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Avoiding Adverse Health Impacts from Contaminated Vegetables:Options for Three Wetlands in Phnom Penh,Cambodia

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This report assesses the cost-effectiveness of several strategies to stop the production of contaminated vegetables in wetland areas near Phnom Penh, Cambodia. These wetlands act as sewage disposal areas for the city and, as a result, the vegetables grown there contain high levels of heavy metal and other toxins. Five options are investigated. Each would stop farmers from cultivating edible vegetables in the contaminated land. They would also either compensate them for lost income or give them alternative ways of making a living. These options are assessed and a cost-effectiveness analysis undertaken to see which would provide an effective solution at the lowest cost.

The report finds that the most cost-effective solution would be to relocate the farmers who currently cultivate the polluted wetlands to unpolluted farmland to provide irrigation for the new fields using treated household wastewater. It recommends that the relocation program be accompanied by a public awareness campaign to explain the dangers of consuming contaminated vegetables.

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March, 2004

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TABLE OF CONTENTS

Executive Summary			**1**
1.0	**Introduction**		**2**
2.0	**Background information on farmers & their incomes**		**3**
3.0	**Assessment of mitigation options**		**7**
	3.1	Base case scenario	8
		3.1.1 Farmers' gross revenue (GR)	8
		3.1.2 Total vegetable production costs	9
		3.1.3 Net present value (NPV) of incomes in the base case	10
	3.2	Assessment of the Compensation Option	13
		3.2.1 Compensation costs according to the Municipality's method	13
		3.2.2 People's willingness to accept compensation (WTA)	155
		3.2.3 Comparison between NPV, WTA and compensation rates	16
		3.2.4 Compliance costs of the Compensation Option	17
	3.3	Assessment of the Relocation Options	19
		3.3.1 Legal basis for relocation	20
		3.3.2 Initial capital investment of the Relocation Options	21
		3.3.3 Estimation of vegetable production costs in new farms	22
		3.3.4 Estimation of future net returns earned by farmers	23
		3.3.5 Conclusion for the Relocation Options	24
	3.4	Assessment of the Conversion Options	25
		3.4.1 Conversion Option 1	25
		3.4.2 Conversion Option 2	28
4.0	**Cost-effectiveness analysis**		**31**
	4.1	Incremental net costs	31
	4.2	Sensitivity analysis	32
	4.3	Limits to cost-effectiveness	33
5.0	**Conclusion**		**34**
6.0	**Policy recommendations**		**36**
Glossary of terms			**38**
References			**39**
Appendix 1			**40**
Appendix 2			**41**
Appendix 3			**43**
Appendix 4			**44**

LIST OF TABLES

Table 1. Vegetable varieties and daily production 5

Table 2. Summary of field investigation results in the three wetlands 6

Table 3. Daily gross revenues of farmers in the base case 6

Table 4. Gross revenue (GR) of farmers in the three wetlands 8

Table 5. Vegetable production costs in the base case 10

Table 6. NPV of a farmer's income in the base case in Boeng Trabek 11

Table 7. NPV of a farmer's income in the base case in Boeng Tumpun 12

Table 8. NPV of a farmer's income in the base case in Boeng Cheung Ek 13

Table 9. Municipality's compensation value (Cv) for affected farmers 14

Table 10. Willingness of farmers in study areas to accept compensation 15

Table 11. Comparison between NPV, WTA, and compensation values 16

Table 12. Compensation values for farmers after adjustment 16

Table 13. Estimating the NPV of total project costs in the Compensation Option 17

Table 14. Public awareness campaign procedures and cost estimations 18

Table 15. Worksheet on public sector funding for the Compensation Option 18

Table 16. Investment costs incurred in the Relocation Options 21

Table 17. Estimation of vegetable production costs in the new farmlands 22

Table 18. Estimation of future net returns in the new farmlands 23

Table 19. Income changes in Relocation Options relative to the base case 24

Table 20. Worksheet on public sector funding for the Relocation Options 25

Table 21. Initial capital investment for the water hyacinth production project 26

Table 22. Initial capital investment for the flower production project 27

Table 23. Initial capital investment for the lotus production project 28

Table 24. Initial capital investment for the establishment of new industrial zones 28

Table 25. Net benefits of vegetable, industrial zone and flower projects 29

Table 26. Worksheet on public sector funding for the Conversion Options 30

Table 27. Present value (PV) of incremental net costs, ranked by cost-effectiveness 31

Table 28. Summary results of the sensitivity analysis 33

Table 29. Annual costs and present value (PV) of incremental net costs, ranked by cost-effectiveness 35

LIST OF FIGURES

Figure 1. Wetland use in the base case 4
Figure 2. Alternative farmlands in the Relocation Options 20
Figure 3. Schemes of wetland use in Conversion Option 1 **Error! Bookmark not defined.**
Figure 4. Schemes of wetland use in Conversion Option 2 **Error! Bookmark not defined.**

LIST OF ABBREVIATIONS

Av.	Average
CEA	Cost-effectiveness analysis
Cv	Compensation value
FV	Future value
GR	Gross revenue
Max.	Maximum
Min.	Minimum
NPV	Net present value
O&M	Operational and maintenance
POWTPs	Public-owned wastewater treatment plants
PPM	Municipality of Phnom Penh
PV	Present value
USD	United States dollar
WTA	Willingness to accept
ha	hectare
kg	kilogram
km	kilometer
m	meter
m^2	square meter
m^3	cubic meter
mm	millimeter
t	metric tons

Avoiding Adverse Health Impacts from Contaminated Vegetables: Options for Three Wetlands in Phnom Penh, Cambodia

Sideth Muong

EXECUTIVE SUMMARY

Farmers in several wetlands near Phnom Penh make a good living by growing vegetables and selling them in local markets for human consumption. These vegetables, however, pose serious health hazards to consumers, since they are grown using wastewater, much of it polluted with heavy metals from industries. This study examines five options to induce farmers to cease vegetable production, while preserving their livelihoods. The options were designed to be roughly equal in effectiveness; their costs were then compared to identify the least costly method of achieving the stated objective. Each option includes a public awareness campaign to warn consumers that the consumption of vegetables grown in polluted wetlands poses serious health risks.

In the first of these options, the Compensation Option, the Municipality of Phnom Penh gives each farmer USD 4 for each square meter of farmed land if they cease vegetable production. The average total annual cost to the Municipality is about USD 100,850 over a 20-year period at a 10% discount rate (Table 15).

Other options involve the relocation of farmers to new agricultural lands that draw irrigation water either from a river (Relocation Option 1), or from treated household wastewater (Relocation Option 2). These options offer farmers a financial package in term of investment and infrastructure costs. The average total annual costs (to the Municipality) of Relocation Options 1 and 2 would be USD 70,091 and USD 71,115 respectively over a 20-year period.[1]

The other alternatives consist of converting vegetable farms into non-edible production areas, or industrial zones (Conversion Options 1 and 2). Their annual costs for the Municipality are not significantly different; USD 166,021, and USD 169,076 respectively over a 20-year period.[2] The affected farmers would each receive a financial package to assist them in securing new jobs.

A cost-effectiveness analysis was used to estimate the incremental net costs relative to the base case scenario. The net costs of the five options were then ranked to identify the one with the lowest incremental net costs. There was no assessment of the monetary value of environmental and health impacts in the base case scenario.

Relocation Option 2 turned out to be the most cost-effective, followed by Relocation Option 1, and Conversion Option 1. An average individual farmer's net benefits in the new agricultural lands was estimated at about USD 7,868 in Relocation Option 2 compared with USD 1,686 in the base case scenario (see Table 19). A sensitivity analysis showed that Relocation Option 2 ranked first even if various assumptions about costs, vegetable prices and discount rates were varied.

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[1] The annual costs to the Municipality in the Relocation Options are the sum of the annualized capital costs and total compliance costs given in Table 20.

[2] The annual costs to the Municipality in the Conversion Options are the sum of the annualized capital costs, O&M costs of producing water hyacinth, and compliance costs given in Table 26.

1.0 INTRODUCTION

After 28 years of war, Cambodia has started a reconstruction program, financed largely by foreign aid. Political stability has brought about national efforts to restore the urban infrastructure, especially in Phnom Penh, the capital city. However, with a per capita income of only USD 260 per year, investment funds are scarce and must be put to their highest-value use. With such extreme poverty, it is also very important to take into account any effects that rehabilitation projects may have on people's livelihoods.

Phnom Penh, located on the left bank of the Mekong River, has a population of nearly one million people. The sewerage and wastewater treatment facilities to serve this population are seriously inadequate. The sewage networks, mostly built in the 1960s, are a combined sewage overflow from many sources including households, storm water, and industrial effluents. There are about 160 km of sewer networks in the city core including 2.6 km of open channels (JICA 1999). There is no wastewater treatment plant, so 10 percent of the effluents flow directly into the Mekong River without any treatment. The remaining 90 percent is loaded into retention basins that are the natural wetlands.

Every day, about 55,600 m^3 of household wastewater (equivalent to 2,414 tons per year of biological oxygen demand (BOD_5) discharge) and nearly 1 million m^3 of storm water are discharged into three wetlands; Boeng Trabek, Boeng Tumpun and Boeng Cheung Ek, when rainfall intensity is at 30 mm per 24 hours (Muong 2003).

The wetland of Boeng Trabek is located within the urban center of Phnom Penh. Its surface area varies from 35 ha in the dry season to 40 ha in the wet season (BAU 1997). The author's previous research (Muong 2003) reported household wastewater and storm water discharge volumes into this wetland at about 20 million m^3 with a rainfall intensity of 1,081 mm in 2002.

The wetland of Boeng Tumpun (47.5 ha in the dry season) is located in suburban areas. About 23 million m^3 of household waster water and storm water was discharged into this wetland in 1998 (Muong 2000). Industrial effluents are also loaded into this wetland.

The wetland of Boeng Cheung Ek is the largest. Its surface area is as large as the centre of Phnom Penh (about 2,000 ha) in the wet season and shrinks to 1,300 ha in the dry season (Muong 2000). Effluents from the wetlands of Boeng Trabek and Boeng Tumpun are discharged into this wetland, together with industrial effluents from the surrounding areas.

Untreated industrial effluents are discharged into the wetlands of Boeng Tumpun, and Boeng Cheung Ek. In 2002, the quantity of industrial effluents was estimated at 4.6 million m^3 (based on water consumption), a 14% increase compared with 2001 (MOE 2003). There are more than 3,000 industrial firms in the wetland catchment areas, dealing in battery fabric and repair, paint manufacture, zinc, and metal products, pulp and paper, textiles, plastics, etc., and a municipal dumping landfill that is now full. The rapid growth of these pollution-producing plants, and the absence of necessary effluent treatment has led to the deterioration of wetland water quality.

The three wetlands mentioned and their floodplains are completely flooded in the monsoon season (June to November). The squatter settlements on these wetlands face serious sanitation problems. Furthermore, many of these squatters use the polluted water in the wetlands to grow vegetables for sale in local markets.

According to a field survey conducted by the author in early 2002, there were 294 farmers who produced up to 26 tons/day of edible vegetable on 123 ha of farmland located in the three wetlands. These three wetland areas contain large quantities of household wastewater and storm water. Their water has been found to be severely contaminated with heavy metal pollutants from industrial sources, especially lead (Pb), and mercury (Hg). This raises very serious concerns about the health risks of consuming vegetables grown in the wetlands. Although the presence of the industrial pollutants in the vegetables has not been proven, it is known that vegetables can absorb and retain heavy metal pollutants. Precaution thus necessitates stopping the production of vegetables for human consumption in these wetlands.

2.0 BACKGROUND INFORMATION ON FARMERS & THEIR INCOMES

As at the time of this report, the Municipality of Phnom Penh has not taken any measures to stop the practice of vegetable cultivation in the polluted wetlands. Previous relocation projects that took place in these wetland areas (from 1998 to 2001) were intended only to facilitate the urban infrastructure and industrial development in these areas. It did not prevent the cultivation of vegetables in these polluted areas.

The absence of reliable data on suburban agriculture from the Ministry of Agriculture of Cambodia and the local authorities indicate that the production of edible vegetables in the polluted wetlands is poorly controlled. In order to devise measures to deal with this problem and to assess the costs of such measures, the author with two assistants undertook a series of extensive field visits and surveys from April to June 2002 to the three wetlands of Boeng Trabek, Boeng Tumpun, and Boeng Cheung Ek.

One of the findings of the visits was that there is much confusion among farmers over the relocation policy of the Municipality. This policy was intended to relocate all those housed in poor sanitation urban squatter areas to suburban areas. From early 1998 to late 2001, the Municipality relocated 6,454 families from various parts of Phnom Penh to several new sites located 3 to 20 km from the urban center (URC 2002). The reasons given for these relocations were the facilitation of the Municipality's urban infrastructure improvement projects, particularly to upgrade roads, rehabilitate drainage channels and flood protection dykes, and more recently, the launching of the city's 'beautification' project.

This relocation policy has resulted in the displaced families being worse off due to many factors which include: (1) the absence of preliminary consultation with the affected families; (2) the lack of basic infrastructure especially water supply, sanitation facilities, schools, and hospitals in the new relocation sites; (3) the new sites being located far from the urban center, imposing additional travel costs; (4) the dramatic reduction (up to 20%) of personal income after the relocation (URC 2002); (5) low monetary compensation, which does not take into account the social and psychological costs of the relocation; (6) the absence of technical assistance for the affected people to find alternative jobs at the new sites; and (7) insufficient time to prepare for the relocation.

The negativity and suspicion such relocations have created in the people made fieldwork data collection difficult, especially in assessing people's willingness to relocate. However, reliable information relating to costs and incomes that could be used in assessing the cost effectiveness of various options for dealing with the problems of vegetable production in polluted wetlands was successfully obtained. An earlier survey (conducted by the author in March 2000) showed many differences among farmers with respect to (1) incomes; (2) the principal markets that farmers sold their products to; (3) the wetland water quality that affected the choice of vegetable species grown; and (4) the potential commercial price of farmlands in each wetland.

At the beginning of this research project, there was no official report about the number of farmers who were involved in vegetable production. We, therefore, assembled a team of three researchers to question farmers in the three wetlands of Boeng Trabek, Boeng Tumpun, and Boeng Cheung Ek and found that there were 294 farmers involved in the production of edible vegetables using wastewater for irrigation (34, 55, and 205 farmers in Boeng Trabek, Boeng Tumpun, and Boeng Cheung Ek respectively). They were interviewed on issues such as vegetable species, farmland surface area, daily production, year of occupation, and willingness to accept compensation for relocation.

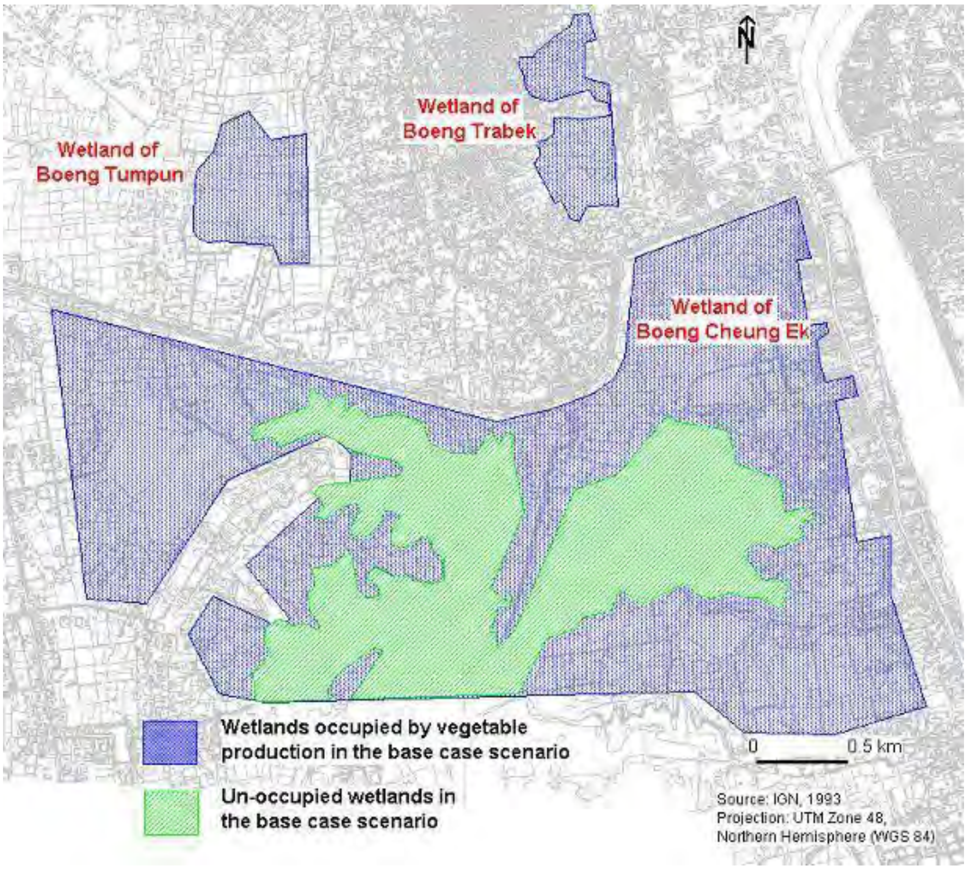

Figure 1. Wetland use in the base case

The results of the field survey were classified by farmer and wetland, after which data about the quantity of vegetable production, the costs, the farmers' net incomes, the compensation in monetary terms according to the Municipality's method of calculation, and the opportunity costs of the farmers' own labor (if they kept the same job but in new farm perimeters) were estimated. This study's field investigation showed an increase in vegetable varieties planted in the wetlands; twelve species compared with six in the previous survey in 2000.

All 294 farmers questioned said they produced up to 26 tons/day of vegetable products on 123 ha of farmland. According to the report from the Ministry of Health (2002), the daily consumption of vegetables in Phnom Penh is estimated at 0.125 kg per capita, so the daily vegetable products from these wetlands would feed at least 20% of the Phnom Penh vegetable market. But according to the AGRISUD report, the daily amount of vegetables consumed in Phnom Penh was 174 tons/day, so the vegetable production in the wetlands would represent up to only 15% (AGRISUD, 2001a).

The Water Convolvulus (*Ipomoea aquatica*) is the most common species grown in the wetland of Boeng Cheung Ek. Three species dominating the production in the wetland of Boeng Trabek; cresson (*Oldenlendra fraterna*), peppermint (*Mentha arvensis*), and leaf lettuce (*Latuca sativa*), have a high pollutant tolerance; they are grown close to household wastewater discharge points.

Table 1. Vegetable varieties and daily production

English Name	**Scientific name**		**Farmers involved**	**Surface** (m^2)	**Production** (kg/day)	**Price** USD/kg
	Species	**Family**				
Amaranth	*Amaranthus tricolor*	*Amarantaceae*	7	4,240	230	0.17
Mustard green	*Brassica oleracea*	*Cruciferae*	8	19,397	210	0.21
Chili pepper	*Caspicum annuum*	*Solanaceae*	2	4,600	23	0.21
Chinese kale	*Brassica juncea*	*Cruciferae*	13	21,010	498	0.26
Cresson	*Oldenlandia fraterna*		21	25,175	1,167	0.38
Angled luffa	*Luffa acutangula*	*Cucurbitaceae*	5	1,776	83*	0.06
Yard-long bean	*Vigna unguiculata*	*Leguminocae*	2	3,000	60	0.21
Lotus	*Nelumbo nucifora*	*Nymphaeceae*	4	7,000	390*	0.03
Peppermint	*Mentha arvensis*	*Labiatae*	18	29,803	660	0.10
Leaf lettuce	*Latuca sativa*	*Compositacae*	17	23,452	655	0.77
Water convolvulus	*Ipomoea aquatica*	*Convolvulaceae*	248	1,086,116	21,787	0.03
Water Mimosa	*Neptunia Oleracea*		2	3,300	70	0.38
Total			**294**	**1,228,869**	**25,359**	

Source: Field survey by author in 2002.
Notes: * = Number of items.

The farmers' serious concerns about their diminished welfare after relocation is expressed in a dramatic drop from 64% in 2000 to 39% in 2002 in their willingness to change jobs. Another sign of refusing to move is seen in their demanding up to USD 30/m^2 of farmland in answer to the question; "*If you had to abandon your farmland, how much money would you want to get for a square meter of your farmland?*" The land price for housing construction in the wetlands would never exceed USD 5/m^2.

Fifty nine percent of the farmers do not have property rights to their farmlands, and 48% of them have occupied their lands for less than five years. According to the Land Law 2001, released by the Ministry of Land Management, Urban Planning and Construction (2001), occupation of land for at least five years would automatically entitle the owner to property rights. This means that 48% of the farmers are farming illegally in the wetland areas, or hiring land for farming there. The real function of the wetlands is to absorb flood waters in upper urban catchments areas, and remove pollutants before the waters reach the Mekong River.

Nearly all farmlands in Boeng Trabek and Boeng Tumpun – 88% and 78% respectively – are permanently flooded. Only 56% of the farms in Boeng Cheung Ek are permanently flooded; the rest in this wetland are flooded only during the wet season (June to November).

Table 2. Summary of field investigation results in the three wetlands

Wetland	Farmers involved	Flooded Farms	Farm surface (ha)	Production (kg/day)	Ownership (farmer)	WTA	Farm price (USD/m^2)
Boeng Trabek	34	30	7.96	2,118	23	12	1.59
Boeng Tumpun	55	43	14.92	2,941	23	27	5.02
Boeng Cheung Ek	205	114	100.01	20,300	76	116	0.90
Total	**294**	**187**	**122.89**	**25,359**	**122**	**155**	

Source: Field survey by author in 2002.
Notes: The figures for Ownership and WTA indicate the number of farmers responding positively to the following questions: "Do you hold secure ownership to your farm?" and "Would you be willing to cease vegetable production if offered fair compensation?"

The average farmer's household size is six persons, of which usually two work the vegetable farm. Fifty percent of the farmers sell their vegetable products at the principle market named Phsa Demkor, even though there are other markets located next to their farms. Nearly all farmers (90%) use pesticides to improve vegetable yields. Pesticide use costs them from USD 0.5 to USD 15.4 per month per farmland.

Table 3. Daily gross revenues of farmers in the base case

Wetland	Daily incomes USD/day				Incomes if change job				Incomes > USD 10/day				Incomes < USD 5/day			
	F.	Min.	Max.	Av.	F.	Min.	Max.	Av.	F.	Min.	Max.	Av.	F.	Min.	Max.	Av.
Boeng Trabek	34	0.3	114.5	27.3	4	11.6	62.2	24.6	25	11.4	114.5	34.6	5	0.3	4.4	2.3
Boeng Tumpun	55	0.1	50.9	5.9	18	0.1	4.5	1.4	7	10.7	50.9	30.7	43	0.1	4.5	1.1
Boeng Cheung Ek	205	0.2	54.7	3.7	93	0.3	22.5	3.5	13	12.0	54.7	19.1	166	0.2	4.8	1.9
Average		0.2	60.9	6.8		1.6	23.7	5.6		11.7	60.9	23.1		0.2	4.7	1.8
Total	**294**				**115**				**45**				**214**			

Source: Field survey by author in 2002.
Notes: **F** = number of farmers involved. The high gross revenues of farmers in the wetland of Boeng Trabek are proportional to the high costs of pesticide use.

Table 3 shows that the farmers in the wetland of Boeng Trabek have relatively high average household gross revenues (GR) (up to USD 27.3 per farmer household per day compared to the minimum salary in Phnom Penh of USD 1.5). The rich farmers (GR>USD 10/day) in the wetland of Boeng Trabek represent up to 74% (25 out of 34 farmers) of total farmers in this wetland. All poor farmers (GR<USD 5/day) did not want to change jobs, and 4 farmers (12%) who expressed their willingness to change jobs had comfortable daily GRs.

In the wetland of Boeng Tumpun, all farmers who wanted to change their jobs (33%) were low-income farmers. They expressed their willingness to change jobs for various reasons such as increased industrial effluent discharge destroying their harvest, and year-round flooding which made access to their farms and houses difficult.

The wetland of Boeng Cheung Ek is dominated by poor farmers (81%) – there are only three rich farmers here. Forty four percent (the highest score in the study area) of all the farmers indicated a willingness to change jobs. Reasons given included yield declines due to industrial pollutant loads, their own health degradation caused by direct contact with polluted water, having no property rights (63%), and high farm rent prices.

3.0 ASSESSMENT OF MITIGATION OPTIONS

This research project is based on the premise that it is important to stop the production of vegetables for human consumption in the wastewater wetlands/lagoons of Phnom Penh, in order to safeguard and improve the health status of the consumer. This is because there is a strong likelihood that these vegetables are contaminated by heavy metal industrial effluents and other pollutants from urban wastewater used to irrigate the vegetable farms.

This report does not comprise a full social economic benefit-cost analysis, but includes six steps: (1) evaluate the problem in the base case scenario; (2) define potential mitigation options; (3) estimate the total annualized costs of each option; (4) calculate the present values of incremental net costs; (5) compare incremental net cost values; and (6) conduct sensitivity analysis.

Proposals made in this study to cease vegetable cultivation in the three polluted wetlands address the following factors:

- Wetlands absorb large quantities of household wastewater, storm water, and industrial effluents. These effluents are in all likelihood contaminated with heavy metal pollutants (lead and mercury), which are extremely damaging to human health.
- The daily production of vegetables in the wetlands reaches approximately 26 tons, equivalent to about 20% of the sales in Phnom Penh markets. The average daily gross revenue of each farmer household in the wetlands is about USD 6.8, which is equivalent to four times a Phnom Penh resident's minimum wage. The opportunity cost of vegetable production to these farmers is, thus, quite high.
- Property rights over some farmlands are uncertain with both the Municipality of Phnom Penh and farm owners claiming land rights.

This study assessed a relatively narrow range of mitigation options, ones which seemed feasible in the light of the above factors. These alternatives do not include the clean-up of the lagoons due to the following reasons: (1) excessive costs of pollution abatement technology; (2) even if effluent discharges to the lagoons could be stopped, sediments seriously contaminated with heavy metal pollutants would remain – the costs of removing them are prohibitive; and (3) high costs of enforcement and monitoring.

All alternatives must, nevertheless, include a public campaign to warn consumers that the consumption of vegetables grown in the wetlands could result in serious health problems, as well as an enforcement program on banning edible vegetable production in the wetlands.

The mitigation options identified are described below.

1. **Compensation Option:** Pay farmers to stop producing edible vegetables in the wetlands. The farmers are free to remain in the area and engage in alternative wetland occupations, but education and enforcement measures would be taken to discourage them from resuming vegetable cultivation.
2. **Relocation Options:** Relocate farmlands to new uncontaminated areas. Farmers in Boeng Trabek will be moved to the production zone named "Areikhsat", located about 15 km northeast of Boeng Trabek. Farmers in Boeng Cheung Ek and Boeng Tumpun will be moved to "Prey Sar" (12 km southwest), and "Kok Roka" (17 km northwest) respectively. These new production zones are located

in the rural areas of Phnom Penh. There are two Relocation Options, differentiated by the methods of irrigation and fertilizer production used for farming in the new agricultural areas. Relocation Option 1 involves using water from rivers, wells, or rain to irrigate the farmlands, and compost production or purchase. Relocation Option 2 involves using treated household wastewater from two public-owned wastewater treatment plants (POWTPs) for irrigation and as fertilizer. The rehabilitation of former farmlands is further necessary to avoid resettlement by new migrants.

3. **Conversion Options:** There are two options. Conversion Option 1 involves converting present wetland vegetable farms into farms producing aquatic plants, lotus and decoration flowers. Conversion Option 2 involves converting present wetland vegetable farms into farms producing aquatic plants and lotus, and into industrial zones. The industrial zones will generate revenue for programs to grow aquatic plants (namely, water hyacinth) to remove pollutants, to subsidize the production of non-edible plants (lotus and decoration flowers), and to provide alternative jobs for the farmers who cease the production of edible vegetable in the wetlands.

Before assessing the mitigation options, we will examine the base case scenario in order to establish the initial situation of farmers in each wetland, mainly the present values of net returns of farmlands. The estimation of farmers' incomes in the base case would help in evaluating the change in their welfare after applying each option.

3.1 Base case scenario

The base case scenario assumes that no changes are made to the current consumption of contaminated vegetables. Farmers are freely allowed to grow vegetables in polluted wetlands. The present value of net economic benefits in the base case is calculated, taking a production time period of 20 years, at a 10% discount rate. The major category of net benefits will be net returns accruing to farmers engaging in vegetable production in the wetlands. There is no attempt to estimate the reduced welfare of consumers, environmental degradation, health impacts due to the production of the edible vegetables, or increase in morbidity and mortality rates, in monetary terms.

3.1.1 Farmers' gross revenue (GR)

The calculation of the farmers' gross revenue is based on the quantity of daily vegetable production and its price in the market. Due to the absence of official statistical data from the Ministry of Agriculture, we estimated the quantitative data from the field survey conducted at the beginning of the project. The farmers' gross revenue in each wetland was estimated according to the different characteristics of each wetland in terms of surface area, vegetable species planted, etc.

Table 4. Gross revenue (GR) of farmers in the three wetlands

	GR in Boeng Trabek (USD)				**GR in Boeng Tumpun** (USD)				**GR in Boeng Cheung Ek** (USD)			
	Min.	Max.	Av.	Total	Min.	Max.	Av.	Total	Min.	Max.	Av.	Total
Daily	0.3	115	27.3	929	0.1	51	5.9	325	0.2	55	3.7	752
Yearly	99	41,793	9,979	339,246	44	18,579	2,157	118,559	66	19,966	1,340	274,335

Source: Field survey by author in 2002.
Note: See Appendix 1 for more details.

Table 4 illustrates that the average gross revenue per farmer in the wetland of Boeng Trabek reaches almost USD 10,000 per year compared with USD 1,340 for farmers in Boeng Cheung Ek. This high revenue is generated from the production of vegetables such as leaf lettuce and cresson, which have high market value. Boeng Trabek is free of industrial effluents that cause significant damage to vegetable yields in other wetlands. All farmers who grow these two species have gross revenues of at least USD 10/day.

3.1.2 Total vegetable production costs

The main points concerning methods, and data used to estimate vegetable production costs can be broken into three components: capital costs, overhead costs, and ongoing costs. The capital costs of the base case scenario would involve the purchase of farmland, boats, and seeds. [3] These costs would be incurred only once, in the early phase of farming, and is considered as sunk costs. These do not affect the calculation of net returns, and are thus not taken into account. The bigger the surface area of the farmland, the higher the capital costs.

The overhead costs cover indirect vegetable production costs, which include:

- *Costs of farm preparation for vegetable planting*: These would be the costs to purchase materials (bamboo, wood, vegetable roots, etc.), and labor costs for constructing vegetable support beds. According to the field investigation, 10 m^2 of vegetable bed costs up to USD 2.6, USD 0.8 and USD 0.3 for the wetlands of Boeng Trabek, Boeng Tumpun, and Boeng Cheung Ek respectively. The high variation in costs of vegetable support beds depends upon on the price of construction materials that are suitable for each vegetable species.
- *Farm rental*: Most farmers who do not have property rights to their farmlands and have occupied the land for less than five years, have to pay rentals to land owners at the price of USD 0.02, USD 0.07, and USD 0.22 per square meter per year, for farms located in the wetlands of Boeng Tumpun, Boeng Cheung Ek, and Boeng Trabek respectively.

The on-going costs are direct costs to insure vegetable production, and farm operational and maintenance (O&M) costs. These include:

1. *Pesticide and fertilizer costs*: The most common frequency for pesticide use is four applications per month but it varies depending on the frequency of rainfall. These costs would include the costs of insecticide, and IBA (Indole Bytyric Acid is a hormone to promote fast growing vegetable terminal buds).
2. *Transport costs from farm to market:* These costs do not apply to all farmers as some sell their products on site. Middlemen are able to go door to door to collect vegetable products. Some farmers hire local transport means (motorbike, tricycle) to sell their vegetable products at the main market. This cost ranges from USD 0.4 – 0.6 per trip. To calculate the transport costs, let's assume a fixed average transport cost of USD 0.5 per trip. According to the field investigation, the middlemen's trucks come frequently to collect vegetables from the farmers' doorsteps in Boeng Tumpun and Boeng Cheung Ek. We can assume that the average frequency is one trip per week for farmers in these wetlands. Conversely, farmers in Boeng Trabek have to take their vegetables to

[3] Farmers in the wetland need vegetable seed only when they start to grow vegetables for the first time. After each yield, the roots assure the next crop, so farmers do not purchase additional seeds.

the market themselves, using their own motorbikes, or renting motorbike-taxis, as their farms are difficult for the middlemen's trucks to access – the roads are too small. As the vegetables are all-year-round crops, we shall take the fixed transport cost for Boeng Trabek at USD 0.5/trip, at an average frequency of three trips per week.

3. *Labor costs*: These would be the costs of hiring additional labor (beyond family members) during harvest time (USD 2.0 per working day per person). According to the field investigation, the average duration for additional labor is two days per week, and on average, one additional worker per farm is hired.
4. *Farm O&M costs*: These costs are essentially for repairing or replacing vegetable support beds. If the farmland is flooded all year round, the vegetable support beds would have to be replaced every four years, but if the farmland is flooded only in the rainy season, then the farmer would have to replace the vegetable support bed every year.

To estimate the opportunity cost of a farmer's own labor, we extrapolated the results of a project conducted by AGRISUD over 82 farmers in the Kandal Province (AGRISUD, 2001c). With the same farmland surface area, and variety of vegetable species, the average daily net returns of each farmer would equal USD 7.3, USD 3.4 and USD 2.6 per day in the wetlands of Boeng Trabek, Boeng Tumpun and Boeng Cheung Ek respectively. Compared with the minimum wage of USD 1.5/day for Phnom Penh area, the opportunity costs of a farmer's own labor would be equal to USD 7.3, USD 3.4 and USD 2.6 per day for the three wetlands.

Table 5. Vegetable production costs in the base case

Base case scenario		Boeng Trabek				Boeng Tumpun				Boeng Cheung Ek			
		Min	**Max**	**Av.**	**Total**	**Min**	**Max**	**Av.**	**Total**	**Min**	**Max**	**Av.**	**Total**
O'head	Farm bed	31	2,179	601	20,418	8	1,542	209	11,476	3	769	125	25,642
Costs	Farm rental	34	990	244	2,933	2	425	60	2,227	7	150	122	16,345
(USD/	Total				23,351				13,703				41,987
year)	per farmer				687				249				205
	Labor	200	200	200	4,600	200	200	200	1,800	200	200	200	15,400
On-	O/M	8	1,321	228	7,740	2	1,542	102	5,627	1	385	62	12,760
Going	Pesticide	9	185	70	1,742	6	123	52	2,861	6	126	30	6,100
Costs	Transport	81	81	81	2,758	27	27	27	1,487	27	27	27	5,543
(USD/	Total				16,840				11,775				39,803
year)	Per farmer				495				214				194
Opportunity farmer labor costs*					2,650				1,248				938
Total annual costs					**42,841**				**26,726**				**82,728**
Average total costs per farmer					**1,260**				**486**				**404**

Source: Field survey by author in 2002.
Note: * = extrapolated results from AGRISUD (2001)

3.1.3 Net present value of incomes in the base case (NPV)

Let us assume that the income of each farmer in the wetland areas is a measure of net cash flow, equal to total gross cash returns (gross revenues) less all total cash costs (direct and indirect vegetable production costs). As the estimation of wages earned by farmers and their family members involved in vegetable production is a complicated task, we do not include these wages in the calculation of the incomes earned by the farmers.

To calculate the net present value (NPV) of farmers' returns in the base case scenario, we take into account the average farmer's gross revenues, overhead costs, ongoing costs, and opportunity costs of his own labor. We assume that the capital costs are the base costs that will not affect the project. All values are estimated over a 20-year period at a discount rate of 10%. To simplify the calculation, we do not take into account the annual increase in material costs, labor costs, and farmers' gross revenues, assuming these to be constant over time.

Table 6. NPV of a farmer's income in the base case in Boeng Trabek (in USD)

Year	Gross Revenue	Overhead Costs	Ongoing Costs	Opp. Cost Own labor	Total Cost	Net Returns & Value		
1	9,978	687	495	2,650	3,832	6,146		
2	9,978	687	495	2,650	3,832	6,146		
…	…	…	…	…	…	…		
18	9,978	687	495	2,650	3,832	6,146	Total area, ha	8
19	9,978	687	495	2,650	3,832	6,146	No of farms	34
20	9,978	687	495	2,650	3,832	6,146	Av farm size, ha:	0.234
PV	84,947	5,847	4,217	22,560	32,624	52,323	**NPV USD per m^2**	**22.34**

Source: Field survey by author in 2002.
Notes: Opp. Cost is opportunity cost.

Table 6 shows that the ongoing costs of vegetable production in the wetland of Boeng Trabek make up only 5% of gross revenues. The net returns of USD 6,146 of farmers in Boeng Trabek are very high compared with the wages of blue collar workers in Cambodia (workers in garment export industries earn an average of USD 820 per year).

Thirty five percent of the farmers in Boeng Trabek responded in the affirmative to the question of whether they would abandon their vegetable production in return for money. They were also required to state how much compensation they wished to receive for doing so.

The high NPV of returns of USD 22.3/m^2 of farmland corresponds with the low percentage of farmers willing to change jobs (12%) – compared with the two other wetlands. The highest compensation value cited by farmers in this wetland is only USD 6.5/m^2. This amount is very low compared with the NPV of returns, so we assume that farmers in Boeng Trabek would only stop farming for strong reasons as given below:

- The work is too physically demanding, and the poor sanitation of the work environment. Direct contact with wastewater in the wetland causes numerous dermatological and respiratory diseases with resultant increases in health care costs. Some farmers revealed that family members, especially children, had also drowned in the lagoon.
- No land ownership or land lease for farming.
- Their children do not want to take over the business.
- Floods during rainstorms damage their property.

Table 7. NPV of a farmer's income in the base case in Boeng Tumpun (in USD)

Year	Gross Revenue	Overhead Costs	Ongoing Costs	Opp. Cost Own labor	Total Cost	Net Returns & Value		
1	2,157	249	214	1,248	1,712	446		
2	2,157	249	214	1,248	1,712	446		
…	…	…	…	…	…	…		
18	2,157	249	214	1,248	1,712	446	Total area, ha	15
19	2,157	249	214	1,248	1,712	446	No of farms	55
20	2,157	249	214	1,248	1,712	446	Av farm size, ha:	0.271
PV	18,365	2,121	1,823	10,627	14,571	3,794	**NPV USD per m^2**	**1.40**

Source: Field survey by author in 2002.
Notes: Opp. Cost is opportunity cost.

Table 7 shows that the net returns plus opportunity costs of a farmer's own labor in the wetland of Boeng Tumpun are much lower than in the Boeng Trabek – only USD 1,694/year per farmer's household (USD 446 + USD 1,248). With an average of 2.5 farm workers per household, the income earned by a farmer and his family is thus only USD 678/year. In analyzing a farmer's willingness to accept (WTA) compensation, it is not surprising to find a high percentage of farmers (49% i.e. 27 out of total of 55 farmers) willing to accept compensation to abandon vegetable production.

The maximum compensation value cited by farmers in the wetland of Boeng Tumpun is USD 30/m^2. The average WTA value of USD 5.0/m^2 (see Table 2) is much higher than the NPV shown in Table 7 above (USD 1.4/m^2). This high expectation is caused due to several reasons namely those given below:

- Farmland is located near to the market.
- Experience of past relocations programs where the people affected always ended up worse off.
- Soil is rich and suitable for vegetable production, and
- Sentimental attachment to the land that the farmers have occupied for a long time, and/or a high regard for the heritage of their farming profession.

The percentage of farmers willing to accept compensation is much higher than those in Boeng Trabek. Reasons are as follows:

a. Working in poor sanitation conditions which cause numerous dermatological and respiratory diseases, and raise medical expenses.
b. Decline in vegetable production yields caused by increased pollutant loads.
c. No land ownership rights and having to hire land for farming, and
d. Floods during rainy seasons cause damage to farm and property.

Table 8. NPV of a farmer’s income in the base case in Boeng Cheung Ek (in USD)

Year	**Gross Revenue**	**Overhead Costs**	**Ongoing Costs**	**Opp. Cost Own labor**	**Total Cost**	**Net Returns & Value**		
1	1,340	205	194	938	1,337	3		
2	1,340	205	194	938	1,337	3		
…	…	…	…	…	…	…		
18	1,340	205	194	938	1,337	3	Total area, ha	100
19	1,340	205	194	938	1,337	3	No of farms	205
20	1,340	205	194	938	1,337	3	Av farm size, ha:	0.488
PV	11,404	1,744	1,653	7,986	11,383	21	**NPV USD per m^2**	**0.0044**

Source: Field survey by author in 2002.
Notes: Opp. Cost is opportunity cost.

A farmer’s income after costs in the wetland of Boeng Cheung Ek is the lowest in the study areas. It is about USD 941/year (USD 3 of net returns plus USD 938 of opportunity costs of the farmer’s own labor). With an average of 2.6 workers per farm, the daily wage earned by a farmer and his family would not exceed USD 1.4. With the lowest incomes, a high percentage of farmers (57%) in this wetland indicate willingness to accept compensation (WTA) to abandon their vegetable production.

The maximum compensation value cited is USD 15/m^2, with an average of only USD 0.9, still higher than the NPV of incomes. This high expectation is caused due to several reasons: (1) farmland is located near to the market; (2) some farmers expect their farmlands to have a housing construction value of up to USD 5/m^2; (3) the soil is rich and suitable for vegetable production; (4) sentimental attachment to the land (some are ancestral lands) that the farmers have occupied for a long time; and (5) uncertainty as to how to find new forms of livelihood after accepting compensation, because many of the farmers are illiterate.

The percentage of farmers willing to accept compensation, and change jobs is high (45%). Reasons for this would be: (a) working in poor sanitation conditions that cause numerous dermatological and respiratory diseases, and raise medical expenses; (b) decline in vegetable production yields caused by increased pollutant loads; (c) no land ownership rights and having to hire land for farming; (d) floods during wet seasons cause damage to farm and property, and restrict mobility; and (e) low incomes.

3.2 Assessment of the Compensation Option

In the Compensation Option, all farmers are allowed to remain on site. This section will examine how much money needs to be paid to the farmers as fair compensation for them to stop producing all edible vegetables in the wetlands. It will also evaluate the incremental capital costs and ongoing costs over a period of up to 20 years, relative to the base case situation. The application of the Compensation Option will free the Phnom Penh market from the risk of consuming vegetables contaminated with the heavy metal pollutants.

3.2.1 Compensation costs according to the Municipality’s method

Compensation costs are the real costs to effect the prohibition of edible-vegetable production in the wetlands. These costs would include all expenditures associated with compensating all affected farmers. We compare three cost estimations: (1) the rate set by the current policy taken as the base rate of compensation to farmers to stop producing edible vegetables; (2) evaluation of the farmers' WTA; and (3) estimation of farmers' net cash flow in the base case scenario.

By cross-checking the results of these three different methods, we can get an idea of the reasonableness of the compensation offered. The Municipality's method provides approximate costs which would represent: (a) a fixed baseline compensation rate for each farmer; and (b) additional compensation rate for each square meter of farmland, duration of farm occupation, and price unit of all vegetable species. The compensation value is calculated as per the following equation:

$$\mathbf{Cv = Bv + \alpha\ As + \beta\ Dw + \delta\ Vp}$$

where:

Cv = compensation value to each farmer (in USD),
Bv = fixed baseline rate of USD 380 according to the Municipality's guideline for compensation (PPURBPOR 2001),
As = surface area of farm (in m^2) with the coefficient α as the average WTA of 2.5,
Dw = duration of land occupation (in years) with the coefficient β equal to the number of workers in each farm, if they have property rights; otherwise $\beta = 0$,
Vp = 10 times the market price of vegetable species (in USD/kg*10), with the coefficient δ as the total number of farmers cultivating the vegetable species.

The payment of this compensation to affected farmers could take the form of a lump sum payment, financed by public funds. This would enable farmers to invest in other businesses to replace vegetable production. The compensation in monetary value to farmers in this policy of prohibition of edible vegetable production in the three wetlands is shown in Table 9.

Table 9. Municipality's compensation value (Cv) for affected farmers

Wetland	**Occupation** (year)			**Farm surface area** (ha)				**Compensation value Cv** (USD)				**Cv** USD/m^2
	Min	Max	Av	Min	Max	Av.	Total	Min.	Max.	Av.	Total	
Boeng Trabek	3	22	12	0.01	0.85	0.23	7.96	745	21,883	6,355	216,065	2.71
Boeng Tumpun	1	23	12	0.01	2.01	0.27	14.92	645	50,552	7,198	395,877	2.65
Boeng Cheung Ek	1	23	11	0.01	3.00	0.49	100.01	689	75,483	12,651	2,593,480	2.59
Total											**3,205,422**	

Source: Field survey by author in 2002.

The present value of yearly payback to farmers in the wetland of Boeng Cheung Ek is equal to the gross revenue; USD 1,340. We conclude that the current Municipality's compensation rate would, at least, maintain the current capitalized value of farming for farmers in Boeng Cheung Ek. If we introduce the concept of "job conversion costs"[4] in the fixed baseline rate of compensation, this compensation policy would make farmers in this wetland better off.

Conversely, if we apply the Municipality's compensation policy to Boeng Trabek, and Boeng Tumpun, it would make farmers there worse off. Here, we would have to try to integrate the concept of WTA (willingness to accept the compensation), and the average farmer's income in order to re-evaluate the compensation value.

[4] "Job conversion costs" would be the additional amount of money that the Municipality would give to affected farmers to assist them in finding new jobs.

3.2.2 People's willingness to accept compensation (WTA)

In order to assess the farmers' willingness to accept compensation in return for giving up vegetable production, the research team carried out a brief survey of the farmers' attitudes. We asked the farmers a direct question: *"If the production of edible vegetables is banned in the wetlands, how much money would you want to get in compensation?"* followed by a range of sums (in USD); <400, 400-700, 700-1,000, 1,000-1,500 and >1,500. About 47% of the farmers did not respond to this question, mostly from the wetland of Boeng Trabek where vegetable production generated comfortable incomes. The survey was difficult because of strategic bias[5] and the negative politicized atmosphere created by previous unsuccessful compensation programs. However, it did provide a rough idea of the range of values that would be accepted by some of the farmers (see Table 10 below).

Table 10. Willingness of farmers in study areas to accept compensation

Wetland	**Farmer**		**Household**	**Farm surface** (m^2)			**WTA** (USD/m^2)			
	Total	**WTA**	**size (Av.)**	**min.**	**Max.**	**Av.**	**Min.**	**Max.**	**Av.**	**No ambit***
Boeng Trabek	34	12 (35%)	6.5	120	8,500	2,342	0.2	6.5	1.6	1.6
Boeng Tumpun	55	27 (49%)	5.9	100	20,050	2,712	0.1	30.0	5.0	3.2
Boeng Cheung Ek	205	116 (57%)	6.4	100	30,000	4,878	0.1	15.0	0.9	0.9

Source: Field survey by author in 2002.
Notes: * 'No ambit' is the average WTA that ignores WTA values higher than USD 15/m^2.

Fifty three percent of the farmers expressed their willingness to accept the compensation if they have no other legal means to continue farming on their land. We took into account the monetary value of the compensation, price of land in the area, and flood exposition of the farmland. The price of land for construction in these areas is about USD 5/m^2, and the monetary value of the farmland would be even lower. Nearly all farmlands are, however, flooded – these areas have no construction value. [6]

In the wetland of Boeng Trabek, if the Municipality of Phnom Penh forces farmers to stop producing edible vegetable, they would agree to do so at a compensation value of about USD 1,300/farmer. If we express this amount according to the surface area of farmland, it ranges from USD 0.2/m^2 to 6.5/m^2, with an average of USD 1.6/m^2. Compared with the average NPV of income of USD 22.3/m^2, we assume that our sample group (35%) does not represent the overall WTA of farmers in this wetland.

At the time of the survey, the Municipality had already moved about 50 families out of Boeng Tumpun to make way for the construction of a pumping station. This move had a deep impact on the farmers' WTA. The number of farmers willing to accept compensation dropped sharply from 64% in 2000 to just 39% in 2002 (field survey 2000 and 2002). Moreover, some farmers would only abandon vegetable production if they received a compensation of USD 30/m^2. However, if we ignore the WTA of these farmers, we find that the average WTA is only USD 3.2/m^2 (Table 10).

The result of the field survey in the Boeng Cheung Ek is more uniform. As their farms are located far from urban areas and are heavily flooded during rainy seasons, they have no construction value, thus the average willingness to accept compensation is less than USD 1/m^2.

[5] Strategic bias refers to errors that will occur if respondents deliberately give answers to sway the outcome of a survey in their favour.
[6] The Municipality considers the wetlands as retention basins to absorb flooding in upper urban areas.

3.2.3 Comparison between NPV, WTA and compensation rates

Table 11. Comparison between NPV, WTA and compensation values

	Boeng Trabek (USD/m^2)			Boeng Tumpun (USD/m^2)			Boeng Cheung Ek (USD/m^2)		
	NPV[1]	**WTA[2]**	**PPM[3]**	**NPV**	**WTA**	**PPM**	**NPV**	**WTA**	**PPM**
Maximum	138.0	6.5	2.7	52.9	30.0	2.7	32.5	15.0	2.6
Average	22.3	1.6	2.7	1.4	5.0	2.7	0.0044	0.9	2.6
Total (USD)	**1,778,934**	**126,612**	**215,797**	**208,655**	**748,899**	**395,335**	**4,400**	**900,050**	**2,590,145**

Source: Field survey by author in 2002, and PPURBPOR 2001.

Notes: (1) NPV: Net present value

(2) WTA: Willingness to accept compensation

(3) PPM: Compensation rate of the Municipality

For the wetland of Boeng Trabek, the net difference (USD 22.3/m^2 and USD 1.6/m^2 of farmland) in the NPV of farmers' incomes and their WTA is confirmed by the reassessment of the field survey in December 2002. For farmers in the two other wetlands, NPV of incomes, farmers' WTA and the Municipality's compensation is much more uniform. Since the main goal of the project is to make affected farmers better off, we assume that the Municipality's compensation value should be USD 4.0/m^2 at least so that farmers in the two wetlands would be better off with accepting the Compensation Option to stop producing vegetables. The value of USD 4.0/m^2 is obtained by the adjustment of the average Boeng Tumpun farmer's WTA excluding the ambit claim.[7] This value of USD 4.0/m^2 is lower than the land price for new housing construction.

Table 12. Compensation values for farmers after adjustment

Wetland	**Farmer**	**Occupation** (year)			**Farm surface** (ha)				**Compensation value Cv** (USD)			
		Min.	**Max.**	**Av.**	**Min.**	**Max.**	**Av.**	**Total**	**Min.**	**Max.**	**Av.**	**Total**
Boeng Trabek	34	3	22	12	0.01	0.85	0.23	7.96	480	34,000	9,368	318,520
Boeng Tumpun	55	1	23	12	0.01	2.01	0.27	14.92	400	80,200	10,850	596,732
Boeng Cheung Ek	205	1	23	11	0.01	3.00	0.49	100.01	400	120,000	19,513	4,000,224
Total	**294**							**122.89**				**4,915,476**

Source: Field survey by author in 2002.

The compensation value of USD 4.0/m^2 could take the form of a yearly basic payment to affected farmers. Then we would have to estimate the present values of net returns over a time period of 20 years at a discount rate of 10% and determine when their values would double. (See Table 13.)

Because not all vegetable growers presently have property rights to their farmlands, there is scope for negotiating the amount of compensation that would be needed to induce farmers to stop growing vegetables for human consumption.

[7] An ambit claim is a way of overstating what compensation people should be paid for them to meet new policy initiatives. In this project, this is taken as the initial bargaining price.

Table 13. Estimating the NPV of total project costs in the Compensation Option

Year	**Boeng Trabek** (USD)		**Boeng Tumpun** (USD)		**Boeng Cheung Ek** (USD)	
	NR of FV	**PV**	**NR of FV**	**PV**	**NR of FV**	**PV**
1	1,100	1,000	1,274	1,159	2,292	2,084
2	1,210	1,000	1,402	1,159	2,521	2,084
…	**…**	**…**	**…**	**…**	**…**	**…**
20	6,730	1,000	7,794	1,159	14,018	2,084
FV	20,007		23,171		41,673	
FV per m^2	8.54		8.54		8.54	
PV	9,368		10,850		19,513	
NPV per m^2	**4**		**4**		**4**	

Source: Field survey by author in 2002.
Note: NR = net returns; FV = future value; PV = present value

3.2.4 Compliance costs of the Compensation Option

The Municipality, through its administrative agencies, is responsible for prosecuting those who violate prohibitive orders on the production of edible vegetables in the wetlands. It is also responsible for preventing new farms from being set up in these contaminated areas. For public health purposes, these restrictions apply to the present and future use of farmlands in the study areas.

Compliance costs are all costs that the local authorities and the Municipality of Phnom Penh incur in order to take action, and include the expenses for program administration, training, monitoring, reporting, enforcement, and inspection. The Municipality uses three effective primary tools: enforcement, compliance incentives, and compliance assistance.

1. Enforcement activities take the form of (a) on-site inspections – frequent unannounced visits to the wetland over a period not exceeding three years – to ensure no edible vegetable production, and (b) penalty measures ranging from warnings to the confiscation of farm property rights for repeated non-compliance.
2. Compliance incentives aim at encouraging farmers to voluntarily comply – this accomplishes the goal of the prevention of future production of vegetables in contaminated areas in a more cost-effective manner.
3. Compliance assistance consists of information and technical assistance provided to the farmers to help them comply. The Municipality offers compliance assistance services in a variety of ways such as meetings, training, and on-site visits.

Public awareness campaigns on the risk of consuming vegetables grown in contaminated wetlands should be increased. These should encompass several activities such as: posters to show the pathway of toxic substances in the human body, and their impact on human health; newsletters; and workshops on the impact of contaminated vegetables on public health. Table 14 provides details of these activities. The costs would include the costs of highlighting environmental education in schools and public places, local press publications, television broadcasting, and so on.

Table 14. Public awareness campaign procedures and cost estimations

Action	How to be done	When	Where	Who will do what	Cost (USD)
Develop poster to show the pathway of toxic chemical substances in the human body	*Discuss with experts and relevant persons about the pathway of toxic substances in the human body and the possible impacts. *Source for related information from scientific documents. *Discuss poster layout with designer.	June 2004	Put poster up at all markets and contaminated wetland areas.	Project Coordinator and assistant to hire the designer and printer for the poster	4,000
Produce newsletter on the risk of consuming contaminated vegetables	*Discuss with experts from different fields about the pathway of toxic substances in human body and the possible impacts. *Create newsletter and print 10,000 copies *Distribute newsletter to NGOs involved in health, agriculture and environmental concerns at village level.	July 2004	Distribute to the local authorities, and at markets, and wetland areas.	Ministry of Environment to do the printing. Project Coordinator, assistant and other staff with relevant experience in newsletter production to create newsletter.	2,000
Organize workshops on the impact of contaminated vegetables on public health.	*Invite guest speaker to speak on the impact of toxic substances on human health. *Invite the village chiefs, farmers, consumers, local community, and relevant NGOs to attend the workshop. *Give away T-shirts with a relevant slogan to those who attend the workshop	Aug 2004	In the wetlands of Boeng Trabek, Boeng Tumpun and Boeng Cheung Ek	Project Coordinator, and assistant to organize these in cooperation with local authorities	3,500 **Total Cost** **9,500**

Table 15. Worksheet on public sector funding for the Compensation Option
(Calculation of total annual project costs using the Municipality's method)

Description of cost items	**Costs** (USD)
A. Capital Costs	
Capital investment	4,915,476
Costs of conducting awareness campaigns	9,500
Other one-time costs:	
Project preparation	5,000
Project implementation	10,000
Total capital costs to be financed	**4,939,976**
Discount rate (i)	10%
Time period of the Option (in years) (n)	20
Annualization factor = $i/(1+i)^n - 1$	0.0175
Annualized capital costs	**86,450**
B. Compliance Costs	
Administration, assistance, monitoring	2,400
Inspection, on-site visits	2,400
Labor (6 inspectors at USD 100/month each)	7,200
Logistics for inspectors (transport & office expenses)	2,400
C. Total annual costs of the Compensation Option	**100,850**

3.3 Assessment of the Relocation Options

The main element in the Relocation Options is the moving of all farmers to other places by encouraging them to produce suitable vegetable species in new agricultural lands. The Relocation Options consist of: (1) creating new agricultural perimeters in uncontaminated areas; (2) purchasing fertilizers, farm working tools, and seeds; (3) installing irrigation systems; and (4) constructing essential individual and social infrastructures (houses, hospitals, recreation grounds, sanitation facilities, water and electricity supply networks, public transport, etc.).

In order to prevent people from growing vegetables again in the wetlands, all edible vegetables there will be replaced with water hyacinth. The production of this aquatic plant would help remove pollutants in the water. All costs incurred in this project are assessed in Table 16.

There are two Relocation Options, differentiated according to the two methods of irrigation and fertilizer production used in farming the new agricultural lands:

1. ***Relocation Option 1*:** uses water from rivers, wells, or rain to irrigate the farmlands, and uses compost production or purchase.
2. ***Relocation Option 2*:** uses treated household wastewater from two public-owned wastewater treatment plants (POWTPs) for irrigation and as fertilizer. Two small POWTPs will be built – even in the absence of a relocation project – to treat household wastewater in the urban catchment area of Tuol Kork, to the north of Phnom Penh, as a part of the World Bank funded "Cambodia Urban Water Supply Project" (PARSON 2001). This project is a pilot sewerage system encompassing the construction of two pumping stations and two POWTPs. In this catchment area with 41,600 inhabitants, we noted the absence of industrial plants, although there were some battery repair shops, and painting enterprises that could generate some heavy metal-based effluents. In order to avoid these effluents from contaminating treated wastewater that would be used for irrigating new farms, the strategy of pollutant reduction at the source is recommended. (See No. 16 of Appendix 2 for more details.)

In order to estimate the value of compensation to affected farmers in the Relocation Options, we need to evaluate the following: (1) initial capital investments that would include all costs to create new operational farmlands, individual and social infrastructures for all relocated farmers and their families; (2) estimated incomes that would be earned by the farmers in the new agricultural perimeters; and (3) farmers' loss of wages due to farm relocation – this should be the value of the compensation given to all relocated farmers to cover moving and other costs that would be incurred.

The new farmlands are divided into three zones. All farmers located in Boeng Trabek would be moved to the new agricultural perimeter of "Areikhsat" (located on the Mekong river bank). The farmers in the Boeng Tumpun, and Boeng Cheung Ek wetlands would be moved to "Kok Roka" and "Prey Sar" respectively (see Figure 2).

After the relocation takes place, the Municipality should implement enforcement programs to avoid other people from becoming new squatters in the former farmlands. Squatters are easily identified by their houses – made from temporary construction materials, such as plastic boards, recuperated woods, etc. According to the 1998 population census, this population represents 984 households comprising some 5,680 people.

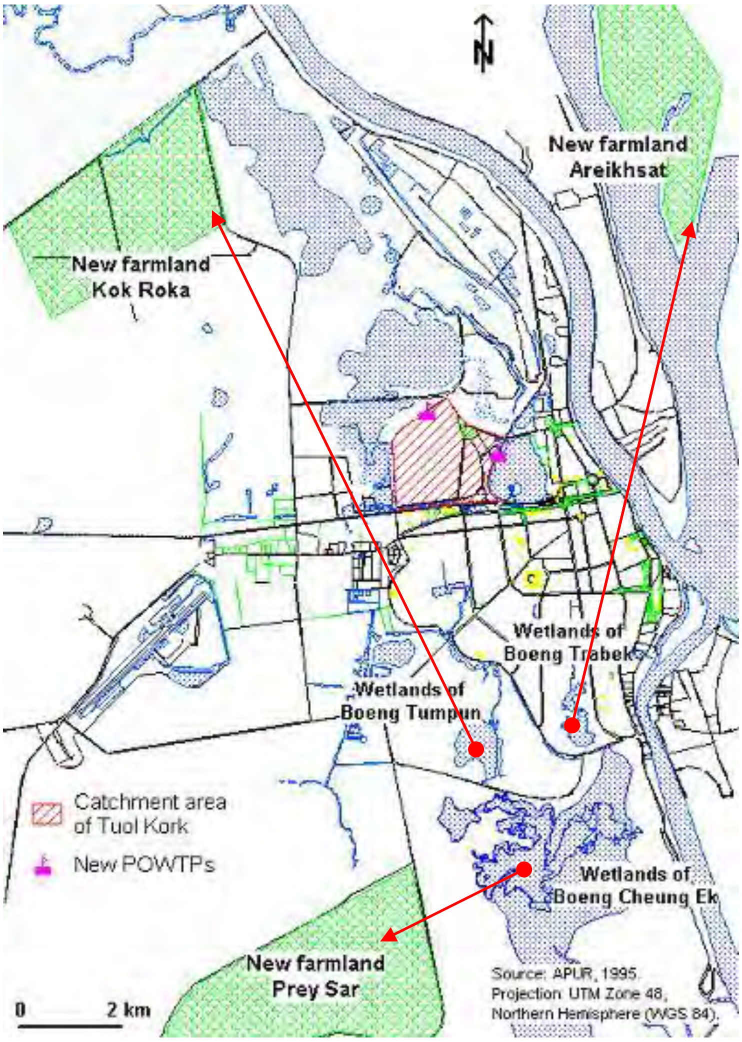

Figure 2. Alternative farmlands in the Relocation Options

3.3.1 Legal basis for relocation

The Land Law 2001 contains provisions that are relevant to informal settlements in Phnom Penh. Article 30 stipulates that people who have, for no fewer than five years prior to 2001, enjoyed peaceful and uncontested possession of land which can lawfully be privately appropriated, are entitled to demand a definitive title of ownership.

On expropriation, Article 5 states that no person can be deprived of land ownership unless it is in the interests of the public, that any deprivation must follow the forms and procedures determined by the law and regulations, and that it can be effected only after the payment of just and equitable compensation. [8]

Nevertheless, property, which is part of the public domain of the State[9] cannot be the subject of acquisition of ownership (Article 43), and people who occupy property in the public domain cannot claim compensation (Article 19), even if they acquired the land before the law came into effect and they have documents proving that they bought the land from another person (Article 259). However, the State may authorize the occupation or temporary use of its public property (Article 16).

[8] The law does not define the terms “public interests” and “just and equitable”.

[9] The public domain of the State includes in particular: waterways, natural lakes, banks of rivers, railways, train stations, roads, gardens, public parks, schools, administrative buildings, and public hospitals. This list is not exhaustive.

The three wetlands of Boeng Trabek, Boeng Tumpun and Boeng Cheung Ek are defined by the Municipality as natural lakes in the public domain. The property rights of people living on these wetlands are not protected by the existing Land Law, although there may be room for fair compensation to be paid before relocation takes place.

3.3.2 Initial capital investment of the Relocation Options

The initial capital investment of the Relocation Options would be a package to relocate farmers from the wetland areas to new agricultural perimeters. These new perimeters are chosen according to land price, suitability for farming, (road) accessibility to markets in the capital, and proximity to water sources (rivers, underground water, etc.). According to the field survey, the costs of agricultural lands located in the Phnom Penh perimeter are unlikely to exceed USD 2.0/m^2.

Table 16. Investment costs incurred in the Relocation Options

Description of cost items	**Unit**	**Total units**	**Price/unit** (USD)	**Relocation Option 1**	**Relocation Option 2**
Water Hyacinth production costs					
Vegetable removal	ha	123	50	6,144	6,144
Municipal landfill fee	USD			1,500	1,500
Labor costs for vegetable removal	ha	123	65	7,988	7,988
Water hyacinth planting and labor costs	ha	123	50	6,144	6,144
Water hyacinth seeds	ha	123	10	1,229	1,229
Training in water hyacinth production techniques	day	10	100	1,000	1,000
Individual and social infrastructure costs					
Land for housing construction	ha	5.3	20,000	105,800	105,800
Houses (1)	farmer	294	1,000	294,000	294,000
Sanitation facilities (2)	farmer	294	200	58,800	58,800
Water supply networks, electricity equipment (3)	item	12	1,850	22,200	22,200
Hospitals, schools, roads (4)			50,000	50,000	50,000
Recreation park, playground			5,000	5,000	5,000
Costs of assistance to relocated farmers					
Social and psychological assistance (5)	farmer	294	100	29,400	29,400
Subsidy for farmers' children's education (6)	child	294	10	2,940	2,940
Food supply for 6 months transitional period (7)	farmer	294	300	88,200	88,200
Farmland installation costs *					
Agricultural land purchase	ha	117.6	20,000	2,352,000	2,352,000
Labor costs (8)	ha	117.6	20	2,352	2,352
Vegetable production investment *					
Vegetable production tools (9)	ha	117.6	30	3,528	3,528
Vegetable seeds	ha	117.6	12	1,411	1,411
Vegetable production infrastructure costs *					
Pumping machines (10)	farmer	294	90	26,460	26,460
Dug wells (11)	farmer	294	50	14,700	14,700
Plastic pipes (12)	m/ha	117.6	50	5,880	5,880
Additional labor costs (13)	ha	117.6	10	1,176	1,176
Training in compost production techniques (14)	day	100	100	10,000	10,000
Irrigation system using treated wastewater (15)					
Tank trucks for transporting treated wastewater	item	1	25,000		25,000
Construction of retention basins					25,000
Specific pollutant reduction at the source (16)					
Removal of heavy metal based effluents or waste	year	1	5,000		5,000
Collection of effluents and transportation to landfill	year	1	1,000		1,000
Education program (17)	year	1	2,500		2,500
Supporting program and monitoring costs (18)	year	3	10,000	30,000	30,000
Total cost per option (USD)				**3,127,852**	**3,186,352**

Sources: URC 2002, except for *: AGRISUD 2001b.
Note: The numbers after the items refer to corresponding notes given in Appendix 2.

3.3.3 Estimation of vegetable production costs in new farms

To maximize profits, we select only the vegetable species with high market value for the new farmlands, namely carrot, cauliflower, Chinese kale, cresson, cucumber, French bean, green mustard, green pepper, leaf lettuce, round cabbage, and tomato. These species are commonly imported from Vietnam in large quantities, approximately 17,800 tons in 2000, equivalent to 23% of the Phnom Penh market (AGRISUD 2001a).

Vegetable production costs will start to accrue once the farmland is ready for farming. We estimate these costs by taking into account the production costs in the base case scenario and extrapolating the estimates derived from the AGRISUD program (2001b) on the setting up of a new farmlands in Siem Reap Province (350 km north of Phnom Penh). Here, the production costs were calculated according to vegetable species. We assume that the relocated farmers will get the same farm surface area to produce the vegetable species quoted above.

Table 17 outlines the following costs:

- *"Seed"* costs are for the purchase of vegetable seeds after harvesting.
- *"Fertilizer"* costs are for the purchase of urea, diammonia phosphate (DAP), and potash (K_2O), and the production of compost.
- *"Irrigation"* costs are for the irrigation system. In Relocation Option 1, these costs would include gasoline to run the pumping machine, repair, and replacement every three years. The irrigation costs in Relocation Option 2 would include the purchase of gasoline for trucks that transport the treated household wastewater from POWTPs to new farms, and repair services.
- *"Labor"* costs refer to the average costs of hiring additional workers for land preparation and other work; estimated at USD 120/ha per yield cycle.
- *"Transport"* costs are calculated according to distance from farm to market. For this study, we quantify these at USD 2.0 per farmer per yield cycle.

Table 17. Estimation of vegetable production costs in the new farmlands

Vegetable Species	Seed costs	Pesti. costs	Irrig. costs	Trans. & labor	Fertilizer ($/ha)		Total costs ($/ha)		Yield cycle	Area	Prod-uction
					Relocation		Relocation				
	$/ha	$/ha	$/ha	($/ha)	Option 1	Option 2	Option 1	Option 2	month	(ha)	t/year
Carrot	64	23	95	122	71	15	375	319	3.5	2.1	155
Cauliflower	155	113	95	122	91	13	576	498	3	98	3,316
Chinese kale	89	154	67	122	83	13	515	445	3	2.7	85
Cresson	89	154	67	122	83	8	515	440	2	2.2	177
Cucumber	165	56	95	122	91	11	529	449	2.5	0.5	52
French bean	509	90	95	122	71	13	887	829	3	0.4	19
Green mustard	180	154	92	122	91	8	639	556	2	1.9	242
Green pepper	36	90	95	122	91	15	434	358	3.5	0.5	16
Leaf lettuce	132	33	123	122	43	8	453	418	2	2.4	281
Round cabbage	79	133	121	122	91	15	546	470	3.5	0.6	59
Tomato	123	79	133	122	40	15	497	472	3.5	12	1,076
Total	**18,247**	**13,386**	**12,109**	**15,403**	**10,404**	**1,600**	**69,188**	**60,384**		**123**	**5,477**

Source: AGRISUD 2001.
Notes: All costs are in USD/ha per yield cycle
Pesti. Costs = Pesticide use costs. Irrig. Costs = Irrigation costs.
Trans. & labor = Transport and labor costs.

3.3.4 Estimation of future net returns earned by farmers

Table 18. Estimation of future net returns in the new farmlands

ESTIMATION OF INCOMES EARNED BY FARMERS PER YEAR IN NEW PRODUCTION FARMS														
Relocation Option 1														
Wetland	**Farm surface** (ha)			**Total Production** (ton/year)	**Gross revenue** (USD/year)			**Production costs** (USD/year)			**Incomes** (USD/year)			
	Min.	Max.	Av.		Min.	Max.	Av.	Min.	Max.	Av.	Min.	Max.	Av.	
Boeng Trabek	0.012	0.85	0.23	713	364	19,795	5,546	28	1,524	437	312	18,007	5,003	
Boeng Tumpun	0.01	2.01	0.27	1,360	229	42,304	5,903	13	4,401	403	192	36,919	5,375	
Boeng Cheung Ek	0.01	3.00	0.49	3,407	218	65,385	10,476	18	5,449	884	176	58,471	9,368	
Relocation Option 2														
Wetland	**Farm surface** (ha)			**Total Production** (ton/year)	**Gross revenue** (USD/year)			**Production costs** (USD/year)			**Incomes** (USD/year)			
	Min.	Max.	Av.		Min.	Max.	Av.	Min.	Max.	Av.	Min.	Max.	Av.	
Boeng Trabek	0.012	0.85	0.23	713	364	19,795	5,546	23	1,314	366	317	18,217	5,074	
Boeng Tumpun	0.01	2.01	0.27	1,360	229	42,304	5,903	12	3,815	364	193	37,505	5,414	
Boeng Cheung Ek	0.01	3.00	0.49	3,407	218	65,385	10,476	15	4,505	731	179	59,416	9,521	

Source: Field survey by author in 2002.

In Table 18, we maintain the same surface area of farmland for each farmer, and the eleven high-value vegetable species quoted in Table 17, for the new agricultural perimeters. The results show that the farmers in the wetland of Boeng Trabek, who have the smallest farmland surface, would have their net incomes reduced by 43% compared with the base case scenario (the opportunity cost of the farmers' own labor is not taken into account). For the farmers with larger farmland areas in Boeng Tumpun and Boeng Cheung Ek, the production of the eleven vegetable species (with appropriate farming techniques) would raise their incomes by 220% and 900% respectively. This indicates that the choice of vegetable species in the new agricultural farms would determine the farmers' incomes.

For better management, and in order to optimize the profits of all relocated farmers, each farmer should get the same portion of new land, 0.018 ha (180 m^2) for housing construction, and 0.4 ha for producing the eleven high-value vegetable varieties. Then each farmer would generate a net income of approximately USD 21.9 and USD 22.2 per day for Relocation Options 1 and 2 respectively. The farmers in the wetland of Boeng Trabek would generate the same net income as in the base case scenario, while the farmers in the two other wetlands would be able to at least quadruple their net incomes. However, the opportunity cost of each farmer's own labor is not taken into account. See Table 19.

Table 19. Income changes in Relocation Options relative to the base case

ESTIMATION OF WELFARE CHANGE PER FARMER IN THE NEW FARMS						
Wetland	**Farmland Surface** (ha/farmer)	**Farmer's average income** (USD/year)			**Farmer's income change** (USD/year)	
		Base case Scenario	Relocation Option 1	Relocation Option 2	Relocation Option 1	Relocation Option 2
Boeng Trabek	0.4	8,557	8,537	8,658	-20	101
Boeng Tumpun	0.4	1,522	7,830	7,889	6,308	6,367
Boeng Cheung Ek	0.4	599	7,645	7,770	7,046	7,171
Average		**1,686**	**7,756**	**7,868**		

Source: Field survey by author in 2002.

3.3.5 Conclusion for the Relocation Options

There is no significant difference in terms of initial investment costs for creating new agricultural perimeters for Relocation Options 1 and 2 (USD 10,824 and USD 11,023 per farmer respectively i.e. the total capital costs to be financed divided by 294 farmers – see Table 20), although there is a slight difference between the net incomes of farmers due to the difference in irrigation costs. If the construction of the two planned POWTPs were completed, we could combine the two options to minimize production costs, and reduce the use of chemical fertilizers. In treated wastewater, there are essential plant nutrients like nitrogen (N) and phosphor (P), so its use would reduce the need for chemical fertilizers like urea, diammonia phosphate (DAP), and potash (K_2O). Enforcement measures should be implemented to ensure that no further production of vegetables for human consumption takes place in the wetlands. This includes preventing people from squatting in these areas.

If each farmer receives at least 0.4 ha of new farmland, the application of the Relocation Options will make the majority of the farmers better off. Their net incomes would rise spectacularly, up to 360% relative to the base case scenario. Furthermore, there will be no fall in market demand. In addition, the import of fresh vegetables from Vietnam will be reduced by 30% (from 17,800 to just 12,300 tons/year).

The higher incomes and improvements to health and environment in the new production sites in the Relocation Options would compensate for any adverse effects from the change of neighborhood and lifestyle due to the move from urban to rural areas, reducing the social impacts during the adaptation period.

Table 20. Worksheet on public sector funding for the Relocation Options
(Calculation of total annual project costs)

Description of cost items	Relocation Option 1 (USD)	Relocation Option 2 (USD)
A. Capital costs		
Capital investments	3,127,852	3,186,352
Costs of conducting awareness campaign	9,500	9,500
Other one-time costs of the Option		
Project preparation	15,000	15,000
Project implementation	30,000	30,000
Total capital costs to be financed	**3,182,352**	**3,240,852**
Discount rate (i)	10%	10%
Time period of the Option (year) (n)	20	20
Annualization factor = $\mathbf{i/(1+i)^n - 1}$	0.0175	0.0175
Annualized capital costs	**55,691**	**56,715**
B. O&M of vegetable production costs	218,295	182,362
C. Compliance costs		
Administration, assistance, monitoring…	2,400	2,400
Inspection, on-site visits	2,400	2,400
Labor (6 inspectors for US$ 100/month each)	7,200	7,200
Logistics for inspectors (transport & office expenses)	2,400	2,400
Total O&M and compliance costs	**232,695**	**196,762**
D. Total annual costs of the Relocation Options	**288,386**	**253,477**

3.4 Assessment of the Conversion Options

In the Conversion Options, all farmers and their families in the wetland areas are allowed to remain on site, and the Municipality will not pay them monetary compensation. Thus, the focus here is how to create alternative jobs for farmers who stop producing edible vegetables in the wetland areas. All farmlands will be expropriated for alternative use. We shall consider the combination of three measures that would involve the farmers according to their farm location, and future wetland uses. These are: (1) to undertake the production of aquatic plants, especially water hyacinth, to remove pollutants, (2) to carry out the production of non-edible plants, in particular, decoration flowers and lotus, and (3) to establish new industrial zones.

3.4.1 Conversion Option 1

(i) Production of aquatic plants to remove pollutants

Approximately 343 ha in this project cover: (a) all farms in the wetland of Boeng Trabek and Boeng Tumpun; (b) some of the farmlands in Boeng Cheung Ek located close to wastewater discharge points; and (c) all unoccupied wetland zones (see Figure 3 in Appendix 3). These farms will remain, but the vegetable crops will be replaced with water hyacinth *(Eicchornia Crassipes)* which has a high capacity to remove pollutants in the wetland waters.

In addition, 98 farmers[10] with the lowest revenue in the base case scenario would be recruited to work for the Sewage Department in the Municipality. Their role would be to maintain aquatic plants in the wetlands to ensure optimal pollution abatement. Therefore, the cost estimation of this project would include the costs of: (1) farm preparation for the planting of water hyacinth – removing edible vegetables, constructing racks for supporting water hyacinth, purchasing boats and production tools, and training; and (2) operational and maintenance (O&M) costs of the pollution abatement system – salaries of farm owners, and logistic costs for the recording and management team.

Table 21. Initial capital investment for the water hyacinth production project

Investment costs for water hyacinth production	**Unit**	**Total units**	**Price/unit** (USD)	**Total costs** (USD)
Wetland preparation				
Vegetable removal & labor costs	ha	123	100	12,289
Municipal landfill fee	USD			1,500
Production investment				
Rack construction, planting, and labor costs	ha	343	500	171,268
Boats and production tools	farmer	98	50	4,900
Water hyacinth seeds	ha	343	10	3,425
Training in water hyacinth production techniques	day	30	100	3,000
Costs of assistance for job conversion				
Social and psychological assistance	farmer	98	100	9,800
Indemnity to farmers during training (30 days)	farmer	98	100	9,800
Supporting program, and monitoring costs	year	3	3,500	10,500
Total investment costs				**226,482**

Source: Field survey by author in 2002.

(ii) Production of decoration flowers

The farmers who produce vegetables in the base case scenario would be encouraged to produce decoration flowers in two areas (about 75 ha) in the wetland of Boeng Cheung Ek: one located in the east and other in the middle of the wetland (see Figure 3 in Appendix 3). According to the field investigation, about 37 ha in the two areas is suitable for flower production but the areas are flooded during the rainy season (from June to November). Therefore, it would be necessary to undertake land elevation works to ensure year-round flower cultivation.

[10] Comprises 10, 12 and 77 farmers from the wetlands of Boeng Trabek, Boeng Tumpun, and Boeng Cheung Ek respectively.

Table 22. Initial capital investment for the flower production project

Description of cost items for flower production project	Unit	Total units	Price/unit (USD)	Total costs (USD)
Flower production investment costs				
Protection dike, retention basin	ha	75	250	18,750
Labor costs for farm preparation	ha	75	40	3,000
Flower production tools	ha	75	30	2,250
Flower seeds	ha	75	12	900
Training in flowers production techniques	day	30	100	3,000
Flower production infrastructure costs				
Pumping machines for irrigation	farmer	121	90	10,890
Plastic pipes	m/ha	75	50	3,750
Labor costs	ha	75	10	750
Costs of assistance to relocated farmers				
Indemnity for moving house	farmer	121	340	41,140
Social and psychological assistance	farmer	121	100	12,100
Food supply for 3 months transitional period	farmer	121	150	18,150
Supporting program and monitoring costs	year	3	4,000	12,000
Total investment costs				**126,680**

Source: Field survey by author in 2002.

To calculate the future net incomes of farmers planting decoration flowers, we extrapolate the costs estimated from a flower production project in the Kandal Province (20 km south of Phnom Penh). The most popular flower species in the Phnom Penh market are rose, anthurium, carnation, chrysanthemum, and calla lily. The market price of such flowers rises from 500% to 2,400% on special occasions like Cambodian saints' days (every two weeks), New Year's Day, and Valentine's Day.

The cost of flower production ranges from USD 3,850 to 5,700 per hectare with net returns (excluding general overheads quoted in Table 22) ranging from USD 6,900 to 8,800 per hectare per yield cycle, depending on the flower species, investment costs and market prices. Let us assume that the average net return is the minimum value of USD 6,900/ha, and that the production cost is the average of all costs (about USD 4,780/ha) per yield cycle (the gross revenue is USD 37,900/ha per year). According to flower production practice, generally only 70% of farmland is productive, so the 37 ha of farmland would generate up to USD 4,680/year in terms of net incomes for each farmer involved in this project (0.3 ha per farmer).

(iii) Production of Lotus

Lotus plants are grown for their flowers, which are used for decoration, and for their leaves, which are used for wrapping food and flowers. The unoccupied zones (the less polluted zones) of 239 ha in the wetland of Boeng Cheung Ek will be transformed into lotus farms, to be occupied by 75 farmers (3 ha per farmer). Four farmers who produced lotus in the base case (0.7 ha in the wetland of Boeng Trabek) will be moved to this wetland. The costs incurred in this project would include the costs of: (1) wetland preparation; (2) lotus production investment – materials, seeds, production technique training for farmers; and (3) job conversion project expenses.

Table 23. Initial capital investment for the lotus production project

Investment costs for lotus production	Unit	Total units	Price/unit (USD)	Total costs (USD)
Wetland preparation & labor costs	ha	239	100	23,900
Production investment				
Boats and production tools	farmer	75	50	3,750
Lotus seeds	ha	239	10	2,390
Training in lotus production techniques	day	10	100	1,000
Costs of assistance for job conversion				
Social and psychological assistance	farmer	75	100	7,500
Indemnity to farmer (100 days)	farmer	75	300	22,500
Supporting program, and monitoring costs	year	3	3,500	10,500
Total investment cost				**71,540**

Source: Field survey by author in 2002, AGRISUD 2001.
Notes: The indemnity is for 100 days as this is the time it takes for the first crop in lotus production.

The average price of lotus flowers is about USD 0.026 per flower. The GR generated by each farmer is estimated at approximately USD 2,800/year (extrapolated from lotus production project figures in the wetland of Boeng Trabek in the base case scenario). Lotus production costs are low; only the pesticide and transport costs (up to USD 204/year and USD 100/year respectively) are taken into account.

3.4.2 Conversion Option 2

As the wetlands play a key role in reducing flooding in the upper urban areas, it is not feasible to convert all present farmlands into industrial zones. This option would include the production of aquatic plants and lotus, but the 75 ha allocated in Conversion Option 1 for decoration flowers will be used to set up industrial parks instead. A field visit found that only 60 ha of the farmlands in the wetland of Boeng Cheung Ek would be converted into new industrial parks. The remaining 15 ha is more suitable for housing and will be allocated for new houses for the 121 farmers affected by this project (Figure 4 in Appendix 3). The cost estimation for this option is given in Table 24.

Table 24. Initial capital investment for the establishment of new industrial zones

Investment costs for creating industrial zones	Unit	Total units	Price/unit (USD)	Total costs (USD)
Housing construction for affected farmers	farmer	121	1,000	121,000
Land elevation works and labor costs	ha	60	2,500	150,000
Social and psychological assistance	farmer	121	100	12,100
Indemnity to affected farmers for job conversion costs	farmer	121	150	18,150
Total investment costs				**301,225**

Source: Field survey by author in 2002; URC 2002.

For the 75 ha of farmlands in the wetland of Boeng Cheung Ek that will be converted to alternative uses in Conversion Options 1 and 2, the NPV of revenue in the base case scenario (vegetable production) is estimated at about USD 1.47 million (over a 20-year period and at a 10% discount rate) while the corresponding figure for the new industrial zones, and flower production is USD 2.45 million and 7.03 million respectively (see Table 25).

Table 25. Net benefits of vegetable, industrial zone and flower projects

	Vegetable production		Industrial zones	Flower production
	100.01 ha*	75 ha**		
Overhead costs (USD/year)	41,987	31,487	301,225	126,680
O/M costs (USD/year)	39,803	29,849	0	562,650
Total costs (USD/year)	81,790	61,336	301,225	689,330
Total benefit (USD/year)	274,335	205,731	3,000,000	1,402,300

Discount rate	*10%*					
COSTS	**PV**	**Year 1**	**Year 2**	**…**	**Year 19**	**Year 20**
Vegetable production (USD)	**282,748**	61,336	29,849	…	29,849	29,849
Industrial zones (USD)	**273,841**	301,225	0	…	0	0
Flower production (USD)	**4,905,320**	689,330	562,650	…	562,650	562,650
BENEFITS	**PV**	**Year 1**	**Year 2**	**…**	**Year 19**	**Year 20**
Vegetable production (USD)	**1,751,501**	205,731	205,731	…	205,731	205,731
Industrial zones (USD)	**2,727,273**	3,000,000	0	…	0	0
Flower production (USD)	**11,938,570**	1,402,300	1,402,300	…	1,402,300	1,402,300
NET BENEFITS						
Vegetable production (USD)	**1,468,753**					
Industrial zones (USD)	**2,453,432**					
Flower production (USD)	**7,033,250**					

Source: Result of field survey by author in 2002.
Notes: *: 100.01 ha is the total surface area of farmland in Boeng Cheung Ek in the base case.
**: 75 ha is the surface area of this wetland for alternative use in the Conversion Options.

Affected farmers should be given priority in employment opportunities directly generated by the creation of the new industrial zones. The benefits of such employment are, however, not taken into account in the benefit calculation of this project. After the Conversion Options are implemented, an enforcement and monitoring program is needed to prevent new people from squatting or farming in the wetlands.

Table 26. Worksheet on public sector funding for the Conversion Options
(Calculation of total annual project costs)

Description of cost items	Conversion Option 1 (USD)	Conversion Option 2 (USD)
A. Capital costs		
Capital investments for producing water hyacinth	226,482	226,482
Capital investments for producing decoration flowers	126,680	-
Capital investments for producing lotus	71,540	71,540
Capital investments for creating new industrial zones	-	301,225
Costs of conducting awareness campaigns	9,500	9,500
Other one-time costs		
Project preparation	5,000	5,000
Project implementation	10,000	10,000
Total capital costs to be financed	**449,202**	**623,747**
Discount rate (i)	0.1	0.1
Time period of the Option (year) (n)	20	20
Annualization factor = $\mathbf{i/(1+i)^n - 1}$	0.0175	0.0175
Annualized capital costs	7,861	10,916
B. O&M costs of producing water hyacinth		
Salary for farmers (98 farmers with $100/month)	117,600	117,600
Logistic support for the pollution abatement system	11,760	11,760
C. O&M costs of producing lotus	22,800	22,800
D. O&M costs of producing decoration flowers	562,650	-
E. Compliance costs		
Administration, assistance, monitoring	4,800	4,800
Inspection, on-site visits	4,800	4,800
Labor (12 inspectors at US$ 100/month each)	14,400	14,400
Logistics for inspectors (transport & office expenses)	4,800	4,800
Total O&M and compliance costs	**746,310**	**180,960**
F. Total annual costs of the Conversion Options	**751,471**	**191,876**

4.0 COST-EFFECTIVENESS ANALYSIS

The cost-effectiveness analysis of alternative measures to bring about the cessation of the production of edible vegetables in contaminated wetlands is a decision-support tool on how efficiently the proposed options can carried out in the least costly manner. It is a method that compares the incremental net costs of the five options to the base case scenario. Such comparisons are useful for ascertaining whether a new alternative is better than the status quo.

A summary of the five mitigation options are as follows:

1. **Compensation Option**: involves payments to all farmers to stop producing edible vegetables in the wetlands.
2. **Relocation Option 1**: the moving of the farmers and their families in the wetlands to new agricultural perimeters which use water from rivers, wells or rain for irrigation.
3. **Relocation Option 2**: the moving of the farmers and their families in the wetlands to new production sites, which will reuse treated household wastewater from two wastewater treatment plants to be constructed, for irrigation.
4. **Conversion Option 1**: the prohibition of vegetable cultivation by undertaking the production of non-edible plants namely, aquatic plants (to remove pollutants), decoration flowers and lotus.
5. **Conversion Option 2**: the prohibition of vegetable cultivation by undertaking the production of aquatic plants (to remove pollutants) and lotus, and creating new industrial zones.

4.1 Incremental net costs

In this cost analysis, the revenues earned by the farmers are considered a cost offset or negative cost. Net costs are the difference between total costs and total direct economic benefits to farmers in each option. If net costs are negative, this means the option is less costly than the current (base case) situation.

The incremental net costs are the difference between the net costs of each option and the net costs accruing in the base case. The present values of net costs and incremental net costs are estimated over a 20-year period at a discount rate of 10%. The lower the incremental net cost, the more cost-effective is the option. A negative incremental net cost would mean that the alternative option would yield greater economic benefits to the farmers compared with the base case scenario.

Table 27. Present value (PV) of incremental net costs, ranked by cost-effectiveness

Discount rate: 10%		Time period of PV: 20 years
Mitigation Options	**PV of net costs** (million USD)	**PV of incremental net costs** (million USD)
Relocation Option 2	**-18.03**	**-13.05**
Relocation Option 1	**-17.78**	**-12.80**
Conversion Option 1	**-7.04**	**-2.06**
Base Case Scenario	-4.98	0
Conversion Option 2	-2.46	2.52
Compensation Option	4.61	9.59

Source: Field survey by author in 2002.

Note: See Appendix 4 for more details on the calculation of incremental net costs of the five options.

The analysis in Table 27 suggests that Relocation Options 2 and 1 are the most preferred on economic efficiency grounds. The shortage of fresh vegetables in Phnom Penh is observed during the wet season. This yields a high market demand. Thus, the application of either of the two Relocation Options would have a significant impact on the availability of vegetable products and considerably reduce the volume imported from Vietnam.

Indeed, the two Relocation Options, as well as Conversion Option 1, have negative net costs relative to the base case scenario (i.e. they yield positive incremental net benefits). As the primary objective is the cessation of the production of vegetables in the sewage wetlands while creating additional economic benefits to the community, these alternatives represent "win-win" outcomes.

The base case scenario is ranked fourth. Recall that the health impacts of consuming contaminated vegetables is not considered in these calculations.

Two less cost-effective options are the Compensation Option and the Conversion Option 2. These have positive incremental net costs (i.e. negative net benefits). Although these two alternatives would produce increases in consumer welfare through health improvements, the total capital costs of the Compensation Option are too high (USD 4.94 million) compared with that of the most cost-effective option; Relocation Option 2, at USD 3.24 million (see Tables 15 and 20), while the PV of incremental net costs of Conversion Option 2 is a positive value that yields negative incremental net benefits relative to the base case scenario.

In summary, the analysis shows the two Relocation Options to be the most cost-effective. These options provide for new vegetable farms in uncontaminated areas for the farmers from the wetlands. The Compensation Option is ranked the least cost effective.

4.2 Sensitivity analysis

A sensitivity analysis was also conducted to investigate the effects of varying key assumptions (costs, revenues, and discount rate) on the present values of incremental net costs.

This analysis provides a measure of the degree to which these variables can deviate from their estimated values before the preferred options cease to be cost-effective. Three scenarios were tested. In all cases, the health and welfare improvements have simply been assumed with no attempt to value them in economic terms:

1. **Scenario 1 - change the capital costs accruing in each option:** If we apply a farmer's lowest willingness to accept (WTA) compensation at USD 0.9/m^2 (this value is the average WTA compensation for farmers in the wetland of Boeng Cheung Ek – see Table 10) instead of USD 4/m^2 (see Section 3.2.3) to cease the production of edible vegetables, this would mean that total costs are reduced by 76% (reducing USD4/m^2 to USD0.9/m^2) for all options compared with the base case scenario.
2. **Scenario 2 - change the benefits generated from each option:** According to market research (AGRISUD 2001a), the price of vegetables would double in the rainy season even with the massive importation from Vietnam.
3. **Scenario 3 - change the discount rate for all options from 10% to 15%** (lowest and highest interest rates of commercial banks in Cambodia).

Table 28. Summary results of the sensitivity analysis

Discount rate: 10%	Time period of PV: 20 years						
Mitigation Options	**Initial PV incr.**	**Scenario 1**		**Scenario 2**		**Scenario 3**	
		PV incr.	**Change in %**	**PV incr.**	**Change in %**	**PV incr.**	**Change in %**
Relocation Option 2	**-13.05**	-16.57	27%	-35.74	174%	-8.02	**-39%**
Relocation Option 1	**-12.80**	-16.35	28%	-35.61	178%	-7.95	-38%
Conversion Option 1	**-2.06**	-7.21	**250%**	-15.87	**671%**	-1.41	-31%
Base Case Scenario	0	0	0%	0	0%	0	0%
Conversion Option 2	2.52	1.01	-60%	0.64	-74%	1.38	**-45%**
Compensation Option	9.59	6.02	-37%	9.59	0%	8.05	-16%

Source: Field survey by author in 2002.

Notes: (1) PV incr.: Present values of incremental net costs (in million USD).

(2) The discount rate in Scenario 3 is 15% which is the official interest rate of commercial banks in Cambodia (for loans over 5 years).

(3) Change in % refers to the degree of deviation of the PV of incremental net costs in each scenario compared with the initial PV of incremental net costs.

(4) The values in bold highlight the maximum sensitivity values of alternative options.

Table 28 shows that the reduction of costs (Scenario 1) has very low impact on the Relocation Options and Compensation Option. The PV of incremental net costs for the latter reduces by only 37% while the compensation rate reduces 76% from USD 4/m^2 (initial PV of incremental net costs) to USD 0.9/m^2 in Scenario 1. Therefore, by offering a higher rate of compensation to relocated farmers in the Compensation Option (i.e. +76%), the PV of incremental net costs rises by only 37%.

The table shows the reduction of the PV of incremental net costs from USD 2.52 million to USD 1.38 million in Conversion Option 2 if we raise the discount rate from 10% to 15%. This means that the PV of incremental net benefits rises by about 45%.

Table 28 also illustrates that with each variation of the basic assumptions, the ranking of the options remains the same; Relocation Option 2 is always the least costly, with Relocation Option 1 close behind. Conversion Option 1 is defensible in Scenarios 1 and 2 only if costs reduce and benefits increase – as the PV of incremental net costs is low and the variation in flower prices is great, the PV value could easily turn positive. Then this option would not be cost-effective anymore. Relocation Option 2 and Conversion Option 2 are sensitive to changes in the discount rate (Scenario 3).

4.3 Limits to cost-effectiveness

Through various statistical simulations, it was calculated that Relocation Options 1 and 2 will cease to be cost-effective if the price of vegetables falls by 57%. This means that the choice of vegetable species grown in the new farmlands and their market price play a key role in adopting these options. According to the market survey conducted by AGRISUD in 2001, the price of vegetable species mentioned in Table 17 increased by about 36% from 1997 to 2000, except for cauliflower and carrot (price decreased by about 27% and 2% respectively). Generally, the price of most of these vegetable species is unlikely to fall. Indeed, these two options are quite resilient against increases in vegetable production costs. These costs would have to climb by at least 700% to make these options cost-ineffective.

Conversion Option 1 will cease to be cost-effective if the price of lotus and flowers were to fall by 15%, or if production costs were to rise by 40%. The extreme sensitivity of this option to the value of the non-edible plants shows that the application of Conversion Option 1 should be carried out with great caution. Hence, the calculation of initial incremental net costs computes the minimum value of non-edible plants.

Conversion Option 2 would become cost-effective if the price of lotus climbs by about 270% permanently. But this is an unrealistic hypothesis. Even if the total O&M and compliance costs were to come down to zero, this option will never become cost-effective.

If we were to change the discount rate from the initial 10% to 140%, all options would cease to be cost-effective, except for Conversion Option 2. Thus, private sector funding is strongly recommended for the conversion of farmlands into industrial zones.

5.0 CONCLUSION

The wetlands of Boeng Trabek, Boeng Tumpun, Boeng Cheung Ek and their floodplain paths play a key role in absorbing flood waters in urban areas, and in reducing pollutant loads. These wetlands receive a daily discharge up to 55,600 m^3 of household wastewater from more than 653,000 inhabitants (equivalent to 6.6 tons per day of BOD_5 discharge), and industrial effluents from more than 3,000 installations.

The wetlands also house squatter settlements on their stream banks and surface. This presents serious sanitation problems not only for the squatters themselves, but also for the production of edible vegetables in the wetlands. There are two production practices. The first is the combined method of using poor quality water for the irrigation of vegetable farms, and applying untreated sludge as fertilizer on agricultural lands– this applies to farms that are flooded during the wet season (Table 2). The second is the cultivation of vegetables on the water surface of the wetlands – this applies to farms that are permanently flooded (Table 2).

The principal objective of this study is to identify the best practical options for eliminating or reducing negative health impacts by stopping the production of edible vegetables in the wetlands. Five mitigation options have been assessed, and their incremental net costs calculated. Each option includes a public campaign on the health risks of consuming vegetables grown in the contaminated wetlands. These options are given below after the base case scenario:

Base Case: A total of 294 farmers within the contaminated wetlands currently produce twelve varieties of fresh vegetables for human consumption. Daily production represents up to 26 tons (20% share of the Phnom Penh market). Over a 20-year period, at a 10% discount rate, the PV of net benefits in the base case is about USD 16,931 per farmer (PV of net benefits of USD 4,977,721 over 294 farmers – see Appendix 4). The NPV of incomes per square meter of farmland varies considerably from one wetland to another. This value represents USD 22.3, USD 1.4 and USD 0.0044 for farms located in Boeng Trabek, Boeng Tumpun and Boeng Cheung Ek respectively (Tables 6, 7 and 8).

Compensation Option: All farmers are allowed to remain on site, but they will be ordered to cease the production of edible vegetables in exchange for a compensation payment equal to USD 4/m^2 (Section 3.2.3). The NPV of incremental net costs relative to the base case scenario is a positive value of USD 32,623 per farmer (Table 29). So, this option is not cost-effective.

Relocation Options: These consist of relocating farmers to new agricultural perimeters by providing each farmer with 0.4 ha of new farmland. Individual houses and social infrastructures will be provided at the new sites (180 m^2 for housing construction). The two options are differentiated mainly according to the irrigation method used in the new farmlands. Relocation Option 1 will use clean water for irrigation, and Relocation Option 2 will use treated household wastewater from two public-owned wastewater treatment plants to be constructed.

According to cost estimations, the annual vegetable production costs under Relocation Option 1 are about 18% higher than under Relocation Option 2. The NPV of incremental net costs in each option are, however, only slightly different (negative values of USD 43,537, and USD 44,397 per farmer respectively – Table 29). The two options are cost-effective relative to the base case, but Relocation Option 2 is more cost-effective. The reuse of treated household wastewater for irrigating new farms is highly recommended.

Conversion Options: These involve the replacement of vegetables with non-edible plants. There are two options. Conversion Option 1 consists of producing (a) aquatic plants (water hyacinth) to remove pollutants, and (b) decoration flowers and lotus. Conversion Option 2 is very similar, but the part of Boeng Cheung Ek used for producing decoration flowers will be transformed into new industrial zones. The affected farmlands (60 ha) are located around existing industrial zones, so the social impact of the conversion would be minimal.

Table 29 shows that with the negative PV of incremental net costs of USD 7,002 per farmer, Conversion Option 1 comes third after the two Relocation Options. If Conversion Option 1 were adopted, it should be done with extreme caution. Farmers' net benefits might drop sharply because of the wide variations in market flower prices. In any case, the Municipality should help farmers acquire and apply new farming skills with mid-term assistance programs.

Even though the total annual costs are very low (USD 653/farmer), Conversion Option 2 could never become cost-effective. The PV of its incremental net costs is a positive value that yields negative incremental net benefits relative to the base case scenario.

Table 29. Annual costs and present value (PV) of incremental net costs of alternative options, ranked by cost-effectiveness

Mitigation Options	**Total annual costs** (USD)		**PV of incremental net costs** (USD)	
	Total	**Per farmer**	**Total**	**Per farmer**
Relocation Option 2	**253,477**	**862**	**-13,052,635**	**-44,397**
Relocation Option 1	**288,386**	**981**	**-12,799,899**	**-43,537**
Conversion Option 1	**751,471**	**2,556**	**-2,058,590**	**-7,002**
Conversion Option 2	191,876	653	2,521,228	8,576
Compensation Option	100,850	343	9,591,203	32,623

Source: Field survey by author in 2002.

In conclusion, Table 29 and the sensitivity analysis suggest that the relocation of farms in the wetlands to new agricultural lands is an attractive measure, under every assumption, for ending the production of contaminated vegetables in the three wetlands. The farmers' net benefits are estimated to rise by at least 360% while imports of fresh vegetables from Vietnam will be reduced by 30%. The main potential products of the new farmlands are carrot, cauliflower, Chinese kale, cresson, cucumber, French bean, green mustard, green pepper, lettuce, round cabbage, and tomato.

The new farmlands are a contrast to the base case where farmers use water contaminated by heavy metal pollutants to produce edible vegetables. Maintaining this current form of production would endanger human health.

We, therefore, recommend that the Municipality (a) launch a public awareness campaign to inform people of the dangers of eating contaminated vegetables from the affected wetlands; (b) enforce prohibitions on the sale of such products, even for animal feed; (c) relocate all farmers from the wetlands to newly-created farmlands, under the terms described in Relocation Options 2 or 1; and (d) take effective measures to prevent the reoccupation of the wetlands by new residents. These areas are suitable only for industrial use, not for residential or agricultural purposes.

These recommendations will increase the availability of fresh vegetable products, the farmers' net incomes, and improve the health status of consumers.

6.0 POLICY RECOMMENDATIONS

The results of this study make a strong case for a program to relocate farmers from the contaminated wetlands to practice agriculture in safer locations. This will require the trust of the farmers. Unfortunately, many previous relocation projects have only made the affected people worse off. Most farmers, therefore, want to be assured that new programs will provide real benefits; they will also want to see how these programs work before accepting them. The real benefit of higher net returns from the new farmlands would help reduce skepticism among the farmers. Furthermore, they must believe in the Municipality and its efforts to contain any negative impacts of the Relocation Options.

The application of the Relocation Options must be followed by wetland rehabilitation programs that consist of replacing the edible vegetables farmed with water hyacinth in order to discourage others from growing vegetables in the wetlands. It is also important to monitor and enforce the ban on all edible plants production in the contaminated wetlands.

The use of public funds to cover the full costs of relocation would greatly help in overcoming resistance to the schemes. The Municipality should at least provide the land required for housing and new farms. This support "in kind" of USD 2.46 million would represent up to 77% of the total costs (USD 3.21 million[11]) of the Relocation Options. The amount of USD 54,500 could be obtained in cash from government funds to cover project implementation, and awareness campaign costs. The remaining amount of nearly USD 700,000 should be requested from aid agencies.

To help share the costs, the Municipality could also seek partnerships with local and international organizations. The Urban Resource Centre (URC) and United Nations Human Settlement Program (UN-Habitat) are involved in relocation projects. The AGRISUD-Cambodge and Support Program for the Agriculture Sector in Cambodia (PRASAC) program of the European Commission are very active in suburban agriculture projects. Projects such as these to improve public health and the livelihood of marginal groups like squatters, are generally given high priority by aid agencies.

[11] This amount is the average total project costs of the two Relocation Options.

The relocation options are entirely feasible and would bring about multiple benefits: improving public health; providing a safer environment and better livelihood for current squatters; promoting suburban agriculture; and creating a safe source of vegetables to replace imports.

Failure to take action today will be detrimental to consumers' health for decades to come. Heavy metals like lead and mercury are particularly harmful to children and pregnant women; they can lead to deformities and permanent mental impairment among other effects. A cost of USD 754,500[12] does not seem too high a price for the Municipality and aid agencies to pay to free Phnom Penh's vegetables of these life-threatening pollutants.

[12] This amount is the difference between the total project costs of USD 3.21 million and the support "in kind" by the Municipality in providing land for new farms and houses (USD 2.46 million).

GLOSSARY OF TERMS

BOD_5 (biological oxygen demand**):** The measure of biological oxygen demand after five days of incubation at 20°C is used as an indicator of the degree of pollution in effluents.

Cost-effectiveness analysis (CEA): A method of comparing the cost and effectiveness of two or more alternative options with the base case scenario in terms of "least-cost means" of meeting a stated objective.

Discount rate: A rate used to convert future costs or benefits to their present value, referred to in this project as the internal rate of return (IRR). When calculating NPV, we assume a particular discount rate of 10%.

Gross revenue (GR): Refers to total gross cash returns.

Incremental net costs: A relative measure of the net costs of one mitigation option compared with the net costs of the base case scenario. The net costs are the difference between the total costs and total benefits of each alternative option. The most cost-effective option has the lowest incremental net costs.

Present value of net return (PV): calculated as: $PV = \sum (R_t - C_t)/(1 + r)^t$ in which t = 1, 2…..20 years where R_t represents the gross revenue earned by farmers from vegetable production and sales in year t, C_t is their production cost in year t, and r is the rate of discount. $(R_t - C_t)$ represents the net returns in year t.

Sensitivity analysis: the study of how the variation in the output of a model (numerical or otherwise) can be apportioned, qualitatively or quantitatively, to different sources of variation. Sensitivity analysis aims to ascertain how the model depends upon the information fed into it, upon its structure and upon the framing assumptions made to build it.

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APPENDIX 1

DETAILS ON VEGETABLE PRODUCTION IN THE BASE CASE

MONETARY VALUE OF VEGETABLE PRODUCTION IN THE BASE CASE SCENARIO

English Name of Vegetable	**Price (P)** $/kg	**Boeng Trabek** **Qv** kg/year	**F**	**A** ha	**Mv** $/year	**Boeng Tumpun** **Qv** kg/year	**F**	**A** ha	**Mv** $/year	**Boeng Cheung Ek** **Qv** kg/year	**F**	**A** ha	**Mv** $/year
Amaranth	0.17	-				83,950	8	0.4	14,272	-			
Mustard green	0.21	7,300	1	0.6	1,533	69,350	7	1.3	14,564	-			
Chili pepper	0.21	-				8,395	2	0.5	1,763	-			
Chinese kale	0.26	-				21,900	3	0.1	5,694	159,701	10	2.0	41,522
Cresson	0.38	358,673	17	2.2	136,296	65,700	3	0.2	24,966	1,460	1	0.1	555
Angled luffa*	0.06	-				156	1	0.1	10	4,328	4	0.1	278
Yard-long bean	0.21	-				14,600	1	0.2	3,066	7,300	1	0.1	1,533
Lotus*	0.03	20,336	4	0.7	644	-				-			
Peppermint	0.10	168,265	12	2.1	16,827	34,310	4	0.4	3,431	38,325	2	0.5	3,833
Leaf lettuce	0.77	238,893	17	2.3	183,947	-				-			
Water convolvulus	0.03	-				775,260	50	11.8	23,258	7,176,995	198	96.8	215,310
Water mimosa	0.38	-				-				25,550	2	0.3	9,709
Total		793,467	**34**	**8.0**	339,247	1,073,621	**55**	**14.9**	91,023	7,413,659	**205**	**100**	272,739

Source: Field survey by author in 2002.

Notes: * Quantity is "item per day" and not kg/day as for the other vegetables.
A: farm surface area,
F: number of farmers involved,
Qv: quantity of vegetable production,
Mv: monetary value of vegetable (**Mv = Qv * P)**

APPENDIX 2

DETAILS ON INVESTMENT COSTS IN THE RELOCATION OPTIONS

These notes explain the costs described in Table 16:

1. *Houses*: the average costs to cover the construction of individual wooden or concrete houses.
2. *Sanitation facilities*: the average costs to cover the construction of individual toilets, and septic tanks costing USD 80 per unit. The remaining USD 120 would cover the construction of sewer pipes and drainage canals.
3. *Water supply networks, electrical equipment*: the costs of installing hand-wells (dug wells) for assuring water supply for household use, and electricity transmission lines to new houses.
4. *Hospitals, schools, roads*: all costs to cover the construction of hospitals for health care, schools for children's education, and roads (red clay) within the new sites and linking to existing roads.
5. *Social and psychological assistance*: the compensation paid to all relocated farmers to cover the trauma caused by the relocation.
6. *Subsidy for farmers' children's education*: the costs of all education programs for all farmers' children during the first year of relocation, and subsidies for school registration fees, school materials, etc.
7. *Food supply for 6 months transitional period*: the food costs of all farmers' and their families for the first six months from the date of relocation until the first harvest in the new farmlands.
8. *Labor costs*: the costs of additional labor required to turn the new lands into vegetable farms.
9. *Vegetable production tools*: the costs to cover the purchase of all indispensable tools for farming in the new agricultural areas.
10. *Pumping machines*: the costs to cover the purchase of pumping machines for farm irrigation. The AGRISUD project found that one seven-horse-capacity pumping machine (USD 175) could irrigate two hectares of farmland. So we can assume the pumping machine costs to be USD 90 for one hectare of farmland.
11. *Dug wells*: the costs to cover all materials for the construction of wells which are used as water sources for consumption and irrigation. We allocate one well to each farmer's household.
12. *Plastic pipes*: used for the irrigation system. Fifty meters of plastic pipe is required for the irrigation of one hectare of farmland (costs vary from USD 15 to 20).
13. *Additional labor costs*: required to set up vegetable production infrastructure, such as installing an irrigation system.

14. *Training in compost production techniques*: the costs of recruiting a specialized team of 10 persons and training them on organic compost production (a method to transform animal excreta and tree leaves into liquid or solid compost). The salary per person is USD 8 per working day, with logistic costs of USD 2 per working day.

15. *Irrigation system using treated wastewater*: Two small POWTPs will be built to treat household wastewater in the urban catchment area of Tuol Kork (41,600 inhabitants). The total estimated cost of using treated household wastewater would include the costs of truck transportation of treated effluents used to irrigate new farmlands, and the installation of irrigation systems.

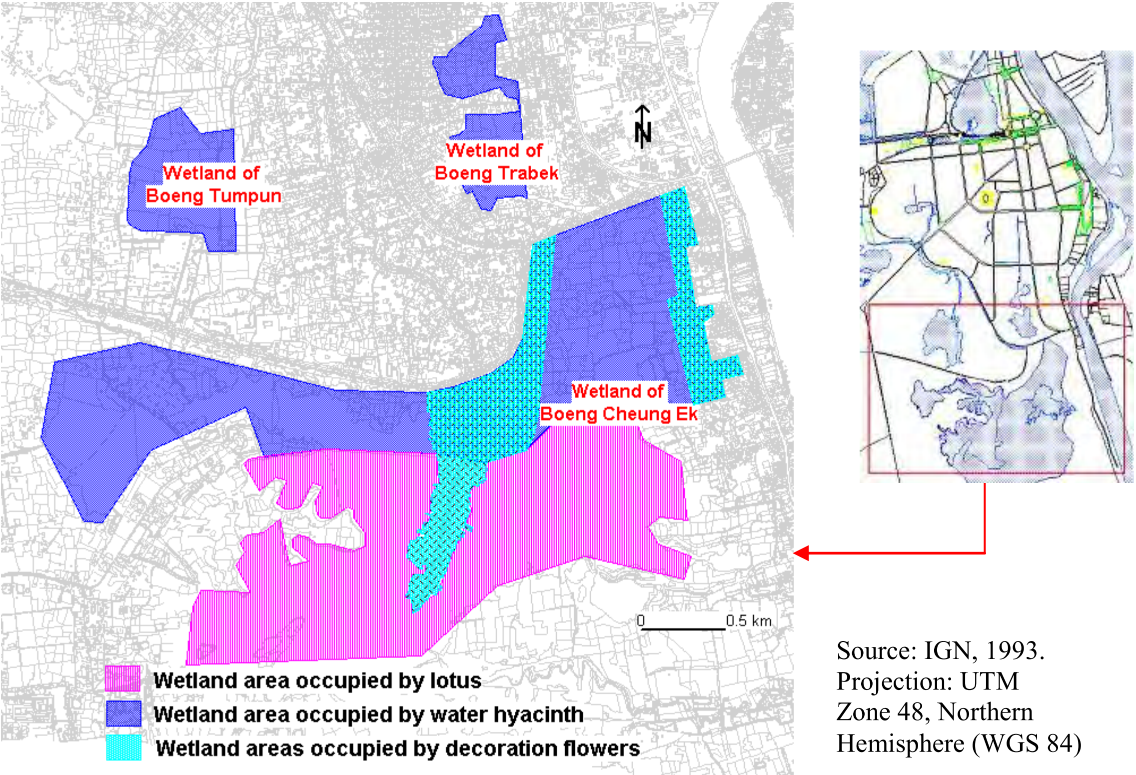
16. *Specific pollutants reduction*: the costs of: (a) maintaining, removing or encapsulating deteriorated heavy metal-based effluents or waste, and removing dust and soil, (b) purchasing special containers to stock these effluents and the transportation costs of moving them to disposal sites, and (c) education programs for small-scale enterprise owners (namely, producers of heavy metal based effluents especially battery repair shops, and painting enterprises).

17. *Education program*: the costs to cover education program for heavy metal based effluents producers in the Tuol Kork catchment area to help them properly discharge their effluents.

18. *Supporting program and monitoring costs*: the costs of recruiting the technical team to assist farmers in farming techniques for the initial duration of three years. This technical team would comprise: (i) an organic compost production sub-team to train farmers in how to produce compost from natural materials; (ii) a social integration sub-team to help farmers settle in new sites and assist them in finding new jobs there; and (iii) a coordination sub-team to manage logistics and monitoring.

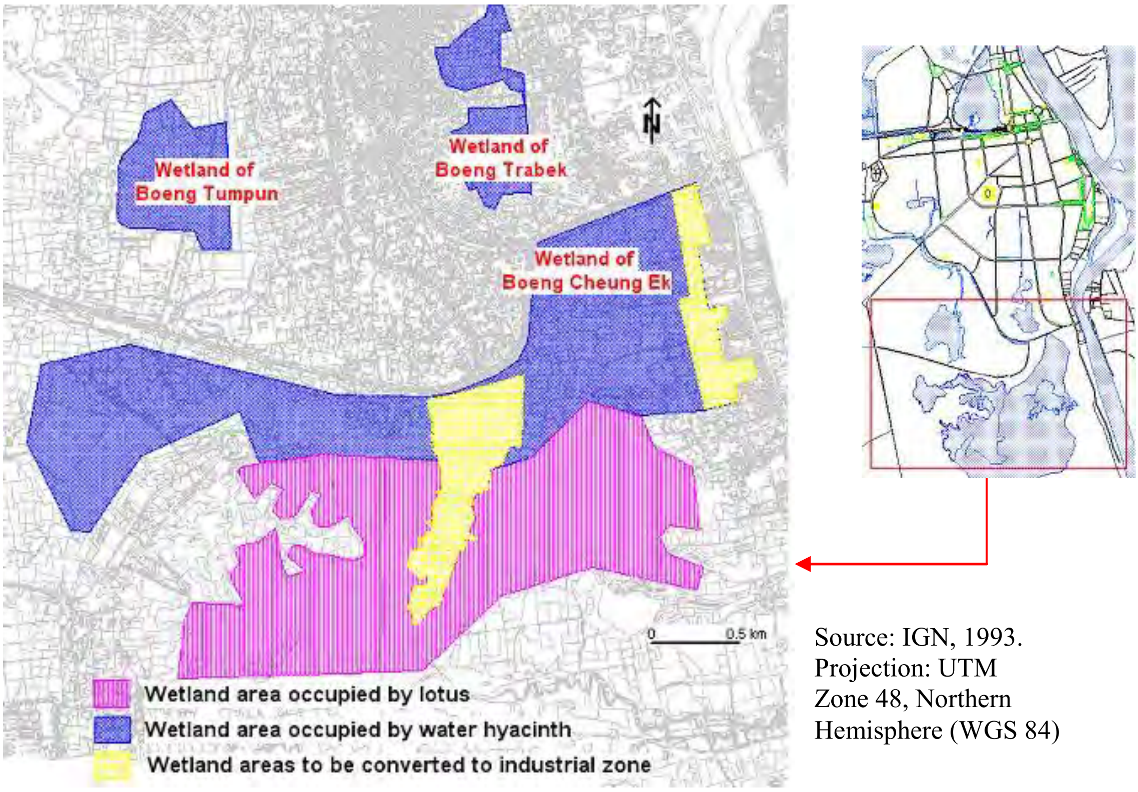
APPENDIX 3

SCHEMES OF WETLAND USE IN THE CONVERSION OPTIONS



Source: IGN, 1993.
Projection: UTM
Zone 48, Northern
Hemisphere (WGS 84)

Figure 3. Schemes of wetland use in Conversion Option 1



Source: IGN, 1993.
Projection: UTM
Zone 48, Northern
Hemisphere (WGS 84)

Figure 4. Schemes of wetland use in Conversion Option 2

APPENDIX 4

CALCULATION OF NPV OF INCREMENTAL NET COSTS

AVOIDING ADVERSE HEALTH IMPACTS FROM THE CONSUMPTION OF CONTAMINATED VEGETABLES: OPTIONS FOR THREE WETLANDS IN PHNOM PENH

NB: Variables that can be changed for sensitivity analyses are marked in bold.

Select Discount Rate: **10%**

BASE CASE SCENARIO: Wastewater reused in vegetable production

Farmers involved (no.)	294
Farmland surface (ha)	123
Vegetable species (no.)	12
Average production (t/y)	9,256
Average value of vegetable (USD/t)	**79**
Vegetable production cost (USD/y)	**68,418**
Value of vegetable (USD/y)	732,140

COSTS - Base case scenario (USD)	**PV**	**Year 1**	**Year 2**	**…**	**Year 19**	**Year 20**
Capital (sunk costs)	*0*	0	0	…	0	0
Overhead costs	*672,919*	79,041	79,041	…	79,041	79,041
Ongoing cost (O&M, production, ...)	*582,481*	68,418	68,418	…	68,418	68,418
Total Costs	*1,255,400*	147,459	147,459	…	147,459	147,459
BENEFITS (USD)	*21,201*					
Value of vegetable production	*6,233,121*	732,140	732,140	…	732,140	732,140
Total Benefits	*6,233,121*	732,140	732,140	…	732,140	732,140
TOTAL COSTS (USD)	*1,255,400*	147,459	147,459	…	147,459	147,459
TOTAL BENEFITS (USD)	*6,233,121*	732,140	732,140	…	732,140	732,140
NET BENEFITS (PV) (USD)	*4,977,721*	584,681	584,681	…	584,681	584,681
NET COSTS (PV) (USD)	***-4,977,721***					

COMPENSATION OPTION - Compensation to farmers for ceasing to grow edible vegetables

Farmers involved (no.)	294
Farmland surface (ha)	123
Vegetable species (no.)	12
Av. compensation rate (USD/ha)	**40,000**
Compliance cost (USD/y)	**14,400**
Initial value of compensation (USD)	4,915,476

COSTS - Compensation Option (USD)	**PV**	**Year 1**	**Year 2**	**…**	**Year 19**	**Year 20**
Capital	*4,468,615*	4,915,476	0	…	0	0
Project preparation costs	*22,273*	24,500	0	…	0	0
Compliance costs	*122,595*	14,400	14,400	…	14,400	14,400
Total Costs	*4,613,483*	4,954,376	14,400	…	14,400	14,400
BENEFITS: Total benefits (USD)	*0*	0	0	…	0	0
INCREMENTAL COSTS (USD)	*3,358,083*	4,806,917	-133,059	…	-133,059	-133,059
INCREMENTAL BENEFITS (USD)	*-6,233,121*	-732,140	-732,140	…	-732,140	-732,140
NET BENEFITS (PV) (USD)	*-9,591,203*	-5,539,057	-599,081	…	-599,081	-599,081
NET COSTS (PV) (USD)		***4,613,483***				
INCREMENTAL NET COSTS (PV) (USD)		***9,591,203***				

(Continued)

Table in Appendix 4 continued

RELOCATION OPTIONS - Relocate farmers to new farms and encourage safe vegetable production						
	Relocation Option 1	***Relocation Option 2***				
Farmers involved (no.)	294	294				
Farmland surface (ha)	118	118				
Vegetable species (no.)	11	11				
Average production (t/y)	**5,477**	**5,477**				
Average value of vegetable (USD/t)	**486**	**486**				
Vegetable production costs (USD/y)	**218,295**	**182,362**				
Value of vegetable (USD/y)	2,660,664	2,660,664				
COSTS - Relocation Option 1 (USD)	**PV**	**Year 1**	**Year 2**	**…**	**Year 19**	**Year 20**
Capital investment	*2,843,502*	3,127,852	0	…	0	0
Project preparation	*49,545*	54,500	0		0	0
Compliance costs	*122,595*	14,400	14,400		14,400	14,400
Vegetable production costs	*1,858,469*	218,295	218,295	…	218,295	218,295
Total Costs	*4,874,112*	3,415,047	232,695	…	232,695	232,695
COSTS - Relocation Option 2 (USD)						
Capital investment	*2,896,684*	3,186,352	0	…	0	0
Project preparation	*49,545*	54,500	0		0	0
Compliance costs	*122,595*	14,400	14,400		14,400	14,400
Vegetable production costs	*1,552,552*	182,362	182,362	…	182,362	182,362
Total Costs	*4,621,376*	3,437,614	196,762	…	196,762	196,762
BENEFITS - Value of vegetables (USD)	*22,651,732*	2,660,664	2,660,664	…	2,660,664	2,660,664
RELOCATION OPTION 1						
INCREMENTAL COSTS (USD)	*3,618,712*	3,267,588	85,236	…	85,236	85,236
INCREMENTAL BENEFITS (USD)	*16,418,611*	1,928,524	1,928,524	…	1,928,524	1,928,524
NET BENEFITS (PV) (USD)	*12,799,899*	-1,339,064	1,843,288	…	1,843,288	1,843,288
RELOCATION OPTION 2						
INCREMENTAL COSTS (USD)	*3,365,976*	3,290,155	49,303	…	49,303	49,303
INCREMENTAL BENEFITS (USD)	*16,418,611*	1,928,524	1,928,524	…	1,928,524	1,928,524
NET BENEFITS (PV) (USD)	*13,052,635*	-1,361,631	1,879,221	…	1,879,221	1,879,221
NET COSTS (PV) Relocation Option 1 (USD)			***-17,777,620***			
NET COSTS (PV) Relocation Option 2 (USD)			***-18,030,356***			
INCREMENTAL NET COSTS (PV) Relocation Option 1 (USD)			***-12,799,899***			
INCREMENTAL NET COSTS (PV) Relocation Option 2 (USD)			***-13,052,635***			

(Continued)

Table in Appendix 4 concluded

CONVERSION OPTIONS - Replace vegetables with non-edible plants, and create alternative jobs						
	Hyacinth	*Lotus*	*Flower*		*Industrial*	
Farmers involved (no.)	98	75	121		121	
Farmland surface (ha)	**343**	**239**	**37**		**60**	
Average production (item/y)	**0**	**8,599,500**	**-**		**0**	
Av. value of aquatic plants (USD/item)	**0**	**0.026**	**3.79**			
Average production costs (USD/y)	**129,360**	**22,800**	**562,650**			
Value of non-edible plants (USD/y)		220,500	1,402,300			
Av. value of land (USD/ha)					**50,000**	
Income generated (USD)					**0**	
Total land value (USD)					3,000,000	
COSTS - Conversion Option 1 (USD)	**PV**	**Year 1**	**Year 2**	**…**	**Year 19**	**Year 20**
Capital investment	*386,093*	424,702	0	…	0	0
Project preparation	*62,636*	68,900	0	…	0	0
Compliance costs	*245,191*	28,800	28,800	…	28,800	28,800
Average production costs	*6,085,580*	714,810	714,810	…	714,810	714,810
Total Costs	*6,779,500*	1,237,212	743,610	…	743,610	743,610
COSTS - Conversion Option 2 (USD)						
Capital investment	*544,770*	599,247	0	…	0	0
Project preparation	*62,636*	68,900	0	…	0	0
Compliance costs	*245,191*	28,800	28,800	…	28,800	28,800
Average production costs	*1,295,424*	152,160	152,160	…	152,160	152,160
Total Costs	*2,148,021*	849,107	180,960	…	180,960	180,960
BENEFITS (USD)						
Value of Conversion Option 1	*13,815,811*	1,622,800	1,622,800	…	1,622,800	1,622,800
Value of Conversion Option 2	*4,604,514*	3,220,500	220,500	…	220,500	220,500
CONVERSION OPTION 1						
INCREMENTAL COSTS (USD)	*5,524,100*	1,089,753	596,151	…	596,151	596,151
INCREMENTAL BENEFITS (USD)	*7,582,691*	890,660	890,660	…	890,660	890,660
NET BENEFITS (PV) (USD)	*2,058,590*	-199,093	294,509	…	294,509	294,509
CONVERSION 0PTION 2						
INCREMENTAL COSTS (USD)	*892,621*	701,648	33,501	…	33,501	33,501
INCREMENTAL BENEFITS (USD)	*-1,628,607*	2,488,360	-511,640	…	-511,640	-511,640
NET BENEFITS (PV) (USD)	*-2,521,228*	1,786,712	-545,141	…	-545,141	-545,141
NET COSTS (PV) Conversion Option 1 (USD)			***-7,036,311***			
NET COSTS (PV) Conversion Option 2 (USD)			***-2,456,493***			
INCREMENTAL NET COSTS (PV) Conversion Option 1 (USD)			***-2,058,590***			
INCREMENTAL NET COSTS (PV) Conversion Option 2 (USD)			***2,521,228***			

SUMMARY OF NET COSTS AND RANKING OF OPTIONS

SUMMARY OF NET COSTS	Discount Rate	10%
	PV OF NET COSTS (USD)	**PV OF INCREMENTAL NET COSTS** (USD)
Base case scenario	-4,977,721	0
Compensation Option	4,613,483	9,591,203
Relocation Option 1	-17,777,620	-12,799,899
Relocation Option 2	-18,030,356	-13,052,635
Conversion Option 1	-7,036,311	-2,058,590
Conversion Option 2	-2,456,493	2,521,228
RANKING OF OPTIONS IN TERMS OF INCREMENTAL NET COSTS		
	PV OF NET COSTS (USD)	**PV OF INCREMENTAL NET COSTS** (USD)
Relocation Option 2	**-18,030,356**	**-13,052,635**
Relocation Option 1	**-17,777,620**	**-12,799,899**
Conversion Option 1	**-7,036,311**	**-2,058,590**
Base case scenario	-4,977,721	0
Conversion Option 2	-2,456,493	2,521,228
Compensation Option	4,613,483	9,591,203