CHAPTER 4

LEAST-COST ANALYSIS

CONTENTS

Boxes

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4.1 Introduction

1. Given the project's objectives and after having arrived at the demand forecast, the next task is to identify the options or alternative ways of producing the required project output. The selection of the least-cost alternative in economic terms from the technically feasible options promotes production efficiency and ensures the most economically optimum choice. The alternatives need not be limited to technical or physical ones only but could also include options related to policy measures. The options related to the technical measures may include:

(i) different designs and technologies;

(ii) different scale (large-scale or small-scale) and time phasing of the same project;

(iii) the same project in different locations.

2. The options related to policy measures may include demand and supply management. Both can achieve optimum use of the existing facilities: the former by introducing proper tariff or pricing and metering of supply; the latter by, for instance, leakage detection and control of an existing water distribution system to reduce the unaccounted-for-water (UFW) to the maximum extent possible. The options considered must be realistic, not merely hypothetical, and can be implemented.

3. Once the alternatives are identified, the next step is to estimate the entire life-cycle costs (initial capital costs and future operating and maintenance costs) for each option, first in financial prices and then in economic prices by applying appropriate shadow price conversion factors. Estimating the entire life-cycle costs involves close cooperation between the economist and the engineer.

4. Finally, the discounted value of the economic costs for each option is to be worked out using the economic discount rate of 12 percent. On this basis, the alternative with the least economic cost can be selected. The different methodological approaches are explained in this chapter.

5. It must be noted that least-cost analysis, while ensuring production efficiency, does not provide any indication of the economic feasibility of the project since even a least-cost alternative may have costs that exceed the benefits (in both financial and economic terms).

4.2 Identifying Feasible Options

4.2.1 Technological Measures and Options

6. Depending on the source of water supply and the configuration and characteristics of the area where the water is needed, the following technological options can be considered:

i) surface or ground water supply scheme; and

ii) gravity or pumping scheme.

These options are not necessarily mutually exclusive: a ground water supply scheme requires pumping while a surface water scheme may make use of gravity flow of water, at least, partially.

7. Again, for the choice of components in a water supply scheme, there may be several technological options for both urban and rural areas. Some of these options are listed in Box 4.1 and Box 4.2.

Box 4.1 Technological Options in Rural Areas

1. *Increasing the quantity of available water*
   - new source of water - ground water with use of hand pumps or community wells;
   - new source of water – surface water with house connections, yard connection or public standposts;
   - rainwater collection, treatment, and distribution;
   - water conservation through rehabilitation of existing distribution system, or through better uses of existing source.
2. *Storage systems*
   - building new community storage systems like ground level reservoir or overhead tanks;
   - extending existing storage systems (if possible).
3. *Distribution systems*
   - new systems incorporating either house connections and/or community standposts; and
   - extending existing water delivery systems.

Box 4.2 Technological Options in Urban Areas

1. *Increasing the quantity of available water*
   - water conservation through rehabilitation of existing distribution system;
   - new source of surface water - nearby river or canal, etc.;
   - ground water from deep or shallow wells.
2. *Treatment plants*
   - Different types and processes in treatment plants and installations.
3. *Storage systems*
   - building new storage tanks - overhead or ground level;
   - extending the existing storage systems.
4. *Distribution systems*
   - Standpipes (community use)
   - Yard connections
   - House connections
   - Tanker
   - Bottled water

8. Box 4.3 below illustrates the identification of feasible options for three Indonesian villages.

Box 4.3 Identifying Feasible Project Options in a Rural Setting

Three Indonesian villages identified for inclusion in a rural water supply project are exposed to the effects of degrading ground water quality and dry dugwells in the dry season. Rainfall, on the other hand, occurs with reasonable frequency. Options identified for the least cost analysis appropriately included the following:

- rainwater collection (with storage);
- hand pumps, small bore well;
- hand pumps, small bore well with upflow filter units; and
- piped water supply system.

By including all these options in the consideration of alternatives, the analysis explored not only the conventional water supply systems but also the use of relevant and potentially viable traditional options.

Source: RETA 5608 Case Study Report, RWS&S Sector Project, Indonesia.

4.2.2 Policy Measures and Options

9. Management measures and options may include any of the following:

(i) reducing the percentage of UFW (especially technical losses and particularly in urban areas) through leakage detection and control, thus increasing water availability from existing facilities;

(ii) reducing water consumption from consumers by introducing metering for the first time;

(iii) reducing water consumption through appropriate cost recovery measures where there was no or very little cost recovery before, or through the introduction of progressive tariff structures;

(iv) carrying out public health education programs to promote efficient use of water; and

(v) implementing a commercial management system.

10. In Box 4.4, an illustration shows how supply of water was augmented by reducing UFW.

Box 4.4 **Identifying Project Options in an Urban Setting**
Case 1 : Unaccounted-for-Water

The city of Murcia in Spain (pop. 350,000) was faced with a high unaccounted-for-water (UFW) level of 44 percent. By implementing a new commercial management system that better accounted for all water uses and users, the municipal company reduced UFW to 23 percent over five years. The resulting water savings proved adequate to increase the number of water connections by 19,000 and achieve 100 percent coverage.

Source: Yepes, Guillermo. 1995. Adopted from *Reduction of unaccounted-for-water, the job can be done*. The World Bank.

11. Box 4.5 shows an illustration of “metering” in combination with leakage reduction programs in Singapore.

Box 4.5 Identifying Project Options in an Urban Setting
Case 2: Metering and Leakage Control

The city-state of Singapore (pop. 2.8 million) has scarce water resources. By sustaining a consistent metering and leak reduction program, the Public Utilities Board has succeeded in reducing unaccounted-for-water (UFW) from the already low level of 10.6 percent in 1989 to 6 percent in 1994. "The goal of the utility is not to have zero UFW, but rather to reduce it to a point where benefits equal costs."

Source: Yepes, Guillermo. 1995. Adopted from *Reduction of unaccounted-for-water, the job can be done*. The World Bank.

12. Based on cross-sectional data for 26 industrial firms in Jamshedpur, India, a price elasticity of demand of –0.49 was estimated, meaning that a 100 percent price increase would cause industrial demand to fall by 49 percent. (Source: World Bank-ODI Joint Study. 1992 draft. *Policies for Water Conservation and Reallocation, "Good Practice" Cases in Improving Efficiency and Equity*.) The calculation is shown in Box 4.6.

Box 4.6 Demand Management Through Pricing

Price elasticity of demand = -0.49
Percentage increase of tariff = 100%

$$\text{Percentage change of water use} = \left(\frac{\text{Percentage change in demand}}{\text{Percentage change in price}} \right)$$

$$= -0.49 \times 100\% = -49\%$$

Meaning a 49 percent decrease in water consumption.

13. In situations where tariffs are substantially below cost, an increase in tariffs is likely to lead to a reduced demand; in this way, more water will become available for additional supply. This measure stimulates a more efficient use of water (avoiding wasteful overuse) and will result in postponing physical expansion of the water supply system.

4.3 Identification and Valuation of Costs for Feasible Options

4.3.1 Identification of Cost Elements

14. The economic costs associated with each of the identified options should be the life-cycle costs: i.e., initial capital costs, replacement costs, and future operating and maintenance costs. Such costs should include both adjusted financial and non-market costs.

15. The non-market costs reflect costs due to external effects which are not reflected in the project's own financial cost stream. These costs may include:

(i) environmental costs, such as depletion premium (scarcity rent) for the use of ground water if the normal replenishment of the aquifer falls short of the extraction from it, and

(ii) opportunity cost of water, e.g. if water is diverted from existing uses such as agricultural uses, etc.

The costs may also include household costs (if any) to bring the quality of the water service to the same standard for all the comparable options. This would also be the case in rural schemes where, for instance, yard connections installed at different distances from the house would involve different values of collecting time for the household (Refer to Section 4.3.2.3).

4.3.1.1 Capital Costs

16. Typical items to be included in the capital cost streams of a ground water pumping scheme with output of say 60,000m^3/day supply in a town in Viet Nam is shown in Table 4.1.

Table 4.1 Capital Cost Items for a Ground Water Pumping Scheme

Capital Costs Items	Unit	Quantity	Unit Cost (VND'000)	Total (VNDmillion)
1. Rehabilitation of existing boreholes for supply of 10,000 m^3/day	m^3/day	10,000	L.S.	1,665
2. Constructing new boreholes for supply of 50,000 m^3/day	no.	28	1,111	28,305
3. Installing pumps	m^3/day	50,000	266	13,220
4. Treatment installation	m^3/day	50,000	444	22,200
5. Constructing elevated storage	m^3	6,000	1,221	7,326
6. Constructing ground storage	m^3	7,500	777	5,828
7. Water transmission pipelines				
i) 375 mm dia.	m	10,000	1,365	13,653
ii) 525 mm dia.	m	2,300	2,309	5,310
iii) 600 mm dia.	m	10,000	3,108	31,080
8. Distribution system				
i) Clear water pumping station	m	60,000	172.05	10,323
ii) Secondary and other connections	no.	70,000	621.60	43,512
Subtotal Costs				182,422
Physical contingency		8%		14,594
Total Costs excluding tax				197,015
Tax (weighted average)		7%		13,791
TOTAL COSTS				210,806

Source: Adopted from RETA 5608 Case Study of Thai Nguyen (Viet Nam) Provincial Towns Water Supply and Sanitation Project

17. Alternatively, the cost of a surface water scheme with the same output of 60,000m^3/day in the same town in Viet Nam will be as follows:

Table 4.2 Capital Cost Items for a Surface Water Scheme				
Capital Costs Item	Unit	Quantity	Unit Cost (VND'000)	Total (VND million)
1. Raw Water Pumping Station of 60,000 m^3/day	m^3/day	60,000	188.7	11,322
2. Storage Pond at intake of 60,000 m^3/day	m^3/day	60,000	5.55	3,330
3. Water Treatment plant of 60,000m^3/day	m^3/day	60,000	1,165.5	69,930
4. Elevated Storage tank	m^3	6,000	1,221	7,326
5. Ground Level Storage tank	m^3	7,500	777	5,827
6. Water Transmission Mains:				
i) Canal to treatment plant 525 mm dia.	m	6,000	2,308	13,853
ii) Clean water to distribution system				
- 600 mm dia.	m	1,200	3,108	3,4230
- 525 mm dia.	m	2,300	2,308.8	5,310
7. Distribution system				
i) Clear water pumping stations	m^3/day	60,000	172.05	10,323
ii) Secondary and other connections	no.	70,000	621.60	43,512
SUBTOTAL COSTS				174,163
Physical Contingency		8%		13,933
Total Costs excluding Tax				188,096
Tax (weighted average)		7%		13,166
TOTAL COSTS including tax				201,263
Source: Adopted from RETA 5608 Case Study of Thai Nguyen (Viet Nam) Provincial Towns Water Supply and Sanitation Project				

18. According to the Tables 4.1 and 4.2, the capital cost in financial terms of the ground water-pumping scheme of VND210,807 million exceeds the capital cost in financial terms of the surface water scheme of VND201,263 million by some five percent.

4.3.1.2 Annual Operation and Maintenance Costs

19. The next step is to estimate the operation and maintenance costs for both options. In Table 4.3, the O&M costs are shown for the two options (ground water and surface water) in the town in Viet Nam. The capital cost used in the base capital cost excludes physical contingency and taxes.

Table 4.3 Operation and Maintenance Costs for Two Alternatives

ALTERNATIVE 1 (Ground Water) O&M Costs		
Costs of annual O&M (weighted average percentage of the Capital Costs	=	1.135%
Hence, annual O&M cost yearly in financial price	=	(182,422) x (0.01135)
	=	VND2,070 million
Add, physical contingency of 8 percent	=	(2,070) x (1.08)
	=	VND2,236 million
Add, taxes and duties of 7 percent	=	(2,236) x (1.07)
TOTAL O&M COSTS PER YEAR	=	VND2,393 million
ALTERNATIVE 2 (Surface Water Scheme) O&M Costs		
Costs of annual O&M (weighted average percentage of the Capital costs)	=	1.432%
Hence, annual O&M cost per year in financial price	=	(174,163) x (0.01432)
	=	VND2,494 million
Add, physical contingency of 8 percent	=	(2,494) x (1.08)
	=	VND2,694 million
Add, taxes and duties of 7 percent	=	(2,694) x (1.07)
TOTAL O&M COSTS PER YEAR	=	VND2,882 million

Source: Adopted from RETA 5608 Case Study of Thai Nguyen (Viet Nam) Provincial Towns Water Supply and Sanitation Project

4.3.2 Non-Market Cost Items

4.3.2.1 Opportunity Cost of Water

20. Some situations may arise where water availability is limited so that the town's demand for water cannot be fully met by the new, previously unused sources. In such cases, it may be necessary to divert water from its existing uses, e.g., from agriculture, to meet the town's demand for drinking water. In this example, the opportunity cost of water diverted from its use in agriculture will be the agricultural benefits foregone as a result of reduced agricultural production.

21. A sample calculation is shown in Table 4.4 for the town in Viet Nam for its water supply alternative 2 (surface water). A maximum of 25,000 m^3/day can be drawn from the existing canal source. This leaves a gap of 5,000 m^3/day, assuming that the water demand to be supplied is 30,000 m^3/day. This gap is to be met by diverting water from its existing agricultural use.

22. The value of water in agricultural use is estimated through the marginal loss of net agricultural output, at economic prices, per unit of water diverted to the town users (refer also to Chapter 6).

23. The net benefit in financial prices derived from the loss of agricultural output is estimated at VND2,800 per m^3 of water used in agriculture. Since agricultural prices for the staple crops grown are regulated and some of the inputs are subsidized, the conversion factor for the output from the agricultural water is estimated at 1.98. In economic prices therefore, it amounts to VND5,544 (=2,800 x 1.98) per m^3 of water. The opportunity cost of diverted water is therefore expected to be VND10,118 million per day (=(5,544 x 5,000) x 365) when 5,000 m^3/day is diverted from agricultural use.

Table 4.4 Calculating the Opportunity Cost of Water for Alternative 2 (Surface Water)

Year	*Quantity of water diverted from agriculture water use (m^3 per day)*	*Economic value of diverted water (10^6 VND)*
0 – 8	NIL	-
9	1,088	1.088 x 5.544 x 365 = 2,202
10 - 25	5000	5.00 x 5.544 x 365 = 10,118

24. Annex 4.1 presents a more detailed example of how the opportunity cost of water can be calculated, based on foregone irrigation benefits.

4.3.2.2 Depletion Premium for the Withdrawal of Ground water

25. The depletion premium is a premium imposed on the economic cost of depletable resources, such as ground water, representing the loss to the national economy in the future of using up the resource today. The premium can be estimated as the additional cost of an alternative supply of the resource or a substitute, such as surface water, when the least-cost source of supply has been depleted.

26. In this example, the time until exhaustion is assumed to be 25 years and the alternative source to replace the ground water is surface water to be brought from a long distance. The marginal economic cost of water supply (ground water) without depletion premium is assumed to be about VND2,535 per m^3. It is expected that the marginal cost of replacing water (surface water) will be around VND2,578 per m^3, which is VND43 per m^3 higher.

27. The formula to calculate the scarcity rent (refer to Appendix 6 of the *ADB Guidelines for the Economic Analysis of Projects*) is as follows:

$$\text{Depletion premium} = (C_2 - C_1)e^{-r(T-t)}$$

where C_2 = cost of water per m^3 of alternative source;
C_1 = cost of water per m^3 of exhausting source;
T = time period of exhaustion;
t = time period considered;
r = rate of discount ($r = 0.12$);
e = exponential constant = 2.7183

28. For example, the depletion premium in year 2 is calculated as:

$$(2{,}578 - 2{,}535) \times 2.7183^{-0.12(25-2)} = \text{VND}2.72 \text{ per } m^3;$$

and for year 3 as,

$$(2{,}578 - 2{,}535) \times 2.7183^{-0.12(25-3)} = \text{VND}3.07 \text{ per } m^3.$$

As can be seen, the premium or scarcity rent increases each year as the stock of water diminishes. Table 4.5 shows the depletion premium for the ground water supply.

Table 4.5 Depletion Premium for Replacing Ground Water with Surface Water (Alternative 1)

Year	Depletion Premium (VND/m³)	Annual Premium (VND million)	Discounted Value (10^6 VND) at 12%	at 15%	at 10%
0	-	-	-	-	-
1	2	2	1.79	1.74	1.82
2	3	5	3.99	3.78	4.13
3	3	8	5.69	5.26	6.01
4	3	11	6.99	6.29	7.51
5	4	18	10.21	8.95	11.18
6	4	23	11.65	9.94	12.98
7	5	34	15.38	12.78	17.45
8	6	49	19.79	16.02	22.86
9	6	57	20.55	16.21	24.17
10	7	77	24.79	19.03	29.68
11	8	88	25.30	18.91	30.84
12	9	99	25.41	18.50	31.54
13	10	110	25.21	17.88	31.87
14	11	120	24.55	16.96	31.60
15	13	142	25.94	17.45	33.99
16	15	164	26.75	17.53	35.69
17	16	175	25.48	16.26	34.62
18	19	208	27.04	16.81	34.42
19	21	230	26.70	16.17	37.61
20	24	263	27.27	16.07	39.08
21	27	296	27.40	15.72	39.99
22	30	329	27.17	15.20	40.40
23	34	372	27.45	14.95	41.55
24	38	416	27.41	14.52	42.22
25	43	471	27.69	14.32	43.47
			517.54	347.25	686.68

4.3.2.3 Household Cost Associated with a Technological Option (Tubewell with Hand Pump).

29. This section considers the household cost associated with a technological option when such an option is analyzed vis-a-vis other options with no such associated costs, assuming that the benefits are the same. This could, e.g., be the case in a rural setting where rainwater collectors are compared with tubewells.

30. The following illustration shows how such a cost can be arrived at. In Jamalpur. a semi-urban town in Bangladesh, the following costs were identified in connection with the operation of tubewells with hand pumps:

(i) Economic life of tubewells = ten years

(ii) Capital Cost (Annualized) with Economic Price

Initial Installation Cost = Tk2,500

Capital Recovery Factor for 10 years @ 12 percent discount rate = 0.177.

Annualized capital cost = (2,500) x (0.177) = Tk442.5

The annual cost including operation and maintenance cost (10 percent of annualized capital costs) = (442.5) x (1.1) = Tk486.75

(iii) Time Cost in Collecting Water:

The total use of water per household per year with an average of six members per household is 153 m^3. Household members spend on average a total of 1.0 minute per 20 liters of water in travelling and collecting water. Hence, the number of hours spent on collection 153 m^3 of water per year is equal to:

$$= \frac{153 \times 1{,}000}{20 \times 60} = 128 \text{ hours}$$

Unskilled labor wage rate = Tk4.00 per hour

Value of travelling and collecting time in a year = 128 x 4
= Tk512 in financial price

Shadow Wage Rate Factor = 0.85 (refer to Chapter 6)

Value of travelling and collecting time in economic prices = 512 x 0.85
= Tk435.2

(iv) Storage Costs

The investment cost in economic terms of the household storage in connection with tubewell and hand pump is about Tk150 per household. With an economic life of five years and an economic discount rate of 12 percent, the annual value is estimated to be Tk41.61 (= 150 x capital recovery factor for five years and 12 percent interest).

With annual operation and maintenance cost of 10 percent of the annualized capital cost, the annual cost of storage facility works out to be 41.61 x 1.1 = Tk45.77.

(v) Total Cost per m^3 of Water

The total annual household cost in economic prices with the tubewell and hand pump in Jamalpur in Bangladesh is equal to: [Installation plus O&M Cost] + [Time Costs in Collecting Water] + [Storage Costs] or 486.75 + 435.2 + 45.77 = Tk967.72

$$\text{Therefore, the economic cost per m}^3\text{ of water} = \frac{967.72}{153} = \text{Tk6.32 per m}^3$$

4.4 Conversion Factors for Costing of Options *in Economic Prices*

31. The cost in market prices must be converted to its economic price before applying least-cost analysis. The procedures for such conversion are detailed in Chapter 6.

32. The calculation of composite Conversion Factors (CF) for the capital and operating and maintenance costs of the two options for the Viet Nam town is illustrated in Tables 4.6 and 4.7.

Table 4.6 Calculation of Composite Conversion Factor for Alternative 1 (Ground Water Supply)

Items	Break-up of financial costs (A)	Basic C.F. (using domestic price numeraire (B)	C.F. (Composite) (A x B)
A. Capital Costs			
(i) Traded Elements:			
(Direct and Indirect)	0.67	1.25	0.838
(ii) Non-Traded Elements:			
Domestic material and Equipment	0.18	1.00	0.180
Labor (skilled)	0.02	1.20	0.024
Labor (unskilled)	0.06	0.80	0.048
(iii) Taxes and Duties	0.07	0.00	-
	1.00		1.09
B. Operation and Maintenance Costs			
(i) Traded Elements:			
(Direct and Indirect)			
(ii) Non-Traded Elements:	0.05	1.25	0.063
Domestic material (including			
Chemicals and Equipment)	0.20	1.00	0.200
Labor (skilled)	0.12	1.20	0.144
Labor (unskilled)	0.10	0.80	0.080
Power supply	0.46	1.30	0.598
(iii) Taxes and Duties	0.07	0.00	-
	1.00		1.085

Table 4.7 Calculation of Composite Conversion Factor for Alternative 2 (Surface Water Supply)

Items	Break-up of financial costs (A)	Basic C.F. (using domestic price numeraire (B)	C.F. (Composite) (A x B)
A. Capital Costs			
(i) Traded Elements:			
(Direct and Indirect)	0.50	1.25	0.625
(ii) Non-Traded Elements:			
Domestic material and Equipment	0.30	1.00	0.300
Labor (skilled)	0.02	1.20	0.024
Labor (unskilled)	0.11	0.80	0.088
(iii) Taxes and Duties	0.07	0.00	-
	1.00		1.037
B. Operation and Maintenance Costs	0.10	1.25	0.125
(i) Traded Elements:			
(Direct and Indirect)			
(ii) Non-Traded Elements:	0.20	1.00	0.200
Domestic material and Equipment	0.10	1.20	0.120
Labor (skilled)	0.12	0.80	0.096
Labor (unskilled)	0.41	1.30	0.533
(iii) Taxes and Duties	0.07	0.00	-
	1.00		1.074

4.5 Methodologies for Carrying Out *Least-Cost Analyses*

33. Least-cost analyses generally deal with the ranking of mutually exclusive options or alternative ways of producing the same output of the same quality. In some cases, there may be differences in the outputs (quantity wise or quality wise) of the alternatives. Two types of cases may arise in choosing between alternatives through the least-cost analysis:

(i) alternatives deliver the same output;

(ii) outputs of the alternatives are not the same.

4.5.1 Alternatives Delivering the Same Output: *Overview of Methods*

34. There exist different methods to choose between alternatives:

(i) the lowest Average Incremental Economic Cost or AIEC;

(ii) the lowest Present Value of Economic Costs or PVEC;

(iii) the Equalizing Discount Rate or EDR.

All methods are illustrated here. The *Guidelines for the Economic Analysis of Water Supply Projects* recommend the use of the AIEC method.

4.5.2 Lowest AIEC Approach

35. The average incremental economic cost is the present value of incremental investment and operation costs of the project alternative in economic prices, divided by the present value of incremental output of the project alternative. Costs and outputs are derived from a with-project and without-project comparison, and discounting is done at the economic discount rate of 12 percent. The equation is as follows:

$$AIC = \left(\sum_{t=0}^{n} (C_t / (1+d)^t)\right) / \left(\sum_{t=0}^{n} (O_t / (1+d)^t)\right)$$

where C_t = incremental investment and operating cost in year t;
O_t = incremental output in year t;
n = project life in years;
d = discount rate.

36. Tables 4.B.3 and 4.B.4 in the Annex show the calculation of AIEC using a discount rate of 12 percent for both alternatives 1 and 2 (ground water supply scheme and the surface water supply scheme respectively). The results are as follows:

	Alternative 1 *(ground water scheme)*		Alternative 2 (*surface water scheme)*
AIEC	VND2,545 per m^3	<	VND2,616 per m^3

37. Since the AIEC for the ground water scheme of VND2,545 per m^3 is lower than the AIEC for surface water scheme of VND2,584 per m^3, the least-cost solution for the supply of water to the town is alternative 1 (ground water scheme).

4.5.3 Lowest PVEC Approach

38. This straightforward method can be applied to the cost streams (in economic prices) for all options. The choice of the least-cost option will be based on the lowest present value of incremental economic costs, discounted at the economic discount rate of 12 percent.

39. Tables 4.B.3 and 4.B.4 in the Annex show the application of this approach for the two options in the Viet Nam town mentioned above, i.e., ground water supply scheme and surface water supply scheme. The results are as follows:

Alternative 1 (ground water supply)

$PVEC_1$ = VND123.8 billion (see Table 4.B.3)

Alternative 2 (surface water supply)

$PVEC_2$ = VND127.8 billion (see Table 4.B.4)

As $PVEC_1 < PVEC_2$

The alternative 1 (ground water scheme) is the least-cost option.

4.5.4 Equalizing Discount Rate Approach

40. A third approach on which the choice between mutually exclusive options can be based, is to calculate the equalizing discount rate (EDR) for each pair of options. The EDR is the discount rate at which the present values of two life-cycle cost streams are equal, thus indicating the discount rate at which preference changes. The EDR can be interpolated if the present values of the cost streams have been determined at two different discount rates, or may be arrived at by calculating the IRR (internal rate of return) of the incremental cost stream, that is the difference between the cost streams for each pair of alternatives.

41. Table 4.B.5 in the Annex shows the calculation of EDR. Both diagrammatic and algebraic approaches are illustrated. They are shown for the two options considered (the ground water and the surface water schemes). Table 4.B.6 in the Annex shows the IRR of the incremental cost stream.

4.5.5 Comparative Advantages and Disadvantages of the Three Approaches

42. AIEC Approach. This method not only arrives at the least-cost option but also clearly indicates the long-run marginal cost (LRMC) in economic prices, an essential core information for tariff design. The methodology, however, needs explaining why discounting the water quantity is to be done to arrive at the unit price of water.

43. PVEC Approach. This method is easiest to apply as straightforward discounting is needed at one fixed rate of discount. However, information available is limited. It does not indicate the per unit cost of water, nor does it indicate which option will be the least-cost if the discount rate is different from what has been used for calculation.

44. EDR Approach. Unlike the other two methods, this approach gives a clear indication as to which option is the least-cost at different discount rates rather than at a fixed discount rate. However, the calculations needed are more than in the other two methods and it requires understanding that EDR is also the IRR of the incremental cash flow of one option over the other.

Results

45. The results show that the EDR is 13.66 percent. In other words, the additional capital costs involved in choosing option 1 (ground water scheme) as against option 2 (surface water scheme) has a return of 13.66 percent, which is above the acceptable rate of return of 12 percent. Therefore, the lowest life-cycle cost option is option 1 (ground water scheme).

4.6 Outputs from the Alternatives are not the same

46. In principle, the LCA is applied to mutually exclusive options, which generate identical benefits. If those benefits are not the same, a normalization procedure can be applied to allow for comparison

4.6.1 Normalization Procedure

47. Where one alternative has a larger but identical output than another, the costs of the smaller project should be increased to allow for its smaller output. This can be done by adding the value of the foregone benefits to the cost of the smaller alternative. Box 4.7 shows an example of the normalizing method, applied to the data of two alternatives considered (ground water and surface water supply schemes) for the Viet Nam town. It is assumed that while the ground water supply scheme is able to meet the full demand of the town (30,000 m^3/day), the surface water scheme is only able to supply 25,000 m^3/day. The surface water source is limited due to shortage of availability of water resources.

Box 4.7 Normalizing Procedure

Present Value of Outputs		
Ground water scheme	=	48.858 m^3 (in millions)
Surface water scheme	=	44.127 m^3 (in millions)
Present Value of Costs		
Ground water scheme	=	VND123,858.00 (in millions)
Surface water scheme	=	VND101,578.00 (in millions)

Output of the surface water scheme is lower than that of ground water scheme by

$$= \left[\frac{48.858 = 44.127}{48.858}\right] = 9.68\%$$

The marginal cost of supply or AIEC of surface water scheme

$$= \frac{101,578.26}{44.127} = \text{VND}2,301.95 \text{ per } m^3$$

The normalized cost of surface water should be increased by 9.68 percent to ensure equivalence.

Normalized cost of surface water = 2,301.95 x 1.0968 = VND2,524.78 per m^3

This normalized cost (not the un-normalized AIEC of the surface water VND2,301.95 per m^3) should be compared with the AIEC of the ground water scheme.

ANNEX 4.A.
Opportunity Cost of Water Calculation : Case Study

1. Introduction

The opportunity cost of water (OCW) can be calculated in numerous ways which are indicative of the foregone benefit of utilizing the water for a water supply project (WSP)[1] as compared to its next best alternative. In particular, the foregone benefit in irrigation and in hydropower generation are common methods of estimating the opportunity cost of water. In the former case, the value is based on the highest value irrigation crop being displaced when water is diverted from irrigation purposes for water supply schemes. In the latter, it is based on the reduced value of electricity production caused by water being diverted for water supply purposes upstream of the hydropower station. (i.e., less water is available for electricity generation). In either case, the OCW value in economic terms gets charged as a cost in the economic analysis of the WSP.

This annex proceeds with an example of how the opportunity cost of water based on foregone irrigation benefits may be calculated. The basis for the example is a case study in the Philippines undertaken during preparation of the *Handbook for the Economic Analysis of Water Supply Projects.*

2. Economic Assumptions

Through comparison of cropping patterns, intensities and yields, rice was demonstrated to be the highest value irrigation crop in the project affected area. The case study country is a net importer of rice. Consequently, the basis for the estimation of the opportunity cost of water is the import parity price of rice.

Economic costs and benefits were denominated in terms of the domestic price numeraire and are expressed in constant 1996 dollar prices. For purposes of illustration all prices and costs are presented in foreign currency costs, the $ being the foreign currency unit selected. Traded components were adjusted to economic prices using a shadow exchange rate factor (SERF) of 1.11 and non-traded components were valued at domestic market prices. Labor was adjusted using the Shadow Wage Rate Factor (SWRF) for unskilled labor in the country of .9.

The without-project scenario has one rainfed crop wheras the with-project scenario has one dry season irrigated crop and one wet season irrigated crop.

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[1] A water supply project is defined as non-irrigation water supply for purposes of this example.

The estimate of OCW is calculated for an indicative production year when full yields have been achieved from the irrigation scheme.

3. Import Parity Price of Rice

The calculation of the opportunity cost of water is presented in Table 4.A. For ease of presentation the reference to line numbers are all with respect to Table 4.A.

The calculation begins with the calculation of the **import parity price of rice** for the rainfed, dry season irrigated and wet season irrigated crop scenarios. The **benchmark world price of rice** used for analysis purposes is Thai (5 percent broken). This benchmark price may be obtained from the World Bank's quarterly publication *Commodity Markets and the Developing Countries*.[2] This benchmark price is equivalent for the without-project and with-project scenarios. It is shown in line 2.

The quality of the rainfed and the wet season irrigated crop are equivalent and are 10 percent lower quality than Thai (5 percent broken). The wet season crop is of the same quality as Thai (5 percent broken). The **quality adjustment factors** for the without-project and the with-project scenarios are presented in line 3.

To calculate the **quality adjusted price FOB Bangkok** shown in line 4, the benchmark price presented in line 2 is multiplied by the quality adjustment factor given in line 3 for each scenario.

It is now necessary to estimate the economic price at the port of importer (i.e., border price). This is done by adding the costs of shipping and handling from the port in Bangkok to the port of destination (say, Manila). These costs are based on weight or volume and are assumed identical for the with-project and the without-project scenarios. They are estimated at $33 as shown in line 5. By adding the quality adjusted price FOB Bangkok (line 4) and the shipping and handling costs (line 5) the CIF Port of Destination, or in this case CIF Manila, price is calculated. This is given in line 6.

As the domestic price numeraire has been selected for purposes of economic analysis it is now necessary to convert the CIF Manila price from a financial price to an economic price by applying the shadow wage rate factor (SERF). The CIF Manila price (line 6) is muliplied by the SERF (line 7) to derive the quality adjusted economic price at the border, as shown in line 8. All costs are traded to this point and must be adjusted by the SERF.

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[2] The prices used in the example may not be identical to those presented in the World Bank Commodity Markets and the Developing Country Reports.

It is also necessary to determine the economic farmgate price by calculating the costs incurred in transporting and handling the rice from the port to the farmgate. In practice, this typically includes consideration of dealer's margins, milling costs and other costs associated with the transportation and handling from the port to the farmgate. It is necessary to apportion these costs on the basis of being traded and nontraded and further separate labor costs. The SERF is to be applied to the traded components and the shadow wage rate factor (SWRF) to the labor component. For ease of illustration, all costs are considered under the category local shipping and handling in line 9 and are considered to be nontraded. The farmgate price can be calculated by adding the CIF Manila price (line 8) and the local shipping and handling costs (line 9). The farmgate prices for the rainfed, dry season irrigated and wet season irrigated crops are presented in line 10. This represents the import parity price of rice at the farmgate. It is not necessary to calculate an average farmgate price for the incremental analysis. It will be accomodated in the comparison of the with-project and the without-project analysis of crop production and farm inputs.

4. Crop Production Analysis

The next step is to perform a simplified crop production analysis. In practice, this requires knowledge of the cropping patterns, cropping intensities, yields, dry paddy to milled rice conversion factors and other factors impacting on the quality and quantity of rice yields without-project and with-project. In this illustration, the analysis of alternative crop production models indicated that paddy production had the highest value both without the project and for both the wet and dry season cropping pattern with the project. The paddy yields in tons per hectare for the rainfed, wet season irrigation and dry season irrigation are shown in line 12. The paddy yields represent dry paddy. The production of rice from dried paddy is calculated by applying the processing factor (0.59) shown in line 13 to the paddy yields in line 12. Rice production in tons per hectare are given in line 14. The gross returns in dollars per hectare given in line 16 are then calculated by multiplying the rice production estimates shown in line 14 by the farmgate price shown in line 15 (i.e., identical to the farmgate price calculated in line 10). The incremental gross margin is the difference in the with-project and the without-project scenarios calculated by taking the sum of the gross margins for irrigated crops and deducting the gross margin from rainfed crops.

5. Farm Inputs

Farm inputs represent the input costs required for crop production including labor, draught animals or machinery, seed, fertilizer, irrigation and other input factors. In practice, the market price of each input are shadow priced to derive economic values on a dollar-per-hectare basis. For purposes of this illustration farm inputs are shown as non-labor and labor inputs only. Non-labor inputs are assumed to be non-traded, requiring no further shadow pricing and are shown in line 18. Labor requires adjustment by the shadow wage rate factor (SWRF). The economic price of labor shown in line 21 is calculated by multiplying the price of labor shown in line 19 by the SWRF given in line 20. Total farm inputs shown in line 22 are the sum of non-labor inputs (line 18) and economic labor costs (line 21). Incremental farm inputs from the project are calculated by taking the sum of the wet season and dry season farm inputs (i.e., with-project production) and deducting the rainfed farm inputs (i.e., without-project production) as given in line 22.

6. Net Return

The net return for each scenario given in line 26 is the difference between the gross returns (line 24) and farm inputs (line 25), where the values of gross returns and farm inputs are equivalent to the values calculated in lines 16 and 22 respectively. Incremental net returns from the project are calculated by taking the sum of the wet season and dry season net returns (i.e., with-project production) and deducting the rainfed net returns (i.e., without-project production) as shown in line 26.

7. Water Requirements

Water requirements for irrigation purposes are now introduced into the calculation. As shown in line 28 in the rainfed scenario, there is no additional water requirement, and dry season irrigation requirements are less than wet season irrigation requirements. This is because during the wet season, rainfall provides much of the water requirement and irrigation provides the additional requirement to increase productivity. During the dry season, irrigation water accounts for the entire crop requirement. As shown in line 29, there are also losses from evaporation, transpiration and non-technical reasons incurred in the supply of irrigation water. The total irrigation water requirements for the wet and dry season are shown in line 30 and is equivalent to the sum of lines 28 and 29 . The incremental water requirement is equal to the sum of the wet and dry season irrigation water requirement.

8. Opportunity Cost of Water

It is now possible to calculate the opportunity cost of water (OCW). It is calculated by taking the incremental net return shown in line 32 which is derived from line 26 and dividing by the incremental gross water requirement shown in line 33, which is derived from line 30. In this example, as shown in line 34, the opportunity cost of water is approximately \$0.02 per m^3. This OCW can now be used as an input cost in the economic cost estimate for the WSP.

Opportunity Cost of Water based on Irrigation Benefits Foregone (Based on Import Parity Price of Rice						
Line No.	Item	Units	Rainfed Crop	Dry Season	Wet Season	Incre-mental
1	a) Import Parity Price of Rice Calculation					
2	Rice FOB Bangkok	$/ton	323	323	323	
3	Quality Adjustment		0.9	0.9	1.0	
4	Quality Adjusted Price FOB Bangkok	$/ton	290.7	290.7	323	
5	Shipping and Handling	$/ton	33	33	33	
6	Landed Price(CIF Port of Entry)	$/ton	323.7	323.7	356	
7	Shadow Exchange Rate Factor (SERF)		1.11	1.11	1.11	
8	Quality Adjusted Economic Border Price	$/ton	359.3	359.3	395.2	
9	Local Shipping and Handling	$/ton	5	5	5	
10	Farmgate Price	$/ton	364.3	364.3	400.2	
11	b) Crop Production Analysis					
12	Paddy Yields	tons/ha	1.5	3.7	2.6	
13	Processing Factor		0.59	0.59	0.59	
14	Processed Rice Production	tons/ha	0.9	2.2	1.5	
15	Farmgate Price	$/ton	364.3	364.3	400.2	
16	Gross Returns	$/ha	322.4	795.3	613.8	1,086.7
17	c) Farm Inputs					
18	Non-labor Farm Inputs	$/ha	66	226	150	
19	Labor Inputs	$/ha	66	155	119	
20	Shadow Wage Rate Factor (SWRF)		0.9	0.9	0.9	
21	Economic Price of Labor	$/ha	59.4	139.5	107.1	
22	Farm Inputs in Econ. Prices	$/ha	125.4	365.5	257.1	497.2
23	d) Net Return	$/ha				
24	Gross Returns	$/ha	322.4	795.3	613.8	1,086.7
25	Farm Inputs in Econ. Prices	$/ha	125.4	365.5	257.1	497.2
26	Net Return	$/ha	197.0	429.8	356.7	589.5
27	e) Water Requirements					
28	Water Required at Farm	m^3/ha	0	13,500	9,500	23,000
29	Water Losses Reservoir to Farm	m^3/ha	0	3,500	2,500	6,000
30	Gross Water Requirement	m^3/ha	0	17,000	12,000	29,000
31	f) Opportunity Cost of Water					
32	Net Return	$/ha				589.5
33	Gross Water Requirement	m^3/ha				29,000.0
34	Opportunity Cost of Water	$/$m^3$				0.0203

ANNEX 4.B
Data for the Illustrated Case of a Viet Nam Town Water Supply

1. Water Demand Forecast

The quantity of water demanded per day in the town is estimated at 23,077 m^3 in year 0 and it is expected to grow at the rate of 7.2 percent per year. Thus it is projected that the demand will amount to 46,145 m^3 per day in year 10.

Even though the demand will continue to grow beyond year 10, the proposed water supply project (WSP) will have a maximum output so as to meet the growing demand for only ten years from year 0.

It is expected that the new project will supply the incremental quantity of water demanded from year 1 up to the end of the life of the project, which is assumed to be 25 years.

As the non-revenue water in the system is approximately 30 percent, the quantity to be produced to meet the required revenue demand will vary from 30,000 m^3 per day (= 23,077 x 1.3) in year 0 to 60,000 m^3 per day (= 46,165 x 1.3) in year 10. Columns 1 to 5 of Table 4.B.1 show the quantity to be produced by the WSP.

Table 4.B.1 Discounted Value of Quantity of Water Supplied

Column 6 of this table shows the discounted value when the water quantities are discounted at the rate of 12%.

Col 1 Year	*Col 2* Sale Quantity per day (m³)	*Col 3* Quantity to be produced per day (sale quantity x 1.3*) (m³)	*Col 4* Incremental quantity to be produced/day by the project (m³)	*Col 5* Quantity to be produced by the project in a year (Mm³)	*Col 6* Discounted value @ 12% discount rate (Mm³)
0	23,077	30,000	-	-	-
1	24,738	32,160	2,160	0.79	0.705
2	26,520	34,476	4,476	1.63	1.299
3	28,428	36,957	6,957	2.54	1.808
4	30,475	39,618	9,618	3.51	2.231
5	32,670	42,471	12,471	4.55	2.582
6	35,022	45,528	15,528	5.67	2.872
7	37,544	48,807	18,807	6.86	3.103
8	40,246	52,320	22,320	8.14	3.288
9	43,145	56,088	26,088	9.52	3.329
10	46,154	60,000	30,000	10.95	
11	46,154	60,000	30,000	10.95	
12	46,154	60,000	30,000	10.95	
13	46,154	60,000	30,000	10.95	
14	46,154	60,000	30,000	10.95	
15	46,154	60,000	30,000	10.95	
16	46,154	60,000	30,000	10.95	
17	46,154	60,000	30,000	10.95	
18	46,154	60,000	30,000	10.95	=27.537 (years 10–25)
19	46,154	60,000	30,000	10.95	
20	46,154	60,000	30,000	10.95	
21	46,154	60,000	30,000	10.95	
22	46,154	60,000	30,000	10.95	
23	46,154	60,000	30,000	10.95	
24	46,154	60,000	30,000	10.95	
25	46,154	60,000	30,000	10.95	
					48.858

**UFW is assumed to be 30 percent.*

2. Supply of Water from the Two Alternatives of the Project

Whereas alternative 1 (ground water scheme) will be supplying the annual water requirements of the town from year 1 to year 25 (see Column 5 of Table 4.B.1), alternative 2 (surface water scheme) will be supplying the project from year 1 to year 8; but from year 9 to year 25, the project water supply will be confined to 25,000 m^3 per day. The remaining quantity of 1,088 m^3/day (= 26,088 m^3 – 25,000 m^3) in year 9 and

5,000 m^3/day (= 30,000 m^3 – 25,000 m^3) from year 10 to year 25 will be met by water diverted from agricultural use. This is shown in Table 4.B.2.

Table 4.B.2 Quantity of Water to be Produced for the Ground water and Surface Water Alternative

Year	Alternative 1 (ground water)	Alternative 2 (surface water)	
	from the project (Mm^3)	from the project (Mm^3)	diverted from agricultural use
0	-	-	-
1	0.79	0.79	-
2	1.63	1.63	-
3	2.54	2.54	-
4	3.51	3.51	-
5	4.55	4.55	-
6	5.67	5.67	-
7	6.86	6.86	-
8	8.14	8.14	-
9	9.52	9.125	0.395
10	10.95	9.125	1.825
11	10.95	9.125	1.825
12	10.95	9.125	1.825
13	10.95	9.125	1.825
14	10.95	9.125	1.825
15	10.95	9.125	1.825
16	10.95	9.125	1.825
17	10.95	9.125	1.825
18	10.95	9.125	1.825
19	10.95	9.125	1.825
20	10.95	9.125	1.825
21	10.95	9.125	1.825
22	10.95	9.125	1.825
23	10.95	9.125	1.825
24	10.95	9.125	1.825
25	10.95	9.125	1.825

3. Construction Period

The project construction period is expected to be four years. The physical progress determining the financial expenditure during the construction period will be as follows:

Year	Physical Progress
0	5%
1	30%
2	45%
3	20%
	100%

4. Depletion Premium for Alternative 1 (Ground Water Supply)

The depletion premium worked out in section 4.3.2.2 is to be added as “other costs” in the case of alternative 1 (see data in Table 4.5).

5. Opportunity Cost of Water for Alternative 2 (Surface Water Supply)

The opportunity cost of water diverted from agricultural use (0.395 million m^3 in year 9 and 1.825 million m^3 in years 10 to 25) are to be added as “other costs” (see data in Table 4.4).

6. Capital Costs (Ground Water Supply) and (Surface Water Supply)

They are given in Tables 4.1 and 4.2.

7. Operation and Maintenance Costs

They are given in Table 4.3.

LEAST-COST SOLUTION OF THE CASE

1. Capital Costs:

A. Alternative 1 (ground water scheme)

The total economic cost of the scheme for a daily supply of 60,000 m^3 is estimated at VND229,779 million (from section 3.A below). The maximum water supply of the project will be only half of 60,000 m^3 per day i.e. 30,000 m^3 per day. The cost function of capital and O&M cost of the water supply scheme shows that the economics of scale factor is 0.7 as ascertained in the Viet Nam Town by the RETA 5608 Study.

The cost function of water supply with the use of scale factor is as follows:

$$C = k (Q)^{\alpha}$$

Where C = Cost
k = constant
Q = Quantity
α = Scale factor

Applying this for 60,000 m^3 water per day, the cost function is:

$$C_{60000} = k (60{,}000)^{0.7}$$

To arrive at the cost for 30,000m^3/day, the following relationship can be used:

$$\frac{C_{30000}}{C_{60000}} = \frac{k (30{,}000)^{0.7}}{k (60{,}000)^{0.7}}$$

or

$$\begin{aligned} C_{30000} &= C_{60000}\ (1/2)^{0.7} \\ &= (229{,}779)\ \text{x}\ (1/2)^{0.7} \\ &= 229{,}779\ \text{x}\ 0.61557 \\ &= \text{VND141,445 million.} \end{aligned}$$

This cost is expected to be distributed as follows during the construction period.

(Year)	(%)	VND Million
0	5%	7,072
1	30%	42,434
2	45%	63,651
3	20%	28,289
	100%	141,446

B. Alternative 2 (surface water scheme)

The maximum amount of water which can be drawn from the canal is 25,000 m^3 per day. The remaining 5,000 m^3 per day will be met by diverting water from existing agricultural use. The capital economic cost for supply of 60,000m^3/day has been worked out to be VND208,710 million (from Section 3A below). Hence, the capital cost for a supply of 25,000m^3/day from the surface water scheme

$$= (208,710) \times \left[\frac{25,000}{60,000} \right]^{0.7} = (208,710) \times (0.54182) = \text{VND113,083 million}$$

The distribution of this cost over the construction period is as follows:

(Year)	(%)	VND million
0	5%	5,654
1	30%	33,925
2	45%	50,887
3	20%	22,617
	100%	113,083

2. Operating and Maintenance Costs

A. For Alternative 1 (ground water scheme)

The economic O&M costs per year for supply of 60,000 m^3/day was worked out to be VND2,596 million (from Section 3.B below). The supply in year 1 is 2,160 m^3/day and it is expected to rise up to 30,000 m^3/day in year 10. The scale factor is expected to be the same 0.7 as O&M is proportional to the size of the plant. Hence, the O&M costs will be:

In year 1: (2,596) x $\left[\frac{2{,}160}{60{,}000}\right]^{0.7}$ = VND253.35 million

In year 10: (2,596) x $\left[\frac{30{,}000}{60{,}000}\right]^{0.7}$ = VND1,598.03 million

B. Alternative 2 (surface water scheme)

The economic O&M costs per year for supply of 60,000 m^3/day was worked out to be VND3,095 million (from section 3.A below). Hence the O&M costs will be:

In year 1: (3,095) x $\left[\frac{2{,}160}{60{,}000}\right]^{0.7}$ = VND 302.05 million

In year 10: (3,095) x $\left[\frac{25{,}000}{60{,}000}\right]^{0.7}$ = VND 1,676.92 million

3. Economic Costs of the Two Options

They can now be arrived at:

(A) Capital Costs for 60,000 m^3/day Supply

Alternative 1 (ground water supply)
Economic Costs = [Market Costs] x CF_I
Economic costs = [VND210,806.5 mn] x [1.09] = VND229,779 mn
(Note: CF_I = 1.09 from Table 4.6; Market costs are taken from Table 4.1.)

Alternative 2 (surface water supply)
Economic Costs = [Market Costs] x CF_2
Economic Costs = [VND201,262.92 mn] x [1.037] = VND208,709 mn.
(Note: CF_2 = 1.037 from Table 4.7; Market costs are taken from Table 4.2.)

(B) O&M Costs for 60,000m^3/day Supply

Alternative 1 (ground water supply)
Economic Costs = [Market Costs] x CF_I
Economic Costs = [VND2,392.67mn] x [1.085] = VND2,596.05 mn
(Note: CF_I = 1.085 from Table 4.6; Market costs are taken from Table 4.3.)

Alternative 2 (Surface Water Supply)

Economic Costs = [Market Costs] x CF_2

Economic Costs = [VND2,882.09mn] x [1.074] = VND3,095.36 mn

(Note: CF_2 = 1.074 from Table 4.7; Market costs are taken from Table 4.3.)

Table 4.B.3 Life Cycle Costs Stream of Alternative 1

(Ground Water Supply)

(A) Without Depletion Premium

Year	Capital costs (VND10^6)	O&M Costs (VND10^6)	Total Costs (VND10^6)	Discount Factor for 12% discount rate	Discounted value (VND10^6)
0	7,072	-	7,072.00	1.0000	7,072.00
1	42,434	253.35	42,687.25	0.8929	38,115.54
2	63,651	421.91	64,072.91	0.7972	51,078.04
3	28,289	574.50	28,863.50	0.7118	20,545.04
4		720.71	720.71	0.6355	458.01
5		864.43	864.43	0.5674	490.48
6		1,007.81	1,007.81	0.5066	510.56
7		1,152.45	1,152.45	0.4523	521.25
8		1,299.23	1,299.23	0.4039	524.76
9		1,499.13	1,499.13	0.3606	522.55
10		1,598.03	1,598.03	0.3220	514.57
11-25		1,598.03	1,598.03	2.1929[a/]	3,504.31
					123,858.00

[a/] Discount factor 2.1929 = 7.8431 – 5.6502 where 5.6502 is the sum of discount factors for the first ten years.

PVEC = VND123,858.00 million.

The discounted value of water = 48,858 million m^3 (from Table 4.B.1).

$$\text{AIEC} = \frac{123,858}{48.858} = \text{VND2,535 per } m^3$$

(B) With Depletion Premium

Total PVEC = Total Discounted Costs

= [Discounted cost without D.P.]

+ [Discounted value of depletion premium (from Table 4.4)]

= (123,858) + (517.54) = VND124,375.54million.

Therefore, the $$\text{AIEC} = \frac{124,375.54}{48.858} = \text{VND2,545 per } m^3$$

Table 4.B.4 Life Cycle Cost Stream for Alternative 2
(*Surface Water)*

Year	Capital Costs (VNDmn)	O&M costs (VNDmn)	Other costs *from Table4.5* (VNDmn)	Total (VND mn)	D.F. for 12% D.R.	Discounted Cost (VNDmn)
0	5,654	-		5,654.00	1.0000	5,654.00
1	33,925	302.05		34,227.00	0.8929	30,561.29
2	50,887	503.01		51,390.00	0.7972	40,968.11
3	22,617	684.94		23,302.00	0.7118	16,586.36
4		859.24		859.24	0.6355	546.00
5		1,030.59		1,030.59	0.5674	584.80
6		1,201.53		1,201.53	0.5066	608.70
7		1,373.97		1,373.96	0.4523	621.40
8		1,548.96		1,548.96	0.4039	625.60
9		1,676.92	2,202	3,878.92	0.3606	1,398.70
10		1,676.92	10,118	11,794.92	0.3220	3,798.00
11-25		1,696.72	10,118	11,794.92	2.1929[a/]	25,865.10
						127,818.06

[a/] 2.1929 = 7.8431 – 5.6502

PVEC = VND 127818.06 million, and AIEC = $\frac{127,818.06}{48.858}$ = VND2,616.11 per m^3

PVEC (without other costs) = VND101,578.26 million (in column 4)

Table 4.B.5 Equalizing Discount Rate

Year	ALTERNATIVE I (Ground Water Supply)			ALTERNATIVE II (Surface Water Supply)		
	Cost Stream (excluding depletion premium) VND(10^6)	*Discounted Costs* (VND10^6) at 12% rate of discount	*Discounted Costs* (VND10^6) at 15% rate of discount	*Cost Stream* (excluding depletion premium) (VND10^6)	*Discounted Costs* (VND10^6) at 12% rate of discount	*Discounted Costs* (VND10^6) at 15% rate of discount
0	7,072.00	7,072.00	7,072.00	5,654.00	5,654.00	5,654.00
1	42,687.25	38,115.54	37,120.80	34,227.00	30,561.29	29,763.80
2	64,072.91	51,078.04	48,445.50	51,390.00	40,968.11	38,856.00
3	28,863.50	20,545.04	18,977.80	23,302.00	16,586.36	15,321.07
4	720.71	458.01	412.10	859.24	546.00	491.30
5	864.43	490.48	429.80	1,030.59	584.80	512.40
6	1,007.81	510.56	435.70	1,201.53	608.70	519.40
7	1,152.45	521.25	433.20	1,373.96	621.40	516.50
8	1,299.23	524.76	424.70	1,548.96	625.60	506.40
9	1,499.13	522.55	426.20	3,878.92	1,398.70	1,102.80
10	1,598.03	514.57	395.00	11,794.92	3,798.00	2,915.70
11-25	1,598.03	3,504.31	2,309.60	11,794.92	25,865.10	17,047.20
		123,858.00	116,882.40		127,818.06	113,206.57
Add discounted value of depletion premium (from Table 4.5)		517.54	347.25			
		124,375.54	117,229.65			

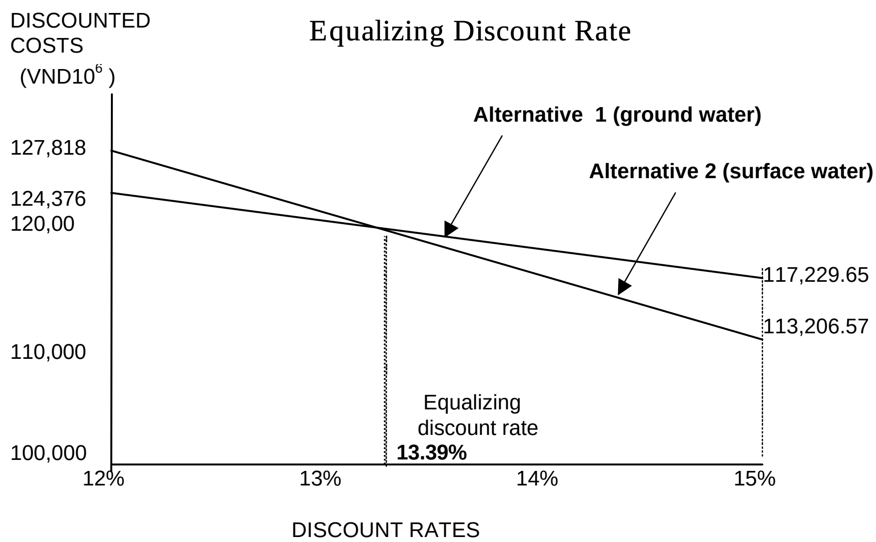
DISCOUNTED
COSTS
(VND10^6)
Equalizing Discount Rate
Alternative 1 (ground water)
Alternative 2 (surface water)
127,818
124,376
120,00
110,000
100,000
117,229.65
113,206.57
Equalizing
discount rate
13.39%
12%
13%
14%
15%
DISCOUNT RATES

Table 4.B.6 IRR of the Incremental Cash Flow *(Alternative 1 - Alternative 2)*

Year	Alternative 1 (Ground water) Cost stream (VND10^6)	Alternative 2 (Surface Water) Cost stream (VND10^6)	Difference in cost streams (Alt 2 - Alt 1) (VND10^6)	Discount factor for 15% DR	Discounted value of cost stream differences (VND10^6)	Discount factors for 12% DR	Discounted value of cost-stream differences (VND10^6)
0	7,072.00	5,654.00	-1,418.00	10000	-1,418.00	1.0000	-1,418.00
1	42,687.25	34,227.00	-8,460.25	0.8696	-7,357.74	0.8929	-7,553.79
2	64,072.91	51,390.00	-12,682.90	0.7561	-9,590.09	0.7972	-10,110.70
3	28,863.50	23,302.00	-5,561.5	0.6575	-3,656.78	0.7118	-3,958.57
4	720.71	859.24	+138.53	0.5718	+79.20	0.6355	+88.04
5	864.43	1,030.59	+166.16	0.4972	+82.61	0.5674	+94.28
6	1,007.81	1,201.53	+193.72	0.4323	+83.75	0.5066	+98.14
7	1,152.45	1,373.96	+221.51	0.3759	+83.27	0.4523	+100.20
8	1,299.23	1,548.96	+249.73	0.3269	+81.64	0.4039	+100.86
9	1,449.13	3,878.92	+2,429.79	0.2843	+690.79	0.3606	+876.21
10	1,598.03	11,794.92	+10,196.89	0.2472	+2,520.52	0.3220	+3,283.13
11-25	1,598.03	11,794.92	+10,196.89	1.4453[a/]	+14,738.39	2.1929[b/]	+22,360.92
					-3,661.53		+3,960.69

[a/] 1.4453 = 6.4641 – 5.0188

[b/] 2.1929 = 7.8431 – 5.6502

Notes for Table 4.B.6:

(1) Without depletion premium in Alternative 1:

IRR of the incremental cash flow $= 12 + (15 - 12) \times \frac{3,960.69}{3,960.69 + 3,661.53}$

$= 12 + 1.56 = 13.56\%$

(2) With depletion premium in Alternative 1:

Discounted value of depletion premium (refer to Table 4.5 in para. 4.3.2.2)

(i)	at 12% Rate of Discount	=	VDN517.54 million
(ii)	at 15% Rate of Discount	=	VND347.25 million

Discounted cost stream differential:

(i)	at 12% Rate of Discount	=	3,960.69 – 517.54
		=	3,443.15
(ii)	at 15% Rate of Discount	=	–3,661.53 – 347.25
		=	–4,008.78

IRR of the incremental cash flow $= 12 + (15 - 12) \times \frac{3,443.15}{3,443.15 + 4,008.78}$

$= 12 + 1.39 = 13.39\%$