 5.4.59** and during the 24-hour flow measurement two transmission pumps, Pump No.1 and No.2, were alternately operated. Total flow rate transmitted from Km18.5 Carretera Masaya Pumping Station to the southeast along Carretera Masaya was 4,622 m^3/day.

There is an existing flow meter at almost same location as the location at where the JICA flow meter was installed. The comparison between the readings of the existing flow meter and JICA flow meter is as **Table 5.4.8**. It can be said that the existing flow meter is accurate.

Table 5.4.8 Comparison between JICA and Existing Flow Meters

	at 14:45 on 12-Oct	at 15:20 on 13-Oct
JICA Flow Meter	215.7 m^3/h	207.3 m^3/h
Existing Flow Meter	217.8 m^3/h	207.6 m^3/h

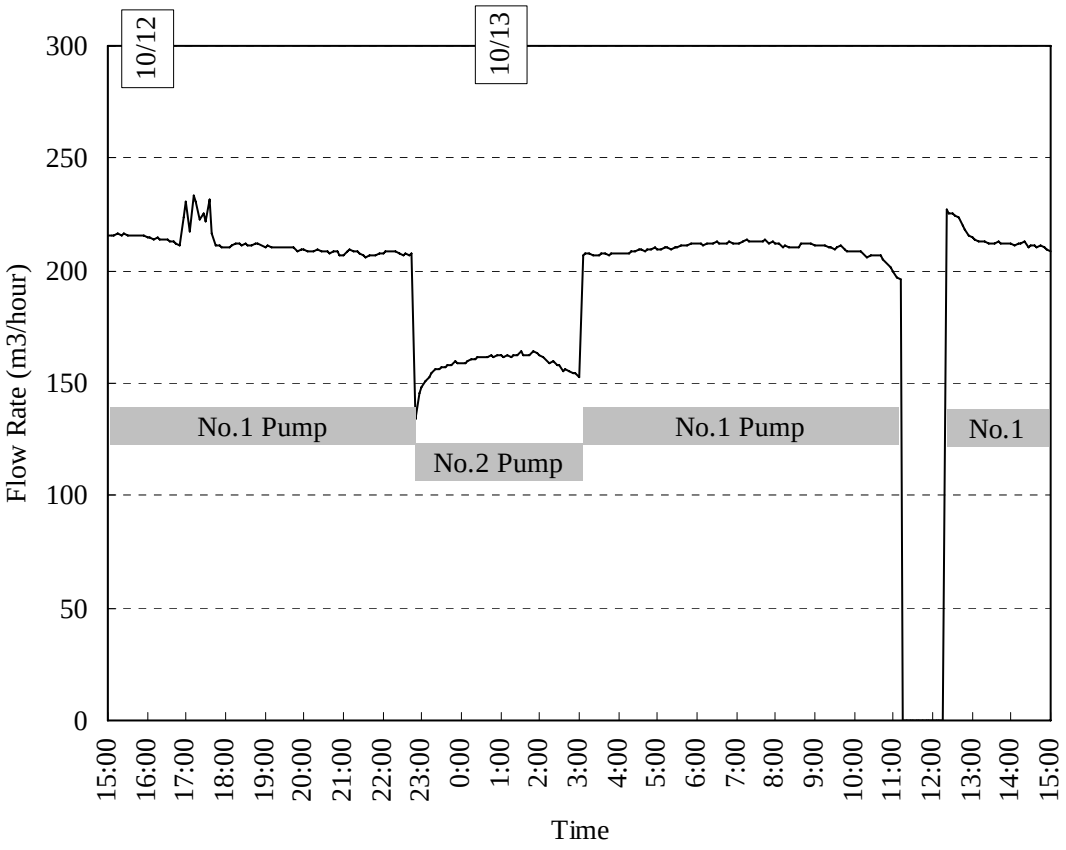


Figure 5.4.59 Result of Flow Measurement

5.4.17 Km 16 Carretera Sur

For the flow measurement of Km16 Carretera Sur, the existing flow meter located at outlet pipe from Km17 Carretera Sur Well to Km16 Carretera Sur Tank as shown in **Figure 5.4.60** was read every day from 30th October to 2nd November 2004. The result of the readings is summarized as shown in **Figure 5.4.61**.

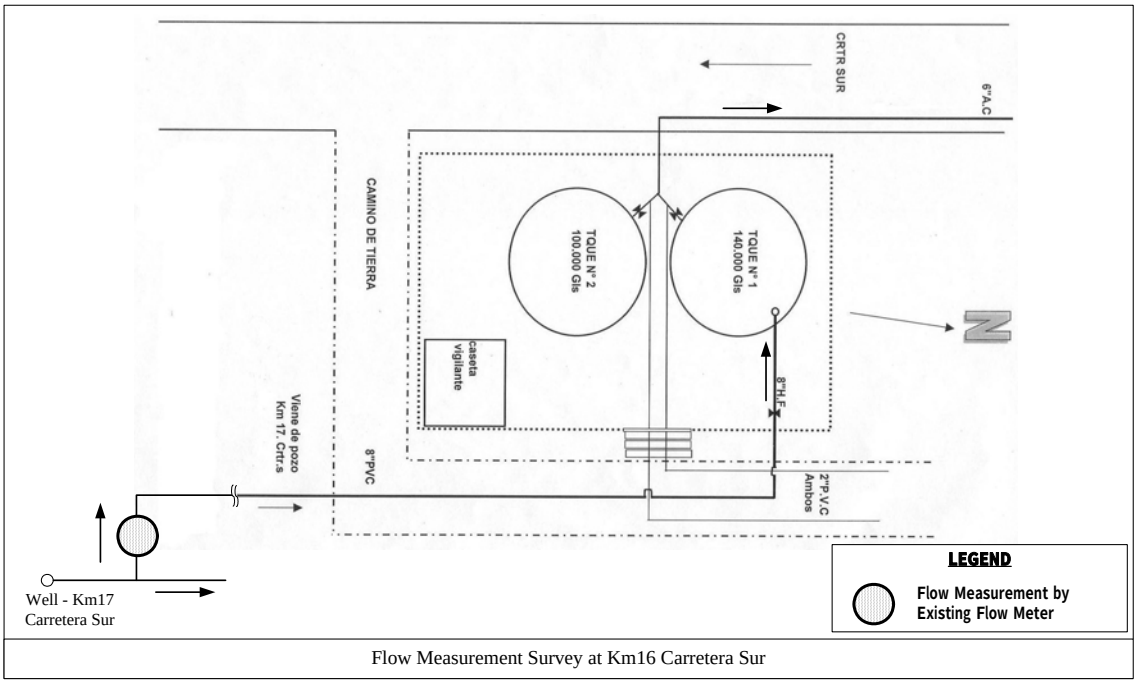


Figure 5.4.60 Point of Flow Measurement at Km 16 Carretera Sur

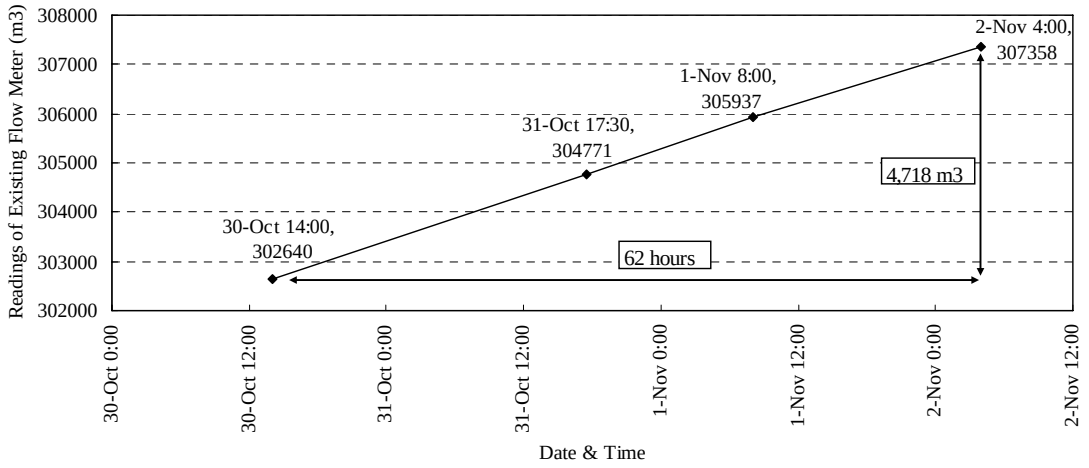
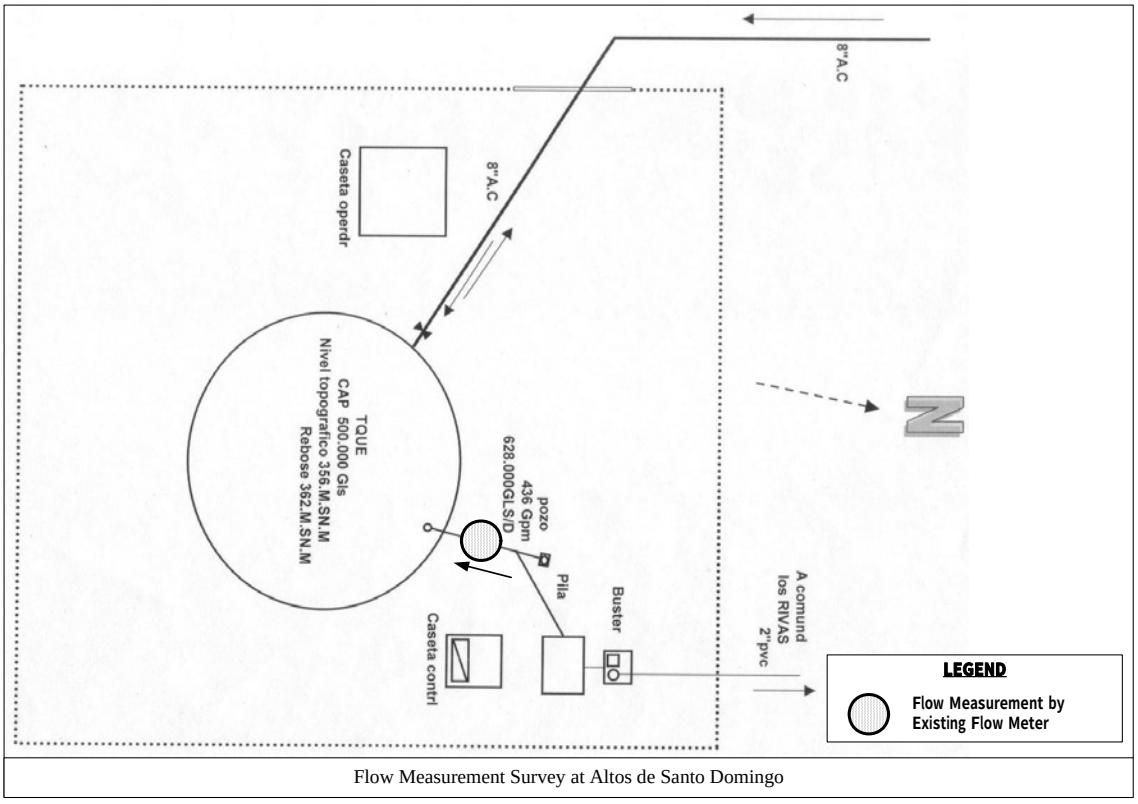


Figure 5.4.61 Result of Meter Readings

As the result inlet flow to Km16 Carretera Sur Tank is calculated at 1,826 m^3/day, which can be assumed to be the same flow as outlet from the tank.

5.4.18 Altos de Santo Domingo

In Altos de Santo Domingo the existing flow meter located at inlet pipe to the tank as shown in **Figure 5.4.62** for measuring production amount of well was read every hour from 1:00 am on 1st November to 8:00 am on 4th November 2004. The result of the readings is summarized as shown in **Figure 5.4.63**.



Flow Measurement Survey at Altos de Santo Domingo

Figure 5.4.62 Point of Flow Measurement at Altos de Santo Domingo

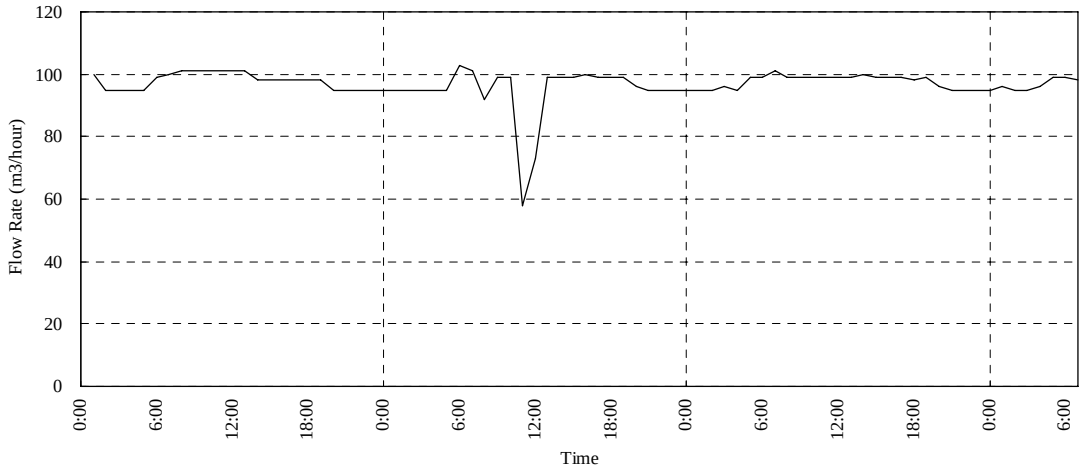


Figure 5.4.63 Result of Meter Readings

As the result flow rate from Altos de Santo Domingo was estimated at 2,321 m^3/day. Well at Altos de Santo Domingo has a production capacity of 2,300 m^3/day (422 gpm). **Figure 5.4.64** shows production records of Altos de Santo Domingo Well in 2004 for reference. Average

daily production amount is calculated at 2,280 m^3/day.

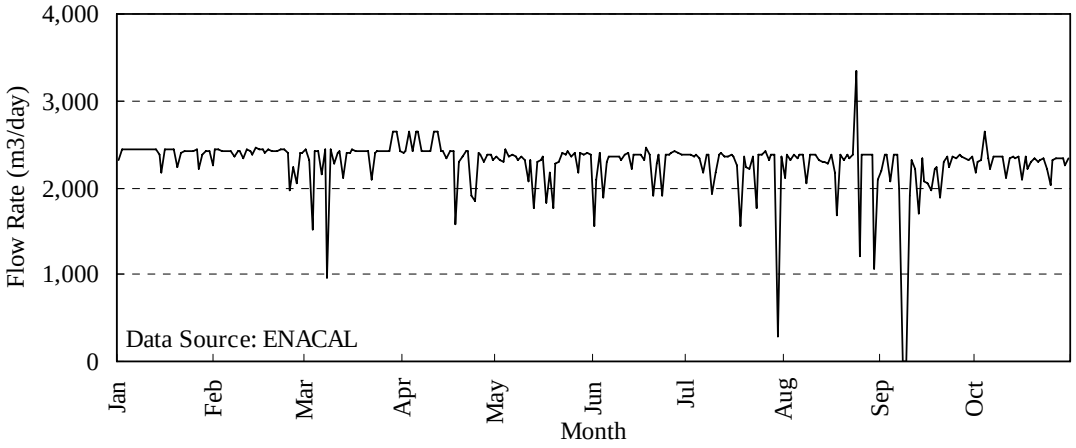


Figure 5.4.64 ENACAL Record of Altos de Santo Domingo Well Production in 2004

5.4.19 Olof Palme Well

Production of Olof Palme Well located in Zona Baja Centro was measured at outlet pipe as shown in **Figure 5.4.65** for 24 hours from 10:00 am on 22nd November 2004. The result of the measurement is shown in **Figure 5.4.66** with results of water pressures.

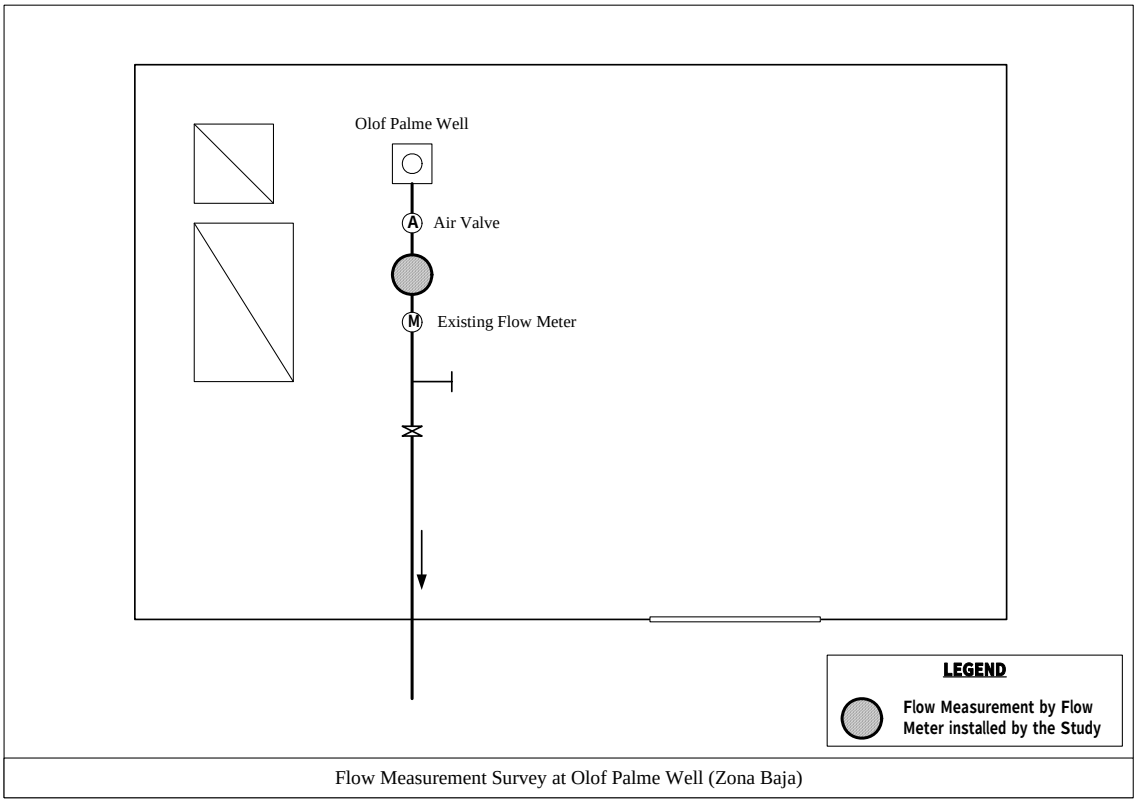


Figure 5.4.65 Point of Flow Measurement at Olof Palme Well

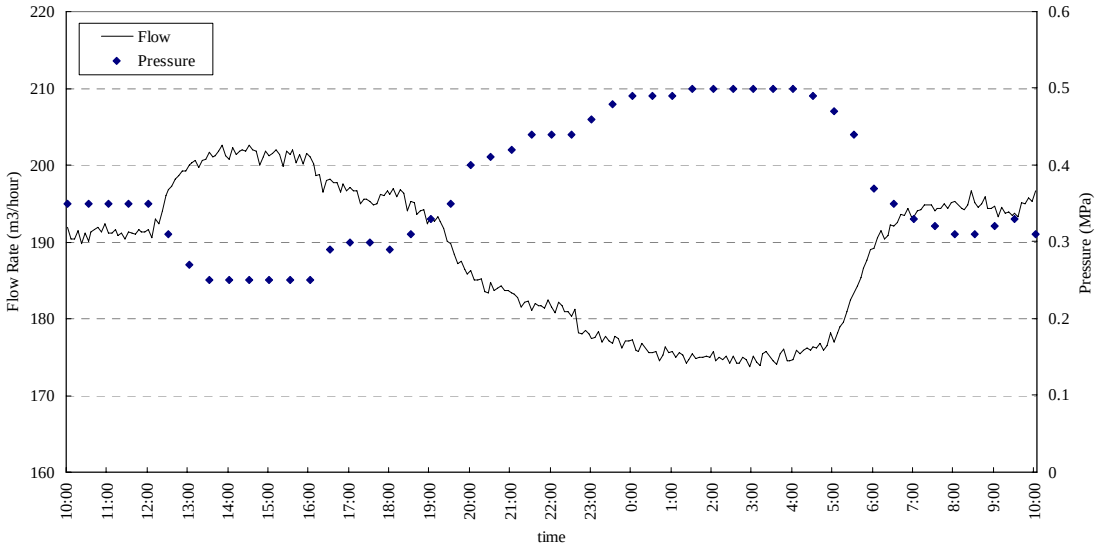


Figure 5.4.66 Result of Flow Measurement

As shown in **Figure 5.4.66** flow rate decreases if water pressure rises. Flow rate is fluctuated according to the water pressure, because water pumped up from well is directly flowed into

distribution pipeline. This means that the actual production amount of the well is depended on the water pressure in the network.

As the result flow rate from Olof Palme Well to the network system in Zona Baja was 4,520 m^3/day. Olof Palme Well has a production capacity of 4,317 m^3/day (792 gpm). **Figure 5.4.67** shows production records of Olof Palme Well in 2004. Daily average production amount is calculated at 4,275 m^3/day, which is almost the same amount as the production capacity.

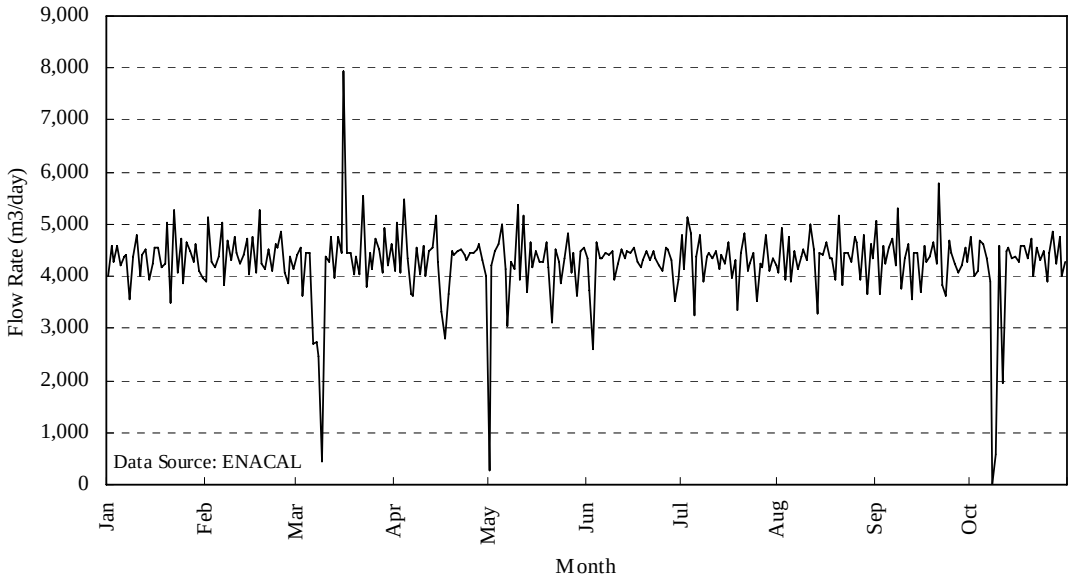


Figure 5.4.67 ENACAL Record of Olof Palme Well Production in 2004

5.4.20 Rafaela Herrera Well

Production of Rafaela Herrera Well located in Zona Baja Oeste was measured twice at outlet pipe as shown in **Figure 5.4.68**. The results of the measurement from 12:00 am on 11th November 2004 and from 10:00 am on 15th November 2004 are shown in **Figure 5.4.69** and **Figure 5.4.70** respectively.

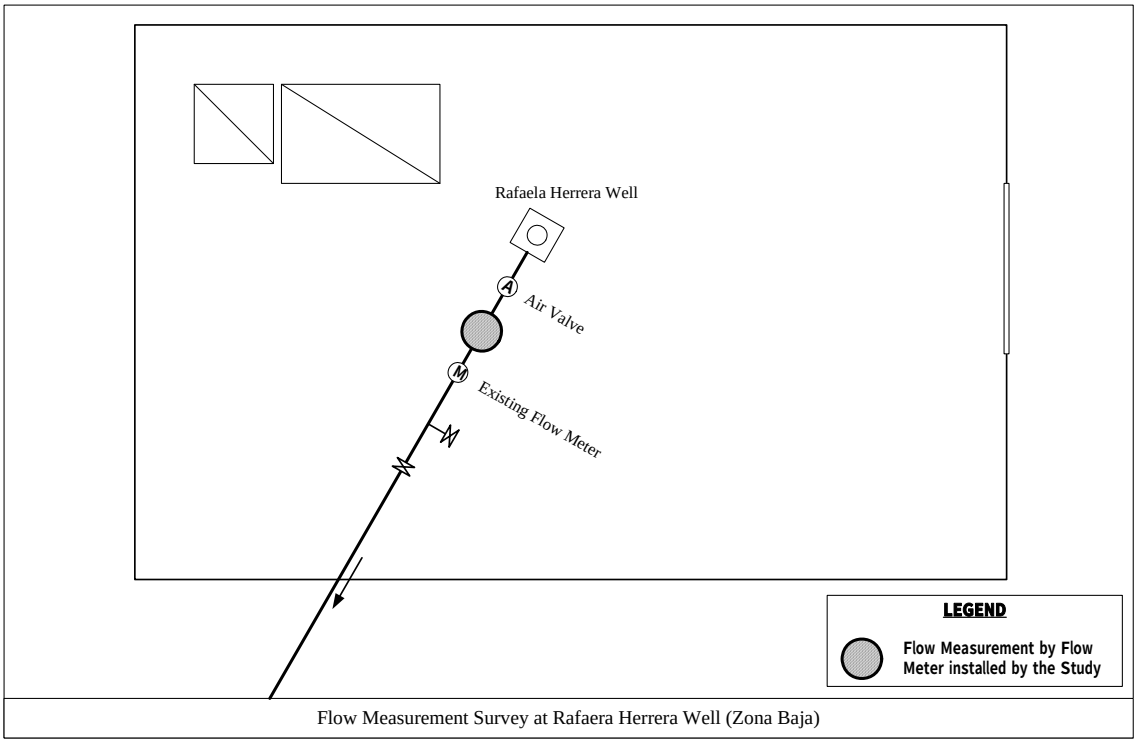


Figure 5.4.68 Point of Flow Measurement at Rafaela Herrera Well

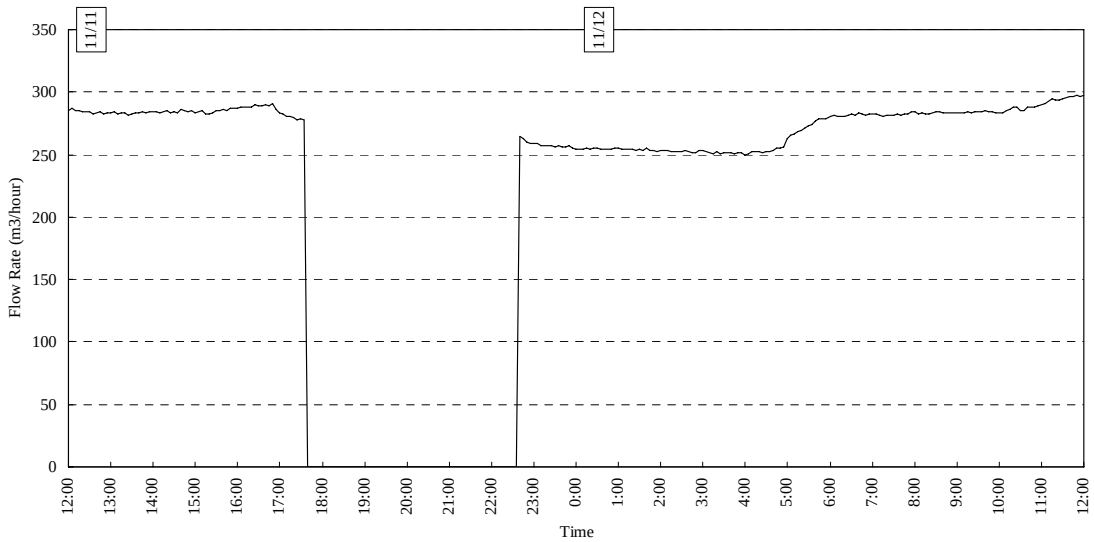


Figure 5.4.69 Result of Flow Measurement on 11th – 12th November 2004

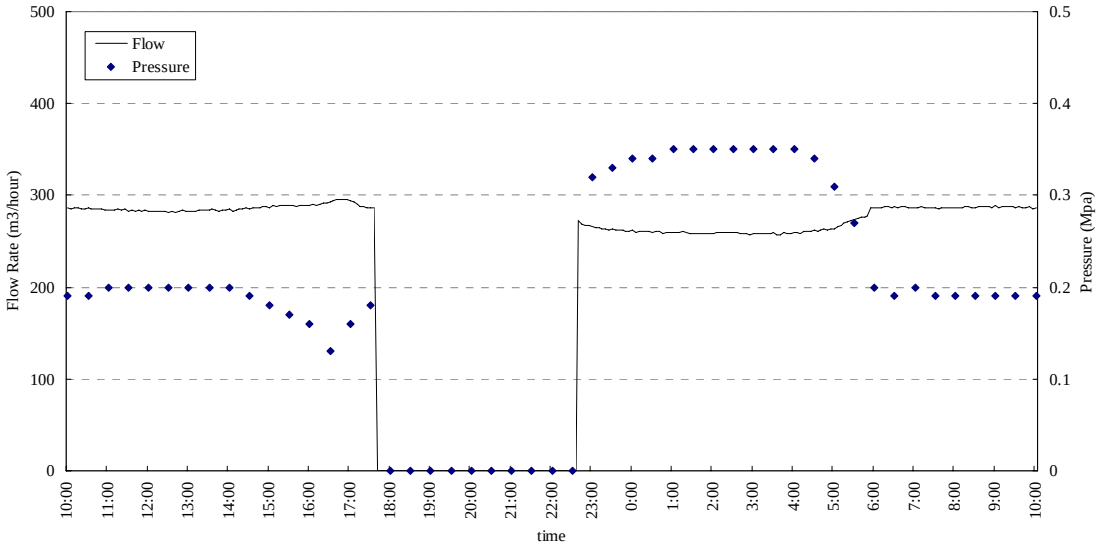


Figure 5.4.70 Result of Flow Measurement on 15th – 16th November 2004

Figure 5.4.70 also shows the results of water pressures. As shown in **Figure 5.4.70** flow rate decreases if water pressure rises. Flow rate is fluctuated according to the water pressure, because water pumped up from well is directly flowed into distribution pipeline. This means that the actual production amount of the well is depended on the water pressure in the network.

As the results flow rates from Rafaela Herrera Well to the network system in Zona Baja were 5,207 m^3/day for first measurement and 5,265 m^3/day for second measurement. Rafaela Herrera Well has a production capacity of 6,780 m^3/day (1,244 gpm). Since well pump was stopped for five hours during the both measurement, average production amount per operation hour are calculated at 274 m^3/hour and 277 m^3/hour, which is almost the same amount as the production capacity of 283 m^3/hour. **Figure 5.4.71** shows production records of Rafaela Herrera Well in 2004 for reference.

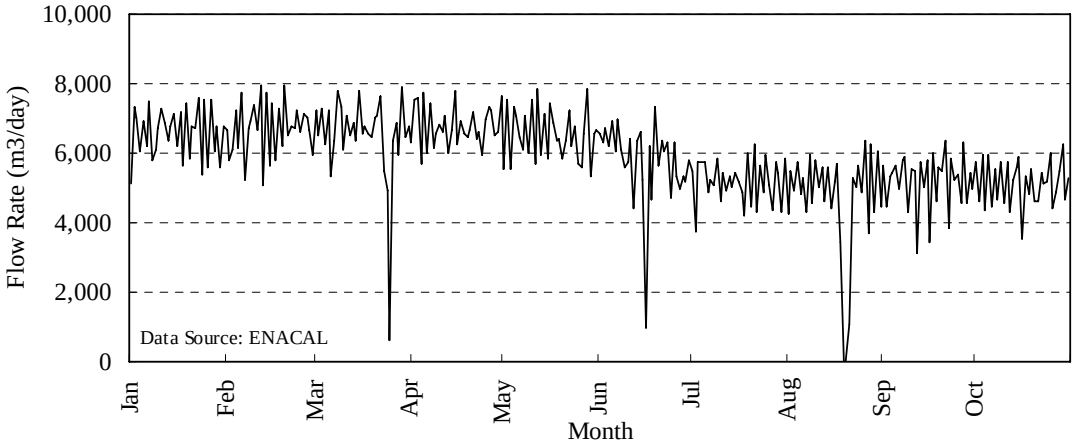


Figure 5.4.71 ENACAL Record of Rafaela Herrera Well Production in 2004