The Philippine Water Revolving Fund Support Program

TECHNICAL ASSESSMENT OF PROPOSED SURFACE WATER DEVELOPMENT PROJECT FOR THE CABANATUAN CITY WATER DISTRICT: A FINAL REPORT

This project is implemented by Development Alternatives, Inc. in association with:

- The Community Group International LLC
- Resource Mobilization Advisors
- CEST, Inc.

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LIST OF ABBREVIATIONS

ADTSI	Aqua-Dyne Technological Services Inc.
BRS	Bureau of Research and Standards
CCWD	Cabanatuan City Water District
DPWH	Department of Public Works and Highways
GOP	Government of the Philippines
LGUs	Local Government Units
lps	Liters per second
MCM	Million cubic meter
NPV	Net Present Value
NWRB	National Water Resources Board
O&M	Operation and Maintenance
PNSDW	Philippine National Standards for Drinking Water
PWRF SP	Philippine Water Revolving Fund Support Program
SWL	Static Water Level
TA	Technical Assistance
TDS	Total dissolved solids
USAID	United States Agency for International Development
VES	Vertical Electric Sounding
WDs	Water Districts
WPA	Water Permit Application

CHAPTER 1. INTRODUCTION

1.1 Background

The USAID made available a Technical Assistance Grant to the Government of the Philippines to support the Philippine Water Revolving Fund Support Program (PWRF SP). This grant covers the period from October 1, 2007 to September 30, 2011. PWRFSP aims to help USAID and GOP develop an innovative and sustainable financing mechanism for water supply and sanitation projects. The Program dovetails the completion of the feasibility assessment and design and implementation framework, also supported by USAID. The current Program focuses on:

1. Setting up the PWRF, a financing mechanism involving private sector participation, which can include: co-financing arrangement with a GFI, securitization or bond financing;
2. Strengthening and/or addressing policy and institutional constraints of the water and finance sectors vital to PWRF's success; and
3. Assisting LGUs and WDs to develop a pipeline of viable projects.

Under the third area of concern, the PWRFSP provided technical assistance (TA) to the Cabanatuan City Water District (CCWD). The TA was for the evaluation of CCWD's plan to tap the Pampanga River as a future water supply source for its service area. CCWD studies have shown that present groundwater sources will be inadequate to meet the long-term demand of Cabanatuan City.

The TA focused on the evaluation of the flow capacity and water quality of Pampanga River as drinking water source, and development of a water treatment plant(s) and appurtenances.

This technical report contains the data collected, analysis, findings and recommendation of the TA and includes the following:

Subject	Details
Riverflow	Review of available riverflow data to determine if source flow is adequate and has reasonable allowance for water demand over the next 20 years.
Water Quality	Review of available water quality data to assess the bacteriological, physical, and chemical characteristics of the water source.
Intake Point and Treatment Plant Location	Assessment of river intake/extraction points and alternative treatment plant locations in consideration of the centralized and decentralized treatment system options.
Treatment Processes Alternatives	Identification of alternatives for treating raw water sources, based on the nature and quality of the raw water, and the desired water quality specified under the Philippine National Standards for Drinking Water (PNSDW). Recommendation, based on the list of alternatives, of the more desirable/applicable treatment process for treating raw water from the identified surface water source.
Treatment Capacity Staging	In consideration of the projected water demand for the next 20 years, and the lead time for financing and construction, recommendations on the plant capacity staging/phasing.
Capital and Operational Cost Estimates	Preliminary capital and operation and maintenance (O&M) cost estimates for the different water treatment alternatives.

CHAPTER 2. WATER RESOURCES

2.1 Introduction

This chapter gives an overview of available water resources in Cabanatuan City, based mostly on the data supplied by the CCWD. In particularly, the data come from the study commissioned by CCWD, entitled "Groundwater Resources Assessment of Cabanatuan City" which was prepared by Aqua-Dyne Technological Services Inc. (ADTSI) in 2004. The rapid assessment particularly looks at the viability of tapping Pampanga River as surface water source to meet the water demand of the City.

2.2 Current Situation

As of 2006, the actual monthly production of the CCWD is 960,623 cum/ month giving a total production of approximately 11,527,476 cum for that particular year.

The water source for CCWD is groundwater. It has 22 deep wells, of which 21 are operational. These wells have pumping stations and disinfection facilities. The wells and pumping stations are located in:

1. Sta Arcadia
2. Kapitan Pepe - City Hall Road
3. Mabini Extension
4. Daan Sarile
5. Aduas
6. Kapitan Pepe - Melencio
7. Burgos Extension
8. Bitas
9. Circumferential
10. Sumacab Sur
11. Villa Benita
12. Don Jose De Real
13. Lourdes
14. Pagas
15. Barrera
16. Mayapyap Sur
17. CLPC Compound
18. Nehs Compound
19. Camp Tinio
20. Bonifacio
21. San Isidro

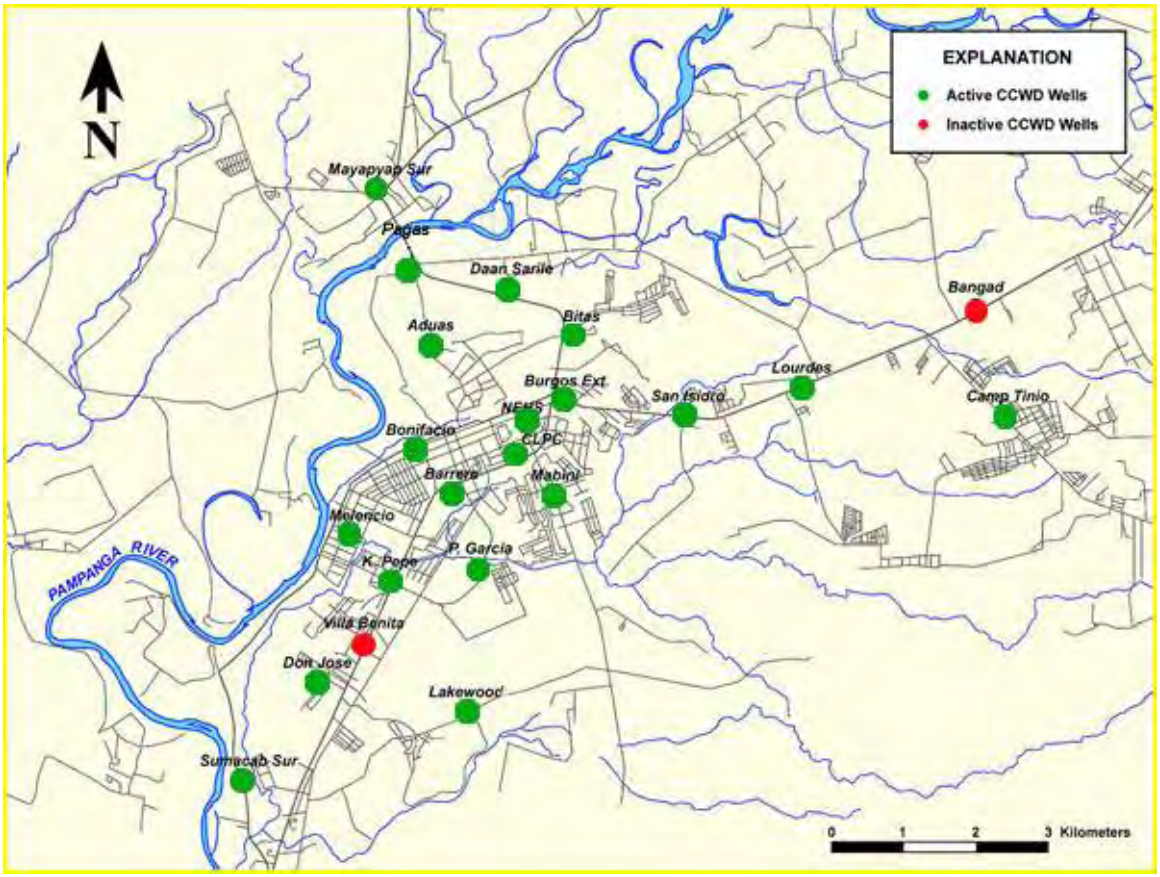


Figure 2- 1 Location of CCWD wells (source: CCWD website)

Static Water Levels

The capacity of the aquifer supplying the water can best be represented by the static water level (SWL). Fig. 2-2 shows a declining trend of the SWL for most of the wells of CCWD. This indicates that water is being pumped out at a much higher rate than the groundwater recharge. This basically suggests that the safe yield for the aquifer of CCWD's wells has already been exceeded. Groundwater mining probably exists in the aquifer under consideration.

Based on the production records of the CCWD there had been a steady increase in the production of the wells from 1991 up to 2003 (see Fig. 2-3). This increase is directly related to the decline in the SWL.

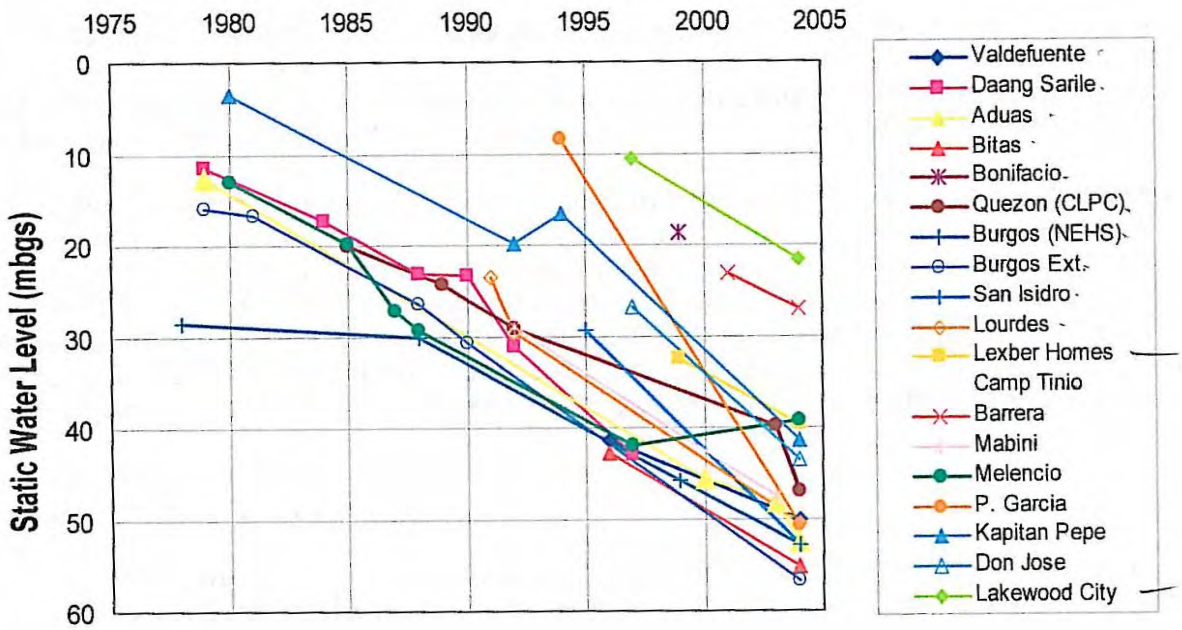


Figure 2- 2 Static Water Levels of various wells (source ADTSI, 2004)

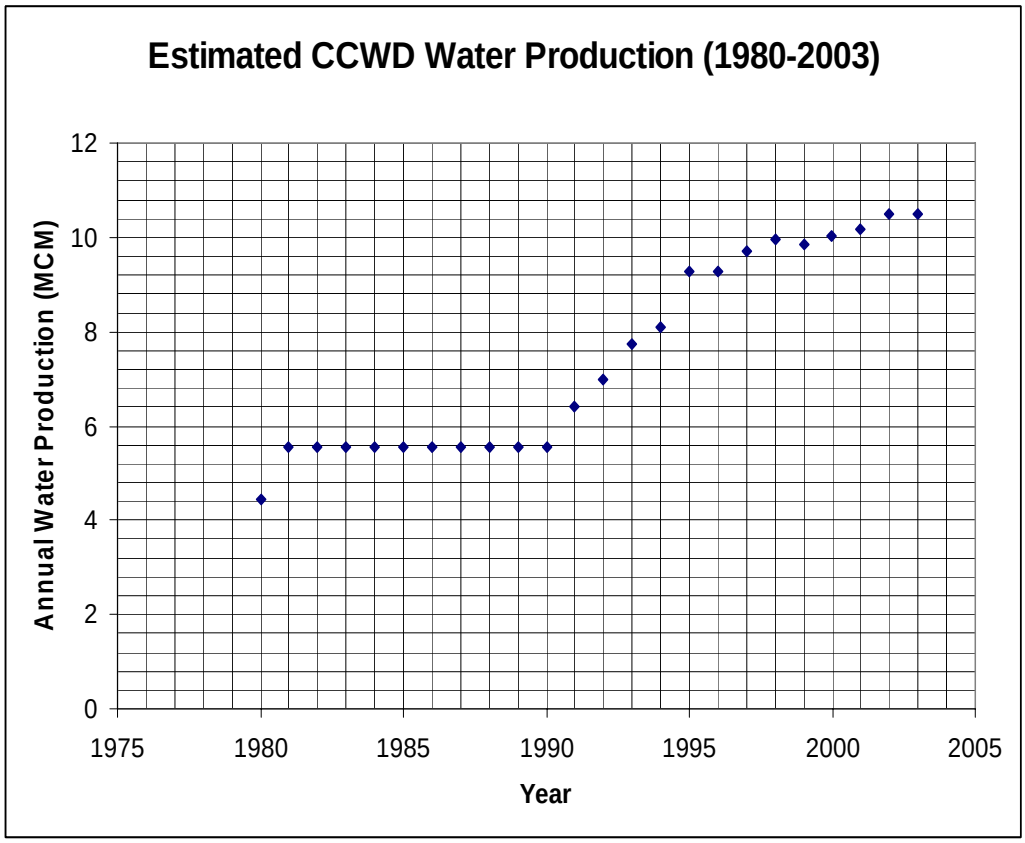


Figure 2- 3 Estimated Water Production of CCWD Wells (1980-2003)

Groundwater Recharge

Quantifying groundwater recharge is one of the most difficult tasks in hydrological modeling due to the intricacies involved in the acquisition of various data such as evapotranspiration, infiltration capacity of soils, surface run-off, etc. However, certain tools can be regarded as worthy alternatives in estimating groundwater recharge.

In the case of the aquifer in Cabanatuan City, this recharge could be inferred by correlating water production with the rate of decline in the static water levels (ADTSI, 2004).

Production records show that the water output remained fairly constant at approx. 6 MCM/yr from 1981-1990 (see Fig. 2-2). During the same period, the static water level of some wells (although declining) did not decline much as compared during the period from 1990 to 2003. With this observation, we could more or less infer that the recharge to the aquifer being tapped by the CCWD wells is in the order of approximately 6 MCM/year.

ADTSI performed a flow net analysis which estimated the recharge to be 8.26 MCM/year or 22,630 m^3/day. This amount is the "working budget" by which the CCWD should be guided in its operations. Therefore, CCWD, with its existing wells is withdrawing from the aquifer more than 3.5 MCM/ year or approximately 10,000 m^3/day. This has caused stress to the aquifer and is probably now withdrawing water from its storage (reserves).

Surface Water

Since groundwater resources have been deemed insufficient for the growing population in Cabanatuan City, the tapping of surface water should be considered for the long term expansion plans of CCWD. One such source is the Pampanga River. Data gathered from the Bureau of Research and Standards (BRS) of the Department of Public Works and Highways (DPWH), indicate that Pampanga River has adequate quantity to meet the maximum day supply for the City. The maximum day demand for the city is shown below.

Year	Maximum Day Demand (cum/day)
2010	45,409
2015	56,911
2020	68,000
2025	76,986

The minimum discharge of Pampanga River (for the observation period 1982-1987) is 3,650 lps or 397,584 cum/day. Hence even if only 20% of this is tapped, the projected Maximum Day Demand in the year 2025 could still be met.

The important data about the Pampanga River are:

- Mean Annual Flow for (6 year of record): 72,552 lps or 6,268,493 cum/day
- Maximum Discharge: 2,331,940 lps or 201,479,616 cum/day
- Minimum Discharge: 3,560 lps or 307,584 cum/day

Various data analyses for the Pampanga River are presented in the Appendices.

2.3 Resource Allocation

With the enactment of the Water Code of the Philippines in 1976 and the promulgation of its Implementing Rules and Regulation in 1979, the National Water Resources Board (NWRB) was vested the power to control and regulate the utilization, exploitation, development, conservation and protection of all water resources of the country. To carry out its functions, NWRB is charged with the responsibility of assessing water resources specifically on the quality and available quantity for allocation to users (water permit applicants).

<u>Allocation Based on Safe Yield</u>

Safe yield is the extraction rate in the aquifer so that groundwater contained in it could be used continuously ($t = \infty$) without drawing groundwater from its reserve/storage (see Figure 2.4). Safe yield is also the rate of recharge into the aquifer system. Water permits thus allocate water based on Safe Yield, i.e., it specifies that groundwater withdrawals should not exceed the aquifer's Safe Yield except under proscribed conditions.

<u>Allocation Based on Mining Yield</u>

Mining Yield is the extraction rate in the aquifer exceeding the Safe Yield limit (figure 4). The amount of groundwater drawn in excess of the Safe Yield is mined from its reserve/storage annually until groundwater in the aquifer is exhausted.

Section 43 of the Implementing Rules and Regulation of the Water Code of the Philippines states that Groundwater Mining may be allowed provided that the life of the groundwater reservoir (aquifer) system is maintained for at least 50 years.

With this provision, the NWRB uses the 50-year Groundwater Mining Yield in the allocation of groundwater for highly urbanized cities like Cabanatuan City. It adheres to the logic that groundwater in the aquifer could not be set aside or reserved for the future generation when the present one is in dire need of it.

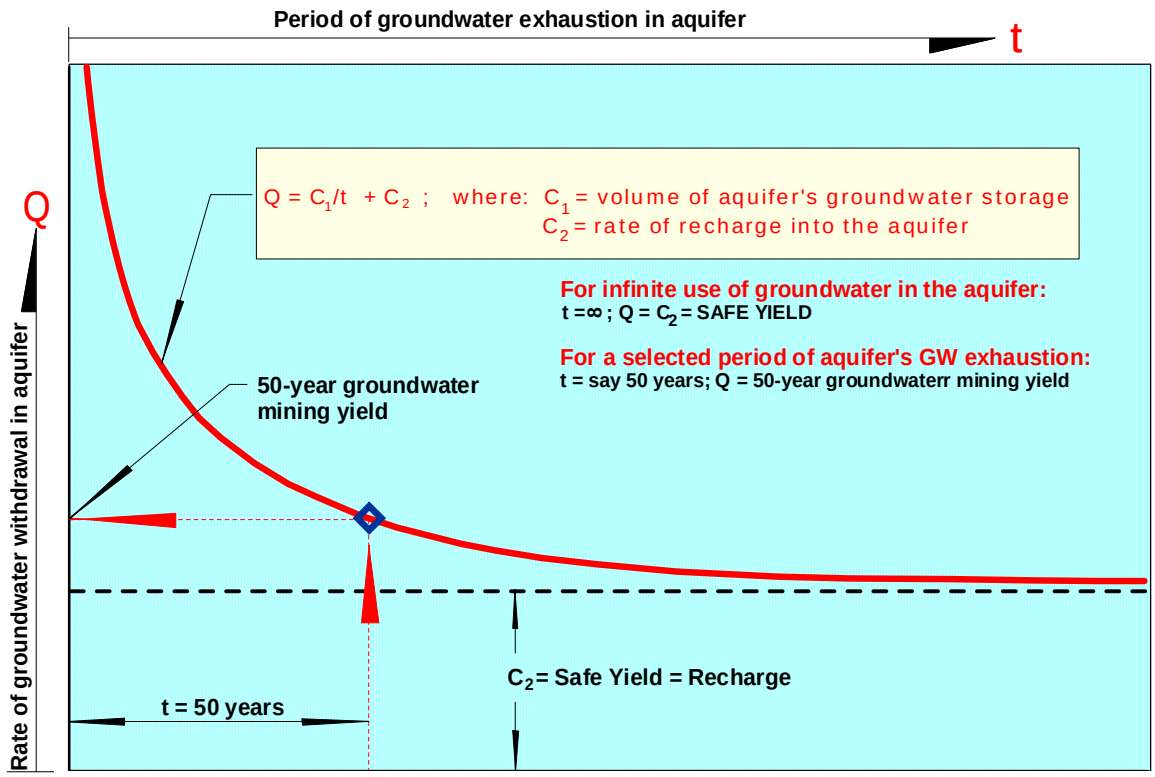


Figure 2- 4 Concept of Safe Yield/ Mining Yield
(Source: CEST 2004, Water Resources Assessment for Prioritized Critical Areas-Phase 1)

Appropriation of Waters

Appropriation of waters is the acquisition of rights over the use of waters or taking or diverting from a natural source in the manner and for any purpose allowed by law.

Water Right

Water right is the privilege granted by the government to appropriate and use water and is evidenced by a water permit issued by the NWRB.

Processing of Water Permit Application

Figure 2-5 presents the flowchart in processing Water Permit Application (WPA).

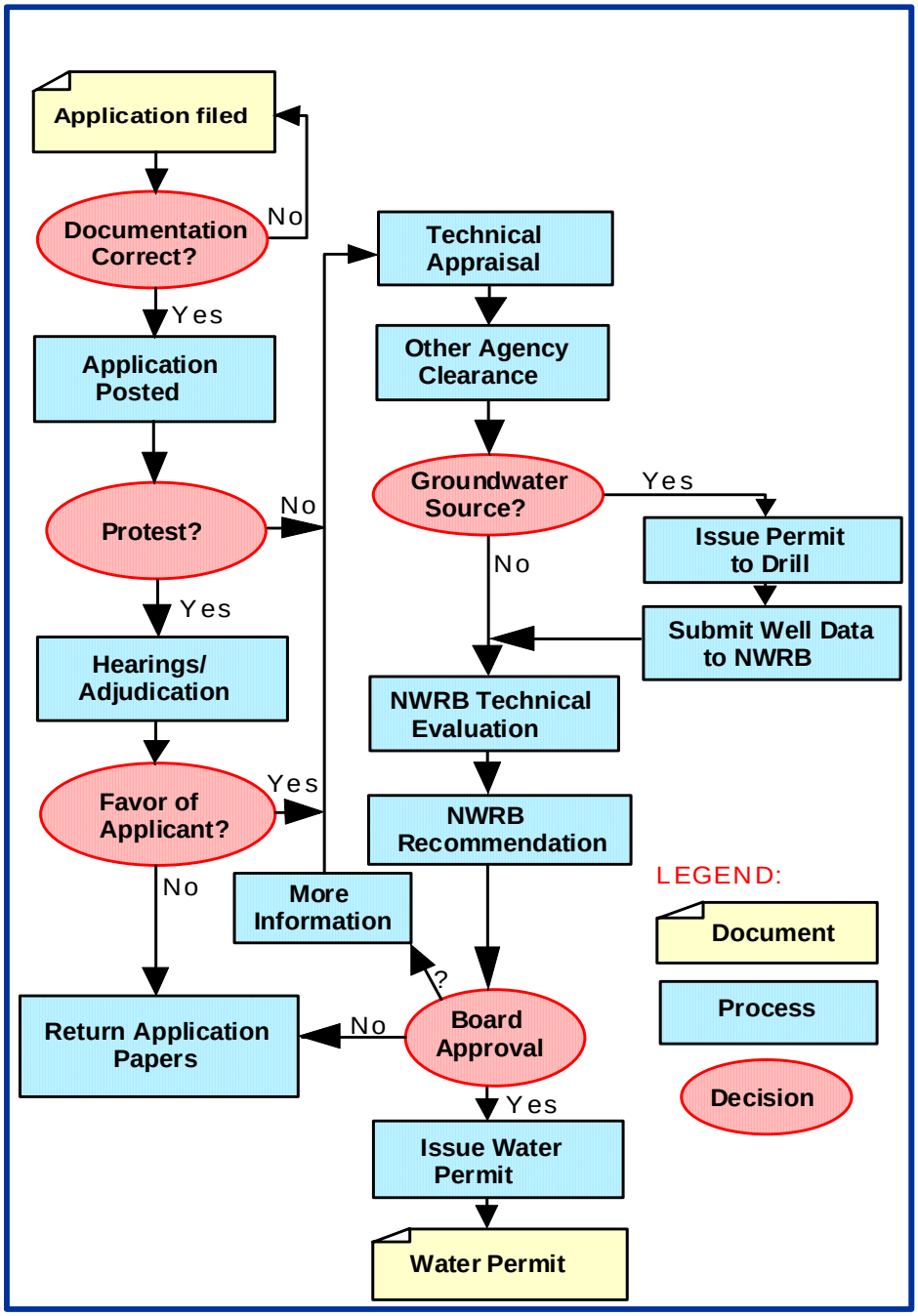


Figure 2- 5 Flow Chart in Processing Water Permit Application
(Source: CEST 2004, Water Resources Assessment for Prioritized Critical Areas-Phase 1)

2.4 Conclusion and Recommendations

Based on the Groundwater Resources Assessment of Cabanatuan City as conducted by ADTSI, groundwater mining may already be occurring in the aquifers of Cabanatuan City. This is confirmed by the declining static water levels in the various wells being utilized by CCWD.

In order to meet the water supply demand in the service area, particularly in the long-term, CCWD should look for alternative water sources. These water sources should not contribute to further deterioration of the groundwater supplies in the aquifers being tapped by the CCWD wells.

One such source worth considering is the Pampanga River. With a minimum discharge of 307,584 cum/day and average yield of 6,268,492 cum/day, the long-term water requirements of the City can be easily supplied by the River. Water from the river can be extracted through an intake along the river, or by developing shallow wells along the bank of the river. The latter is further discussed below.

Sustainability of Shallow Wells

Based on the study by ADTSI, shallow wells near the Pampanga River have a depth range from 6 to 18 meters. These wells are normally used by individual residences (not connected to the CCWD) for their water supply. The wells are cased with 38 to 50mm pipes and are fitted with pitcher pumps, jack pumps and centrifugal pumps.

Shallow wells are also being used for irrigation purposes. The average depth of such wells is approximately 6 to 9 meters.

According to the ADTSI study, the yield of these shallow wells may reach up to 18 lps. The most probable source of these wells aside from rain fall is the induced infiltration from the Pampanga River.

Not all portions of the Pampanga River banks have productive aquifers. Based on the georesistivity data and interpretation conducted in the area, the most favorable areas for groundwater development are the ones in blue shade (see Figure 6.6). Drilling outside of this area may yield lower chances of finding a productive aquifer with large quantities of water. Drilling within this area, increases the chances of the wells being recharged by the Pampanga River since the aquifer most probably has a hydraulic connection with the River.

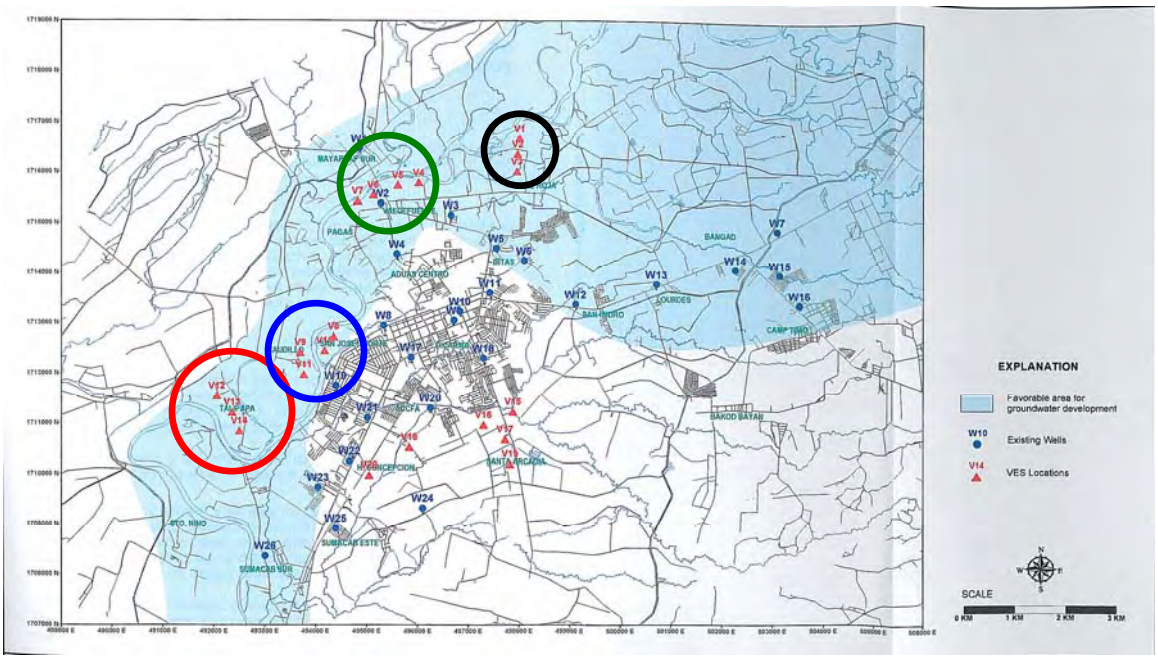


Figure 2- 6 Location of georesistivity sounding points
(Source: Final Report GW Resources Assessment of Cabanatuan City- ADTSI)

The area enclosed by the red circle (see Figure 2-6) is marked by the presence of a very limited upper aquifer approximately 10m below the surface. These are the areas labeled gravel aquifers (see Figure 2-7). The gravel deposits might provide high yield. However, its connectivity with the Pampanga River must be ascertained in order to guarantee the long term sustainability of the wells. On the other hand, the layer comprised of sand (see Figure 2-7) could also provide a significant quantity of water but much lower than the gravel layer.

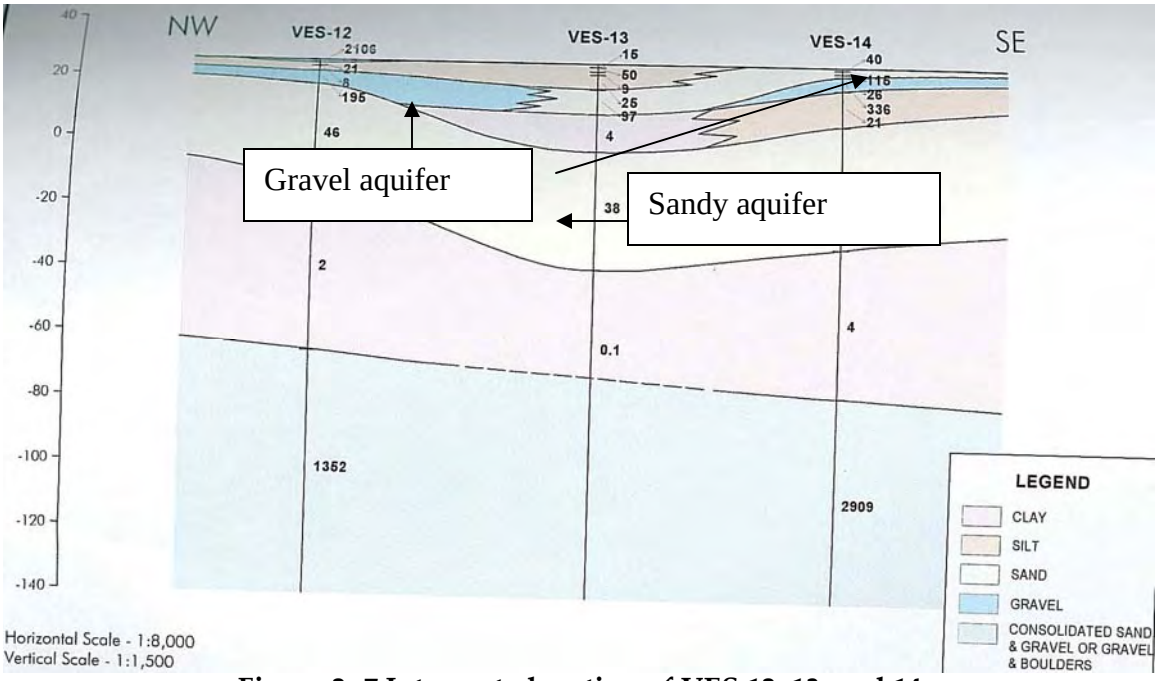


Figure 2- 7 Interpreted section of VES 12, 13, and 14
(Source: Final Report GW Resources Assessment of Cabanatuan City -ADTSI)

In the area enclosed by the blue circle (see Figure 2.6), the aquifer is probably connected to the Pampanga River and may provide a sustainable yield for the wells (see Figure 2.8)

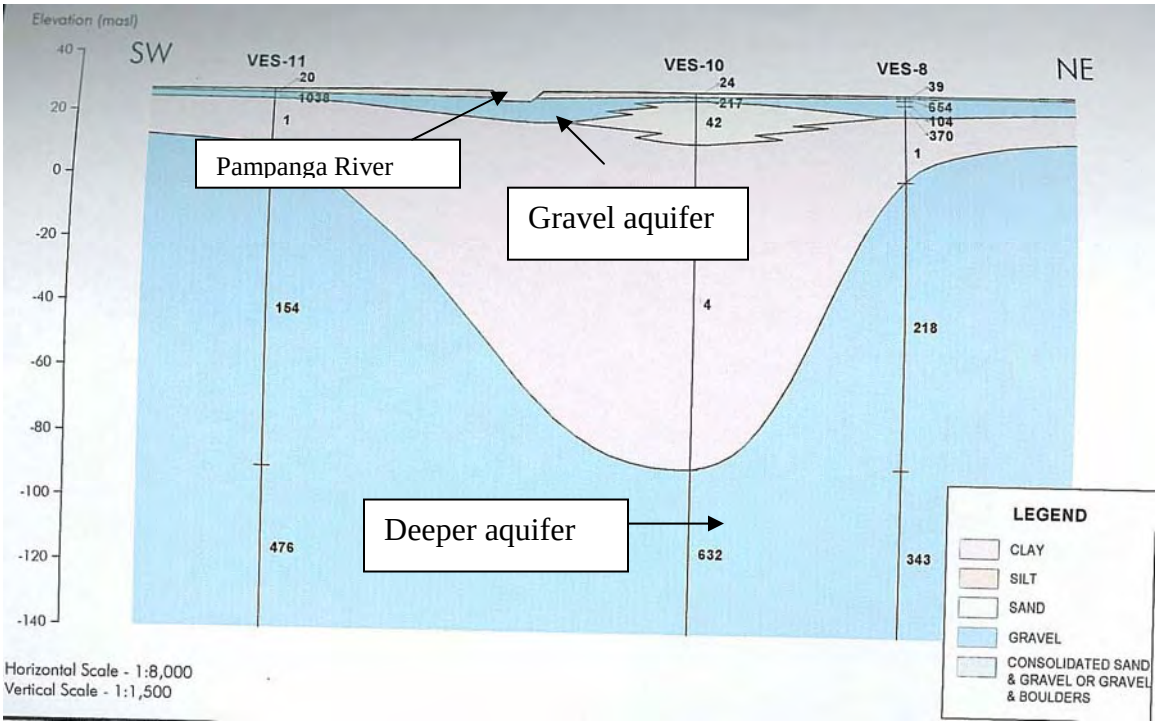


Figure 2- 8 Interpreted section of VES 11, 10, and 8
(Source: Final Report GW Resources Assessment of Cabanatuan City -ADTSI)

For the area enclosed by the green circle (see Figure 2.6), the aquifer near VES 5 and VES 4, might provide a good yield for the wells, since the gravel aquifer is quite continuous (see Figure 2.9) and probably connected to the Pampanga River.

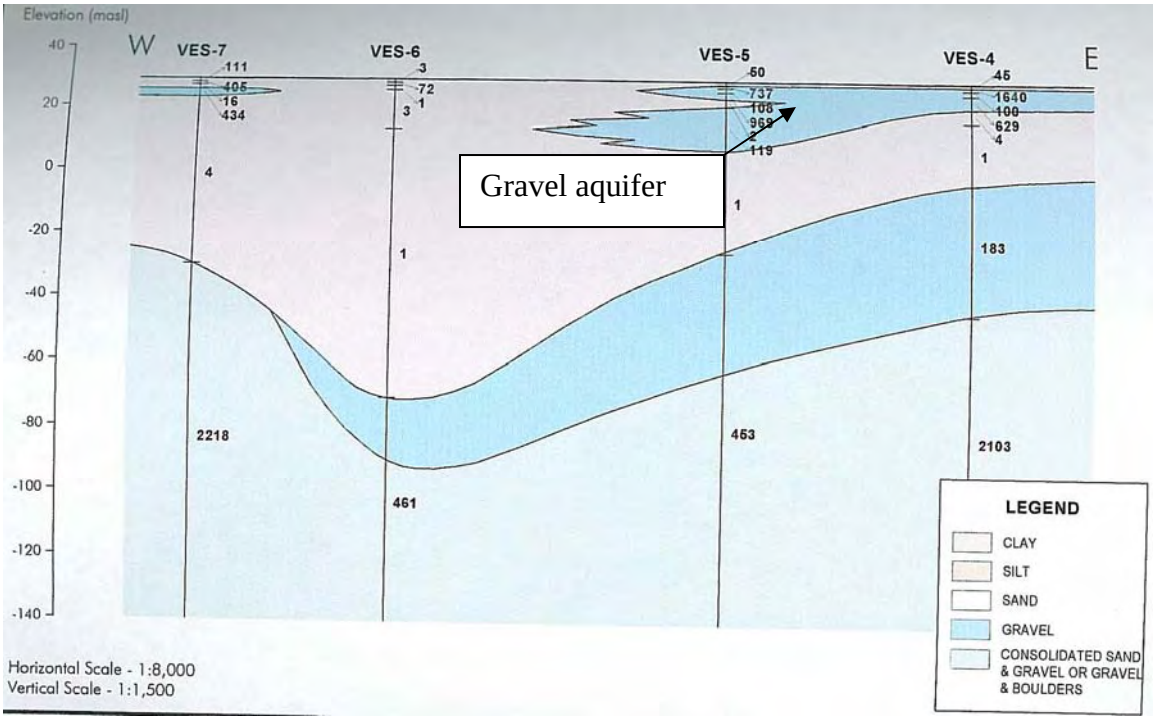


Figure 2- 9 Interpreted section of VES 7, 6, 5, and 4
(Source: Final Report GW Resources Assessment of Cabanatuan City -ADTSI)

In the area enclosed by the black circle (see Figure 2.6), the gravel aquifer is below a sandy layer (see Figure 2.10). It is possible that the Pampanga River will supply water to the gravel aquifer through the sand layer.

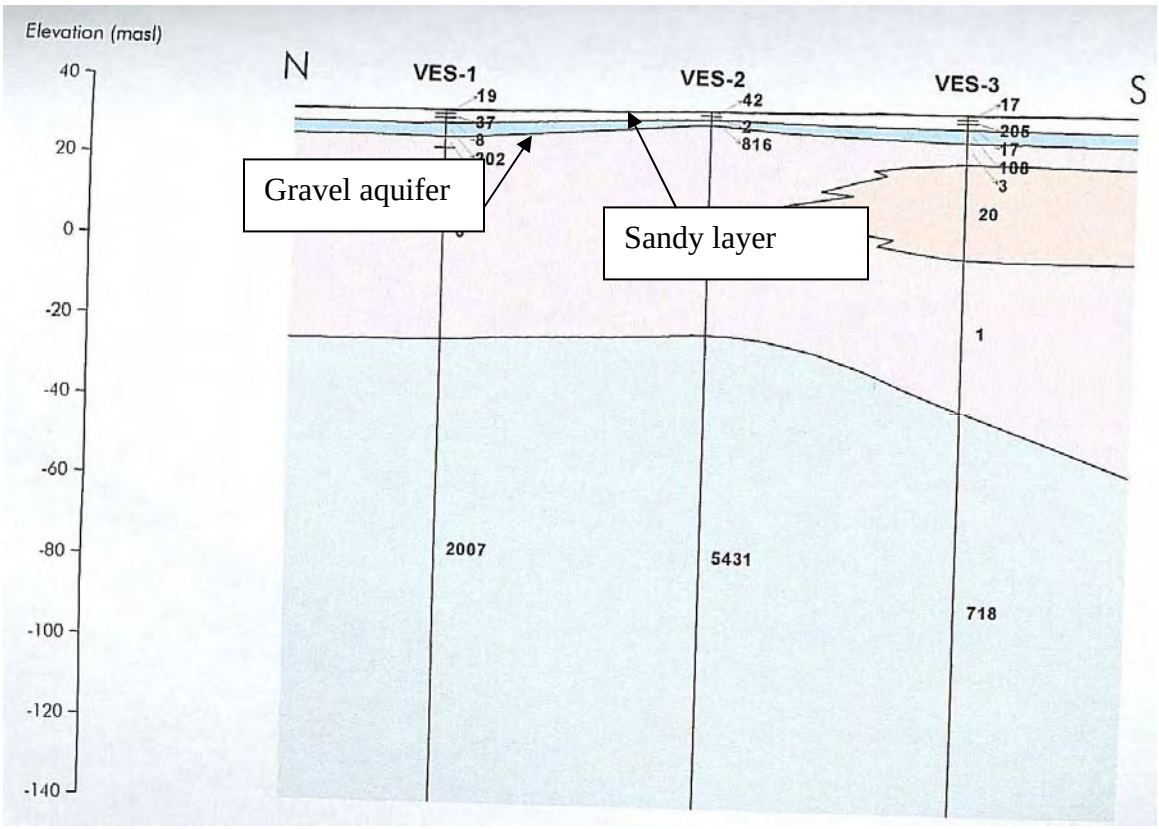


Figure 2- 10 Interpreted section of VES 1, 2, and 3
(Source: Final Report GW Resources Assessment of Cabanatuan City -ADTSI)

The drilling of exploratory wells is recommended in order to determine the composition of the layers beneath. This would enable also the verification of the interpreted sections of the georesistivity data. On the aspect of groundwater quantity, pumping tests should be conducted in order to assess the sustainability of the aquifer/s in the study area. A 72 hour pumping test is recommended. This should include the monitoring of water levels in the different shallow wells near the prospective well to be pumped.

Note possible contamination from agricultural, domestic, industrial sources. This should be evaluated and addressed since unconfined aquifers near the surface can be easily reached by contaminants.

CHAPTER 3. SYSTEM DEVELOPMENT AND ALTERNATIVE ANALYSES

3.1 Alternative Development

As discussed in Chapter 2, there is a need to develop surface water resource, to meet the long-term water supply requirements of CCWD, and at the same time, conserve groundwater sources.

Looking at 2025 water requirements, if groundwater pumping will be limited to the estimated natural aquifer recharge rate of 8.26 MCM per year (based on Aquadyne Study[1]), there will be a need to secure a minimum of 54,000 m^3/day of water supply, either from surface water sources, or any other bulk water supply independent of the Cabanatuan City groundwater resource.

The Pampanga River can easily deliver the long-term requirements, given a mean annual flow of 6,270,000 m^3/day and minimum discharge of 397,000 m^3/day[2].

If groundwater pumping is limited to 8.26 MCM per year, which is 28% less than the present extraction rate of 11.53 MCM per year (2006 data), Phase 1 (2010) capacity of the surface water facilities should be around 23 MLD. With a more conservative target of 10 MLD for Phase 1, the average groundwater extraction will be around 10.16 MCM per year, which is between the estimated aquifer recharge and present groundwater production. This is still lower than the 15 MCM annual extraction rate set in the groundwater resource development plan proposed in the ADTSI Study (see Figure 3-1). The 10 MLD supply from Pampanga River will be less than 26% of the average water demand during Phase 1 operations.

Considering that this is the first attempt by the CCWD to tap Pampanga River, limiting production to 10MLD may be more prudent. Operational experience for the first years will be invaluable, and the design of the treatment plant expansion can be based thereon. Also, by limiting the surface water source (to less than 26%), the impact of the risks will be manageable.

[1] Groundwater Resources Assessment of Cabanatuan City, Aquadyne, July 2004
[2] Based on 1982-1987 records

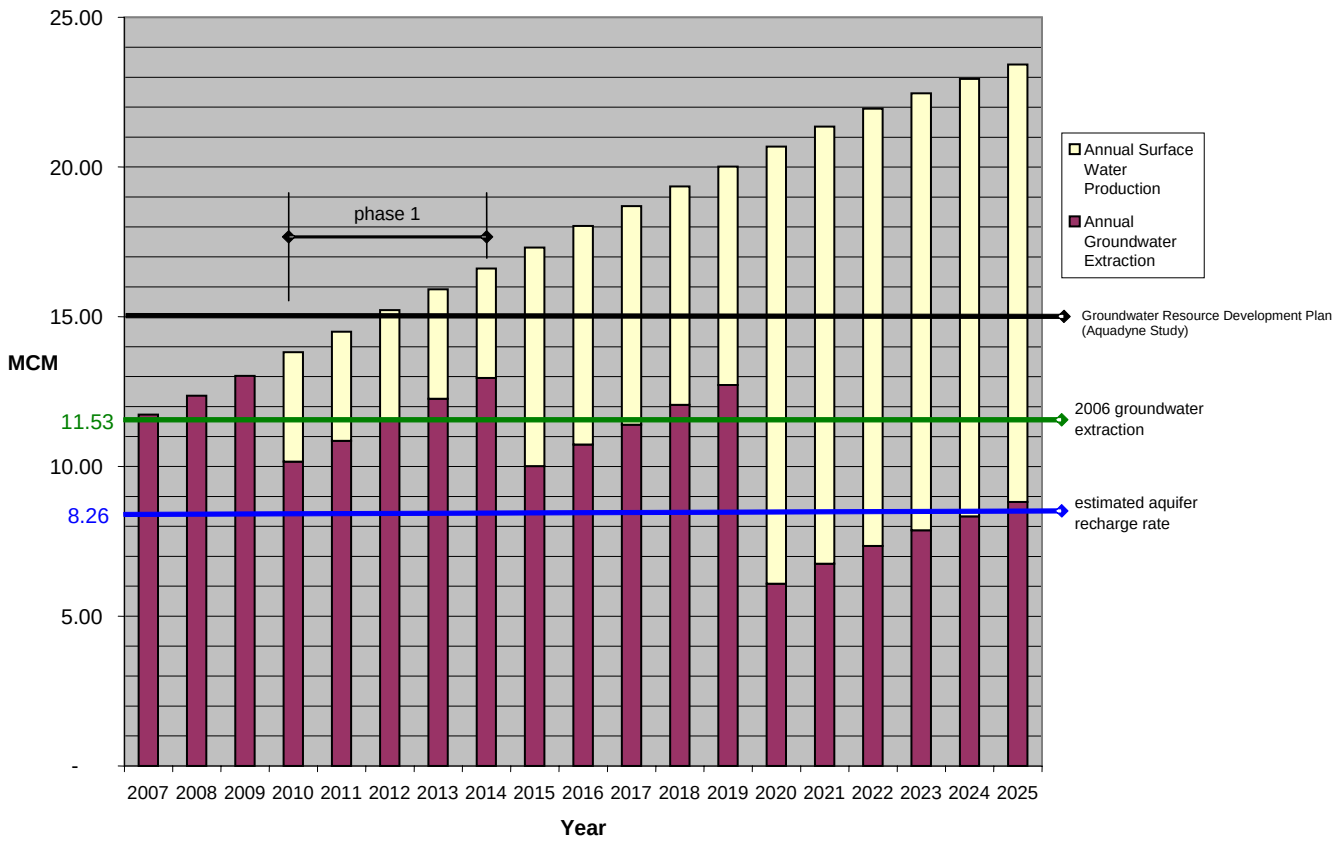


Figure 3 - 1 Annual Production Mix

The succeeding phase which should be operational by 2015 can either be 10 MLD or 20 MLD, depending on the actual water supply demand and the financial capacity of the CCWD to expand the surface water treatment facilities. The projected production mix for maximum day levels is shown in Figure 3.2, based on 10 MLD capacities for both Phase 1 and Phase 2. In Phase 2, the CCWD can rely more on surface water sources, up to 42% of average water demand.

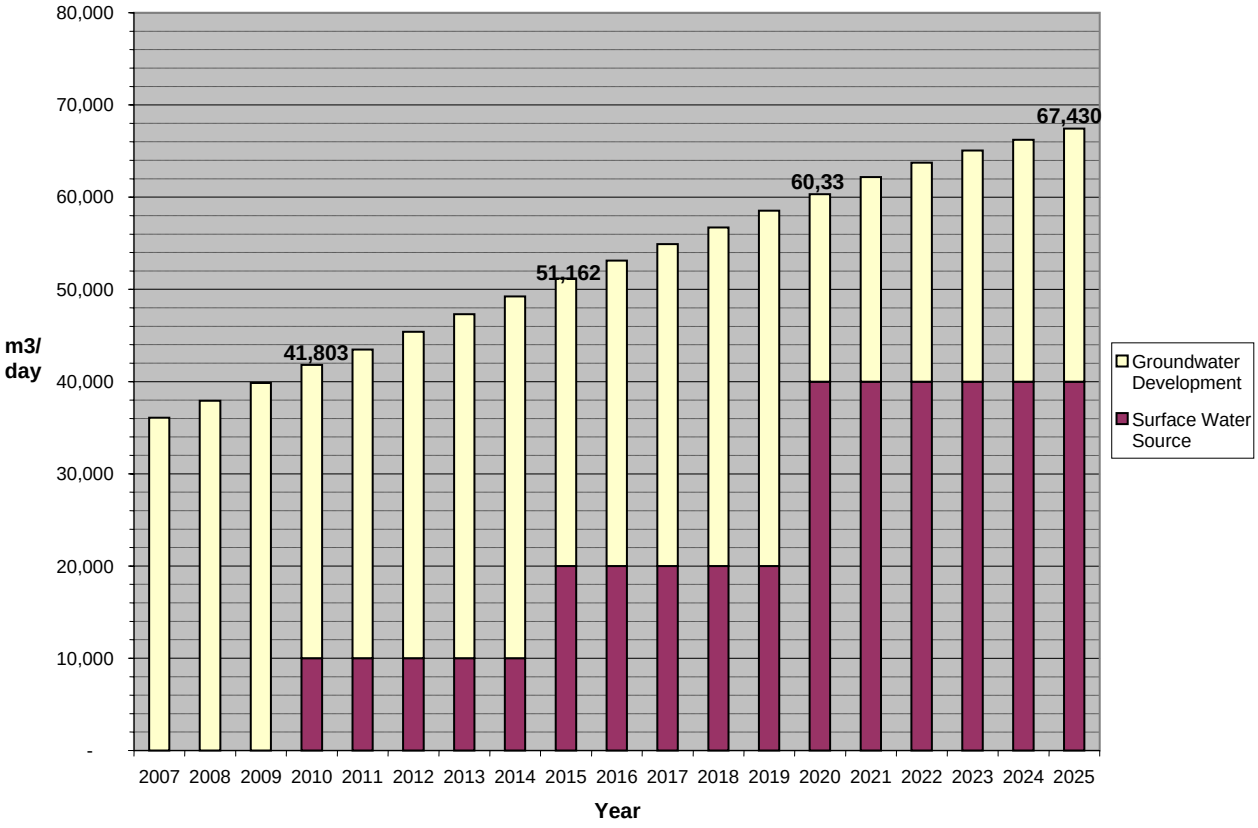


Figure 3 - 2 Proposed Production Mix for Service Area 1
(Daily Maximum)

Tapping the Pampanga River can be done through three (3) schemes, as discussed below:

1. *Through a surface water intake*. Raw water will be pumped from an intake along Pampanga River to a water treatment plant in Brgy. Valdefuente.

2. *Through shallow wells along Pampanga River*. Riverbed water will be extracted and pumped to a water treatment plant in Brgy. Valdefuente. A marginally higher water quality may be expected from the shallow wells as compared to direct surface water intake.

3. *Through shallow wells along Pampanga River*, as with the second scheme, but extracted riverbed water will be treated in several locations, rather than in a central location.

These alternatives are further discussed in the following sections.

3.2 Intake and Raw Water Transmission Facilities

Alternative 1

A surface water intake shall be constructed downstream of the bridge connecting Brgy. Valdefuente and Brgy. Mayapyap Sur (see Figure 3-3). The intake will connect, through a 900mm diameter pipeline, to a pump house which will be constructed on the secondary bank of the river (see Figure 3-4). Civil works for both the intake and pump house shall be designed for the ultimate capacity of 55 MLD. On the other hand, electromechanical equipment shall be phased accordingly.

A high water intake will be integrated with the pump house. Grit chambers and trash racks will be provided to provide protection to the pump, pipeline and treatment systems. The pump house shall be designed with five (5) pump compartments, to allow for a flexible phasing of capacities, and at the same time ensure system reliability with back-up pumps. The location and design of the pump house should allow for access by small service vehicles for maintenance purposes. A 700 mm diameter raw water treatment pipeline which can convey up to 55 MLD will connect the pump house with the water treatment facility.

Alternative 2

At least seven shallow wells will be constructed along the banks of Pampanga River. To prevent well interference, the wells will be at least 250m apart. Each well is projected to provide a maximum of 18 lps, of around 1,500 m^3/day. This projected yield should be verified with the development of a test well.

From the shallow wells, the raw water shall be pumped through a transmission line (150-300 mm diameter) to a centralized treatment plant, the location of which could be the same as in Alternative 1. For Phase 2, future shallow well development can be pursued at the other side of the Pampanga River.

Alternative 3

Similar to Alternative 2, seven shallow wells will be constructed. The difference is that instead of a centralized treatment plant, treatment facilities shall be provided in three pump sites. One treatment plant will serve three (3) wells, while two more treatment plants will each serve two (2) wells.

The raw water from deep wells will be conveyed through 150-200mm diameter transmission lines to the treatment plants.

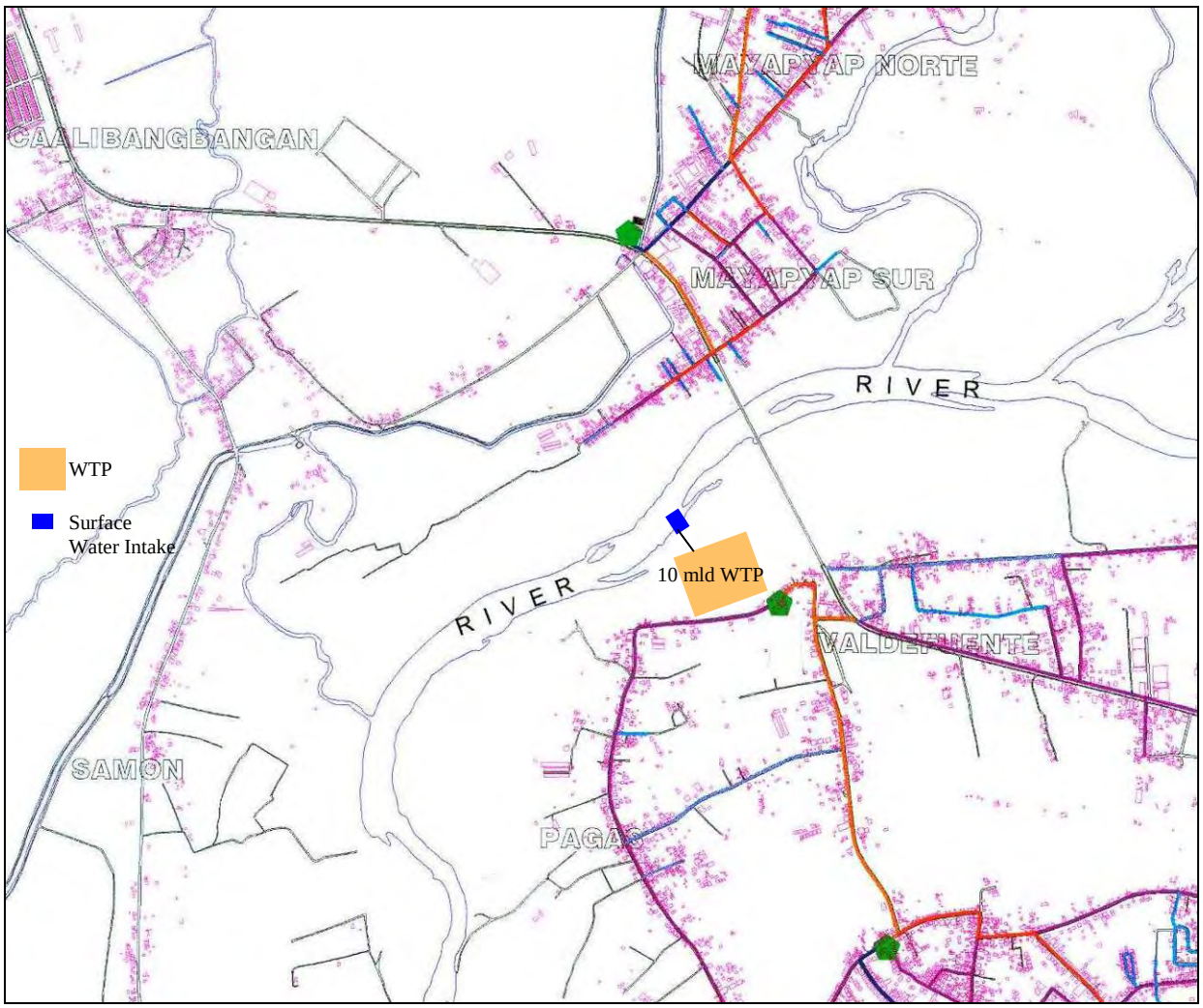


Figure 3 - 3 Alternative 1. River Intake, 10 mld WTP

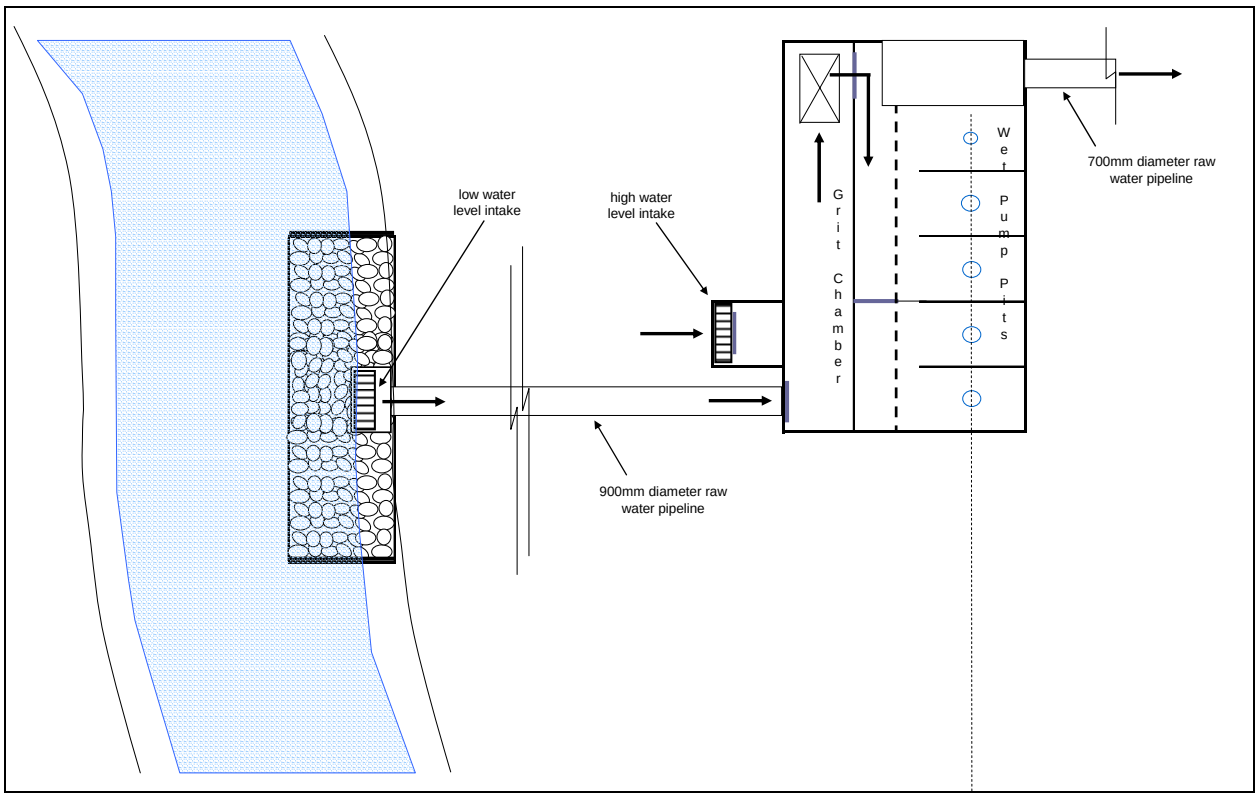


Figure 3 - 4 Alternative 1. Intake and Pump Station Preliminary Plan

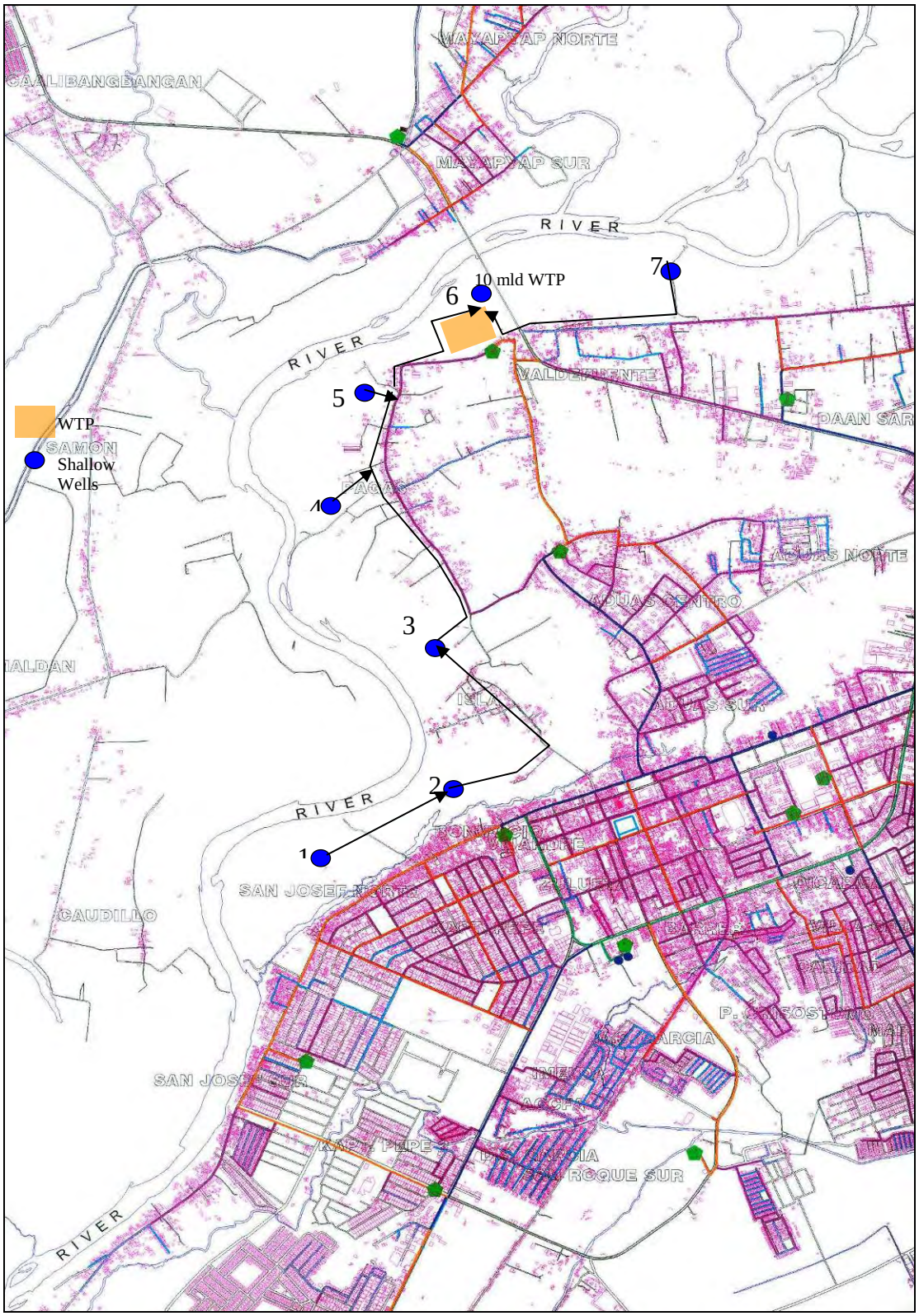


Figure 3 - 5 Alternative 2. 7 Shallow Wells, 10 mld WTP

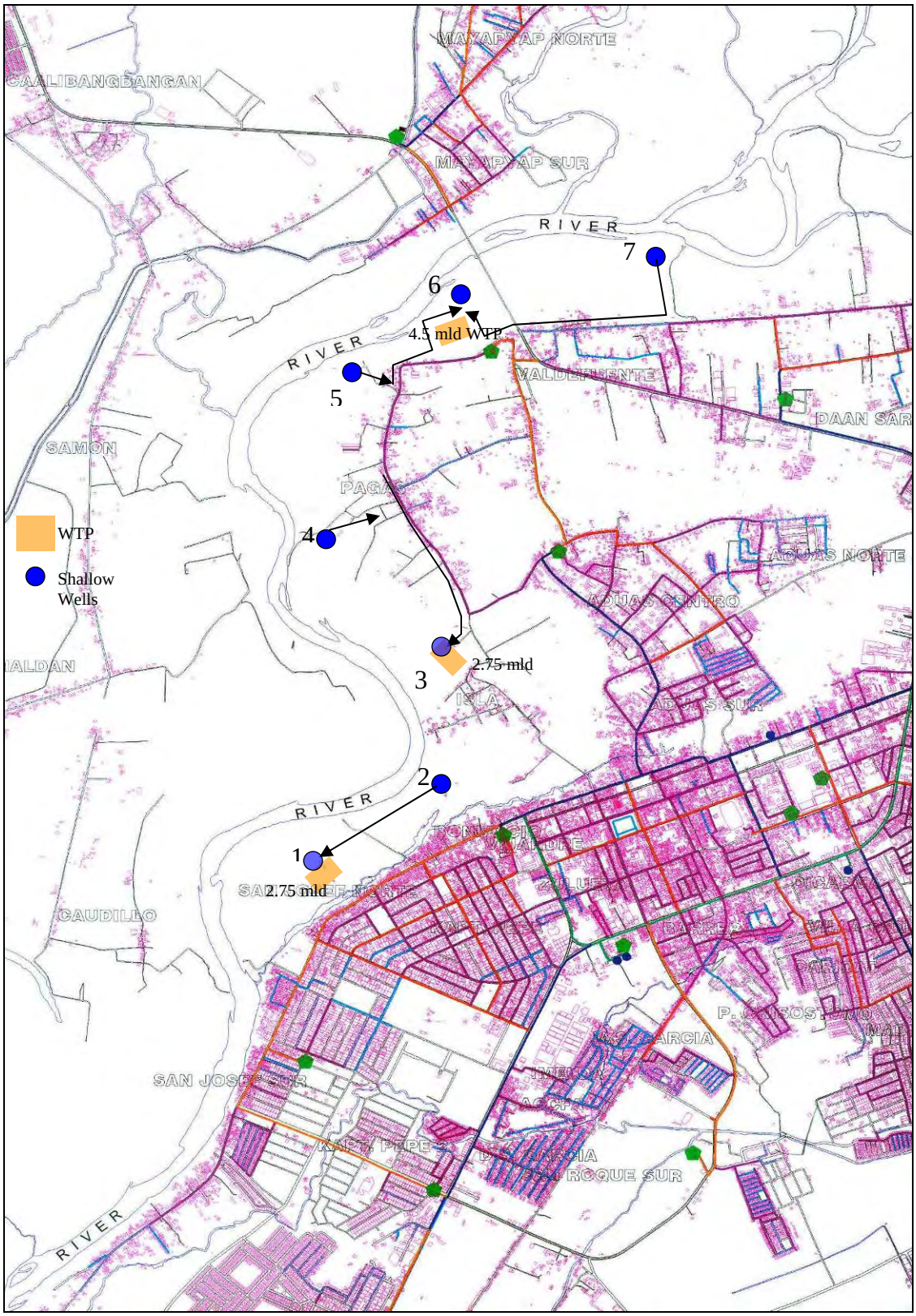


Figure 3 - 6 Alternative 3.7 Shallow Wells, 1 x 4.5 mld WTP, 2 x 2.75 mld WTP

3.3 Water Treatment

3.3.1 Raw Water Quality Data

The CCWD conducted water sampling at various points of the proposed surface water source, Pampanga River. The water samples were brought to the laboratory and were analyzed for the following parameters: pH, color, total dissolved solids, total hardness, alkalinity, acidity, iron and manganese. As a reference for shallow wells development, water quality from the CCWD's Sumacab well was evaluated. The results of the laboratory analysis for both surface water and groundwater are presented in Tables 3-1 and 3-2 below.

Table 3 - 1 Results of Laboratory Analysis on Various Points of Pampanga River

Parameter	Unit	Up stream	Up stream	Up stream	Up Stream	Midstream	Downstream
Date of Sampling		8-14-07	6 -18-07	7-9-07	6-20-07	6-20-07	6-20-07
Ph					7.15	7.49	7.65
Color	PCU	50	25	40	33	29	20
Turbidity	NTU	8.26	2.3	10	3.56	8.48	4.98
Total Dissolved Solids	mg/L	604*	228	125	99	107	108
Total Hardness	mg/L	154.98	121.55	86.1	83.56	86.63	96.23
Total Alkalinity	mg/L	322.10	120.33	88.42	82.66	82.66	89.98
Iron	mg/L	2.86	1.3	3.54	4.76	5.62	3.99
Manganese	mg/L	0.18	0.03	0.12	0.28	0.18	0.12
Odor		Soap Scent	Unobjec-tionable	Unobjec-tionable	Soil Scent	Soil Scent	Soil Scent
Coliform	mg/L	less than 2	3000	30000			

*TDS rise maybe due to addition of prechlorination prior to water analysis. The chlorine is used to determine the impact of chlorination to iron content

Table 3 - 2 Ground Water Quality (Sumacab Station)

Parameter	Unit	Sumacab	Sumacab	Sumacab	Sumacab	Sumacab	Sumacab
Date		2/22/2007	2/22/2007	2/22/2007	10/3/2006	7/3/2006	4/18/2006
pH		6.82	6.98	6.88	6.93	6.95	7
Color	PCU	7	5	15	4	5	2.5
Turbidity	NTU	3.2	1.2	4.4	1	1.75	0.3
Total Dissolved Solids	mg/L	251	251	365	146	258	265
Chlorides	mg/L	14	9	2.78			11
Nitrate Nitrogen	mg/L	0.87	0.72	1.01			
Total Hardness	mg/L	193	122	183	126	108	85
Total Alkalinity	mg/L	317	266	348	197	4	205
Total Acidity	mg/L	10	5	11		211	3
Iron	mg/L	0.19	0.19	0.48	0.14	0.25	0.30
Sulfate	mg/L		15	0.2			
Manganese	mg/L	nil	nil	nil	0.08		nil
Coliform	mg/L	480	421	558		362	

3.3.2 Evaluation and Assessment of Raw Water Quality

a. Surface Water Source

As shown in Table 3-1, raw water quality of Pampanga River has turbidity less than 10 NTU; color ranges from 10 to 50 PCU and hardness less than 300 NTU. The iron concentration ranges from 0.30 mg/L to 5.74 mg/L and manganese concentration is found negligible.

Although the raw water showed low turbidity and color concentrations, the data cannot be considered conclusive due to the limited samples obtained for this study. More samples should be taken prior to the preparation of the detailed engineering plans.

Direct filtration can be used as treatment method to address low turbidity and color concentrations. However, the limitation of direct filtration systems is the inability to handle high concentration of suspended solids. At some point during the plant's operation, the amount of suspended solids is expected to rise as a result of typhoons and heavy monsoon rains. Heavy runoff will scour the bottom of the river and will cause the suspended solids to rise, and in turn increase the turbidity level. In this situation, direct filtration will not be an effective treatment. To ensure that the plant is able to treat and produce potable water even at higher levels of turbidity and color, ***flocculation, settling and filtration*** is the recommended treatment method.

High iron content is evident in the laboratory analysis. To remove iron, and even manganese, the recommended treatment method is ***aeration, oxidation, and filtration.***

b. Shallow Well Source

Table 3-2 indicates raw water quality of Sumacab well has turbidity less than 5 NTU; color ranges from 4 to 15 PCU and hardness less than 300 NTU. The iron concentration is less than 1 mg/L and manganese concentration is found to be negligible.

Except for the presence of coliform, the water extracted from the Sumacab well is considered to be of good quality. However, since the proposed wells along the Pampanga River will essentially extract water from this surface water source, other contaminants such as iron and manganese may reach the shallow wells. Iron, which is found high in the surface water sampling, could discolor the proposed shallow well water sources. Therefore, the recommended treatment method should include iron and manganese removal.

The recommended minimum treatment is **prechlorination, settling, filtration (rapid sand pressure filtration) and disinfection**. Prechlorination will ensure that any iron that may be present is precipitated, settled, and filtered. Disinfection will ensure that all pathogenic bacteria or miroorganisms are eliminated.

3.3.3 Water Treatment Methods

a. Turbidity and Color Removal

a.1 Coagulation, Flocculation, and Settling Process

In the conventional system, raw water is initially passed through a rapid mix tank, which is equipped with a rapid mixer. A coagulant, e.g., aluminum sulfate, is fed to the water to come in contact with water molecules. The mixing or blending will force multiple contacts between each of the colloidal particles. This overall process is controlled by hydrodynamic parameters, geometry, molecular properties of the water, and kinetics of the coagulation reactions. The flocculation process aggregates destabilized particles into larger and more easily settle-able floc. Destabilization results from chemical reactions between the coagulant and the colloidal suspension, while flocculation is the transport step that causes the necessary collision between the destabilized particles.

Polymer is added to aid the coagulation process. Polymer will prevent the floc from being broken. After the coagulation and flocculation processes, flocs are settled in the sedimentation tanks.

Usually, the sedimentation tanks used are long horizontal concrete structures. The long horizontal design allows particles to settle quiescently and efficiently.

The conventional horizontal sedimentation tanks are usually designed without sludge scrapers, especially when turbidity concentrations are not really high. Intermittently, sludge deposited at the bottom is removed by pumping to sludge lagoons.

The conventional horizontal sedimentation tank is sometimes modified with the installation of ***lamella settlers or steeply inclined tubes***. The influent flow enters either at the top or bottom of the clarification basin and is then directed through a series of parallel plates. The settlers are used to improve performance and increase capacity of clarifiers. Because of the additional effective area of tube or plate settlers, the tank has a smaller footprint.

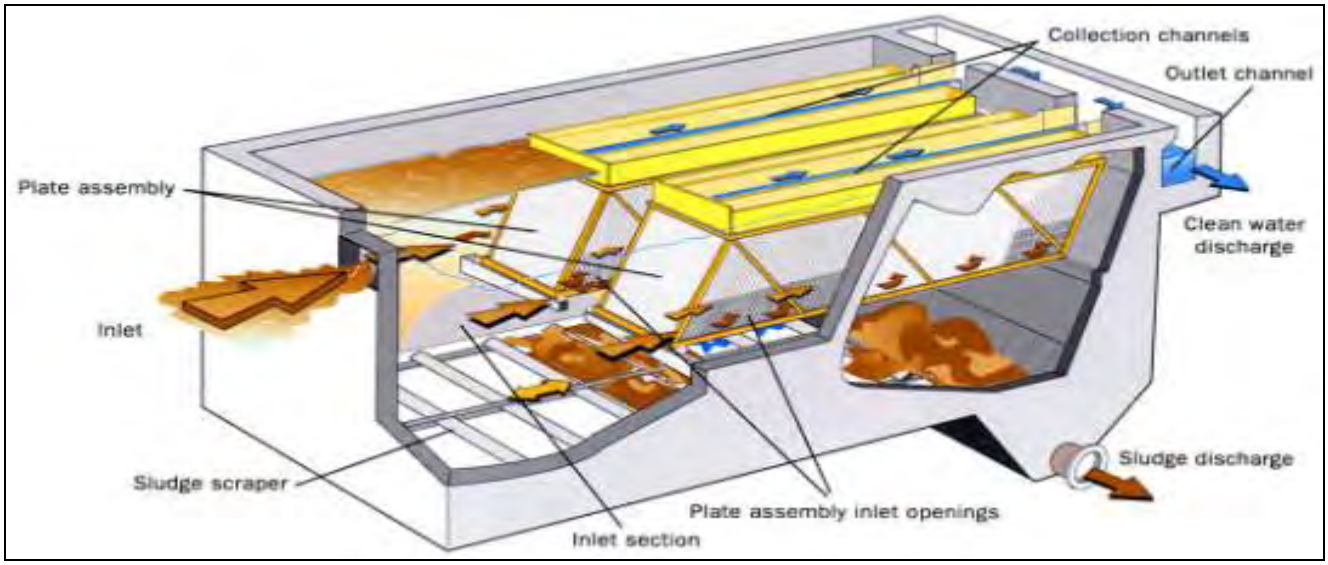


Figure 3 - 7 Typical horizontal type sedimentation tank with lamella settlers

a.2 Solid Contact Clarifier System

The most popular solid contact clarifier system is the "Pulsator" Clarifier, which was developed and is marketed by *Infilco Degremont*. The Pulsator is a sludge blanket type clarifier, which utilizes hydraulic pulsating system to maintain a homogenous sludge solids layer within the clarifier. Initially, the chemical coagulated water first enters a vacuum chamber adjacent to the clarifier. A vacuum pump draws the water up into the chamber; an air vent releases the vacuum and allows the water to flow into the clarifier. This creates a hydraulic pulsing action within the clarifier, and flocculation energy imparted is a function of pulse intensity and duration. The coagulated water enters through a series of

perforated distribution laterals at the clarifier floor. The passage of the coagulated water upward through the sludge blanket results in contact of the water with previously formed floc particles. During the introduction of flow into the clarifier, the sludge blanket expands uniformly upward. Continuous pulsing of the sludge blanket maintains a uniform sludge layer within the clarifier, thereby reducing the potential for short circuiting of flow through the sludge blanket. As a result of intimate contact of the incoming flow with the sludge blanket, high coagulant utilization may be achieved, and high clarity water is produced.

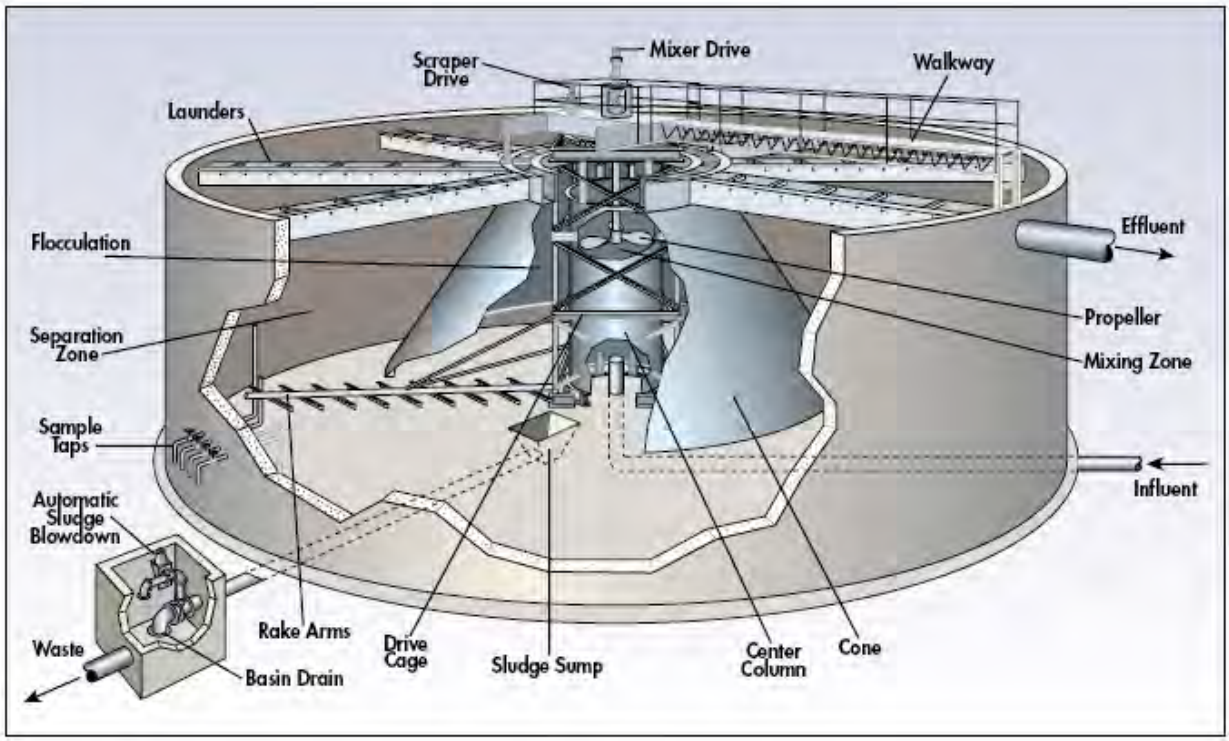


Figure 3 - 8 Pulsator "Sludge Blanket" Solid Contact Clarifiers
(Courtesy of Infilco Degremont, Inc.)

A comparison of the conventional horizontal sedimentation tanks, horizontal sedimentation tanks with lamella settlers and the solid contact clarifier is shown below.

Table 3 - 3 Comparison of Conventional, Lamella, and Pulsator Systems

Parameters	Conventional Coagulation +Flocculation+ Horizontal Sedimentation	Conventional Coagulation +Flocculation+ Horizontal Sedimentation With Lamella Settlers	Pulsator-Clarifiers	Remarks
Performance	Excellent, in most cases	Excellent, in most cases	Excellent, in most cases	
State of the Art Technology	No	Lamella settlers are proprietary	Yes	
Area Requirements	More	Less than horizontal sedimentation tanks by about 20%	Least	Due to its compact design, Pulsator systems saves space by 30% compared to conventional system. Lamella settlers save 20% of area requirements.
Chemical Feeding	Not required during low turbidity and TSS influent quality	Not required during low turbidity and TSS influent quality	Always, to support sludge blanket all the time	Chemical feeding such as polymer is needed to maintain sludge blankets
Design	Not Proprietary	Tanks are not proprietary	Proprietary	Proprietary means the design is "exclusive" to a supplier
Controls	Automatic with manual override	Automatic with manual override	Automatic with manual override	
Remote Control	No	No	Yes, program logic control (PLC) is part of the component	The operation of the clarifier is PLC based, and state of the art.
Sludge Removal Mechanisms	Mostly, designed without sludge scrapers. Provision of scrapers is an option to improve efficiency of operations	Mostly, designed without sludge scrapers. Provision of scrapers is an option to improve efficiency of operations	Scraper	Mechanical scraper is provided and required for the pulsator clarifier
Solid Removal	Manual desludging, if scrapers are not provided	Manual desludging, if scrapers are not provided	Desludging is automatic, and regularly removed by sludge scraper	Manual desludging which can be undertaken during low turbidity inflow requires a downtime upon cleaning, compared to sludge scraper already installed. However, conventional settling system can easily be upgraded.
Spare Parts	Locally available	Locally available	Not available locally, need to source it from supplier	Generally, parts of the Pulsators are difficult to obtain and are expensive. However, some components can be fabricated locally
Cost	Less	More	Most	The capital expenditure of using pulsator-clarifiers is 40%more than the conventional system. The lamella settler is about 20% of the cost of horizontal sedimentation tanks.
Operation Cost	Lease	Same as conventional system	Slightly more by 10 %	The operation cost of Pulsator is slightly more than the conventional system

b. Iron and Manganese Removal

The presence of even small amounts of iron in water stain clothing materials, induce red color, and affect the taste of water and beverages such as tea and coffee. Manganese produces a brownish color in laundered clothing, leaves black particles on fixtures and affects the taste of water and beverages.

Iron exists in surface water supply in many forms, namely: Ferric ion, Ferrous Ion and Iron Bacteria. It is usually present in suspensions of silt, clay and fine particulates of ferric oxides. It may also exist in colloidal form or in chelated form with humic acids. As for manganese, it exists in suspensions in tetravalent state as stable soluble complex. Iron and manganese are practically present in all reservoirs.

b.1 Iron Bacteria Control

Iron bacteria can be controlled by periodic chlorination. The treatment involves the following: *Chlorination, Sedimentation, Filtration*. Activated carbon is usually used as the filter material so the excess chlorine can also be removed.

b.2 Ferric Iron Removal

Ferric iron can be removed by simply using properly sized media filter to filter it from the water. However, the following issues should be considered:

- Some ferric ion is present in colloidal form. It will generally stick together to form large flakes. The tiny particles of colloidal iron do the opposite. Their large surface area and charge relative to their mass cause the individual particles to repel one another. As a result they will not coagulate. Their small size, then, makes them difficult to filter, and a coagulating agent is often required to obtain adequate filtration.
- Most water containing ferric iron also contains ferrous iron. This can add complexity to the process, since some of the methods for removing ferrous iron will also remove ferric iron.

b.3 Ferrous Iron Removal

There are a variety of ways for removing ferrous iron, each with its own strengths and limitations. One of the most common methods is by oxidation and filtration.

b.3.1 Oxidation/Filtration

Oxidation followed by filtration is relatively the simplest process and most common process. The oxidant chemically oxidizes the iron or manganese and kills iron bacteria and any other disease-causing bacteria that may be present. The oxidized iron and manganese are in particulates form forming large floc. The filter then removes the iron or manganese particles.

Before iron and manganese can be filtered out, they need to be oxidized to a state in which they can form insoluble complexes. Oxidation involves the transfer of electrons from the iron, manganese, or other chemicals being treated to the oxidizing agent. Oxidation methods fall into two groups: those using additives like chlorine, ozone or air; or those using an oxidizing filter media. Oxidation can be undertaken **by aeration, chlorination, chlorine dioxide, potassium permanganate.**

Aeration can be fulfilled in two (2) processes: initially, oxygen is dissolved in water, followed by the oxidation processes and the removal of volatile gases.

Chemical Reaction:

$$4Fe(HCO_3)_2 + O_2 + 2H_2O \rightarrow 4\,Fe(OH)_3 + 8\,CO_2$$

$$2MnSO_4 + 2\,Ca(OH)_2 + O_2 \rightarrow 2\,MnO_2 + 2CaSO_4 + 2\,H_2O$$

Chlorine is used in the oxidation of divalent iron and manganese, because unlike aeration, it has a faster oxidation rate and is capable of oxidizing organically bound iron.

Chemical Reaction:

$$2Fe(HCO_3)_2 + Ca(HCO_3)_2 + Cl_2 \rightarrow 2\,Fe(OH)_{3\,(ppt.)} + CaCl_2 + 6\,CO_2$$

$$Mn(HCO_3)_2 + Ca(HCO_3)_2 + Cl_2 \rightarrow MnO_{2\,(ppt.)} + CaCl_2 + 4CO_2 + 2\,H_2O$$

Chlorine Dioxide is a strong oxidant that effectively oxidizes organically complexed iron and manganese. The pH level necessary for oxidation a very important factor in the reaction rate and should be a minimum of 7.0.

Chemical Reaction:

$$Fe(HCO_3)_2 + NaHCO_3 + ClO_2 \rightarrow Fe(OH)_{3\,(ppt.)} + NaClO_2 + 3\,CO_2$$

$$Mn\,(HCO_3)_2 + 2\,NaHCO_3 + 2ClO_2 \rightarrow MnO_{2\,(ppt.)} + 2\,NaClO_2 + 4\,CO_2 + 2H_2O$$

Potassium Permanganate is a strong oxidant. The reaction time is fast and covers a wide range of pH. The oxidation time varies from as short as 5 min to 10 min for both iron and manganese, provided that the pH is over 7.0.

$$3Fe(HCO_3)_2 + KMnO_4 + 7H_2O \rightarrow 3\ Fe(OH)_{3\ (ppt)} + MnO_2 + KHCO_3 + 5\ H_2O$$

$$3Mn(HCO_3)_2 + 2KMnO_4 + 2\ H_2O \rightarrow 5\ MnO_2\ (ppt) + 2\ KHCO_3 + 4\ H_2CO_3$$

Other methods of removing iron and manganese are **Manganese-Zeolite Filtration, Lime Softening, Ion Exchange (Zeolite Softening), and Stabilization or Sequestering.**

b.3.2 Manganese-Zeolite Filtration

Water is passed through a filter using manganese impregnated greensand (zeolite) media. Manganese greensand is produced by treating glauconite with manganous sulfate and potassium permanganate to provide an active supply of iron and manganese oxides on sand grains. When the oxidizing power of iron is exhausted, it is regenerated with permanganate, reused, and returned to service. The manganese zeolite filtration is found effective in high-carbonate, iron-bearing waters, but is exhausted too quickly if other reducing substances such as organic matter, nitrogenous matter, or hydrogen sulfide are present. Greensand has the ability to oxidize and filter.

A major disadvantage of greensand is the continuous need for regeneration which is time consuming. Greensand is effective wherein potassium permanganate is installed ahead of the filter, resulting in reduced soluble iron and manganese loading to the filter.

b.3.3 Lime Softening

Chemical precipitation of iron and manganese using lime is also found effective at pH values approximating their isoelectric point of 9.4. Manganese and iron are effectively removed by lime addition. Significant precipitation of ferrous hydroxide and manganous hydroxide generally proceeds only above pH values of 9.5 and 10.0, respectively. Precipitation of iron and manganese with lime is usually not cost-effective unless lime treatment is also required for hardness reduction.

b.3.4 Ion Exchange (Zeolite Softening)

Sodium cation zeolite exchange and hydrogen cation exchange units can remove ferrous iron (Fe (II)) and manganous manganese (Mn(II)). The ion exchange treatment removes hardness as well as iron and manganese. This process is best undertaken in the absence of oxygen to prevent oxidation of any ferrous hydroxide, which can foul the zeolite, stop ion exchange reactions, and clog filters. It is important that iron and manganese be preoxidized to make ion exchange more effective. The ion exchange process is limited to water supplies containing low concentration of iron and manganese of less than 1 mg/L.

b.3.5 Stabilization or Sequestering

Another alternative to removing iron and manganese is by holding them in solution by stabilization, sequestering, or dispersion. Iron and manganese must be in the ionic state for this process to be effective. Generally it is appropriate to well waters containing sufficient carbon dioxide to ensure that iron and manganese are present as bicarbonates. The sequestering agent is pumped into the well to contact iron and manganese prior to oxidation. Sequestering agents include sodium hexametaphosphate, trisodiumphosphate, and sodium silicates. Sequestering is applicable only when iron and manganese concentration are less than 2.5 mg/L.

Table 3 - 4 Comparison of Iron and Manganese Treatment Methods

Treatment Methods	Chlorination or Chlorine Dioxide Oxidation, Preciptation, Filtration	Aeration, Precipitation Filtration	Manganate Zeolite Filtration	Stabilization, Sequestration	Ion Exchange
Application	Surface Water or Groundwater	Surface Water or Groundwater	Surface Water or Groundwater	Groundwater	Groundwater
Remarks	Effective over a wide range of pH (4 to 10) Effective even at high of iron and manganese concentration	Slow in low pH Less effective without chlorine and potassium permanganate	Limited to iron and manganese less than 1 mg/L Regeneration of media is required and time consuming	Iron and Manganese has to be in ionic state to be effective Recommended for iron and manganese less than 2.5 mg/L only	Used as advance treatment to remove iron and manganese less than 1 mg/L only
Chemicals	Chlorine/ Chlorine Dioxide	Chlorine Potassium Permanganate	More effective with aid of chlorine and potassium permanganate	Sodium Hexameta-phosphate Trisodium-phosphate Sodium Silicate	Cation and Anion Resin
Capital Cost	Least Expensive	Moderate	Moderate	Use for special case only, cost is very high	Use as post treatment only, or add on treatment

c. Filtration

In water treatment process, the fundamental system that removes particulate matter is filtration. The most common filtration process employs a granular medium of a certain size and layer depth. The pretreated water from coagulation, flocculation and settling

processes passes through the filter bed where majority of the particulates are removed in the top portion, and the remaining throughout the entire depth of the bed.

Filters can be categorized in a variety of ways. The table below shows the characteristics of two types of filters based on the hydraulic regime: rapid gravity sand filters and pressure filters.

Table 3 - 5 Comparison of Rapid Sand Filters vs Pressure Filtration

Parameters	Rapid Sand Filters	Pressure Filters
Advantages	• Relatively small and compact	• Low investment cost because there are readily available package pressure filters sold in the market. • Low operation cost in small filtration plants, but expensive and high operational cost in large plants.
Disadvantages	• Requires chemical pretreatment. • Doesn't remove pathogens .	• Less reliable than gravity filters • Filter bed cannot be observed during operation. • Requires chemical pretreatment. • Doesn't remove pathogens
Filter Media	• Sand. • Sand and anthracite coal. • Sand and anthracite coal and garnet.	• Sand. • Sand and anthracite coal. • Sand and anthracite coal and garnet.
Flow Method	• Gravity	• Pressure
Filtration Mechanism	• Primarily adsorption and straining.	• Primarily adsorption and straining
Cleaning Method	• Backwashing either by water or combination of air water backwashing	• Backwashing either by water or combination of air water backwashing
Common Applications	• Most commonly used type of filter for surface water treatment	• Iron and manganese removal in small groundwater systems

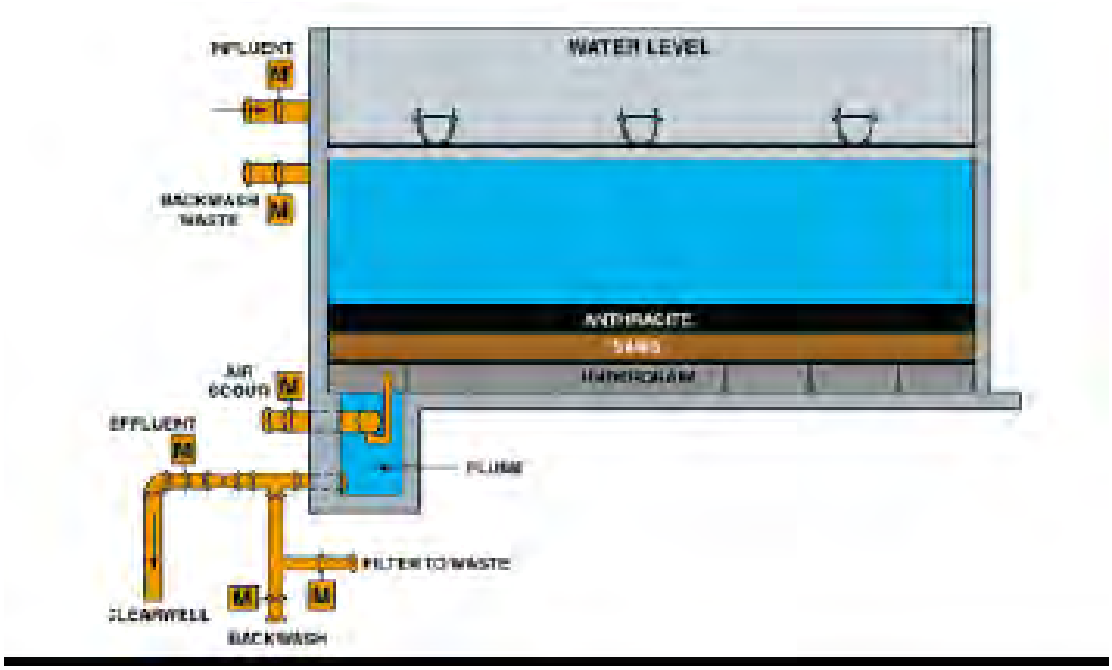


Figure 3 - 9 Typical Rapid Sand Filters

d. Advanced Filtration Systems

Although the water quality of the samples taken at Pampanga River did not indicate significant presence of total dissolved solids, there is the risk of pollution discharges to the river bringing contaminants such as heavy metals, asbestos, paint pigments, pesticides and herbicides. There are more advance filtration systems that address these contaminants applied as either pretreatment or post treatment.

Membrane filtration allows the passage of water through the membrane pores, while retaining various amounts of suspended and/or dissolved substances. There are a wide variety of membrane polymers available with physical arrangements for crossflow filtration to meet variety of industry demands. Membranes comprised of a plastic materials that must perform in a variety of environments with high efficiency. There are four types of membrane filtration that operates on various conditions. The four (4) types of membranes are microfilter, ultrafilters, nanofilters, and reverse osmosis.

d.1 Microfiltration

Microfilters (range 0.10 to 2.0 micrometer) will remove suspended solids, large colloids, some emulsions, and high volume of bacteria. Microfilter operates on

pressure range from 1 to 25 psig. Microfilter is used as pretreatment in high-purity water applications.

d.2 Ultrafiltration

Ultrafilters (range 0.008 to 0.10 micrometer) will remove large organics (over 1,000 MW) such as proteins, pyrogens, bacteria and celluloids. Ultrafilters act as pretreatment and post treatment to ion exchange and other high-purity processes. Ultrafilters operate on pressures ranging from 10 to 200 psig.

d.3 Nanofiltration

Nanofilter (range 0.001 to 0.01 micrometer) is a new type of membrane. It is used to remove organics and dissolved salts, thus changing the characteristics of the water. Nanofilters operate on pressure that ranges from 50 to 300 psig.

d.4 Reverse Osmosis

Reverse osmosis (range, up to 0.001 micrometer) removes most of the soluble dissolved solids. The operating pressure varies from 400 to 800 psig. Osmosis is the diffusion of a water of less concentration of dissolved solids through a semipermeable membrane to a water of greater concentration of dissolved solids.

The advantages of membrane systems are:

- It consistently separates a wide variety of emulsion, surfactant, and chelating substances and various mixtures
- It require no specific chemical knowledge
- Complex instrumentation is not required
- Easy to operate, and does not need constant operator
- It is simple to understand

The disadvantages of membrane systems are:

- Membranes are expensive. They need to be replaced on a regular basis.
- Certain solvents can destroy membrane permanently.
- Certain colloidal solids can permanently foul the membrane surface.
- Membranes are sensitive to the presence of disinfectant chemicals.
- The energy cost is higher compared to chemical coagulation, flocculation and settling process.
- Oil emulsions are not chemically separated.

e. Disinfection

The purpose of disinfection process is to kill the growing form of pathogenic microorganisms through the use of chemicals such as chlorine. Many types of disinfectant are used for municipal water systems, but the most common is the use of strong chemical oxidants such as chlorine (Cl_2); bromine (Br_2), iodine (I_2), ozone (O_3), chlorine dioxide (ClO_2), potassium permanganate ($KMnO_4$).

The principal sources of chlorine are:

- The elemental form, as liquefied compressed gas
- Calcium hypochlorinte
- Calcium bleach solution
- Chlorine dioxide

For this particular project, calcium hypochlorite is recommended. The choice of calcium hypochlorite is based on the following factors: it is commonly available; it is easy to operate; it costs less compared to sodium hypochlorite; it is less dangerous compared to the liquefied chlorine gas; and above all, it is also effective in removing all pathogenic substances.

Calcium hypochlorite, a dry bleach, contains at least 70% available chlorine and about 3 to 5 percent lime. Calcium hypochlorite is readily soluble in water. Tablet forms dissolve more slowly than the granular materials, and provide a fairly steady source of available chlorine over an 18 to 24 hour period.

Chlorine Reactions:

When Calcium hypochlorite is dissolved in water at room temperature, it reacts to form hypochlorous and hypochloric acids, as follows:

$$Cl_2 + H_2O \rightarrow HOCl + H^+ + Cl^-$$

This reaction is essentially complete within a very few seconds. The hypochlorous acid ionizes or dissociates practically instantaneously into hydrogen and hypochlorite ions:

$$HOCl \rightarrow H^+ + OCl^-$$

These reactions represent the basis for the use of chlorine in most applications.

3.3.4 Recommended Water Treatment Processes

After evaluation of the water quality data, the following are the recommended water treatment processes for the 10mld (Phase 1) water treatment plant for the CCWD:

a. Iron and Manganese Removal

Iron and manganese removal by chlorine oxidation, settling and filtration is recommended among the five (5) methods cited. The advantages of this method compared with the others are:

- It is applicable for treating water containing iron and manganese concentrations over 5 mg/L, unlike aeration, manganate zeolite, sequestration and ion exchange which are applicable to lower concentrations only (Less than 2.5 mg/L).
- Chemical oxidation is applicable to wide pH range (4 to 10) compared to aeration which is ineffective at low pH.
- It is easy to operate and is less expensive.
- Oxidants like chlorine are widely available in the market and relatively inexpensive.

b. Turbidity and Color Removal

The recommended turbidity and solids removal is by coagulation, flocculation and sedimentation. Some of the key advantages for this process combination are:

- It requires lower capital investment ;
- It is simple and easy to operate;
- Chemical coagulants are not required during times of low turbidity
- The same facilities can be used to remove iron and manganese
- Conventional sedimentation basins are upgradable to include sludge scrapers or lamella settlers to improve treatment efficiency. Pulsators can be considered over conventional sedimentation systems.

c. Solid Removal

The recommended final solid removal is rapid sand filtration. For treatment plants with capacities higher than 10 MLD, the use of rapid sand filters is economical compared to pressure filters. However, for plants of smaller capacities, readily available pressure filters can be used. As an alternative, membrane systems can be evaluated during later project development stages.

d. Disinfection System

The recommended disinfection system is the use of calcium hypochlorite solution, similar to the existing system.

e. Sludge Management

All sludge generated from the water treatment plant shall be initially pumped to the sludge lagoons to allow solids to settle and dry for a period of time. Supernatant water shall be returned to the head of the treatment plant.

3.3.5 Water Treatment Alternatives

Water treatment schemes for the three alternatives are developed to address the water demand of Cabanatuan City. The three (3) schemes assumed that water quality of the source water in terms of major constituents which should be removed, are the same. Although the results of analysis from the Sumacab Well may indicate good water quality for shallow wells near Pampanga River, the data set cannot be considered sufficient and conclusive. Because of the proximity of the proposed shallow wells to the Pampanga River, it is possible that extracted water may be at some point in time have the same quality as surface water.

Table 3 - 6 Comparison of Water Treatment Schemes

Parameters	Alternative 1	Alternative 2	Alternative 3
Type of Water Treatment Plants	Surface Source, Centralized WTP	Shallow Wells Source, Centralized WTP	Shallow Wells Source, Decentralized WTP
Source of Water	Pampanga River	7 shallow wells, bank of Pampanga River	7- shallow wells, bank of Pampanga River
Plant Capacities	10 MLD	10 MLD	1-4.50 MLD 1-2.75 MLD 1-2.75 MLD
No. of WTPs	1	1	3
Treatment Methods			
Iron and Manganese Removal	Oxidation with chlorine	Oxidation with chlorine (but may be of less frequency than Alternative 1)	Oxidation with chlorine (but may be of less frequency than Alternative 1)
Turbidity and Color Removal	Coagulation, Flocculation and Sedimentation	Coagulation, Flocculation and Sedimentation *design criteria is less conservative than Alt 1, because some degree of filtration had already taken place in the strata	Coagulation, Flocculation and Sedimentation *design criteria is less conservative than Alt 1, because some degree of filtration had already taken place in the strata
Final Solid Removal	Rapid Sand Filters	Rapid Sand Filters	Pressure Filters, plants are considered relatively small
Disinfection	Hypochlorite Disinfection	Hypochlorite Disinfection	Hypochlorite Disinfection
Sludge Treatment	Sludge Lagoons	Sludge Lagoons	Off-site sludge treatment most likely
Area Requirements	One compact area is required (around 9,000 m^2 which can accommodate future plant expansions)	One compact area is required (around 9,000 m^2 which can accommodate future plant expansions). Additional lots to be acquired for the seven shallow wells.	Three sites for treatment plants (total of around 7,000 m^2). No expansion. Additional lots to be acquired for the three shallow wells.
Interpiping System (from extraction point to treatment plant)	Not Required	Required	Required
Expandable	Yes	Yes	No
Monitoring of Treated Water Quality	Monitoring is relatively easiest	Monitoring is relatively easiest	More difficult to control and monitor, considering multiple WTPs
Manpower	Less	Less	More

3.4 Storage and Pumping Facilities

For all alternatives, storage and pumping facilities will be provided after the treatment plant facilities. Storage facilities shall be ground concrete reservoirs and design capacity will be four (4) hours of daily average flow. Alternative materials for the reservoir can be explored in the detailed engineering stage, especially if overall costs of these alternatives are shown to be less costly. Prefabricated reservoirs may prove to be applicable and advantageous for Alternative 3, where storage facilities would be of smaller capacities since these have to be located in three (3) areas.

For the pumping facilities, it is proposed that variable speed pumps be considered to allow for optimum operations.

3.5 Estimated Capital Investment and Operational Costs

For comparison purposes, the estimated investment costs for the three (3) system alternatives, in 2007 prices, are shown in Table 3-7. The least cost is Alternative 2 (centralized WTP, shallow wells source), at PhP 66.34 million pesos. For this alternative, the water treatment plant cost is lowest and offsets the cost for the raw water transmission line and shallow wells required for this alternative. However, the costs do not vary significantly among the alternatives: the capex for Alternative 1 and 3 is slightly higher compared to Alternative 2, by 11% and 13%, respectively.

Table 3 - 7 Estimated Investment Costs (in constant 2007 prices)

Items	Alternative 1	Alternative 2	Alternative 3
1.0 Intake Structure/Raw Water Pump Station	**11.45**	**-**	**-**
1.1 Civil works	5.20		
1.2 Mechanical and Electrical Works	6.25		
2.0 Shallow Wells	**-**	**9.85**	**9.85**
3.0 Raw Water Transmission Line	**0.90**	**4.62**	**2.11**
3.1 150 mm diameter steel pipe	-	1.31	2.11
3.2 200 mm diameter steel pipe	-	0.96	-
3.3 250 mm diameter steel pipe	-	1.57	-
3.4 300 mm diameter steel pipe	-	0.78	-
3.5 700 mm diameter steel pipe	0.90	-	-
4.0 Water Treatment Plant	**41.25**	**32.56**	**39.07**
4.1 Civil Works	20.51	19.36	23.23
4.2 Mechanical and Electrical Works	20.74	13.20	15.85
5.0 Treated Water Reservoir	**2.73**	**2.73**	**3.54**
6.0 Treated Water Pump Station	**2.66**	**2.66**	**4.12**
6.1 Civil Works	0.84	0.84	1.05
6.2 Mechanical and Electrical Works	1.82	1.82	3.07
7.0 Treatment Site Plant Development	**2.00**	**2.00**	**2.50**
Sub-total (1)	**58.26**	**51.69**	**57.65**
8.0 Land Acquisition	**6.00**	**6.00**	**7.50**
Sub-total (2)	**64.26**	**57.69**	**65.15**
Physical Contingencies (10%)	6.43	5.77	6.52
Price Contingencies (5%)	3.21	2.88	3.26
TOTAL	**73.90**	**66.34**	**74.93**

In terms of operating and maintenance expenses, Alternative 1 (centralized WTP, surface water intake), would be the lowest, at Php 13.70 million per year. For this alternative, there is minimal raw water pumping costs since the intake head would not be more than 10 meters, as compared to shallow well pumping head at 30 meters and more.

Table 3 - 8 Annual Operating and Maintenance Costs (in constant 2007 prices)

Items	Alternative 1	Alternative 2	Alternative 3
1.0 Raw Water Pumping	**2.84**	**7.10**	**6.39**
2.0 Treatment Systems	**5.20**	**3.87**	**4.26**
2.1 Energy	4.38	3.21	3.53
2.2 Chemicals	0.82	0.66	0.72
3.0 Maintenance	**0.30**	**0.25**	**0.30**
4.0 Personnel	**1.10**	**1.10**	**1.50**
5.0 Treated Water Pumping	**4.26**	**4.26**	**4.26**
TOTAL	**13.70**	**16.58**	**16.71**

3.6 NPV Analysis

At a discount rate of 10%, Alternative 1 (centralized WTP, surface water intake) is shown to be the least-cost among the three (3) alternatives, with a NPV of Php 338 million. While the capital costs of Alternative 1 is the higher than Alternative 2 (centralized WTP, shallow wells source), the lower operating costs of the alternative more than offsets the higher capital costs.

The NPV of Alternative 2 is computed at Php 389 million, or 15% higher than Alternative 1. For Alternative 3, NPV is at Php 399 million, or 18% higher than Alternative 1.

Table 3 - 9 NPV Analyses

Year	Alternative 1		Alternative 2		Alternative 3	
	Capex	Opex	Capex	Opex	Capex	Opex
2008	36.95		33.17		37.465	
2009	36.95		33.17		37.465	
2010		13.7		16.58		16.71
2011		13.7		16.58		16.71
2012		13.7		16.58		16.71
2013		13.7		16.58		16.71
2014		13.7		16.58		16.71
2015		13.7		16.58		16.71
2016		13.7		16.58		16.71
2017		13.7		16.58		16.71
2018		13.7		16.58		16.71
2019		13.7		16.58		16.71
2020		13.7		16.58		16.71
2021		13.7		16.58		16.71
2022		13.7		16.58		16.71
2023		13.7		16.58		16.71
2024		13.7		16.58		16.71
2025		13.7		16.58		16.71
2026		13.7		16.58		16.71
2027		13.7		16.58		16.71
2028		13.7		16.58		16.71
2029		13.7		16.58		16.71
NPV	64.13	274.00	57.57	331.60	65.02	334.20
@10%		**338.13**		**389.17**		**399.22**

CHAPTER 4. SUMMARY OF FINDINGS AND FINAL RECOMMENDATIONS

Data on water quality of Pampanga River show high concentrations of iron. This will require removal through oxidation and filtration processes. Based on limited data from an existing CCWD well (Sumacab), shallow wells apparently produce better quality water. However, water that will be produced from the proposed shallow wells essentially originates from the Pampanga River, and therefore, there is a risk that the water pumped out will also have high iron content, and maybe, even high manganese levels. The water treatment for either source therefore must include provisions for iron and manganese removal.

The water data available is limited, thus CCWD is advised to continue undertaking water monitoring tests for Pampanga River and to develop a new test shallow well along the bank of Pampanga River, which should give not only additional water quality data, but also gauge the safe yield of similar wells.

Regardless of the water source, whether directly from Pampanga River or from shallow wells along the bank of Pampanga River, the recommended treatment process is oxidation with chlorine, followed by coagulation, flocculation, and sedimentation, filtration, and finally, disinfection by chlorine. However, coagulation, flocculation and sedimentation facilities for a system fed by shallow wells can be smaller considering the expected better water quality.

For filtration, rapid sand filters are reliable and easy to maintain, but for decentralized systems, pressure filters can be considered. Another option is membrane systems, which have been shown to be effective treatment systems. However, the issue with the membrane system is the cost of the membrane itself, and the higher energy cost of operation. While membrane prices have gone down, a detailed comparison of membrane systems should be made with conventional filter systems, either by: small-scale pilot-testing of membrane systems, or by bidding the water treatment plant through a design-build scheme, applying performance specifications with an extended guarantee period.

A centralized WTP is shown to be less expensive, largely due to economies of scale. Also, a WTP will be slightly less expensive and cheaper to operate if the source of water comes from the proposed shallow wells. NPV analysis show that Alternative 1 (centralized WTP, surface water source) has the least-cost. The other alternatives are more expensive, costs are higher by 15-18%.

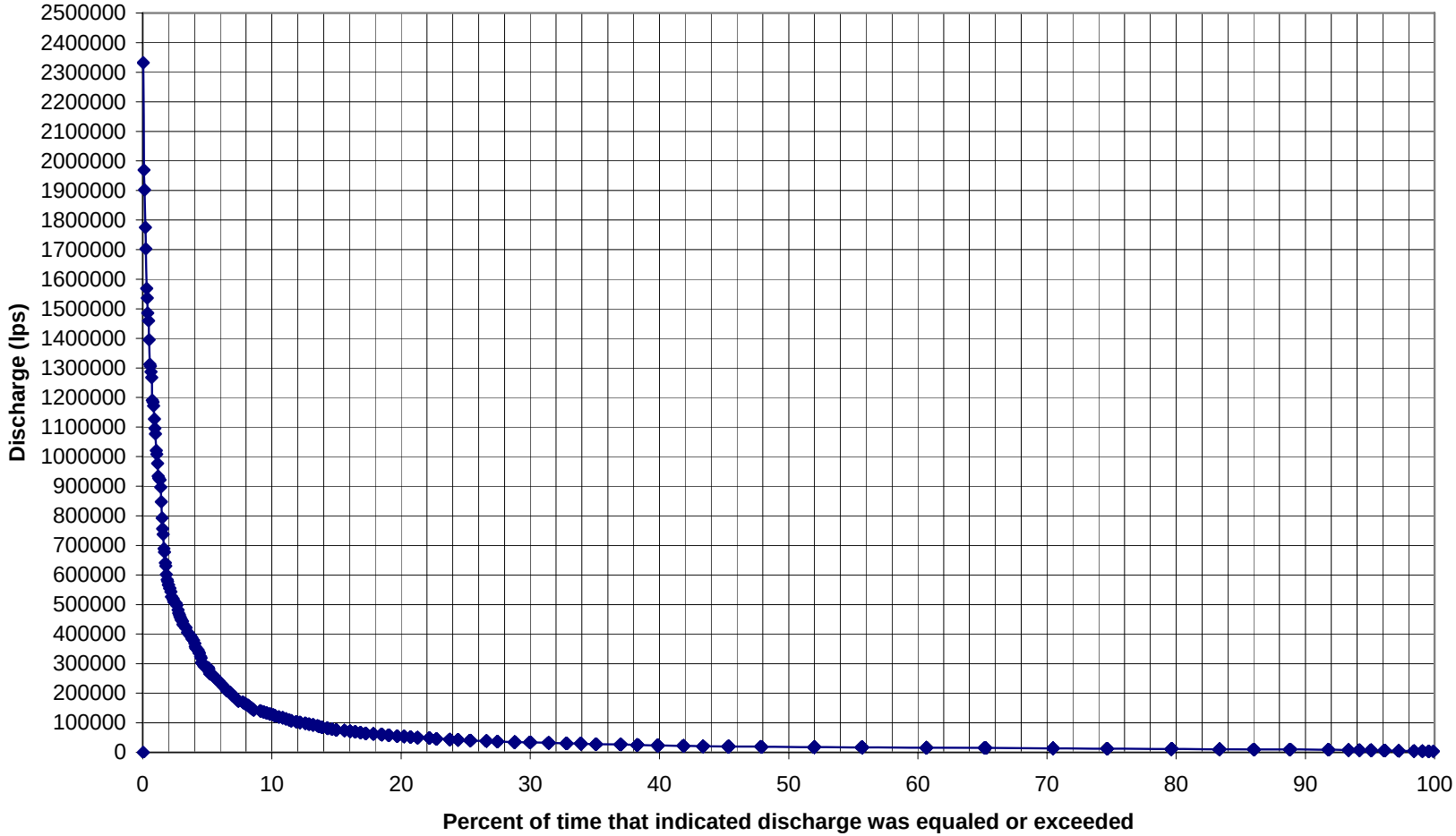
In summary, the recommendations under this study for developing new water sources from Pampanga River are:

1. Install test shallow wells along Pampanga River and assess the safe yield from these wells.
2. Continue monitoring water quality of Pampanga River and from the new shallow wells.

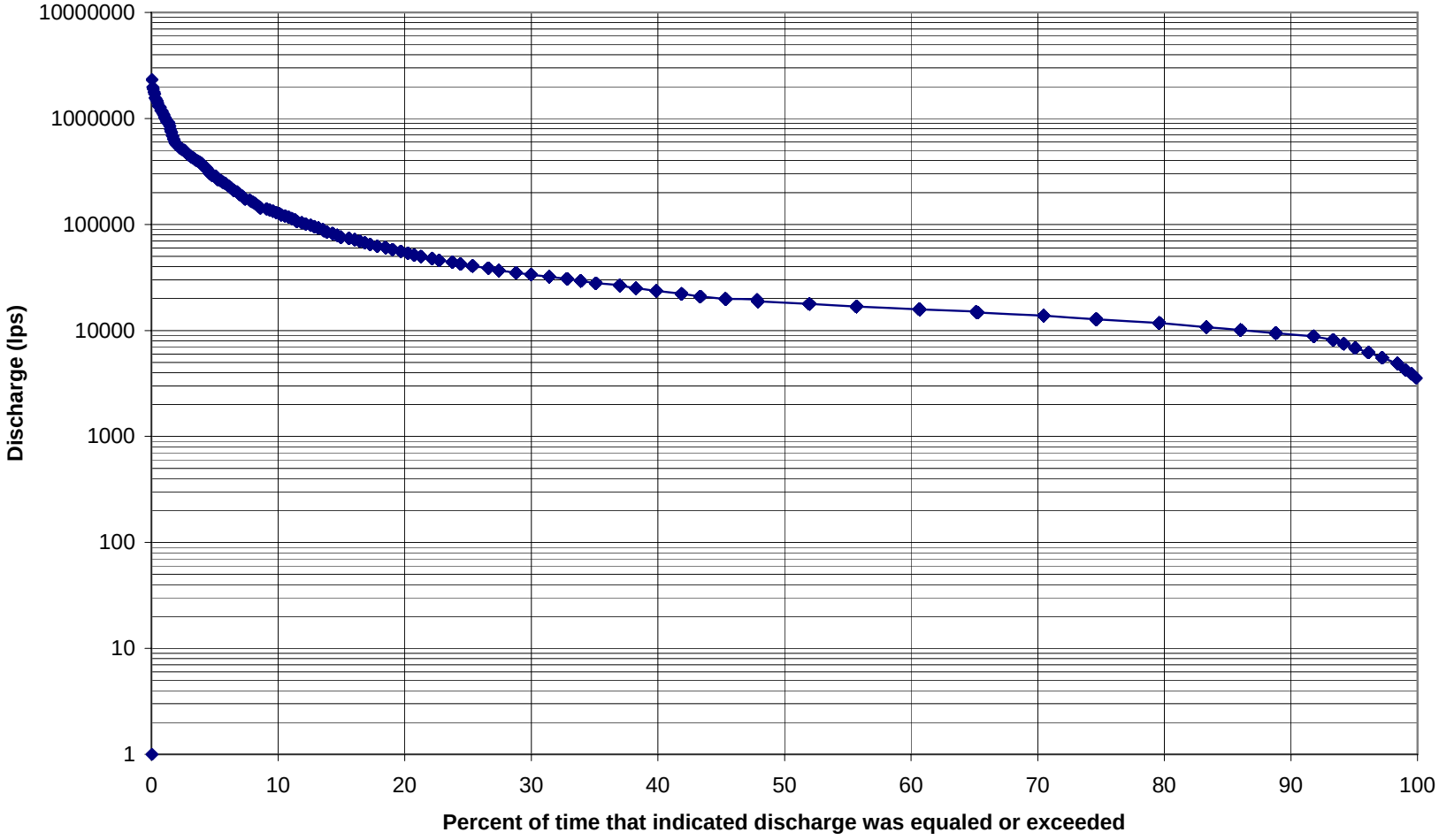
3. After a certain period of monitoring water quality, conduct more detailed appraisal of treatment options, through detailed vendor product appraisal or pilot-testing of specific systems.
4. An alternative for the above (Item 3) is to pursue a design-build tender, with set performance specifications and an extended commissioning/guarantee period, say 2 and 5 years, respectively. The performance specifications will include the general treatment processes based on the extended set of water quality data.

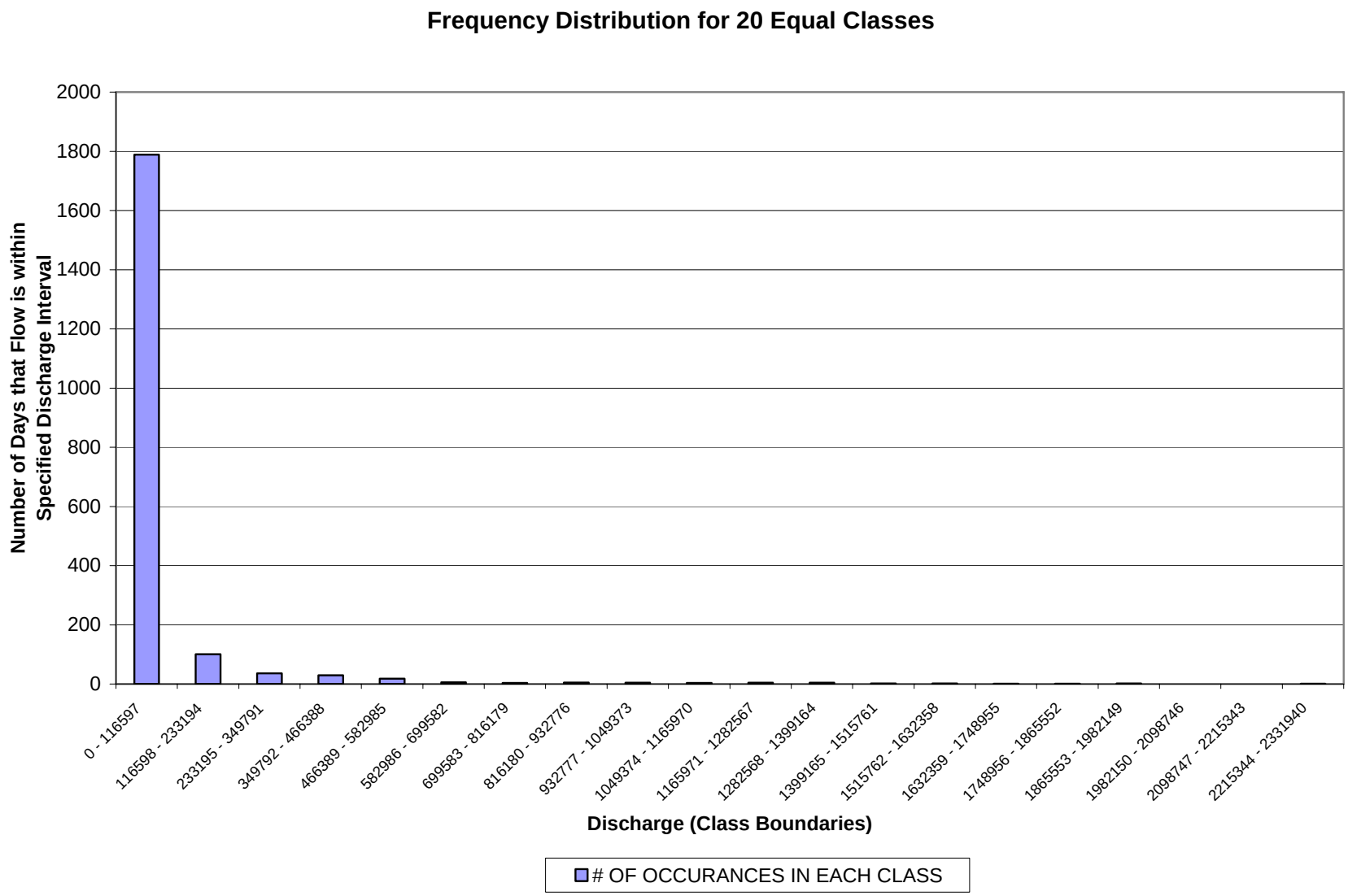
APPENDIX 1. FLOW DURATION ANALYSIS OF THE PAMPANGA RIVER

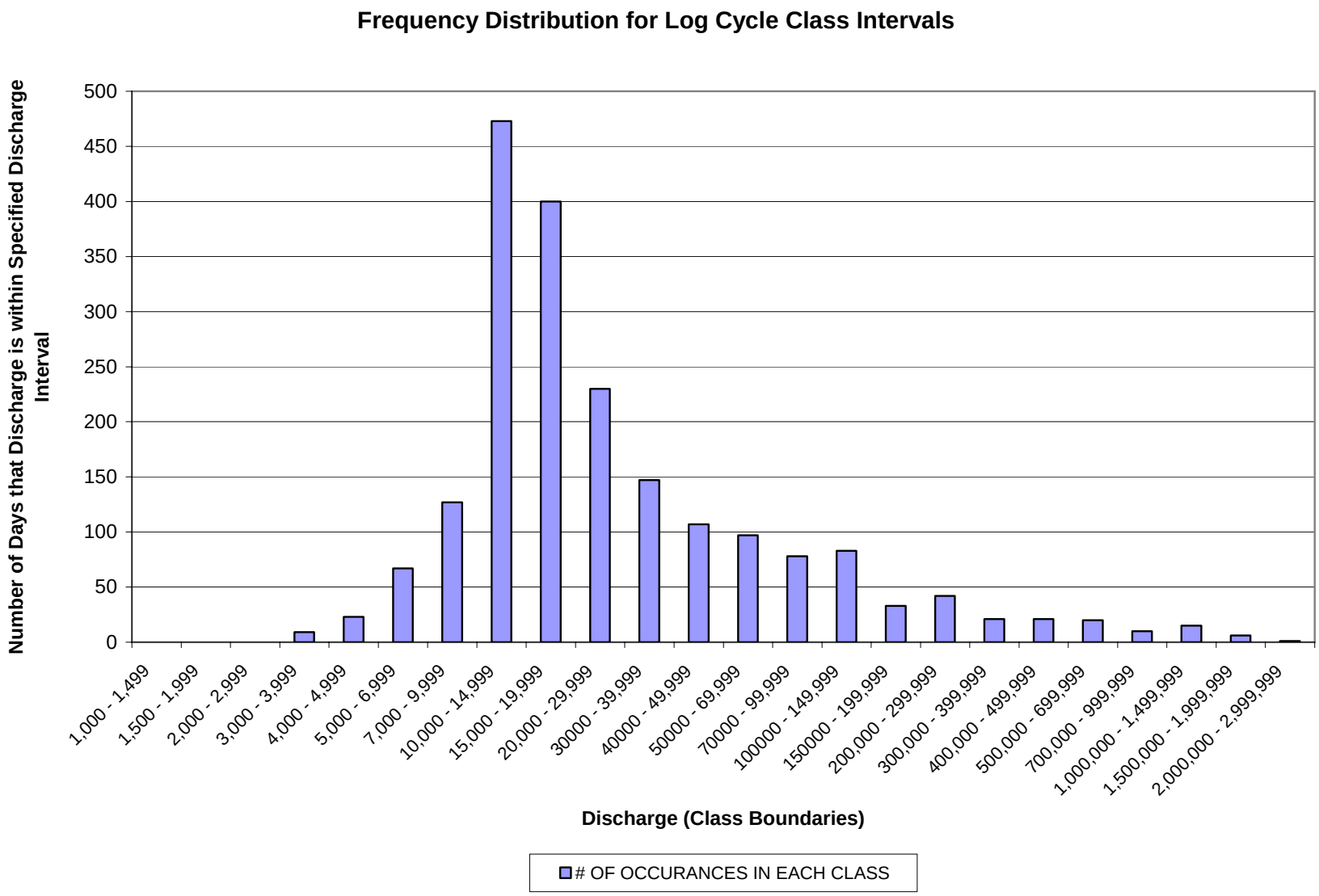
Flow Duration Curve for Pampanga River at Valdefuente Cabanatuan City(1982-1987)

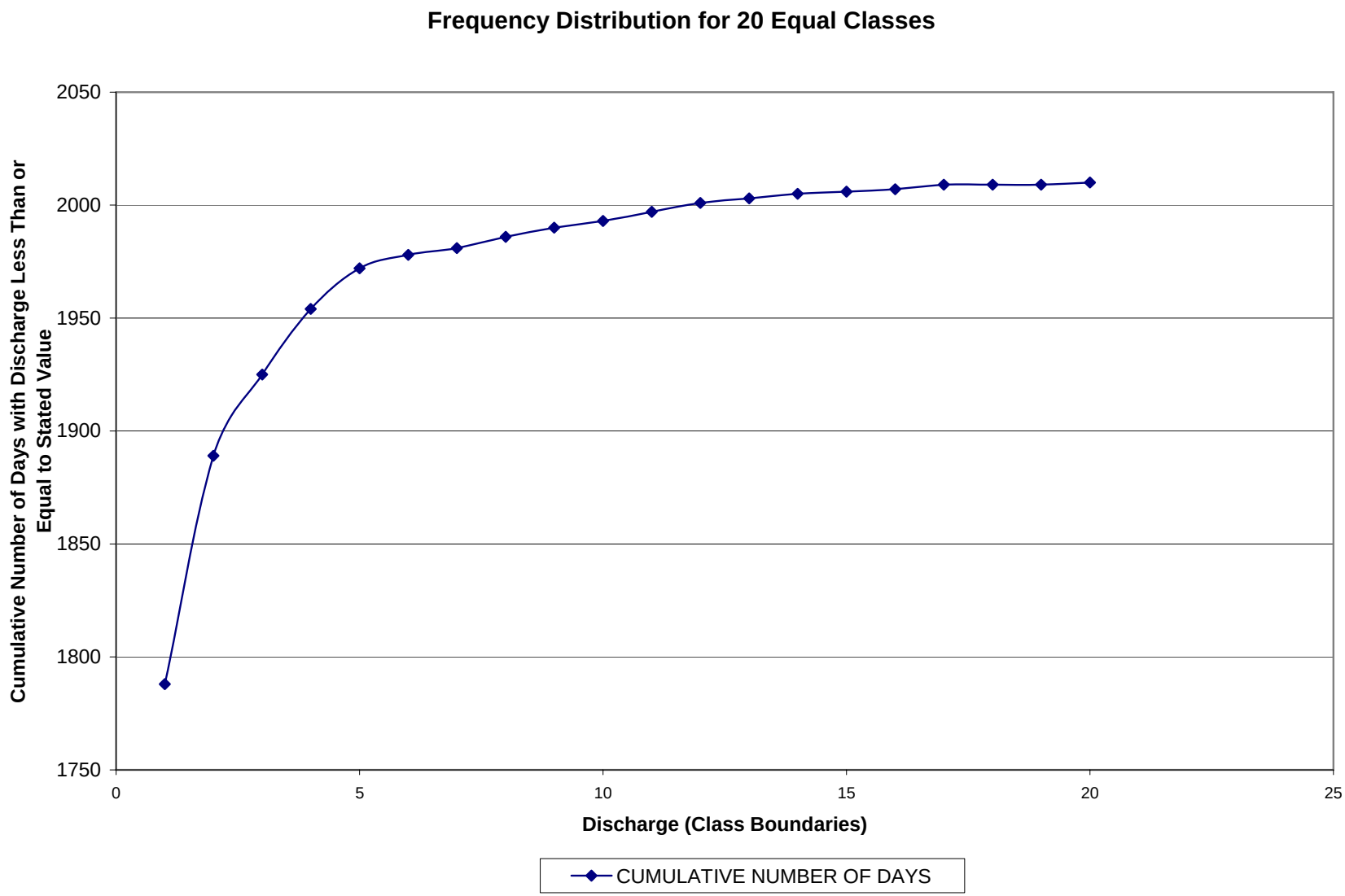


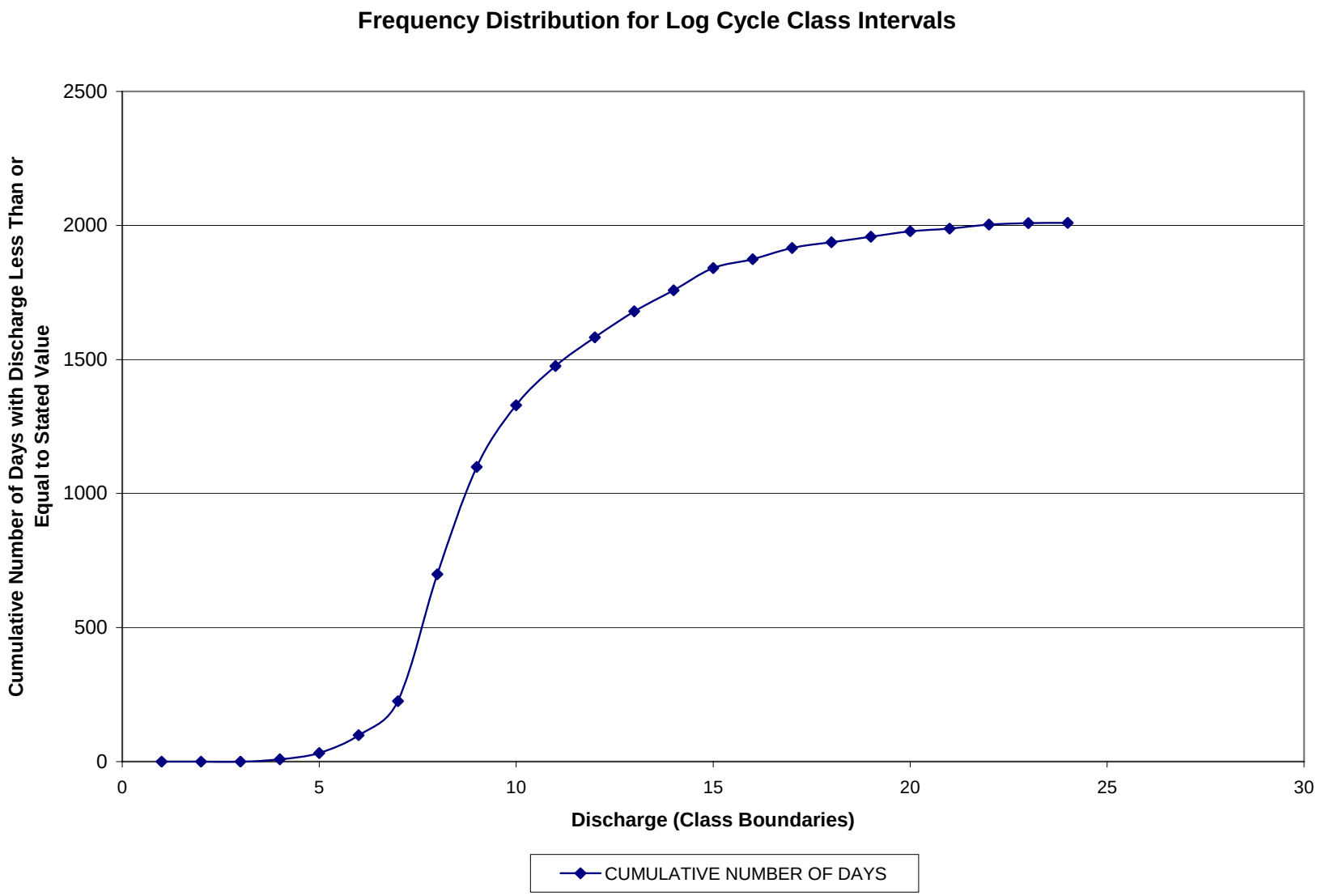
Flow Duration Curve (Log Intervals) for Pampanga River at Valdefuente Cabanatuan City (1982-1987)



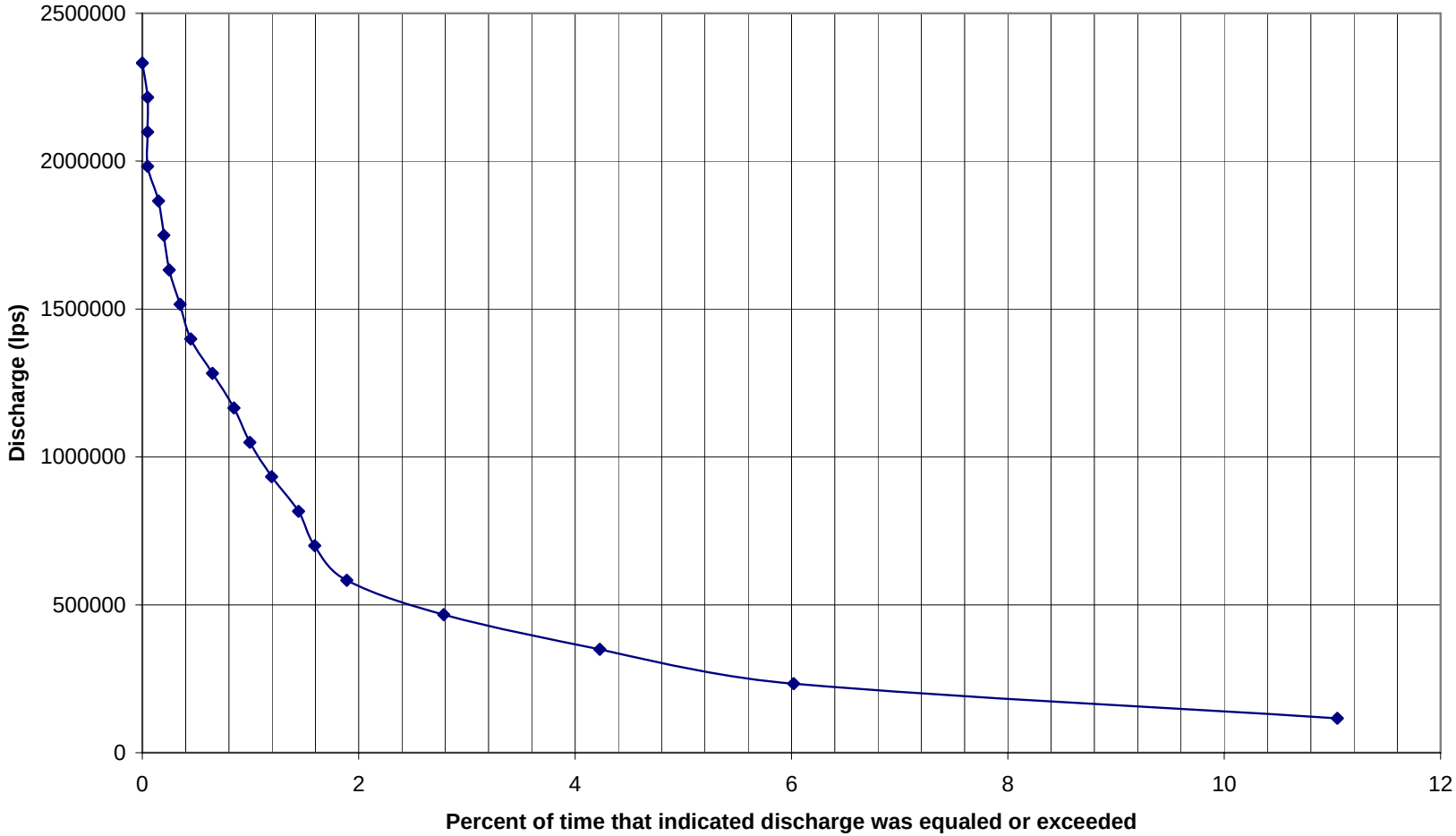

Frequency Distribution for 20 Equal Classes
Number of Days that Flow is within Specified Discharge Interval
2000
1800
1600
1400
1200
1000
800
600
400
200
0
0 - 116597
116598 - 233194
233195 - 349791
349792 - 466388
466389 - 582985
582986 - 699582
699583 - 816179
816180 - 932776
932777 - 1049373
1049374 - 1165970
1165971 - 1282567
1282568 - 1399164
1399165 - 1515761
1515762 - 1632358
1632359 - 1748955
1748956 - 1865552
1865553 - 1982149
1982150 - 2098746
2098747 - 2215343
2215344 - 2331940
Discharge (Class Boundaries)
OF OCCURANCES IN EACH CLASS


Frequency Distribution for Log Cycle Class Intervals
Number of Days that Discharge is within Specified Discharge Interval
500
450
400
350
300
250
200
150
100
50
0
1,000 - 1,499
1,500 - 1,999
2,000 - 2,999
3,000 - 3,999
4,000 - 4,999
5,000 - 6,999
7,000 - 9,999
10,000 - 14,999
15,000 - 19,999
20,000 - 29,999
30000 - 39,999
40000 - 49,999
50000 - 69,999
70000 - 99,999
100000 - 149,999
150000 - 199,999
200,000 - 299,999
300,000 - 399,999
400,000 - 499,999
500,000 - 699,999
700,000 - 999,999
1,000,000 - 1,499,999
1,500,000 - 1,999,999
2,000,000 - 2,999,999
Discharge (Class Boundaries)
OF OCCURANCES IN EACH CLASS

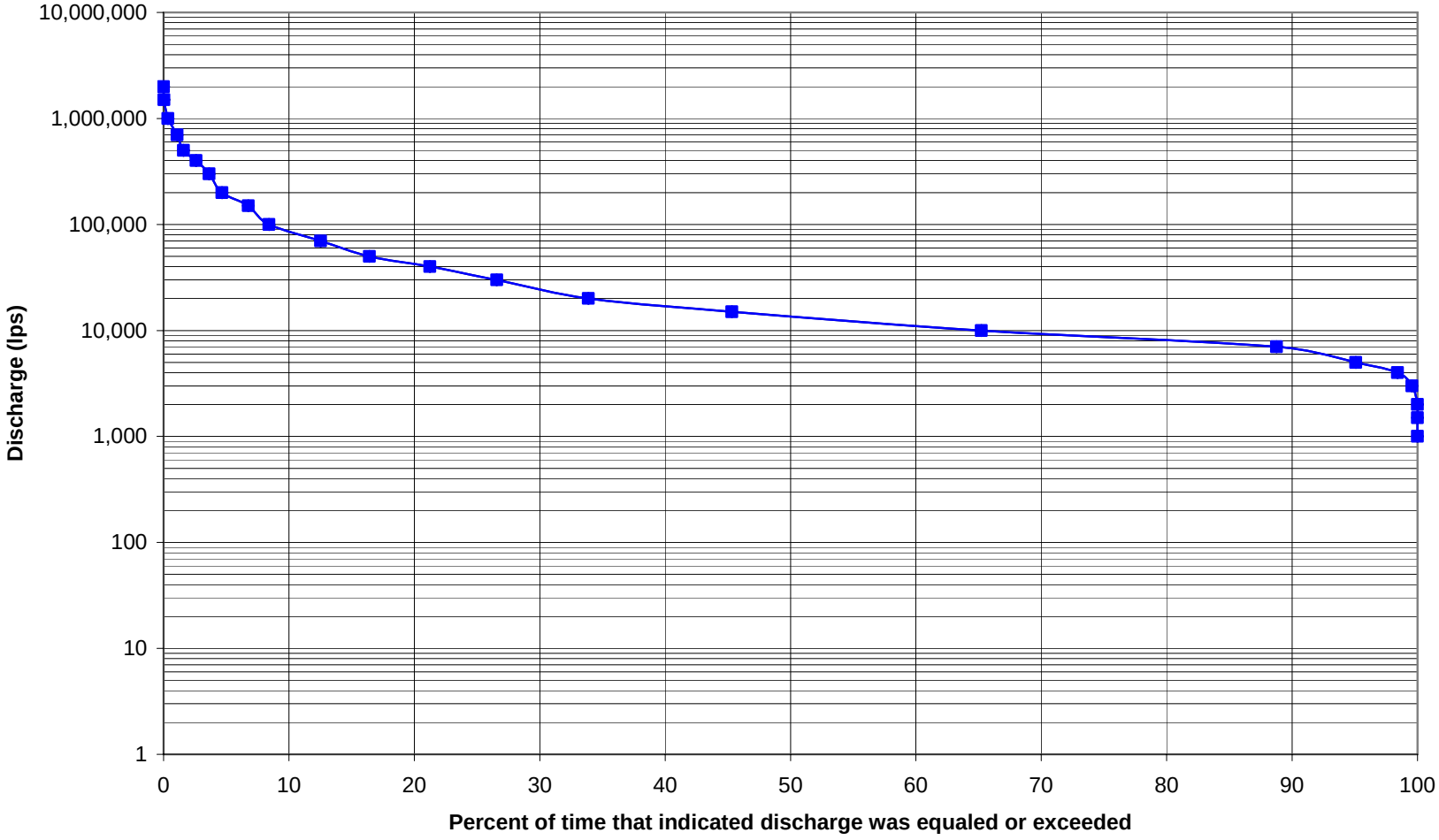

Frequency Distribution for 20 Equal Classes
Cumulative Number of Days with Discharge Less Than or Equal to Stated Value
2050
2000
1950
1900
1850
1800
1750
0
5
10
15
20
25
Discharge (Class Boundaries)
CUMULATIVE NUMBER OF DAYS


Frequency Distribution for Log Cycle Class Intervals
Cumulative Number of Days with Discharge Less Than or Equal to Stated Value
2500
2000
1500
1000
500
0
0
5
10
15
20
25
30
Discharge (Class Boundaries)
CUMULATIVE NUMBER OF DAYS

Flow Duration Curve (20 Equal Intervals) for Pampanga River at Valdefuente Cabanatuan City (1982-1987)

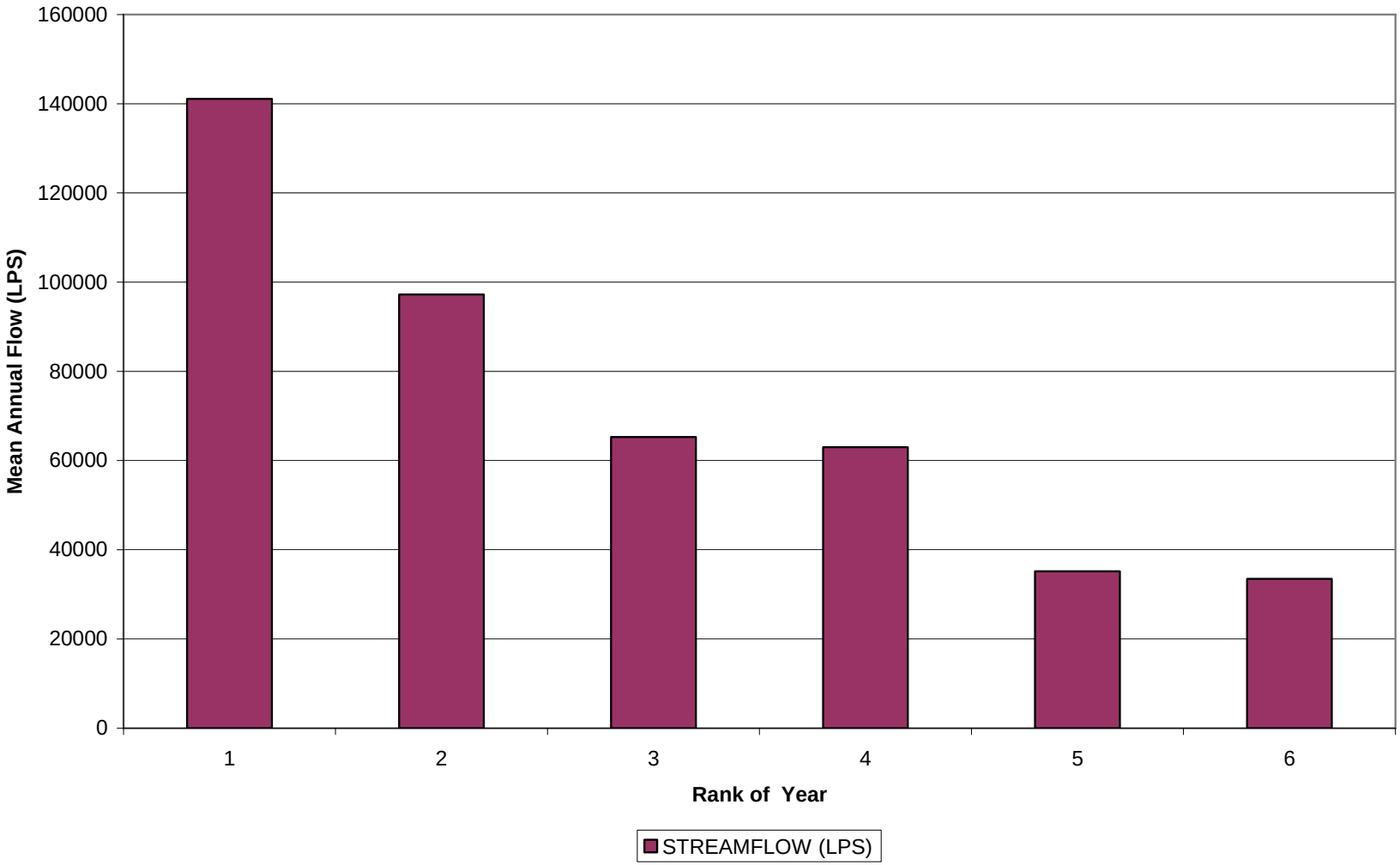


Flow Duration Curve (Log Intervals) for Pampanga River at Valdefeunte Cabanatuan City (1982-1987)

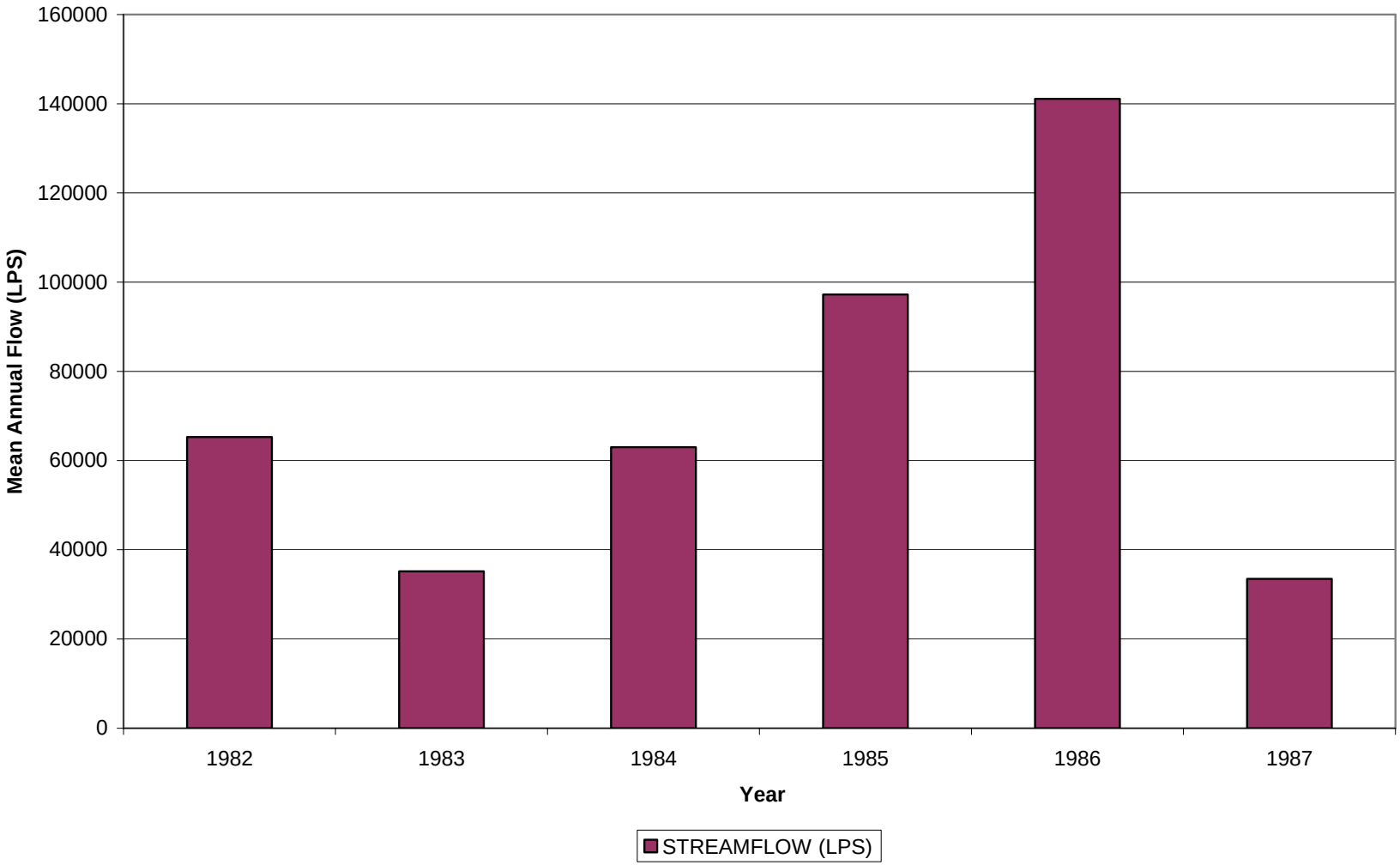


APPENDIX 2. ANNUAL FLOW ANALYSIS OF THE PAMPANGA RIVER

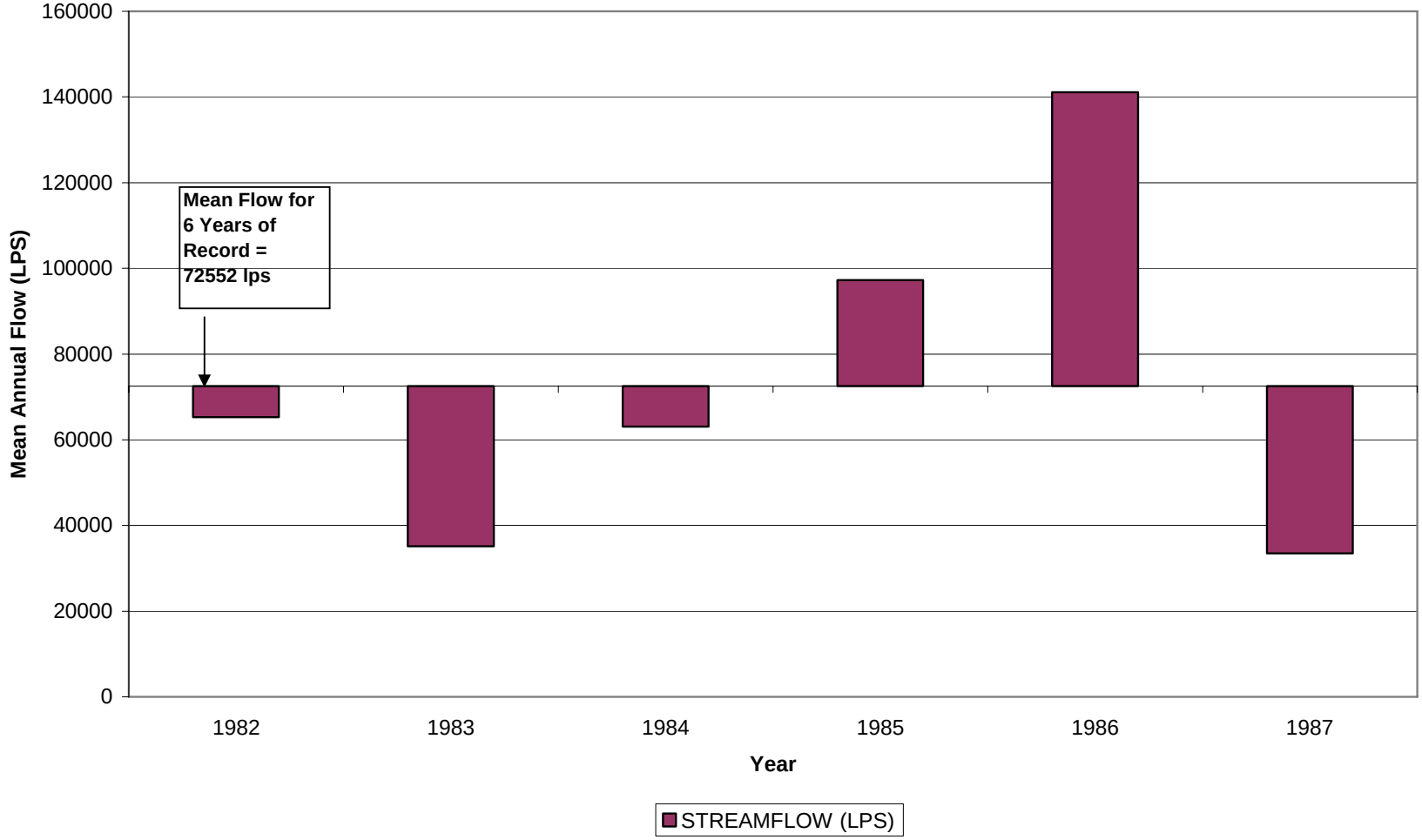
Ranked Mean Annual Flow, Pampanga River at Valdefuente Cabanatuan City (1982-1987)



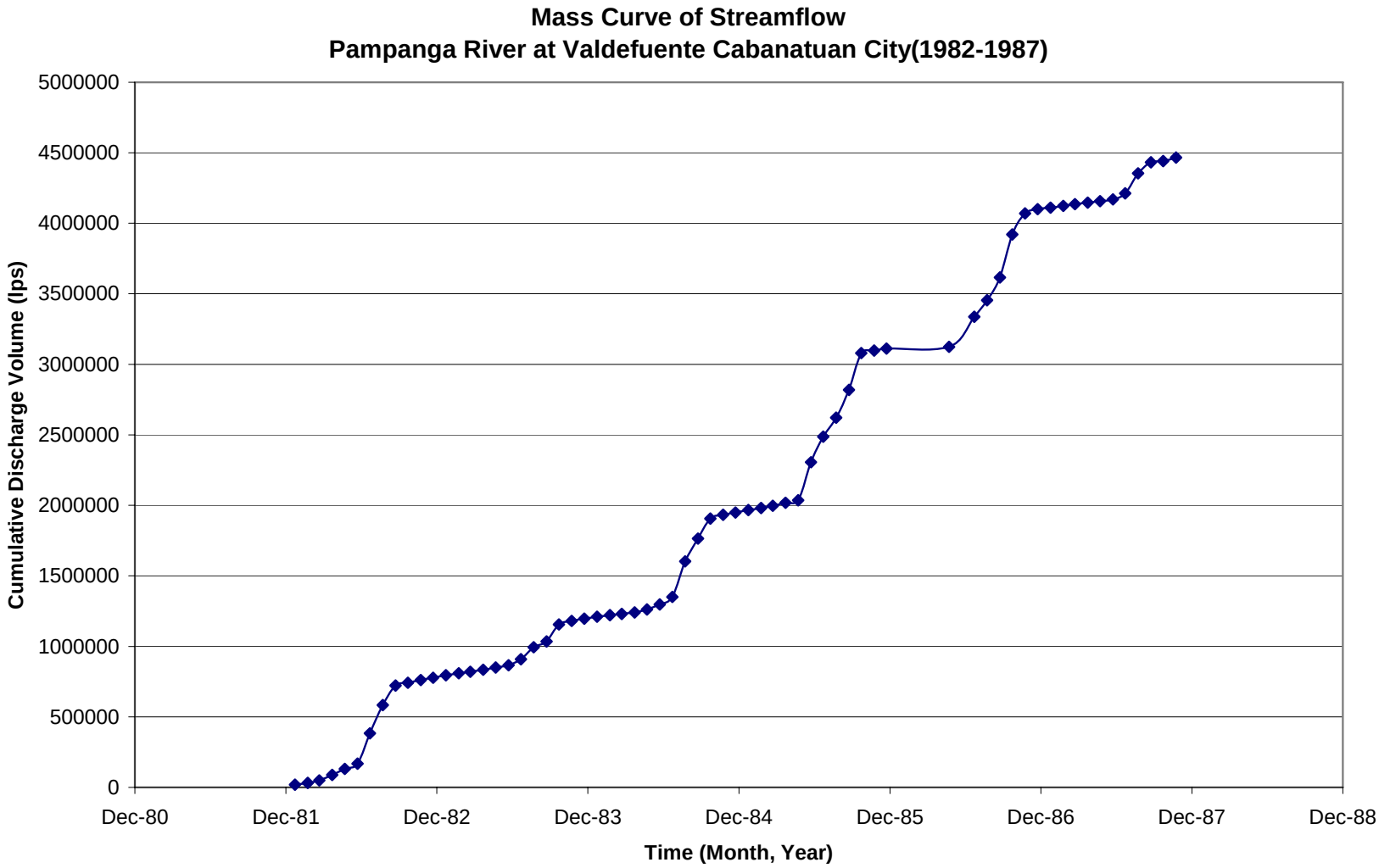
Mean Annual Flow, Pampanga River at Valdefuente Cabanatuan City (1982-1987)



Variation of Mean Annual Flow around Mean Flow for Period of Record, Pampanga River at Valdefuente Cabanatuan City(1982-1987)



Mean Annual Flow, 3-Year Moving Mean, 5-Year Moving Mean
Pampanga River at Valdefuente Cabanatuan City (1982-1987)


Mass Curve of Streamflow
Pampanga River at Valdefuente Cabanatuan City(1982-1987)
Cumulative Discharge Volume (lps)
5000000
4500000
4000000
3500000
3000000
2500000
2000000
1500000
1000000
500000
0
Dec-80
Dec-81
Dec-82
Dec-83
Dec-84
Dec-85
Dec-86
Dec-87
Dec-88
Time (Month, Year)

Station Description

STATION.--Valdefuente Cabanatuan City

LOCATION.--Lat 15°31'00", long 120°57'14",
Located downstream from the confluence of the Pampanga River and Dalampang Creek at Valdefuente Bridge, Cabanatuan City

DRAINAGE AREA.--2441 km^2.

PERIOD OF RECORD.--Jan 1982 to Nov 1987.

GAGE.--Staff Gage read three times a day. Elevation of zero gage is 23.066 meters above mean sea level

REMARKS.--Records are fair
1986 record are incomplete. NO record from Jan 1986-April 1986, June 1986

AVERAGE DISCHARGE.--6 yrs 64,000 second-liters

EXTREMES FOR PERIOD OF RECORD.--Maximum discharge, 2331940 lps Oct 19,1985, gage height, 5.71 m ft; minimum discharge,3560 lps Oct 27, Nov 9, 1987.

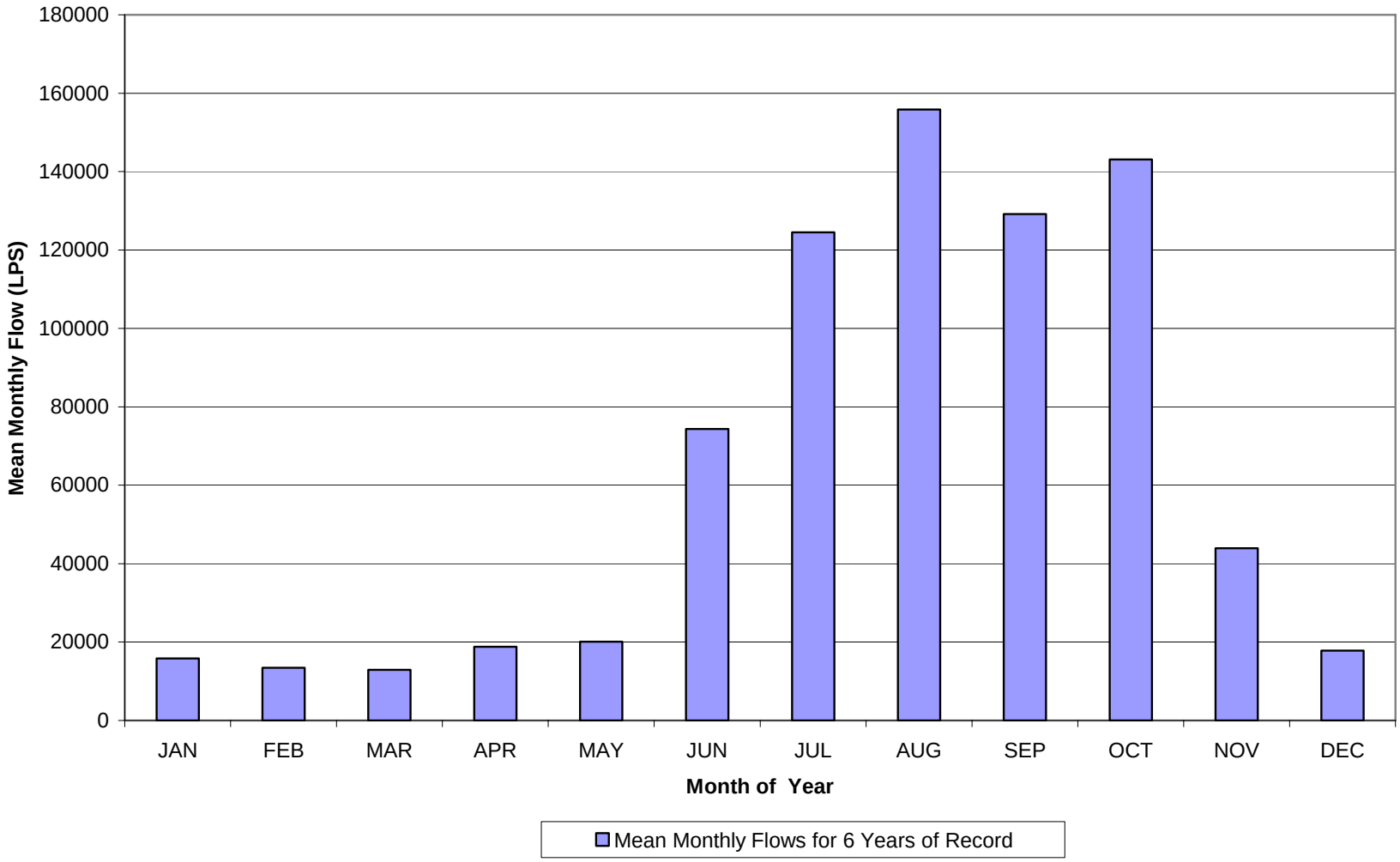
$$\text{Discharge per Unit Area} = \frac{\text{Mean Flow for 10 Years of Record}}{\text{Drainage Area for Gaging Station}}$$

$$\text{Discharge per Unit Area for Alsea River at Tidewater} = \frac{72552 \text{ lps}}{2441 \text{ sq km}}$$

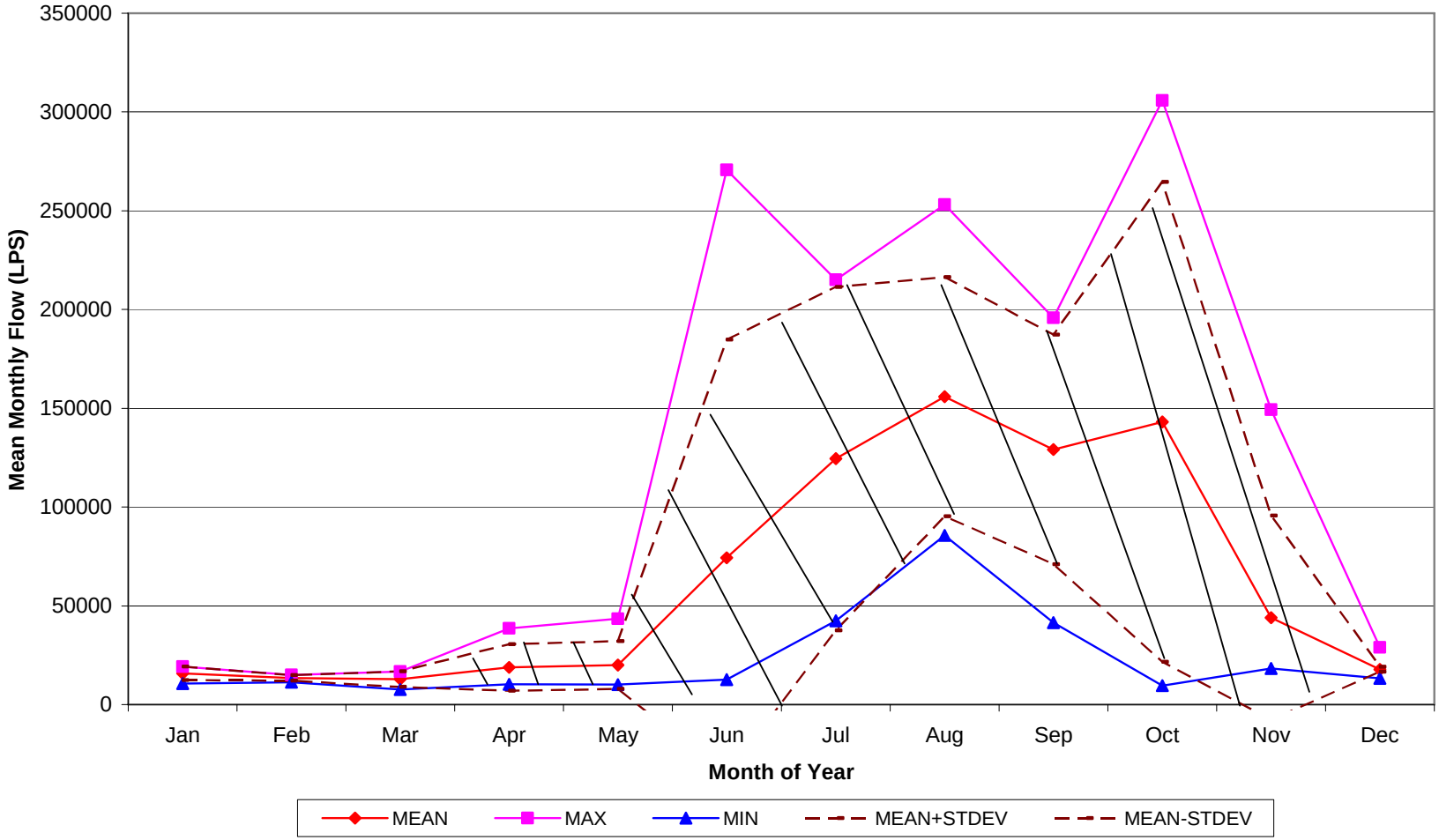
Discharge per Unit Area = 29.7 lps/ km^2
for Pampanga River at Valdefuente Cabanatuan City

APPENDIX 3. MONTHLY ANALYSIS OF THE PAMPANGA RIVER

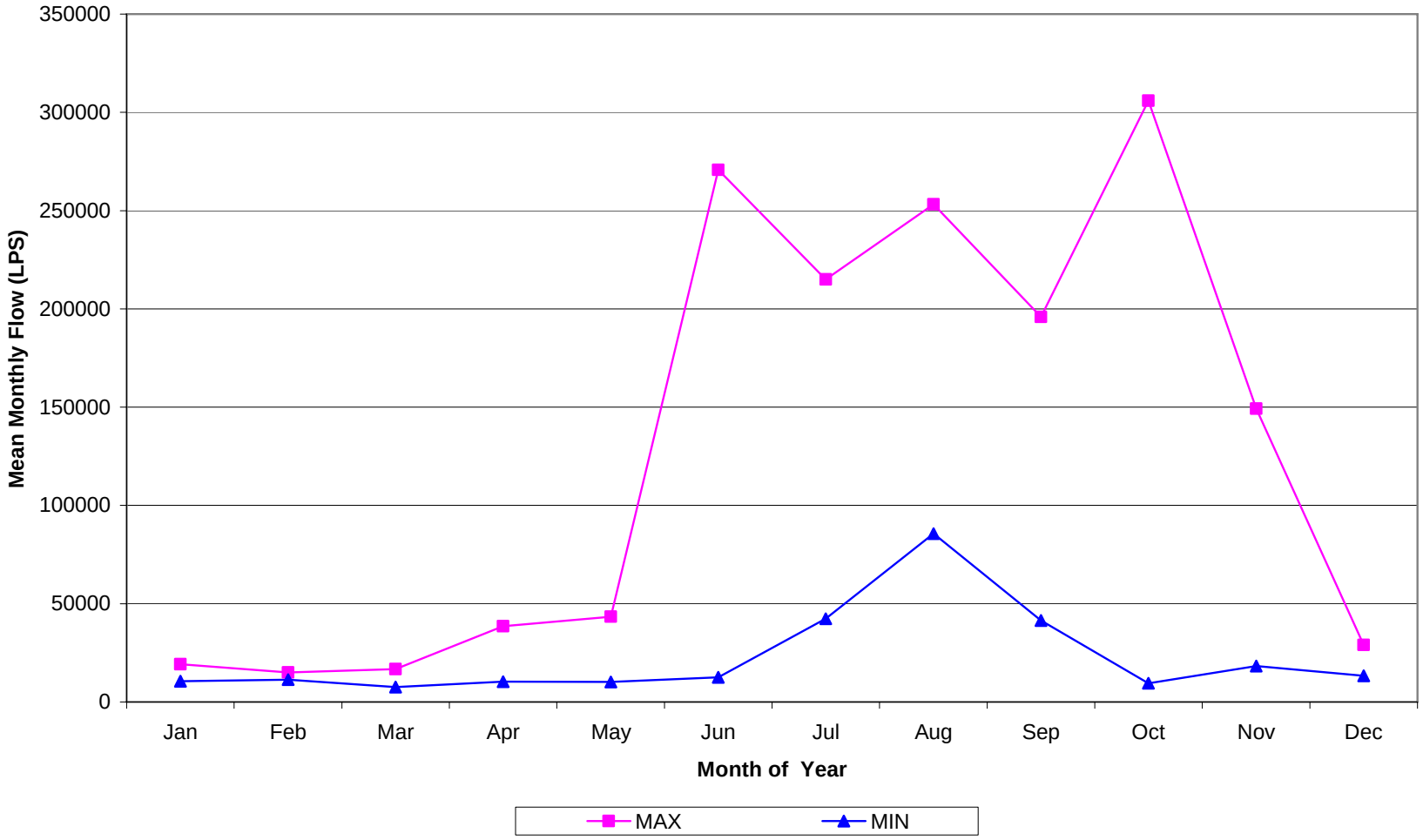
Mean Monthly Flows (LPS), Pampanga River at Valdefuente Cabanatuan City (1982-1987)



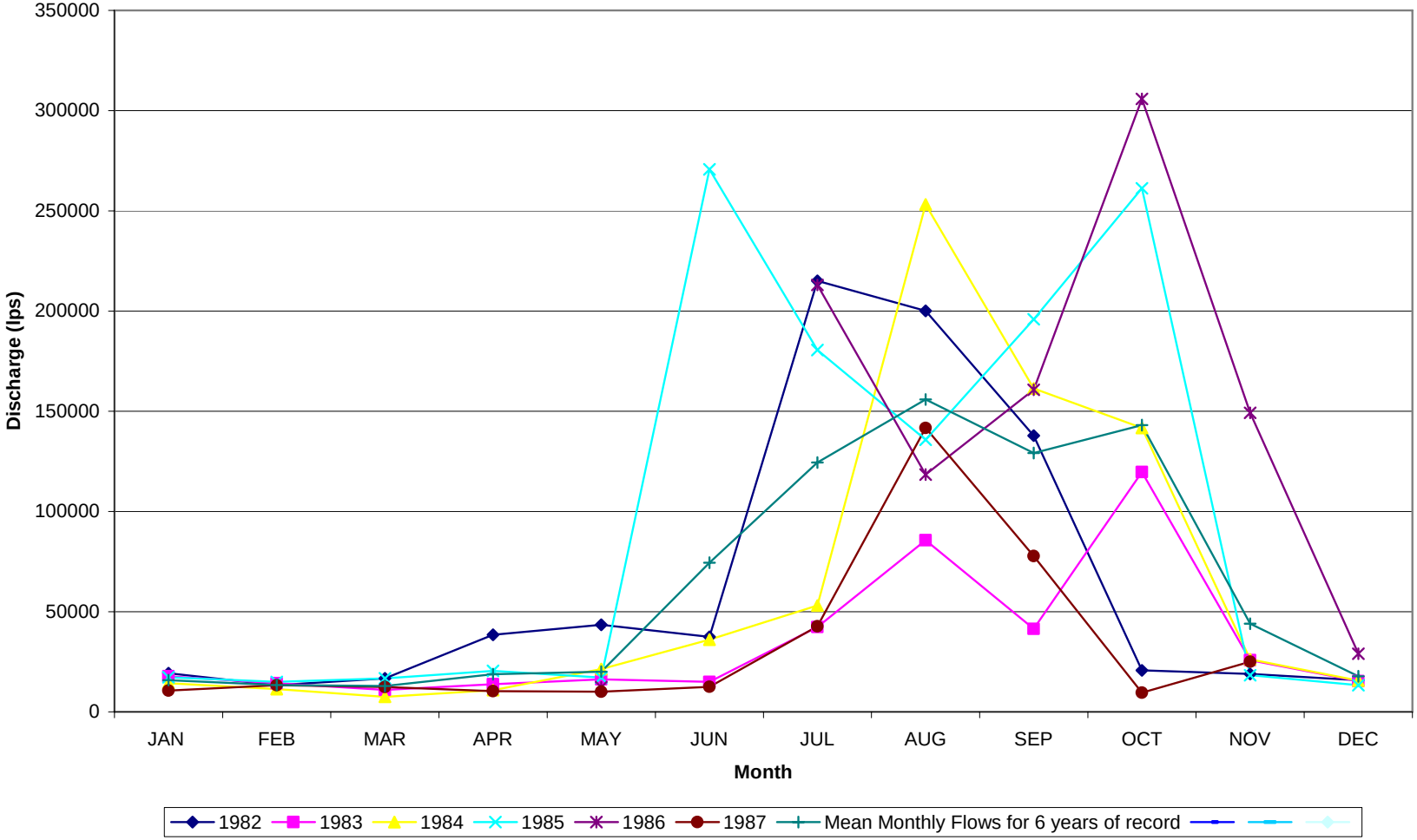
Mean, Max, Min and One Standard Deviation values of Mean Monthly Flow Data, Pampanga River at Valdefuente Cabanatuan City (1982-1987)



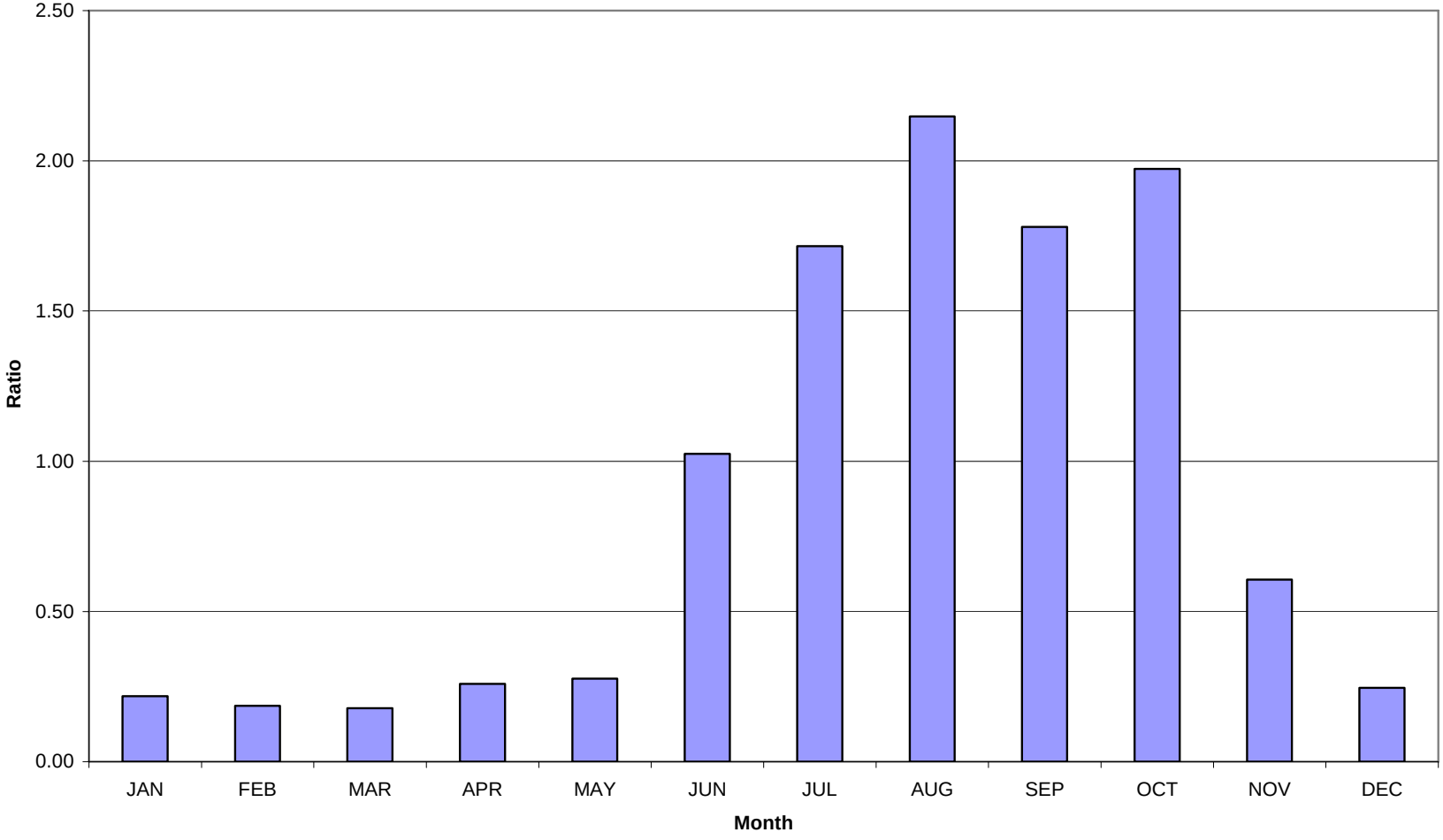
Maximum and Minimum values of Mean Monthly Flow Data, Pampanga River at Valdefuente Cabanatuan City (1982-1987)



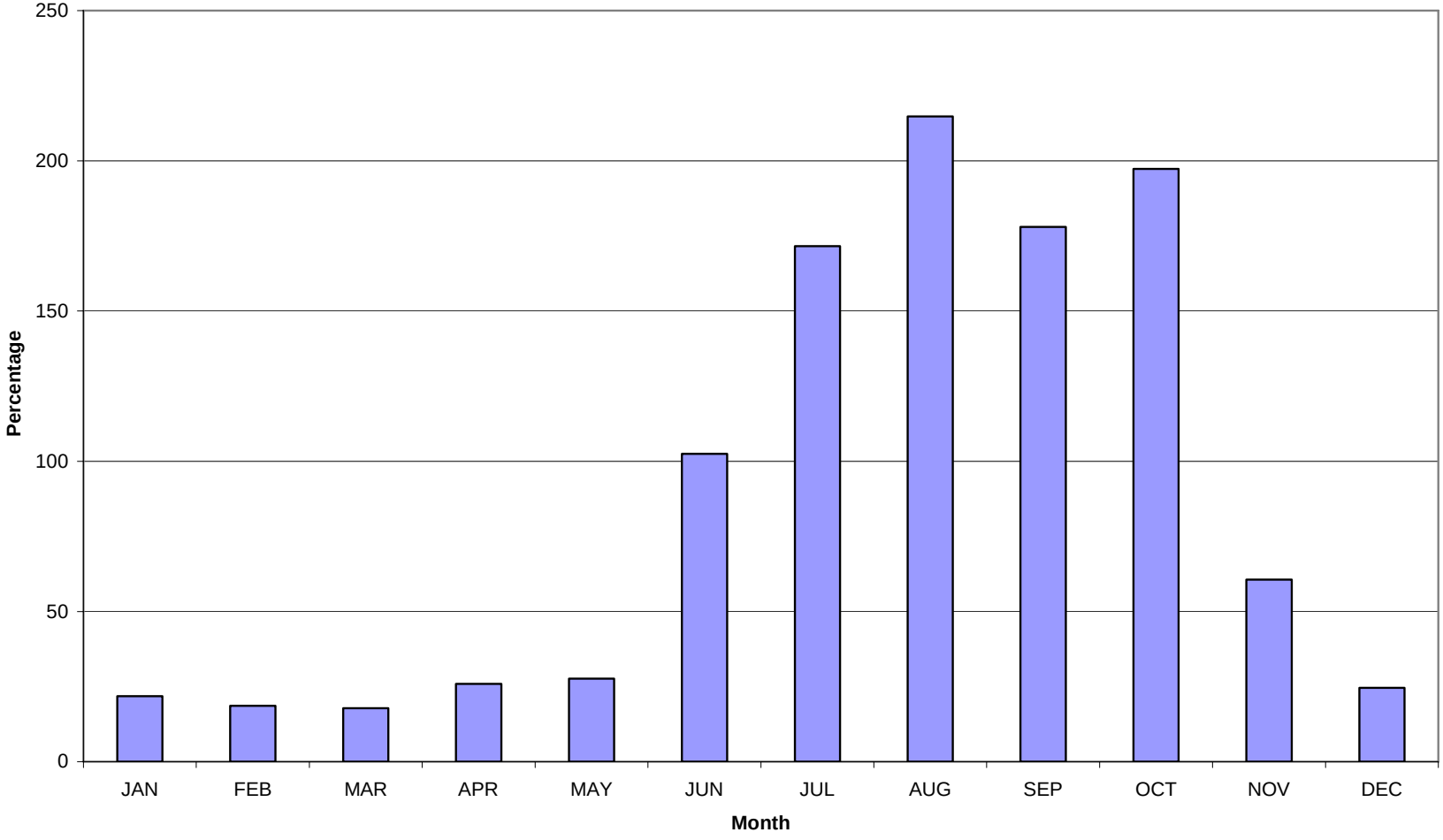
Mean Monthly Values for Various Years,
Pampanga River at Valdefuente Cabanatuan City(1982-1987)



Mean Monthly Flow as Ratio of Mean Annual Flow
Pampanga River at Valdefuente Cabanatuan City (1982-1987)



Mean Monthly Flow as Percentage of Mean Annual Flow
Pampanga River at Valdefuente Cabanatuan City (1982-1987)



APPENDIX 4. STREAMFLOW DATA FOR THE PAMPANGA RIVER (1982-1987)

PAMPANGA RIVER BASIN
PAMPANGA RIVER
VALDEFUENTE, CABANATUAN CITY

LOCATION: Latitude 15-31-00 Longitude 120-57-14
Located downstream from the confluence of the Pampanga River and Dalampang Creek at Valdefuente Bridge, Cabanatuan City.

DRAINAGE AREA: 2441 sq. km.

RECORDS AVAILABLE: January 1, 1982 to December 31, 1982

GAGE: Staff gage read three times a day. Elevation of zero gage is 23.088 meters above Mean Sea Level

AVERAGE DISCH.: 1982; 1yr, 64740 second-liters

STATION ID.:

EXTREMES:

Maximum discharge during year,		2628140	liters/sec
July 18	gage height,	5.02	m
Minimum discharge,		6190	liters/sec,
December 11	gage height,	0.33	m

REMARKS: Records are fair.

1982 MEAN DISCHARGE (liters/sec)

DAY	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC
1	12760	15790	13770	18800	36780	33530	45980	143880	297840	27890	14780	14780
2	14780	14780	14780	15790	36780	34940	38820	110340	282440	25070	12760	12760
3	17810	17810	23660	18820	44140	32120	45980	191240	282440	18820	18800	19830
4	15790	18800	18820	18800	38620	44140	42300	101080	231560	17810	25070	18820
5	15790	14780	17810	18800	34940	49660	51500	543240	113590	30710	18820	15790
6	14780	13770	18820	19830	32120	40460	42300	432840	92800	25070	18800	12760
7	18820	13770	18820	17810	26480	33530	36780	526240	64790	19830	14780	9440
8	17810	12760	18800	18820	40460	29300	40460	601240	42300	18820	12760	8140
9	14780	12760	16800	17810	38620	25070	47820	303240	27890	22250	12760	7490
10	30710	12760	15790	27890	34940	19830	303240	188500	583840	18820	13770	6840
11	19830	12760	14780	29300	36780	17810	133090	129840	351840	16800	15790	6190
12	18820	11750	14780	27890	64790	25070	67080	76240	136340	15790	16800	10740
13	16800	10090	13770	62500	51500	25070	57920	92800	81760	18800	15790	11750
14	18820	11750	17810	45980	44140	47820	92800	84520	49660	17810	12760	10090
15	26480	12760	16800	67080	42300	42300	221860	71680	27890	18820	12760	12760
16	20840	10740	19830	47820	45980	34940	1988640	73950	485240	19830	26480	26480
17	18820	10740	17810	40460	45980	47820	357240	56830	341040	19830	30710	22250
18	36780	10740	15790	62500	51500	53340	129840	51500	49660	17810	23660	18820
19	32120	10090	14780	44140	69370	40460	81760	42300	33530	17810	18820	19830
20	23660	10090	16800	49660	80210	29300	62500	27890	22250	18820	16800	42300
21	20840	9440	16800	45980	40460	29300	405840	400440	47820	20840	17810	27890
22	18820	9440	15790	53340	45980	30710	481440	319440	30710	80210	14780	20840
23	18820	20840	14780	49660	32120	38620	515840	265440	20840	23660	32120	17810
24	17810	16800	15790	45980	32120	62500	526240	140110	33530	18820	20840	15790
25	15790	15790	16800	62500	53340	45980	265440	123340	84790	17810	16800	11750
26	16800	15790	19830	57920	67080	33530	103840	84520	49660	18820	20840	17810
27	16800	14780	16800	49660	49660	33530	55630	191240	136340	14780	40460	15790
28	16800	13770	17810	45980	32120	33530	84520	129840	103840	14780	23660	18800
29	16860		15790	42300	45980	57920	120090	208440	27890	16800	16800	14780
30	15790		13770	38620	40460	51500	120090	212740	19830	14780	15790	12760
31	15790		16800		32120		120090	303240		13770		11750
Total	597860	373940	519580	1156440	1347870	1123630	6666190	6204960	4133950	640280	589370	491630
Mean	19279	13355	16761	38548	43480	37454	215038	200160	137798	20654	18979	15859
Li/sec/sq.km	7.90	5.47	6.87	15.79	17.81	15.34	88.09	82.00	56.45	8.46	7.78	6.50
Runoff,mm	21.15	13.24	18.39	40.93	47.71	39.77	235.95	219.63	146.32	22.66	20.15	17.40
Vol,Ha-m	5164	3231	4489	9992	11646	9708	57598	53611	35717	5532	4919	4248
Maximum	36780	20840	23660	67080	69370	62500	1988640	601240	583840	80210	40460	42300
Minimum	12760	9440	13770	15790	26480	17810	36780	27890	19830	13770	12760	6190

ANNUAL Mean 64780 li/sec/sq.km 28.54 Runoff mm 843.31 Runoff Hg m 205852 Maximum 1988840 Minimum 6190

64780 28.54 205852 1988840 6190

PAMPANGA RIVER BASIN
PAMPANGA RIVER
VALDEFUENTE, CABANATUAN CITY

LOCATION: Latitude 15-31-00 Longitude 120-57-14
Located downstream from the confluence of the Pampanga River and Dalampang Creek at Valdefuente Bridge, Cabanatuan City.

DRAINAGE AREA: 2441 sq. km.

RECORDS AVAILABLE: January 1, 1982 to December 31, 1983

GAGE: Staff gage read three times a day. Elevation of zero gage is 23.066 meters above Mean Sea Level

AVERAGE DISCH.: 1982-1983, 2yrs, 49785 second-liters

STATION I.D.

EXTREMES: Maximum discharge during year, 801240 liters/sec
July 16 gage height, 1.91 m
Minimum discharge, 8140 liters/sec,
June 14 & December 20 gage height, 0.36 m

1982 - 1983: Maximum discharge, 2628140 liters/sec, July 18, 1982 gage height, 5.02
Minimum discharge, 6190 liters/sec,
December 11, 1982 gage height, 0.33 m

REMARKS: Records are fair.

1983 MEAN DISCHARGE (liters/sec)

DAY	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC
1	15790	20840	10090	10090	13770	9440	17810	30710	29300	395040	32120	13770
2	15790	18820	9440	14780	12760	8790	16800	20840	23660	335840	40460	12760
3	15790	17810	11750	14780	12760	8790	15790	18820	32120	208440	36780	11750
4	14780	15790	10090	14780	11750	9440	14780	25070	32120	143660	32120	11750
5	13770	16800	9440	14780	10740	32120	19830	23660	45960	143660	36780	15790
6	16800	14780	9440	13770	10740	30710	17810	25070	38620	136340	32120	13770
7	10740	12760	8790	13770	10090	40460	16800	42300	27890	133090	29300	10740
8	10090	12760	10740	12760	11750	18820	19830	49660	38620	128590	26480	8790
9	11750	13770	10090	12760	12760	15790	17810	44140	26480	79000	26480	9440
10	15790	13770	9440	11750	11750	10740	16800	64790	36780	49660	27890	10090
11	16800	12760	12760	13770	11750	9440	15790	101060	64790	76240	27890	34940
12	15790	11750	11750	13770	15790	9440	23660	140110	57920	95560	26480	27890
13	16800	10740	10740	12760	15790	8790	22250	64790	49660	62500	23660	18820
14	16800	10740	10090	11750	14780	8140	38620	110340	42300	55630	20840	11750
15	16800	10090	10090	13770	14780	14780	53340	143660	38620	53340	33530	10090
16	23660	10090	10740	14780	27890	11750	578040	155190	30710	140210	29300	9440
17	25070	15790	10090	14780	25070	10090	76240	123340	30710	51500	23660	19830
18	18820	15790	9440	13770	19830	9440	33530	84520	30710	40460	18820	22250
19	17810	13770	10740	13770	18820	10740	23660	79000	36780	33530	16800	11750
20	36780	18820	10090	14780	17810	10090	17810	250920	30710	32120	14780	8140
21	27890	17810	11750	12760	15790	10740	18820	422040	27890	34940	19830	10740
22	19830	18820	13770	14780	17810	15790	16800	204140	25070	459840	14780	19830
23	16800	15790	12760	16800	17810	16800	17810	87080	33530	405640	16800	14780
24	15790	12760	15790	14780	15790	13770	16800	47820	34940	174040	14780	15790
25	15790	12760	13770	13770	25070	12760	17810	57920	32120	81760	13770	14780
26	14780	12760	13770	13770	29300	18820	33530	45960	40460	47820	12760	17810
27	16800	11750	12760	13770	25070	17810	25070	38620	51500	42300	44140	16800
28	25070	10740	11750	12760	19830	18820	29300	29300	42300	36780	34940	19830
29	17810		10740	14780	14780	17810	30710	40460	71860	40460	33530	18820
30	16800		10090	13770	10740	19830	25070	36780	140110	38620	13770	17810
31	15790		9440		10090		25070	67080		34940		16800
Total	549370	401430	342230	413460	503260	450750	1313790	2855450	1244060	3709990	775390	477340
Mean	17722	14337	11040	13782	16234	15025	42380	85860	41489	119677	25846	15398
Lt/sec/sq.km	7.26	5.87	4.52	5.65	6.65	6.16	17.36	35.09	18.99	49.03	10.59	6.31
Runoff,mm	19.45	14.21	12.11	14.63	17.81	15.95	46.50	93.99	44.03	131.32	27.45	16.90
Runoff,Ha-m	4747	3468	2957	3572	4348	3894	11351	22943	10749	32054	6699	4124
Maximum	36780	20840	15790	16800	29300	40460	578040	422040	140110	459840	44140	34940
Minimum	10090	10090	8790	10090	10090	8140	14780	18820	23660	32120	12760	8140

ANNUAL Mean 34891 lt/sec/sq.km 14.29 Runoff,mm 454.35 Runoff,Ha-m 110908 Maximum 578040 Minimum 8140

PAMPANGA RIVER BASIN
PAMPANGA RIVER
VALDEFUENTE, CABANATUAN CITY

LOCATION: Latitude 15-31-00 Longitude 120-57-14
Located downstream from the confluence of the Pampanga River and Dalampang Creek at Valdefuente Bridge, Cabanatuan City.

DRAINAGE AREA: 2441 sq. km.

RECORDS AVAILABLE: January 1, 1982 to December 31, 1984

GAGE: Staff gage read three times a day. Elevation of zero gage is 23.068 meters above Mean Sea Level

AVERAGE DISCH.: 1982-1984; 3yrs, 53830 second-liters

STATION ID:

EXTREMES: Maximum discharge during year, 2304340 liters/sec,
August 29 gage height, 4.58 m
Minimum discharge, 3900 liters/sec,
March 31 & April 10 gage height, 0.29 m

1982 - 1984 : Maximum discharge, 2628140 liters/sec, July 18, 1982 gage height, 5.02
Minimum discharge, same as above

REMARKS: Records are fair.

1984 MEAN DISCHARGE (liters/sec)

DAY	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC
1	18820	12760	9440	8140	11750	9440	73950	36780	1020440	18820	162730	10090
2	17810	13770	9440	7490	18820	10740	69370	42300	896440	20840	98320	9440
3	17810	12760	8790	8190	16800	13770	76240	40460	792740	19830	60210	14780
4	17810	11750	9440	8190	16800	10740	81760	45980	689440	17810	38780	14780
5	20840	10740	13770	5540	15790	10740	71660	62500	841040	18820	30710	14780
6	19830	20840	12760	4890	14780	12760	79000	90040	133090	17810	25070	12760
7	22250	17810	11750	4890	29300	11750	67080	69370	57920	14780	26460	16800
8	18820	13770	10090	4240	25070	10090	73950	62500	42300	17810	18820	16800
9	17810	12760	9440	4240	30710	14780	62500	55630	38820	20840	18800	15790
10	16800	11750	8790	3900	27890	11750	57920	62500	69370	20840	14780	17810
11	16800	10740	7490	6190	45980	11750	57920	47820	33530	17810	11750	19830
12	14780	10090	7490	8190	34940	22250	69370	40460	23660	17810	10740	16800
13	13770	12760	8190	5540	25070	16800	62500	45980	20840	15790	20840	15790
14	12760	11750	5540	10090	19830	14780	55630	103640	26460	14780	30710	20840
15	10090	10740	8140	16800	16800	17810	44140	147650	18820	16800	16800	25070
16	12760	10090	8790	18820	25070	15790	40460	162730	17810	29300	15790	22250
17	12760	10090	8140	16800	23660	20840	36780	174040	14780	20840	12760	18820
18	11750	9440	7490	15790	20840	18820	34940	246080	12760	15790	18820	15790
19	10740	9440	6840	16800	23660	23660	36780	241240	23660	12760	14780	14780
20	10090	8790	6840	14780	19830	18820	45980	147650	34940	14780	12760	13770
21	9440	8790	6840	13770	25070	22250	38620	87280	22250	18820	13770	12760
22	8790	9440	8190	12760	23660	22250	34940	47820	18820	107090	14780	11750
23	13770	10090	5540	12760	19830	34940	33530	241240	15790	270640	12760	10740
24	12760	9440	5540	11750	27890	40460	33530	586440	27890	933640	13770	15790
25	11750	9440	8190	14780	19830	282440	40460	260600	22250	647640	12760	13770
26	10090	10090	8190	17810	15790	101080	44140	116840	20840	378840	13770	16800
27	9440	9440	4890	16800	12760	98320	60210	79000	34940	143860	12760	15790
28	9440	9440	4890	14780	14780	60210	49660	151420	26460	136340	11750	14780
29	14780	9440	4240	13770	14780	53340	42300	1702740	22250	395040	13770	14780
30	14780		4240	12760	12760	57920	36780	1485140	20840	503840	11750	13770
31	13770		3900		10090		32120	1184540		292440		13770
Total	443710	328250	235310	325250	660630	1081090	1844220	7848610	4841030	4393070	788090	482070
Mean	14313	11319	7591	10842	21311	36036	53039	253181	161368	141712	26270	15551
Lt/sec/sq.km	5.86	4.64	3.11	4.44	8.73	14.76	21.73	103.72	66.11	58.05	10.76	6.37
Runoff,mm	15.71	11.62	8.33	11.51	23.38	38.27	58.20	277.80	171.35	155.49	27.89	17.06
Runoff,Ha-m	3834	2836	2033	2810	5708	9341	14206	67812	41826	37956	6809	4165
Maximum	22250	20840	13770	18820	45980	292440	81760	1702740	1020440	933640	162730	25070
Minimum	8790	8790	3900	3900	10090	9440	32120	36780	12760	12760	10740	9440

ANNUAL Mean 82711 lt/sec/sq km 25.89 Runoff,mm 816.82 Runoff,Ha-m 199336 Maximum 1702740 Minimum 3900

PAMPANGA RIVER BASIN
PAMPANGA RIVER
VALDEFUENTE, CABANATUAN CITY

LOCATION: Latitude 15-31-00 Longitude 120-57-14
Located downstream from the confluence of the Pampanga River and Dalampang Creek at Valdefuente Bridge, Cabanatuan City.

DRAINAGE AREA: 2441 sq. km.

RECORDS AVAILABLE: January 1, 1982 to December 31, 1985

GAGE: Staff gage read three times a day. Elevation of zero gage is 23.066 meters above Mean Sea Level.

AVERAGE DISCH.: 1982-1985; 4yrs, 64610 second-liters

STATION I.D.:

EXTREMES: Maximum discharge during year, 3137680 liters/sec
October 19 gage height, 5.71 m
Minimum discharge, 8140 liters/sec.
December 31 gage height, 0.38 m

1982 - 1985: Maximum discharge, same as above
Minimum discharge, 3900 liters/sec.
March 29 & April 10, 1984 gage height, 0.29 m

REMARKS: Records are fair.

1985 MEAN DISCHARGE (liters/sec)

DAY	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC
1	22250	15790	15790	17810	18820	33530	324840	40460	113590	27890	53340	13770
2	22250	14780	13770	20840	18820	30710	351840	84790	49880	32120	38820	12760
3	23660	13770	13770	18820	18820	19830	178340	76240	81760	45980	32120	16800
4	20840	12760	12760	18820	17810	36780	129840	55830	1171840	27890	27890	14780
5	18820	11750	11750	20840	18800	36760	71660	76240	737840	29300	22250	18800
6	18800	15790	14780	18820	15790	23660	1395540	103840	432840	47620	19830	15790
7	15790	18800	18800	18820	14780	23660	1008040	260600	178340	27890	18820	13770
8	15790	14780	14780	33530	13770	27890	384240	107090	129840	20840	25070	13770
9	23660	13770	13770	27890	13770	23660	188940	33530	422040	19830	22250	12760
10	19830	12760	12760	22250	12760	26480	92800	33530	449040	56830	19830	12760
11	15790	12760	11750	20840	12760	29300	87280	84520	292440	33530	18820	18820
12	14780	11750	20840	23660	22250	25070	95560	123340	368040	23660	16800	22250
13	12760	10740	18820	16800	16800	29300	78240	509440	246080	123340	15790	18800
14	17810	14780	16800	16800	14780	36760	67080	378840	221880	81760	14780	14780
15	19830	13770	14780	22250	12760	32120	84790	226720	260800	33530	23660	12760
16	17810	12760	13770	18820	12760	36760	71660	110340	158960	25070	17810	12760
17	16800	26480	26480	26480	11750	40460	174040	116840	107090	18820	15790	12760
18	16800	23660	23660	20840	13770	29300	69370	186500	76240	29300	14780	10740
19	15790	17810	18820	16800	14780	22250	69370	116840	73950	2331940	13770	10090
20	14780	13770	16800	14780	18820	23660	29300	87280	49660	1568340	13770	9440
21	13770	11750	15790	19830	18800	42300	25070	191240	36780	1190890	12760	9440
22	17810	12760	18820	18820	15790	76240	18820	126590	33530	630240	12760	14780
23	15790	13770	19830	18820	17810	927440	40460	151420	27890	384240	11750	19830
24	14780	25070	18820	13770	19830	977040	116840	147650	22250	267040	11750	13770
25	12760	18820	17810	18800	18820	1077140	143880	98320	20840	221880	11750	11750
26	11750	15790	15790	22250	17810	877440	60210	98320	27890	182640	10740	10740
27	14780	14780	13770	18820	17810	1286740	33530	140110	20840	231580	10090	10090
28	14780	16800	19830	25070	18820	400440	36780	158960	26480	143880	9440	9440
29	20840		19830	23660	26480	1312340	98320	123340	19830	87280	12760	9440
30	18820		18820	19830	19830	758140	55830	101080	17810	73950	10740	8790
31	16800		17810		26480		40460	101080		62500		8790
Total	535320	430570	520170	614180	529450	8121280	5598770	4210720	5875870	8100580	560330	411820
Mean	17268	15378	16780	20473	17079	270709	180805	135830	195862	261309	18679	13285
L/sec/sq.km	7.07	6.30	6.87	8.39	7.00	110.90	73.99	55.65	80.24	107.05	7.65	5.44
Runoff,mm	18.95	15.24	18.41	21.74	18.74	287.45	198.17	149.04	207.98	286.72	19.83	14.58
Runoff,Ha-m	4625	3720	4494	5307	4574	70168	48373	36381	50768	69999	4841	3558
Maximum	23660	26480	26480	33530	26480	1312340	1395540	509440	1171840	2331940	53340	22250
Minimum	11750	10740	11750	13770	11750	19830	18820	33530	17810	18820	9440	8790

ANNUAL Mean 96938 l/sec/sq.km 39.71 Runoff,mm 1258.85 Runoff,Ha-m 306798 Maximum 2331940 Minimum 8790

PAMPANGA RIVER BASIN
PAMPANGA RIVER
VALDEFUENTE, CABANATUAN CITY

LOCATION: Latitude 15-31-00 Longitude 120-57-14
Located downstream from the confluence of the Pampanga River and Delampang Creek at Valdefuente Bridge, Cabanatuan City.

DRAINAGE AREA: 2441 sq. km.

RECORDS AVAILABLE: January 1, 1982 to December 31, 1996 (Fragmentary)

GAGE: Staff gage read three times a day. Elevation of zero gage is 23.068 meters above Mean Sea Level

AVERAGE DISCH.: 1982-1996; 5yrs, 70720 second-liters

STATION ID:

EXTREMES: Maximum discharge during year, 2090940 liters/sec,
October 7 gage height, 4.25 m
Minimum discharge, 3900 liters/sec,
May 17 gage height, 0.29 m

1982 - 1996: Maximum discharge, 3137880 liters/sec, October 19, 1985 gage height, 5.71
Minimum discharge, 3900 liters/sec,
Mar 29 & April 10, 1984 & same as above gage height, 0.29 m

REMARKS: Records are fair.

1996 MEAN DISCHARGE (liters/sec)

DAY	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC
1					8840		42300	133090	470840	34940	45980	8140
2					6190		30710	95560	509440	38820	33530	7490
3					6190		97260	51500	449040	76240	28300	8840
4					8840		44140	30710	554840	30710	26480	18800
5					18800		32120	25070	292440	38780	23660	79000
6					15790		27890	335640	443840	34940	19830	182640
7					13770		23660	265440	389640	1901840	22250	95560
8					10740		34940	250920	208440	1096040	255760	80210
9					10090		427440	241240	140110	498240	95560	23660
10					8790		1774740	107090	55830	221880	34940	18820
11					7490		1536340	55830	45980	155190	27890	17810
12					8840		498240	33530	33530	199840	47820	10090
13					5540		208440	26480	57920	1127540	34940	9440
14					4890		84520	92800	92900	586440	1305940	8790
15					4240		427440	73950	57920	241240	1267540	6140
16					4240		170270	51500	38780	143880	554840	7490
17					3900		95560	26480	32120	107090	250920	6840
18					19830		98320	44140	26480	71880	103840	6840
19					26480		90040	29300	38820	84520	84790	6190
20					10740		101080	32120	32120	927440	38820	6190
21					7490		79000	27890	30710	520840	76240	5540
22					23660		166500	33530	34940	265440	22250	5540
23					18800		80210	101080	113590	143880	18800	12760
24					9440		80210	346440	422040	199840	10090	123340
25					8840		55830	136340	87080	174040	18820	45980
26					22250		81760	107090	40460	113590	11750	38780
27					18820		81760	174040	29300	49660	10090	27890
28					20840		84790	143880	26480	76240	8790	15790
29					17810		53340	126590	84790	49660	10740	13770
30					20840		34940	191240	23660	174040	8790	12760
31					17810		32120	281640		120090		11750
Total					378830		6805730	3671950	4821180	9482190	4478790	898880
Mean					12220		213086	118450	160706	305877	149293	28996
Li/sec/sq.km					5.01		87.30	48.53	65.84	125.31	61.16	11.88
Runoff,mm					13.41		233.81	129.97	170.65	335.63	158.53	31.82
Runoff,Ha-m					3273		57074	31726	41655	81926	38697	7766
Maximum					26480		1774740	346440	554840	1901840	1305940	182640
Minimum					3900		23660	25070	23660	30710	8790	5540

PAMPANGA RIVER BASIN
PAMPANGA RIVER
VALDEFUENTE, CABANATUAN CITY

LOCATION: Latitude 15-31-00 Longitude 120-57-14
Located downstream from the confluence of the Pampanga River and Dalampang Creek at Valdefuente Bridge, Cabanatuan City.

DRAINAGE AREA: 2441 sq. km.

RECORDS AVAILABLE: January 1, 1962 to November 30, 1987

GAGE: Staff gage read three times a day. Elevation of zero gage is 23.088 meters above Mean Sea Level

AVERAGE DISCH.: 1962-1987; 8yrs, 84000 second-liters

STATION ID.:

EXTREMES: Maximum discharge during year, 1728540 liters/sec.
August 19 gage height, 3.71 m
Minimum discharge, 3560 liters/sec.
Oct. 27 & Nov 9 gage height, 0.28 m

1962 - 1987 : Maximum discharge, 3137680 liters/sec, October 19, 1985 gage height, 5.71
Minimum discharge, same as above liters/sec,
gage height, m

REMARKS: Records are fair.

1987 MEAN DISCHARGE (liters/sec)

DAY	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC
1	11750	14780	12760	12760	5540	4890	32120	27890	25070	14780	9440	
2	11750	10090	15790	12760	4890	4240	27890	17810	509440	17810	8140	
3	10090	12760	14780	11750	4890	30710	20840	15790	351840	12780	10090	
4	9440	10090	13770	11750	4890	16800	17810	13770	208440	10090	8140	
5	15790	8790	11750	15790	4240	10740	16800	17810	84790	7490	5540	
6	11750	8140	12760	14780	20840	9440	15790	73950	107090	6840	4890	
7	10740	7490	12760	12760	30710	8790	14780	29300	118840	9440	4240	
8	9440	6840	11750	14780	19830	11750	14780	23660	73950	7490	3900	
9	8790	6840	11750	13770	14780	8790	19830	19830	22250	6840	3560	
10	6840	8790	10740	12760	8790	8140	12760	17810	23660	5540	13770	
11	8190	7490	10740	11750	7490	7490	15790	71660	14780	5540	11750	
12	5540	14780	10090	11750	8140	6840	15790	40460	26480	8190	9440	
13	5540	10740	15790	11750	5540	11750	27890	25070	18820	16800	8790	
14	13770	10090	14780	10740	8190	12760	22250	22250	80210	14780	13770	
15	16800	9440	12760	10090	5540	10740	17810	73950	84520	12760	10740	
16	16800	8790	13770	9440	5540	10740	16800	44140	32120	9440	8790	
17	18800	19830	12760	9440	5540	16800	27890	51500	80210	7490	23660	
18	13770	29300	12760	8790	4890	18820	23660	170270	34940	6840	26480	
19	9440	26480	11750	8140	15790	16800	49660	1459540	120090	9440	19830	
20	8140	15790	11750	7490	25070	14780	113590	921240	133090	7490	18800	
21	6840	20840	10740	10740	9440	12760	68370	454440	57920	8190	11750	
22	8790	15790	10090	10090	8840	10090	53340	226720	49660	4890	11750	
23	8190	14780	10090	9440	8190	9440	42300	27890	33530	4240	53340	
24	5540	13770	9440	8790	5540	8140	34940	51500	19830	3900	23660	
25	15790	13770	9440	8140	5540	9440	57920	36780	14780	3900	15790	
26	11750	17810	12760	8190	4890	10740	92600	32120	11750	3900	10740	
27	9440	14780	10740	8190	27890	10090	40460	27890	9440	3560	162730	
28	8790	13770	10740	8190	17810	9440	103840	101080	17810	25070	174040	
29	14780		16800	5540	8790	11750	78240	195540	11750	18820	44140	
30	11750		14780	5540	6840	44140	107090	71660	15790	15790	20840	
31	10740		13770		5540		120090	29300		11750		
Total	329570	372650	384950	309890	314440	377840	1322920	4392620	2330890	297860	750540	
Mean	10631	13309	12418	10330	10143	12595	42675	141697	77696	9608	25018	
Li/sec/sq km	4.36	5.45	5.09	4.23	4.16	5.16	17.48	58.05	31.83	3.94	10.25	
Runoff,mm	11.67	13.19	13.63	10.97	11.13	13.37	46.83	155.48	82.50	10.54	26.57	
Runoff,Ha-m	2847	3220	3326	2677	2717	3265	11430	37952	20139	2574	6485	
Maximum	16800	29300	16800	15790	30710	44140	120090	1459540	509440	25070	174040	
Minimum	5540	6840	9440	5540	4240	4240	12760	13770	9440	3560	3560	

APPENDIX 5. STREAMFLOW DATA FOR THE PAMPANGA RIVER (1964-1970) and CABU RIVER (1957-1970)

RIVER = PAMPANGA R. LOCATION= VALFUENTE,CABANATUAN CITY
STA ID= 03SW153205PW034 GRID NO.= 3 7 7 ABT 700 M D/S FR CONFL OF PAMPANGA R.AND DALAMPA
LAT: 15 31 0 LONG: 120 57 20 NG CR.

DRAINAGE AREA(SQ.KM)= 2441. ELEV.OF Z GAGE= 2.09 METERS OF BM NO.1 GAGE TYPE=
START OBSERVATION =MAR 1964 GAGE OPERATION= WATER-STAGE RECORDER AGENCY =BPW-WRSD
OBS LAST CONSIDERED =DEC 1970 REMARKS= RECORD GOOD,ABV 740 FAIR STATUS =ABANDONED

A. ANNUAL DISCHARGE CHARACTERISTICS (Q IN CU.M./SEC.)

YEAR	PEAK Q	GAGE HT. -METERS-	DATE	TIME	MAX.DLY Q	MEAN Q	MIN.DLY Q	GAGE HT. -METERS-	DATE	RUNOFF --MM--
1964	1170.00	3.860	DEC 14	05PM	*******	*******	14.00	.60	JUN 21	******
1965	2524.00	6.220	JUL 11	01PM	1988.00	111.86	5.00	1.66	MAY 19	1445.0
1966	1516.00	4.960	NOV 23	07AM	1388.00	145.19	3.60	1.56	APR 19	1875.0
1967	1812.00	5.330	OCT 18	07AM	1468.00	180.52	8.00	1.80	MAR 31	2328.2
1968	1129.00	4.430	SEP 29	07AM	1012.00	109.92	6.80	1.76	MAY 22	1423.2
1969	958.00	4.150	AUG 08	07AM	*******	*******	2.40	1.44	MAY 02	******
1970	1436.00	4.860	OCT 12	07AM	*******	*******	4.10	1.61	MAR 17	******

C. MEAN MONTHLY DISCHARGE IN CU.M./SECOND

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1964	******	******	******	40.80	43.94	94.21	144.32	329.68	262.33	314.68	335.30	274.06
1965	54.52	63.15	15.56	8.97	14.36	106.76	359.80	194.75	289.57	78.54	109.16	44.62
1966	14.86	11.97	9.74	4.19	260.32	79.81	122.77	201.63	357.46	82.93	362.73	228.15
1967	96.03	27.91	16.45	11.31	9.05	102.42	202.44	522.23	505.27	339.02	261.84	62.56
1968	26.34	23.40	15.40	11.62	9.29	11.49	93.74	287.90	471.27	219.20	81.40	66.80
1969	******	******	******	******	******	******	******	******	******	******	******	******
1970	******	21.57	5.99	5.15	5.21	17.29	16.95	34.84	569.77	535.04	489.11	139.44

NOTE: ***** INDICATES MISSING DATA,NOT INCLUDED IN CALC OF STATISTICAL PARAMETERS

RIVER = CABU R.
STA ID= C3SW153210PW033 GRID NO.= 3 7 8
LAT: 15 31 45 LONG: 121 3 30

LOCATION= CABU,CABANATUAN CITY
ABT 20 M D/S FR HWY BR ALONG CABANATUAN-BO- NGABON
RD.,12KMS. FR CITY

DRAINAGE AREA(SQ.KM)= 143.
START OBSERVATION =JUN 1957
OBS LAST CONSIDERED =DEC 1970

ELEV.OF Z GAGE= 39.25 METERS ABV MSL
GAGE OPERATION= WATER-STAGE RECORDER
REMARKS= RECORDS GOOD,ABV 70 FAIR

GAGE TYPE=
AGENCY =BPW-WRSD
STATUS =OPERATING

A. ANNUAL DISCHARGE CHARACTERISTICS (Q IN CU.M./SEC.)

YEAR	PEAK Q	GAGE HT. -METERS-	DATE	TIME	MAX.DLY Q	MEAN Q	MIN.DLY Q	GAGE HT. -METERS-	DATE	RUNOFF --MM--
1957	93.65	2.670	JUL 15	07AM	*******	*******	******	******		******
1958	129.15	3.130	SEP 26	04AM	58.30	3.64	******	3.54	APR 13	802.9
1959	129.95	3.140	NOV 17	12NN	103.25	4.04	******	3.54	APR 16	890.8
1960	241.45	4.380	OCT 13	10PM	179.35	7.16	******	******	MAR 05	1614.4
1961	139.75	3.250	JUN 27	07PM	*******	*******	******	******	MAR 01	******
1962	145.15	4.380	JUL 21		*******	*******	.01	.07	MAY 18	******
1963	271.15	4.710	SEP 09	08PM	57.75	3.69	******	******	JAN 22	813.8
1964	76.40	2.410	AUG 08	07AM	*******	*******	******	******	MAR 22	******
1965	118.75	3.000	JUL 14	06AM	*******	*******	.05	.30	JUL 16	******
1966	110.75	2.990	MAY 20	09PM	82.25	4.04	******	******	MAR 22	890.8
1967	243.25	4.460	NOV 04	11PM	117.95	6.75	******	******	MAY 01	1488.4
1968	35.50	1.650	OCT 04	06AM	32.45	2.91	******	******	MAR 17	644.0
1969	129.95	3.140	SEP 07	11PM	57.75	3.68	******	******	APR 14	810.1
1970	174.85	3.640	AUG 31	530PM	67.45	5.06	******	******	MAR 16	1115.1

B. EXTREMES OF DISCHARGE AND STATISTICAL PARAMETERS

EXTREME DISCHARGE IN CMS

MAX.Q = 271.15
DATE = SEP 09,1963
GAGE H= 4.71
INSTANTANEOUS PEAK

MIN.Q = *****
DATE = DS
GAGE H= ******
SAME WITH PREVIOUS Y

STATISTICS	PEAK Q	MAX.DLY Q	MEAN Q	MIN.DLY Q
MEAN FLW=	145.693	84.056	4.552	.030
STD.DEV.=	66.611	44.141	1.477	.028
SKEWNESS=	.583	1.338	1.084	.000
KURTOSIS=	3.499	5.873	3.998	.000
NO.YEARS=	14	9	9	2

C. MEAN MONTHLY DISCHARGE IN CU.M./SECOND

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1957	******	******	******	******	******	******	8.43	9.88	9.17	5.38	12.26	1.52
1958	.45	.18	.11	.01	******	2.03	4.56	7.18	23.24	3.60	1.76	.60
1959	.14	.07	.06	.02	******	.05	.70	21.27	8.57	5.34	9.94	2.04
1960	.42	.15	.05	.01	.77	4.10	2.42	33.78	20.44	21.11	21.64	.48
1961	.14	.06	.09	******	.82	7.14	22.69	21.21	******	******	******	******
1962	******	******	******	******	******	******	12.89	******	******	3.38	.76	.25
1963	.01	.04	******	******	******	6.32	7.11	10.66	14.41	3.14	1.19	1.27
1964	.69	.36	.07	.02	.11	1.80	4.85	13.29	******	******	******	******
1965	******	******	******	******	******	******	******	******	15.65	6.96	3.67	.78
1966	.24	.11	.05	******	10.69	1.92	5.40	11.76	4.79	1.17	9.38	2.60
1967	.94	.54	.34	.09	.13	1.00	1.94	14.35	34.23	14.05	12.66	.81
1968	.31	.20	.02	******	.16	.84	1.03	8.75	15.41	6.40	.68	1.19
1969	.71	.20	.18	.07	******	1.43	5.91	9.77	16.62	7.26	1.32	.52
1970	.21	.06	.03	.03	.06	.94	1.69	10.22	16.72	14.58	10.26	5.73
MEAN =	.39	.18	.10	.04	1.82	2.51	6.12	14.34	16.30	7.70	7.13	1.48
ST.DEV=	.29	.15	.10	.03	3.92	2.33	6.04	7.60	7.97	5.88	6.62	1.50
SKEWSS=	.702	1.594	2.061	1.177	2.609	1.259	1.951	1.775	.923	1.315	.864	2.339
KURTSS=	3.460	6.078	8.024	4.561	10.717	4.193	7.696	6.650	5.409	4.780	4.004	9.429
NO.YRS=	11	11	10	7	7	11	13	12	11	12	12	12

NOTE: ***** INDICATES MISSING DATA,NOT INCLUDED IN CALC OF STATISTICAL PARAMETERS