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WATER SUPPLY PLANNING FOR METRO MANILA: SOME ECONOMIC CONSIDERATIONS

University of Hawaii PH.D. 1984

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WATER SUPPLY PLANNING FOR METRO MANILA:

SOME ECONOMIC CONSIDERATIONS

A DISSERTATION SUBMITTED TO THE GRADUATE DIVISION OF THE
UNIVERSITY OF HAWAII IN PARTIAL FULFILLMENT OF
THE REQUIREMENTS FOR THE DEGREE OF

DOCTOR OF PHILOSOPHY

IN AGRICULTURAL AND RESOURCE ECONOMICS

MAY 1984

By

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ACKNOWLEDGMENTS

I want to thank two institutions: one, the Human Settlements Regulatory Commission for granting my four-year study leave; and two, the East-West Center for the grant which enabled me to pursue graduate study at the University of Hawaii.

Special thanks are due to my two advisers: Dr. Hiroshi Yamauchi and Dr. Maynard M. Hufschmidt for their invaluable technical and editorial advise, suggestions and criticisms which brought considerable improvements to my earlier drafts.

I also want to express my thanks to Dr. Jack R. Davidson for his suggestions and comments especially on the practical and philosophical view of the methodology; to Dr. Yu-Si Fok for his comments and suggestions on the organization of presenting the formulae and symbols; and to Dr. Yung C. Shang for agreeing to act as a committee member although it was at the later stage of my study.

I also wish to thank all EAPI secretaries: Lyn Moy for giving me an account number for word processing; Jan Watanabe, June Kuramoto, Maureen Murakami, Joan Nakamura, and Laura Miho for their technical assistance whenever I had word processing problems.

Finally, I would like to acknowledge all those who contributed to the kind of life I lived in Hawaii.

ABSTRACT

The purpose of this study is to investigate the issue of to what extent economic concepts and principles can be designed into water supply expansion planning using Metro Manila as a case. Two hypotheses were investigated: first, water consumption patterns in Metro Manila significantly respond to pricing policies; second, tolerance of shortages in a water supply expansion plan can reduce its total costs.

Regression results using annual time series data from 1970 to 1981 show that water consumption, except public use, responded to changes in economic variables. Household monthly consumption is affected by family income, difference price, and domestic marginal price (price of the last block consumed). Residential demand showed an income elasticity of 0.542 and a combined price elasticity of -0.287. Annual aggregate industrial and commercial uses are affected by their respective prices and the region's income (gross domestic regional product). Industrial demand had a price elasticity of -0.213 and an income elasticity of 0.347. Commercial demand exhibited a price elasticity of -0.163 and an income elasticity of 1.18. These elasticities are comparable with findings for cities in the U.S. as well as in developing countries.

The evaluation of four alternative supply expansion plans formulated to reflect varying degrees of economic consideration in both demand projections (either by "requirements" demand or by econometric demand approach) and in supply policies ("with-shortage" or "without-shortage") indicates that designing shortages into expansion plans reduces the cost of the plans.

The major implications for decision-making and research are: (1) The application of economic concepts such as price allocation, marginal cost pricing, and demand theory to water supply management is limited by such practical constraints as institutional and legal requirements, financial targets, social goals, and physical site characteristics; and (2) Further research is needed on planning methodology to accommodate any functional form of demand and to consider practical institutional and physical constraints. In addition, the statistical system in the Philippines should be strengthened to record monthly water consumption data and such other information related to time, place, and type of use.

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LIST OF SYMBOLS AND ABBREVIATIONS

a	economy of scale parameter, $0 < a < 1$
a_0	a parameter in a firm's production function
A_t	projected total area of the city in year t, hectares
ADSS	actual demand-side shortage, MCM/year
ASSEC	actual supply-side excess capacity, MCM/year
α_i	elasticity of firm's output Q_0 with respect to input x_i
B	benefit (willingness to pay) measured by the area under the demand curve, $
B_i	quantity of water consumed in block i, M^3
b_i	regression coefficient for price p_i
b_0	intercept for a demand function
C	construction cost of a project, $
C_A	cost avoided by a supplier (producer), $
C_a	actual quantity of water produced, MCM/year
C_i	construction cost of project i, million pesos/year
Cs	capacity of the entire water supply system, MCM/year
C(s)	sum of all discounted future costs of an expansion excluding shortage penalty cost, $
C(s,y)	present value of total cost (construction cost and shortage penalty cost but excluding OMR cost) of an expansion plan, $
c_t	construction cost (at base year price) incurred in year t of the project in question, million pesos
CDM	Camp, Dresser and McKee Engineers, Inc.
CP	commercial price of water, ₱/M^3
CU	commercial use of water, MCM/year
D	rate of increase of water demand, quantity/year

D_a	water consumption of the area actually served, MCM/year
D_0	initial water shortage, MCM/year
D_s	water consumption (all uses) of the entire service area, MCM/year
D_t	level of water demand in year t for all uses, MCM
D(w)	demand curve for car-wash water solved for price and expressed as function of quantity
DMP	domestic marginal price (price of the marginal block faced by the average household consumer, pesos/M^3
DP	difference price, pesos
Δp_i	change in the price of good i
Δx_i	change in the quantity demanded of good i
e	base of natural logarithm, equals 2.71828
E_i	price elasticity of demand for good i
F	an approximating parameter for y* in terms of k, D, a, and p
f_{it}	projected use factor for land use i at time t
f_t	projected overall weighted use factor in year t
FDWD	full development water duty, quantity of water use per unit area
G	population of the region, unit specified in equations
G_t	projected population of the city (or region) at time t
GDP	gross domestic product of the region, million pesos
IA	industrial land use area (in land use map), hectares
IP	industrial price of water, pesos/M^3
IU	industrial use of water, MCM/year
k	scale parameter, cost of 1-capacity unit system
L	Langrangian expression in classical programming
lpcd	liters per capita per day
l_{it}	projected area of land use i at time t, hectares

m	individual's budget (money income), $
MC	marginal cost, pesos/M^3
MCM	million cubic meters
MWSS	Metropolitan Waterworks and Sewerage System
N	total number of land uses
OMR	operation, maintenance and replacement, million pesos
omr_i	operation, maintenance and replacement cost for project i, million pesos
p	penalty price of shortage, pesos/M^3
$\hat{p}$	imputed penalty price of shortage, pesos/M^3
P_a	population served by the system
p_{bi}	unit price (of water) of block i, pesos/M^3
p_i	unit price of good i, $/unit
$\overline{p_i}$	mean of p_i
p(i)	penalty price for water use i, pesos/M^3
p_0	price of the firm's output Q_0, $/unit
p_{sl}	average price of social loss, $/unit volume
p_t^f	forecast price of water at time t, $/unit volume
PoD	percent of development, or the degree to which an area is developed
PE	production efficiency, ratio of C_a to C_s
PP	public price of water, Pesos/M^3
PPS	percent population served by the system, ratio of P_a to P_s
PQS	percent quantity served, ratio of C_a to D_s
P_s	total population of the entire service area
PS	planned shortage, MCM/year
PTC	present value of total cost (construction and shortage costs, but excluding OMR) of an expansion plan, $ or pesos

PU	public use of water, M^3/capita/year
PV	present (discounted) value
PVC	present value of total cost (includes construction, shortage and OMR costs) of an expansion plan, million pesos
PVC_{ns}	present value of cost of an expansion plan based on the "without-shortage" supply policy, million pesos
PVC_s	present value of cost of an expansion plan based on the "with-shortage" supply policy, million pesos
ϕ	an approximating parameter for y* in terms of "a" and "r"
Q	project capacity added, MCM/year
q	water "use factor," gallons or liters per capita per day
Q_0	quantity of firm's output in physical units
r	discount rate, percent annually
RS	resulting (actual) shortage, MCM/year
RU	residential use of water, M^3/household/month
s	time interval (spacing) between successive expansion projects, years)
s*	optimal time interval between successive expansion projects, years
s_1	initial design period, or time after which the initial project addition is fully used up, years
s_1*	optimal initial design period, years
s_0	hypothetical elapsed period from time of zero demand (or zero excess capacity) to the present, years
S_t	cumulative supply of the system in year t, MCM/year
SL	total net social losses, $
SSEC	supply-side excess capacity, MCM/year
SSS	supply-side shortage, MCM/year
t	time, year
TC	theoretical water consumption, quantity/year

TD	theoretical demand for water, quantity/year
TIC	theoretical industrial water consumption, quantity/year
U	level of utility derived from consumption of goods or services
u_i	weight, ratio of water use i to total use
US	unintentional (unplanned) shortages incurred during the implementation of the expansion plan, MCM/year
U_w	percentage of water produced which is unaccounted-for
UW	quantity of unaccounted-for water, quantity/year
V	error term in regression
w_i	water demanded at price p_i, M^3
W_t	projected water consumption in year t for any type of use (or all uses) depending on the use factor employed
x_i	quantity of good i bought or demanded
$\overline{x}_i$	mean of x_i
Y	average family income, pesos/household/month
Y_t	average family income in year t
y	waiting (delay) time before a project is constructed, years
y*	optimal waiting time before a project is constructed, years
z	an approximating parameter for y* in terms of "a" and "r"

CHAPTER I

INTRODUCTION

1.1 The Problem

The major task of a water-supply utility, whether publicly or privately owned, is to provide potable water for its service area with an adequate level of service in as economic a manner as possible. In the face of a growing demand for water over time, and given an estimate of that demand in the future, water supply must be expanded, and the utility management is faced with the following major decisions:

a. What alternative supply and associated transmission, treatment, and distribution facilities to build. The supply could either be surface water dam, groundwater well field, or sea-water desalting plant.

b. How much to build. This refers to the sizes or capacities of the projects to be constructed.

c. When to build. This refers to the timing of constructing the projects.

The process of making the above choices is called "water supply expansion planning." There are two broad approaches to water supply expansion planning namely: the traditional approach; and what I will call the "new" approach.

Under both approaches, a prerequisite step has to be taken before the above-mentioned problems can be solved, that is, the projection of the quantity of water that must be provided.

Under the traditional approach, this quantity of water is estimated by the "requirements approach" (Ciriacy-Wantrup, 1961) which is based on the assumption that a certain quantity of water is required for a certain number of persons or a specified unit area. The issue of what alternative supply to develop would be decided by using the least-cost criterion. Engineers develop from the various alternatives a site (source) with the lowest cost per unit of capacity. The size of each project is determined by the cost of development and the available water yield. Given the different alternative projects with given capacities and costs, the order of constructing these projects is determined by a dynamic programming technique which searches a construction schedule under which the present value of the construction and other associated costs is minimized. Note that only the construction order is determined. Conventionally, practicing engineers have adopted the "without-shortage" policy because of institutional rules that have controlled their decision-making. Under this policy, a project is put into operation right at the (regeneration) point where the total consumption of the service area equals the cumulative supply capacity of the system. Thus, at each regeneration point, a project is built according to the sequence determined earlier.

Under the new approach, the quantity of water to be serviced is determined by economic demand. This approach recognizes the fact that a person's consumption is affected by factors such as prices, income, taste, etc. (Miller, 1978). On the issue on which site (source) is to be developed, this approach derives a relationship between the costs and capacities of the projects. In doing this, it assumes that projects have more or less the same site characteristics. With this

assumption, this approach does not specify which source should be developed first. The size and timing of projects are determined simultaneously, and the classic example of this technique is the work of Manne (1967). It starts with solving a cost minimization problem with the objective of minimizing the present value of costs. Under the policy of "without-shortage," the objective function is expressed in terms of capacity (via a pre-established cost-capacity relationship) and project spacing. This program results in what is claimed as the optimal expansion size and spacing. Under the policy of "with shortage," a delay time variable enters the objective function. The solution yields an economic criterion which expresses delay time in terms of shortage price. Then to determine the optimal delay of projects, it is necessary to determine the price of having a shortage. If this price is bearable, construction may be delayed until such economic criterion is met. If the price is too high and unbearable for the society, i.e. very large to infinity, then the conventional policy of without-shortage is adopted.

The major decisions (Doll & Orazem, 1978) in planning are interrelated, and are subject to both engineering and economic considerations. Engineering considerations are involved because the actual site configuration may influence the choice of the project site, and the physical availability of water may limit the size of the project. Economic considerations are relevant because water is an economic good (Hirshleifer et al., 1969). Note that under the traditional approach demand has been projected by the "requirement" approach, while the supply policy is such that supply is always kept equal to or greater than demand: that is, the "without-shortage policy." This policy is the result of conforming to the traditionally recognized practical, physical,

and institutional realities. We could say that this approach has not emphasized economic considerations in planning.

A closer look at the "new" approach would tell us that economic principles may be incorporated in demand projections, and in supply policy, particularly in the timing of expansion projects. Demand is projected according to demand theory, and the supply policy of "with shortage" delays the construction of projects according to certain economic criteria. This emphasizes the economic concept of scarcity (Ciriacy-Wantrup, 1968). Considering the fact that resources are scarce, and society's resources are not efficiently used in having large idle excess capacity, it might be worthwhile to delay the construction of projects.

To sum it up, traditional water supply planning has underemphasized economic considerations, while the "new" approach holds that economic considerations could be taken into account.

Our problem then is the issue of whether economic considerations can be designed into the water supply expansion plans.

We will investigate this problem under a Philippine setting, specifically Metropolitan Manila.

1.2 Objectives of the Study

This research will examine the effects of pricing and the tolerance of shortages on achieving a least-cost strategy for meeting water service responsibilities. To this end, categorical water consumption will be estimated and projected, and a set of alternative water supply expansion plans will be developed and analyzed.

This overall objective is an assemply of several sub-objectives namely:

1. To determine what factors affected the water consumption in the Metropolitan Manila Region during the period 1970-1981;
2. To project water consumption considering the factors identified in (1), while identifying the problems, if there are any, associated with using the established relationship between consumption and the factors.
3. To estimate the penalty price of water shortage;
4. To determine whether the policy of allowing shortages is applicable in the Metro Manila Region, and determine its effects, if there are any, on the outcome of planning decisions; and
5. To develop and evaluate alternative expansion plans. This will show the effect of the tolerance of shortage as stated in (4).

1.3 Working Hypotheses

From the objectives given above, the general working hypotheses that this research will investigate are:

1. Water consumption in Metropolitan Manila is sufficiently responsive to pricing so as to alter consumption levels and patterns; and
2. Tolerance of shortages is a viable policy in reducing the cost of supply expansion plans.

1.4 Outline of the Study and Scope and Limitations

This chapter has introduced the problem, the general objective, the specific objectives and the working hypotheses.

Chapter II deals with the theory of economic demand and demand elasticity, and discusses the different approaches for projecting water consumption. Empirical studies of demand, demand elasticity and consumption projection are reviewed, and their meaning or importance to water supply planning is discussed.

Chapter III deals with the theory of water supply capacity expansion planning. Both the "traditional" and the "new" approaches to expansion planning are discussed and evaluated to identify what aspects of them can be merged into a workable compromise.

Chapter IV provides the background information on the study area --the Metropolitan Waterworks and Sewerage System's service area. The information includes the general description and composition of the service area, the existing water supply and demand situations, and the plans and programs with emphasis on supply expansion and the provision for water distribution systems.

Chapter V outlines the methodology involved in attaining the objectives. This includes the procedures for forecasting the demand for water, estimation of the shortage (penalty) price and the determination of the applicability of the shortage supply policy, and the derivation and evaluation of expansion plans. The data requirements and sources are also discussed.

Chapter VI presents and discusses the results of the analyses. Estimated categorical (i.e., residential, industrial, commercial, and public uses) consumption functions are presented and used to project

water consumption. Price and income elasticities of demand for these types of uses are reported. The penalty price of shortage is estimated and projected. The projected consumption and a constant penalty price are then used in the development of alternative expansion plans which show the viability and effects of a with-shortage policy upon the planning decisions. Sensitivity analysis is done to assess the response of the waiting (delay) times of projects and the components of the cost of expansion plans to the changes in the values of the discount rate and penalty price.

Finally, Chapter VII summarizes the procedures and the major findings of the study. Implications for policy and research are drawn and the contribution of this study to research is discussed.

It is known that planning tasks are multi-disciplinary and broad in scope or aspects. Plans, in actual practice, take years to prepare, require different types of expertise, need a lot of funds, and involve many important aspects.

In a study of this scope it is not possible to deal with all of the aspects that should be dealt with by a planning body. Aspects which may be important are: land use analysis and future city area expansion plans; environmental, social, economic and technological goals; pricing policies which are set by political decisions rather than by economic theory and which reflect revenue requirements for some other activities of the agency; population policies brought about by decreed new town development; and projection of political policies which might affect the overall regional activity and finally the water demand level. Information on such aspects is taken and used as given

conditions in this study, and the analyses to derive or justify them are beyond the scope of this study.

Finally, there may be some aspects which seem to be vital to planning, but judged on the basis of what is strictly necessary for this study in order to solve its proposed hypotheses, they are not treated in detail.

CHAPTER II

THEORY OF DEMAND AND WATER CONSUMPTION PROJECTION

2.1 The Economic Concept of Demand

Demand can be defined simply as the quantity that a person is willing to buy at a certain price, ceteris paribus. A person's demand for a commodity is affected by his income, tastes and preferences, prices of related goods including substitutes and complements, changes in the expectations of future prices, sex, cultures, and others (Miller, 1978).

Demand is based on the simple theory that a person wants to maximize his utility from the consumption of a good (Layard and Walters, 1978). This utility is a function of the goods being consumed. To date, the exact relationship between the utility level U and the amount of goods consumed has not yet been expressed in terms of a generally acceptable form. This relationship may vary in form from one consumer to another, and is difficult to express explicitly. One's utility level may be expressed as the sum or product of the quantity of the goods, and another's maybe of the Cobb-Douglas type function. These relationships appear as examples in Layard and Walters (1978, p. 137).

Textbooks in economics like Mansfield (1970) and Layard and Walters (1978) usually present the utility relationship in an implicit form:

$$U = U(x_1, x_2, \ldots x_n) \qquad (1)$$

where x_i is the quantity of the ith good consumed; and U is the level of utility.

Mathematically, the person's problem is to:

$$\text{Maximize } U = U(x_1, x_2, \ldots x_n) \tag{1a}$$

subject to his budget constraint:

$$p_1x_1 + p_2x_2 + \ldots p_nx_n \leq m \tag{2}$$

where p_i is the unit price of the ith good; and m is the available budget. Solving this by classical programming, we form the Lagrangian expression:

$$L = U(x_1, x_2, \ldots x_n) + \lambda(m - p_1x_1 - p_2x_2 - \ldots p_nx_n) \tag{3}$$

where λ, which is called the Lagrangian multiplier, measures the marginal utility per dollar spent on each good. Taking partial derivatives and setting results equal to zero, we get the first-order conditions:

$$\begin{aligned}
\frac{\partial L}{\partial x_1} &= \frac{\partial u}{\partial x_1} - \lambda p_1 = 0 \\
\frac{\partial L}{\partial x_2} &= \frac{\partial u}{\partial x_2} - \lambda p_2 = 0 \\
&\vdots \\
\frac{\partial L}{\partial x_n} &= \frac{\partial u}{\partial x_n} - \lambda p_n = 0 \\
\frac{\partial L}{\partial \lambda} &= m - p_1x_1 - p_2x_2 = 0
\end{aligned} \tag{4}$$

The system of equations (4) provides the solution to one particular problem, with given prices and income. Inspection of these equations would tell us that the solution to (4) depends only on prices,

income, and the utility function. So, for a given utility function, the following demand functions can be derived:

$$\begin{aligned} x_1 &= f^1(p_1, p_2, \ldots p_n, m) \\ x_2 &= f^2(p_1, p_2, \ldots p_n, m) \\ &\vdots \\ x_n &= f^n(p_1, p_2, \ldots p_n, m) \\ \lambda &= f\ (p_1, p_2, \ldots p_n, m) \end{aligned} \tag{5}$$

These equations tell us that a person's demand for a good is affected by the price of the good, price of other goods including substitutes and complements, and his income.

To see the relationship between the demand for a good and its own price only, values of the other variables in the demand equation are substituted in the equation. By doing this, we are assuming that these other variables remain constant. This is called the "ceteris paribus" assumption which literally means "other things being equal." Using this assumption will result into a demand equation in its simplest form:

$$x_i = f(p_i) \tag{6}$$

which says that the demand for good x_i is a function of its price p_i.

Usually the demand for a normal good is inversely related to its price. This is because of the fact that a rational person will always buy less of a good if its price is increased, and will buy more if the price is decreased. The simple demand equation when graphed, illustrates this mechanism in Figure 2.1:

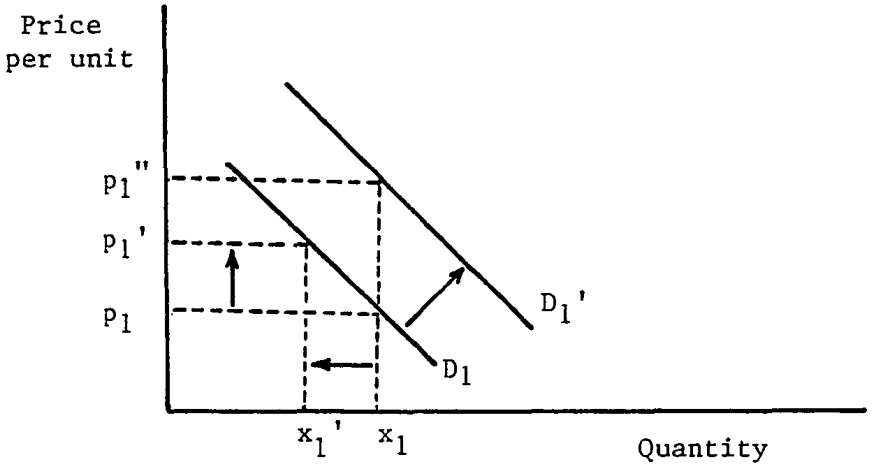


Figure 2.1 Hypothetical Demand Curve

With a given income a consumer's demand for a certain good is a negative function of its price. If a person's demand curve is D_1, then at price p_1, he buys the quantity x_1 of the good. Now if the price is increased to p_1', then he would buy only x_1'.

Suppose that his income has increased. His demand curve will shift outward to D_1'. With this new demand curve, this person is still willing to buy the quantity x_1 even if the price is increased to $p_1"$.

A producer's demand for inputs is different from the consumer's demand for consumption goods. A producer demands inputs for producing a given product for sale. The demand for a production input is called "derived demand." This is estimated in the same way as the consumer's demand, except that in derived demand estimation, the firm maximizes its profit subject to a given production function or technology.

Residential demand for water traditionally would fall under the consumer type of demand. But the new theory of consumer behavior

(Michael and Becker, 1973) views a household as a unit which produces a commodity out of the goods it buys from the market. In this framework, the goods bought from the market are considered inputs to the production process in the household. Thus the demand for water in this case is a derived demand analogous to the derived demand by a firm for any input for production.

Industrial and commercial demand would fall under the category of derived demand because industrial and commercial establishments use water in the production of goods and services.

Institutional or public demand for water may either be viewed as consumer or derived demand.

In empirical works (Pindyck and Rubinfeld, 1976) demand is usually derived by econometric methods, specifically by regressing consumption against factors which affect it. The procedure would start with a model specification like:

$$\text{Consumption} = f(\text{price, other variables})$$

Once the model has been estimated, i.e., coefficients are found to be statistically significant, consumption can be expressed as a function of price only by substituting values for the other variables into the equation. The resulting function is a simple demand curve similar to the one mentioned earlier in Equation (6).

2.2 Elasticity of Demand

The preceding section has pointed out that demand is affected by price and other variables. When any of these variables changes, demand changes. This interaction is important for management purposes (Grima,

1972). Variables which can be controlled are manipulated by management in order to effect a desired change in the demand. Such variables are called "policy variables."

The management has to assess the responsiveness of demand to changes in policy variables so that they could at least estimate how much change in the policy is necessary to bring about the desired change in demand. This responsiveness is called the elasticity of demand.

With price as the policy variable, the price elasticity of demand is the percentage change in the quantity demanded divided by the percentage change in the price. In symbols,

$$E_i = \frac{\Delta x_i / x_i}{\Delta p_i / p_i} \tag{7}$$

where E_i = price elasticity of demand for good i;

Δx_i = change in quantity demanded for good i;

x_i = original quantity demanded for good i;

Δp_i = change in price of good i; and

p_i = original price of good i.

Elasticities are not constant. They change when measured at the different points along the demand curve. In econometrics, the demand curve is usually represented by a multivariate regression line. The elasticities usually printed out by computer packages are calculated at the point of the mean of each of the independent variables. For a given independent variable, the elasticity of the dependent variable is equal to the product of the estimated coefficient and the mean value of the independent variable divided by the mean value of the dependent

variable. Suppose we have the model

$$x_1 = b_0 + b_1 p_1 + b_2 p_2 \tag{8}$$

The elasticity of demand x_1 with respect to its price p_1 at the mean is:

$$E_1 = b_1 \frac{\bar{p}_1}{\bar{x}_1} \tag{9}$$

where: E_1 = elasticity of x_1 with respect to p_1

b_1 = estimated coefficient of p_1

$\bar{p}_1$ = mean of p_1

$\bar{x}_1$ = mean of x_1

2.3 Demand Elasticity in the Case of Increasing Block Rates

There is a difficulty involved in estimating the price elasticity when the pricing structure takes the form of increasing block rates (IBR). Billings and Agthe (1980) argued that in the case of IBR, the average price, defined as the ratio of revenue to the quantity consumed, which was used by several researchers like Wong (1972), Gottlieb (1963) and others, would result to excessively large estimates of the price elasticity of demand.

Consider the pricing shown in Figure 2.2. This is an example of an example of an increasing block structure where the first block of 10 cu.m. of water is priced at $0.20 per cu.m., the next 10 cu.m. of water is priced at $0.30 per cu.m., and the next block, which is unlimited, is priced at $0.40 per cu.m.

Billings and Agthe (1980) proposed two measures or concepts of price. The first is the price (domestic marginal price, or DMP) for the last block within which the consumption level x_1 of the average

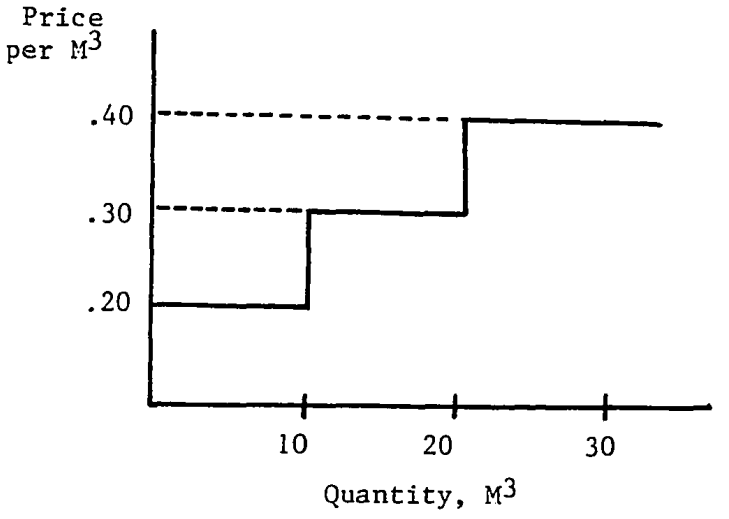


Figure 2.2 Block Pricing

household falls. This block is called the "marginal block." The second is the difference price DP which is equal to the actual water bill minus the bill if the water was sold at the price DMP. To clarify this concept, let us compute the difference price if the average household consumes x_1 = 30 cu.m. of water per month.

Actual Bill = cost of 1st block + cost of 2nd block + cost of 3rd block

= (10 x .2) + (10 x .3) + (10 x .4) = \$9.00

Bill if water sold at DMP = (30 x .4) = \$12.00

Difference price DP = 9 - 12 = -\$3.00

The difference price represents a savings to the consumer compared to what would be paid if all water were priced at the marginal rate (unit price of the marginal block, or DMP), thereby providing an implicit subsidy for water consumed in the intramarginal blocks.

They also argued that the use of price defined by MP alone as in the study of Howe and Linaweaver (1967) would also lead to erroneous results.

With IBR, the derivative of demand x with respect to the difference price DP, that is (dx/dDP), remains negative, and the value of DP is itself negative. This will result in an elasticity (with respect to DP) with a positive sign, which simply means that a case of IBR is being examined.

In applying the two price concepts in econometrics, since both prices enter the demand model, there are two price elasticities that are estimated by the computer: one is the elasticity of demand with respect to the price DMP of the marginal block; and the price elasticity with respect to the difference price DP.

There are three kinds of rate changes in IBR under which the manner of interpreting the price elasticities are specified. First is where the rate schedule shifts upward so that all the rates rise by the same amount keeping the value of difference price DP constant. If this happens, since DP is constant, the elasticity with respect to DMP describes the whole impact of the rate changes. To see how DP assumes a constant value, let us consider an example where 30 cu.m. is consumed and where the block rates under policy 1 are increased by $0.10 under policy 2:

Blocks	Rate Policy 1	Rate Policy 2
1st block (10 M^3)	\$ .20/M^3	\$ .30/M^3
2nd block (10 M^3)	\$ .30/M^3	\$ .40/M^3
3rd block (20 M^3)	\$ .40/M^3	\$ .50/M^3

Difference price under policy 1 is:

$$DP_1 = (10 \times .2) + (10 \times .3) + (10 \times .4) - (30 \times .4) = -3$$

Difference price under policy 2 is:

$$DP_2 = (10 \times .3) + (10 \times .4) + (10 \times .5) - (30 \times .5) = -3$$

Comparison of DP_1 and DP_2 proves that the difference price remains constant under the above price increase.

Second is where only the rates for intramarginal blocks change, leaving DMP constant. Under this situation, since DMP is constant, the elasticity with respect to DP describes the entire impact of the price change.

Third is the case where the values of both prices change. Under this, the total impact is found by summing the two elasticities. The sum should be absolute but the sign should be negative, the usual sign of price elasticity.

2.4 Theory of Water Consumption Projection

The terms "forecasting" and "projection" have been used interchangeably in the literature. But Ciriacy-Wantrup (1961) points out the difference by using the term "prediction" to mean generally any process of inductive inference where all the undetermined cases of a theory are future cases. Predictions differ with respect to the degree of articulation the way hypotheses (or theory) are formulated and with respect to the degree of quantification. It is on the basis of these differences that sometimes "projection" is differentiated from "forecast." Thus prediction is the general term for projection and forecasting.

Although the two classes of predictions have not been clearly delineated in scientific literature, it seems safe to use the term "forecast" to refer to the more sophisticated type of prediction, and the term "projection" to the less sophisticated one.

With this difference in mind, the following section enumerates and discusses the different techniques of predicting water consumption. Altogether, these techniques constitute the theory on this subject.

A. Prediction Techniques

A.1 Econometric Forecasting

Pindyck and Rubinfeld (1976) define econometric forecasting as a process of making a quantitative estimate (or set of estimates) about the likelihood of the future events based on past and current information. This set of "past and current information" is embodied in the form of a single-equation structural model. This implies the notion that forecasting applies solely to time series problems.

There are two types of forecasting namely: ex post and ex ante. Both types predict values of a dependent variable beyond the estimation period of the independent variable.

The distinction is that in an ex post forecast, the forecast period is such that observations on both the endogenous variables and the exogenous explanatory variables are known with some degree of certainty; while in an ex ante forecast, the explanatory variables used are not known with certainty. The accuracy of the forecast depends on the quality of the data and correct specification of the variables including the length of the lags associated with the explanatory variables. This

distinction, as made by Pindyck and Rubinfeld (1976), is shown in Figure 2.3.

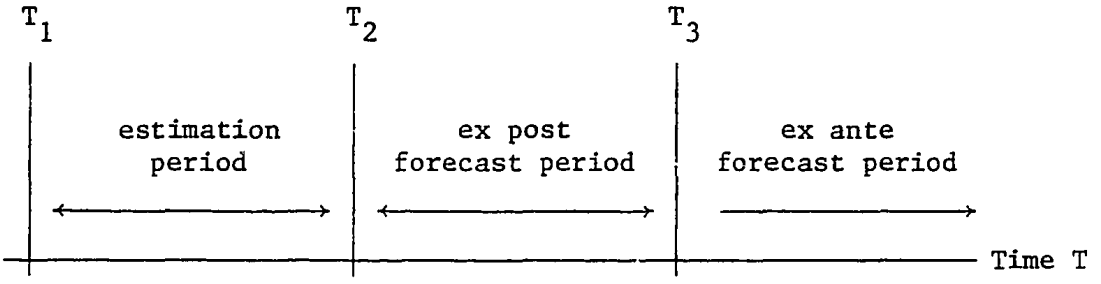


Figure 2.3 Types of Forecasting Based on Time

Another distinction must also be made between conditional and unconditional forecasts. In an unconditional forecast, the values of all the explanatory variables in the forecasting equation are known with certainty; while in the conditional forecast, the values for one or more explanatory variables are not known with certainty, so that the forecast for them must be used to arrive at the forecast of the dependent variable.

Econometric forecasting involves estimating a regression model expressing the consumption, either in aggregate terms or on a per unit basis, as function of a set of economic, social, and physical explanatory variables. These variables are specified based upon some existing economic, regional science, land use planning, and other social science theories.

Consider a simple two-variable regression model expressing water consumption W_t at time t as a function of water price p_t at time t:

$$W_t = b_0 + b_t p_t + V \qquad (10)$$

where b_0 is the intercept; b_t is the coefficient of price p_t; and V is the error term.

Then, given a known value of p_{t+1}, the unconditional forecast for W in time t + 1 is given by:

$$W_{t+1} = b_0 + b_t p_{t+1} \tag{11}$$

The conditional forecast for W in time t + 1, conditional upon the forecast of p^f_{t+1} is:

$$W_{t+1} = b_0 + b_t p^f_{t+1} \tag{12}$$

Econometric forecasting or rather projection, actually predicts consumption rather than demand. Every point on the estimated consumption function when graphed against time, is an intersection between the supply and aggregate demand curves at that point in time. Refer to Figure 2.4.

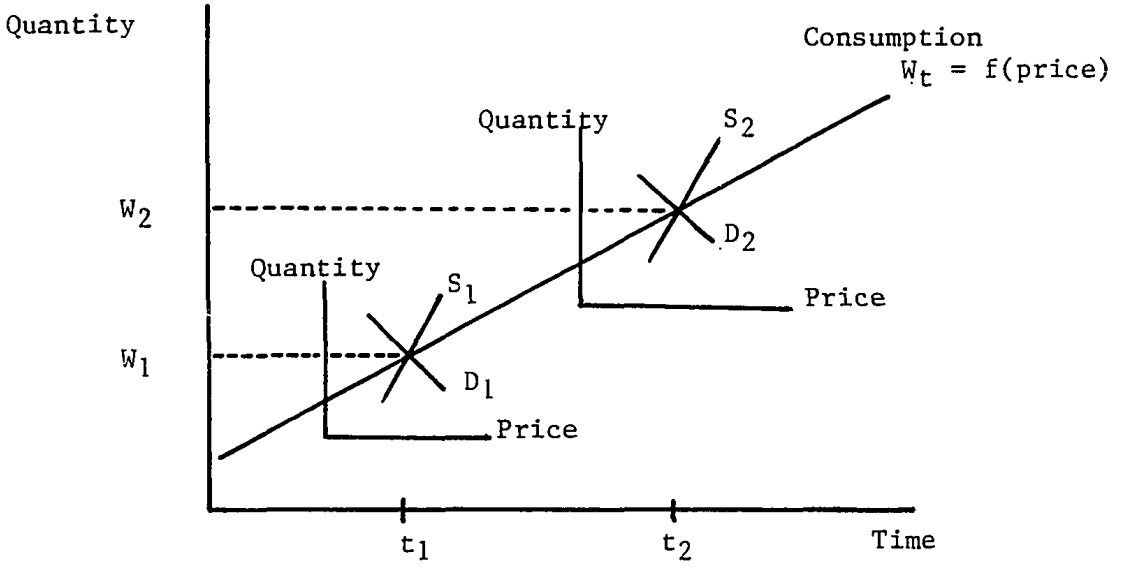


Figure 2.4 Consumption Projection

The estimated consumption function $W_t = f(p_t)$ is plotted against time. In year t_1, the consumption level W_1 is defined by the intersection between the demand and supply curves D_1 and S_1, respectively. Then in year t_2, the consumption level W_2 is defined by the intersection between the demand D_2 and supply S_2, respectively.

A.2 Simplified Rules of Thumb: Population Based

This approach is based on the concept that a person "needs" or "requires" a certain quantity of water in his daily activities. This specified quantity of water, which is called the "use factor" and denoted here as "q," is computed in three ways. First is by approximately accounting or assigning the quantity of water required for every household activity (Reid, 1970). Thus every household activity like food preparation, bathing, laundry, and so on, each uses a certain amount of water. Summing these quantities up and dividing by the total household members results in a per capita use factor. Reid's (1970) approach of course applies only to residential use.

Second is by computing from the past consumption data. Consumption, on aggregate or by major type of use (i.e., residential, commercial, industrial, institutional) basis is divided by the total population of the region to arrive at a per capita use factor.

Third, the use factor can be derived by empirical formula. Two formulae for use factor have been derived for metered supply area in the United States. Given the population size of the city or region, Capen (1937) and Csallany (1965) derived different formulae:

$$\text{Capen's formula:} \quad q = 54(G/1000)^{0.125} \tag{13}$$

where q is the use factor in gallon per capita per day; and G is population of the city.

$$\text{Csallany's formula:} \quad q = 34 \log G/40 \tag{14}$$

where q is as defined above; and G is the population size and must be greater than 360.

Having the estimate for the use factor "q," the projected aggregate consumption in year t would be the product of q and the projected population in year t:

$$W_t = q \cdot G_t \tag{15}$$

where W_t is the projected water consumption in year t; q is the use factor per capita; and G_t is the projected population of the region in year t. The unit (of measure) for W_t depends on the unit for q.

A.3 Simplified Rules of Thumb: Land-Use Based

This approach derives a use factor per unit area at a given overall population density (Camp Dresser and McKee, 1976a). There are two ways of estimating this use factor. First is where a specified area of a given land use type is selected. The quantity of water that flows in and out (usable water and not wastewater) of the area is actually measured at appropriate points. The difference between these two flows is then divided by the area to arrive at a use factor per unit area of that type of land use.

Second is by using consumption data. Classification of the types of water uses corresponds with the classification of the types of land uses. Thus for example, having the data on residential water use, we can divide this by the residential area to arrive at the water use

factor per unit residential area of a given population density. The water use projection therefore would be based upon the projection of a given land use and a factor per unit area of a specified overall population density:

$$W_t = \Sigma_{i=1}^{N} l_{it} \cdot f_{it} \qquad (16)$$

where W_t = projected total water demand at time t. The unit depends on the units for l_{it} and f_{it}.

l_{it} = projected area of land use i at time t

f_{it} = projected use factor for land use i at time t

N = total number of land uses

A variation of this would have a weighted use factor applicable for the total area, so that:

$$W_t = A_t \cdot f_t \qquad (17)$$

where W_t as defined above

A_t = projected total area of the city in year t

f_t = projected overall weighted use factor in year t

A.4 Forecasts based on Economic Base Studies and Water Pricing Policies

Howe (1968) proposed an approach that would follow the following sequence of steps:

1. Undertake an economic base study with forecasts of activity levels for a few sectors;
2. Make preliminary estimates of water demands using historical coefficients of water uses;
3. Formulate a preliminary water system design with cost estimate to meet the estimated demand computed in (2);

4. Postulate financial and pricing policies for the urban utility;
5. Make detailed forecasts of demands in the major sectors (i.e., residential, commercial, industrial, public) based upon estimated demand functions and approximate water price structures determined in steps 3 and 4.

Other examples of economic base studies are input-output analysis and an export-base study. The input-output analysis derives water use coefficients applicable to each industrial sector of the economy. The export base study derives a "service-to-export ratio" (Irving, 1958) which defines the level of local service industry, say water industry, needed to support the extrapolated export base and associated population.

A.5 Production Process or Derived Demand Approach

Bower (1968) suggested that, given an economic base study on the projection of demands for the outputs of the various heavy water-using industries, forecasting industrial water demand involves the following steps:

1. Classify existing plants according to process, region, product mix and size;
2. Forecast trend in production technology, that is, production processes, product mix, and regional location patterns;
3. Relate the production process-product mix combinations to gross water applied and waste loads generated;
4. Analyze the alternative internal water utilization patterns and costs thereof, considering the in-plant water quantity

requirements in relation to output quality and cost of other inputs;

5. Forecast political decision on water pricing policy and on waste discharge;

Then he says that given 3, 4, and 5, water demand can be forecasted.

The above approach is stated at the macro level, but it is unclear how the approach would work at the firm level. At the firm level, suppose the firm has a production function:

$$Q_0 = a_0 x_1^{\alpha_1} x_2^{\alpha_2} \tag{18}$$

where Q_0 = quantity of output in physical units

a_0 = parameter

x_1 and x_2 are inputs

α_1, α_2 = elasticity of output with respect to x_1 and x_2, respectively.

Given the forecast of demand from an economic base study, we can then estimate the firm's derived demand (Nerlove, 1965) for water. Assuming that the firm behaves to maximize its profits,

$$\text{Max profit} = p_0 Q_0 - p_1 x_1 - p_2 x_2 \tag{19}$$

where p_0 is the price of the product or output Q_0; p_1 and p_2 are prices of inputs x_1 and x_2, respectively.

Substituting the production function here, and setting the partial derivatives of the Langrangian function for the profit expression with respect to the multiplier, Q, x_1, and x_2, equal to zero, we will have the conditions from which we can solve the derived demand for inputs x_1

and x_2. Let us say x_1 is water, then following Nerlove (1965), we can have the derived demand for water as:

$$x_1 = \frac{p_0}{p_1} \alpha_1 Q_0 \tag{20}$$

Doing this process for all industrial classes, an aggregate forecast of industrial demand for water is arrived at.

A.6 Water Duty Approach

This approach, used by Camp, Dresser and McKee Engineers, estimates the theoretical industrial consumption for a region or a metro area as:

$$TIC = IA \times PoD \times FDWD \tag{21}$$

where: TIC = theoretical industrial consumption

IA = land use area (industrial) in land use map

PoD = percent of development, or the degree to which an area is developed, i.e., 80%

FDWD = Full development water duty. This is a use factor in terms of quantity of water use per unit area. This is derived by selecting a fully developed area and observing the water consumption (either actually or from the water bills). Dividing this consumption by the land use area gives the FDWD.

This approach can also be applied to forecast commercial consumption.

2.5 Summary of Empirical Studies

Metcalf (1926), using data for 30 cities in the United States, found out that per capita water consumption is negatively affected by

water rates (prices), and positively by the size of the city population. To cite a figure from his table, a 20 percent increase in population would increase per capita consumption by 2 percent; and a 20 percent increase in rates would decrease per capita consumption by 13 percent.

Gottlieb (1963), using cross section data of 1962 and 1957 in Kansas, regressed in logarithmic form aggregate demand against average household income and price, and found out that income and price elasticities in 1952 were 0.45 and -1.23 respectively; and in 1957, were 0.58 and -0.65 respectively. The coefficient of regression R was reported to be .67 and .69 in the same years, respectively.

Headly (1963), using cross section data for 1950 and 1959, and time series data from 1950 to 1959 for 14 cities in the San Francisco-Oakland Metro Area, analyzed the relationship between residential water consumption and family income. He concluded that there is a significant relationship between family income and residential water consumption, but pointed out that income elasticities derived from time series analysis are more useful for planning purposes than the income elasticities derived from cross-section data.

Howe and Linaweaver, Jr (1967), in their study from 1961 to 1966 using cross-section data from 39 areas scattered all over the United States, formulated models of domestic water demand and sprinkling water demand in different residential areas such as metered, flat rate, septic tank, and apartment areas. Their major findings were:

1. Demand behavior is best represented by separate linear equations for different types of residential areas.

2. Domestic demands are quite inelastic, evidenced by the price elasticity of -0.23 for metered public sewer areas.
3. The number of persons per dwelling unit strongly affects domestic demand in flat rate and septic tank areas, and it appears to be the only significant determinant in the septic tank areas.
4. Billing frequency and regional price index do not have significant impact on demand or upon price elasticities.
5. Sprinkling demands are elastic with respect to price, but less on the West Coast in the East.
6. Elasticity of demand is about -0.4, which is a weighted average of the domestic and sprinkling elasticities.

North (1967), using cross-section data from a stratified ramdom sampling of households in each of the 14 municipal districts in Georgia (1965, 1966), regressed yearly water consumption per household against water price and yearly income. He found an income elasticity of 0.83 and price elasticity of -0.67.

Meroz (1968) estimated the effects of income, prices, weather (temperature and rainfall), and number of people served on the consumption of water from cross-section data from 38 cities of developing countries in Africa, Asia, and Latin America. He reported a price elasticity of -.43 at the mean values of 42.5 gpcd consumption and price of $0.26 per 1000 gallons. The income elasticity was .33 with income (GDP per cap) at $286 and consumption and price at the same mean values as above.

Saunders (1969) identified the factors related to water usage in areas both on a inter- and intra-community basis. For the

inter-community study, where he used 1960 data on variables from the 93 largest United States cities, he found that population, land area, value added, and number of cars were the most important variables affecting total water usage. For the intra-community study, using data from Louisville, he found that assessed value (proxy for income), total white collar workers, and total households to be the most important factors affecting daily water consumption per service account.

Turnovsky (1969) studied the response of consumer demand for water to uncertainty in water supply. Using a combination of cross-section (1962 and 1965) and time series data (1950-65, which were also used to derive supply variance), he found that domestic consumption is affected by the variance in supply, average price of water, housing space, and population under 18 years of age. The average price elasticity of domestic demand was -0.3. He also reported that industrial consumption was affected also by the variance of supply, average price of water, and industrial production. The average price elasticity for industrial use was -0.5.

Reid (1970) argues that planning should be geared toward the attainment of goals, toward making things happen. He emphasizes a goal-oriented water requirement model. He suggests that if the goal of living standard is such that an average family of 4 in the future will have 2 cars, 2 bathrooms, 1 garbage disposal unit, 1 dishwater, 1 washer, the domestic consumption should be computed according to requirements as follows:

Family use/day	gal/day
Cooking and drinking: 2 gal/per x 4	8
Dishwasher: 5 gal/load x 3 load/day	15
Toilet: (2) 4 flush/per x 6 gal/flush x 4	96
Bathing: 20 gal/bath x 4	80
Laundry: 6 loads/week x 40 gal/load/7	34
Sprinkling: 2 hrs/day x 90 days/yr x 200 gal/hr	100
Car Wash: (2 car x 1 wash/car/mo x 150 gal/wash)/30	10
Garbage disposal: 1 percent x 343	3
Total	346
Unit domestic consumption: 346/4 = 86.5 gal/cap/day	

Hanke (1970), using time series data from 1956-68 in Boulder, Colorado, analyzed the effects on the residential water use (broken down into domestic and sprinkoing use) of changing from a flat rate price structure to a metered rate structure. The results of the study were: 1. sprinkling demands were reduced by the introduction of meters; 2. sprinkling use subsequently continued to decline after the introduction of meters; 3. domestic use (in house) was reduced by 36 percent after the installation of meters; and 4. domestic use stabilized at these low levels.

Wong (1972), using both time series (1951-1961) and cross sectional (1961) data to assess the influences of price, income, and average summer temperature on water consumption in Chicago and surrounding areas, found that: income and summer temperature were the only significant variables for Chicago; while for the surrounding areas, only price and summer temperature affected the demand.

De Rooy (1974) determined the sensitivity of the industrial demand for water to changes in price. Derived demand equations for four different types of industries (cooling, processing, steam generation, and sanitation) were formulated and tested using cross-section data from 30 large industrial plants in New Jersey. Ordinary least square estimates of the equations show that demands by cooling, processing, and steam generation industries are affected by their output, price of water, and technological improvement, while the demands by sanitation industries are affected only by their level of imployment. The reported price elasticities are: -.894 for cooling; -.354 for processing; and -.59 for steam generation. The study reports a very low significance level for the price elasticity for processing demand.

Mercer and Morgan (1974) derived water use per employee by two digit Standard Industrial Classification (SIC) level for use in the estimation of commercial, industrial and governmental water use for local areas. The relevant 2-digit classes are agriculture, mining, construction, manufacturing, transportation and utilities, wholesale and retail trade, finance, services, state and local government.

McCuen et al (1975) derived by linear regression commercial water use relationships for different types of commercial establishments in four shopping centers, one of which is in Greendale, Wisconsin, one in Baltimore, Maryland, and two in Washington D.C. They found out that, for department stores without restaurants, water use is affected by the gross area occupied by the store. For the mall shops, water use is affected by the gross store area and by the average number of employees per shift. They indicated that, for forecasting water demand by commercial establishments, water use relationships should be derived

for each of the four digit Standard Industrial Classification (SIC) categories.

Katzman (1977) estimated the income elasticity of demand for domestic water from a cross-section analysis of a random sample of 1400 households in Penang, Malaysia to be zero for low income families (per capita income less than US $300) and 0.2 to 0.4 for higher income families. He estimated a short run price elasticity of -0.1 to -0.2 from a time series (1970 to 1975) analysis of a sub-sample of varying income levels.

Lynne et al.(1978), using cross-section data, estimated the derived demand for water by the commercial establishments in the Miami, Florida area. They reported the following price elasticities: -1.33 for department stores; -.762 for grocery stores and supermarkets; -.24 for motels and hotels; -.174 for eating and drinking establishements; and -.48 for other commercial establishments like furniture, drug, hardware, men's and women's apparel stores.

Billings and Agthe (1980), using a new approach for analyzing price elasticities in the case of increasing block rates as described earlier, estimated from a time series data a consumption function for Tucson, Arizona. They found that monthly household consumption is affected by price (i.e. difference price, and price for the marginal block), monthly income, and the difference between evapo-transpiration and rainfall. Their best fitting equation reported a total price elasticity of -.39. No income elasticity is reported by their article.

Yamauchi (1981), after separating both the seasonal and annual trend components of water consumption patterns in Honolulu, found that economic factors such as per capita income and water rates were largely

responsible for the rising trend in average annual per capita water consumption. He reported an index of price elasticity of -.021 and an income elasticity of .376 over the period 1960-1978. The index of price elasticity, as derived by using a dummy variable, is not the usual elasticity but rather an index of arc elasticity relative to the frequencies (explicit) and magnitudes (implied) of water rate changes over time.

2.6 Importance of Empirical Studies to Planning

Water supply planning, which will be discussed in the next chapter, involves the projection of water consumption and the expansion of the capacity of the system to meet such consumption at the right size and timing of the project.

Closely related to water supply planning is the field of supply management which manipulates the way water is supplied to consumers. This manipulation comes in the form of metering, scheduling supply service for a certain number of hours, intentional tolerance of supply shortage, and water pricing. Because of the possible effects of these manipulative policies on consumers' behavior and finally on demand, this field may alternatively be called water demand management (Grima, 1972).

The empirical studies have dealt on aspects of water supply planning and management particularly on projection of water consumption and policy variables identification. (See Table 2.1) Most of these studies have derived water consumption functions which can be used to project water consumption. These functions are in terms of variables which are of economic, social, or physical nature. In most cases,

Table 2.1. Summary Results of Empirical Studies

Author/year	Study Area	Dependent Variable	Significant Explanatory Variables	e_p	e_i	R^2
Metcalf, 1926	30 U.S. cities	Consumption/capita/day	Water rates, population growth	- .502		
Gottlieb, 1963	Kansas State	Aggregate demand/year	Household income, price	- .65	.58	.69
Headly, 1963	San Francisco-Oakland Area	Use/capita/day	Family income		.40	.69
Howe & Linaweaver, 1967	39 U.S. areas	Use/dwelling unit/day	Domestic: Value of homes, price	- .23	.35	.70
			Sprinkling: Irrigable area, price, value of homes	- .70[a]	.43[a]	.72[a]
				-1.6[b]	1.4[b]	.92[b]
North, 1967	15 cities in Georgia	Use/household/year	Among communities: price, income	- .67	.83	.69
			Within communities: number of persons, no. of baths, lawn area, value of homes	- .61	.38	.54
Meroz, 1968	38 cities of developing countries	Gallon/capita/day	Price, income (GDP/cap)	- .43	.33	.58
Saunders, 1969	94 U.S. cities	Use/account/day	Among communities: city size, economic level, growth effect			
			Within a community: income, population			
Turnovsky, 1969	19 towns in Massachusetts	Use/capita/day	Residential: housing, space, price, variance of supply	- .3	1.2	.82
			Industrial: variance of supply, price, industrial production	- .5		.86
Hanke, 1970	Boulder, CO.	Use/house/year	Flat rate, metered rate			
Wong, 1972	Chicago and 103 communities	Use/capita/year	Within community: income, summer temperature		.195	.81
			Among communities: price, summer temperature	- .28		.57
De Rooy, 1974	30 industries in N.J.	Total use	Output, price, technology change	- .89		.806[c]
				- .354		.651[d]
				- .59		.678[e]
McCuen et al., 1975	4 shopping centers in U.S.	Total use	Dept. stores: gross area			.915[f]
			Mallshops: gross area, employment/ shift			.826[g]
						.989[h]
Katzman, 1977	Penang, Malaysia	Use/household/month	No. of person/family, income, urban dummy variable	- .1 to - .2	.45	.81

Table 2.1 (continued) Summary Results of Empirical Studies

Author/year	Study Area	Dependent Variable	Significant Explanatory Variables	e_p	e_1	R^2
Lynne et al., 1978	Miami, FL	Monthly use	Dept. Stores: price, store area, restaurant area	-1.33		.78
			Grocery & Supermkt: price, store area, bakery/kitchen dummy	- .762		.73
			Motels/Hotels: price, no. of rooms, price of room, dining/bar area	- .24		.96
			Eating/drinking Est.: price, dining room area, bar room area	- .174		.25
			Others: price, store area, no. of hours open, air-condition dummy	- .48		.35
Billings & Agthe, 1980	Tucson, AZ	Use/household/ month	Price of marginal block, difference price, personal income/household, Weather variable	- .39 (log linear) - .63 (linear)		
Yamauchi, 1981	Honolulu	Use/capita/year	Personal income per capita, water rates, dummy variable	- .021[i]	.376	

Notes:

[a] West Coast

[b] East Coast

[c] Cooling industries

[d] Processing industries

[e] steam generation

[f] department stores

[g] women's shops

[h] men's shops

[i] index of price elasticity derived by using a dummy variable

e_p-price elasticity

e_1-income elasticity

price and income are the significant variables which show that water is not different from other economic goods. One study (Turnovsky, 1969) showed that the variance of supply affects consumption. These mean that pricing and variation of supply can be used as policies to alter consumer behavior.

Estimated water consumption functions present price and income elasticities. With the information on elasticities, management can estimate how much changes in the policy variables are needed to bring about a desired change in the consumption level.

Other studies have expressed water consumption in terms of physical variables rather than economic ones, while others like Reid (1970) have challenged the economic or econometric approach by proposing a straightforward goal-oriented requirement approach to water use projection. Perhaps this view is consistent with the claim that the economic approach to water demand projection is difficult because other important variables such as changes in institutions, technology and taste and preferences cannot be quantified and are therefore neglected in the analysis (Ciriacy-Wantrup, 1959). Yamauchi and Oh (1974) also found that for practical purposes refinements in the requirements approach can serve just as well or better than the econometric demand approach. Examination of the approaches by Howe (1968) and Bower (1968) attests to the difficulty of using the pure economic approaches to demand projection.

Most of the studies have dealt with residential uses or if not aggregate uses which combine all types of uses. The works of Mercer and Morgan (1974), De Rooy (1974), and Lynne et al. (1978) indicate

that more attention are being devoted to study the other types of water uses--industrial, commercial, and institutional uses.

Overall, the empirical studies give us a variety of variables to consider when undertaking a study for planning purposes; a range of elasticities with which to compare one's findings; and a collection of lessons from the results of the different policies tested in the studies.

CHAPTER III

THEORY OF WATER SUPPLY CAPACITY EXPANSION PLANNING

3.1 Definition of Capacity Expansion Planning

Capacity expansion planning is simply the process of increasing the capacity of a system to deliver goods or services in response to an increase in the demand for them. In a water supply system, this capacity refers to the quantity of water which the system can possibly supply to a specified level of reliability (e.g. 95% probability). Because water supply expansion requires the investment of a large amount of resources, it has to be planned very carefully.

In planning water supply capacity expansion, three major decisions have to be made. First is the selection of what supply and associated facilities to develop from among the alternatives available. The required addition to supply can be achieved by: rehabilitating the existing system to increase its capacity; importing water; or by constructing new projects such as surface water impounding dams, groundwater wells, or sea-water desalting plants. The second decision is to select how much capacity to add, and the scale of the project to build. A very small addition may be impractical because of high unit costs, and because there may be economies of scale in bigger additions; whereas very large additions may result in a long period of idle excess capacity, with consequent waste of resources. The third decision is to select the time to build the project. Sometimes a project is built right at the point in time when demand catches up with supply, and

sometimes a project may be delayed intentionally in order to postpone investment costs even at the risk of incurring water supply deficits.

As a prerequisite to the above decision-making activities, the planning horizon must be defined and the demand must be projected up to that horizon.

The time horizon, according to Loucks et al. (1982, p. 39), can be selected as far in the future as the projections of future costs and capacity demands are reasonably realiable, but not for so short a period as to "influence the size of the expansion in the current period." This means that it is not advisable to make plans beyond the time for which our information on costs and demand is reliable. Also, if our planning horizon is very short, say one year, the size of the expansion project will be so small as to be uneconomic. The product of these activities is an expansion plan which is a schedule for developing a given number of economically-sized alternative projects required to satisfy a given water demand over a selected time horizon. Such expansion plans can be shown in graph form as in Figure 3.1 below:

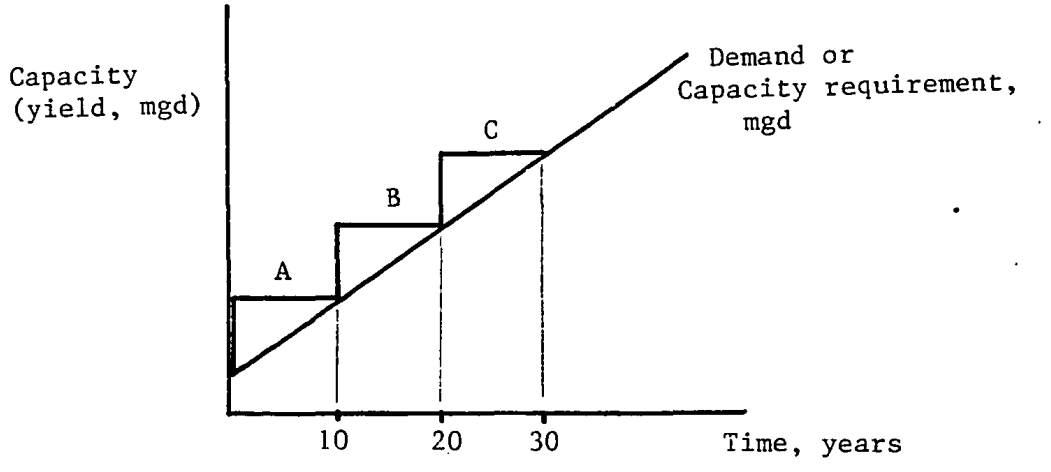


Figure 3.1 Hypothetical Expansion Plan

According to this plan, in order to satisfy at all times the demand within the time horizon of 30 years, project A should be built in year 0, project B in year 10, and project C in year 20. Project A has the capacity to meet the demand through year 9, project B will meet the demand through year 19, and project C will meet the demand through year 30.

3.2 Approaches to Supply Expansion Planning

In general, water supply expansion planning has been approached in two ways namely: the traditional approach; and a second which I will call the "new" approach. The details of each approach are presented below.

A. Traditional Approach

The discussion of this approach was derived from the water supply literature as well as from the reports submitted by the different consultants, both previous and present, to the MWSS. The steps are the following.

A.1 Consumption Projection

Traditionally, there are three techniques used to project demand. First, is the population-based simplified rule of thumb. This technique, as discussed in Chapter II (Section 2.4, A.2), employs the "use factor" or water requirement per capita. The projected demand in year t is computed as the product of the use factor and the projected population in year t.

The second is the land use-based rule of thumb. As discussed in Chapter II (Section 2.4, A.3), this technique also employs a use factor

which is on a per unit area of a land use category. The projected demand for a given land use category is computed as the product of the use factor and the projected area of that land use category. The total projected consumption of the city is the sum of all of the projected demands for all of the land uses.

The third is the water duty approach which is discussed in Chapter II (Section 2.4, A.6). This technique is usually used to project industrial as well as commercial consumption. In this approach a use factor called "full development water duty" (FDWD) is used. The projected water consumption of a land use category is estimated as the product of this FDWD factor, the land use area, and the percent (or degree) of development of that land use area.

As for the population projection needed for the first technique, engineers usually project population by means of land use analysis, and historically their projections have not been bad. In fact, a study of how well engineers project population made by Berthouex and Thiele (1974) found that engineers' projections of population are "about as accurate as those made by professional demographers, although the engineers are dealing with smaller population units."

A.2 Capacity Expansion Planning

Once the demand has been projected, usually in the form of a time series over a specific time horizon, the next step is decide on the size and timing of expansion.

Conventionally, engineers formulate and evaluate different supply alternatives in the region. Each alternative site has its own range of available yields or capacities. For each site a "best" project size,

in terms of yield or capacity, is formulated based on storage cost and yield data. In general, the lowest unit cost is the criterion. Evaluation normally presents these formulated projects with their costs of construction, operation and maintenance costs, and resulting unit costs of water along with their capacities. These data are needed for expansion planning.

Scheduling problems have been approached in two ways. The first is by simple ranking of alternatives by the least cost per unit quantity of water criterion. This ranking indicates the order in which the alternatives are to be developed. This means that the project with the least cost per unit quantity of water is developed first, while the one with the highest unit cost is developed last. The second way is by optimal sequencing. Given the information on capacities and costs of the alternatives, the optimal sequence can be achieved either by dynamic programming (Butcher et al., 1969; Morin and Esogbue, 1971), network theory (Doulliez and Rao, 1975), or by some other scheduling techniques (Conway et al., 1967) in operations research. Assuming that plan formulation yields a number of independent alternatives, each with data on water yields and costs, the optimal sequencing method will find the timing and the order of constructing these alternative projects such that (1) water demands are met at all times and (2) the present value of total construction and OMR costs is minimized. This order is the optimal sequence or plan.

The two scheduling approaches (i.e., ranking and optimal sequencing) do not determine the sizes of the alternative projects. Once the sizes are specified, they determine the order of constructing the alternatives, given the yield and cost of development of each.

In the survey and evaluation of alternatives, the determination of the size that can be tapped is affected by the actual physical configuration, costs, and water yields of the site. Often, large projects are divided into smaller sub-projects called "stages" which are identifiable and developable parts or sections of the whole source. If the local physical condition requires that the whole source be tapped by one dam, then the "best" dam size as determined by cost and yield data is taken as the size of the expansion derivable from that source. The source may or may not be divisible into smaller units. In effect project sizes are controlled primarily by physical conditions and cost.

Conventionally, the timing of expansion is based on the without-shortage supply policy, that is, whenever demand catches up with supply, an expansion project is put into operation. This means that supply is always equal to or greater than the projected demand.

Suppose we have a projected consumption W_t and projects A, B, and C with given capacities in Figure 3.2:

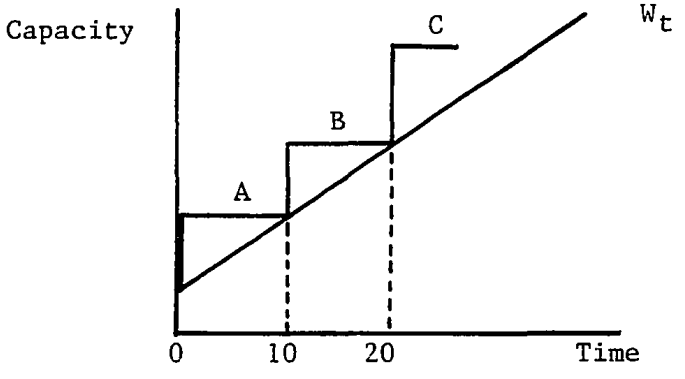


Figure 3.2 Without-Shortage Supply Policy

At time 1, project A is constructed. As time goes by, W_t catches up with the supply capacity of A at time 2. At this point, project B is constructed to keep supply greater than consumption. The excess capacity of project B lasts until time 3, and at this point again, project C is constructed. Thus, the cumulative supply is always kept greater than or equal to the consumption.

B. The New Approach

The steps herein are those suggested by Curran et al. (1976). These include the projection of consumption, determination of the cost of expansion, estimation of the penalty price for shortage, and project sizing and scheduling (expansion planning). Each step is discussed below.

B.1 Consumption Projection

There are three approaches for economic projection of demand for water. The first is the econometric projection. This approach estimates a demand function using past information (data). Demand is projected by plugging in values for the explanatory variables into the estimated demand function. The values of the explanatory variables may either be known or not known with certainty. For details, refer to Chapter II (Section 2.4, A.1).

The second is by forecasting based on economic base studies. As discussed in Chapter II (Section 2.4, A.4), this approach undertakes an economic base study to forecast the activity levels of all the sectors for which water demand is in turn estimated initially by using historical water use coefficients, and finally by an estimated demand function.

The third is by derived demand approach. This approach estimates the derived demand function for a production input (water in this case) from a given production process (or function) by classical programming. This derived demand function is expressed in terms of the firm's output and prices (of the firm's output, and of the production input). Thus, with the information on the firm's target output and prices, the demand for a production input (say water) can be projected. See Chapter II (Section 2.4, A.5) for details.

B.2 Estimation of the Cost of Expansion

One of the controlling factors affecting the choice of supply alternative is the cost. In analyzing supply alternatives, it is necessary to determine a functional form relating capital cost to capacity. This relationship will serve as a rough method (Moore, 1959) for measuring increases in capital cost as capacity is expanded.

Water systems exhibit economies of scale (Lauria, 1973). The equation of the typical cost curve for a water system that reflects economies of scale is:

$$C = kQ^a \qquad (22)$$

where C = construction cost

k = scale parameter, cost of 1 capacity unit system

Q = project capacity

a = economy of scale parameter, whose value is between 0 and 1. As long as "a" < 1, economies exist, otherwise if "a" ≥ 1, economies are absent.

One way of estimating parameters "a" and "k" is to regress cost against capacity, the data for which maybe either the observed costs

and installed capacities, or the indicative costs and the design capacities of the different alternative sources proposed (Curran et al. (1976).

In calibrating this function, it is important to note that the different observations or sources should be at least of a comparable, if not similar, nature or technical characteristics and local construction conditions (Berthouex, 1972). That is to say we cannot calibrate this model using combined observations from a gravity system, pumping station, and desalting system. Instead, observations must be from one type of supply source at a time.

B.3 Estimation of the Penalty Price for Shortage

When water supply falls below the demand, shortages occur. There is a cost attached to shortages because of the following consequences:

1. Consumers, in trying to offset the inconvenience of shortages, incur expenses for obtaining alternative supplies. These alternatives may be importing water or activating standby supplies.

2. Consumers lose the benefit they derive from using water.

Under the first consequence, the import price of water has been used by Erlenkotter (1967) to estimate the penalty price of shortage. Curran et al. (1976) pointed out that one could suspect that the true cost of shortage relate to alternatives like importing or activating standby supplies.

Under the second consequence, the gross benefit from using water is estimated as the area under the demand curve (or willingness to pay) up to the level of consumption. Lauria (1973) pointed out that when there is shortage, the benefits of publicly-supplied water are foregone,

and the unit benefit foregone becomes a measure of social losses associated with unserved demand. Thus, the unit benefit becomes the penalty price for shortage.

Strictly speaking, when estimating the benefit derived from using water by the area under the demand curve, the appropriate concept is the net benefit, that is, the area under the demand curve minus the area under the supply curve up to the level of consumption.

The benefits lost due to shortage have been alternatively estimated as an impact. Impacts of water shortage may include the lost revenues by industries due to shutdown, lost residential consumers' surplus, number of trees dead due to lack of water, lost revenue for the government in the form of taxes from establishments which could have been built and operated if water were available, health effects, fire hazards, and so on. If we account in detail for all the impacts, there is a possiblity that our estimate of penalty price could be significantly higher than the one estimated by the area under the demand curve.

The major study of supply shortage to date is that of Russel et al. (1970). They generally defined water shortage losses as "gross annual benefits lost by disappointed users less the cost avoided by the supplier."

A similar example of the application of their concept will clarify their approach. Suppose we want to measure the losses from prohibiting car washing. If the (annual) demand for car washing water is DD in Figure 3.3, then at price p_1, W_1 cu.m. per year will be demanded. The benefit (B) (or the willingness to pay) from car-washing water is the area under the demand curve from the origin to w_1, that is:

$$B = \int_0^{w_1} D(w)dw \qquad (23)$$

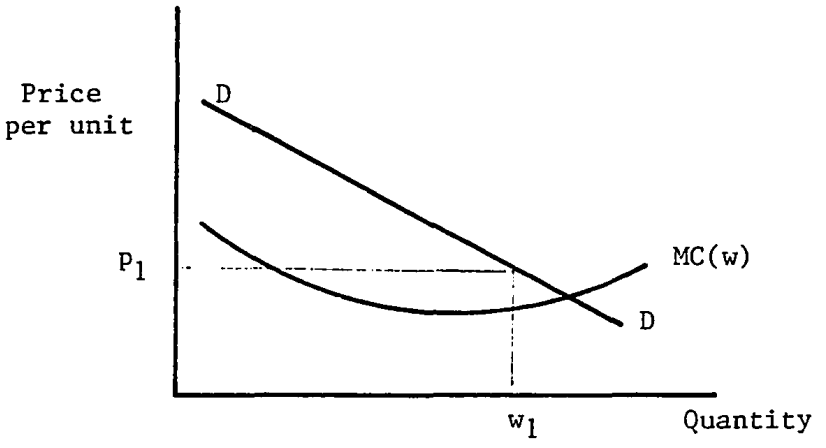


Figure 3.3 Hypothetical Demand for Car-Washing Water

The cost (C_A) avoided by the supplier is the area under the marginal cost curve MC from the origin to the quantity w_1:

$$C_A = \int_0^{w_1} MC(w)\,dw \tag{24}$$

The total net social losses (SL) from the prohibition of car-washing is:

$$SL = B - C_A \tag{25}$$

from which we can say that the average price "p_{s1}" of this social loss due to prohibition is equal to the net area (SL) divided by the quantity:

$$p_{s1} = SL/w_1 \tag{26}$$

This unit price for social losses becomes the penalty price.

Theoretically, if the demand curve for water and the marginal cost of producing water are known, the above estimation is convenient. Alternatively, what Russell et al. (1970) did to estimate the benefit

lost (area under the demand curve) and the cost avoided by the supplier was to account for the losses by interviewing the different sectors affected on how much they lost as a result of the drought. These losses included: business losses due to shutdown; lost water revenue by the municipal government; lost consumer surplus and resources diverted by domestic users to meet the crisis; and miscellaneous losses such as crop failure, trees lost, and others. This kind of methodology requires a lot of funds and time to do.

We have to face the fact that at the moment no empirical work has yet proven whether the willingness to pay approach (area under the demand curve) and the accounting of losses method yield the same estimate of the penalty price.

The penalty price can also be imputed from recently made investment decisions.

Lauria (1973), recognizing the fact that very little work had been done to estimate the benefits of public water supplies in developing countries, suggests that instead of trying to measure the benefits of water supplies, they can be set by judgment. This is done by "imputing" or ascribing water supply values for recently made investment decisions.

To impute the penalty price, we need to make use of the optimality condition for delaying projects. This condition, which is discussed more in the next section, delays projects up to the point when:

$$pDy = rC \tag{27}$$

where: p is the penalty price per unit water shortage;

D is the rate of increase of demand, quantity/year;

y is waiting time in years before a project is built;

r is the discount rate; and

C is the construction cost of the project.

The left hand side of the equation is the rate of penalty cost accrual, and the right hand side is the annual interest cost of the project.

For example, a recently constructed water system in a town costs $100,000. At the discount rate of 10 percent, the interest cost is $10,000 yearly. Suppose that shortage Dy at the time of construction was 200 mgd (73,000 million gallons per year), then the imputed penalty price "p" is:

$$p = rC/Dy = 10,000/73,000 \doteq 13.69 \text{ c per mil. gal.}$$

We can say that the decision to invest implicitly assigned a value p of 13.69 c per million gallon. That is, for the decision to be rational, the correct value of the water would have to be at least 13.69 cents per million gallons.

B.4 Capacity Expansion Planning

There is a vast literature on capacity expansion planning. One of the first to formulate a capacity expansion model was Chenery (1952). Starting from a given production function and demand forecast, he showed that there is an optimal relation between capacity and output that is a function of the economy of scale, discount rate, planning period, and the rate of demand increase. Manne (1967) extended his work to cases of dynamic conditions, single and multiple producing areas. Manne's work was in turn extended and applied to water treatment systems by Scarato (1969), Rachford et al. (1969), Thomas (1970), and others.

Capacity expansion is also treated in textbooks like Loucks et al. (1981) and Hall and Dracup (1970).

The expansion models in the above-mentioned works generally have assumed a policy of without-shortage, that is, that the capacity of supply facilities must equal or exceed demand at all times. Some models assumed the demand rate of increase linearly, others geometrically or monotonically. Also, some models assumed deterministic demand and others stochastic. So far only Thomas (1970) considered the case where there is an initial supply deficit.

Lauria et al. (1975) observed that the above models derived optimality conditions that are mathematically complicated and are of limited use unless a computer is available. So they presented approximating equations for the optimality conditions derived by Manne (1967) and Thomas (1970). In addition, they extended the works of Manne (1967) and Thomas (1970) by presenting a model for determining the waiting period prior to initial construction of a system for which a shortage in the linearly growing demand already exists.

Manne's model is considered the classic work in capacity expansion. Having been the basis of follow-up work on this subject, it contains the basic expansion theory which economists adopt. His model has the objective of determining the minimum cost capacity expansion policy which will meet a linearly increasing demand over time. His assumption are:

1. Deterministic linearly increasing demand
2. Constant economies of scale
3. Continuous discount rate

4. Infinite penalty costs (without-shortage)

5. Infinite planning horizon

The analytical idea is illustrated in Figure 3.4. The cost function is:

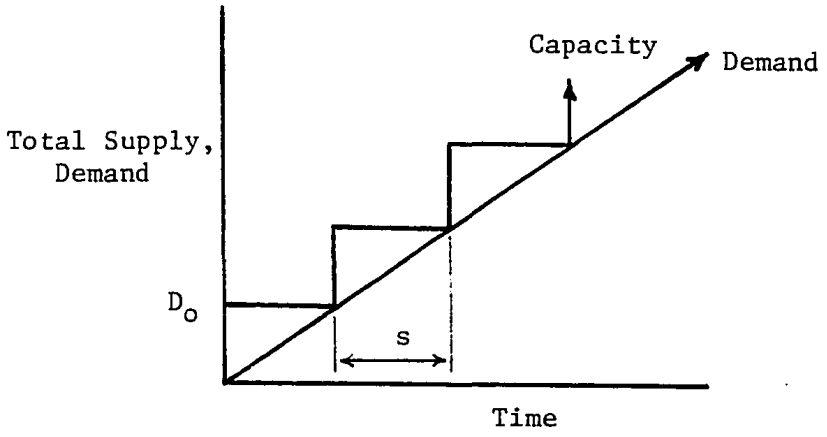


Figure 3.4 Manne's Basic Expansion Model

$$\text{Cost} = kQ^a \qquad (22a)$$

where: k is a scale parameter, cost of 1 unit capacity;

a is economy of scale factor, $0 < a < 1$; and

Q is the amount of capacity added.

The following additional definitions are utilized:

D is the annual increase in demand, quantity/year;

s is the time interval between successive expansions;

$sD = Q$, is the expansion capacity;

s^* is the optimal time spacing between expansion;

r is the annual rate of discount; and

e = base of natural logarithm, equals 2.71828.

The objective is to minimize the sum of all discounted future costs C(s) looking forward from a point of regeneration (point where demand = supply). The problem then is:

$$\text{Min } C(s) = kQ^a + (e^{-rs})\ C(s) \tag{28}$$

The first term on the right hand side is the cost of adding Q units of capacity right now. The second term measures the sum of the discounted future costs of subsequent expansions. Factoring C(s), it follows from equation (28) that

$$C(s) = \frac{k(sD)^a}{1 - e^{-rs}} \tag{29}$$

Taking logarithms of both sides we have:

$$\ln C = \ln k + \ln sD - \ln (1 - e^{-rs})$$

Differentiating with respect to s and equating results to zero:

$$o + a \frac{1}{sD} \cdot D - \frac{1}{1 - e^{rs}} \cdot (-e^{-rs})(-r) = 0$$

$$\frac{a}{s} = \frac{re^{-rs}}{1 - e^{-rs}} = \frac{s}{e^{rs}\ (1 - e^{-rs})}$$

$$a = \frac{r}{e^{rs} - e^{rs-rs}} \quad \text{or} \quad \frac{a}{s} = \frac{r}{e^{rs} - 1}$$

Thus, we have:

$$a = \frac{rs^*}{e^{rs^*} - 1} \tag{30}$$

To solve for the optimal spacing s*, Lauria et al. (1975) derived the following approximating equation:

$$s^* = \frac{2.6\ (1 - a)^{1.12}}{r} \tag{31}$$

Thus, having the optimal time spacing s* between expansions, the optimal expansion capacity is found as:

$$Q = s^*\ D \tag{32}$$

Lauria (1973) and Lauria et al. (1975) claim that the situation in developing countries is such that the decision is made to wait y years before constructing the first expansion project. Hence, they formulated the waiting period model. Let us examine the theory behind this model as represented by Figure 3.5.

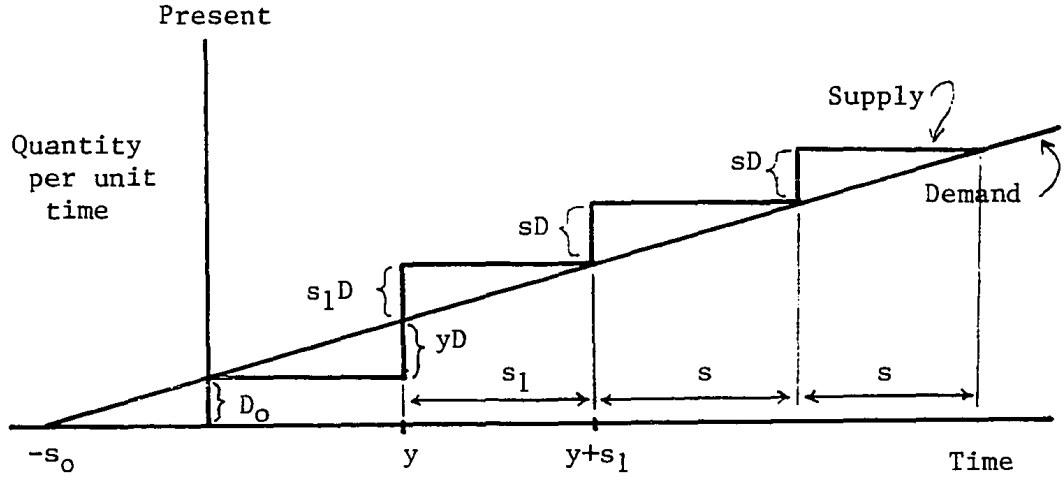


Figure 3.5 Waiting Time Expansion Model

The notations used are:

$-s_0$ is the hypothetical elapsed period (in years) from the time of zero demand (or zero excess capacity) to the present;

y is the waiting period, years, before the initial project is built;

D_0 is initial shortage or deficit;

s_1 is initial design period, or time after which the initial project addition is fully used up; and

s* is the optimal spacing of subsequent expansion.

In this model, there is an initial deficit of D_0, and after y waiting years, the first project with the capacity of $(D_0 + yD + s_1D)$

is built. The excess capacity brought about by this project is $s_1 D$, which will last for s_1 years. After that, the subsequent expansions are determined in the same way as in Manne's model.

Penalty costs are incurred during the waiting period from time zero to y, so that the total value of costs PTC will be composed of the sum of the present value of penalty and construction costs for an infinite time horizon.

$$PTC = \int e^{-rt}\, p(D_0+tD)\, dt + e^{-ry} k\, (D_0+yD+s_1 D)^a + e^{-r(y+s_1)}\, \frac{k(sD)^a}{1 - e^{-rs}} \qquad (33)$$

The first term on the right hand side is the discounted penalty costs of waiting from time zero to y. The second and third terms are the discounted initial project costs and subsequent expansion costs, respectively.

Now setting the derivative with respect to s equal to zero and solving, results in an optimal condition for expansion identical to that of Manne's model. Taking the derivatives with respect to s and y gives the condition for optimal waiting period:

$$p(D_0 + y^*D) = r[k(D_0 + y^*D + s_1^*D)^a] \qquad (34)$$

which says that the construction of the first project should be delayed until its annual interest cost is equal to the rate of penalty cost accrual. Solving for the optimal waiting period y*, we have:

$$y^* = \frac{rk\, (D_0 + y^*D + s_1^*D)^a}{pD} - \frac{D_0}{D} \qquad (35)$$

from which we can see that the optimal waiting time decreases as the penalty price increases. Now, if no waiting time is optimal, that is

$y^* = 0$, p would have a large value but still be finite. This is called the boundary price $\hat{p}$ and is found by setting $y = 0$ in the above equation and solving

$$\hat{p} = \frac{rk\ (D_0 + s_1 * D)^a}{D_0} \qquad (36)$$

If the actual p is greater than $\hat{p}$, y will be negative, which means that the construction should have taken place in the past. If actual p is lesser than $\hat{p}$, then y is positive, which means that the project should be deferred.

They derived an approximating equation for y^*:

$$y^* = zF^{\phi} - s_0$$

where: $F = kD^a/pD$;

$z = 0.012\ a^{-4.7}\ r^{0.4}$; and

$\phi = 5.58\ a^{1.3}\ r^{0.18}$.

Erlenkotter (1967) extended Manne's work to the case where shortages are allowed and satisfied by unlimited exports at a constant penalty cost per unit. Other assumptions are that the demand is growing over time at a constant annual arithmetic rate D, and the discount rate and investment cost function for constructing plants remain constant. The time horizon and the plant life are infinite. His model is illustrated by Figure 3.6. The notation used are:

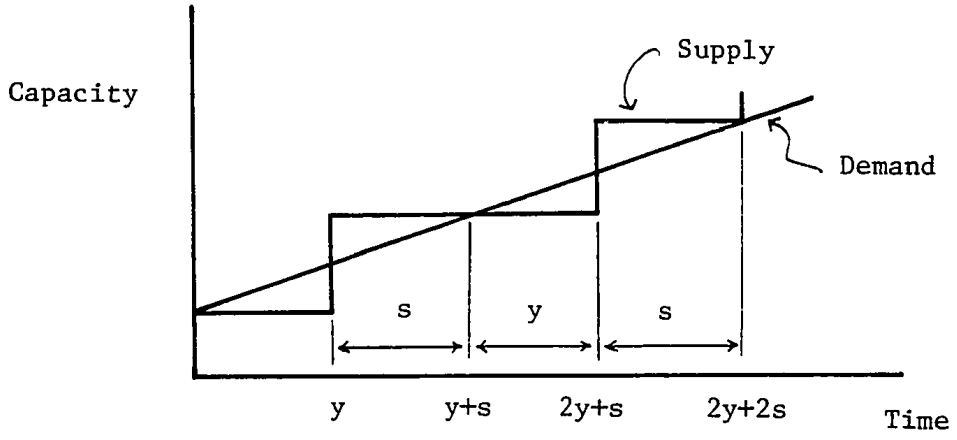
y is duration of the temporary import phase;

s is excess capacity time, or spacing;

D is rate of demand increase;

sD is size of the plant to be constructed; and

p is penalty price per unit shortage.



Expansion 3.6 Expansion Model with Deficits, Linear Demand

The total discounted cost and penalty cost is:

$$C(s,y) = \int_0^y p(tD)\, e^{-rt}\, dt + e^{-ry}\, f(sD) + e^{-rs}\, C(s,y) \qquad (38)$$

where the first term on the right is the discounted sum of penalty costs; second term is the present value of the plant investment made in year y; and the last term is the present value of all future costs.

By the same manipulations as Manne's, that is, classical programming, the following optimality conditions are arrived at:

1. $$pDy = rf(sD) \quad \text{or} \quad pDy = rC \qquad (39)$$

2. $$a = \frac{\frac{rs^*}{e^{rs^*} - 1}}{\frac{ry^*}{e^{ry^*} - 1}} \qquad (40)$$

In condition 1, Dy is the shortage at the time of construction, and f(sD) is the cost of construction. This condition says that a project should be delayed up to the time when the penalty cost is equal to the interest cost accrual. Condition 2 expresses the economy of scale in terms of the optimal s* and y*. The solution for s and y

requires numerical methods. Erlenkotter's article provides solutions in terms of graphs for some assumed values for parameters.

There are of course some approaches which formulate the problem of expansion into computationally difficult models such as those presented by Grossman and Marks (1977). Two of their models were formulated using stochastic programming. One is the case with an uncertain demand, shortage supply policy, and open loop control; and the other is a case with uncertain demand, shortage supply policy, and closed loop control. They claimed that because these models are algorithmic, they are very costly to operate, and difficult to use in sensitivity testing. They also concluded that such models should only be used after sensitivity testing in comparison with simpler approaches.

3.3 Evaluation of the Approaches

A. On Demand Projection

The traditional approach usually projects demand by using use coefficients. While it is true that this approach does not take into account the effect of policy variables like price, it has some strength.

The accuracy of traditional projections depends on the method used for estimating the coefficients. All else being equal, the coefficients of the poorest quality are those estimated from past consumption data which are usually assumed constant over time. Some engineering groups like Metcalf and Eddy Inc. show the coefficients as increasing as the population of the city increases. This is supported by the study conducted by Metcalf (1926). This reflects the thinking that perhaps as people become more urbanized and crowded, they become

more luxurious in their ways, and use more water. These thoughts are not far from the economic line of thinking.

Camp Dresser and McKee Engineers also show the coefficients as increasing over time, an assumption that reflects the development process. In a developing region, industrial, commercial, and institutional uses will tend to increase. Per capita domestic use for settled areas has the tendency to be constant over time. Due to the high demand for water during the construction phases of buildings and infrastructures, water requirements for construction projects increases and then settles down to a stable level after some time passes (Yamauchi and Oh, 1974).

Some coefficients are computed in an interesting way. An area of known population where water service is available for 24 hours per day is selected for study, and water use is calculated by actually measuring the difference between the potable water inflow and outflow from the area. The resulting water use coefficient implies a full service level, that is, the quantity that people will consume if water is available 24 hours a day.

Some engineers estimate the water use coefficients based on the land use plans. A land use plan is a more or less definite physical requirement of what is wanted to happen. It is the physical dimension of society's development plan. If this plan envisions a creation of a new town, that means specific increases in residential, commercial, industrial, and institutional areas. Sometimes the plan calls for the reclamation of a certain area and this is taken into account.

In addition to projecting average daily per capita water use, engineers also take into account the daily peak use of water which

usually occurs during times when kitchen and bathroom uses are heavy. Projections also consider seasonal peak loads so that the system can be designed to provide water during summer, when outdoor sprinkling and washing uses are high.

The above points are important and are valid aspects to consider when forecasting water use. They show the degree of detail of the traditional approach, which constitutes one of its strengths.

Strictly speaking, projecting demand by explicit use of economics is difficult. In fact Wantrup (1959) implies that we always tend to disregard changes in taste and preferences, institutions and technology, which usually are more important than the price. These factors are difficult to account for. Economic forecasting is a complicated process. Take the approach by Howe (1968) which starts with forecasting of activity levels by means of an economic base study. Forecasting activity levels is itself difficult. Then he proceeds by estimating preliminary demand from water use coefficients, then designing the water system, pricing structure, and finally goes somehow to an econometric estimation of demands using the forecast activity levels and prices. This is in fact a combination of traditional and economic approaches.

Take also the industrial forecasting method presented by Bower (1968). His approach involves the classification of all firms according to type of technology, forecasting technology, and so on. There will be some complications in the classification because some firms are multi-product firms, and each product is more or less produced by a given technology. More complication is encountered in cases where a technology produces a major product and some by-products. Estimation

of the derived demand for water from these multi-product production functions seems more demanding than projecting water demand itself.

In fact a study of Honolulu by Oh (1973) which was refined by Yamauchi and Oh (1974) claims that within the economic demand model, the task of forecasting future water consumption is more complex than meets the eye. The study accepts the requirements approach as a practical means of forecasting future consumption, yet it can be improved by taking into account expected future changes in economic activities with definite relations to water use. They assert that the economic demand approach can be useful in addressing the problem of how much payment should be made for the additional water supply (i.e., rate making policy, which in the literature is generalized to "pricing" policy).

The most widely used demand forecasting technique in the literature are econometric in form. This method regresses past consumption data against variables believed to affect it. Income and price undoubtedly affect consumption. In fact this is where the strength of this approach lies. The relationship between price and quantity is an essential aspect of the demand concept (Ciriacy-Wantrup, 1959).

There are some weaknesses that go with this approach. Consumption data may have been for the consumption during the time when water was available only for 8 hours a day. Consumption would be different if water had been available for 24 hours. While this problem can be handled through a supply variance variable, data on this are difficult to get especially in the developing countries where the statistical systems are not well established.

If this supply variation were a part of the policy, people could be notified in advance before the interruption in service. People would store enough water until the time of service continuance. In this case, the consumption data is less affected by the shortage.

Another limitation is that, based on the estimated equation, there is a possibility of getting a negative forecast when the value of the price variable goes high. When this happens, one has to use his judgment whether the resulting forecast is realistic or not. It is important to bear in mind that a consumption function is estimated from a given set of data, and there is no guarantee that the estimated demand function would work under a different set, which in this case, large and abrupt changes in prices. That is why we should carefully judge the forecast results considering how the function was estimated and the kind of data used to estimate it.

B. On Capacity Expansion

The traditional approach on capacity expansion places a strong emphasis on reality. Each project is treated independently of the others, that is, each project has its own unique physical site characteristic and has therefore a unique cost. This cost has not been derived from a generalized cost-capacity function because doing so will assume that all sites have the same physical characteristics. The cost and capacity of each project are determined by engineering survey analysis and formulation once that source is chosen from a number of alternatives on the basis of least-cost per unit quantity of water criterion. This means that the size of an expansion project is dictated by the relation between the actual capacity of the source and the cost of exploiting

that capacity, i.e., the sources' cost-capacity function. The priority of a project is determined by its unit cost in comparison with those of the other projects.

On the aspect of drawing demand projection curves in the expansion planning, both the traditional and the new approach use the "smoothed" curve. If one is really after the actual measurement of shortage quantity, one should use the actual demand figures as projected over time. Besides, smoothing the curve defeats the purpose of pricing policies designed to change the demand even for just a little degree. However, we should recognize that there is much uncertainty regarding these projected demands.

Nowadays there is a widespread use of optimization techniques in almost all disciplines. Optimization techniques have found their best use in planning and management problems, like minimization of cost from the number of inputs, labor, machines, etc. These techniques are really useful. The limits to the usefulness of optimization techniques should be recognized though. In structural engineering, minimization of cost resulting in the reduction in sizes of structural members or the abolition of the safety factor is one thing that engineers would not dare to do. The risks due to natural factors are very difficult to assess, so that the only way to provide for them is the application of the safety factor which almost doubles the magnitude of the design in some regions.

The application of optimization techniques in the new approach is fitting and proper. But the worth of the optimizing solution could be determined by examining the assumptions on which it is based, and bringing the solution to the real world situation if in fact it can be

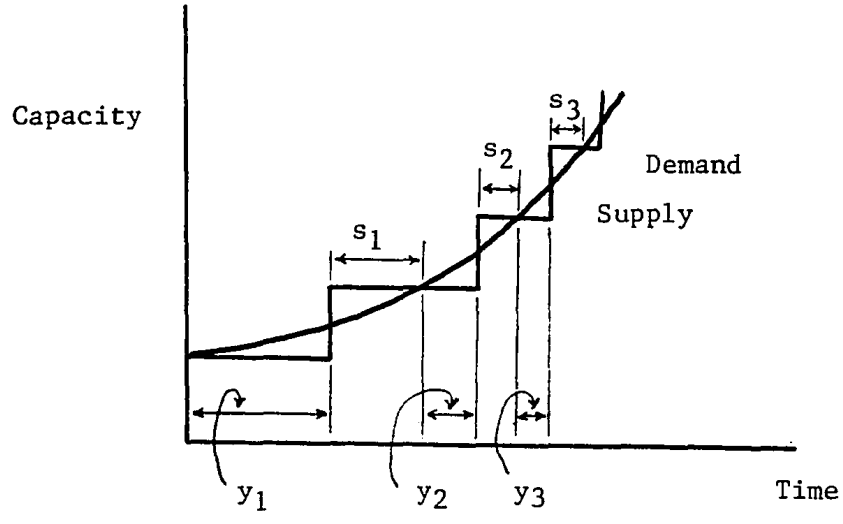
done. Following this argument, the simplifying assumptions of the economic approach are those that are not likely to be found in reality. Take each assumption one by one. First, the straight line demand projection curve. If we examine the literature, we will find that the attainment of the explicit solution with straight line assumption is almost impossible. How much more if the curve were parabolic, or fluctuating, or any pattern? Any pattern could be possible because of the effects of pricing policies. To show the computational difficulty, let us see what happens when the curve is parabolic. There are two possible supply policies namely: identical expansion policy; and identical delay policy. These are shown in part A and B respectively in Figure 3.7.

In the identical expansion policy, identical sizes are added but what happens is that the delay time y decreases in such a way that $y_1 > y_2 > y_3$, and so with the excess capacity time s in such a way that $s_1 > s_2 > s_3$. The result is that we have to build more frequently as time goes on.

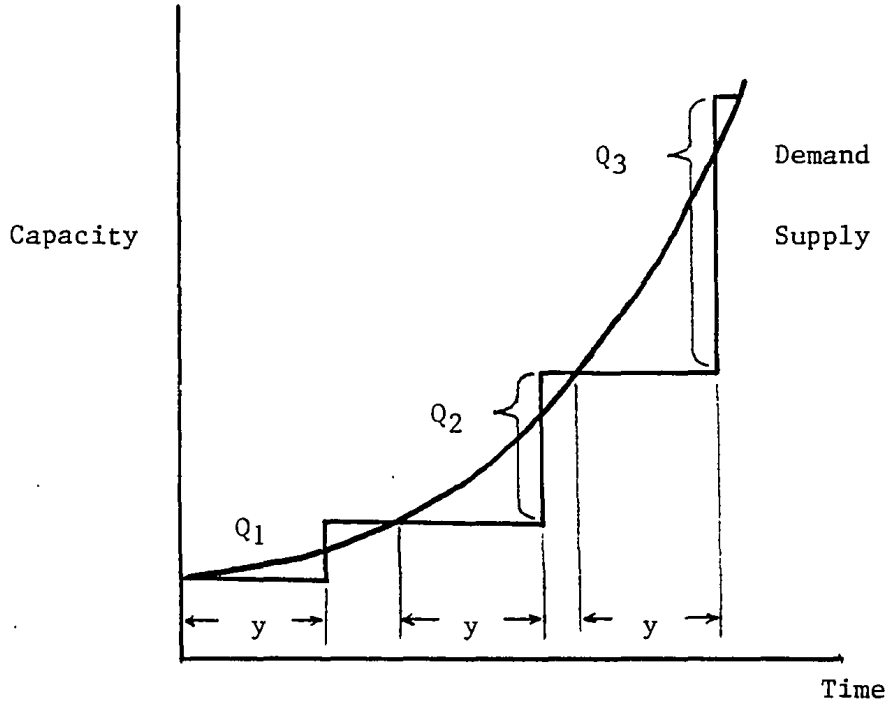
Conversely, in the identical delay and excess times, we have to build bigger dams ($Q_1 < Q_2 < Q_3$) as time goes on.

The theoretical optimal solution of these models is far more complicated mathematically than for the straight line demand curve. Such solutions are not necessary to investigate this study's hypotheses. It is an interesting subject though to pursue separately as an extension of Manne's work.

Next, take the simplifying relationship between the cost and the expansion quantity. This assumes that all project sites are similar in terms of hydrology, geology, and other physical factors, and the only



A. Identical Capacity Expansion



B. Identical Delay Times

Figure 3.7 Expansion Model with Deficits, Parabolic Demand

difference is the project size. This is not the case in reality. Each project has its own characteristics which affect the construction cost. If these assumptions fail, the economic optimizer has the problem of relating cost to quantity. The best way out of this difficulty is take the cost estimates of each project as they are unique, i.e., develop cost-capacity functions for each project, which if done, leads towards the traditional approach.

Another point of scrutiny is what happens if we bring the theoretical economic optimum to the real world. We will encounter the problem of lumpiness in the presence of uncertainty. Say that our economically optimal solution tells us to add 20 mgd and that this would cost $1.5 million. Since the site has not yet been determined, we go out and find that the source of the closest size to 20 mgd has 30 mgd capacity, and would cost $2 million to build. The choice between the 20 or 30 mgd is a difficult one. If the resource is scarce, our common sense might distort the economic optimal solution. This means that if we tap only 20 mgd out of the available 30 mgd, we would leave the remaining 10 mgd unused. Now if alternative sources are scarce, we may not be able to find a source for the next expansion. We will be forced to go back to the previous source and tap what we have left--the remaining 10 mgd. Doing this might result to tearing down the previous 20 mgd facilities and changing them with those fitted for the 30 mgd. Instead of this "tearing down" action, what is done is to build right away at the initial expansion a 20-mgd structure which could be rehabilitated later on to accommodate the remaining 10 mgd.

C. The Possible Compromise

In summary, on the traditional side, projection is more detailed (see Section 3.2, A.1 of this chapter) but fails to account for the effect of policy variables, and the expansion technique is more realistic. On the new approach side, which places more emphasis on economics, projection takes into account the response of consumption to policy variables, but the expansion technique is more theoretical.

What can be done is to have a compromise approach where the better aspects of each approach are taken into account. This compromise could be made either or both in the demand projection procedure and in the expansion technique. On the projection procedure, we know that the traditional approach uses the use factor per capita. Actually such factor can be approximated by the coefficient of the population as an explanatory variable in the regression model. Also, the use factor per unit area can be approximated as the coefficient of the land use area variable. Works in the literature that have combined the population and land use area as explanatory variables in regression models are actually trying to find the relationships between consumption and these variables in terms of the coefficients. For example, the coefficient of the population variable is nothing more than the consumption of one unit of population, that is, the use factor. When these physical variables are combined with the economic variables such as prices and income, the result is to integrate the traditional requirements and the econometric approaches to projection. This seems to be a practical compromise.

Another possible compromise on projection will involve the determination of that part of human needs for water that is more or less

"fixed," and that part which is variable and could be subjected to policy changes. Hirshleifer et al. (1969) call the fixed part the "physiological needs." With this concept, the projected consumption would consist of the fixed consumption plus the variable consumption. The determination of these two parts will require considerable research and involves some degree of controversies.

On the expansion technique, the traditional approach to sizing project stages is a reasonable one, and this may be combined with the economic concept of a supply policy where shortages are allowed. It is this compromise on expansion technique that this study will use to investigate the proposed hypotheses.

CHAPTER IV

BACKGROUND ON METROPOLITAN MANILA AND THE METROPOLITAN WATERWORKS AND SEWERAGE SYSTEM

4.1 General Description of the Area

The Metropolitan Manila region is the national capital region of the Philippines and is located strategically by Manila Bay (see Figure 4.1). It was created by Presidential Decree (PD) No. 824 in 1975. It is composed of: the four cities of Manila, Caloocan, Pasay, and Quezon; and 13 municipalities: Las Pinas, Makati, Malabon, Mandaluyong, Marikina, Muntinlupa, Navotas, Paranaque, Pasig, Pateros, San Juan, Taguig, all of Rizal Province; and Valenzuela of Bulacan Province (see Figure 4.2).

The region has a total area of 633 sq. kms. and a 1980 population of 5.9 million (see Table 4.1), which is increasing at the rate of 3.4 percent per year (Maramag, 1976). It has a population density of 7,774 persons per sq. km., with the highest density of 39,997 persons per sq. km. at its center, the city of Manila.

To meet the water needs of Metro Manila, the Metropolitan Waterworks and Sewerage System (MWSS) was created by Republic Act 6234 in 1971 by reorganization of the previous water management system. The MWSS was established to perform the following primary functions:

1. To construct, maintain and operate waterworks facilities for the purpose of supplying adequate potable water to the inhabitants of its assigned area;

2. To construct, maintain and operate such sanitary sewerage facilities as may be necessary for proper sanitation;

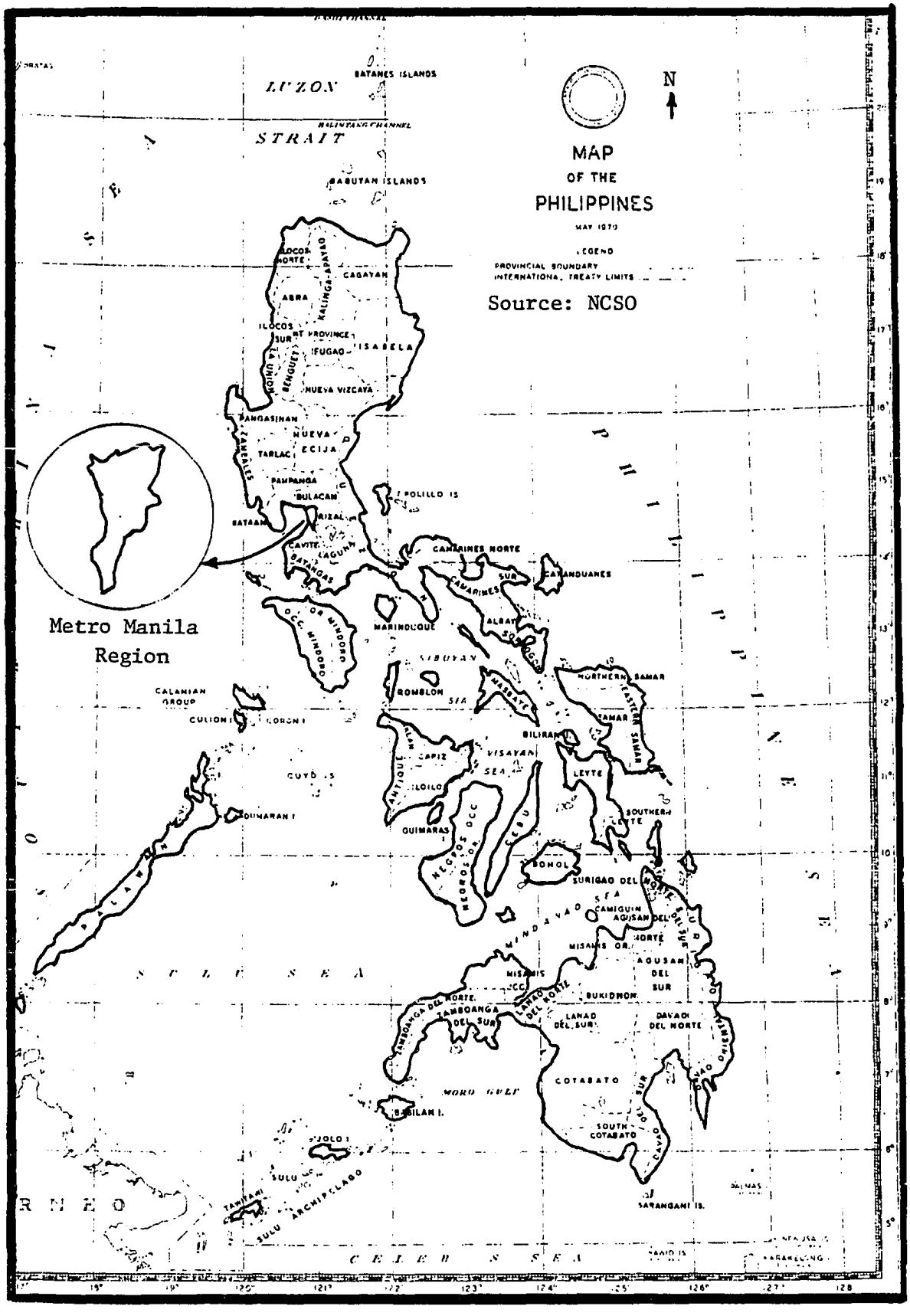


Figure 4.1 Location of the Metropolitan Manila Region

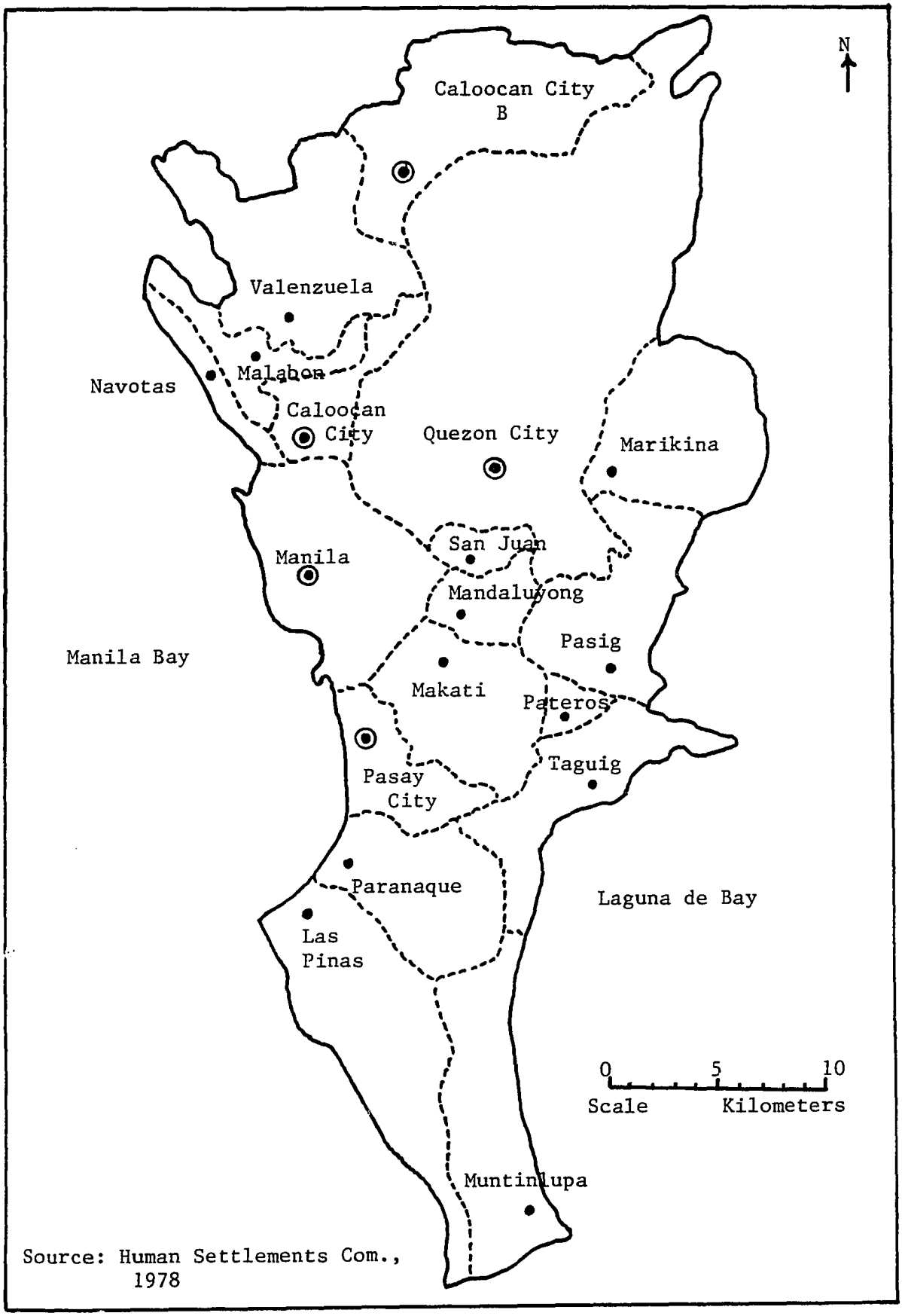


Figure 4.2 Map of the Metropolitan Manila Area

Table 4.1

Area and Population of Metro Manila, 1980

Administrative Unit	Area[a] (km^2)	Population[b] (1,000)
Cities:		
Caloocan	55.8	468
Manila	38.3	1,630
Pasay	13.9	288
Quezon	166.2	1,166
Municipalities:		
Rizal Province		
Las Pinas	41.5	136
Makati	29.9	373
Malabon	23.4	191
Mandaluyong	26.0	205
Marikina	38.9	212
Muntinlupa	46.7	137
Navotas	2.6	126
Paranaque	38.3	209
Pasig	13.0	269
Pateros	10.4	40
San Juan	10.4	130
Taguig	33.7	134
Bulacan Province		
Valenzuela	47.0	212
Total	636.0	5,926

Notes: [a]From Maramag (1976), p. 26

[b]From NEDA, 1982

3. To fix periodically just and equitable water rates and sewerage service fees.

The service area as defined by the Act is composed of: the administratively defined area of Metro Manila; the municipalities of Antipolo, Cainta, Montalban, San Mateo, and Taytay, all of Rizal Province; the city of Cavite and the municipalities of Bocoor, Imus, Kawit, Noveleta, and Rosario, all of Cavite Province. The assigned service area as composed of 5 cities and 23 municipalities, had a total area of 144,021 hectares (Camp Dresser and McKee, 1976a).

In 1977, the service area was expanded by Presidential Decree No. 1269 to include the new city of Lungsod Silangan and other area that may come within the periphery of expansion of Metro Manila.

This expanded the service area to 6 cities and 23 municipalities with a total area of 148,000 hectares (MWSS, 1981b). See Figure 4.3. The total population of this service area was 5.8 million in 1977 and 6.53 million in 1980, and is increasing at a rate of approximately 3.5 percent yearly.

4.2 Existing Conditions

In order to give the reader a better understanding of the system's performance as a whole, conditions that existed at two points in time, 1975 and 1982, are discussed below. But before doing this, it is necessary to define the concepts that are relevant in characterizing the system's conditions.

A. Concepts of Shortages and System's Supply Performance

We will define some concepts on shortage and the system's supply performance with the aid of a diagram which typifies the actual situation in Manila. See Figure 4.4.

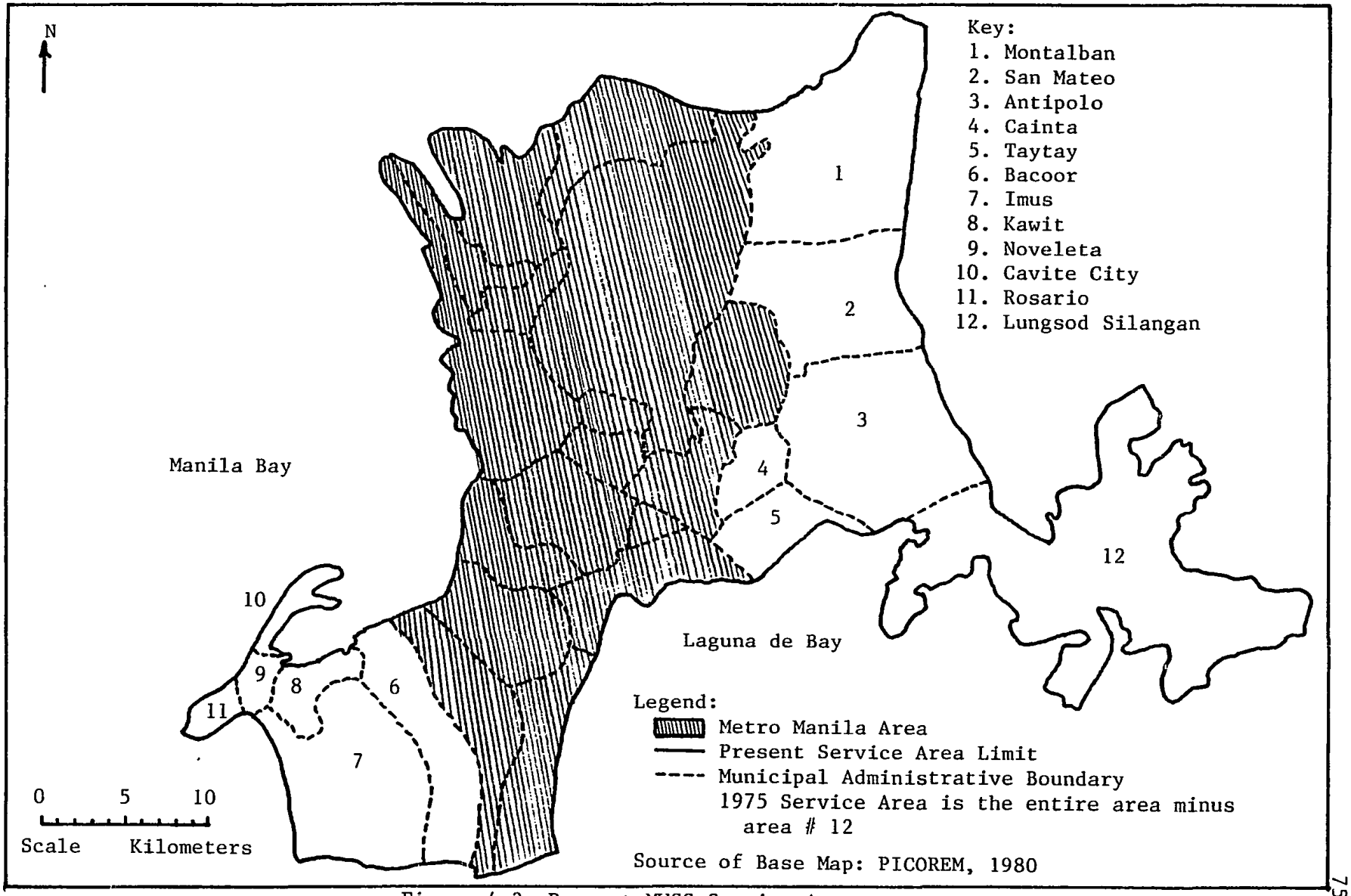


Figure 4.3 Present MWSS Service Area

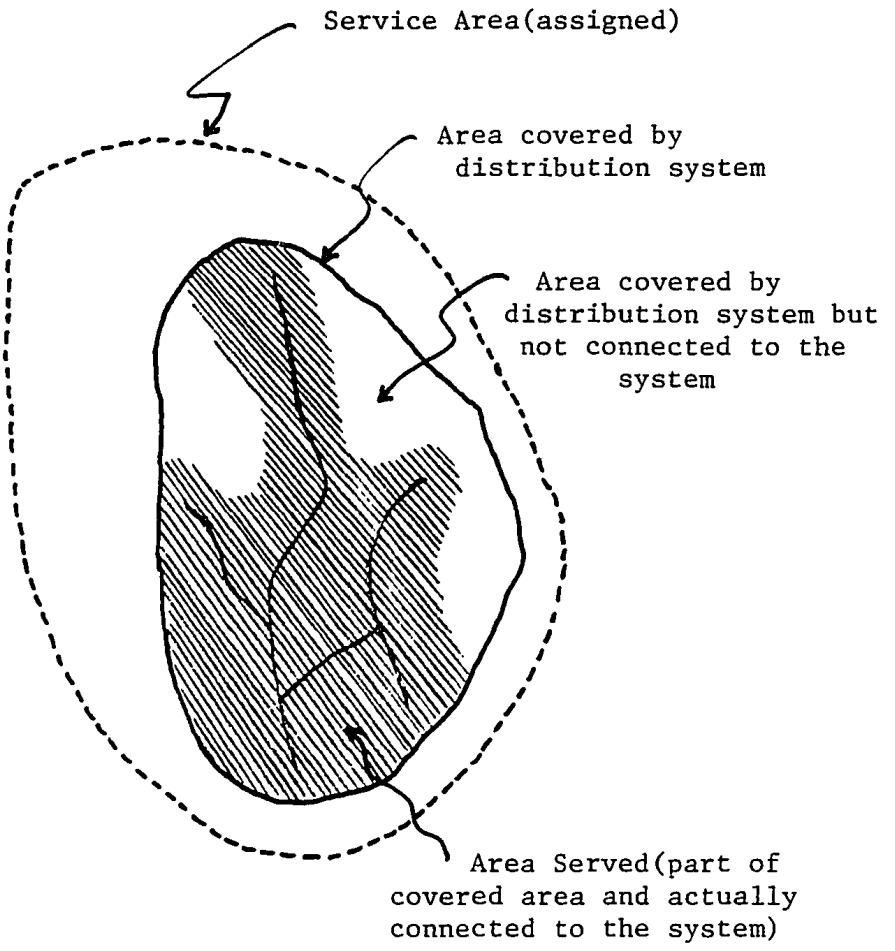


Figure 4.4 Relation Between Service Area and Area Served

Consumption of the Entire Service Area (D_s)

This is the consumption that will be realized if all households in the entire service area are connected to the system. The term "service area" is defined as the total area which is assigned by law for the MWSS to serve. In Figure 4.4 we have a hypothetical service area defined as the area within the dotted line. In actuality this is composed of the different cities and municipalities mentioned earlier. We will denote this area by D_s.

Consumption of the Area Actually Served (D_a)

In actuality, the MWSS distribution system cover a part of the entire service area. That covered part is represented by the area within the solid line in Figure 4.4. Within this covered area, some households are connected to the distribution system and some are not. On this basis, this covered area is divided into two sub-parts namely: the unserved area, represented by the unshaded area within the solid line; and the area served, represented by the shaded area within the solid line. We will denote the consumption of this shaded area by D_a. Normally, D_a cannot be more than D_s, that is, $D_a \leq D_s$. In reality it is difficult to delineate the covered area which are not connected to the system because it is not a continuous area. Some parts of it maybe found in between the main transmission lines, and some portions maybe distributed all over the area covered.

Actual Demand-Side Shortage (ADSS)

The difference between the consumption of the entire service area and the consumption of the area actually served may be called "actual demand-side shortage" (ADSS). This corresponds to the consumption of

the total unserved area which is composed of that area which is not covered area but is not connected to the system. Arithmetically,

$$ADSS = D_s - D_a \qquad (41)$$

Capacity of the Water Supply System (C_s)

The capacity of the system, C_s, is the quantity of water that the system is theoretically capable of supplying. If the system has two or more sources, the capacity of the system is the sum of the capacities of all the sources.

Supply-Side Shortage (SSS)

The capacity of the system C_s may be greater, equal, or less than the consumption of the service area D_s. If D_s is greater than C_s, we have a shortage, which we may call the "supply-side shortage" (SSS). In symbols,

$$SSS = D_s - C_s \qquad (42)$$

If D_s is less than C_s, then we have a supply-side excess capacity (SSEC). Thus,

$$SSEC = C_s - D_s \qquad (43)$$

Actual Quantity of Water Produced (C_a)

Water production is the process involved in making raw water available for use in such a quality that would satisfy the standard set by law. The output of this process is the actual quantity of water that is produced and delivered out of its theoretical capacity C_s. This means that C_a cannot be more than C_s.

Actual Supply Side Shortage (ASSS)

If the demand of the entire service area D_s is greater than the actual production C_a, we have a shortage which we call the "actual supply-side shortage" (ASSS). In symbols,

$$ASSS = D_s - C_a \qquad (44)$$

If D_s is less than C_a, then we can call the difference as the actual supply-side excess capacity (ASSEC). Thus,

$$ASSEC = C_a - D_s \qquad (45)$$

Percentage Quantity Served (PQS)

This concept is a variation of ASSS which expresses what percentage of D_s is being served by the system's actual production C_a. It is the ratio of C_a to D_s. In symbols,

$$PQS = (C_a/D_s) \times 100 \qquad (46)$$

Production Efficiency (PE)

Production efficiency PE is the ratio of the actual quantity of water produced C_a to the capacity of the system C_s. In symbols,

$$PE = C_a/C_s \qquad (47)$$

Percentage Population Served (PPS)

This concept is defined as the ratio of the number of population P_a served by the system to the total population P_s of the entire service area. In symbols,

$$PPS = (P_a/P_s) \times 100 \qquad (48)$$

B. The 1975 Conditions

In 1975, the MWSS had a total supply capacity C_s of 480.65 MCM/year from its five sources as shown in Table 4.2. The sources are: La Mesa Dam with a capacity of 35.91 MCM/year; Ipo Dam with 131.21 MCM/year; Alat Dam with 6.91 MCM/year; Marikina Pump No. 2 with 6.91 MCM/year; and Angat Multi-Purpose Dam with 299.71 MCM/year.

Table 4.2

MWSS Water Supply Sources
And Capacities

Source	Capacity, MCM/year
La Mesa Dam	35.91
Ipo Dam	131.21
Alat Dam	6.91
Marikina Pump #2	6.91
Angat Multi-Purpose Dam	299.71
Total	480.65

Source: Camp Dresser and McKee, 1976b

Water from these sources is treated at the Balara Treatment Plant whose average output is 447 MCM/year. The treatment plant has an overload capacity of 587 MCM/year, and its output is being adjusted to coincide with the downstream demand so that the level at the San Juan Reservoir remains nearly constant. The configuration of the system is shown in Figure 4.5.

Out of the system's supply capacity (C_s) of 481 MCM/year, 457.58 MCM/year was actually produced (C_a) and distributed, and of which only

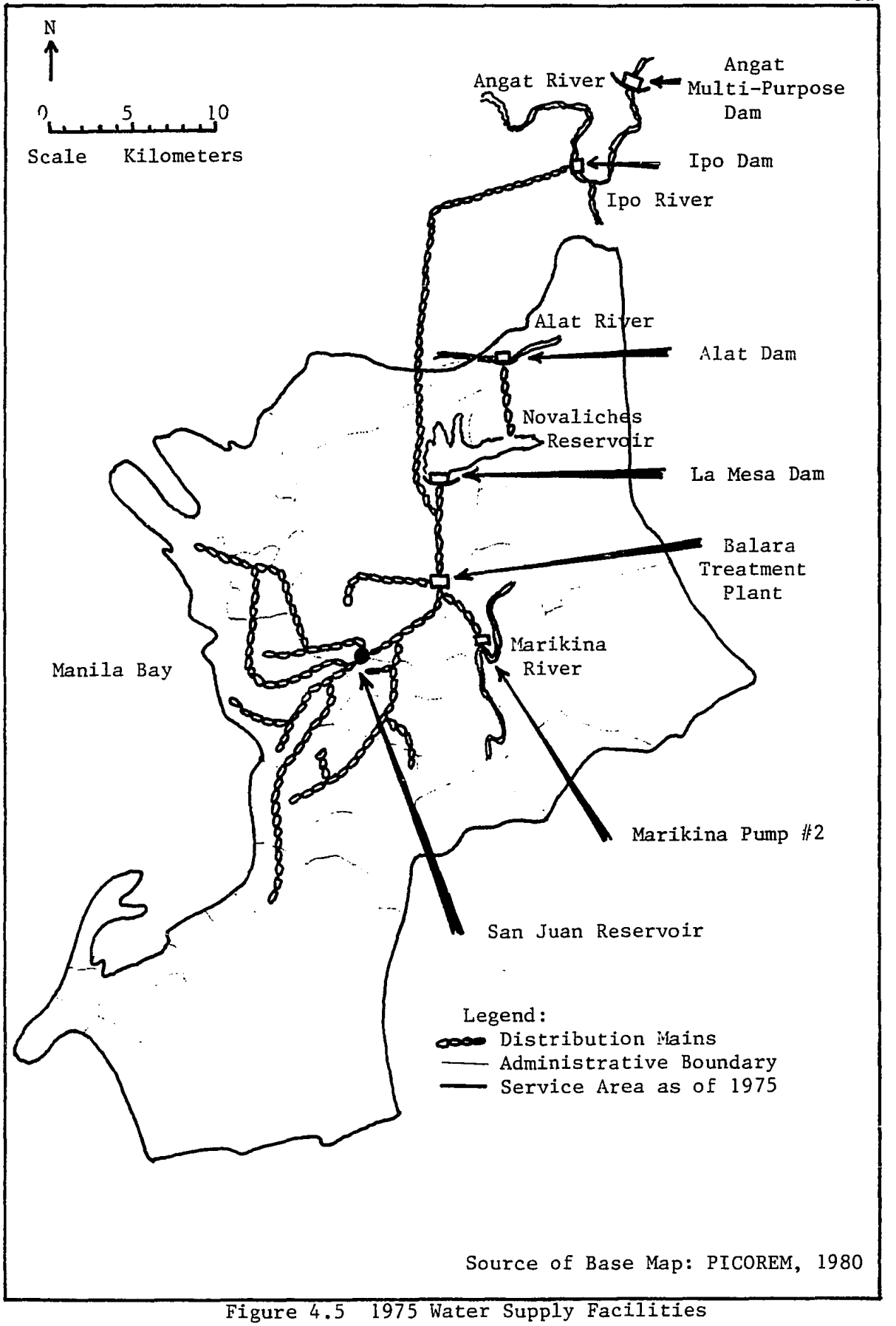


Figure 4.5 1975 Water Supply Facilities

230.28 MCM/year was billed (MWSS, 1981a, p. 13). The ratio between the actual production C_a and the supply capacity C_s gives a high production efficiency of 95.2 percent as computed below:

$$PE = C_a/C_s$$
$$= (457.58/480.65) \times 100\% = 95.2\%$$

The amount of water unaccounted for was 227.3 MCM/year, which is the difference between the water delivered and the water billed. This is attributed to defective meters, unmetered services like the MWSS plants and offices, unmetered public and fire hydrants, illegal connections, leakage, etc.

The actual measured consumption D_a of the area served totalled 230.28 MCM/year, while the total service area of 144,021 hectares would have had a total consumption D_s of 459.422 MCM/year, computed using the estimated demand equations in Chapter VI. These figures gave an overall actual demand-side shortage of:

$$ADSS = D_s - D_a$$
$$= 459.422 - 230.28 = 229.142 \text{ MCM/year}$$

This ADSS of 229.142 MCM/year is the demand of the total unserved area, or the unmet demand of the service area, on the assumption that the unaccounted water is lost water.

The total service area's demand D_s when compared against the system's theoretical supply capacity C_s of 480.65 MCM/year showed a supply-side excess capacity of

$$SSEC = C_s - D_s$$
$$= 480.65 - 422 = 21.288 \text{ MCM/year}$$

This means that if the system produced and delivered water at 100 percent efficiency, there would have been a surplus of 21.228 MCM/year.

When the service area's demand is compared against the actual production of 457.58 MCM/year, there is an actual supply-side shortage of

$$ASSS = D_s - C_a$$
$$= 459.422 - 457.58 = 1.842 \text{ MCM/year}$$

This ASSS means that the system actually was short only by 1.842 MCM/year, assuming that 100 percent of the actually produced water was delivered and accounted for. This assumes that the unaccounted 227.3 MCM/year is counted as serving the combined unmetered and illegal uses.

For the residential, there were recorded 233,681 legal connections and there were 8.065 persons per connections. This means that out of the service area's total population P_s of 5.313 million, only 1.8846 million (P_a) or 35.47 percent were served by the system. This would mean that, with the residential consumption of 129.224 MCM/year in 1975, per capita domestic use was 68.568 M3/year (or 187.85 lcpd).

There was of course a fraction of the population, about 5 percent, which was served by public standpipes and wells, but their consumption was paid by the local government concerned, so that their consumption is classified under the public use.

Overall, with the total recorded aggregate consumption of 230.28 MCM/year and the entire service area population of 5.313 million, the per capita aggregate use was 43.343 M3/year (or 118 lcpd).

The summary of demand and supply conditions in 1975 is presented in Table 4.3.

Table 4.3

Summary of Demand and Supply Conditions, 1975

Supply Side	Demand Side
Capacity: 480.65 MCM/year	Total[a] Demand (D_s): 459.422 MCM/year
Production: 457.58 MCM/year	Actual Demand (D_a): 230.28 MCM/year
Water Billed: 230.28 MCM/year	Population Served: 1,884,600
Unaccounted: 227.3 MCM/year	Percent Population Served: 35.47
Production Eff.: 95.2 percent	Residential Use: 129.224 MCM
	Per Capita RU: 187.85 lpcd
	Per Capita Aggregate Use: 118 lpcd

Note: [a]Computed using estimated demand equations in Chapter VI.

The distribution zones are defined and shown in Figure 4.6, while the flow scheme is shown in Figure 4.7. From the Balara Treatment Plant, the treated water goes into three directions: one, to zone 11 by gravity; two, to zone 5 by means of Balara Pump Station; and three, by aqueduct to San Juan Reservoir. Along the way, the Cubao Pump Station draws water to supply water to zone 5. From the San Juan Reservoir, the other zones are supplied by either gravity or pumping stations.

C. The 1982 Conditions

Between 1975 and 1982, two minor developments provided a small increase in supply capacity and in the delivery and production efficiency.

First, the MWSS has started operating some groundwater wells to serve the outlying areas. The wells increased the total system

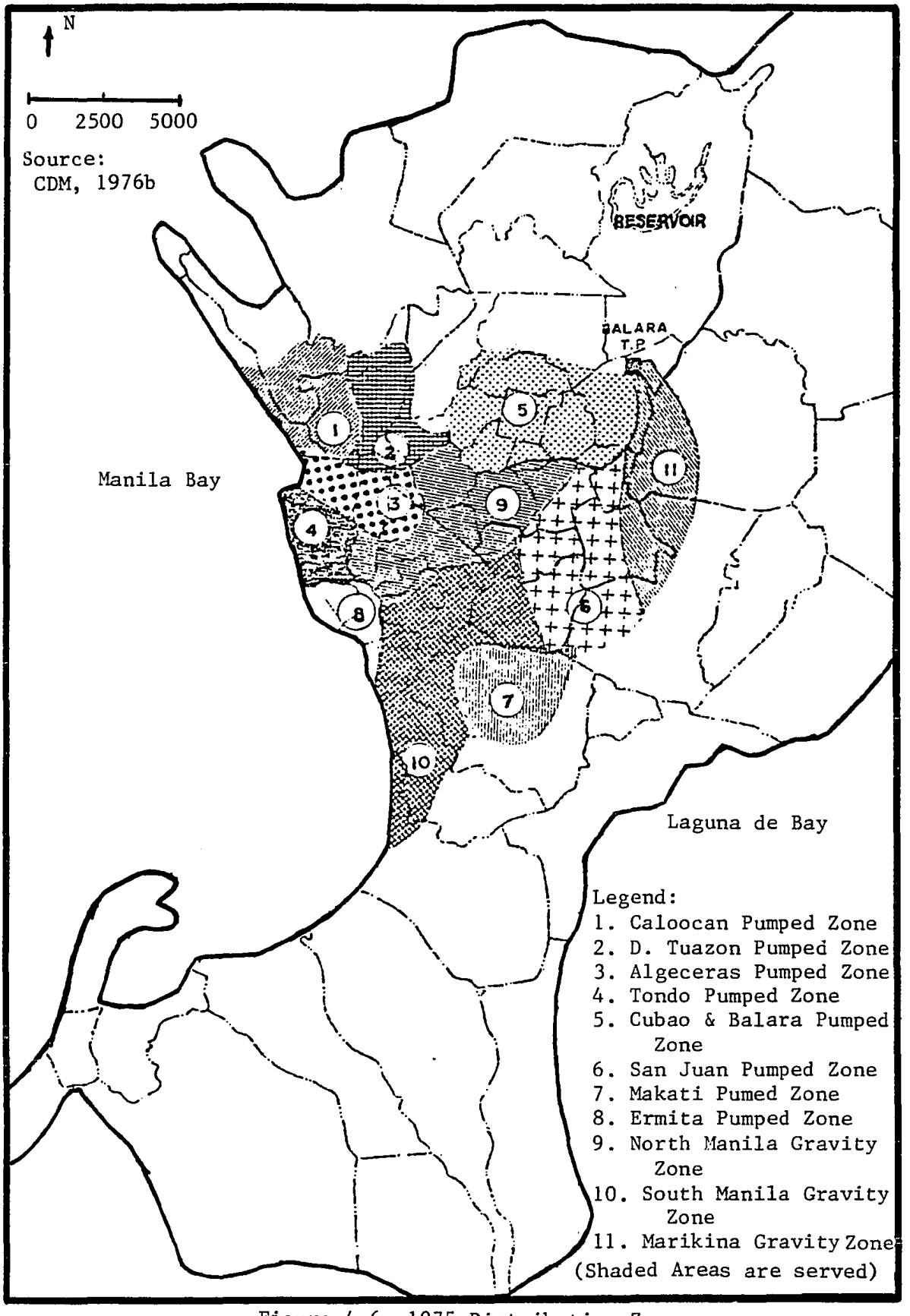


Figure 4.6 1975 Distribution Zones

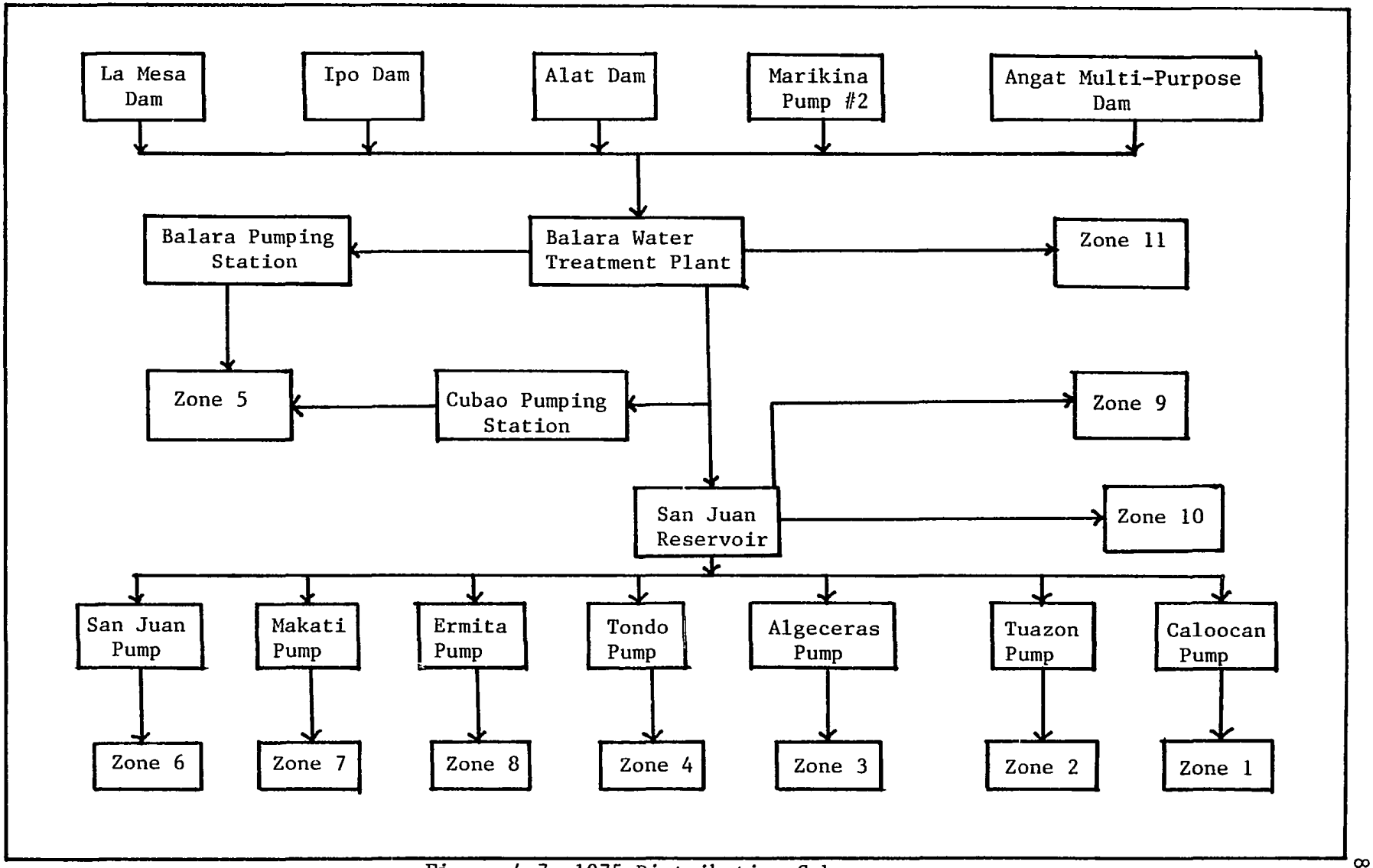


Figure 4.7 1975 Distribution Scheme

capacity by around 4.35 MCM/year. Second, the MWSS undertook improvement works on the treatment and distribution facilities in mid-1981 which increased the production efficiency by 3 percent and the quantity of water delivered by 18.98 MCM/year from their 1975 levels.

In 1982 then, the total water supply capacity increased to 485 MCM/year, this time supplied by those same sources in 1975 and the groundwater wells. Refer to Table 4.4.

Table 4.4

1982 MWSS Water Supply Sources
And Capacities

Source	Capacity, MCM/year
La Mesa Dam	35.91
Ipo Dam	131.21
Alat Dam	6.91
Marikina Dam	6.91
Angat Multi-Purpose Dam	299.71
Groundwater Wells	4.35
Total	485.00

Sources: 1. Camp Dresser and McKee, 1976b, p. 7
2. MWSS, 1981b

Although an expansion project, MWSP II which will be discussed later, was started back in August 1975, it was not operational until the end of 1982. So, basically, except for the wells, the same components in 1975 make up the 1982 system.

Due to the improvement in the treatment facilities, the system produced at an efficiency of 98.26 percent[1], that is, out of the 485 MCM/year capacity, 476.561 MCM/year was produced (MWSS, 1982).

The estimated[2] measured consumption of the area served D_a was 263.807 MCM/year, while the economic demand D_s of the entire service area of 148,000 hectares was estimated to be 717.15 MCM/year. This resulted in an actual demand-side shortage of

$$ADSS = D_s - D_a$$
$$= 717.15 - 263.807 = 453.343 \text{ MCM/year}$$

This ADSS of 453.343 MCM/year is the actual unmet consumption of the entire unserved area, assuming that the unaccounted water is lost.

If we compare the service area's total demand D_s to the system's theoretical capacity C_s of 485 MCM/year, we would have a supply-side shortage of:

$$SSS = D_s - D_a$$
$$= 717.15 - 485 = 232.15 \text{ MCM/year}$$

This means that 232.15 MCM/year is the theoretical unmet demand of the service area, assuming 100 percent production and delivery efficiencies.

Then if we compare D_s to the system's actual production C_a of 476.561 MCM/year, we would have an actual supply-side shortage of:

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[1]Actually 1980 efficiency, but due to the delay in MWSP II, this efficiency is assumed to have been maintained until the operation of the project at the end of 1982.

[2]The author was in the field up to September 1982, thus the 1982 measured consumption presented herein was estimated by extrapolating the 1970-81 data for the total consumption. The total economic demand of the entire service area was computed using the estimated demand equations in Chapter VI.

$$ASS = D_s - C_a$$

$$= 717.15 - 476.561 = 240.589 \text{ MCM/year}$$

This means that, assuming that the actual quantity of water produced is delivered at 100 percent efficiency, the unmet demand of the service area would have been 240.589 MCM/year.

The residential performance indicator can be computed from the 1982 extrapolated number of residential connections of 292,263. At an average of 8.15 persons per connection, this would mean that there were 2,381,944 persons served in 1982. This is equivalent to 33.78 percent of the service area's population of 7,050,000. With the residential use of 142.283 MCM, the per capita residential consumption was 59.734 M3/year (or 163 lpcd). On the aggregate, the total use of 263.807 MCM would mean a per capita use of 37.419 M3/year (or 102.517 lpcd).

The 1982 demand and supply conditions are summarized in Table 4.5.

Table 4.5

Summary of Demand and Supply Conditions, 1982

Capacity: 485 MCM/year	Total[a] Demand (D_s): 717.15 MCM/year
Production: 476.561 MCM/year	Actual[b] Demand: 263.807 MCM/year
Water Billed: 263.807 MCM/year	Population Served: 2,381,944
Unaccounted: 212.754 MCM/year	Percent Population Served: 33.78%
Production Eff.: 98.26 percent	Residential Use: 142.283 MCM/year
	Per Capita RU: 163.65 lpcd
	Per Capita Agg. Use: 102.517 lpcd

Notes: [a]Computed using estimated demand equation in Chapter VI.
[b]Extrapolated from 1970-81 data.

The distribution system for 1982 will be presented as part of the plans and programs discussed in the next section.

D. Plans and Programs

Before presenting the MWSS capacity expansion plan, it is necessary to point out that it was derived by a conventional engineering approach where many parties (consultants) were involved. Camp Dresser and McKee Inc. (CDM) studied the demand side, although after evaluation, the MWSS, instead of adopting CDM's demand projection, made its own projections which were finally made the basis of the plan. On the supply side, a committee, acronymed PICOREM, composed of foreign and local engineering groups, was organized by the Office of the President to study and select the different supply alternatives for the MWSS service area. The committee developed several alternatives, and based on these, the MWSS, upon recommendation from the different groups, came up with the final expansion plan.

The presentation here more or less follows the generalized procedure for the traditional approach for expansion.

D.1 Consumption Projections by CDM

First, CDM projected the population to the year 2000 at an annual growth rate of 4.5 percent (CDM, 1976a). In arriving at this rate, it utilized separate projections made by the previous consultants (Metcalf and Eddy Inc. [Boston], Lahmeyer International [Germany], Black and Veatch International [Kansas]), and by the National Census and Statistics Office (NCSO) which used a medium growth rate of 3.4 percent (Maramag, 1976).

Second, CDM conducted land use analysis to project the area of the different land uses especially the industrial and commercial land uses. They did this by gathering existing land use maps from several government offices, evaluated them, and came out tentatively with a straight line (CDM, 1976a) growth rate of land use increase. Because the available maps did not cover the entire service area, CDM applied a methodology known as the Neighborhood Unit Concept (NUC) to estimate the land uses in the outlying areas. Under the NUC, a prototype neighborhood population of 12,500 persons was assumed, which when distributed at some specified densities, would occupy from 50 to 100 hectares. For each neighborhood, commercial, industrial, institutional and open space uses were taken to occupy 2.25, 10, 7, and 2 to 4 hectares, respectively. Carrying out this routine, CDM came up with a final straight line annual rate of growth for the different land uses. The results were: 2.48 percent for residential; 3.16 percent for commercial; 5.34 percent for industrial; 3.39 percent for institutional; and -0.85 percent for open space.

Third, CDM projected water consumption by type of use. To project domestic use, a sample was selected from the 1967-75 meter records which represented an area having adequate pressure and 24-hour water service. The sample was stratified according to income class, and for each class, per capita consumption was determined. See Table 4.6. CDM then projected the percentage of each class in the total projected population. Multiplication of these class percentages and their respective per capita consumption resulted in the "weighted average per capita consumption" (WAPCC). The product of this WAPCC and the total population gives the theoretical domestic consumption. They then measured

Table 4.6

Domestic Consumption per Capita, lpcd

Income Class	Year 1975	1982	1990
Upper Income	235	310	405
Middle Income	176	215	280
Lower Income	125	160	220

Source: Camp Dresser and McKee, 1976a, p. IV-8

actual 1975 consumption of sample communities. By dividing these actual consumption figures by the theoretical consumption of the sample communities, they arrived at a factor called "percentage served by MWSS," which they projected to 1982 and 1990. This concept of percentage served is not based on population, but rather on quantity. Being defined as the ratio of the actual to the theoretical consumption, it refers to the percentage of the required water that is satisfied by MWSS. By projecting the percentage served, CDM assume that MWSS would not provide domestic consumption to everybody in the service area, but would improve the 1975 60 percent performance to 79 percent and 80 percent by 1982 and 1990, respectively. See Table 4.7. Multiplication of the percentage served by the theoretical consumption yields the "projected MWSS domestic consumption." MWSS here does not mean that it was done by MWSS, but to emphasize the consumption that will be serviced by MWSS.

Projection of the industrial use was done by the following process. CDM selected two fully developed areas--one light industry and the other

Table 4.7

Percent Water Quantity Served by
CDM Demand Projection

Year	Percent served (by quantity of water)
1975	60
1982	79
1990	80

Source: Camp Dresser and McKee, 1976a

heavy industry, and took note of their consumption. By dividing the consumption by the area for each, they derived what was termed "Full Development Water Duty" (FDWD) for each area. An overall FDWD was derived by weighting each FDWD by the area occupied by each type--light and heavy industry. This came out to be 0.178 MLD/ha.

From their land use projection, they determined the percent of development (PoD), or the degree to which a specified land use is developed for industrial uses. Theoretical consumption was then calculated as the product of the industrial land use map area, PoD, and the overall FDWD.

The same approach was followed to estimate the theoretical commercial consumption. The overall FDWD for commercial uses was the weighted average of the region's inner core FDWD and the outlying area FDWD.

For institutional uses, CDM assumed the 1975 institutional theoretical consumption to be 1.6 times the billed consumption, or 40.868 MCM/year. Then, assuming a straight line growth rate of 6.37 percent,

they estimated that it would reach 59.114 MCM/year and 81.738 MCM/year in 1982 and 1990, respectively.

The results of these projections are presented in Table 4.8.

Table 4.8

CDM Demand Projection of MWSS Consumption

Year	Residential Use	Industrial Use	Commmercial Use	Public Use	Total
		(In MCM/year)			
1980	357.40	54.77	144.73	48.37	605.169
1981	396.29	61.17	153.94	51.04	662.438
1982	437.07	67.89	163.16	53.79	721.916
1983	480.52	79.24	172.38	56.56	788.7
1984	526.51	91.28	181.59	59.32	858.7
1985	576.12	103.99	190.82	62.08	933.015
1986	626.40	117.38	200.03	64.85	1008.662
1987	680.34	131.45	209.25	67.61	1088.635
1988	737.28	146.19	218.47	70.37	1172.313
1989	796.49	161.61	227.69	73.13	1258.929
1990	859.31	177.77	236.91	75.89	1349.882
1991	925.22	194.73	246.12	78.66	1444.728
1992	991.39	212.37	255.38	81.42	1540.516
1993	1064.50	229.98	264.56	84.18	1643.227
1994	1141.55	249.71	273.78	86.94	1751.976
1995	1222.69	269.41	282.99	89.70	1864.809
1996	1308.15	289.79	292.22	92.47	1982.628
1997	1398.12	310.87	301.43	95.23	2105.651
1998	1492.80	332.63	310.65	97.99	2234.073
1999	1592.42	355.88	319.87	100.75	2368.123
2000	1697.21	378.22	329.09	103.52	2508.176

Source: Camp Dresser and McKee, 1976a

D.2 Demand Projections by MWSS

Claiming that CDM's demand projections were quite high, and that more recent information was available, the MWSS in 1982 made projections based on its own targets and assumptions. The projection process for each year is as follows:

1. Set a target percentage of population to be served;

2. Using an assumed number of persons per connection, estimate the number of connections or services;

3. Multiply the number of connections by an assumed average consumption per connection per month, they arrived at the total consumption which, when multiplied by 12 gives the consumption for the year. The assumption on the average consumption per connection per month and the number of connections include all other uses. Thus the resulting estimate of demand includes all uses.

4. The next step is based on the engineering concept of theoretical demand. The definition of theoretical demand, which is equated to the quantity of water produced and delivered, is based on the practical view that one part of water delivered is consumed by the population, and one part is lost or unaccounted for. Thus,

$$TD = TC + UW \tag{49}$$

where TD is the theoretical demand (equals C_a earlier defined); TC is the theoretical consumption; and UW is the quantity of unaccounted-for water. Theoretical consumption is the total consumption which would occur if all residents, institutions, commercial and industrial establishments were connected to the distribution facilities which provides a 24-hour day water service. Unaccounted-for water is the quantity of

water which could not be recorded due to defective meters, unmetered services like water plants and offices, unmetered fire hydrants, illegal connections, leakages, and others.

Using this concept, the MWSS assumed a certain percentage "U_w" of the water produced (equals TD) as unaccounted-for, that is:

$$UW = U_w\ (TD) \tag{50}$$

Formulating based on the above concept, we have:

$$TD = TC + U_w\ (TD) \tag{51}$$

Solving for TD, we have:

$$TD = TC/(1 - U_w) \tag{52}$$

The theoretical consumption TC is the consumption determined in step 3. Thus, with assumed values for U, the MWSS estimated the theoretical demand using the above equation.

The assumptions used in the projection and the results are shown in Tables 4.9 and 4.10, respectively.

D.3 Evaluation and Ranking of Alternative Supply

The Marikina River had been known to be the next major source of water supply for Manila after the capacity of the Angat source will have been fully utilized. But recently, MWSS indicated that serious siltation problem would be a threat to the project.

So, in 1978, a committee[3] called the Presidential Inter-Agency Committee for the Re-Study of the Marikina River Multi-Purpose Project

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[3]Headed by the MWSS Chairman and composed of: Electrowatt Engg Services, Ltd.; Renardet Engg/Renardet S.A.: Technospere Consultants Groups, Inc.; Philippine Technical Consultants, Inc; and F.F. Cruz & Co., Inc.

Table 4.9

Assumptions for Demand Projection by MWSS

Year	Population of service area (1000)	Percent Population served	Connection (1000)	Average Consumption[a] M3/conn/month
1980	6530	37.81	281.99	74.50
1981	6790	35.09	287.85	73.7
1982	7050	46.24	388.0	71.13
1983	7320	62.25	454.02	66.75
1984	7600	68.53	561.5	60.75
1985	7900	65.21	603.6	72.86
1986	8180	65.49	650.029	73.33
1987	8480	66.63	698.5	74.63
1988	8790	65.75	718.5	78.69
1989	9100	62.82	744.42	84.83
1990	9420.93	63.00	772.83	84.83
1991	9753.17	64.0	812.79	84.83
1992	10097.13	65.0	854.6	84.83
1993	10453.23	66.0	898.35	84.33
1994	10821.88	67.0	944.12	84.33
1995	11203.53	68.0	992.01	84.83
1996	11598.6	69.0	1042.09	84.83
1997	12007.69	70.0	1094.48	84.83
1998	12431.16	71.0	1149.27	84.83
1999	12869.57	72.0	1206.55	84.83
2000	13323.44	73.0	1266.45	84.83

Source: MWSS, 1982

Note: [a]Aggregate average for all types of uses.

Table 4.10

Projected Demand for Water, by MWSS

Year	Consumption MCM	Percent Unaccounted	Demand MCM
1980	252.09	47.1	476.54
1981	254.57	48.85	497.69
1982	288.5	50.0	577
1983	363.68	48.0	699.38
1984	409.34	46.0	758.04
1985	527.71	43.0	925.81
1986	572.0	40.0	953.33
1987	625.0	35.0	926.38
1988	678.5	30.0	969.29
1989	757.78	29.0	1067.3
1990	786.7	28.40	1098.74
1991	827.37	27.80	1145.95
1992	869.94	27.20	1194.97
1993	914.47	26.60	1245.87
1994	961.07	26.0	1298.74
1995	1009.81	25.40	1353.63
1996	1060.8	25.0	1414.4
1997	1114.12	25.0	1485.50
1998	1169.89	25.0	1559.86
1999	1228.21	25.0	1637.61
2000	1289.18	25.0	1718.91

Source: MWSS, 1982

(PICOREM) was formed by the Office of the President to identify and rank viable alternatives to the Marikina River.

The following are the eight alternatives that were evaluated. The components discussed herein exclude the distribution system. The concept of unit cost per cubic meter of water as used here was estimated by dividing the discounted construction and OMR costs by the discounted quantity of water that will be produced within the specific period of operation--the planning horizon. Unless otherwise specified, the unit cost is evaluated for 25 years of operation at 10 percent discount rate (PICOREM, 1979). Costs are based on 1978 prices.

1. Kaliwa River Basin

This alternative is the source of an expansion project MWSP III discussed later in Part D.4.

The main components of this project are those enumerated under MWSP III except those relating to distribution system. The construction cost is estimated to be P2734 million. The components will have an OMR cost of P62 million a year. Unit cost of water produced would be PO.73 per cu.m.

2. Kanan River Basin

This project, which in combination with Kaliwa River, is also a multi-purpose project that would provide a yield of 1199.116 MCM/year for water supply and, with an installed hydropower capacity of 32.5 MW, its hydroplant would generate an average of 245 GWH annually.

The components include a 175-meter high rockfill dam with a usable water storage volume of 255 MCM; a powerhouse at Pantay; a 1447.12 MCM/year water treatment plant at Pantay; a treated water storage tank of

572,000 cu. m capacity at Cogeo; and spillways, transmission tunnels and pipelines.

The estimated construction cost is P4190 million while the OMR cost would be P101 million a year. This would result to a unit cost of P0.75/M3 of water produced.

3. Umiray River

This project would yield 410.2 MCM/year for water supply. The main components of the project are: five low diversion dams; a water treatment plant at Novaliches with a capacity of 354.68 MCM/year; a treated water storage tank at Novaliches with a capacity of 160,000 cu. m.; and tunnels and pipelines from the dams to the treatment plant and storage tank.

The estimated construction cost is P1403 million and the OMR cost would be P34 million per year. It would cost P0.65/M3 to produce water.

4. Laguna de Bay

This project would yield 946.085 MCM/year for water supply. The project would require the construction of dikes and copper sulfate basin. Other components are: a low lift pumping station with a discharge of 394.092 MCM/year; raw water pipe to treatment plant; a 394.092 MCM/year treatment plant and related facilities; high lift pumping station; treated water storage tank of 170,000 M3 capacity; and pipelines connecting these components.

Construction cost would be about P1982 million while the OMR cost estimated to be P414 million yearly. Water would cost about P0.85/M3 to produce.

5. Taal Lake

This is not a viable source for public water supply because of its high content of chloride and total dissolved solids. The source of these contaminants is the volcanic activity by Taal Volcano which is unpredictable and uncontrollable.

If developed, this source would yield 315.27 MCM/year. This project requires the following components: a check dam with a usable water storage capacity of 440 MCM; a treatment plant of 394.092 MCM/year capacity; a mixing tank of 40,000 M3 capacity; a 130,000 M3-storage tank; and all intervening pipelines between these components.

The estimated construction cost would be about P930 million, while the OMR cost is placed at P98 million. The unit cost of water is P0.70/M3 plus up to P1.50/M3 for desalination.

6. Pampanga River

This project could yield 946.08 MCM/year. This would require the following components: river intake with a capacity of 1891.64 MCM/year; pumping station at intake with an installed capacity of 315.27 MCM/year; storage reservoir; pumping station at the storage reservoir; water treatment plant at Novaliches with a capacity of 592 MCM/year; treated water storage with a capacity of 260 MCM; and pipelines connecting all these components.

The construction cost of the project is estimated at P3837 million and the OMR cost is about P356 million yearly. It would cost P0.96/M3 to produce water.

7. Calamba-Santa Rosa Groundwater

This project would yield from 37.83 MCM/year to 97.73 MCM/year, which is too small for export to Manila. The project involves the construction of 36 deep well pumps; a booster pump station; a water treatment plant and facilities; electric power network; and interconnecting and transmission lines.

The construction cost of the project is estimated to be about P197 million. With OMR cost of P17.58 million yearly, it would cost P0.69 to produce one cu. m. of water.

8. Lower Marikina Basin Groundwater

This alternative could only provide about 47.291 MCM/year. One problem with this small supply is that, when the local demand increases, the exportable supply to the MWSS system would gradually reduce. If this project has to be developed for the MWSS system, it would require the following components: 52 deep wells and pump sets; two booster pumping stations; a water treatment facilities (chlorination); electric power network; interconnecting and transmission pipelines.

The estimated construction cost is P135 million and the OMR cost would be P19 million a year. The unit cost of water is P0.73 per cu. m. (for 50 years of operation).

The different sources with their respective water yield and estimated construction, OMR, and unit costs are shown in Table 4.11. The locations of these sources are indicated in Figure 4.8.

The sources were ranked on the basis of least cost per unit quantity of water and also on physical constraints. Their findings

Table 4.11

Alternative Supply Sources

	Source	Yield MCM/yr	Construction Cost M P[a]	OMR Cost M P/yr[b]	Unit Cost Pesos/M3
1.	Kaliwa River	725.28	2743	6%	.73
2.	Kanan River	1199.12	4190	101	.75
3.	Umiray River	410.20	1403	34	.65
4.	Laguna de Bay	946.085	1982	414	.85
5.	Taal Lake	315.27	930	98	2.20
6.	Pampanga	946.08	3837	356	.96
7.	Calamba-S. R.	97.73	197	17.58	.69
8.	Lower Marikina	47.29	135	19	.73

Notes: [a]At 1978 prices
[b]For 25 years of operation except #8 which is 50 years.

References: PICOREM, 1979; and PICOREM, 1980.

indicate that the ordering should be as follows: Kaliwa River Basin; Kanan River Basin; Umiray River Basin; Laguna de Bay; and Pampanga River Basin. The other sources are not recommended for MWSS supply.

D.4 Expansion Plan and the Related Distribution Systems

Having the supply alternatives, the MWSS prepared an expansion plan (MWSS, 1981b) that calls for the development of the above sources in the order recommended by the committee. The time phasing of development is determined by how much time the excess capacity of a source could last given the total demand. Given the policy of without-shortage, projects are scheduled so as to be put into operation immediately after the preceding project is fully used.

The schedule of development of these sources is shown in the long range expansion plan which is designed to satisfy MWSS demand up to the

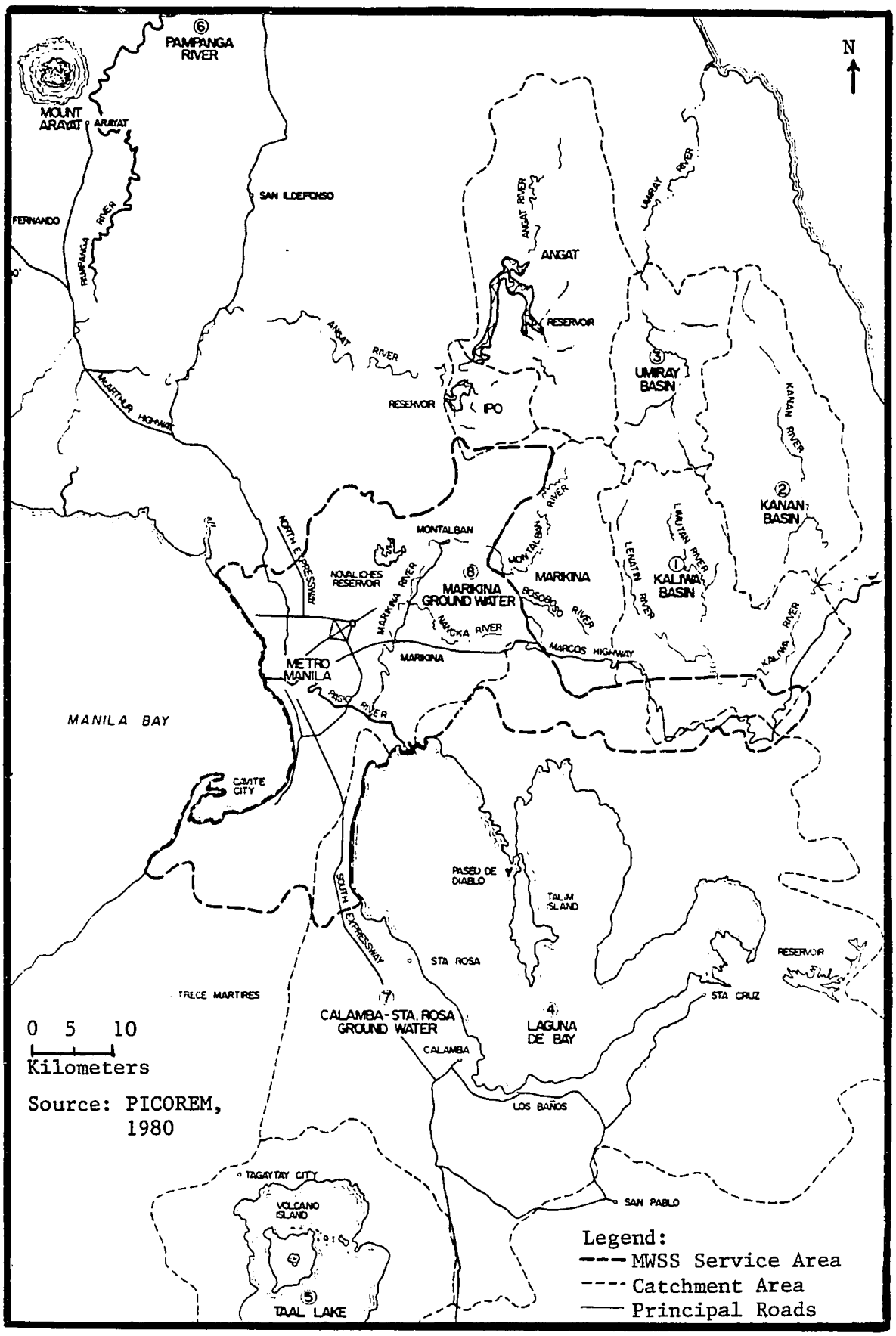


Figure 4.8 Location Map of Alternative Supply Sources

year 2050. This plan is shown in Figure 4.9. The projects are divided into stages. The capacity of each stage is shown roughly by the "rise" of the step function representing the supply curve. For instance, the project MWSP II is divided into two stages of equal capacities--stages 1 and 2.

We can say that beyond the year 2000, the plan is merely an intention to implement those projects in that order. At present, the MWSS is working on the two most immediate projects which are scheduled for operation between 1980 and 2000.

1. Metropolitan Water Supply Project (MWSP) II

This project is the second stage and full development of the existing major source--the Angat River. The first stage of this source is the existing Angat Multi-Purpose Dam which was completed in 1972.

The original plan for MWSP II was made by MWSS as early as 1968 by the joint effort of Metcalf and Eddy Engineers (Boston) and EDCOP Engineers (Manila) as consultants to MWSS. The original plan consisted of an intake structure which will draw water from the existing Ipo Dam, aqueducts, a new 414 MCM/year treatment plant at San Jose, new distribution system, and improvement of the Balara Treatment Plant. The estimated construction cost of this original plan was P1053.24 million at 1978 prices.

The original plan underwent various changes, and it was not until 1976 that the plan was finalized. The components of the final plan include the construction of a new concrete dam at Ipo; a 552.45 MCM/year Treatment Plant at La Mesa; a 200,000 M3 Reservoir at Bagbag; necessary aqueducts; a new distribution system including pumping

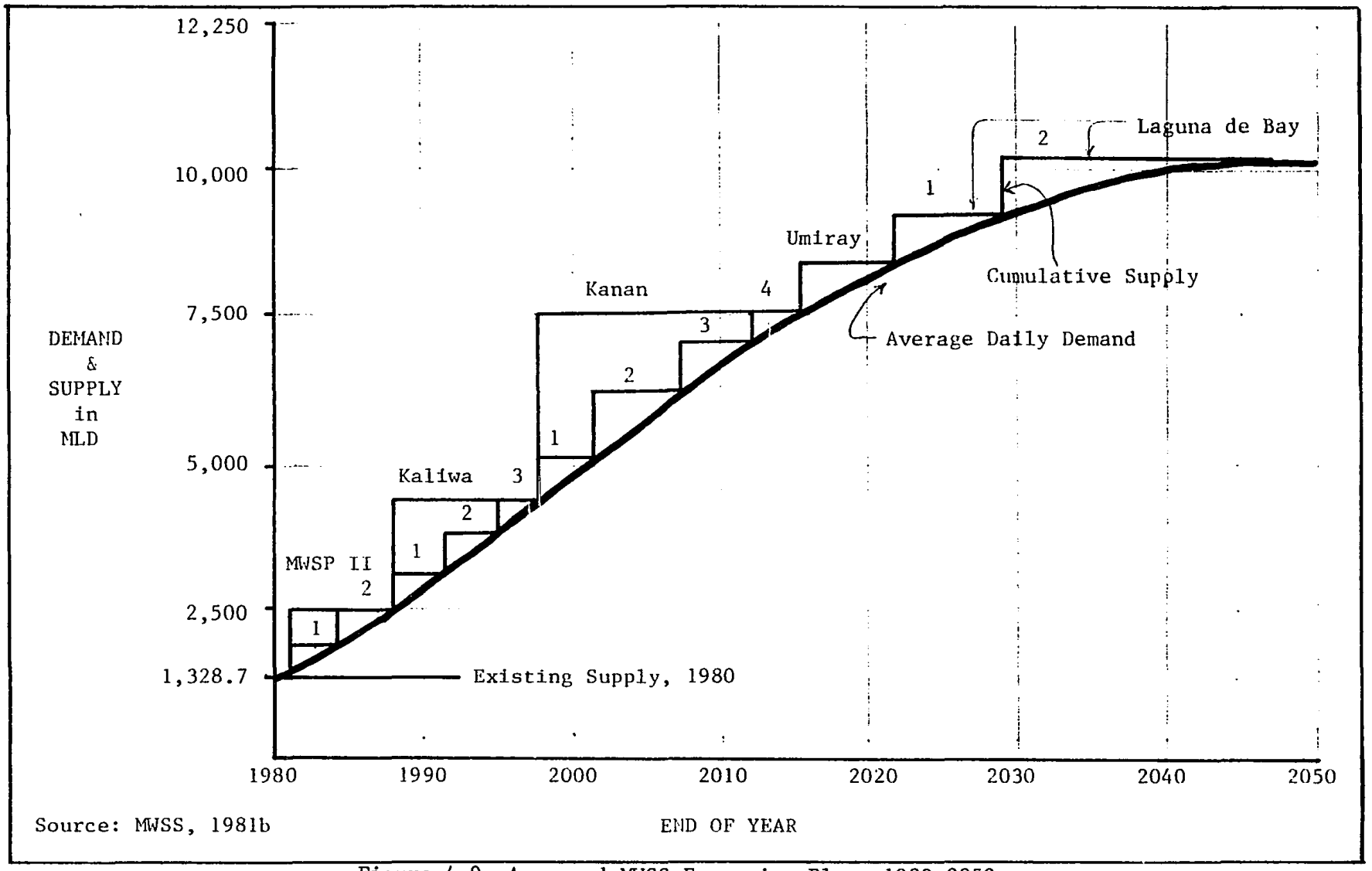


Figure 4.9 Approved MWSS Expansion Plan, 1980-2050

stations; improvement of the Balara Treatment Plant; various modifications to the existing distribution system; construction of 50 wells to serve outlying areas in Antipolo, Muntinlupa, and Upper Marikina Valley; 510,000 service connections; and construciton and equipping various branch offices for centralized operation and maintenance purposes.

This project, which is aimed at catching up with the backlog of the mid-1970s and meeting the projected demand up to 1986-87, would expand the 1982 capacity of 485 MCM to 886.6 MCM/year, an addition of 401.6 MCM excluding the contribution of the wells. The actual cost of the project (final plan) is about P2013.67 million at 1978 prices.

According to the approved expansion plan in Figure 4.9, MWSP II is divided into two stages of equal capacities, the first stage being targeted to operate in 1981, and the second stage in 1984. Actually, construction works which started in 1977, have had many delays. In fact a recent report (MWSS, 1981b) indicates that the project will not be fully operational until the end of 1982. In reality the whole source is being developed as a whole rather than by stages. Some components such as the deep wells have been in operation since the early part of 1982. The supply contribution of these wells is shown in Table 4.4.

To distribute the water from this project, the 1982 Supply Distribution System was designed (Camp Dresser and McKee, 1977). New distribution zones were identified as follows: I--Manila Low-North; II--Manila Low-South; III--Southern Low; IV--Bagbag High; V--Balara High; VI--San Juan High; VII--Mandaluyong High; VIII--Southern High; IX--Marikina Low-North; and X--Marikina Low-South. Refer to Figure 4.10.

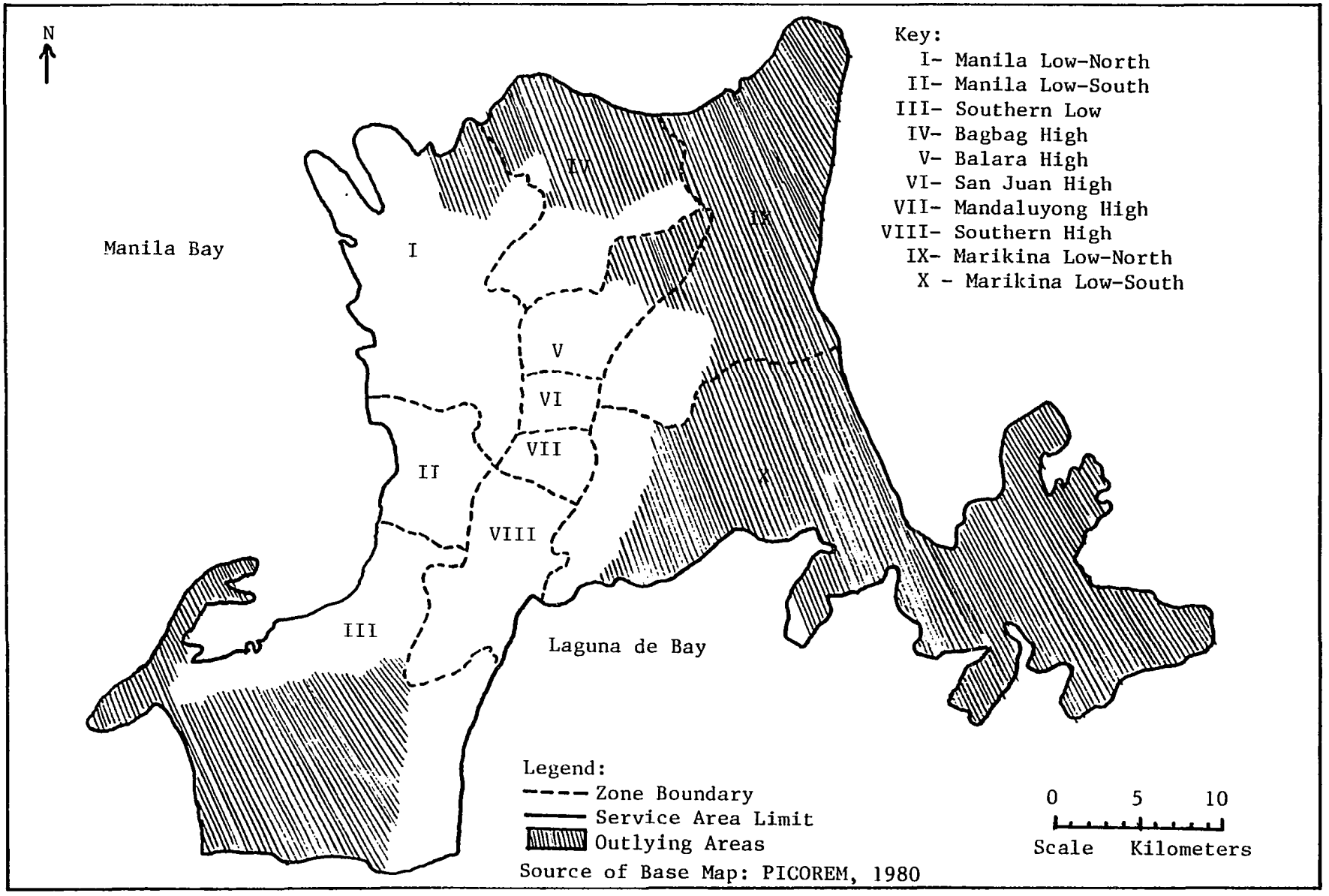


Figure 4.10 1982 Distribution Zones

These zones are not fully served by the distribution system shown in Figure 4.11. As of 1982, the MWSS distribution system covered less than 50 percent of the assigned service area. This coverage is shown by the unshaded area in Figure 4.10.

Based on the existing distribution facilities, the distribution scheme of 1982 as shown in Figure 4.12 makes maximum use of major existing transmission lines and avoids the construction of new lines parallel to or near the existing system. Treated water from Balara Treatment Plant flows to San Juan Reservoir, and then to Zone I, Zone II, and Zone III up to the limit of existing mains. Zones V, VI and VII are served by pumping up to the capacity of existing pumps and mains. The remaining output from Balara T.P. is transmitted via the Marikina Valley to Zones IX, X, and VIII. All the water treated from La Mesa Treatment Plant flows into Zone IV, and from there to Zones I, II and III. The combined transmission lines form a ring.

2. Metropolitan Water Supply Project (MWSP) III

By 1987, the capacity of MWSP II is expected to be fully utilized, and the next project to be developed according to the adopted plan shown in Figure 4.9 is the Kaliwa River Basin, the source for MWSP III.

MWSP III has a total capacity of 725.28 MCM/year and its utilization is divided into 3 stages of equal capacities. Stage 1 is scheduled to operate in 1988, stage 2 in 1992, and stage 3 in early 1995. Refer to Figure 4.9. Each stage will have a capacity of 241.76 MCM/year.

The utilization of the Kaliwa River Basin (PICOREM, 1980) will increase the system's total 1983 capacity of 882.2 MCM/year to 1611.88 MCM/year and will be able to meet the projected demand of the target population up to 1998 (MWSS, 1981b).

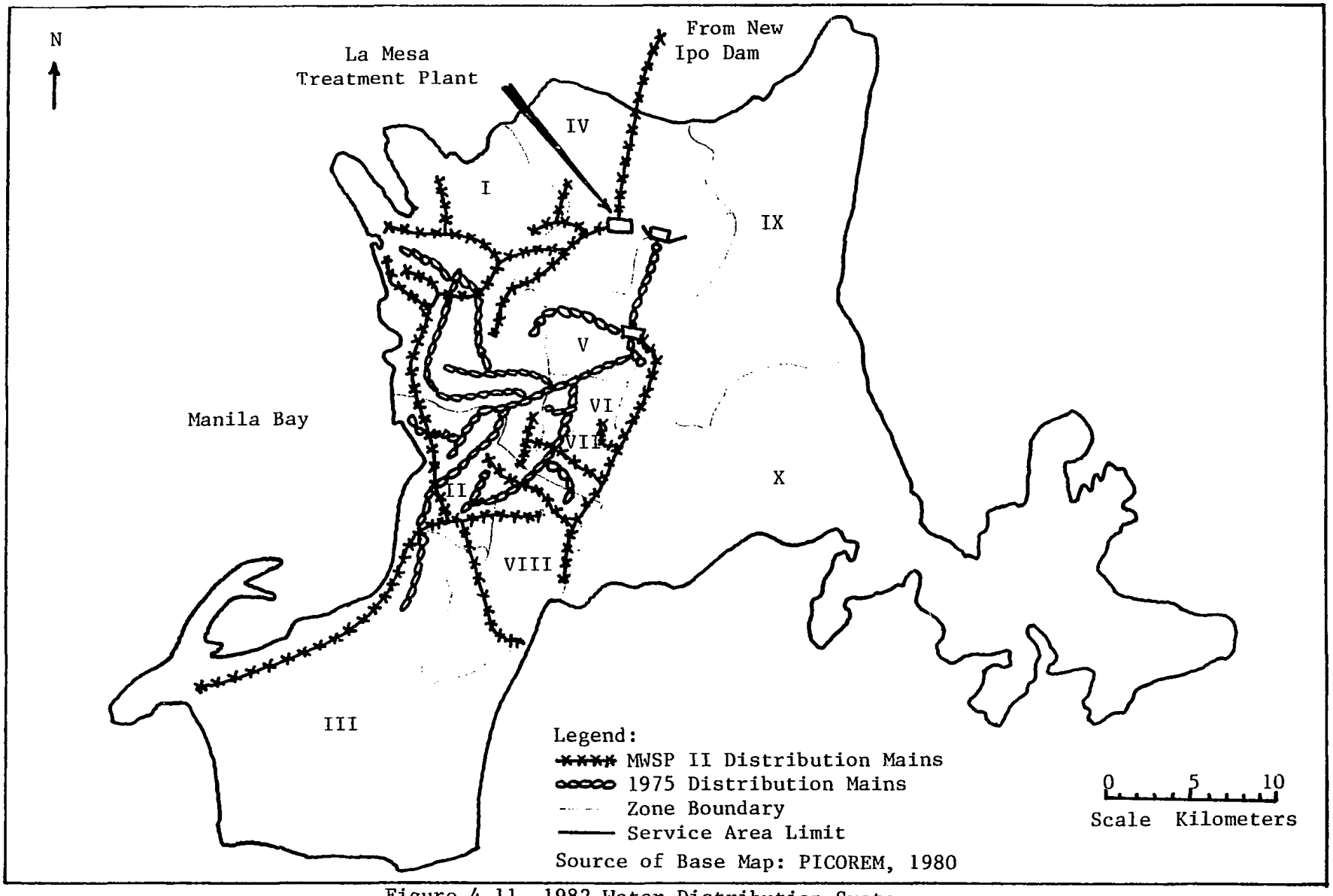


Figure 4.11 1982 Water Distribution System

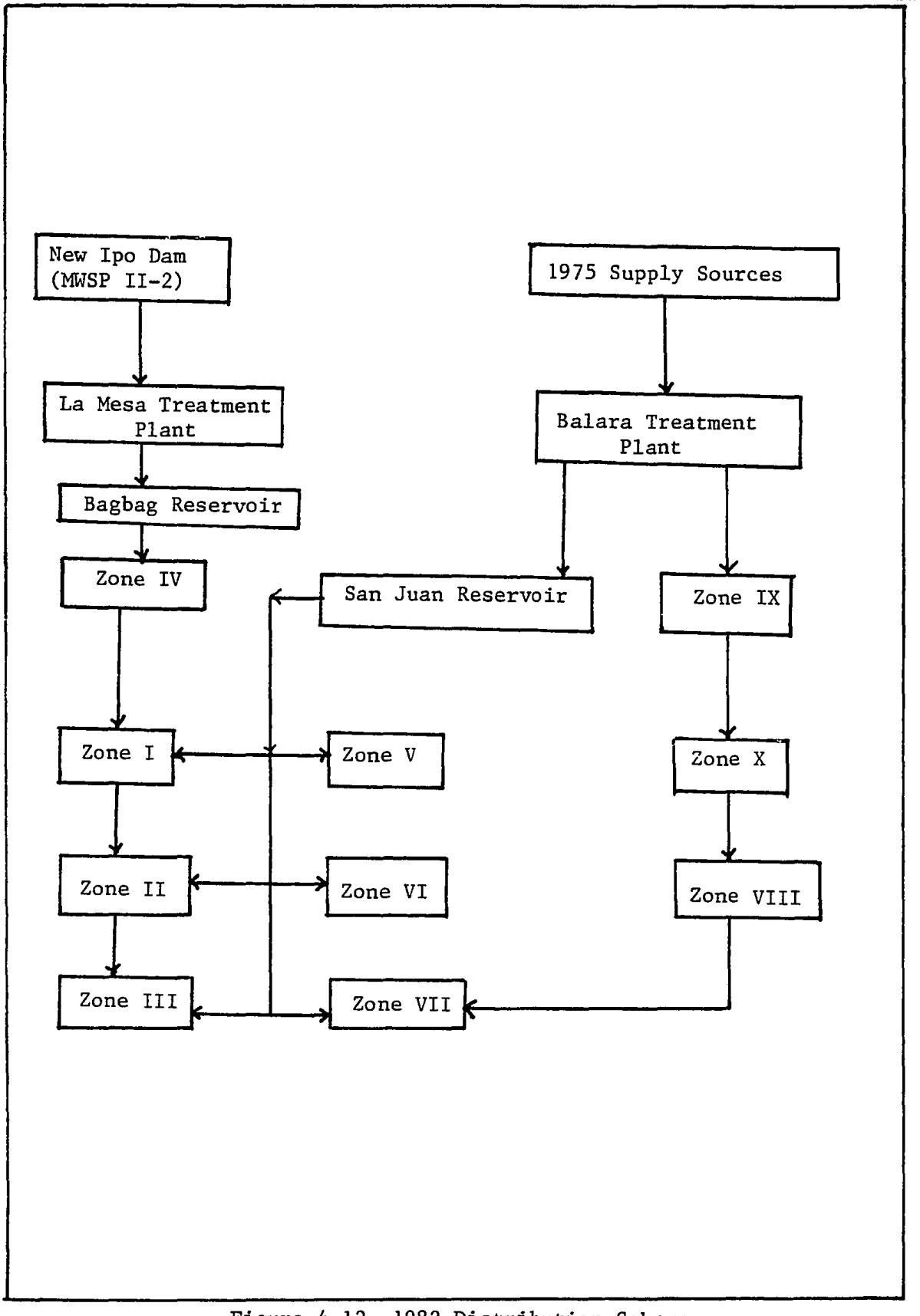


Figure 4.12 1982 Distribution Scheme

The main components of the project are: rockfill dam with a usable water storage of 500 million M3 at Kaliwa Basin; a hydroplant with an installed capacity of 21 MW at Pantay; water treatment plant of 876 MCM/year capacity at Pantay; a 302,800 M3 treated water storage reservoir at Cogeo; a regulating tank; tunnels for water transmission; a new distribution system of primary, secondary and tertiary lines; and 700,000 domestic service connections, and 52,000 service connections for industrial, commercial, and institutional users.

The estimated project construction cost (excluding hydroplant) is P2734 million at 1978 prices.

The distribution component of this project is spelled out in the 1990 Distribution System. See Figure 4.13. The distribution mains are indicated by a heavy broken line, while other notations are the same as those in Figure 4.11 for the 1982 system.

The distribution scheme is shown in Figure 4.14. Treated water from Pantay Treatment Plant goes to two directions namely: (1) to a regulating tank nearby which supplies water to Zone IX and the western portion of Zone X: and (2) to the Cogeo Main Storage Tank which supplies water to Zone X, VIII, VII, and III. Water from the 1975 supply sources and the 1982 MWSP II source are distributed in the same scheme as in the 1982 Distribution System shown in Figure 4.14.

The distribution mains for MWSP II are expanded under MWSP III to serve the northern portion of Zones I, IV, and IX.

As a result of this project, the MWSS expects to bring water to around 75 percent of the total service area. The extent of service coverage is shown by the unshaded area in Figure 4.15.

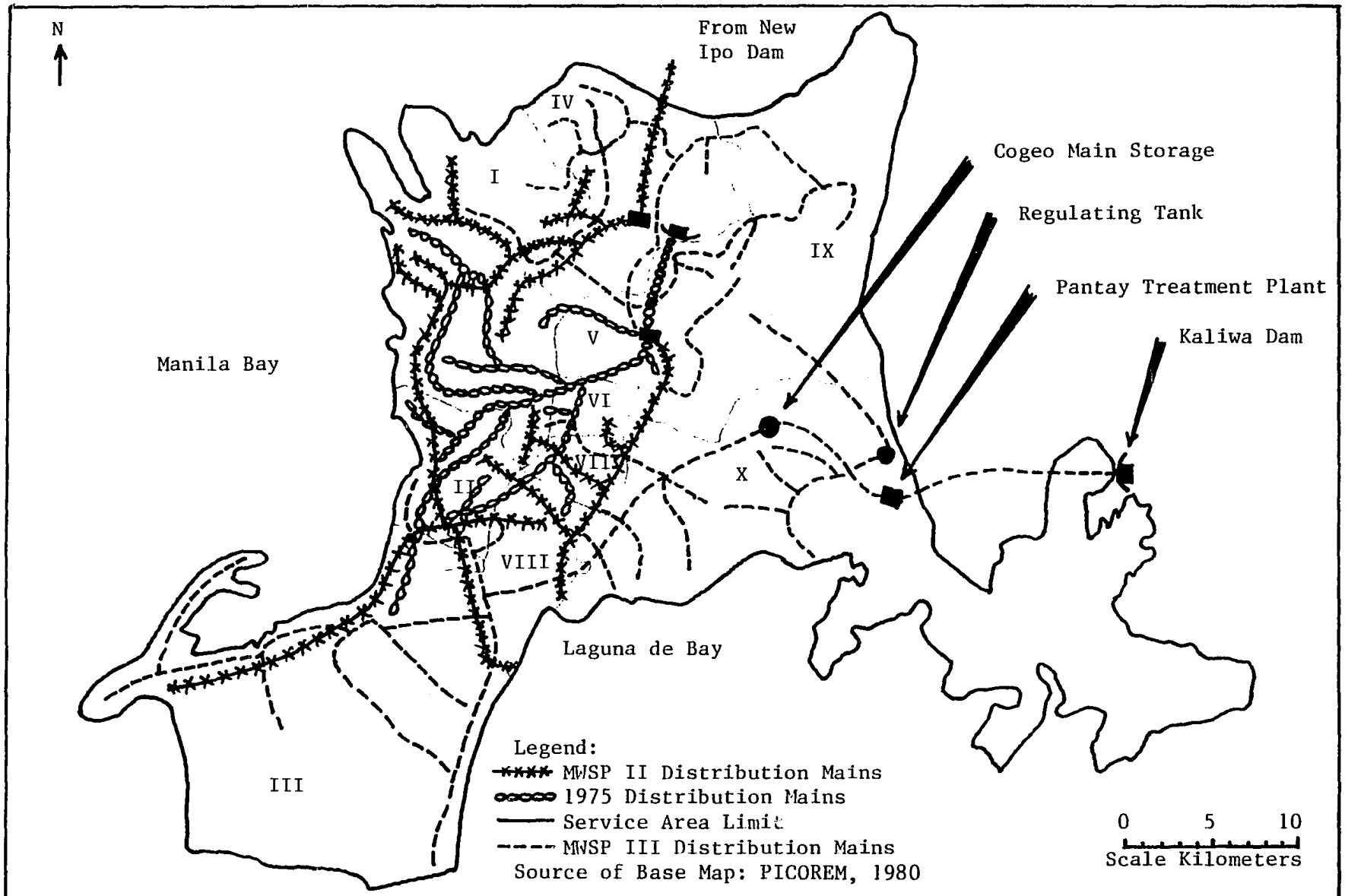


Figure 4.13 1990 Distribution System

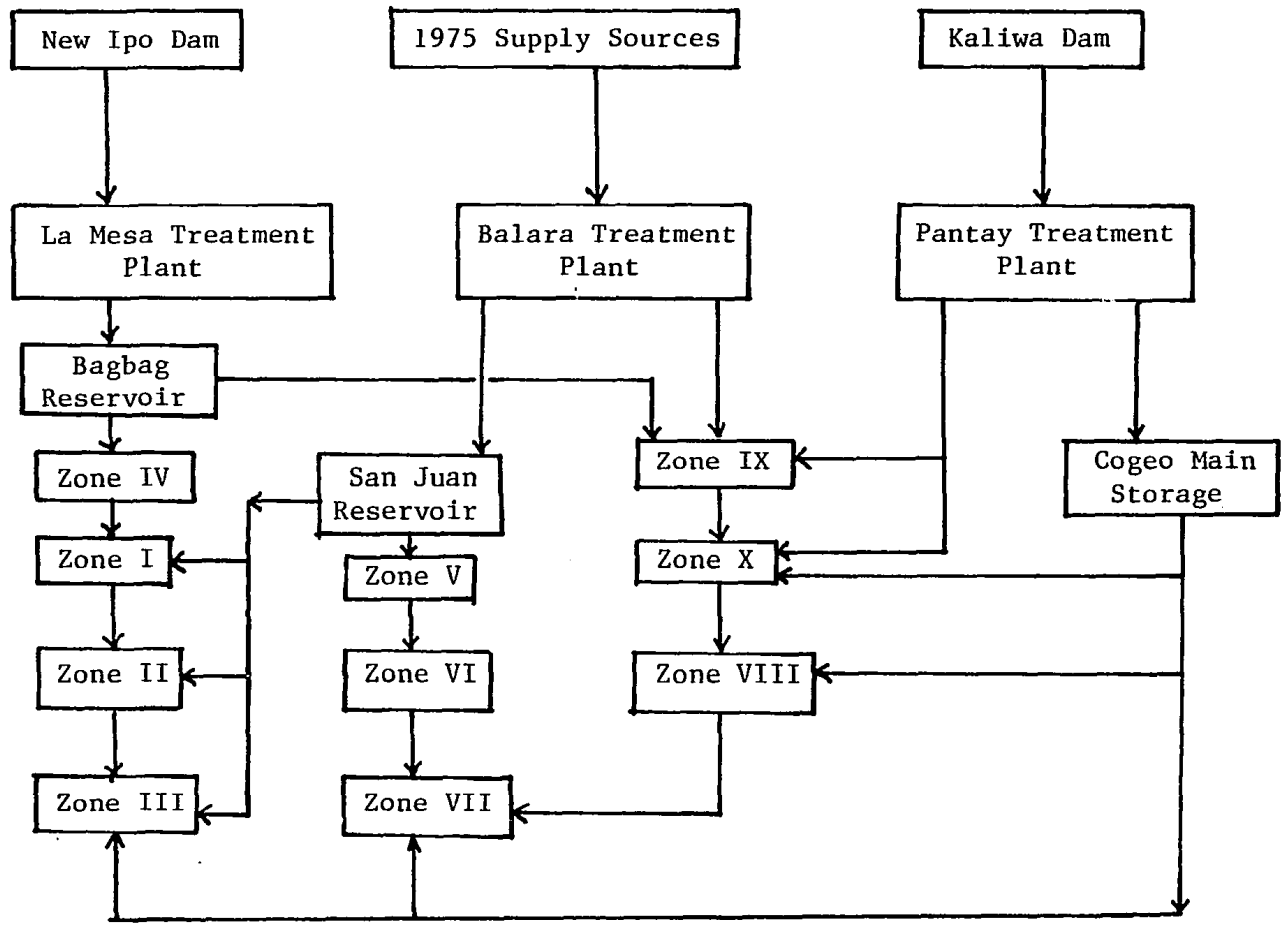


Figure 4.14 1990 Distribution Scheme

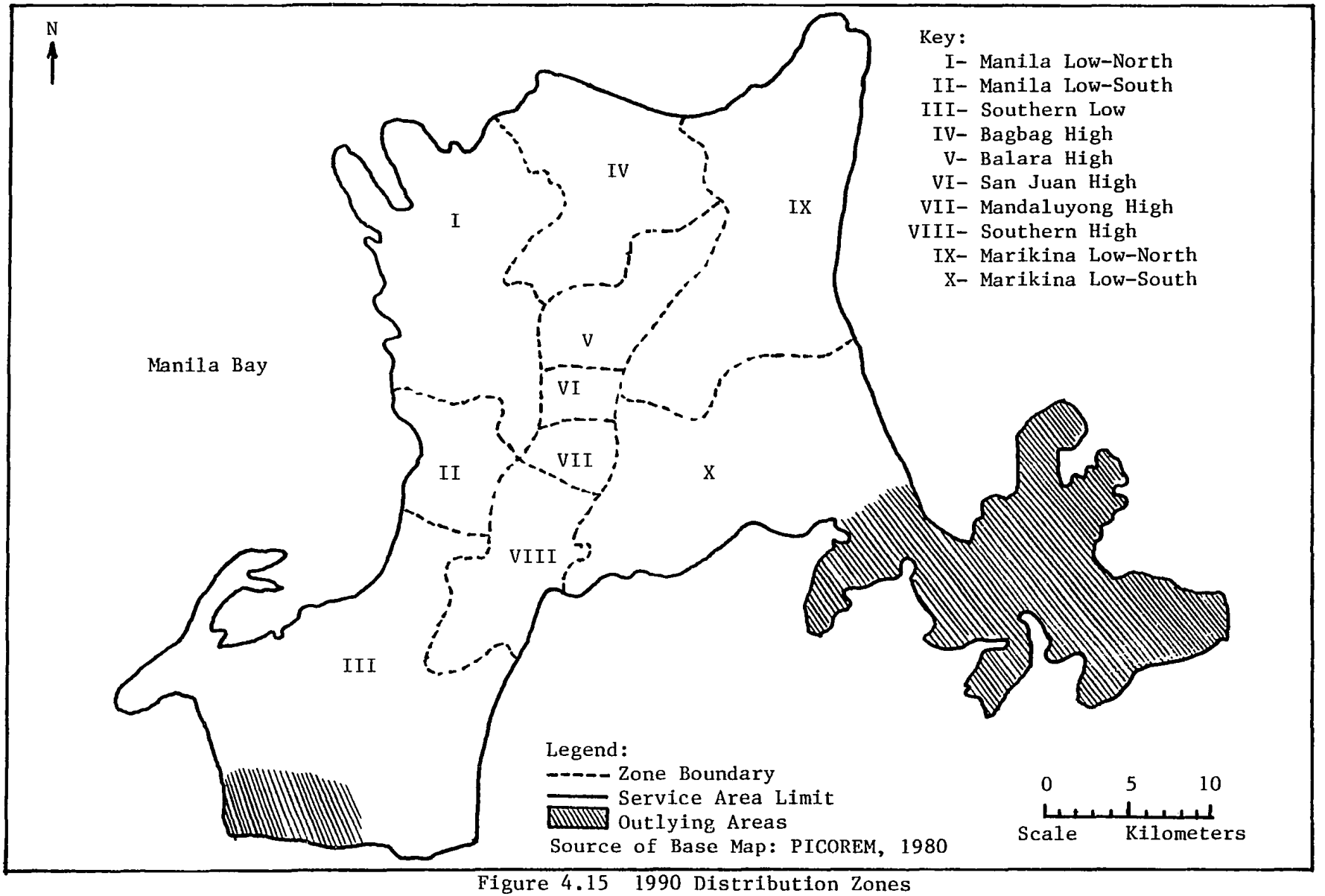


Figure 4.15 1990 Distribution Zones

CHAPTER V

ANALYTICAL FRAMEWORK

5.1 Methodology

The methodoloty and data requirements presented in this chapter are designed to address two working hypotheses which were mentioned in Chapter II: (1) that water consumption in Metro Manila responds to pricing policy, and (2) that tolerance of shortage reduces the cost of an expansion plan and is therefore a viable policy of achieving a least cost plan. The methodology for each of these is discussed below.

A. On the Responsiveness of Consumption to Prices

To investigate the responsiveness of water consumption to pricing policies, a separate consumption function must be specified and estimated for each major type of use because each type faces a different price schedule from that of the others.

The major types of water use in Metro Manila are residential, industrial, commercial, and institutional or public uses. We may specify the consumption function for each below:

Residential Use

The model to be estimated is:

$$RU = f(Y, DMP, DP, V) \tag{53}$$

where RU = residential use, cu. m/household/month;

Y = average income, Pesos/household/month;

DMP = price per cu. m. of the marginal block faced by the average household consumer;

DP = difference price; and

V = error term.

The theory behind the equation is very basic in economics. Demand theory (Miller, 1978) holds that one's consumption is positively related to income, and has a negative relationship to the price of the good. The literature on empirical studies reviewed earlier supports the above specification. The price variables DMP and DP are the two prices defined by Billings and Agthe (1980) for dealing with increasing block rates. The error term accounts for the other factors which are unquantifiable and cannot be explained by the specified variables. These include changes in institutions, technology, tastes and preferences.

Industrial Use

The model to be estimated is:

$$IU = f(IP, GDP, V) \qquad (55)$$

where IU = industrial use in million cu.m/year;

IP = industrial price of water, Pesos/cu.m.;

GDP = gross domestic product of the region, million pesos; and

V = error term.

The industrial use, which actually represents the quantity purchased by the industrial firms, is expected to be negatively related to price. De Rooy (1974) found that industrial demand for water responds negatively to price.

Gross domestic product (GDP) is the closest proxy for the region's income. In fact regional income is the net regional product (NEDA,

1977). Regional income affects the use of water in a similar way as in the theory of investment (Gordon, 1978, p. 29). The availability of income determines the level of industrial investment. This level of investment can somewhow be determined from the level of inputs used in the production of goods and services. One of the most important of these inputs is water. Turnovsky (1969) found out that water consumption is affected by industrial production, an indicator of the level of industrial investment.

Commercial Use

The specified model is:

$$CU = f(CP, GDP, V) \qquad (55)$$

where CU = commercial use or quantity purchased by commercial firms, million cu.m/year;

CP = commercial price of water, Pesos/cu.m.;

GDP = gross domestic product of the region, million pesos;

and V = error term.

Commercial price is expected to affect commercial consumption negatively. Lynne (1978) found that commercial establishments respond negatively to prices in their use of water.

The GDP variable could be explained in the same way as in the case of industrial use. In this case, since commercial establishments contribute also to GDP, we can also say that commercial use of water is affected by the region's product or income, the availability of which dictates the level of investment on commercial activities.

Public Use

The model is:

$$PU = f(PP, G, V) \tag{56}$$

where PU = public (institutional) use, cu.m./capita/year;

PP = public price of water, Pesos/cu.m.;

G = population of the region, thousands; and

V = error term.

Public use is the quantity of water used by such institutions as schools, hospitals, government offices, public parks and other establishments for public uses. Population is expected to affect public use positively. The influence of price depends on whether public users pay for water. If they pay for water, price changes would affect their use negatively, but if they do not pay, their use may not respond to prices.

Statistical tests will be carried out for each of these consumption functions to determine the significance and validity of the alleged response of water consumption to pricing policy.

In particular, suppose we have an estimating equation:

$$CU = b_0 + b_1 CP \tag{57}$$

where CU is commercial use; b_0 is the intercept; CP is the commercial price of water; and b_1 is the estimated coefficient of CP. To test the hypothesis that CU responds to CP, we establish the null hypothesis

$$H_0: \quad b_1 = 0$$

Using the "t" test, and at a specified significance level, if for the appropriate degrees of freedom the calculated t value is equal or

greater than the critical table value of t (as defined in the Statistical Table), then the null hypothesis is rejected, which means that the original hypothesis $b_1 \neq 0$, or CU responds to CP, can be accepted.

B. On the Tolerance of Shortage as a Policy

To investigate the viability of allowing shortages as a policy for reducing the cost of an expansion plan, we need to define the different expansion plans that will be evaluated. An expansion plan, or a schedule of expansion projects, is based on a given projected demand and a given supply policy. Demand projections can vary by the extent of explicit attention given to economic factors such as pricing policy. Two polar extremes are chosen: first, the conventional "requirement" approach; and the second, a projection based on an econometric analysis, the "econometric demand" approach. A supply planning policy may either be a "with-shortage" or a "without-shortage" strategy. With these choices, and given the availability of information, we can derive the different plans from the matrix below:

Table 5.1

Matrix of Alternative Expansion Plans

	Alternative Supply Policies	
	(Without-Shortage) S1	(With-Shortage) S2
Demand by requirement, D1	Plan 1-1	Plan 1-2
Econometric Demand, D2	Plan 2-1	Plan 2-2

The above table shows in the columns the different alternative supply policies: S1 defines the conventional supply policy of without-shortage; and S2 defines the economic supply policy of allowing shortage.

On the rows are two different demand projections namely: D1 defines the demand projected by MWSS by using a conventional requirement approach; and D2 defines the demand projected by econometric approach.

The plans are defined by the intersections of the rows and columns: Plan 1-1 is a plan where the demand has been projected by the requirement approach and the supply policy of without-shortage is adopted; Plan 1-2 is one which is based on the requirement-based projected demand and the supply policy with shortage; Plan 2-1 is one which is based on the econometric projected demand and the without-shortage supply policy; and finally, Plan 2-2 is one which is based on the econometric projected demand and the supply policy of allowing shortage.

To investigate the hypothesis, the present value of the cost of each plan will be evaluated for a planning horizon of 20 years (1981-2000). Then we could transform our hypothesis in terms of the difference between the present value of cost (PVC_{ns}) of a plan based on the without-shortage policy and the present value of cost (PVC_s) of a plan based on the with-shortage supply policy. Our hypothesis can be expressed as:

$$H: \quad (PVC_{ns} - PVC_s) \geq 0$$

If the difference is greater than or equal to zero, then the hypothesis that tolerance of shortages reduces the cost of an expansion plan is not rejected. Thus, it pays to delay projects.

Specifically, the procedures involved in arriving at a cost estimate for each plan are: projecting demand; determining the penalty cost of shortage in the case of with-shortage supply policy; scheduling projects over the time period involved; and estimating the present value of the costs by discounting construction, OMR, and penalty costs, using one or more relevant discount rates.

We proceed by defining the needed information under each plan. For Plan 1-1, the requirement-based demand projection by MWSS is already available (See Figure 4.9) and the without-shortage policy can be applied to the set of supply alternatives that have already been placed by MWSS in an optimal sequence. For Plan 1-2, the requirement-based demand projection is also already available but the precise scheduling of the optimal sequence of supply alternatives has to be determined first by considering the value of penalty price. This calls for the estimation of penalty price. For Plan 2-1, the econometric demand has to be projected after which the without-shortage policy can be applied. Finally, for Plan 2-2, both the econometric demand projections and the estimated penalty price are needed.

C. Projection of Water Consumption

As needed for the expansion plans, we are projecting the econometric demand of the entire service area (See Figure 4.3) by regression methods.

Using the estimated consumption function earlier specified for each of the major uses, the level of each of these must be projected for each year from 1981 up to the year 2000. For each year, the sum of the four types of use is the total demand projected for that year,

of course making the necessary conversion in units. Thus, the projected total consumption for the year t is:

$$\text{Total Consumption} = RU_t + IU_t + CU_t + PU_t \qquad (58)$$

where RU, IU, CU, and PU are as previously defined. The individual projections of these components are conditional upon the projected value of their respective explanatory variables. For instance, the industrial use IU_t at time t is dependent upon the values of industrial price IP_t and gross regional product GDP_t at time t:

$$IU_t = f(IP_t, GDP_t) \qquad (59)$$

and so with the other uses with corresponding time subscripts.

D. Estimation of Penalty Price and the Determination of the Applicability of "With-Shortage" Supply Policy

In Chapter III (Section 3.2, B.3), different concepts of penalty price were discussed. This study will estimate the penalty price from the willingness to pay (area under the demand curve) concept.

It is recognized that the net benefit in the dynamic sense is the area under the demand curve minus the area under the supply curve. In a static sense, the supply curve for water supply can be assumed to be vertical because, once the source has been developed, a fixed amount of water is being produced and delivered. Because of this, the area under the supply curve is assumed to be zero.

Russell et al. (1970) subtract the area under the marginal cost (MC) curve, but they point out that in practice the area under the MC curve can be ignored because it seems reasonable to assume that it is small.

I have found out that for the case of MWSS, the area under the MC curve is very small in comparison to the area under the demand curve. Thus, in this study, the cost of production is neglected in the estimation of the unit benefit (penalty price).

The magnitude of the penalty cost depends on the demand curve. When the demand curve shifts, the penalty cost may change. Thus, to be more precise, the penalty cost for shortages has to be computed each year. This involves estimating by integration the area bounded by the demand curve, the axes, and by the level of consumption, and then by dividing the area by the consumption level to get the unit benefit (or cost). The detailed procedures involved in estimating the penalty cost for a specific year are as follows:

1. Establish the price-quantity relationship for each type of use. Do this by substituting the values of the other variables into the estimated demand equations so that the resulting equations are in terms of prices and quantities only. Graph this relationship to get the demand curve.

2. Estimate the level of economic demand for each type of use of the whole service area by substituting values of variables into the demand equations. This information is generated earlier in Section C on demand projection.

3. Find the area bounded by each demand curve, both axes, and by the consumption level by integrating from the origin to the point where consumption level equals the level of econometric demand for each use determined in step (2).

4. Divide each area by the econometric demand level derived in step (2). The result is the unit benefit per unit quantity of water, which becomes the unit penalty price under this concept.

5. Compute the weighted average of the unit penalty price from each type of use.

$$\text{Weighted Average} = \sum_{i=1}^{4} u_i \cdot p(i) \qquad (60)$$

where u_i = the weight, is the ratio of use i to total use; and

p(i) = penalty price for use i

Thus the overall unit penalty price p_t in year t is the weighted average of all the penalty costs of the different uses.

Projected penalty prices are actually the inflated penalty prices on the ground that the demand curve for each year is expressed in terms of nominal income and prices. This means that the benefit (area under the demand curve) inflates when income and prices increase. The use of either inflated or deflated (nominal or real) penalty price depends on whether we are dealing with inflated or deflated cost. This is discussed in the next section.

Having the estimate for unit penalty cost, the with-shortage policy will be applied to the scheduling or time phasing of projects using Erlenkotter's optimality condition for delaying projects (Erlenkotter, 1967). For purposes of clarification, we can derive the optimality condition in Appendix 1 in a simpler way but which yields the same result:

$$pDy = rC \qquad (27)$$

where p is the penalty price;

D is the rate of demand increase in quantity per year;

y is the waiting time in years before construction;

r is the discount rate;

C is the construction cost of the project in question; and

Dy is the shortage after y waiting years.

This condition states that construction should be delayed until the penalty cost accrues at the same rate as capital cost. To determine whether the policy of delaying projects is applicable in Manila, we solve for y:

$$y = rC/pD \qquad (27a)$$

Now if the penalty price is infinitely large, the waiting time would be zero, which means that the with-shortage policy is not applicable. Even if p is finite but large, we would expect y to be very small and negligible, which boils down to a without-shortage policy.

If p has a certain small finite value, then y takes on a bigger value, which means that we can delay projects for a longer period of time, hence the policy of delay (with-shortage).

E. Scheduling of Projects

For the without-shortage policy, scheduling is quite easy. Recall that in Chapter IV the alternative supplies were ranked by PICOREM on the basis of the least cost criterion. Having the project priorities determined and decided on, the timing is shown easily by graphing the capacity of each project along the demand projection in such a way that the next project is put into operation at each point of regeneration, that is, when demand equals the supply or when the excess capacity of the preceding project is fully utilized.

For the with-shortage policy, the scheduling will be done by manual simulation using the Erlenkotter's rule by comparing the penalty cost against the capital cost. The rule is:

$$\begin{aligned} &\text{If } (D_t - S_t)\, p < rC_i, \text{ defer project;} \\ &\quad (D_t - S_t)\, p = rC_i, \text{ install project;} \\ &\quad (D_t - S_t)\, p > rC_i, \text{ project is overdue.} \end{aligned} \tag{61}$$

where D_t is the level of demand in year t;

S_t is cumulative supply of the system in year t;

C_i is construction cost of project i;

r is the discount rate; and

$(D_t - S_t)$ is the shortage in year t. This is equivalent to Dy earlier defined.

The above rule holds that if the penalty cost is less than the capital cost, then the project should be delayed. If the penalty cost equals the interest cost, then the project must be scheduled so that it can be put into operation in that year. Then if the penalty cost is greater than the interest cost, it means that the project should have been built in the past.

Taking each project at a time in proper sequence, the above relationship will be evaluated yearly. Doing the same process for all of the projects will result in a schedule.

F. Effect of Inflation

The influence of inflation on the optimality condition must be taken into account. For purposes of scheduling, if the penalty price and the construction cost are affected by inflation in such a way that they increase by the same factor, then the inflation factor applied to

both sides of the equation (optimality condition) cancels out. Therefore under this case, it makes no difference whether we inflate or deflate the penalty price and the project cost. If inflation affects the penalty price and project cost in such a way that they increase at different rates, then we have to deflate them, that is, by using base year estimates.

The effect of inflation on the present value of cost of an expansion plan is discussed in the next section and in Appendix 2.

G. Evaluation of Expansion Plans

An expansion plan consists of a number of projects or project increments. To compare plans, they have to be evaluated in terms of the present value of their costs. the present value of the costs of a plan is the sum of the discounted construction costs, annual operation, maintenance and replacement (OMR) costs, and shortage costs when a shortage is incurred. In symbols, the present value of costs (PVC) is:

$$PVC = PV(\text{Construction costs}) + PV(\text{OMR costs}) + PV(\text{Penalty costs})$$

where:
$$PV(\text{Construction costs}) = \sum_{t=1}^{20} c_t \cdot e^{-rt}; \tag{62}$$

$$PV(\text{OMR costs}) = \sum_{t=1}^{20} \sum_{i=1}^{N} omr_i \cdot e^{-rt}; \tag{63}$$

$$PV(\text{Penalty costs}) = \sum_{t=1}^{20} (D_t - S_t)\, e^{-rt}; \tag{64}$$

$$\text{for } (D_t - S_t) > 0. \tag{65}$$

where: PV = present value;

PVC = present value of total cost;

c_t = construction cost (at base year price) incurred in year t, of the project in question;

omr_i = OMR for project i;

D_t = demand level in year t;

S_t = cumulative supply in year t;

r = discount rate;

e = base of natural logarithm, equals 2.7185; and

N = number of projects.

With regard to price changes, there are two cases (Sugden and Williams, 1978, pp. 36-39) under which the effect of inflation on the estimate of present value of cost can be analyzed. First is when there is a change in the general price level, that is, the price of goods increase at the same rate (or factor). In discounting, if we account correctly for this inflation factor both in the numerator (project cost) and the denominator (discounting factor), the inflation factor cancels out, thus leaving a base year estimates of the project cost and the discount rate.

Another case is where there are changes in the relative prices, that is, prices of goods do not increase at the same rate. Under this situation, the inflation rates (or factors) of the cost of project and the discount factor do not cancel out. Thus taking account of the different rates of price changes poses a computational difficulty especially if we are dealing with a planning horizon of say 50 years.

The mathematical analysis for these two cases of inflation effects is presented in Appendix 2.

In reality, prices of different goods change at different rates over time. This makes the evaluation of present value difficult. For our purpose of comparing the present values of costs of different expansion plans, we will assume that there is a uniform change in the

general price level. This means that our project costs and the discount rate are in real terms (or base year estimates).

This completes the outline of our valuation methodology. With the present value of costs of the different plans, we can proceed to the comparisons and shed light on the hypothesis.

H. Sensitivity Analysis

Sensitivity analysis will be done to assess the response of the delay time y and the cost components (i.e., construction, OMR, and shortage costs) of an expansion plan to changes in the discount rate r and penalty price p. Plan 2-2 will be taken as the baseline plan and will be subjected to changes in the values of r and p. The procedure for the analysis will follow the steps for expansion planning with shortage.

5.2 The Data

A. Data for Consumption Functions

For the regression analysis, yearly consumption data from 1970 to 1981, by major type of use, were compiled by staff of the Data Section of MWSS and made available to the author. These data are shown in Table 5.2.

It is recognized that it would have been better if the number of years of observation were greater than what is available. The MWSS does not have data by type of use for years earlier than 1970.

For the residential water prices, the pricing history is presented in Table 5.3. From 1970 to 1981, there were two block changes and three price changes. The data were compiled from the copies of the

Table 5.2

Water Consumption Data, MWSS, 1970-1981

Year	RU[a]	IU[b]	CU[c]	PU[d]	Total
		(In MCM)			
1970	87.890	11.341	38.178	16.567	154.066
1971	92.581	11.952	40.282	16.701	161.516
1972	96.175	11.501	43.386	16.842	167.904
1973	105.000	12.815	48.653	18.457	184.925
1974	121.160	16.191	56.291	21.372	215.014
1975	129.224	17.206	59.429	24.488	230.347
1976	132.529	17.580	60.642	26.502	237.253
1977	135.649	18.087	61.850	27.343	242.929
1978	141.680	18.931	64.452	29.199	254.262
1979	131.439	18.913	65.555	29.637	252.544
1980	138.133	17.798	66.260	29.855	252.046
1981	137.758	17.563	66.843	32.498	254.662

Notes: [a]Residential Use
[b]Industrial Use
[c]Commercial Use
[d]Public Use

Source: Data supplied by MWSS Data Center Staff

various Board Resolutions on Water Rates gathered from the Customers' Service Department of MWSS. The price of the marginal block faced by the average household consumer was found by computing the average monthly consumption for the year and looking at the block rate schedule to find the relevant price. The values for the difference price were computed according to the formula (Billings and Agthe, 1980) defined in Chpater II:

$$DP = \text{Actual Bill} - \text{Bill if water is sold at DMP} \quad (66)$$

Table 5.3

Residential Block Pricing History (Prices in P/M3 otherwise indicated)

Blocks M3/month	Effective Dates			
	July 1, 1964			
1 - 15	1.50 fixed			
16 - 50	.12			
50	.24			
	May 1, 1974			
1 - 30	.20			
31 - 50	.40			
50	.60			
	October 1, 1978	May 15, 1980	July 1, 1981	
1 - 15	4.50 fixed	4.50 fixed	4.80 fixed	
16 - 20	7.00 fixed	7.40 fixed	8.10 fixed	
21 - 25	9.50 fixed	10.50 fixed	12.00 fixed	
26 - 30	12.00 fixed	15.00 fixed	17.40 fixed	
31 - 50	.50	.60	.70	
51 - 70	.70	.80	.93	
71 - 90	.80	.95	1.11	
91 - 100	.90	1.10	1.30	
100	1.00	1.25	1.51	

Source: MWSS, 1981c

where DP is the difference price, in pesos; and DMP is the price of the marginal block faced by the average household consumer, in pesos/M^3.

Given a consumption level, the actual bill is computed by actually referring to the block rates relevant to the blocks covered by the consumption level. In symbols,

$$\text{Actual Bill} = \sum_{i=1}^{BN} p_{bi} \times B_i \qquad (67)$$

where p_{bi} is the unit price of block i;

B_i is the quantity consumed in block i; and

BN is the number of blocks covered by the consumption level.

If the water is sold at the price of the marginal block faced by the average household consumer the bill is computed as the product of the consumption level and the DMP defined above.

The computed values for DMP and DP for the period 1970-81 are shown in Table 5.4.

Table 5.4

Difference Price (DP) and DMP Price, 1970-81

Year	ARU[a] M^3/month	Actual Bill[b] Pesos	DMP[c] P/M^3	Bill at DMP[d] Pesos	DP[e] Pesos
1970	34.129	3.315	.12	4.095	- .78
1971	34.922	3.89	.12	4.19	- .3
1972	35.84	4.00	.12	4.3	- .3
1973	38.509	4.32	.12	4.62	- .3
1974	43.877	9.35	.306	13.42	-4.07
1975	46.082	12.43	.40	18.43	-6.0
1976	46.306	12.52	.40	18.52	-6.0
1977	46.788	12.71	.40	18.71	-6.0
1978	48.067	15.18	.425	20.42	-5.24
1979	43.778	18.89	.5	21.88	-2.99
1980	44.832	22.21	.56	25.10	-2.89
1981	43.893	25.03	.65	28.52	-3.49

Notes: [a]Average residential use/month
[b]Computed by referring to schedule in Table 5.2
[c]From Table 5.2, price for block at which ARU falls
[d]Computed as product of RU and DMP
[e]Computed as Actual Bill - Bill at DMP

The prices for industrial, commercial, and public uses were "blocked" only on May 15, 1980, but the average price information is available for the entire period 1970-1981. (See Table 5.5).

Table 5.5

Pricing History for Industrial, Commercial And Public Uses[a]

Year	Effective Date	Industrial[b]	Commercial[b]	Public[b]
		(In Pesos per M3)		
1970	July 1, 1964	.3	.3	.3
1971		.3	.3	.3
1972		.3	.3	.3
1973		.3	.3	.3
1974	May 1, 1974	.8 (.633)	.6 (.50)	.5
1975		.8	.6	.6
1976		.8	.6	.6
1977		.8	.6	.6
1978	October 1, 1978	1.4 (.95)	1.0 (.7)	.7
1979		1.4	1.0	1.0
1980	May 15, 1980	1.85 (1.68)	1.25 (1.15)	1.35 (1.22)
1981	July 1, 1981	2.45 (2.05)	1.53 (1.39)	1.68 (1.47)

Notes:

[a]Prices in parentheses are weighted prices due to price changes occurring within a year.

[b]Started block pricing in May 15, 1980, but average prices are still reported by MWSS. Actually commercial and public use rates are defined as one, but the difference in rates shown starting in 1980 is due to block pricing which resulted in the public users falling in a higher block and therefore facing a higher price.

Source: MWSS, 1981c

The effective prices for the year during which the price changes occurred were estimated by weighting (multiplying) the previous price by the number of months it was enforced, and the new price by the number of months remaining in the year and dividing by 12.

With respect to the population of Metro Manila, data for three census years (1970, 1975, 1980) are given in the 1982 Philippine Statistical Yearbook. These populations are 3.967 million, 4.97 million, and 5.926 million, respectively. A polynomial curve was fitted and calibrated using these 3 points in time:

$$G_t = G_{1970} + 205.3t - .94t^2, \qquad (68)$$

where G_t if the population in year t;

G_{1970} is the initial population in 1970; and

t is the number of years from the initial year.

Values for the intercensal years and 1981 were calculated using the above equation. These are shown in Table 5.6.

Data on income were available from the National Census and Statistics Office (NCSO) Census of Family Income and Expenditures for the years 1970, 1975 and 1980. The income reported was average yearly family income; however dividing the annual income by 12 converts it to monthly basis. These incomes are P7585, P10469, and P13834, respectively. Intercensus year values were interpolated by using the curve:

$$Y_t = Y_{1970} + 528.7t - .94t^2 \qquad (69)$$

where Y_t = income in year t;

Y_{1970} = income at initial year, 1970; and

t = number of years from the initial year, 1970.

These income data are for the whole Metro Manila area. What are actually needed are the income data of the population served, on which MWSS had no data. Running a primary survey was impossible, considering time and budget constraints. As of 1981, there are over 2.5 million people, or around 262,000 households, served. Theoretically a sample of 10 percent would mean a sample size of 26,200 households. Field research funds were not available to administer such survey. So, instead of conducting a survey with insufficient sample size, the author utilized the secondary data for the Metro Manila area. But an assumption must be made, that is, that the average income of the population served has the same trend as that of the entire Metro Manila area. When this is true, they will yield the same coefficient.

Data on Metro Manila's gross domestic product (GDP) were assembled from different sources. The Five Year Philippine Development Plan 1978-1982, page 53, gives the GDP per capita for the years 1978 and 1977. It also gives the ratio of Metro Manila's GDP/capita to that of the nation from 1978 to 1981. The 1982 Philippine Statistical Bulletin, pp. 156-157, gives us the national GDP/capita from 1970 to 1981. Abueva (1972) also gives the ratio of the national GDP to that of Metro Manila for 1961 and 1965. With these information, figures for other years were estimated by either extra or intra-polation. See Table 5.6.

The data for estimating the demand functions are summarized in Table 5.6.

Table 5.6

Summary of Data[a] for Water Consumption Functions

Year	Y P/year	DP Pesos	DMP	IP	CP (In Pesos Per M^3)	PP	G (x1000)	GDP (P/cap)
1970	7585	.78	.12	.3	.39	.47	3967	3623
1971	7785	- .3	.12	.3	.3	.3	4171	3745
1972	8456	- .3	.12	.3	.3	.3	4374	3866
1973	9127	- .3	.12	.3	.3	.3	4574	3988
1974	9798	-4.07	.306	.633	.5	.5	4773	4109
1975	10469	-6.0	.40	.8	.6	.6	4970	4231
1976	11140	-6.0	.40	.8	.6	.6	5165	4352
1977	11812	-6.0	.40	.8	.6	.6	5358	4474
1978	12485	-5.24	.425	.95	.7	.7	5549	4517
1979	13159	-2.99	.50	1.4	1.0	1.0	5939	4591
1980	13834	-2.89	.56	1.68	1.15	1.22	5926	4659
1981	14510	-3.49	.65	2.05	1.39	1.47	6113	4780

Notes: a -- Income and prices data are in nominal terms
Y -- Average family yearly income, nominal P
DMP -- Domestic price, for marginal block faced by average family
DP -- Difference price, from Table 5.4
IP -- Industrial price, from Table 5.4
CP -- Commercial price, from Table 5.4
PP -- Public price
G -- Population of the region
GDP -- Gross domestic product, pesos per capita
Source for each variable indicated earlier.

B. Data for Projecting Consumption

B.1 Water Prices

Based on the approved engineering expansion plan, MWSS, through its newly formed Corporate Planning Department, plans to increase prices by P0.40 per cu.m. in 1983, P0.50 in 1984, and P0.60 in 1985,

after which prices will remain the same until 1989 (MWSS, 1982). From 1990 to 2000, the MWSS Corplan does not specify the price changes. We need to have the projected prices for this period.

As indicated in the discussion of scope and limitations of the study in Chapter I, the derivation of MWSS prices is beyond the scope of this study. Prices are rather taken as inputs if they are available, otherwise we have to make simplifying assumptions.

Before we make these assumptions, let us take a look at some facts about the MWSS prices.

In 1980, the residential, industrial, commercial, and public prices were P0.87, P1.68, P1.15, and P1.22 per cubic meter, respectively, for a weighted (use level as weights) average of P1.0422 per cu. m. overall. During this year, the operating expenses (MWSS, 1981a) totalled P204,250,698. This included items such as personnel cost, travel, supplies and materials, provision for doubtful accounts (uncollectibles), depreciation cost, electricity cost, amortization and miscellaneous expenses. Other expenses from interest on long term loans totalled P11,632,307. Together these two numbers constitute the yearly total fixed cost and the total variable cost. The MWSS calls it total operating expenses.

The total water produced was 471.5 million cu. m., out of which, only 252.046 million M3 was billed.

If we divide the total operating expenses by the water billed, we get an average price of P0.854/M3. This concept of price is in essence some kind of average cost pricing. Note that this amount is lower than the overall weighted average price of P1.0422 above.

The possibility of marginal cost pricing was investigated by estimating the relationship:

$$OMR = kQ^a \tag{70}$$

where OMR is operation, maintenance and replacement costs in million pesos; k is the unit cost of a system with 1 MCM design capacity; Q is the design capacity of the system; and "a" is the economy of scale factor. Data on all the gravity systems for the Metro Manila area were used. There were only 6 possible observations of OMR costs: 2 from the previous construction; and 4 from the proposed supply alternatives. All the OMR costs are given in 1972 prices. The items included in the OMR costs are those directly incurred in the production of water namely: treatment plant maintenance; mechanical and electrical equipment cost, repair of all civil works, and treatment costs (chemicals). Although the number of observations is limited, the resulting statistics are significant:

$$OMR = 0.025135\ Q^{1.0745} \tag{70a}$$

$R^2 = .93$ $\qquad$ $t = 7.64$

D.W. = 1.99 $\qquad$ $F = 58.8$

Taking the derivatives with respect to Q yields the marginal cost MC (at 1972 prices):

$$MC = 0.027\ Q^{.0745} \tag{71}$$

Using total design Q = 485 MCM/years in 1980, and using the price index of 2.926 for fuel and electricity, we have the 1980 MC = P0.125 per cu. m., which is much lower than the overall weighted average price of P1.0422 above.

It is clear from the 1980 MWSS Annual Report (MWSS, 1981a), that MWSS operate under the policy that it should receive a gross revenue that is enough to operate and maintain the system. It determines the revenue requirement by the "utility basis" (Journal AWWA, 1954). This requires the determination of a rate base, or the amount of capital upon which the utility is entitled to earn a return, and fixing of a fair rate of return on the rate base.

The rate base and the rate of return are determined by management decisions. According to the MWSS Charter, the rate base is the sum of the net fixed assets used in operation and the operating capital. The lending institution may sometimes, as a part of a loan agreement, define the rate base. The Asian Development Bank defines the rate base as equal to the net fixed assets used in operation. What complicates the determination of a rate base is the way the net fixed assets are evaluated. It is the sum of the value of the production and treatment plant, land and land rights, structures, equipment and facilities, and buildings, minus depreciation. These assets are appraised yearly and their values are affected by the revision of estimated life of some assets, inflation, and evaluation techniques. All else equal, the difference in the rate base definition results in the difference in the rate of return.

Thus, with the specified rate base and rate of return, MWSS has to receive a certain level of revenue in order to survive. From this level of revenue, the overall price can be roughly determined. From the relationship

$$\text{Rate of return} = \text{net revenue/rate base} \qquad (72)$$

the net revenue can be solved. To this we add the provision for total operating expenses to get the gross operating revenue, which, when divided by the amount of water (to be) delivered, will give a rough estimate of an overall price per M^3 of water.

In 1980, the unit price of water based on this concept was about P1.18/M^3, close enough to the above-mentioned overall weighted average price of P1.0422/M^3.

Adding to the difficulty of the analysis is the fact that there is sometimes a corporate plan for raising funds for expansion and improvements. This will be added to the revenue requirement, thus increasing the price.

Another complexity arises from the fact that MWSS practices third degree price discrimination, that is, charging different prices to different customers even though the cost of producing the good is the same for all customers. The determination of the prices of the different blocks is solely based on management decisions given the institutional conditions within which management must operate and not on abstract economic theory.

Due to the difference in pricing practice by MWSS and economic theory, and the unpredictability of the decisions affecting the definition of rate base and that of the factors affecting the valuation of assets, we will assume that for the period 1990 to 2000, MWSS will make the same number of price increases, that is, one increase for each supply addition as defined in its plan.

Within the period 1982-89, there are supposed to be 3 supply additions, and as stated earlier, MWSS plans to increase price by P0.40/M^3 in 1983, P0.50/M^3 in 1984, and P0.60/M^3 in 1985. For the

period 1990-2000, there is a difficulty of determining the amount and timing of price increases that MWSS will implement. For convenience, let us say that MWSS will time these increases to coincide with the timing of its planned capacity expansion. Following the same trend in magnitude as that in the period 1982-89, we will assume that price will increase by P0.70/M^3 in 1990, P0.80 in 1995, and P0.90 in 1998, after which the price will remain the same until the next supply addition comes which is beyond the year 2000. We will assume that MWSS has decided to implement these price increases, and this would mean that all of the alternative plans we are evaluating in this study will face these prices.

These price increases are quite simple to incorporate into the 1982 price level in order to arrive at the prices for 1983 up to the year 2000. For the industrial and commercial uses, the new prices are simply the previous price plus the planned increase. See Table 5.7. Note that the public price is not projected because it is an insignificant variable in the public use function.

For the residential use, the new unit price for a block is also equal to the previous price plus the planned increase. This would increase all the block prices by the same amount. For instance, the prices for all the blocks in 1982 increase by P0.40/M^3 in 1983, then the 1983 prices increased by P0.50/M^3 in 1984, and so on. There is a practical problem associated with this planned price increases for residential use. Such prices are so large that, based on the estimated negative coefficient in the residential consumption function, the residential use will drastically decrease over the projection period, yielding projection results that are not realistic.

Table 5.7

Projected Prices for Industrial and Commercial Uses, 1982-2000

Year	Industrial Price (In Pesos Per M^3)	Commercial Price
1982	2.45	1.68
1983	2.85	2.08
1984	3.35	2.58
1985	3.95	3.18
1986	3.95	3.18
1987	3.95	3.18
1988	3.95	3.18
1989	3.95	3.18
1990	4.65	3.88
1991	4.65	3.88
1992	4.65	3.88
1993	4.65	3.88
1994	4.65	3.88
1995	5.45	4.68
1996	5.45	4.68
1997	5.45	4.68
1998	6.35	5.58
1999	6.35	5.58
2000	6.35	5.58

Source: MWSS, 1982

What can be done is not to implement the planned price increases on the residential use. Instead, we will base our price increases on the historical relationship between the price of an important block (block under which the average monthly household consumption of 42.252 M^3 falls, that is, block 31-50 M^3 in Table 5.3) and the average price for

the industrial use. Historically, over the period 1970-81, the price of the block 31-50 M^3 was roughly 1/3 of the industrial price. With this assumption, we can generate the prices of all the blocks throughout the projection period. Starting from 1982, the 1983 block prices can be estimated by the following steps:

1. Compute the price of the block (31-50 M^3) as 1/3 of the average industrial price for 1983 from Table 5.7. This becomes the 1983 price for this block.

2. Find the difference between the 1982 and 1983 prices for the block (31-50 M^3). Call this the "block price increase."

3. Add the "block price increase" to each of the 1982 block prices to get the 1983 prices.

The above process increases the block prices by the same amount, which is one of the possible price increase defined by Billings and Agthe (1980) for the case of increasing block rates. The result of this process is presented in Table 5.8.

With regards to the difference price, this is projected using a monthly household consumption of 42.252 M^3, the average for the period 1970-81. Using the formula earlier defined (Equation 66), the computation is presented in Table 5.9.

B.2 Population

The MWSS developed its own projection of the population of its service area. Although its assumptions are not specified in the data source (MWSS, 1982), their projection roughly follow the polynomial curve

$$G_t = G_{1980} + 238t + 5.065t^2$$

Table 5.8

Projected Residential Block Prices, 1982-2000

Blocks M3	1982	1983	1984	1985	1990	1995	1998
			(In Pesos per cubic meter)				
1-15	.32	.57	.74	.94	1.17	1.44	1.74
16-20	.405	.66	.83	1.03	1.26	1.53	1.83
21-25	.48	.73	.90	1.1	1.33	1.6	1.9
26-30	.58	.83	1.0	1.2	1.43	1.7	2.0
31-50	.70	.95	1.12	1.32	1.55	1.82	2.12
51-70	.93	1.18	1.35	1.55	1.78	2.05	2.35
71-90	1.11	1.36	1.53	1.73	1.96	2.23	2.55
91-100	1.3	1.55	1.72	1.92	2.15	2.42	2.72
> 100	1.51	1.76	1.93	2.13	2.36	2.63	2.93

Note: Computed as discussed in Section 5.2, B.1 of this Chapter

where G_t is the population in year t; G_{1980} is the base year (1980) population; and t is the number of years from the base year. The results are shown in column 3 of Table 5.10.

B.3 Income

The income data were projected from 1980 to 2000 using the polynomial curve fitted against the 1970-81 data:

$$Y_t = Y_{1980} + 528.7t + 9.62t^2$$

where Y_t is the income in year t; Y_{1980} is the income in 1980, and t is the number of years from 1980. The results are shown in column 2 of Table 5.10.

Table 5.9

Projection of Difference Price, 1982-2000

Year	ARU[a] M3/month	Actual Bill[b] Pesos	DMP[c] P/M3	Bill at DMP[d] Pesos	DP[e] Pesos
1982	42.252	20.70	.70	29.57	-8.87
1983	42.252	31.29	.95	40.14	-8.85
1984	42.252	38.47	1.12	47.322	-8.85
1985	42.252	46.92	1.32	55.77	-8.85
1986	42.252	46.92	1.32	55.77	-8.85
1987	42.252	46.92	1.32	55.77	-8.85
1988	42.252	46.92	1.32	55.77	-8.85
1989	42.252	46.92	1.32	55.77	-8.85
1990	42.252	56.64	1.55	65.49	-8.85
1991	42.252	56.64	1.55	65.49	-8.85
1992	42.252	56.64	1.55	65.49	-8.85
1993	42.252	56.64	1.55	65.49	-8.85
1994	42.252	56.64	1.55	65.49	-8.85
1995	42.252	66.04	1.82	76.89	-8.85
1996	42.252	66.04	1.82	76.89	-8.85
1997	42.252	66.04	1.82	76.89	-8.85
1998	42.252	80.72	2.12	89.57	-8.85
1999	42.252	80.72	2.12	89.57	-8.85
2000	42.252	80.72	2.12	89.57	-8.85

Notes:
[a]Average residential use based on 1970-81 data
[b]Bill for ARU using block prices in Table 5.7
[c]Unit price for block (31-50 M3) facing average consumer
[d]Computed as product of ARU x DMP
[e]Difference Price = b - d

B.4 Gross Domestic Product (GDP)

Gross domestic product was projected up to the year 2000 by the use of a polynomial curve which was calibrated using the 1970-81 data:

Table 5.10[a]

Projected Population, Family Income, and Gross Domestic Product, 1982-2000

Year	Income (Y) (P/year)	Population[b] (10^3)	Gross Domestic Product (GDP) Pesos/capita
1982	14930	7050	4918
1983	15507	7320	5046
1984	16103	7600	5161
1985	16718	7900	5266
1986	17353	8180	5359
1987	18006	8480	5442
1988	18679	8790	5512
1989	19370	9100	5572
1990	20083	9421	5710
1991	20621	9752	5838
1992	21179	10097	5953
1993	21756	10453	6058
1994	22352	10823	6151
1995	22967	11205	6234
1996	23602	11600	6304
1997	24255	12009	6364
1998	24928	12431	6502
1999	25619	12871	6630
2000	26332	13323	6745

Notes: [a]Values here are estimated as discussed in Section 5.2 of this Chapter.

[b]Population projection by MWSS.

$$GDP_t = GDP_{1981} + 144t - 5.625t^2$$

where GDP_t is the GDP in year t; GDP_{1981} is the 1981 GDP level; and t is the number of years from 1981. The results are shown in column 4 of Table 5.10.

C. Data on Project Stages for Expansion Planning

The needed information on project stages include the following; stage capacities; construction cost; and yearly operation, maintenance and replacement (OMR) cost. These data are shown in Table 5.11.

Table 5.11

Basic Data[a] on Project Stages

Project	Capacity MCM/Year	Construction Cost[b] Million Pesos	OMR Cost M Pesos/Year
MWSP II[c]			
Stage 1	200.8	1253.52	27.64
Stage 2	200.8	1253.52	27.64
MWSP III[d]			
Stage 1	241.76	1494.95	33.9
Stage 2	241.76	1494.95	33.9
Stage 3	241.76	1494.95	33.9
MWSP IV[d]			
Stage 1	299.79	1433.7	41.42

Notes:

[a]Costs are at 1980 prices, the base year for analysis

[b]Assumed to be linearly related to capacity

[c]Due to the fact that MWSS estimate includes other items such as wells, service connections and branch offices, the Metcalf and Eddy (M & E) estimate (P1727.74) for the whole project is used but adjustments are made to include the same components as that of the other projects. Intake structure (in M & E) costing P255.73 million is changed to a new dam (costing P1035.08 x 10^6) as in the new plan. OMR of P40.46 was adjusted to P55.28 x 10^6.

[d]Are estimated from PICOREM, 1979, p. VIIb.

The stage capacities are estimated from the approved MWSS expansion plan presented in Fugure 4.9. Construction and OMR costs data are taken from PICOREM (1979 and 1980) and for simplicity are assumed to be

linearly related with the capacities, that is, if the stage capacity is 1/3 of the entire source capacity, then the construction and OMR costs of the stage are also 1/3 of those of the entire source. This assumption is based on the condition that the stages are more or less independent projects, that is, each has a separate dam and components.

In actuality, there are certain cases where the stages are not identifiable as independent projects because of the physical configuration of the source. If the source is large and the site allows the construction of only one big dam, then the stages cannot be defined as separate projects but rather must be defined as increments of the quantity of the water that will be tapped from the source. In this case, the first stage is likely to cost more than the other stages because it must be constructed so as to accommodate other stages later. That is, dams and the associated facilities are built under the first stage and less construction work is undertaken under the other stages. Under this assumption, costs may not be proportionately related to capacity.

CHAPTER VI

ANALYSES, RESULTS, AND DISCUSSION

This chapter presents the empirical results according to the analytical framework of the preceding chapter, followed by discussion of results as they are presented.

6.1 Categorical Consumption Functions

Residential Use (RU)

The estimating equation is:

$$RU = 20.129 + 0.0253Y^{***} - 18.926DMP^{**} - 1.775DP^{***} \quad (53a)$$

(4.91) (3.54) (-2.3) (-8.23)

Adjusted R^2 = .956 D.W. = 1.75

F = 80.32 t values are in parentheses

The result shows that the monthly household consumption is positively affected by the nominal monthly household income Y, negatively by the nominal domestic marginal price DMP of water, and negatively by the difference price DP. The regression explains 95.6 percent of the variation in the residential use. The F test shows that the coefficient of determination R^2 (adjusted for degrees of freedom) is significant at the 1 percent level. Individual t tests show that the coefficients are significant at the 1 percent*** level except for the variable DMP which is significant at 5 percent ** level. The Durbin-Watson (D.W.) test at 1 percent level shows that there is no positive first-order serial correlation. If there is positive first-order correlation between errors from different times, the predicting power

of the equation is biased because an overestimate in one year is likely to lead to overestimates in the succeeding years.

The results nevertheless confirm that the residential use is responsive to price changes.

The elasticity of demand with respect to the price of the block at which the average household consumes is -0.153, while the difference price elasticity is 0.134. The total impact then of a price change, which include changes in prices of the marginal block and the intra-marginal block, is the sum of these two price elasticities which, in our case, is -0.287. Recall that the positive sign of the difference price elasticity only indicates that an increasing block is being examined.

The income elasticity of demand is 0.542 at the means.

One assumption has to be pointed out. The dimension for RU is in M3/month/household, while the data for Y is for family. A household may be equal to or larger than a family. A household may consist of a family plus some househelpers. Based on the author's knowledge, these helpers do not add to the family income. In fact in most cases they are supported by family income. The assumption we are making is that the household income is not significantly different from the family income.

The model was also estimated with real (deflated) income and prices. However, the results showed that consumption increased even though the real income decreased. This suggests that for the prices and quantities of residential water use in this study, people's water consumption does not respond to changes in real income and prices, but

instead to nominal income and prices. In other words the econometric demand function here reflects a phenomenon quite distinct from pure economic demand.

Industrial Use (IU)

The estimating equation is:

$$IU = -2.1275 - 3.9226IP^{*} + .000982GDP^{***}$$

$$(-2.079) \qquad (4.366) \qquad (54a)$$

Adjusted R^2 = .8175 D.W. = 1.2577

F = 25.636 t values are in parentheses

The above equation shows that the quantity of water purchased by industrial firms is affected negatively by the industrial price (IP), and positively by the region's income as proxied by gross domestic product (GDP). The line explains 81.75 percent of the variation in the industrial use. The coefficients for the IP and the GDP are significant at 7 percent * and 1 percent*** levels, respectively. The R^2, as the F test reveals, is significant at the 1 percent level. The Durbin-Watson test shows an indeterminate result, which means that the seeming correlation of errors is not due to the serial correlation of the error terms (Pindyck and Rubinfeld, 1976).

At the mean, the price elasticity is -0.213, meaning a 1 percent change in price causes an opposite .213 percent change in the industrial use. This result shows that the industrial use responds to price changes.

The elasticity of the industrial use with respect to the region's income is 1.347, which means that a 1 percent change in income results to a positive 1.347 percent change in the industrial use.

Commercial Use (CU)

The estimating model is:

$$CU = -1.3645 - 14.231CP^{**} + .00306GDP^{***} \quad (55a)$$
$$(-2.208) \qquad (6.392)$$

Adjusted R^2 = .93 D.W. = 1.01

F = 74.96 t statistics are in parentheses)

The commercial demand is affected negatively by price and positively by the region's income. The line explains 93 percent of the variation in the commercial demand, with the adjusted R^2 significant at 1 percent level. The individual t tests show that the coefficients for CP and GDP are significant at the 5 percent** and 1 percent*** levels, respectively. The D.W. test for serial correlation indicates a region of indeterminacy which is due to the fact that the sequence of residuals is influenced by the movement of the explanatory variables. The seeming serial correlation is not due to the error terms.

The price elasticity at the mean is -0.164 indicating a negative .164 percent response by commercial users to a 1 percent change in their price of water.

The income elasticity is 1.18 at the mean. This means that a 1 percent change in the region's income causes a positive 1.18 percent change in the commercial use.

Public Use (PU)

Public use includes the consumption from institutions such as schools, hospitals, government offices, and other uses where the consumers' behavior are less affected by price changes.

Consider our specified equation when estimated:

$$PU = 0.27 - 0.457PP + 0.00936G \quad (56a)$$

$$(-.86) \quad (3.21)$$

$R^2 = .81$ D.W. = .97

F = 10.5 t statistics are in parentheses

The t test for the coefficient of public price PP shows that it has a very low significance level of 80 percent. This suggests that price is an insignificant factor. The F statistic just barely making the critical value, while the D.W. statistic is indeterminate.

Dropping the price variable PP will improve the fit.

$$PU = 1.62 + 0.0006127G^{***} \quad (56b)$$

$$(1.83) \quad (3.55)$$

Adjusted $R^2 = .855$ D.W. = 1.177

F = 66.1 t statistics are in parentheses

This line is considerably better, explaining 86 percent of the total variation in the public use. R^2 is significant at 1 percent level. The t test on the coefficient of the population (G) showed that it is significant at 1 percent*** level. Test on the D.W. statistic shows no presence of serial correlation.

These results suggest that public use of water simply changes with population growth and does not respond to price changes.

Having estimated the consumption equation for each of the major uses, the total consumption was projected to the year 2000 using the procedure discussed in Chapter V (Section 5.1, A). The result of the projection is presented in Table 6.1.

Table 6.1

Projected Econometric Demand, in MCM/Year

Year	Total	Residential	Industrial	Commercial	Public
1980	561.515	429.284	21.158	74.369	36.705
1981	592.373	454.390	21.703	77.032	39.248
1982	717.150	572.133	22.313	80.831	41.874
1983	705.149	555.450	22.961	82.050	44.688
1984	707.249	554.343	23.252	81.952	47.702
1985	701.263	546.315	23.231	80.681	51.037
1986	749.313	582.105	25.429	87.530	54.249
1987	801.035	620.966	27.692	94.581	57.797
1988	855.563	662.374	29.960	101.649	61.579
1989	911.810	705.621	32.171	108.539	65.480
1990	900.375	690.235	32.461	108.038	69.641
1991	958.433	731.171	35.542	117.638	74.083
1992	1019.623	774.775	38.662	127.362	78.823
1993	1084.071	821.174	41.818	137.196	83.884
1994	1152.063	870.612	45.010	147.140	89.301
1995	1123.128	837.221	45.081	145.755	95.071
1996	1195.379	890.036	48.306	155.807	101.231
1997	1271.467	946.225	51.542	165.890	107.811
1998	1233.834	900.099	52.341	166.573	114.821
1999	1319.461	960.041	56.754	180.322	122.345
2000	1409.662	1023.864	61.218	194.233	130.347

Note: Projected by the estimated consumption functions.

One final note about these projections is necessary. For residential use, the projected figures indicate a level which assumes that all households in the service area have water connections, subject to the same availability of water that existed during the period 1970-81. The availability of water here means the number of hours water is available during a day. For industrial use, the figures would indicate the quantity the industrial firms using MWSS water would buy. Some firms have their own private groundwater supply. Others have both the MWSS connection and a private supply (MWSS, 1975).

For commercial use, the forecast would indicate also the quantity the commercial firms would buy. Some commercial establishments such as hotels also have their own standby supply although they are connected to the MWSS water system.

Finally, the public use figures, in addition to the consumption by institutions, include the consumption of people served through the public standpipes.

6.2 Penalty Price and the Applicability of "With-Shortage" Supply Policy

A. Actual Penalty Price

Following the procedure outlined in Chapter V (Section 5.1, D), the overall weighted penalty prices were estimated for each year from 1980 to 2000. The result is presented in Table 6.2. This is projected to show that the rate of increase of this penalty price (1.5 times over the 20-year period) is significantly lower than the rate of increase in the prices of goods which, from 1972 to 1981, increased by 3.73 times. Under this situation, the use of inflated measures of cost and prices

Table 6.2

Projected Penalty Price, 1981-2000

Year	Penalty Price (Pesos/M3)
1980	2.155
1981	2.304
1982	2.553
1983	2.775
1984	2.958
1985	3.163
1986	3.244
1987	3.326
1988	3.407
1989	3.485
1990	3.746
1991	3.853
1992	3.96
1993	4.066
1994	4.172
1995	4.484
1996	4.589
1997	4.691
1998	5.095
1999	5.247
2000	5.396

will distort the result of our evaluation and scheduling of projects. To avoid this, we will use the constant 1980 penalty price and the deflated (1980) project costs in scheduling our expansion projects.

B. Imputed Panalty Price

Following Lauria (1973), the penalty price can be imputed from the recently made investment decision.

Let us take the case of the project MWSP II-1. This project is targeted to be operational in 1981. The cost of the project was P1253.52 million at 1980 prices and the discount rate used by PICOREM was 10 percent. In 1980, the total economic demand of the service area was 561.515 MCM, while the MWSS was capable of supplying only 485 MCM, assuming a 100 percent production efficiency on the supply capacity. The shortage Dy then was equal to 76.515 MCM. Substituting these values into the optimality condition for delaying projects and solving for the imputed penalty price p, we have:

$$p = (10\% \times P1253.52 \text{ million})/76.515 \text{ MCM} = P1.638/\text{cu.m.}$$

The implication of this imputed price being lower than the actual penalty price of P2.155/M3 according to Lauria's model is that, looking from 1980, the project MWSP II-1 should have been built in the past.

C. The Applicability of "With-Shortage" Supply Policy

Looking at the MWSS Plan in Figure 4.9, whose "1980-2000" segment is somewhat refined and magnified in Figure 6.1, we can see that in 1991, a point of regeneration where demand equals supply will occur. The question is whether beyond this point we can delay the construction of the next supply expansion project MWSP III-2. The estimated construction cost of the project is P1494.95 million at 1980 prices. Metro Manila's requirement-based demand increases linearly at approximately 62.1 MCM/year. Then at 10 percent discount rate and penalty price of P2.155/cu. m., we have the delaying time y:

y = 10% x P1494.95 million/(P2.155 x 62.1 MCM) = 1.11 years

This means that the next expansion project can be delayed by 1.11 years. This approximation of waiting time, computed to two decimal places, is close to one year. If we refer to Figure 6.2, MWSP III-2 is delayed by about one year from the original point of regeneration in 1991. This confirms the applicability of the shortage supply policy in Metro Manila region.

6.3 Planning and Evaluation of the Plans

The data on the capacities and costs of the projects we are scheduling and evaluating are presented in Table 5.10 in Chapter V. For convenience, I have called the project MWSP II Stage 1 as MWSP II-1; MWSP II Stage 2 as MWSP II-2; MWSP III Stage 1 as MWSP III-1; and so on.

A. Plan 1-1 ("Requirement" Demand--"Without-Shortage" Policy)

The plan as approved for implementation was not based on the actual projected figures derived by MWSS. Instead this was based on the smoothed curve or plots of these figures. This plan is presented in Figure 4.9.

For the purpose of comparison, this study uses the actual projected figures and draws a more accurate curve. On top of this curve, the projects were scheduled according to the policy of without-shortage, that is, scheduling a project for operation right at the point when the preceding project's excess capacity is fully utilized. The result is shown in Figure 6.1.

The plan calls for the activation of six expansion projects namely: MWSP II-1 towards the end of 1981; MWSP II-2 towards the end of 1983;

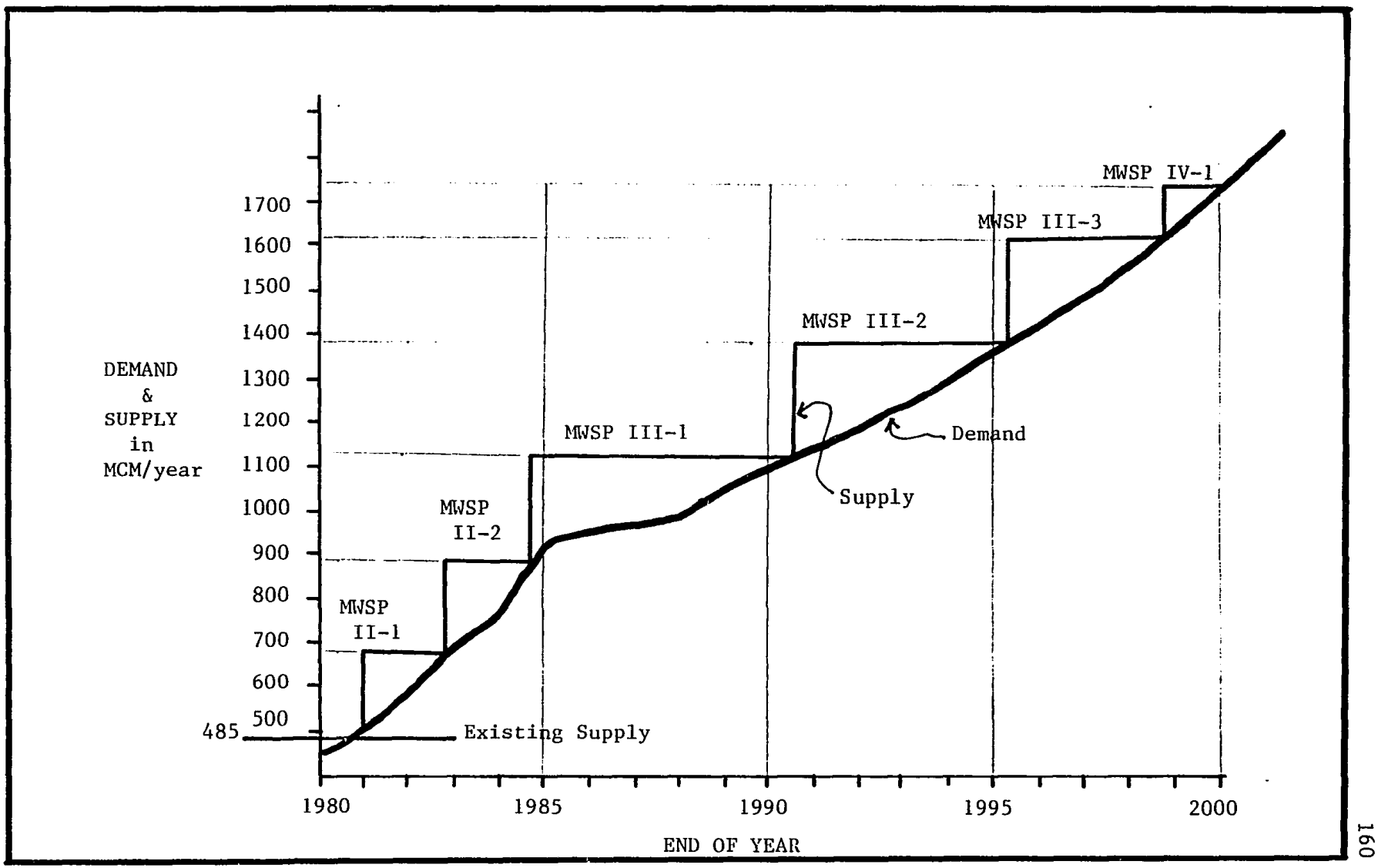


Figure 6.1 Expansion Plan 1-1

MWSP III-1 by late 1984; MWSP III-2 by middle of 1991; MWSP III-3 by early 1996; and MWSP IV by late 1999. This timing, together with the project capacities and the cumulative supply resulting from each addition is shown in Table 6.3.

Table 6.3

Summary of Expansion Timing, Plan 1-1

Project	Capacity Added MCM/year	Cumulative Supply MCM/year	Operational Year
MWSP II			
Stage 1	200.8	685.8	end of 1981
Stage 2	200.8	886.8	late 1983
MWSP III			
Stage 1	241.76	1128.36	late 1985
Stage 2	241.76	1370.12	end 1991
Stage 3	241.76	1611.88	early 1996
MWSP IV			
Stage 1	107.03[a]	1711.91	late 1999

Note: [a]To satisfy the demand within the planning horizon (year 2000), only this capacity is needed out of the total stage capacity of 299.79 MCM/year.

It should be noted that, according to the MWSS projection process, the demand curve here is only of that portion of the population that MWSS is planning to serve, that is, the target percent population to be served, which was shown earlier in Table 4.9 as ranging from 46 percent in 1982 to 73 percent in 2000. The plan is such that supply catches up with the service area's total demand over time.

Considering this assumption, there are shortages, strictly speaking, incurred along the expansion plan, and these represent the demand of those not targeted to be served. These shortages are hidden by this plan, and we will not try to account for these since we are making the comparison given this demand curve.

Using the formulae for discounting specified in the methodology, the discounted construction and OMR costs of all the projects under this plan are presented in Tables 6.4 and 6.5, respectively. In 1981, there was a shortage of 12.69 MCM, which, at the constant 1980 penalty price of P2.155/M^3. had the discounted penalty cost of P24.74 million.

Table 6.4

1980 Discounted Construction Costs, Plan 1-1

Project	Computation[a]	1980 Cost (Million P)
MWSP II		
Stage 1	$e^{-r(1)}(1253.52)$	1134.231
Stage 2	$e^{-r(3)}(1253.52)$	928.630
MWSP III		
Stage 1	$e^{-r(4.7)}(1494.95)$	934.346
Stage 2	$e^{-r(10.6)}(1494.95)$	517.934
Stage 3	$e^{-r(15.3)}(1494.95)$	323.710
MWSP IV		
Stage 1	$e^{-r(18.8)}(511.83)$[b]	78.1
Total		P3916.951 million

Notes:

[a]Discount rate r = 10%. The number of years used in discounting is the exact timing of the project from the year 1980.

[b]This cost is .357 of that of the whole stage because only about .357 of the stage capacity is required to satisfy the demand up to the year 2000, the planning horizon.

Table 6.5

1980 Discounted OMR Costs[a], Plan 1-1, Million P

Year	MWSP II Stage 1	MWSP II Stage 2	MWSP III Stage 1	MWSP III Stage 2	MWSP III Stage 3	MWSP IV Stage 1
2000	3.731	3.731	4.546	4.546	4.546	1.995
1999	4.118	4.118	5.051	5.051	5.051	.44[f]
1998	4.56	4.56	5.593	5.593	5.593	
1997	5.058	5.058	6.203	6.203	6.203	
1996	5.555	5.555	6.813	6.183	5.45[e]	
1995	6.163	6.163	7.559	7.559		
1994	6.799	6.799	8.339	8.339		
1993	7.545	7.545	9.254	9.254		
1992	8.319	8.319	10.204	10.204		
1991	9.176	9.176	11.255	4.502[d]		
1990	10.143	10.143	12.441			
1989	11.22	11.22	13.763			
1988	12.41	12.41	15.221			
1987	13.71	13.71	16.814			
1986	15.146	15.146	18.517			
1985	16.75	16.75	6.163[c]			
1984	18.518	18.518				
1983	20.481	4.096[b]				
1982	22.61					
Sum	202.012	163.017	157.766	68.034	26.813	2.435

Grand Total = P620.077 million

Notes: a -- Computed by Cost = e^{-rt} x OMR from Table 5.10
b -- At .2 of that OMR cost for the whole year
c -- At .3 of that OMR cost for the whole year
d -- At .4 of that OMR cost for the whole year
e -- At .8 of that OMR cost for the whole year
f -- At .2 of that OMR cost for the whole year

Overall, Plan 1-1 would cost P4561.768 million in 1980 prices. See Table 6.6 for the summary of costs.

Table 6.6

Summary of Present Value of Costs, Plan 1-1

Type of Cost	1980 Value (Million P)
Construction	3916.951
OMR	620.077
Shortage	24.74
Total	4561.768

B. Plan 1-2 ("Requirement" Demand--"With-Shortage" Policy)

This plan takes the requirement-based demand projections and allows shortages by delaying the construction of projects according to the economic criterion that the rate of penalty cost accrual be equal to the rate of interest cost accrual at the time of construction.

Following the procedure discussed in Chapter V (Section 5.1, E), manual simulation is done as shown in Table 6.7 to schedule the construction of the projects. The summary of the schedule is presented in Table 6.8.

The plan calls for the operation of: MWSP II-1 by the middle of 1982; MWSP II-2 by late 1984; MWSP III-1 by early 1987; MWSP III-2 by the end of 1992; MWSP III-3 by the middle of 1997; and MWSP IV-1 by the end of 1999. The plan is shown in Figure 6.2.

Table 6.7

Manual Simulation for Expansion Timing, Plan 1-2

Cumulative Supply MCM	Project	Year	Penalty Cost (Million P) Computation	Value	Interest Cost (Mil. P) Computation	Value
485		1980	(476.54-485) (2.155)			
		1981	(497.69-485) (2.155)	27.346	.1 (1253.52)	125.352
685.8	MWSP II-1	1982	(577.00-485) (2.155)	198.26[a]		125.352
		1983	(699.38-685.8) (2.155)	29.264		125.352
886.6	MWSP II-2	1984	(758.04-685.8) (2.155)	155.677[b]		125.352
		1985	(925.81-886.6) (2.155)	84.497		125.352
		1986	(953.33-886.6) (2.155)	143.803	.1 (1494.95)	149.495
1128.36	MWSP III-1	1987	(962.38-886.6) (2.155)	163.305[c]		149.495
		--				
		1991	(1145.95-1128.36) (2.155)	37.9		149.495
1370.12	MWSP III-2	1992	(1194.97-1128.36) (2.155)	143.544	.1 (1494.95)	149.495
		--				
		1996	(1414.4-1370.12) (2.155)	95.423		149.495
1611.88	MWSP III-3	1997	(1485.5-1370.12) (2.155)	248.643[d]		149.495
		--				
1718.91	MWSP IV-1	1999	(1637.61-1611.88) (2.155)	55.448	.1 (511.8)	51.18

Notes: a -- Penalty cost at construction in approximately 129.894 at 1.6 years from the end of 1980
b -- Penalty cost at construction in approximately 117.748 at 3.8 years.
c -- Penalty cost at construction in approximately 149.653 at 6.3 years.
d -- Penalty cost at construction is approximately 141.388 at 16.4 years.

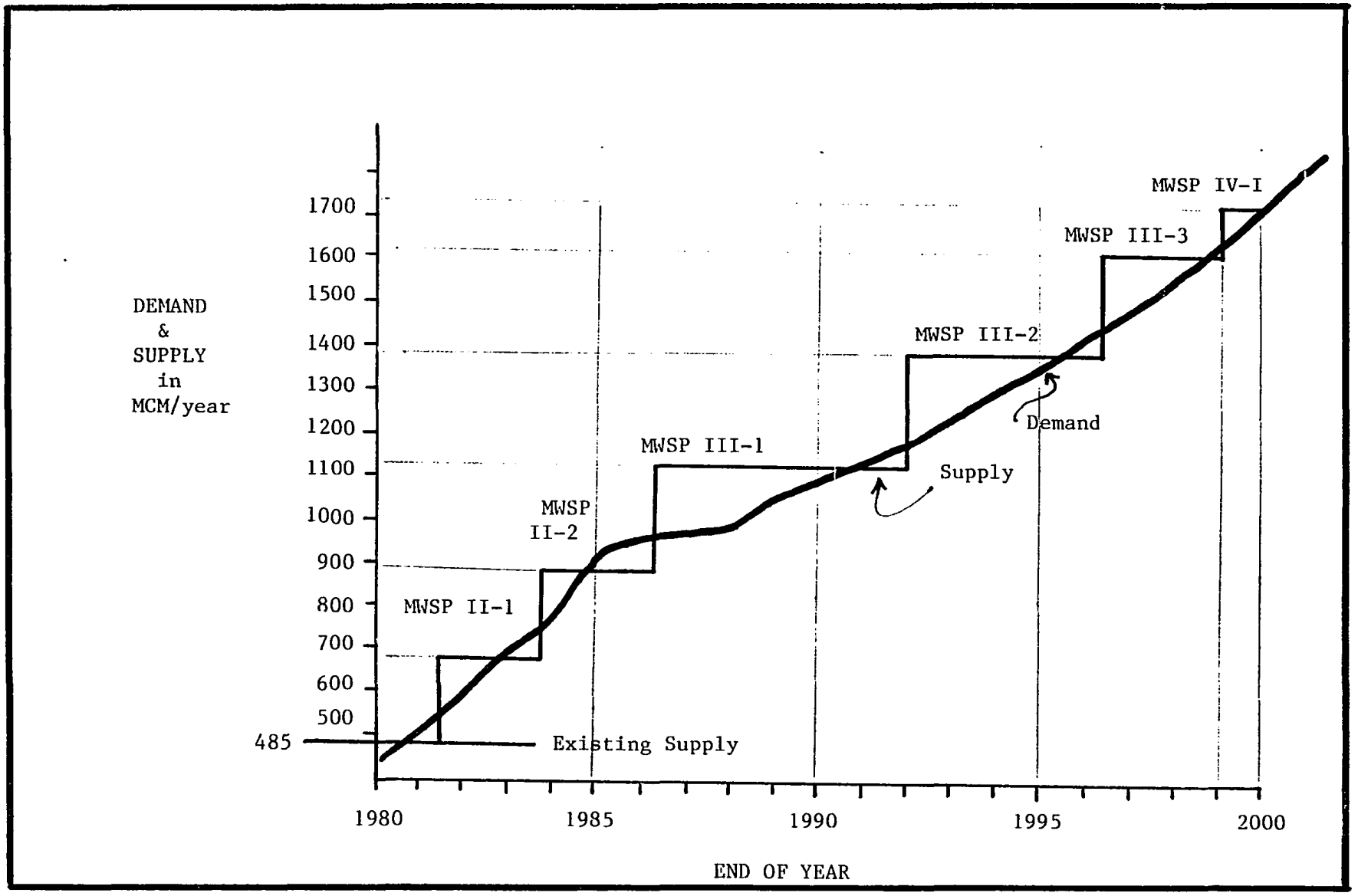


Figure 6.2 Expansion Plan 1-2

Table 6.8

Summary of Expansion Timing, Plan 1-2

Project	Capacity Added (MCM/year)	Cumulative Supply[a] (MCM/year)	Operational Year
MWSP II			
Stage 1	200.8	685.8	mid 1982
Stage 2	200.8	886.8	late 1984
MWSP III			
Stage 1	241.76	1128.36	early 1987
Stage 2	241.76	1370.12	end of 1992
Stage 3	241.76	1611.88	mid 1997
MWSP IV			
Stage 1	107.03[b]	1711.91	end of 1999

Notes: a -- The 1980 existing supply is 485 MCM/year.
Cumulative supply = existing + capacity added.
b -- About .357 of the whole stage.

The discounted construction, OMR, and shortage costs are shown in Tables 6.9, 6.10, and 6.11, respectively. Overall, the plan would cost P4552.671 million in 1980. See Table 6.12 for the summary of costs.

C. Plan 2-1 (Econometric Demand-"Without-Shortage" Policy)

This plan is based on the econometric projected demand and a without-shortage supply policy.

The projects were phased along the demand curve and the resulting expansion plan is shown in Figure 6.3. The plan requires the operation of: MWSP II-1 in 1980; MWSP II-2 roughly in mid-1982; MWSP III-1 in mid-1989; MWSP III-2 in mid-1994; and MWSP III-1 in mid-2000. The schedule, along with the capacities and cumulative supplies resulting from each addition is presented in Table 6.13.

Table 6.9

1980 Discounted Construction Costs, Plan 1-2

Projects	Computation[a]	Discounted Cost (million P)
MWSP II		
Stage 1	$e^{-r(1.6)}(1253.52)$	1068.179
Stage 2	$e^{-r(3.8)}(1253.52)$	857.233
MWSP III		
Stage 1	$e^{-r(6.3)}$ (1494.95)	796.198
Stage 2	$e^{-r(12)}$ (1494.95)	450.269
Stage 3	$e^{-r(16.4)}$ (1494.95)	289.99
MWSP IV		
Stage 1	$e^{-r(19)}(511.83)$[b]	76.554
Total		3538.423

Notes:

[a]Discount rate = 10 percent. Number of years is the exact timing of the projects from the year 1980 determined in Table 6.7.

[b]On the assumption that the cost is linearly related to capacity, 511.83 is the construction cost required for a capacity of 107.03.

Table 6.10

1980 Discounted OMR Costs, Plan 1-2, Million P

Year	MWSP II Stage 1	MWSP II Stage 2	MWSP III Stage 1	MWSP III Stage 2	MWSP III Stage 3	MWSP IV Stage 1[e]
2000	3.731	3.731	4.546	4.546	4.546	1.995
1999	4.118	4.118	5.051	5.051	5.051	
1998	4.560	4.560	5.593	5.593	5.593	
1997	5.058	5.058	6.203	6.203	3.722[d]	
1996	5.555	5.555	6.813	6.813		
1995	6.163	6.163	7.559	7.559		
1994	6.799	6.799	8.339	8.339		
1993	7.545	7.545	9.254	9.254		
1992	8.319	8.319	10.204			
1991	9.176	9.176	11.255			
1990	10.143	10.143	12.441			
1989	11.22	11.22	13.763			
1988	12.41	12.41	15.221			
1987	13.71	13.71	11.769[c]			
1986	15.146	15.146				
1985	16.75	16.75				
1984	18.518	3.704[b]				
1983	20.481					
1982	9.044[a]					
Sum	188.446	144.107	128.011	53.358	18.912	1.195

Grand Total = P534.829 million

Notes:
a -- About .4 of that OMR for whole year
b -- About .2 of that OMR for whole year
c -- About .7 of that OMR for whole year
d -- About .6 of that OMR for whole year
e -- Since the actual capacity needs to satisfy demand up to year 2000 is only .357 of the whole stage capacity, actual OMR cost is also .357 of the OMR for the whole stage on the assumption that costs are linearly related with capacity.

Table 6.11

1980 Discounted Penalty Costs, Plan 1-2, (Million P)

Year	Computation[a]	Penalty Cost
1981	$(27.346)\ e^{-r(1)}$	24.743
1982	$(129.894)\ e^{-r(1.6)}$	110.688
1983	$(29.264)\ e^{-r(3)}$	21.679
1984	$(117.748)\ e^{-r(3.8)}$	80.523
1985	$(84.497)\ e^{-r(5)}$	51.25
1987	$(149.653)\ e^{-r(6.3)}$	79.703
1991	$(37.9)\ e^{-r(11)}$	12.615
1992	$(143.544)\ e^{-r(12)}$	43.234
1996	$(95.423)\ e^{-r(16)}$	19.265
1997	$(141.388)\ e^{-r(16.4)}$	27.426
1999	$(55.448)\ e^{-r(19)}$	8.293
Total		479.419

Note: [a]Number of year indicates exact timing of projects determined in Table 6.7.

Table 6.12

Summary of Costs, Plan 1-2, Million P

Type of Cost	1980 Value
Construction	3538.423
OMR	534.829
Shortage	479.419
Total	4552.671

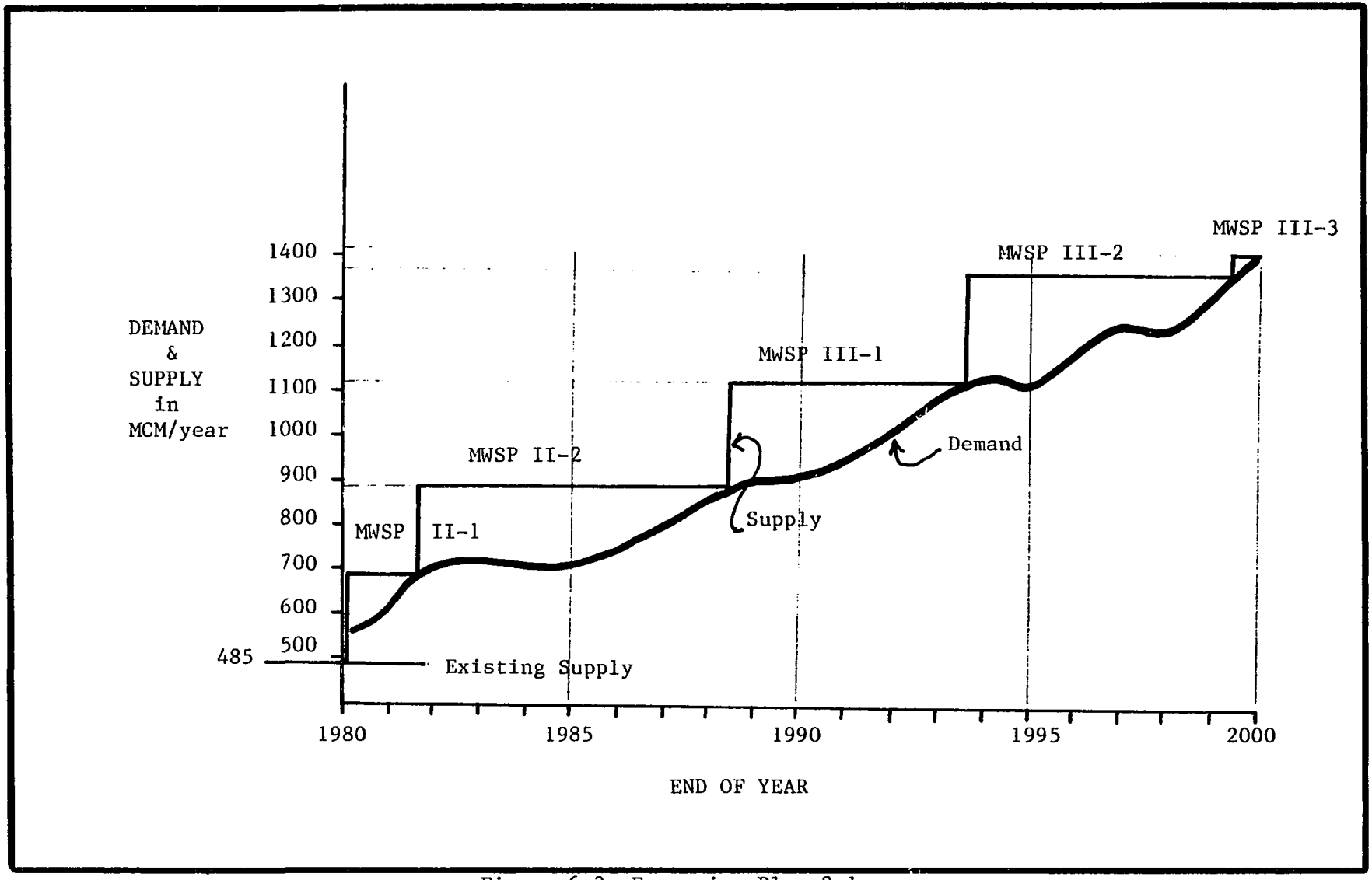


Figure 6.3 Expansion Plan 2-1

Table 6.13

Summary of Expansion Timing, Plan 2-1

Project	Capacity Added MCM/Year	Cumulative Supply MCM/Year	Operational Year
MWSP II			
Stage 1	200.8	685.8	1980
Stage 2	200.8	886.8	mid 1982
MWSP III			
Stage 1	241.76	1128.36	mid 1989
Stage 2	241.76	1370.12	mid 1994
Stage 3	39.542[a]	1409.662	mid 2000

Note: [a]To satisfy the demand within the planning period, only this capacity is needed out of the total third-stage capacity of 241.76.

Using the same procedure and formulae to discount construction and OMR costs, the results are shown in Tables 6.14 and 6.15 respectively. There is a shortage of 76.515 MCM at the time of construction which is valued at P164.889 million at 1980 prices.

Table 6.14

1980 Discounted OMR Costs, Plan 2-1, Million P

Project	Computation	1980 Value (Million P)
MWSP II		
Stage 1		1253.52
Stage 2	$e^{-r(1.7)}(1253.52)$	1057.551
MWSP III		
Stage 1	$e^{-r(8.5)}(1494.95)$	638.964
Stage 2	$e^{-r(13.5)}(1494.95)$	387.55
Stage 3	$e^{-r(19.4)}(244.425)$[a]	35.124
Total		3372.709

Note: [a]Cost is assumed to be linearly related to capacity. Since the needed capacity is only 39.542, which is .1635 of the whole stage capacity of 241.76, this cost is assumed to be .1635 of the entire stage construction cost of P1494.95.

Table 6.15

1980 Discounted OMR Costs, Plan 2-1, Million P

Year	MWSP II Stage 1	MWSP II Stage 2	MWSP III Stage 1	MWSP III Stage 2	Stage 3[a]
2000	3.731	3.731	4.546	4.546	.748[e]
1999	4.118	4.18	5.051	5.051	
1998	4.560	4.560	5.593	5.593	
1997	5.058	5.058	6.203	6.203	
1996	5.555	5.555	6.813	6.813	
1995	6.163	6.163	7.559	7.559	
1994	6.799	6.799	8.339	4.169[d]	
1993	7.545	7.545	9.254		
1992	8.319	8.319	8.319		
1991	9.176	9.176	11.255		
1990	10.143	10.143	12.441		
1989	11.22	11.22	6.882[c]		
1988	12.41	15.221			
1987	13.71	13.71			
1986	15.146	15.146			
1985	16.75	16.75			
1984	18.518	18.518			
1983	20.481	20.481			
1982	22.61	6.783[b]			
1981	27.64				
Sum	229.652	186.185	94.17	39.964	.748

Grand Total = P550.719 million

Notes:

[a]The actual capacity needed and the OMR cost is only .1635 of that for the whole stage.

[b]About .3 of that OMR for whole year

[c]About .5 of that OMR for whole year

[d]About .5 of that OMR for whole year

[e]About .6 of that OMR for whole year

This plan has a total discounted cost of P4088.317 million in 1980. Refer to Table 6.16 for the summary of costs.

Table 6.16

Summary of Present Value of Costs, Plan 2-1

Type of Cost	1980 Value (Million P)
Construction	3372.709
OMR	550.719
Shortage[a]	164.889
Total	4088.317

Note:

[a]Incurred at the time of construction of MWSP II-1.

C. Plan 2-2 (Econometric Demand--"With-Shortage" Policy)

Also based on econometric demand, this plan adopts a supply policy where shortage is allowed.

The manual simulation of the optimality condition for timing of projects is shown in Table 6.17 and summarized in Table 6.18.

This plan requires the operation of: MWSP II-1 in 1980; MWSP II-2 toward the end of 1986; MWSP III-1 in late 1991; and MWSP III-2 at the end of 1996. Refer to Figure 6.4.

Estimation of the discounted construction, OMR, and penalty costs are shown in Tables 6.19, 6.20, and 6.21, respectively.

The 1980 present value of the cost of this plan is P3690.882 million. The breakdown of this cost is shown in Table 6.22.

Table 6.17. Manual Simulation for Expansion Timing, Plan 2-2

Cumulative Supply (MCM)	Project	Year	Penalty Cost (Million P) Computation	Value	Interest Cost (Million P) Computation	Value
485 + 200.8	MWSP II-1	1980	(561.515-485)(2.155)	164.889	.1(1253.52)	125.352
		1982	(717.15-685)2.155	67.559		125.352
		1983	(705.149-685.8)2.155	41.697		125.352
		1984	(707.249-685.8)2.155	46.222		125.352
		1985	(701.263-685.8)2.155	33.323		125.352
886.6	MWSP II-2	1986 -	(749.313-685.8)2.155	136.87[a]		125.352
		1989	(911.81-886.6)2.155	54.337		125.352
		1990	(900.375-886.6)2.155	29.685		125.352
1128.36	MWSP III-1	1991 -	(958.433-886.6)2.155	154.8[b]	.1(1494.95)	149.495
		1994 -	(1152.063-1128.36)2.155	51.079		149.495
1370,12	MWSP III-2	1996 -	(1195.379-1128.36)2.155	144.525		149.495
		2000	(1409.662-1370.12)2.155	85.213		149.495

Notes:

[a]Penalty cost during construction is approx. 126.515 at 5.9 years from 1980

[b]Penalty cost during construction is approx. 142.288 at 10.9 years from 1980

Table 6.18

Summary of Expansion Timing, Plan 2-2

Project	Capacity Added (MCM/Year)	Cumulative Supply[a] (MCM/Year)	Operational Year
MWSP II			
Stage 1	200.8	685.8	1980
Stage 2	200.8	886.6	end of 1986
MWSP III			
Stage 1	241.76	1128.36	late 1991
Stage 2	241.76	1370.12	end of 1996

Notes:

[a]Existing supply is 485 MCM/year

Cumulative supply = existing + capacity added

Table 6.19

1980 Discounted Construction Costs, Plan 2-2

Project	Computation	Value, Million P
MWSP II		
Stage 1		1253.52
Stage 2	$e^{-r(5.9)}(1253.52)$	694.859
MWSP III		
Stage 1	$e^{-r(10.9)}(1494.95)$	502.627
Stage 2	$e^{-r(16)}(1494.95)$	301.825
Total		2752.831

Note: Discount rate r = 10%

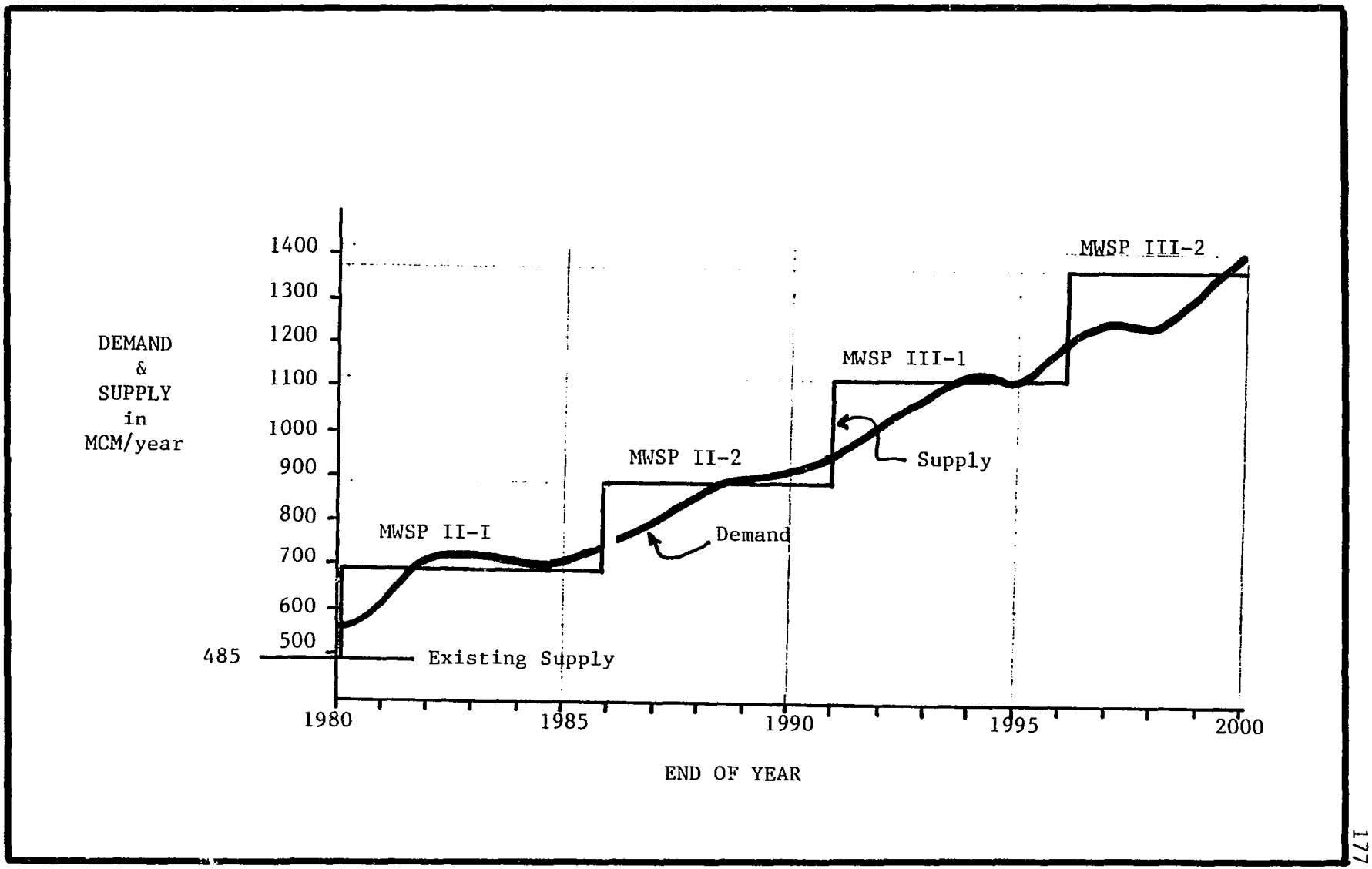


Figure 6.4 Expansion Plan 2-2

Table 6.20

Discounted OMR Costs, Plan 2-2, Million P

Year	MWSP II State 1	MWSP II Stage 2	MWSP III Stage 1	MWSP III Stage 2
2000	3.731	3.731	4.546	4.546
1999	4.118	4.118	5.051	5.051
1998	4.560	4.560	5.593	5.593
1997	5.058	5.058	6.203	6.203
1996	5.555	5.555	6.813	
1995	6.163	6.163	7.559	
1994	6.799	6.799	6.799	
1993	7.545	7.545	9.254	
1992	8.319	8.319	10.204	
1991	9.176	9.176	1.125[b]	
1990	10.143	10.143		
1989	11.22	11.22		
1988	12.41	12.41		
1987	13.71	13.71		
1986	15.146	1.857[a]		
1985	16.75			
1984	18.518			
1983	20.481			
1982	22.61			
1981	20.657			
Sum	229.652	110.364	64.717	12.423

Grand Total = P426.156 million

Notes:

[a]About .1 of that OMR for whole year

[b]About .1 of that OMR for whole year

Table 6.21

1980 Discounted Penalty Costs, Plan 2-2

Year	Computation	1980 Value (Million P)
1980		164.889
--		
1982	$(67.559)e^{-r(2)}$	55.263
1983	$(41.697)e^{-r(3)}$	30.889
1984	$(46.222)e^{-r(4)}$	30.983
1985	$(20.194)e^{-r(5)}$	20.194
1986	$(136.87)e^{-r(5.9)}$	75.87
--		
1989	$(54.337)e^{-r(9)}$	22.061
1990	$(29.685)e^{-r(10)}$	10.894
1991	$(142.288)e^{-r(10.9)}$	47.839
--		
1994	$(51.079)e^{-r(14)}$	12.565
--		
1996	$(144)e^{-r(16)}$	28.944
--		
2000	$(85.213)e^{-r(20)}$	11.504
Total		511.895

Note: Discount rate r = 10%

Table 6.22

Summary of Costs, Plan 2-2, Million P

Type of Cost	1980 Value
Construction	2752.831
OMR	426.156
Shortage	511.895
Total	3690.882

6.4 Discussion of Results

A. Alternative Expansion Plans

The results of the analyses of the four alternative expansion plans are summarized in Table 6.23.

Table 6.23

1980 Value of Costs of Alternative Expansion Plans for MWSS, Million P

Plan	Costs			
	Construction	OMR	Shortage	Total
Plan 1-1	3916.951	620.077	24.74	4561.768
Plan 1-2	3538.423	534.829	479.419	4552.671
Plan 2-1	3372.709	550.719	164.889	4088.317
Plan 2-2	2752.831	426.156	511.895	3690.882

Comparison of the definitions of Plan 1-1 and Plan 1-2 shows that the only difference is that the latter has a supply policy of allowing shortage, a policy based on the economic criterion for optimal delay of projects. They are both based on the requirement-based projected demand.

Plan 1-1 has 6 expansion projects required, and the delaying criterion applied in Plan 1-2 did not reduce this number of planned projects. However, this reduced the construction cost by 9.66 percent (or P378.528 million), and the OMR cost by 13.75 percent (or P85.248 million). The shortage cost though increased by P454.679 million from P24.74 million to P479.419 million. Overall, Plan 1-2 is P9.097 million cheaper than Plan 1-1. This finding supports the hypothesis that delaying projects lowers the cost of an expansion plan.

Comparing Plan 2-1 and Plan 2-2, the difference is that the former has a conventional supply policy of without-shortage, while the latter has a policy of allowing shortage determined by economic criterion for delay.

Plan 2-1 has 5 expansion projects required for the whole 20-year period, and has a present total cost of P4088.317 million. The delaying of these projects in Plan 2-2 reduced the number of required projects to four. Although the penalty cost increased by P347.006 million, the reduction in the construction and OMR costs brought about by the tolerance of delays were large enough to overcome this. The construction cost decreased by P619.878 million from P3372.709 million to P2752.831 million, and the OMR cost decreased by P124.563 million from P550.719 million to P426.156 million. Thus the result is that the total cost of Plan 2-2 of P3690.882 million is P397.435 million

lower than that of Plan 2-1 at P4088.317 million. This finding supports the hypothesis that tolerance of shortage lowers the cost of an expansion plan.

Comparison of Plan 1-2 versus Plan 2-2 reveals that the only difference is the demand forecast. The former is based on the requirement-based demand, while the latter is based on the econometric demand. Both have a policy of allowing shortage. Plan 1-2 costs P4552.671 million while Plan 2-2 costs P3690.882 million. As one would expect, the significantly higher cost of Plan 1-2 is attributable to the fact that the demand based on requirements is higher than the projected econometric demand. This difference is due to the assumptions made in projection. The former uses the concept of demand which is defined as consumption plus unaccounted-for water, and refers to the demand of a certain percentage of the population targeted to be served; while the latter defines demand as consumption only, and refers to the demand of the whole population. A quick look at these assumptions tells us that the econometric projections should be higher because they are for the whole population, but the results are not. This is because under the econometric projection, the rate of increase of demand is less.

Comparison of Plan 1-1 versus Plan 2-1 also reveals that the only difference is demand projections. Plan 1-1 is based on the requirement-based demand while Plan 2-1 is based on econometric demand. Both have a without-shortage supply policy. Plan 1-1 costs P4561.768 million against P4088.317 million of Plan 2-2.

The above comparisons demonstrate the obvious: that expansion plans based on higher demand projections have higher total costs than those based on lower demand projections.

From the above findings, we can then draw the following generalized conclusions relative to our second hypothesis:

1. Given the same supply policy, a plan based on a higher projected demand will be more costly than the one based on lower demand.

2. Given the same projected demand, when projects are scheduled according to the economic criterion (that projects should be delayed up to the time when the rate of penalty cost accrual is equal to the rate of interest cost accrual) then the plan subjected to such criterion is more economical (i.e., less costly) than the plan based on the conventional without-shortage policy.

B. Sensitivy Analysis

It is important to assess the sensitivity of waiting (delay) time and the cost components of an expansion plan to changes in the discount rate and penalty price for shortage. The information on this sensitivity is important to planners and decision makers on the ground that plans and decisions can be properly adjusted to account for uncertainties in the values of discount rate and penalty price.

A sample sensitivity analysis is presented in Appendix 3 to show the effects of the changes in discount rate and penalty price on delay time and the different components of the cost of a given project namely: construction; OMR; and shortage penalty costs. The analysis indicates that waiting (delay) time y varies directly with the discount rate r, and inversely with penalty price p. The estimate for shortage

cost, pDy, obviously tell us that it increases with an increase in y. The discounted construction, OMR, and shortage costs are affected by r and y through the discount factor e^{-ry}. See Table 6.26 in Appendix 3.

With this information on how sensitivity analysis can be done on a project basis, we will then apply the concept on a plan basis, that is, the whole expansion plan.

Let us take the case of Plan 2-2. We will vary the values of r and p and observe the changes in its cost components. Out of this, we create three scenarios namely: I, which is the original Plan 2-2 where r = .10, p = 2.155, and whose cost components are given in Table 6.23; II, where r = .20 and p = 2.155; and III, where r = .10 and p = 4.31. Note that from the baseline scenario I, r is doubled under II, while p is doubled under III.

Basically, with changes in the values of r and p, the estimate for the components of costs under scenarios II and III can be derived by using these values in the same estimation process followed in arriving at the Plan 2-2 (baseline) cost estimate, namely: simulation for expansion timing; and estimating and discounting construction, OMR, and shortage costs. The calculations for scenario II are shown in Tables 6.27 to 6.30, while those for scenario III are shown in Tables 6.31 to 6.34 of Appendix 4.

The response of delay time to changes in the discount rate r and penalty price p is summarized in Table 6.24. Doubling the discount rate of 10 percent under scenario I to 20 percent under scenario II generally increased the delay times of the projects by about one year: delay time for MWSP II-1 increased from 0 to 1 year; MWSP II-2 from 4.2

Table 6.24

Response of Waiting (Delay) Time[a] to Changes in Discount Rate and Penalty Price

Projects	Scenarios		
	I (Base:Plan 2-2) r = .10 p = 2.155	II r = .20 p = 2.155	III r = .10 p = 4.31
MWSP II-1[b]	0	1	0
MWSP II-2[c]	4.2	5.3	0.3
MWSP III-1[d]	2.2	3.3	1.7
MWSP III-2[e]	1	1.9	0.5
MWSP III-3[f]	not needed	not needed	0.1

Notes:

[a]Values in table are waiting times (years) measured from the point of regeneration immediately preceding each project.

[b]Waiting time from 1980

[c]Regeneration point preceding this project occurs at 1.7 years from 1980.

[d]Regeneration point preceding this project occurs at 8.7 years from 1980.

[e]Regeneration point preceding this project occurs at 15 years from 1980.

[f]This project's capacity is just .1635 of the total stage's capacity of 241.76 MCM/year. Regeneration point preceding this project occurs at 19.6 years from 1980.

years to 5.3 years; MWSP III-1 from 2.2 years to 3.3 years; and MWSP III-2 from 1 year to 1.9 years.

Doubling the penalty price of P2.155/M^3 under scenario I to P4.31/M^3 under scenario III reduced the delay times of projects disproportionately: delay time for MWSP II-2 reduced from 4.2 years to .3 year: MWSP III-1 from 2.2 years to 1.7 years; and MWSP III-2 from 1 year to .5 year. There is no change in the delay time for MWSP II-1 from zero year.

Under scenario III an additional project is needed to satisfy the demand within the planning horizon. A capacity of 39.52 MCM is needed from the total 241.76 MCM capacity of MWSP III-3. According to our analysis the construction of this project can be delayed by 0.1 year.

The result of the analysis for the cost components is summarized in Table 6.25.

Comparison of scenarios I and II will tell us the effect of doubling the discount rate r while holding penalty price p constant. Earlier, it was mentioned that delay time y increases with an increase in r. This increase in y means longer delays in the construction of projects and lesser OMR costs because no OMR costs are incurred during delays. This explains the fact that in Table 6.25 construction cost went down from P2752.831 million to P1521.926 million, while the OMR cost decreased from P426.156 million to P141.864 million. Because of longer delays, shortage cost increased from P511.895 million to P634.588 million. Overall, the cost of the expansion plan decreased from P3690.882 million under scenario I to P2298.378 million under scenario II.

Table 6.25

Sensitivity Analysis of Costs of an Expansion Plan to Changes in Discount Rate and Penalty Price

Discounted Costs (1980 Million Pesos)	Scenarios		
	I (Base:Plan2-2) r = .10 p = 2.155	II r = .20 p = 2.155	III r = .10 p = 4.31
Construction	2752.831	1521.926	3161.7057
OMR	426.156	141.864	533.837
Shortage penalty	71.895	634.588	611.945
Total	3690.882	2298.378	4307.4877

The effect of doubling the value of penalty price p while holding r constant can be assessed by comparing scenarios I and III. It was also mentioned earlier that an increase in penalty price p would reduce the delay time y. Because of this, projects would be constructed earlier, and in fact one more project was required under scenario III to satisfy the demand within the planning horizon. This would mean an increase in construction and oMR costs. Observe that the construction cost increased from P2752.831 million to P3161.7057 million, while OMR cost increased from P426.156 million to P533.837 million. Concerning the shortage cost, theoretically an increase in p would shorten the delay time and reduce the penalty cost. But under the present case, doubling the magnitude of p overweighs the effect of reduced y through the estimate of penalty cost itself, pDy, thus resulting in a net increase in the discounted penalty cost from P511.895 million to P611.945 million. Overall, we can say that an increase in the penalty

price would increase the cost of an expansion plan, which is here supported by the fact that the total cost of P3690.882 million under scenario I increased to P4307.488 million under scenario III.

CHAPTER VII

SUMMARY AND CONCLUSION

7.1 The Problem

This study has dealt with the question of to what extent economic concepts and principles can be practically designed into water supply expansion plans. To pursue this problem, two policy-related hypotheses were addressed: one, whether water consumption in Metropolitan Manila responds to price changes; and the second, whether the tolerance of shortages in the water supply expansion plan reduces the cost of the plan.

7.2 Methodology

For the first hypothesis, separate econometric demand functions were specified and estimated for the different consumer classes which face their own respective pricing schedules. The literature was searched to identify the variables to be specified for each use class. Average prices per cubic meter of water were used in the cases of industrial, commercial, and public uses. Two price concepts--price of the marginal block faced by the average household consumer and the "difference price"--were used to analyze the residential use because of the increasing block rates structure facing it.

For the second hypothesis, the framework for analyzing the effectiveness of planned shortages to reduce the cost of an expansion plan involved a matrix of four alternative plan scenarios whose costs were evaluated and compared. In the columns are two supply policies--"with"

and "without" planned shortages. In the rows are two types of water use projections--the requirement-based demand and the econometric demand. Thus, each cell in the matrix represented a plan consisting of a projected demand and a sequence of expansion projects phased according to the selected supply strategy.

Cell 1,1 represented the plan that had already been approved by MWSS for implementation. The information about the requirement-based demand and the sizes and costs of projects was given, and thus was taken as the baseline plan for the study.

The additional information needed to carry out the analysis was the projected econometric demands for the entire service area and the estimated penalty prices for shortages incurred by the alternative plans.

To project future water use, the estimated econometric demand equations for the four different types of uses were utilized. To do this, the explanatory variables in each of the four equations were first independently projected, making the projections of the total use conditional upon the projected values of the variables for the four uses. The total projected use for a given year is the sum of the separate projections.

Regarding the shortage penalty price, the opportunity cost concept of foregone benefits due to shortages was used. The unit foregone benefit was defined as the area under the demand curve up to the level of consumption, divided by the level of consumption. This measure was taken as the unit penalty price of shortage. Each unit penalty price was weighted by its corresponding level of consumption. A constant penalty price was used to determine the applicability of the shortage policy in Metro Manila and in scheduling expansion projects according

to the specified supply policy. This resulted in the different expansion plans.

For each plan, the construction, OMR, and shortage costs were discounted to 1980 present values. The plans were compared according to the present values of their total costs. These comparisons were the basis for testing the second hypothesis.

7.3 Results of the Analytical Methods

The major results of the analytical methods are:

1. Household monthly consumption is affected by monthly household income, price of the marginal block faced by the average household consumer, and the difference price. At the means, the income and the combined price elasticities of residential demand for water are 0.542 and -0.287 respectively.

2. Annual industrial use drawn from the MWSS system is affected by the industrial price of water and by the income of the region. At the means, the price elasticity of industrial demand is -0.213, while the income elasticity is 1.347.

3. The annual commercial consumption drawn from the system is influenced by the commercial price of water and by the income of the region. The price and income elasticities of commercial demand are -0.163 and 1.18 at the means, respectively.

4. The annual institutional use per capita is influenced by changes in the population of the region. The effect of price changes is insignificant.

5. The shortage (penalty) price in the Metro Manila region is not infinite, and is of a small enough magnitude to allow the possibility of with-shortage supply policy.

6. Plans based on higher demand level obviously are more costly than the plans based on lower demand level.

7. Tolerance of shortages according to the economic criterion of delay (that a project may be delayed up to the point when the shortage penalty cost accrual is equal to the interest accrual) reduces the cost of an expansion plan.

8. Waiting (delay) time for a project varies directly with the discount rate and inversely with shortage penalty price. See Table 6.25.

9. The discounted construction and OMR cost components of the cost of an expansion plan varies inversely with the discount rate r and directly with shortage penalty price p. The discounted shortage penalty cost component varies directly with the discount rate and penalty price. Overall, the total discounted cost of an expansion plan varies inversely with the discount rate (holding p constant) and directly with the penalty price (holding r constant).

7.4 Data and Problems

Water consumption data for the years 1970-81 were supplied by the MWSS Data Center Staff. Data on explanatory variables such as population, income, and prices were taken from the most recent information available in reports and books published by various government agencies.

Data on alternative supply projects were taken from the reports of the different consultants to MWSS.

Empirical researchers who propose to use secondary data are more likely to encounter data problems. The data problems are actually built into the study area's statistical system. Let us go over these

problems. First, if a country has a statistical system which surveys its population and economic activities once every five years, then a researcher will have problems where to get the information for inter-censal years. The best he can do is interpolate or extrapolate the missing data from the available information. Second, if the ministry of economic planning reports income or any economic indicator in an aggregate form or uses any measure which includes other variables which are not needed by the researcher, then the researcher will have problems of netting out the unwanted variables. Third, sometimes statistical offices are reluctant to give out up-to-date data on the ground that the information requested has not yet been officially authorized for public release. Fourth, often different agencies or sources give out different estimates of certain information. Finally, sometimes needed information is just not available.

There was a promising piece of information in the form of a national input-output (I-O) analysis where the combined water, electricity, and gas sector was considered. This would have been a useful alternative in estimating the benefit derived by the other sectors of the economy from the water industry if the I-O analysis had been for the Metro Manila and if the water sector had been separated or separable from the electricity and gas sectors. However, there was no way to separate the technical coefficients for the water sector from the combined coefficients.

There was a problem on income data as discussed in Chapter V. What was needed for the regression was the per capita income of the population served by water rather than the per capita income of the entire Metro Manila area. Since our research budget did not allow for a

primary survey, the next best alternative was to use the per capita income of the population as a proxy for that of the population served. The estimated regression coefficient would have to serve the purpose until more refined data become available.

Statistics are compiled for different purposes. Sometimes data for the required purpose are not kept by a certain office but may be available elsewhere. So there is a basic problem of identifying the agency which handles the information needed. For instance, the population projections for Metro Manila (as defined administratively) are done by the National Census and Statistics Office, while the population projections for the service area of the MWSS are available from the MWSS Data Center.

Sometimes there was a minor problem with different estimates of the same information. For instance, the various consultants to the MWSS used different population projections for the service area. This was because the study area considered by each consultant was somewhat different, and because the projection techniques and assumptions used differed among consultants.

Another problem was the delineation of the area served by the public institutions for the purpose of estimating the public use function. Recall that population was the significant variable affecting the public use of water. More specifically, the question is--who are the people served by the institutions? In reality, even the people from other parts of the country come to Metro Manila to make use of the institutions such as hospitals, and public places such as parks. Because it is extremely difficult to estimate this population, the

population of Metro Manila as administratively defined was used as the population variable because this population represents the more proximate and constant users during the estimation period (1970-1981). For the purpose of projecting public water consumption, the population of the entire service area should be used because we are talking about the demand of the entire service area.

7.5 Conceptual Difficulties

There were conceptual difficulties encountered in this study. Generally, these difficulties are the limitations or pitfalls of the theoretical concepts when applied to real problems. This indicates that there is a need for concepts that work in the real world--a need which has not been satisfied by the theoretical side. Some of these needed concepts are discussed in the next section on the implications of this study for further research. In addition, the following are the other conceptual difficulties experienced.

First, as discussed in Chapter II, Billings and Agthe (1980) proposed two price concepts for use in the analysis of price elasticities in the case of increasing block rates. These are the price of the marginal block faced by the average household consumer (DMP), and the difference price (DP) which is defined as the actual bill minus the bill if all water were sold at DMP. There is a problem encountered with DMP and DP when the estimated residential consumption function is used for projection. Let us see this problem in terms of a residential function used to project residential use RU_t at time t:

$$RU_t = f(income_t, DMP_t, DP_t)$$

where the variables are as defined above. The problem stems from the

definitions of DMP and DP which involve the consumption of the average household consumer. To project RU_t, separate projections of these two prices are necessary, and this would require the projected consumption level of the average household consumer, that is, the block relevant to DMP. Technical difficulties arise here because the relevant block is supposed to be the average RU; thus the problem is one of identification. That is, a feedback mechanism exists where the two prices affect RU and conversely RU affects them. Strictly speaking, such problems can be handled by systems dynamic modelling. In this study, DMP and DP were projected on the assumption that the relevant block lies within 31 to 50 M^3, or specifically an average value of 42.252 M^3/month.

Second, the projections of explanatory variables are subject to the capability of the polynomial curves used. For interpolation, polynomial curves are fairly satisfactory. But for extrapolation (projection), the estimate would tend to change drastically as it is expressed as a function of time. To correct this, one should avoid projecting polynomials over a long period of time. It is advisable that, if one is projecting over a long period of time, one divide such period into sub-periods, each period being equal to the length of time over which the curve was calibrated. Suppose we have a curve which was calibrated with a set of data which covers a period of 10 years. Then, if one must project data over a 20-year period, one has to split this period into two 10-year periods, so that the time variable does not assume a large value.

Third, there was a difficulty concerning projections using econometric demand functions. After doing this study, I believe that the

use of the established relationship between the consumption level and the explanatory variables could not be used for water consumption projections. In cases where the elasticity of demand with respect to a variable is high, projection results would not be convincing if the value of that explanatory variable goes high. For instance, if we impose on the residential users the MWSS planned price increases as I have done in a regression run, the projected consumption level dropped drastically to a level which is highly unlikely to happen in reality. The same result could happen with other variables like income. If the family income becomes zero, it does not necessarily mean that the family will not consume water at all. What I am saying is that the use of regression results should be limited to detect and test postulated relations which can then be systematically researched. Examples of these postulated relationships are the price and income elasticities. The use of regression results in projecting water consumption should be avoided if better techniques are workable under local conditions, that is, if the availability of data permits.

Inspite of these conceptual difficulties and data problems discussed earlier, some important implications for decision-making and for further research can be drawn from this study.

7.6 Implications of the Study

In discussing the implications of the results, we point out that these are based on the methodological concepts employed here, and are subject to the data and conceptual difficulties experienced.

A. Implications for Decision Making

It is important to qualify the findings as far as implications for decision-making are concerned.

The finding that consumption responds to price changes means to an economist that demand theory can be used in managing water supply. It is on the basis of this price-quantity relationship that some economists argue that water is not different from other economic goods. The great leap from theory to practice, however, must be carefully scrutinized for pitfalls that can lead to unhappy consequences.

Water is a necessity for life and its development and distribution involves complex institutional systems governing operating decisions. In some parts of the city, water is provided free to poor people through the installation of public standpipes. Water distribution systems are expanded to areas where the government takes no account of the ability to pay of the inhabitants. Foreign loans are obtained to finance water supply projects which must meet public health and repayment criteria that go beyond the simple profit criterion for private business. Thus, supplying water implies a responsibility for the government which is why the functions of a water agency are defined by law. The main function of MWSS is to provide safe and adequate water supplies to the population at equitable rates set by an institutionalized process constrained by revenue self-sufficiency and requiring approval by the MWSS Board. It is difficult to be equitable if we let price allocate water. If we do this, price increases would have regressive effects on the poor, and that would be contrary to the equity requirement. The government, through the water agency managers, cannot afford to let people go thirsty, that is why there are free public standpipes in

areas where people cannot afford to pay. This is based on a traditional value system that a basic need such as water should be freely available in adequate quantities to fill essential needs to all who require it.

Concerning the applicability of demand theory, and pricing in particular, there are a number of practical obstacles that get in the way of a simple application of this concept to regulate water supply. Take the case of the efficient pricing based on the marginal cost principle. This pricing method has not been applied because of the many obstacles (Warford and Whitford, 1973) barring its application. First, there has been a heavy reliance on the accountants' approach to costing and pricing rather than the economists'. Accounting costs, which include repayment of past loans, simply represent a transfer of income within the society, and efficiency in resource allocation dictates that these "sunk costs" be ignored for pricing purposes. An efficient pricing scheme is one where the price of any service or commodity supplied be equated to the cost of producing an additional unit of it, or its marginal cost. Accountants' pricing is usually higher than marginal cost pricing.

Second, capital investments in water supply are "lumpy," that is, only large investments of supply are technically feasible. When marginal cost includes the necessary investment costs, strict application of marginal cost pricing in the context of lumpy investment would imply zero or close to zero rates before capacity is reached, and gradual adjustments to reflect increasing social marginal costs as the capacity limits are approached.

Third, there is an apparent difficulty in measuring marginal cost price. If the interest of the society as a whole is to be considered,

pricing policies should ideally recognize externalities, in which case, optimal pricing would require a price equal to MC minus the benefits to others that accrue from marginal consumption. The process of measuring external effects is difficult, and hence it is clearly a barrier to efficient pricing. Managers of water utilities are typically constrained in their decision-making by different criteria for judging performance in supplying water and achieving certain financial targets for their organization.

Fourth, strict application of marginal cost pricing would lead to financial losses when the average cost of supply is falling. In addition, there are cases where loan obligations require setting prices higher than marginal cost prices. The theoretical counter argument is that the revenue shortfalls can be made up through government subsidies. But the political implications of dependence on such subsidies is to jeopardize the highly cherished independent operating mode of water supply agencies.

If the authorities should require that MWSS move to efficient pricing, then these and other obstacles must be overcome.

Our finding on the possibility of tolerating shortages in the supply expansion plan also deserves interpretation in terms of reality. The fact is that in the past, shortages were never incorporated in the MWSS' expansion plans. But in spite of this, shortages have always occurred during the implementation of the plan. These unintentional or unavoidable shortages are due to various factors including construction delays which may be caused by lack of funds or by some legal and physical constraints such as the need for obtaining the rights of ways for the structures. Also, shortages may be caused by the fact that the

availability of water generates its own demand. Water using industries locate where there is abundant water supply. Economic activities which are water-intensive can flourish. These and other phenomena lead to the water shortages especially in the absence of rationing by price. Better understanding of these phenomena is necessary through well-designed empirical studies before deliberate shortages can be designed into the planning framework. If actual shortages occur even under a supposedly without-shortage plan, then the intentional incorporation of shortage in the plan could mean more severe shortages.

To elaborate on this, the resulting (actual) shortage (RS) is the sum of the planned shortage (PS) and the unintentional shortage (US). In symbols:

$$RS = PS + US \tag{73}$$

In planning, we want the magnitude of RS to equal the magnitude of planned shortage PS. This equality can be achieved by adjustments in PS (by reducing or increasing it) or in US (by trying to avoid or not avoid shortages). If PS = US, then we do not plan intentionally for shortage, that is, PS is set equal to zero because shortage will be incurred in the implementation anyway in terms of the unintentional shortage (US). If PS < US, then we should plan for excess capacity (negative shortage) so that the resulting shortage RS will equal the original planned shortage. If PS > US, we should plan for a shortage which is equal to the difference between the original PS and US.

Shortages are typically related to issues of water rights. Before any water development works can proceed, water rights have to be secured. This requirement serves as a security for the investment.

Water rights may be defined by tradition (customary right) or by law (statutory rights). Water rights define the water flow in the river (source) that can be safely tapped for water supply. This secured flow is used as the basis for the design of dams and related facilities because it is the quantity of water that can be guaranteed to be delivered. Since this secured flow is stipulated in terms of water rights, shortages which may occur during the plan implementation are likely to involve water rights issues. If ever MWSS plans to incorporate shortages, it must consider the fact that the decision is not necessarily its own, but also that of other parties relying on the water source.

Tolerance of shortage involves politics. A very important criterion for judging a manager's performance is how much the water utility satisfies the water requirement of the service area. Some managers always prefer the policy of "without-shortage" because allowing shortages might endanger their job stability. They try their best to avoid shortages. Also, politicians at the higher position may impose upon the water utility the policy of "without-shortage" in order to gain support from the people.

Considering the fact that 50 percent of the water produced is unaccounted for or lost in the distribution, it would be wise for MWSS to prevent these losses. If these losses can be prevented, the number of expansion projects required will be lessened and the expansion expenditures drastically reduced.

One important factor to consider in water supply planning is the land use policies of the area being studied. Land use policies affect the availability of water supply in the Metro Manila region. One

policy, the "Fifty-Kilometer Radius Ban" adopted in the 70s prohibits the establishment of industrial firms within the 50 km radius from the center of Manila. This policy would lessen the pressure which industrial firms will exert on the water supply in the restricted area and shift it elsewhere. Another policy was the creation of a new city of Lungsod Silangan out of a rural area. As a project of the Ministry of Human Settlements, it had to relocate people from blighted areas. This move, as seen from the water planners' side, would increase the water demand of the same group of people. Land use policies should be taken into consideration when planning for water policies in this respect.

B. Implications for Research

Out of the findings of this study, there are some aspects which deserve further investigation.

The literature has given us different ways of estimating the penalty price of shortage. These are: import price of water; cost of alternative standby supplies; willingness to pay (area under the demand curve); and as an impact of not having water.

These approaches do not necessarily result in the same estimate of penalty price. There is a need to study how these approaches compare. The penalty price is central to the methodology and its magnitude dictates the timing of projects under the shortage supply policy. The different concepts of penalty price will result in different timing of projects, hence, different expansion plans and costs.

Also, there is a need to define what is the "true" cost of shortage. Literature has not really pointed out what is the true measure of shortage cost. Then, this "true" shortage cost must be

evaluated for Metro Manila so that, once accounted for, more realistic plans could be made.

An important component of the "true" cost of shortage is an intangible component. Water shortage could affect the health and welfare of the inhabitants. The fact that there is not enough water for fire fighting purposes presents a danger, and if fire occurs the loss could be attributed to the water shortage policy. Water shortage may lead to conflict among people and may end up into a riot. These cost components should be considered in evaluating a "with-shortage" supply policy.

Another aspect which needs to be investigated is the link between the econometric estimated demand and the true demand. This is important because the main purpose of projection, in water economics, is to serve as a basis for public water policy. That is why projection techniques must strive for "completeness" (Ciriacy-Wantrup, 1969) by accounting for the most significant dynamic variables, namely, changes in institutions, technology, and preferences. Against this requirement for a true demand, the econometric demand estimates must be evaluated if they can in fact be useful for policy purposes.

Also there is a need for further research on supply expansion. The survey of literature tells us of the computational complexity of attaining explicit solutions for the optimization approach to supply expansion. Coupled with this problem is the fact that only one functional form of demand (i.e., linear) is fully analyzed in the literature. Furthermore, the existing optimization techniques have not considered the physical site characteristics into the planning process.

There is a need to accommodate nonlinear demand forms, and also physical site characteristics perhaps as constraints.

For practical purposes, approximating equations for the corresponding optimal solutions have to be derived.

The more practical problem that should be dealth with after the completion of this study is how to improve empirical research especially on the economic aspects involved in supply expansion planning. From the point of view of a water utility manager, two major activities must be done. First, as an immediate project, there is a need to estimate the "true" demand. Together with this, the "true" cost of water shortage must be estimated for Metro Manila. These estimates will result to a more realistic water supply expansion plan. To do this task, an inter-agency cooperation between MWSS, University of the Philippines (Economics and Sociology Departments), and other relevant agencies may be organized.

Second, there is a need to reinforce the statistical system of the MWSS in such a way that the monthly water consumption and such other information related to time, place, and type of use are recorded from the present onwards. Monthly time series would provide better estimates of the elasticities as seasonal variation in water consumption can be accounted. Such a project would be of great value to future research.

7.7 Contributions of this Study

First, this study has assembled, analyzed and tested two approaches to water supply capacity planning. The traditional approach to expansion planning was put together from the studies of different foreign and local professional engineering consultants. The different

techniques of traditional water requirements projections and supply expansion presented in this study are the result of the author's analyses and interpretations of the different disorganized and seemingly restricted planning reports submitted by the several consultants to the MWSS. The alternative approach to planning was assembled from the recent literature and reflects some of the more theoretical views of how planning should be done.

The identification of the limitations of these approaches resulted in the "combination" of the more workable aspects from both approaches into compromise approaches which were tested to evaluate the performance of alternative supply policies--"with" versus "without" shortages.

Second, this study has identified some limitations and pitfalls of several concepts such as the straight line demand curve assumption and the optimal solution to project sizing in the "new" approach for expansion planning, difference price and the domestic marginal price when the estimated consumption function is used for projection, estimated econometric demand function as used in projecting the "true" demand, polynomial curves as used in projection, and the economy of scale concept as used in expansion planning. This led to the identification of future research needs.

Third, this study has originated some concepts or terminologies on shortages such as actual demand-side shortage (ADSS), actual supply-side shortage (ASSS), and supply-side shortage (SSS).

Finally, a more theoretical contribution is the alternative derivation of Erlenkotter's optimality condition for delaying projects. This is shown in the Appendix 1.

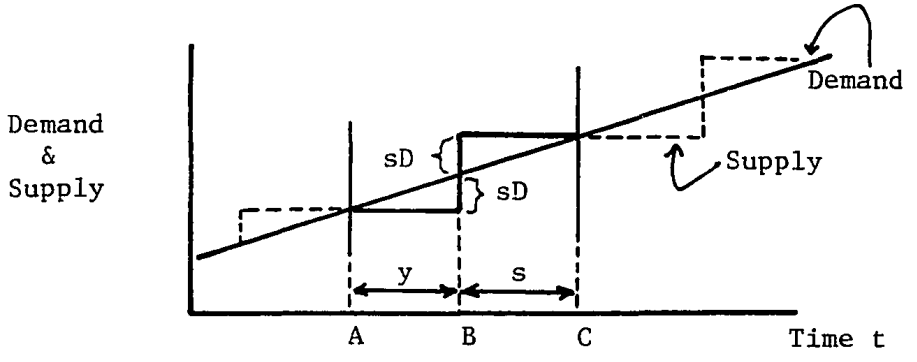
APPENDIX 1

ALTERNATIVE DERIVATION OF OPTIMAL CONDITION

FOR PROJECT DELAY

This condition states that a project may be delayed up to the point when the penalty cost accrue at the same rate as the interest cost. Erlenkotter (1967) derived this condition by expressing the discounted construction and shortage costs in a mathematical expression and simplifying it to arrive at an equation relating penalty price to interest (or discount) rate. His derivation analyzed the entire expansion plan, that is, from the origin to an infinite time horizon.

There is an alternative to his derivation. Consider the figure below:



Instead of analyzing the entire expansion plan, we can analyze the segment between two regeneration points A and C, within which there is one expansion project. We will discount all costs within this segment back to point A. We have the present value of cost (PVC):

$$PVC = \int_0^y \frac{p \cdot t \cdot D \, dt}{(1 + r)^t} + \frac{k(yD + sD)^a}{(1 + r)^y} \qquad (1)$$

where: p = penalty price;

D = yearly increase in demand per year;

t = time in years;

y = waiting time before the project is constructed;

s = excess capacity time of the project;

r = discount rate;

k = scale parameter of the project;

a = economy of scale factor; and

yD + sD = size of the project.

The first term on the right hand side is the total discounted shortage penalty cost from point A to B, while the second term is the discounted capital (construction) cost of the project.

We will minimize the expression while changing the discrete discount factor into a continuous one ($e^{-rt} \cong \frac{1}{(1 + r)^t}$). Rewriting the expression, we have:

$$\text{Min } C = \int_o^y pDe^{-rt}\, t\, dt + e^{-ry}\, k(yD + sD)^a \qquad (2)$$

Working on the first term:

$$\int_o^y pDe^{-rt}\, t\, dt = pD \int_o^y te^{-rt}\, dt$$

Integrating by parts, we have:

$$\frac{t \cdot e^{-rt}}{r} - \int \frac{e^{-rt}}{-r} \cdot dt = \frac{t \cdot e^{-rt}}{-r} - \frac{e^{-rt}}{-r(-r)} = \left[p \frac{De^{-rt}}{-r} \left(t + \frac{1}{r}\right)\right]_o^y$$

$$= \left[p \frac{De^{-ry}}{r} \left(y + \frac{1}{r}\right)\right] - \left[p \frac{De^{-o}}{-r} \left(o + \frac{1}{r}\right)\right]$$

$$= p \frac{De^{-ry}}{-r} \left(y + \frac{1}{r}\right) - \left[\frac{pD}{-r} \cdot o + \frac{pD}{-r^2}\right] = \frac{pD}{-r}\, e^{-ry} \left(y + \frac{1}{r}\right) + \frac{pD}{r^2}$$

$$= \frac{pD}{r} \left[-e^{-ry} \left(y + \frac{1}{r}\right) + \frac{1}{r}\right] = \frac{p}{r}\left[\left(\frac{D}{r}\right) - e^{-ry} \left(yD + \frac{D}{r}\right)\right]$$

Adding this result to the second term, we have:

$$\text{Min } C = \frac{p}{r}\left[\frac{D}{r} - e^{-ry}\left(yD + \frac{D}{r}\right)\right] + e^{-ry}\, k\,(yD + sD)^{a} \qquad (3)$$

Taking the derivative of equation (3) with respect to x and equating to zero, we have:

$$e^{-ry} a\, k\,(yD + sD)^{a-1}\ (D) = 0$$

$$e^{-ry}\, a\, k\,(yD + sD)^{a-1} = 0 \qquad (4)$$

Expanding equation (3), we have:

$$\frac{pD}{r^2} - \frac{p}{r}\, e^{-ry}\ \left(yD + \frac{D}{r}\right) + e^{-ry}\ k(yD + sD)^{a} \qquad (5)$$

Taking the derivative of equation (5) with respect to y and equating the result to zero, we have:

$$= -\left[\frac{p}{r} e^{-ry} D + \left(yD + \frac{D}{r}\right) \cdot \frac{p}{r} e^{-ry}\ (-r)\right] + e^{-ry} a\, k(yD + sD)^{a-1} D +$$

$$k(yD + sD)^{a}\, e^{-ry}\ (-r) = 0$$

$$= e^{-ry}\, p\, Dy + e^{-ry}\ a\, k(yD + sD)^{a-1} D - e^{-ry}\, r\, k(yD + sD)^{a} = 0$$

Substituting equation (4) in equation (6), we get:

$$e^{-ry}\, p\, Dy - e^{-ry}\, r\, k(yD + sD)^{a} = 0$$

$$pDy = r\, k(yD + sD)^{a}$$

This is the optimal condition for delay. The left hand term is the penalty cost, which is the product of penalty price p and the shortage yD. The right hand term is the interest cost, which is the product of the interest rate and the project's construction cost, defined as $k(yD + sD)^{a}$.

Thus, for optimal delay, the project should be delayed until the penalty cost accrue at the same rate as the interest cost.

APPENDIX 2

THE EFFECT OF INFLATION ON DISCOUNTED VALUES

The following analysis of the effect of inlfation on discounted values is taken from Sugden and William (1978), pages 36-39. There are two cases of inflation, namely: one, where there is a general price increase; and second, where there are changes in relative prices.

A. Changes in the general level of prices

Suppose a good is priced at p_0 at the base year--the present. When all prices are expected to increase at the same steady rate of "f" per year, the unit price of this good will be $p_0(1 + f)$ in year 1, $p_0(1 + f)^2$ in year 2, and so on.

With the price increase, the time preference rate becomes:

$$1 + R = (1 + r)\ (1 + f)$$

where R is the nominal discount rate, and r is the real discount rate. If r and f are small, we may approximate:

$$R \cong r + f$$

Consider a project that would require buying $q_0, q_1, \ldots, q_n$ units of good in years 0, 1, . . . , n. The present value of the cost (PVC) of this project will be:

$$PVC = p_0q_0 + \frac{p_0\ (1 + f)q_1}{(1 + r)\ (1 + f)} + \frac{p_0\ (1 + f)^2q_2}{(1 + r)^2(1 + f)^2} + \ldots + \frac{p_0(1 + f)^nq_n}{(1 + r)^n(1 + f)^n}$$

$$= p_0q_0 + \frac{p_0q_1}{(1 + r)} + \frac{p_0q_2}{(1 + r)^2} + \ldots + \frac{p_0q_n}{(1 + r)^n}$$

Note that the term f has been eliminated. This means that under the condition that all prices increase at the same rate, the present value of future costs may be estimated by using base year prices and real discount rate.

B. Changes in relative prices

Suppose the prices of all goods except one are expected to increase at the rate of "f" per year, and that the odd good constitute only a very small part of anyone's expenditures. We can then assume that the discount rate is still:

$$1 + R = (1 + r)\ (1 + f)$$

Assuming that a project requires buying $q_0, q_1, \ldots, q_n$ of the odd good in years 0, 1, . . . , n. If the price of the odd good increases at the rate of f' per year, then the present value of cost (PVC) of the project is:

$$PVC = p_0q_0 + \frac{p_0(1 + f')q_1}{(1 + r)(1 + f)} + \frac{p_0(1 + f')^2q_2}{(1 + r)^2(1 + f)^2} + \ldots + \frac{p_0(1 + f')^nq_n}{(1 + r)^n(1 + f)^n}$$

$$= p_0q_0 + p_0 \frac{\left[\frac{1 + f'}{1 + f}\right]}{1 + r} q_1 + p_0 \frac{\left[\frac{1 + f'}{1 + f}\right]^2}{(1 + r)^2} q_2 + \ldots + p_0 \frac{\left[\frac{1 + f'}{1 + f}\right]^n}{(1 + r)^n} q_n$$

For ease of calculation, it is convenient in practice to use the following approximating equation:

$$p_0q_0 + \frac{p_0q_1}{1 + r - (f' - f)} + \frac{p_0\ q_2}{[1 + r - (f' - f)]^2} + \ldots + \frac{p_0q_n}{[1 + r - (f' - f)]^n}$$

Thus under the situation where prices of different goods change at different rates over time, the effect of inflation on present values is a bit more complex.

APPENDIX 3

SENSITIVITY ANALYSIS FOR A PROJECT

The following is a sample sensitivity analysis to assess the response of waiting (delay) time as well as the different components of the cost of a project to changes in the discount rate and penalty price. We can do this by using Erlenkotter's optimal condition for delaying projects:

$$pDy = rC$$

where y = waiting (delay) time before constructing a project, years;

r = discount rate, percent per year;

p = penalty price for shortage, P/unit volume;

C = construction cost of project at base year price, P; and

D = rate of demand increase, quantity per year.

From the relationship, we can solve for the waiting time:

$$y = (r/p)C/D$$

Let us denote $(r/p) = \theta$.

Suppose we have a project which has a construction cost C of 10 million pesos and annual OMR cost of 2 million pesos. Assume D = 1 MCM/year, and initially r = .10 and penalty price p = $P2/M^3$.

We are going to vary r and p one at a time and observe the effects on the waiting time, and on the discounted penalty, construction and OMR costs. Five scenarios are analyzed: I (as base line), where r = .10 and p = 2; II, where p = 2 and r is doubled to .20; III, where p = 2 and r is halfed to .05; IV, where r = .10 and p is doubled to 4;

and V, where r = .1 and p is halfed to 1. These are shown in Table 6.24.

Other things being held constant, the direction of change in the value of waiting time y follows the direction of change in the value of θ (= r/p). Observe the values of θ and y in Table 6.24. If θ increases, y increases, that is, we delay the project longer. If θ decreases, y decreases, that is, we shorten the delay.

Waiting time y is directly related to r and inversely to p. Observe that in scenario II the value of y doubled to 1.0 year as r doubled. Then under scenario III y reduced to half because r was reduced to half. Under scenario IV, y decreased to half (.25) because p was doubled, and under scenario V, y also doubled (to 1.0 year) because p was reduced to half (to value of 1 from the base value of 2). Thus, a higher discount rate would increase project delays, while a higher penalty price would shorten project delays.

The discounted shortage penalty cost is affected by the delay time y in two ways: one, in the estimate of shortage cost itself, pDy; and two, in the discount factor e^{-ry}. Discounted shortage penalty cost varies in the same direction as the change in the discount rate, on the assumption that penalty price does not change. Observe values under scenarios I, II, III for shortage penalty cost. On the other hand, with r being held constant, shortage cost varies also in the same direction as the change in p. See scenarios IV and V.

Discounted construction cost varies inversely with the delay time y. When we defer construction to some future date, we are reducing the discounted cost via the influence of y on the discount factor. Observe the values of y and construction cost in Table 6.24.

When we delay a project, we do not incur OMR cost during the period of delay. Thus, the effect of delay time y is to reduce the discounted OMR cost. This means that the longer the delays are, the more the discounted OMR cost reduces. The figures for the OMR in Table 6.24 are for one year of operation after delaying the projects for y years.

Overall, the total discounted project cost varies inversely with the discount rate (holding p constant) and directly with penalty price (holding r constant).

Table 6.26

Sensitivity Analysis of Cost[a] of a Project to Changes in Discount Rate and Penalty Price

		Scenarios				
		I (Base) r = .1 p = 2	II r = .2 p = 2	III r = .05 p = 2	IV r = .1 p = 4	V r = .1 p = 1
θ (= $\frac{r}{p}$)		.05	0.1	.025	.025	.025
Delay time y	0	0.5	1.0	0.25	0.25	1.0
Construction cost: Ce^{-ry}	10	9.5	8.2	9.87	9.75	9.04
OMR cost for one year: $(OMR)e^{-r(1 + y)}$	2	1.72	1.34	1.88	1.76	1.64
Shortage cost: $(pDy)e^{-ry}$	0	.95	1.64	.49	1.95	0.904
Total Cost	12	12.17	11.18	12.24	13.46	11.58

Note: [a]Costs are in million pesos

APPENDIX 4

SENSITIVITY ANALYSIS FOR AN EXPANSION PLAN

(CALCULATION TABLES FOR SCENARIOS II AND III)

Table 6.27

Simulation for Expansion Timing for Plan Scenario II

Year	Cumulative Supply/ Expansion Project[a]	Penalty Cost (Million Pesos)	Interest Cost (Million Pesos)
1980	485	164.889	250.704
1981	685.8/MWSP II-1	231.388	250.704
1982	685.8	67.559	250.704
1983	685.8	41.697	250.704
1984	685.8	46.222	250.704
1985	685.8	33.323	250.704
1986	685.8	136.87	250.704
1987	886.6/MWSP II-2	248.331	250.704
--	--	--	--
1989	886.6	54.337	250.704
1990	886.6	29.685	250.704
1991	886.6	154.8	250.704
1992	1128.36/MWSP III-1	286.66	298.99
--	--	--	--
1994	1128.36	51.079	298.99
--	--	--	--
1996	1128.36	144.425	298.99
1997	1370.12/MWSP III-2	308.395[b]	298.99
--	--	--	--
2000	1370.12	85.21	298.99

Note: [a]Capacities are in MCM per year

[b]Actual cost in 291.998 at 16.9 years from the end of 1980

Table 6.28

1980 Discounted Construction Cost, Plan Scenario II

Project/Stage	Computations	Value (Million Pesos)
MWSP II		
Stage 1	$e^{-r(1)}(1253.52)$	1026.295
Stage 2	$e^{-r(7)}(1253.52)$	309.114
MWSP III		
Stage 1	$e^{-r(12)}(1494.95)$	135.618
Stage 2	$e^{-r(16.9)}(1494.95)$	50.899
Total		1521.926

Table 6.29

1980 Discounted OMR Cost[a], Plan Scenario II

	MWSP II		MWSP III	
Year	Stage 1	Stage 2	Stage 1	Stage 2
2000	.5058	.5058	.6203	.6203
1999	.6163	.6163	.7559	.7559
1998	.7545	.7545	.9254	.9254
1997	.9204	.9204	1.1288	.1128[b]
1996	1.1249	1.1249	1.3797	
1995	1.3737	1.3737	1.6848	
1994	1.6805	1.6805	2.0611	
1993	2.0508	2.0508	2.5153	
1992	2.5069	2.5069		
1991	3.0625	3.0625		
1990	3.7396	3.7396		
1989	4.5661	4.5661		
1988	5.5777	5.5777		
1987	6.8132			
1986	8.3251			
1985	10.1659			
1984	12.4186			
1983	15.1688			
1982	18.5271			
1981				
1980				
Sum	99.8984	28.4797	11.0713	2.4144
Grand Total = 141.864				

Note: [a]Costs are in million pesos

[b]About 0.1 of that for the whole year

Table 6.30

1980 Discounted Penalty Costs, Plan Scenario II

Year		1980 Value (Million Pesos)
1980	(164.889)	164.889
1981	$(231.388)e^{-r(1)}$	189.437
1982	$(67.559)e^{-r(2)}$	45.284
1983	$(41.697)e^{-r(3)}$	22.883
1984	$(46.222)e^{-r(4)}$	20.769
1985	$(33.323)e^{-r(5)}$	12.256
1986	$(136.87)e^{-r(6)}$	41.225
1987	$(248.331)e^{-r(7)}$	61.213
--		
1989	$(54.337)e^{-r(9)}$	8.976
1990	$(29.685)e^{-r}(10)$	4.016
1991	$(154.87)e^{-r(11)}$	17.159
1992	$(286.66)e^{-r(12)}$	26.0
--		
1994	$(57.079)e^{-r(14)}$	3.105
--		
1996	$(144.425)e^{-r(16)}$	5.878
1997	$(291.998)e^{-4(16.9)}$	9.941
--		
1000	$(85.21)e^{-r(20)}$	1.559
Total		634.588

Table 6.31

Simulation for Expansion Timing for Plan Scenario III

Year	Cumulative Supply/ Expansion Project[a]	Penalty Cost (Million Pesos)	Interest Cost (Million Pesos)
1980	685.8/MWSP II-1	329.779	125.352
--			
1982	886.6/MWSP II-2	135.118[b]	125.352
--			
1989	886.6	108.655	125.352
1990	886.6	59.370	125.352
1991	1128.36/MWSP III-1	309.6[c]	149.495
--			
1994	1128.36	102.159	149.495
--			
1996	1370.12/MWSP III-2	288.85[d]	149.495
--			
2000	1409.662/MWSP III-3	170.42[e]	24.24

Notes:

[a]Capacities are in MCM per year

[b]Actual cost is about 121.606 at 1.9 years from 1980

[c]Actual cost is about 159.462 at 10.4 years from 1980

[d]Actual cost is about 144.425 at 15.5 years from 1980

[e]Actual cost is about 24.24 at 19.7 years from 1980

Table 6.32

1980 Discounted Construction Cost for Plan Scenario III

Project/Stage		Value (Million Pesos)
MWSP II		
Stage 1	$(1253.52)e^{-r(0)}$	1253.52
Stage 2	$(1253.53)e^{-r(2)}$	1026.2957
MWSP III		
Stage 1	$(1494.95)e^{-r(10.4)}$	528.397
Stage 2	$(1494.95)e^{-r(15.5)}$	317.300
Stage 3	$(244.42)e^{-r(19.1)}$	36.193
Total		3161.7057

Table 6.33

1980 Discounted OMR Cost[a] for Plan Scenario III

	MWSP II		MWSP III		
Year	Stage 1	Stage 2	Stage 1	Stage 2	Stage 3
2000	3.7396	3.7396	4.5866	4.5866	4.128[d]
1999	4.1321	4.1321	5.0680	5.0680	
1998	4.5661	4.5661	5.6002	5.6002	
1997	5.047	5.047	6.1901	6.1901	
1996	5.577	5.5777	6.8410	3.4205[c]	
1995	6.1664	6.1664	7.5631		
1994	6.8132	6.8132	8.3563		
1993	7.5319	7.5319	9.2377		
1992	8.3224	8.3224	10.2073		
1991	9.1985	9.1985	6.7691[b]		
1990	10.1659	10.1659			
1989	11.2356	11.2356			
1988	12.4186	12.4186			
1987	13.7232	13.7232			
1986	15.1688	15.1688			
1985	16.7636	16.7636			
1984	18.5271	18.5271			
1983	20.4757	20.4757			
1982	22.6288				
1981	25.0086				
1980	27.64				
Sum	254.8508	179.5734	70.4194	24.8654	4.128

Grand Total = 533.837 million pesos

Notes: [a]Costs are in million pesos

[b]About 0.6 of that for the whole year

[c]About 0.5 of that for the whole year

[d]About 0.9 of that for the whole year

Table 6.34

1980 Discounted Penalty Cost, Plan Scenario III

Year	Computations	1980 Value (Million Pesos)
1980	$(329.779)e^{-r(0)}$	329.779
--		
1982	$(121.606)e^{-r(1.9)}$	100.563
--		
1989	$(108.655)e^{-r(9)}$	44.175
1990	$(59.37)e^{-r(10)}$	21.841
1991	$(159.462)e^{-r(10.4)}$	56.362
--		
1994	$(102.159)e^{-r(14)}$	25.192
--		
1996	$(144.425)e^{-r(15.5)}$	30.653
--		
2000	$(24.24)e^{-r(19.7)}$	3.38
Total		611.945

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