Table F3-16 Shadow Prices and Opportunity Cost of Capital Used in Previous Studies

**1. Urban Water Supply Project**
(Source : Staff Appraisal Report, Kingdom of Cambodia Urban Water Supply Project, January 12 1998, the International Development Association)

(1) Factors for adjusting financial cost

| | | |
|---|---|---|
| a. Standard conversion factor : | 90% | |
| b. Salaries and wages | 75% | for OM works |
| c. Electricity and chemicals | 90% | |
| d. Maintenance work | 80% | |
| e. Connection works | 80% | |

(2) Opportunity cost of capital : 10%

**2. Urban Water Supply and Sanitation Project**
(Source : Final Report for Urban Water Supply and Sanitation Project volume IV, June 1996, Sogreah Ingeniere, Asian Development Bank)

(1) Factors for adjusting financial cost
a. Standard conversion factor : 90%

(2) Opportunity cost of capital : 10%

**3. Cambodia Urban Environmental Improvement Project**
(Source : Draft Final Report for Cambodia Urban Environmental Improvement Project, November 1997, Gutteridge Haskins & Davey Pty Ltd, Asian Development Bank)

(1) Factors for adjusting financial cost
a. Standard conversion factor : 80%

(2) Opportunity cost of capital : not mentioned.

## Table F3-17 Cost Benefit Stream for Master Plan Projects (1/3)

(US$1,000)

| No. | Year | Construction Cost | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Comp.1 | Comp.2 | Comp.3 | Comp.4 | Comp.5 | Comp.6 | Comp.7 | Comp.8 | Total |
| 1 | 2000 | 0 | 8,462 | 6,297 | 5,629 | 0 | 0 | 0 | 0 | 20,388 |
| 2 | 2001 | 0 | 8,462 | 6,297 | 5,629 | 0 | 0 | 0 | 0 | 20,388 |
| 3 | 2002 | 0 | 0 | 6,297 | 5,629 | 0 | 0 | 0 | 0 | 11,926 |
| 4 | 2003 | 0 | 0 | 6,297 | 5,629 | 0 | 0 | 0 | 0 | 11,926 |
| 5 | 2004 | 0 | 0 | 6,297 | 5,629 | 0 | 0 | 0 | 0 | 11,926 |
| 6 | 2005 | 0 | 0 | 6,297 | 5,629 | 0 | 0 | 0 | 0 | 11,926 |
| 7 | 2006 | 0 | 0 | 6,297 | 5,629 | 0 | 0 | 0 | 0 | 11,926 |
| 8 | 2007 | 0 | 0 | 6,297 | 0 | 5,862 | 0 | 0 | 0 | 12,158 |
| 9 | 2008 | 2,094 | 0 | 0 | 0 | 5,862 | 5,646 | 0 | 0 | 13,603 |
| 10 | 2009 | 0 | 0 | 0 | 0 | 0 | 5,646 | 5,703 | 0 | 11,349 |
| 11 | 2010 | 0 | 0 | 0 | 0 | 0 | 0 | 5,703 | 1,747 | 7,450 |
| 12 | 2011 | 0 | 0 | 3,325 | 5,002 | 1,848 | 0 | 0 | 0 | 10,176 |
| 13 | 2012 | 0 | 0 | 3,325 | 5,002 | 1,848 | 0 | 0 | 0 | 10,176 |
| 14 | 2013 | 0 | 0 | 3,325 | 5,002 | 1,848 | 0 | 0 | 0 | 10,176 |
| 15 | 2014 | 0 | 0 | 3,325 | 5,002 | 1,848 | 0 | 0 | 0 | 10,176 |
| 16 | 2015 | 0 | 0 | 3,325 | 5,002 | 1,848 | 0 | 0 | 0 | 10,176 |
| 17 | 2016 | 0 | 0 | 3,325 | 5,002 | 1,848 | 0 | 0 | 0 | 10,176 |
| 18 | 2017 | 0 | 0 | 3,325 | 5,002 | 1,848 | 0 | 0 | 0 | 10,176 |
| 19 | 2018 | 0 | 0 | 3,325 | 5,002 | 1,848 | 0 | 0 | 0 | 10,176 |
| 20 | 2019 | 0 | 0 | 3,325 | 5,002 | 1,848 | 0 | 0 | 0 | 10,176 |
| 21 | 2020 | 0 | 0 | 3,325 | 5,002 | 1,848 | 0 | 0 | 0 | 10,176 |
| 22 | 2021 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 23 | 2022 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 24 | 2023 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 25 | 2024 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 26 | 2025 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 27 | 2026 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 28 | 2027 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 29 | 2028 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 30 | 2029 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 31 | 2030 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 32 | 2031 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 33 | 2032 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 34 | 2033 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 35 | 2034 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 36 | 2035 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 37 | 2036 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 38 | 2037 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 39 | 2038 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 40 | 2039 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 41 | 2040 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 42 | 2041 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 43 | 2042 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 44 | 2043 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 45 | 2044 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 46 | 2045 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 47 | 2046 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 48 | 2047 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 49 | 2048 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 50 | 2049 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Total | | 2,094 | 16,925 | 83,628 | 89,423 | 30,206 | 11,293 | 11,406 | 1,747 | 246,721 |

## Table F3-17 Cost Benefit Stream for Master Plan Projects (2/3)

(US$1,000)

| No. | Year | O/M/R Cost | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Comp.1 | Comp.2 | Comp.3 | Comp.4 | Comp.5 | Comp.6 | Comp.7 | Comp.8 | Total |
| 1 | 2000 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2 | 2001 | 0 | 42 | 31 | 28 | 0 | 0 | 0 | 0 | 102 |
| 3 | 2002 | 0 | 85 | 63 | 56 | 0 | 0 | 0 | 0 | 204 |
| 4 | 2003 | 0 | 85 | 94 | 84 | 0 | 0 | 0 | 0 | 264 |
| 5 | 2004 | 0 | 85 | 126 | 113 | 0 | 0 | 0 | 0 | 323 |
| 6 | 2005 | 0 | 85 | 157 | 141 | 0 | 0 | 0 | 0 | 383 |
| 7 | 2006 | 0 | 85 | 189 | 169 | 0 | 0 | 0 | 0 | 442 |
| 8 | 2007 | 0 | 85 | 220 | 197 | 0 | 0 | 0 | 0 | 502 |
| 9 | 2008 | 0 | 85 | 252 | 197 | 29 | 0 | 0 | 0 | 563 |
| 10 | 2009 | 10 | 85 | 252 | 197 | 59 | 28 | 0 | 0 | 631 |
| 11 | 2010 | 10 | 85 | 252 | 197 | 59 | 56 | 29 | 0 | 688 |
| 12 | 2011 | 10 | 85 | 252 | 197 | 59 | 56 | 57 | 9 | 725 |
| 13 | 2012 | 10 | 85 | 268 | 222 | 68 | 56 | 57 | 9 | 776 |
| 14 | 2013 | 10 | 85 | 285 | 247 | 77 | 56 | 57 | 9 | 827 |
| 15 | 2014 | 10 | 85 | 302 | 272 | 86 | 56 | 57 | 9 | 877 |
| 16 | 2015 | 10 | 85 | 318 | 297 | 96 | 56 | 57 | 9 | 928 |
| 17 | 2016 | 10 | 85 | 335 | 322 | 105 | 56 | 57 | 9 | 979 |
| 18 | 2017 | 10 | 85 | 352 | 347 | 114 | 56 | 57 | 9 | 1,030 |
| 19 | 2018 | 10 | 85 | 368 | 372 | 123 | 56 | 57 | 9 | 1,081 |
| 20 | 2019 | 10 | 85 | 385 | 397 | 133 | 56 | 57 | 9 | 1,132 |
| 21 | 2020 | 10 | 85 | 402 | 422 | 142 | 56 | 57 | 9 | 1,183 |
| 22 | 2021 | 10 | 85 | 418 | 447 | 151 | 56 | 57 | 9 | 1,234 |
| 23 | 2022 | 10 | 85 | 418 | 447 | 151 | 56 | 57 | 9 | 1,234 |
| 24 | 2023 | 10 | 85 | 418 | 447 | 151 | 56 | 57 | 9 | 1,234 |
| 25 | 2024 | 10 | 85 | 418 | 447 | 151 | 56 | 57 | 9 | 1,234 |
| 26 | 2025 | 10 | 85 | 418 | 447 | 151 | 56 | 57 | 9 | 1,234 |
| 27 | 2026 | 10 | 85 | 418 | 447 | 151 | 56 | 57 | 9 | 1,234 |
| 28 | 2027 | 10 | 85 | 418 | 447 | 151 | 56 | 57 | 9 | 1,234 |
| 29 | 2028 | 10 | 85 | 418 | 447 | 151 | 56 | 57 | 9 | 1,234 |
| 30 | 2029 | 10 | 85 | 418 | 447 | 151 | 56 | 57 | 9 | 1,234 |
| 31 | 2030 | 10 | 85 | 418 | 447 | 151 | 56 | 57 | 9 | 1,234 |
| 32 | 2031 | 10 | 85 | 418 | 447 | 151 | 56 | 57 | 9 | 1,234 |
| 33 | 2032 | 10 | 85 | 418 | 447 | 151 | 56 | 57 | 9 | 1,234 |
| 34 | 2033 | 10 | 85 | 418 | 447 | 151 | 56 | 57 | 9 | 1,234 |
| 35 | 2034 | 10 | 85 | 418 | 447 | 151 | 56 | 57 | 9 | 1,234 |
| 36 | 2035 | 10 | 85 | 418 | 447 | 151 | 56 | 57 | 9 | 1,234 |
| 37 | 2036 | 10 | 85 | 418 | 447 | 151 | 56 | 57 | 9 | 1,234 |
| 38 | 2037 | 10 | 85 | 418 | 447 | 151 | 56 | 57 | 9 | 1,234 |
| 39 | 2038 | 10 | 85 | 418 | 447 | 151 | 56 | 57 | 9 | 1,234 |
| 40 | 2039 | 10 | 85 | 418 | 447 | 151 | 56 | 57 | 9 | 1,234 |
| 41 | 2040 | 10 | 85 | 418 | 447 | 151 | 56 | 57 | 9 | 1,234 |
| 42 | 2041 | 10 | 85 | 418 | 447 | 151 | 56 | 57 | 9 | 1,234 |
| 43 | 2042 | 10 | 85 | 418 | 447 | 151 | 56 | 57 | 9 | 1,234 |
| 44 | 2043 | 10 | 85 | 418 | 447 | 151 | 56 | 57 | 9 | 1,234 |
| 45 | 2044 | 10 | 85 | 418 | 447 | 151 | 56 | 57 | 9 | 1,234 |
| 46 | 2045 | 10 | 85 | 418 | 447 | 151 | 56 | 57 | 9 | 1,234 |
| 47 | 2046 | 10 | 85 | 418 | 447 | 151 | 56 | 57 | 9 | 1,234 |
| 48 | 2047 | 10 | 85 | 418 | 447 | 151 | 56 | 57 | 9 | 1,234 |
| 49 | 2048 | 10 | 85 | 418 | 447 | 151 | 56 | 57 | 9 | 1,234 |
| 50 | 2049 | 10 | 85 | 418 | 447 | 151 | 56 | 57 | 9 | 1,234 |
| Total | | 429 | 4,104 | 17,030 | 17,441 | 5,528 | 2,287 | 2,253 | 341 | 49,413 |

## Table F3-17 Cost Benefit Stream for Master Plan Projects (3/3)

(US$1,000)

| No. | Year | Total Cost | Benefit | | | | | | | | | B-C |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Comp.1 | Comp.2 | Comp.3 | Comp.4 | Comp.5 | Comp.6 | Comp.7 | Comp.8 | Total | |
| 1 | 2000 | 20,388 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | -20,388 |
| 2 | 2001 | 20,490 | 0 | 0 | 436 | 455 | 0 | 0 | 0 | 0 | 891 | -19,599 |
| 3 | 2002 | 12,130 | 0 | 3,730 | 934 | 976 | 0 | 0 | 0 | 0 | 5,641 | -6,489 |
| 4 | 2003 | 12,189 | 0 | 3,999 | 1,502 | 1,570 | 0 | 0 | 0 | 0 | 7,071 | -5,118 |
| 5 | 2004 | 12,249 | 0 | 4,287 | 2,147 | 2,244 | 0 | 0 | 0 | 0 | 8,678 | -3,571 |
| 6 | 2005 | 12,309 | 0 | 4,596 | 2,877 | 3,007 | 0 | 0 | 0 | 0 | 10,480 | -1,829 |
| 7 | 2006 | 12,368 | 0 | 4,926 | 3,702 | 3,868 | 0 | 0 | 0 | 0 | 12,496 | 128 |
| 8 | 2007 | 12,660 | 0 | 5,281 | 4,629 | 4,838 | 0 | 0 | 0 | 0 | 14,748 | 2,088 |
| 9 | 2008 | 14,165 | 0 | 5,661 | 5,672 | 5,186 | 535 | 0 | 0 | 0 | 17,054 | 2,889 |
| 10 | 2009 | 11,980 | 47 | 6,069 | 6,080 | 5,560 | 1,147 | 342 | 0 | 0 | 19,245 | 7,265 |
| 11 | 2010 | 8,138 | 50 | 6,506 | 6,518 | 5,960 | 1,230 | 734 | 100 | 0 | 21,097 | 12,959 |
| 12 | 2011 | 10,900 | 50 | 6,506 | 6,518 | 5,960 | 1,230 | 734 | 199 | 0 | 21,197 | 10,296 |
| 13 | 2012 | 10,951 | 50 | 6,506 | 6,952 | 6,357 | 1,312 | 734 | 199 | 0 | 22,110 | 11,159 |
| 14 | 2013 | 11,002 | 50 | 6,506 | 7,387 | 6,754 | 1,394 | 734 | 199 | 0 | 23,024 | 12,022 |
| 15 | 2014 | 11,053 | 50 | 6,506 | 7,821 | 7,152 | 1,476 | 734 | 199 | 0 | 23,938 | 12,885 |
| 16 | 2015 | 11,104 | 50 | 6,506 | 8,256 | 7,549 | 1,558 | 734 | 199 | 0 | 24,852 | 13,748 |
| 17 | 2016 | 11,155 | 50 | 6,506 | 8,690 | 7,946 | 1,640 | 734 | 199 | 0 | 25,766 | 14,611 |
| 18 | 2017 | 11,206 | 50 | 6,506 | 9,125 | 8,344 | 1,722 | 734 | 199 | 0 | 26,680 | 15,474 |
| 19 | 2018 | 11,256 | 50 | 6,506 | 9,559 | 8,741 | 1,804 | 734 | 199 | 0 | 27,593 | 16,337 |
| 20 | 2019 | 11,307 | 50 | 6,506 | 9,994 | 9,138 | 1,886 | 734 | 199 | 0 | 28,507 | 17,200 |
| 21 | 2020 | 11,358 | 50 | 6,506 | 10,428 | 9,536 | 1,968 | 734 | 199 | 0 | 29,421 | 18,063 |
| 22 | 2021 | 1,234 | 50 | 6,506 | 10,863 | 9,933 | 2,050 | 734 | 199 | 0 | 30,335 | 29,101 |
| 23 | 2022 | 1,234 | 50 | 6,506 | 10,863 | 9,933 | 2,050 | 734 | 199 | 0 | 30,335 | 29,101 |
| 24 | 2023 | 1,234 | 50 | 6,506 | 10,863 | 9,933 | 2,050 | 734 | 199 | 0 | 30,335 | 29,101 |
| 25 | 2024 | 1,234 | 50 | 6,506 | 10,863 | 9,933 | 2,050 | 734 | 199 | 0 | 30,335 | 29,101 |
| 26 | 2025 | 1,234 | 50 | 6,506 | 10,863 | 9,933 | 2,050 | 734 | 199 | 0 | 30,335 | 29,101 |
| 27 | 2026 | 1,234 | 50 | 6,506 | 10,863 | 9,933 | 2,050 | 734 | 199 | 0 | 30,335 | 29,101 |
| 28 | 2027 | 1,234 | 50 | 6,506 | 10,863 | 9,933 | 2,050 | 734 | 199 | 0 | 30,335 | 29,101 |
| 29 | 2028 | 1,234 | 50 | 6,506 | 10,863 | 9,933 | 2,050 | 734 | 199 | 0 | 30,335 | 29,101 |
| 30 | 2029 | 1,234 | 50 | 6,506 | 10,863 | 9,933 | 2,050 | 734 | 199 | 0 | 30,335 | 29,101 |
| 31 | 2030 | 1,234 | 50 | 6,506 | 10,863 | 9,933 | 2,050 | 734 | 199 | 0 | 30,335 | 29,101 |
| 32 | 2031 | 1,234 | 50 | 6,506 | 10,863 | 9,933 | 2,050 | 734 | 199 | 0 | 30,335 | 29,101 |
| 33 | 2032 | 1,234 | 50 | 6,506 | 10,863 | 9,933 | 2,050 | 734 | 199 | 0 | 30,335 | 29,101 |
| 34 | 2033 | 1,234 | 50 | 6,506 | 10,863 | 9,933 | 2,050 | 734 | 199 | 0 | 30,335 | 29,101 |
| 35 | 2034 | 1,234 | 50 | 6,506 | 10,863 | 9,933 | 2,050 | 734 | 199 | 0 | 30,335 | 29,101 |
| 36 | 2035 | 1,234 | 50 | 6,506 | 10,863 | 9,933 | 2,050 | 734 | 199 | 0 | 30,335 | 29,101 |
| 37 | 2036 | 1,234 | 50 | 6,506 | 10,863 | 9,933 | 2,050 | 734 | 199 | 0 | 30,335 | 29,101 |
| 38 | 2037 | 1,234 | 50 | 6,506 | 10,863 | 9,933 | 2,050 | 734 | 199 | 0 | 30,335 | 29,101 |
| 39 | 2038 | 1,234 | 50 | 6,506 | 10,863 | 9,933 | 2,050 | 734 | 199 | 0 | 30,335 | 29,101 |
| 40 | 2039 | 1,234 | 50 | 6,506 | 10,863 | 9,933 | 2,050 | 734 | 199 | 0 | 30,335 | 29,101 |
| 41 | 2040 | 1,234 | 50 | 6,506 | 10,863 | 9,933 | 2,050 | 734 | 199 | 0 | 30,335 | 29,101 |
| 42 | 2041 | 1,234 | 50 | 6,506 | 10,863 | 9,933 | 2,050 | 734 | 199 | 0 | 30,335 | 29,101 |
| 43 | 2042 | 1,234 | 50 | 6,506 | 10,863 | 9,933 | 2,050 | 734 | 199 | 0 | 30,335 | 29,101 |
| 44 | 2043 | 1,234 | 50 | 6,506 | 10,863 | 9,933 | 2,050 | 734 | 199 | 0 | 30,335 | 29,101 |
| 45 | 2044 | 1,234 | 50 | 6,506 | 10,863 | 9,933 | 2,050 | 734 | 199 | 0 | 30,335 | 29,101 |
| 46 | 2045 | 1,234 | 50 | 6,506 | 10,863 | 9,933 | 2,050 | 734 | 199 | 0 | 30,335 | 29,101 |
| 47 | 2046 | 1,234 | 50 | 6,506 | 10,863 | 9,933 | 2,050 | 734 | 199 | 0 | 30,335 | 29,101 |
| 48 | 2047 | 1,234 | 50 | 6,506 | 10,863 | 9,933 | 2,050 | 734 | 199 | 0 | 30,335 | 29,101 |
| 49 | 2048 | 1,234 | 50 | 6,506 | 10,863 | 9,933 | 2,050 | 734 | 199 | 0 | 30,335 | 29,101 |
| 50 | 2049 | 1,234 | 50 | 6,506 | 10,863 | 9,933 | 2,050 | 734 | 199 | 0 | 30,335 | 29,101 |
| Total | | 296,134 | 2,047 | 298,790 | 434,256 | 399,198 | 78,353 | 29,702 | 7,861 | 0 | 1,250,207 | 954,072 |

Note : (1) Rate of annual growth of economic benefit until 2010 : 7.20% /year

(2) A discount rate at 10% per year is applied for deriving B/C ratio and net present value (NPV).

Results : EIRR = 12.86% B/C = 1.25 NPV = 32,120 thousand US$

## Table F3-18 Cost Benefit Stream for Each Component (1/4)

(US$1,000)

| No. | Year | Construction Cost | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Comp.1 | Comp.2 | Comp.3 | Comp.4 | Comp.5 | Comp.6 | Comp.7 | Comp.8 | Total |
| 1 | 2000 | 2,094 | 8,463 | 9,281 | 9,936 | 7,552 | 5,647 | 5,703 | 1,747 | 50,421 |
| 2 | 2001 | 0 | 8,463 | 9,281 | 9,936 | 7,552 | 5,647 | 5,703 | 0 | 46,580 |
| 3 | 2002 | 0 | 0 | 9,281 | 9,936 | 7,552 | 0 | 0 | 0 | 26,768 |
| 4 | 2003 | 0 | 0 | 9,281 | 9,936 | 7,552 | 0 | 0 | 0 | 26,768 |
| 5 | 2004 | 0 | 0 | 9,281 | 9,936 | 0 | 0 | 0 | 0 | 19,217 |
| 6 | 2005 | 0 | 0 | 9,281 | 9,936 | 0 | 0 | 0 | 0 | 19,217 |
| 7 | 2006 | 0 | 0 | 9,281 | 9,936 | 0 | 0 | 0 | 0 | 19,217 |
| 8 | 2007 | 0 | 0 | 9,281 | 9,936 | 0 | 0 | 0 | 0 | 19,217 |
| 9 | 2008 | 0 | 0 | 9,281 | 9,936 | 0 | 0 | 0 | 0 | 19,217 |
| 10 | 2009 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 11 | 2010 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 12 | 2011 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 13 | 2012 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 14 | 2013 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 15 | 2014 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 16 | 2015 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 17 | 2016 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 18 | 2017 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 19 | 2018 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 20 | 2019 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 21 | 2020 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 22 | 2021 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 23 | 2022 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 24 | 2023 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 25 | 2024 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 26 | 2025 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 27 | 2026 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 28 | 2027 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 29 | 2028 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 30 | 2029 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 31 | 2030 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 32 | 2031 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 33 | 2032 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 34 | 2033 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 35 | 2034 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 36 | 2035 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 37 | 2036 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 38 | 2037 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 39 | 2038 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 40 | 2039 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 41 | 2040 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 42 | 2041 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 43 | 2042 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 44 | 2043 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 45 | 2044 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 46 | 2045 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 47 | 2046 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 48 | 2047 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 49 | 2048 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 50 | 2049 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Total | | 2,094 | 16,925 | 83,528 | 89,423 | 30,206 | 11,293 | 11,406 | 1,747 | 246,622 |

## Table F3-18 Cost Benefit Stream for Each Component (2/4)

(US$1,000)

| No. | Year | O/M/R Cost | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Comp.1 | Comp.2 | Comp.3 | Comp.4 | Comp.5 | Comp.6 | Comp.7 | Comp.8 | Total |
| 1 | 2000 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2 | 2001 | 10 | 42 | 46 | 50 | 38 | 28 | 29 | 9 | 252 |
| 3 | 2002 | 10 | 85 | 93 | 99 | 76 | 56 | 57 | 9 | 485 |
| 4 | 2003 | 10 | 85 | 139 | 149 | 113 | 56 | 57 | 9 | 619 |
| 5 | 2004 | 10 | 85 | 186 | 199 | 151 | 56 | 57 | 9 | 753 |
| 6 | 2005 | 10 | 85 | 232 | 248 | 151 | 56 | 57 | 9 | 849 |
| 7 | 2006 | 10 | 85 | 278 | 298 | 151 | 56 | 57 | 9 | 945 |
| 8 | 2007 | 10 | 85 | 325 | 348 | 151 | 56 | 57 | 9 | 1,041 |
| 9 | 2008 | 10 | 85 | 371 | 397 | 151 | 56 | 57 | 9 | 1,137 |
| 10 | 2009 | 10 | 85 | 418 | 447 | 151 | 56 | 57 | 9 | 1,233 |
| 11 | 2010 | 10 | 85 | 418 | 447 | 151 | 56 | 57 | 9 | 1,233 |
| 12 | 2011 | 10 | 85 | 418 | 447 | 151 | 56 | 57 | 9 | 1,233 |
| 13 | 2012 | 10 | 85 | 418 | 447 | 151 | 56 | 57 | 9 | 1,233 |
| 14 | 2013 | 10 | 85 | 418 | 447 | 151 | 56 | 57 | 9 | 1,233 |
| 15 | 2014 | 10 | 85 | 418 | 447 | 151 | 56 | 57 | 9 | 1,233 |
| 16 | 2015 | 10 | 85 | 418 | 447 | 151 | 56 | 57 | 9 | 1,233 |
| 17 | 2016 | 10 | 85 | 418 | 447 | 151 | 56 | 57 | 9 | 1,233 |
| 18 | 2017 | 10 | 85 | 418 | 447 | 151 | 56 | 57 | 9 | 1,233 |
| 19 | 2018 | 10 | 85 | 418 | 447 | 151 | 56 | 57 | 9 | 1,233 |
| 20 | 2019 | 10 | 85 | 418 | 447 | 151 | 56 | 57 | 9 | 1,233 |
| 21 | 2020 | 10 | 85 | 418 | 447 | 151 | 56 | 57 | 9 | 1,233 |
| 22 | 2021 | 10 | 85 | 418 | 447 | 151 | 56 | 57 | 9 | 1,233 |
| 23 | 2022 | 10 | 85 | 418 | 447 | 151 | 56 | 57 | 9 | 1,233 |
| 24 | 2023 | 10 | 85 | 418 | 447 | 151 | 56 | 57 | 9 | 1,233 |
| 25 | 2024 | 10 | 85 | 418 | 447 | 151 | 56 | 57 | 9 | 1,233 |
| 26 | 2025 | 10 | 85 | 418 | 447 | 151 | 56 | 57 | 9 | 1,233 |
| 27 | 2026 | 10 | 85 | 418 | 447 | 151 | 56 | 57 | 9 | 1,233 |
| 28 | 2027 | 10 | 85 | 418 | 447 | 151 | 56 | 57 | 9 | 1,233 |
| 29 | 2028 | 10 | 85 | 418 | 447 | 151 | 56 | 57 | 9 | 1,233 |
| 30 | 2029 | 10 | 85 | 418 | 447 | 151 | 56 | 57 | 9 | 1,233 |
| 31 | 2030 | 10 | 85 | 418 | 447 | 151 | 56 | 57 | 9 | 1,233 |
| 32 | 2031 | 10 | 85 | 418 | 447 | 151 | 56 | 57 | 9 | 1,233 |
| 33 | 2032 | 10 | 85 | 418 | 447 | 151 | 56 | 57 | 9 | 1,233 |
| 34 | 2033 | 10 | 85 | 418 | 447 | 151 | 56 | 57 | 9 | 1,233 |
| 35 | 2034 | 10 | 85 | 418 | 447 | 151 | 56 | 57 | 9 | 1,233 |
| 36 | 2035 | 10 | 85 | 418 | 447 | 151 | 56 | 57 | 9 | 1,233 |
| 37 | 2036 | 10 | 85 | 418 | 447 | 151 | 56 | 57 | 9 | 1,233 |
| 38 | 2037 | 10 | 85 | 418 | 447 | 151 | 56 | 57 | 9 | 1,233 |
| 39 | 2038 | 10 | 85 | 418 | 447 | 151 | 56 | 57 | 9 | 1,233 |
| 40 | 2039 | 10 | 85 | 418 | 447 | 151 | 56 | 57 | 9 | 1,233 |
| 41 | 2040 | 10 | 85 | 418 | 447 | 151 | 56 | 57 | 9 | 1,233 |
| 42 | 2041 | 10 | 85 | 418 | 447 | 151 | 56 | 57 | 9 | 1,233 |
| 43 | 2042 | 10 | 85 | 418 | 447 | 151 | 56 | 57 | 9 | 1,233 |
| 44 | 2043 | 10 | 85 | 418 | 447 | 151 | 56 | 57 | 9 | 1,233 |
| 45 | 2044 | 10 | 85 | 418 | 447 | 151 | 56 | 57 | 9 | 1,233 |
| 46 | 2045 | 10 | 85 | 418 | 447 | 151 | 56 | 57 | 9 | 1,233 |
| 47 | 2046 | 10 | 85 | 418 | 447 | 151 | 56 | 57 | 9 | 1,233 |
| 48 | 2047 | 10 | 85 | 418 | 447 | 151 | 56 | 57 | 9 | 1,233 |
| 49 | 2048 | 10 | 85 | 418 | 447 | 151 | 56 | 57 | 9 | 1,233 |
| 50 | 2049 | 10 | 85 | 418 | 447 | 151 | 56 | 57 | 9 | 1,233 |
| Total | | 513 | 4,104 | 18,794 | 20,120 | 7,174 | 2,739 | 2,766 | 428 | 56,638 |

## TableF3-18 Cost Benefit Stream for Each Component (3/4)

(US$1,000)

| No. | Year | Total Cost | Benefit | | | | | | | | | B-C |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Comp.1 | Comp.2 | Comp.3 | Comp.4 | Comp.5 | Comp.6 | Comp.7 | Comp.8 | Total | |
| 1 | 2000 | 50,421 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | -50,421 |
| 2 | 2001 | 46,832 | 27 | 0 | 646 | 531 | 365 | 196 | 53 | 0 | 1,818 | -45,014 |
| 3 | 2002 | 27,253 | 29 | 3,730 | 1,384 | 1,139 | 784 | 421 | 113 | 0 | 7,600 | -19,654 |
| 4 | 2003 | 27,387 | 31 | 3,999 | 2,226 | 1,832 | 1,260 | 451 | 121 | 0 | 9,919 | -17,468 |
| 5 | 2004 | 19,969 | 33 | 4,287 | 3,181 | 2,618 | 1,351 | 484 | 130 | 0 | 12,083 | -7,886 |
| 6 | 2005 | 20,066 | 35 | 4,596 | 4,263 | 3,508 | 1,448 | 518 | 139 | 0 | 14,508 | -5,558 |
| 7 | 2006 | 20,162 | 38 | 4,926 | 5,484 | 4,513 | 1,552 | 556 | 149 | 0 | 17,218 | -2,943 |
| 8 | 2007 | 20,258 | 41 | 5,281 | 6,858 | 5,644 | 1,664 | 596 | 160 | 0 | 20,244 | -14 |
| 9 | 2008 | 20,354 | 44 | 5,661 | 8,402 | 6,915 | 1,784 | 639 | 171 | 0 | 23,616 | 3,262 |
| 10 | 2009 | 1,233 | 47 | 6,069 | 10,133 | 8,339 | 1,912 | 685 | 184 | 0 | 27,369 | 26,136 |
| 11 | 2010 | 1,233 | 50 | 6,506 | 10,863 | 9,933 | 2,050 | 734 | 197 | 0 | 30,333 | 29,100 |
| 12 | 2011 | 1,233 | 50 | 6,506 | 10,863 | 9,933 | 2,050 | 734 | 197 | 0 | 30,333 | 29,100 |
| 13 | 2012 | 1,233 | 50 | 6,506 | 10,863 | 9,933 | 2,050 | 734 | 197 | 0 | 30,333 | 29,100 |
| 14 | 2013 | 1,233 | 50 | 6,506 | 10,863 | 9,933 | 2,050 | 734 | 197 | 0 | 30,333 | 29,100 |
| 15 | 2014 | 1,233 | 50 | 6,506 | 10,863 | 9,933 | 2,050 | 734 | 197 | 0 | 30,333 | 29,100 |
| 16 | 2015 | 1,233 | 50 | 6,506 | 10,863 | 9,933 | 2,050 | 734 | 197 | 0 | 30,333 | 29,100 |
| 17 | 2016 | 1,233 | 50 | 6,506 | 10,863 | 9,933 | 2,050 | 734 | 197 | 0 | 30,333 | 29,100 |
| 18 | 2017 | 1,233 | 50 | 6,506 | 10,863 | 9,933 | 2,050 | 734 | 197 | 0 | 30,333 | 29,100 |
| 19 | 2018 | 1,233 | 50 | 6,506 | 10,863 | 9,933 | 2,050 | 734 | 197 | 0 | 30,333 | 29,100 |
| 20 | 2019 | 1,233 | 50 | 6,506 | 10,863 | 9,933 | 2,050 | 734 | 197 | 0 | 30,333 | 29,100 |
| 21 | 2020 | 1,233 | 50 | 6,506 | 10,863 | 9,933 | 2,050 | 734 | 197 | 0 | 30,333 | 29,100 |
| 22 | 2021 | 1,233 | 50 | 6,506 | 10,863 | 9,933 | 2,050 | 734 | 197 | 0 | 30,333 | 29,100 |
| 23 | 2022 | 1,233 | 50 | 6,506 | 10,863 | 9,933 | 2,050 | 734 | 197 | 0 | 30,333 | 29,100 |
| 24 | 2023 | 1,233 | 50 | 6,506 | 10,863 | 9,933 | 2,050 | 734 | 197 | 0 | 30,333 | 29,100 |
| 25 | 2024 | 1,233 | 50 | 6,506 | 10,863 | 9,933 | 2,050 | 734 | 197 | 0 | 30,333 | 29,100 |
| 26 | 2025 | 1,233 | 50 | 6,506 | 10,863 | 9,933 | 2,050 | 734 | 197 | 0 | 30,333 | 29,100 |
| 27 | 2026 | 1,233 | 50 | 6,506 | 10,863 | 9,933 | 2,050 | 734 | 197 | 0 | 30,333 | 29,100 |
| 28 | 2027 | 1,233 | 50 | 6,506 | 10,863 | 9,933 | 2,050 | 734 | 197 | 0 | 30,333 | 29,100 |
| 29 | 2028 | 1,233 | 50 | 6,506 | 10,863 | 9,933 | 2,050 | 734 | 197 | 0 | 30,333 | 29,100 |
| 30 | 2029 | 1,233 | 50 | 6,506 | 10,863 | 9,933 | 2,050 | 734 | 197 | 0 | 30,333 | 29,100 |
| 31 | 2030 | 1,233 | 50 | 6,506 | 10,863 | 9,933 | 2,050 | 734 | 197 | 0 | 30,333 | 29,100 |
| 32 | 2031 | 1,233 | 50 | 6,506 | 10,863 | 9,933 | 2,050 | 734 | 197 | 0 | 30,333 | 29,100 |
| 33 | 2032 | 1,233 | 50 | 6,506 | 10,863 | 9,933 | 2,050 | 734 | 197 | 0 | 30,333 | 29,100 |
| 34 | 2033 | 1,233 | 50 | 6,506 | 10,863 | 9,933 | 2,050 | 734 | 197 | 0 | 30,333 | 29,100 |
| 35 | 2034 | 1,233 | 50 | 6,506 | 10,863 | 9,933 | 2,050 | 734 | 197 | 0 | 30,333 | 29,100 |
| 36 | 2035 | 1,233 | 50 | 6,506 | 10,863 | 9,933 | 2,050 | 734 | 197 | 0 | 30,333 | 29,100 |
| 37 | 2036 | 1,233 | 50 | 6,506 | 10,863 | 9,933 | 2,050 | 734 | 197 | 0 | 30,333 | 29,100 |
| 38 | 2037 | 1,233 | 50 | 6,506 | 10,863 | 9,933 | 2,050 | 734 | 197 | 0 | 30,333 | 29,100 |
| 39 | 2038 | 1,233 | 50 | 6,506 | 10,863 | 9,933 | 2,050 | 734 | 197 | 0 | 30,333 | 29,100 |
| 40 | 2039 | 1,233 | 50 | 6,506 | 10,863 | 9,933 | 2,050 | 734 | 197 | 0 | 30,333 | 29,100 |
| 41 | 2040 | 1,233 | 50 | 6,506 | 10,863 | 9,933 | 2,050 | 734 | 197 | 0 | 30,333 | 29,100 |
| 42 | 2041 | 1,233 | 50 | 6,506 | 10,863 | 9,933 | 2,050 | 734 | 197 | 0 | 30,333 | 29,100 |
| 43 | 2042 | 1,233 | 50 | 6,506 | 10,863 | 9,933 | 2,050 | 734 | 197 | 0 | 30,333 | 29,100 |
| 44 | 2043 | 1,233 | 50 | 6,506 | 10,863 | 9,933 | 2,050 | 734 | 197 | 0 | 30,333 | 29,100 |
| 45 | 2044 | 1,233 | 50 | 6,506 | 10,863 | 9,933 | 2,050 | 734 | 197 | 0 | 30,333 | 29,100 |
| 46 | 2045 | 1,233 | 50 | 6,506 | 10,863 | 9,933 | 2,050 | 734 | 197 | 0 | 30,333 | 29,100 |
| 47 | 2046 | 1,233 | 50 | 6,506 | 10,863 | 9,933 | 2,050 | 734 | 197 | 0 | 30,333 | 29,100 |
| 48 | 2047 | 1,233 | 50 | 6,506 | 10,863 | 9,933 | 2,050 | 734 | 197 | 0 | 30,333 | 29,100 |
| 49 | 2048 | 1,233 | 50 | 6,506 | 10,863 | 9,933 | 2,050 | 734 | 197 | 0 | 30,333 | 29,100 |
| 50 | 2049 | 1,233 | 50 | 6,506 | 10,863 | 9,933 | 2,050 | 734 | 197 | 0 | 30,333 | 29,100 |
| Total | | 303,260 | 2,323 | 298,790 | 477,098 | 432,359 | 94,121 | 33,905 | 9,100 | 0 | 1,347,696 | 1,044,436 |

## TableF3-18 Cost Benefit Stream for Each Component (4/4)

| No. | Year | Benefit - Costs | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Comp.1 | Comp.2 | Comp.3 | Comp.4 | Comp.5 | Comp.6 | Comp.7 | Comp.8 |
| 1 | 2000 | -2,091 | -8,463 | -9,281 | -9,936 | -7,552 | -5,647 | -5,703 | -1,747 |
| 2 | 2001 | 16 | -8,505 | -8,682 | -9,454 | -7,224 | -5,478 | -5,679 | -9 |
| 3 | 2002 | 18 | 3,646 | -7,990 | -8,896 | -6,843 | 364 | 56 | -9 |
| 4 | 2003 | 20 | 3,914 | -7,194 | -8,253 | -6,405 | 395 | 64 | -9 |
| 5 | 2004 | 22 | 4,202 | -6,285 | -7,517 | 1,200 | 427 | 73 | -9 |
| 6 | 2005 | 25 | 4,511 | -5,250 | -6,676 | 1,297 | 462 | 82 | -9 |
| 7 | 2006 | 27 | 4,842 | -4,076 | -5,721 | 1,401 | 499 | 92 | -9 |
| 8 | 2007 | 30 | 5,197 | -2,747 | -4,640 | 1,513 | 539 | 103 | -9 |
| 9 | 2008 | 33 | 5,577 | -1,250 | -3,419 | 1,633 | 582 | 114 | -9 |
| 10 | 2009 | 36 | 5,984 | 9,716 | 7,892 | 1,761 | 628 | 127 | -9 |
| 11 | 2010 | 40 | 6,421 | 10,445 | 9,486 | 1,899 | 678 | 140 | -9 |
| 12 | 2011 | 40 | 6,421 | 10,445 | 9,486 | 1,899 | 678 | 140 | -9 |
| 13 | 2012 | 40 | 6,421 | 10,445 | 9,486 | 1,899 | 678 | 140 | -9 |
| 14 | 2013 | 40 | 6,421 | 10,445 | 9,486 | 1,899 | 678 | 140 | -9 |
| 15 | 2014 | 40 | 6,421 | 10,445 | 9,486 | 1,899 | 678 | 140 | -9 |
| 16 | 2015 | 40 | 6,421 | 10,445 | 9,486 | 1,899 | 678 | 140 | -9 |
| 17 | 2016 | 40 | 6,421 | 10,445 | 9,486 | 1,899 | 678 | 140 | -9 |
| 18 | 2017 | 40 | 6,421 | 10,445 | 9,486 | 1,899 | 678 | 140 | -9 |
| 19 | 2018 | 40 | 6,421 | 10,445 | 9,486 | 1,899 | 678 | 140 | -9 |
| 20 | 2019 | 40 | 6,421 | 10,445 | 9,486 | 1,899 | 678 | 140 | -9 |
| 21 | 2020 | 40 | 6,421 | 10,445 | 9,486 | 1,899 | 678 | 140 | -9 |
| 22 | 2021 | 40 | 6,421 | 10,445 | 9,486 | 1,899 | 678 | 140 | -9 |
| 23 | 2022 | 40 | 6,421 | 10,445 | 9,486 | 1,899 | 678 | 140 | -9 |
| 24 | 2023 | 40 | 6,421 | 10,445 | 9,486 | 1,899 | 678 | 140 | -9 |
| 25 | 2024 | 40 | 6,421 | 10,445 | 9,486 | 1,899 | 678 | 140 | -9 |
| 26 | 2025 | 40 | 6,421 | 10,445 | 9,486 | 1,899 | 678 | 140 | -9 |
| 27 | 2026 | 40 | 6,421 | 10,445 | 9,486 | 1,899 | 678 | 140 | -9 |
| 28 | 2027 | 40 | 6,421 | 10,445 | 9,486 | 1,899 | 678 | 140 | -9 |
| 29 | 2028 | 40 | 6,421 | 10,445 | 9,486 | 1,899 | 678 | 140 | -9 |
| 30 | 2029 | 40 | 6,421 | 10,445 | 9,486 | 1,899 | 678 | 140 | -9 |
| 31 | 2030 | 40 | 6,421 | 10,445 | 9,486 | 1,899 | 678 | 140 | -9 |
| 32 | 2031 | 40 | 6,421 | 10,445 | 9,486 | 1,899 | 678 | 140 | -9 |
| 33 | 2032 | 40 | 6,421 | 10,445 | 9,486 | 1,899 | 678 | 140 | -9 |
| 34 | 2033 | 40 | 6,421 | 10,445 | 9,486 | 1,899 | 678 | 140 | -9 |
| 35 | 2034 | 40 | 6,421 | 10,445 | 9,486 | 1,899 | 678 | 140 | -9 |
| 36 | 2035 | 40 | 6,421 | 10,445 | 9,486 | 1,899 | 678 | 140 | -9 |
| 37 | 2036 | 40 | 6,421 | 10,445 | 9,486 | 1,899 | 678 | 140 | -9 |
| 38 | 2037 | 40 | 6,421 | 10,445 | 9,486 | 1,899 | 678 | 140 | -9 |
| 39 | 2038 | 40 | 6,421 | 10,445 | 9,486 | 1,899 | 678 | 140 | -9 |
| 40 | 2039 | 40 | 6,421 | 10,445 | 9,486 | 1,899 | 678 | 140 | -9 |
| 41 | 2040 | 40 | 6,421 | 10,445 | 9,486 | 1,899 | 678 | 140 | -9 |
| 42 | 2041 | 40 | 6,421 | 10,445 | 9,486 | 1,899 | 678 | 140 | -9 |
| 43 | 2042 | 40 | 6,421 | 10,445 | 9,486 | 1,899 | 678 | 140 | -9 |
| 44 | 2043 | 40 | 6,421 | 10,445 | 9,486 | 1,899 | 678 | 140 | -9 |
| 45 | 2044 | 40 | 6,421 | 10,445 | 9,486 | 1,899 | 678 | 140 | -9 |
| 46 | 2045 | 40 | 6,421 | 10,445 | 9,486 | 1,899 | 678 | 140 | -9 |
| 47 | 2046 | 40 | 6,421 | 10,445 | 9,486 | 1,899 | 678 | 140 | -9 |
| 48 | 2047 | 40 | 6,421 | 10,445 | 9,486 | 1,899 | 678 | 140 | -9 |
| 49 | 2048 | 40 | 6,421 | 10,445 | 9,486 | 1,899 | 678 | 140 | -9 |
| 50 | 2049 | 40 | 6,421 | 10,445 | 9,486 | 1,899 | 678 | 140 | -9 |
| Total | | -284 | 277,761 | 374,776 | 322,816 | 56,741 | 19,874 | -5,072 | -2,175 |
| IRR | | -0.54% | 24.76% | 11.04% | 9.11% | 5.26% | 4.77% | -2.07% | - |
| B/C | | 0.18 | 2.92 | 1.10 | 0.91 | 0.57 | 0.51 | 0.14 | - |
| NPV (thousand US$ | | -1,793 | 32,601 | 6,413 | -5,880 | -12,010 | -5,544 | -9,878 | - |

Note : (1) Rate of annual growth of economic benefit until 2010 : 7.20% /year

(2) A discount rate at 10% per year is applied for deriving B/C ratio and net present value (NPV).

## Table F3-19 Expenditures of MPWT, MPP, DPWT and DSD

| Item | 1995 | 1996 | 1997 | Jan.-Aug. 1998 |
|---|---|---|---|---|
| **(Overall Comparison in million Riel)** | | | | |
| 1. Ministry of Public Works and Transport | 8,011 | 7,158 | 8,340 | 4,075 |
| 2. Total of national budget | 667,172 | 793,925 | 870,000 | 482,168 |
| 3. % of MPWT to total | 1.2 | 0.9 | 1.0 | 0.8 |
| 4. Municipality of Phnom Penh | 17,505 | 22,185 | 19,651 | n.a. |
| 5. Department of Public Works and Transport | 1,503 | 994 | 2,065 | n.a. |
| 6. Drainage and Sewerage Division | 313 | 333 | 384 | n.a. |
| **(Detail of DPWT's expenditure in Riel)** | | | | |
| 7. Salary for full-time workers | 370,364,206 | 340,695,191 | 326,991,521 | n.a. |
| 8. Salary for labors | 394,740,000 | 388,260,000 | 388,260,000 | n.a. |
| 9. Cultural and social expense | 4,411,720 | 5,223,130 | 12,056,920 | n.a. |
| 10. Administrative expenditure | 85,976,950 | 56,838,980 | 33,102,285 | n.a. |
| 11. Capital expenditure (big repairs) | 648,189,720 | 202,991,362 | 1,304,537,110 | n.a. |
| Total | 1,503,682,596 | 994,008,663 | 2,064,947,836 | - |
| **(Detail of DSD's expenditure in Riel)** | | | | |
| 12. Salary for full-time workers | 78,891,320 | 70,002,350 | 61,125,530 | n.a. |
| 13. Salary for labors | 62,100,000 | 62,100,000 | 62,100,000 | n.a. |
| 14. Cultural and social expense | 1,052,500 | 2,450,590 | 754,670 | |
| 15. Administrative | 0 | 0 | 0 | n.a. |
| 16. Maintenance and repair | 170,751,950 | 198,700,940 | 259,727,230 | n.a. |
| Total | 312,795,770 | 333,253,880 | 383,707,430 | - |
| **(Expenditure of DPWT by Source of Revenue in Riel)** | | | | |
| 17. Municipality of Phnom Penh(3) | 1,300,926,596 | 898,588,663 | 1,365,861,726 | n.a. |
| 18. Ministry of Public Works and Transport | 202,756,000 | 73,420,000 | 38,000,000 | n.a. |
| 19. Council of Minister | 0 | 22,000,000 | 0 | n.a. |
| 20. Department of Economy and Finance | 0 | 0 | 661,086,110 | n.a. |
| Total | 1,503,682,596 | 994,008,663 | 2,064,947,836 | n.a. |

Note :

(1) Abbreviations

MPWT : Ministry of Public Works and Transport

DPWT : Department of Public Works and Transport, Municipality of Phnom Penh

DSD : Drainage and Sewerage Division, Department of Public Works and Transport

(2) Original source of budget is the Ministry of Public Works and Transport

Source :

(1) Monthly Bulletin of Statistics September 1998, Ministry of Economy ad Finance

(2) Department of Public Works and Transport

## Table F3-20 Estimate of Central Government Revenue in 2010 and 2020

| Item | Unit | Growth Scenario | |
|---|---|---|---|
| | | Standard | Low |
| GDP growth rates | | | |
| 1996-1997 | %/year | 2.0 | 2.0 |
| 1996-2006/2010 (1) | %/year | 7.2 | 3.6 |
| 2010-2020 (2) | %/year | 5.0 | 2.0 |
| GDP in 1996 price level | | | |
| 1996 | million Riel | 8,200 | 8,200 |
| 2006 | million Riel | 15,637 | 11,499 |
| 2010 | million Riel | 22,138 | 13,723 |
| 2020 | million Riel | 36,060 | 16,728 |
| Proportion of government revenue to GDP | | | |
| 1996 | % | 9.1 | 9.1 |
| 2006 (2) | % | 16.9 | 9.1 |
| 2010 | % | 16.9 | 9.1 |
| 2020 | % | 20.0 | 12.0 |
| Government revenue | | | |
| 1996 | million Riel | 749 | 749 |
| 2006 | million Riel | 2,643 | 1,046 |
| 2010 | million Riel | 3,741 | 1,249 |
| 2020 | million Riel | 7,212 | 2,007 |
| Growth rate of government revenue | | | |
| 1996 - 2010 | %/year | 12.2 | 3.7 |
| 2010 - 2020 | %/year | 6.8 | 4.9 |

Note :

(1) Based on Socio-Economic Framework for standard growth scenario and half the standard scenario for the low growth sdenario.

(2) Assumed to be lower than the 1996-2006/2010 period.

Table F3-21 Estimate of DPWT and DSD's Revenue in 2010 and 2020

| Item | DPWT | | DSD | |
|---|---|---|---|---|
| | Standard | Low | Standard | Low |
| Growth Rates (%/year) | | | | |
| 1997-2010 | 12.2 | 3.7 | 12.2 | 3.7 |
| 2010-2020 | 6.8 | 4.9 | 6.8 | 4.9 |
| Projected Revenue | | | | |
| (Riel million) | | | | |
| 1997 | 1,521 | 1,521 | 343 | 343 |
| 2010 | 6,793 | 2,439 | 1,532 | 550 |
| 2020 | 13,115 | 3,935 | 2,958 | 887 |
| ($ million) | | | | |
| 1997 | 0.39 | 0.39 | 0.09 | 0.09 |
| 2010 | 1.75 | 0.63 | 0.39 | 0.14 |
| 2020 | 3.38 | 1.01 | 0.76 | 0.23 |

Note :

$1=Riel 3880 (mid point average in October 1998)

## Table F3-22 Estimated Revenue of PPWSA in 2010 and 2020

| Item | Value | Data as of : | Source |
|---|---|---|---|
| (1998) | | | |
| 1. Population of supplied area | 750,000 | August 1998 | (1) |
| 2. Total production | 3,511,911 $m^3$/month | August 1998 | (1) |
| 3. Number of connections | | | |
| Domestic | 36,138 | May-June 1998 | (1) |
| Commercial & industrial | 6,846 | May-June 1998 | (1) |
| Private wholesaler | 233 | May-June 1998 | (1) |
| Administrative | 411 | May-June 1998 | (1) |
| All | 43,628 | May-June 1998 | (1) |
| 4. Consumption | | | |
| Domestic | 1,630,589 $m^3$/2 months | May-June 1998 | (1) |
| Commercial & industrial | 758,912 $m^3$/2 months | May-June 1998 | (1) |
| Private wholesaler | 43,082 $m^3$/2 months | May-June 1998 | (1) |
| Administrative | 370,141 $m^3$/2 months | May-June 1998 | (1) |
| Free delivery | 4,770 $m^3$/2 months | May-June 1998 | (1) |
| All | 2,807,494 $m^3$/2 months | May-June 1998 | (1) |
| 5. Consumption per connection | | | |
| Domestic | 23 $m^3$/month/connection | May-June 1998 | (1) |
| Commercial & industrial | 55 $m^3$/month/connection | May-June 1998 | (1) |
| Private wholesaler | 92 $m^3$/month/connection | May-June 1998 | (1) |
| Administrative | 450 $m^3$/month/connection | May-June 1998 | (1) |
| All | 64 $m^3$/month/connection | May-June 1998 | (1) |
| 6. Revenue | 13.5 billion Riel | 1996 | (2) |
| 7. Net income before depreciation | 2.5 billion Riel | 1996 | (2) |
| 8. Net income after depreciation | -0.7 billion Riel | 1996 | (2) |
| (2007) | | | |
| 9. Operating Revenue | 53.1 billion Riel | 2007 | (2) |
| 10. Operating Expenses | 25.0 billion Riel | 2007 | (2) |
| 11. Net income | 10.6 billion Riel | 2007 | (2) |
| 12. Service connections | 90,397 | 2007 | (2) |
| 13. Average tariff | 1,359 Riel/$m^3$ | 2007 | (2) |
| (2010/2020) | | | |
| 14. Growth rate assumed for revenue | 3.2 %/year | 2007-2010 | (3) |
| 15. Operating Revenue in 2010 | 58.4 billion Riel | 2010 | (3) |
| 16. Growth rate assumed for revenue | 3.2 %/year | 2010-2020 | (3) |
| 17. Operating Revenue in 2020 | 80.0 billion Riel | 2020 | (3) |

Source :

(1) Phnom Penh Water Supply Authority

(2) Staff Appraisal Report, Kingdom of Cambodia, Urban Water Supply Project, January 12 1998 The International Development Association

(3) Assumption and estimate by JICA study team

## TableF4-1 Cost Benefit Stream for Priority Projects (Compnent 2) (1/3)

| No. | Year | Component 2 | | | | |
|---|---|---|---|---|---|---|
| | | Construction Cost | OMR Cost | Total | Benefit | B-C |
| 1 | 2000 | 164 | 0 | 164 | 0 | -164 |
| 2 | 2001 | 6,125 | 0 | 6,125 | 29 | -6,097 |
| 3 | 2002 | 5,230 | 19 | 5,249 | 1,186 | -4,063 |
| 4 | 2003 | 8,269 | 35 | 8,301 | 2,328 | -5,976 |
| 5 | 2004 | 0 | 59 | 59 | 4,287 | 4,228 |
| 6 | 2005 | 0 | 59 | 59 | 4,596 | 4,536 |
| 7 | 2006 | 0 | 59 | 59 | 4,926 | 4,867 |
| 8 | 2007 | 0 | 59 | 59 | 5,281 | 5,222 |
| 9 | 2008 | 0 | 59 | 59 | 5,661 | 5,602 |
| 10 | 2009 | 0 | 59 | 59 | 6,069 | 6,010 |
| 11 | 2010 | 0 | 59 | 59 | 6,506 | 6,447 |
| 12 | 2011 | 0 | 59 | 59 | 6,506 | 6,447 |
| 13 | 2012 | 0 | 59 | 59 | 6,506 | 6,447 |
| 14 | 2013 | 0 | 59 | 59 | 6,506 | 6,447 |
| 15 | 2014 | 0 | 59 | 59 | 6,506 | 6,447 |
| 16 | 2015 | 0 | 59 | 59 | 6,506 | 6,447 |
| 17 | 2016 | 0 | 59 | 59 | 6,506 | 6,447 |
| 18 | 2017 | 0 | 59 | 59 | 6,506 | 6,447 |
| 19 | 2018 | 0 | 59 | 59 | 6,506 | 6,447 |
| 20 | 2019 | 0 | 59 | 59 | 6,506 | 6,447 |
| 21 | 2020 | 0 | 59 | 59 | 6,506 | 6,447 |
| 22 | 2021 | 0 | 59 | 59 | 6,506 | 6,447 |
| 23 | 2022 | 0 | 59 | 59 | 6,506 | 6,447 |
| 24 | 2023 | 0 | 59 | 59 | 6,506 | 6,447 |
| 25 | 2024 | 0 | 59 | 59 | 6,506 | 6,447 |
| 26 | 2025 | 0 | 59 | 59 | 6,506 | 6,447 |
| 27 | 2026 | 0 | 59 | 59 | 6,506 | 6,447 |
| 28 | 2027 | 0 | 59 | 59 | 6,506 | 6,447 |
| 29 | 2028 | 0 | 59 | 59 | 6,506 | 6,447 |
| 30 | 2029 | 0 | 59 | 59 | 6,506 | 6,447 |
| 31 | 2030 | 0 | 59 | 59 | 6,506 | 6,447 |
| 32 | 2031 | 0 | 59 | 59 | 6,506 | 6,447 |
| 33 | 2032 | 0 | 59 | 59 | 6,506 | 6,447 |
| 34 | 2033 | 0 | 59 | 59 | 6,506 | 6,447 |
| 35 | 2034 | 0 | 59 | 59 | 6,506 | 6,447 |
| 36 | 2035 | 0 | 59 | 59 | 6,506 | 6,447 |
| 37 | 2036 | 0 | 59 | 59 | 6,506 | 6,447 |
| 38 | 2037 | 0 | 59 | 59 | 6,506 | 6,447 |
| 39 | 2038 | 0 | 59 | 59 | 6,506 | 6,447 |
| 40 | 2039 | 0 | 59 | 59 | 6,506 | 6,447 |
| 41 | 2040 | 0 | 59 | 59 | 6,506 | 6,447 |
| 42 | 2041 | 0 | 59 | 59 | 6,506 | 6,447 |
| 43 | 2042 | 0 | 59 | 59 | 6,506 | 6,447 |
| 44 | 2043 | 0 | 59 | 59 | 6,506 | 6,447 |
| 45 | 2044 | 0 | 59 | 59 | 6,506 | 6,447 |
| 46 | 2045 | 0 | 59 | 59 | 6,506 | 6,447 |
| 47 | 2046 | 0 | 59 | 59 | 6,506 | 6,447 |
| 48 | 2047 | 0 | 59 | 59 | 6,506 | 6,447 |
| 49 | 2048 | 0 | 59 | 59 | 6,506 | 6,447 |
| 50 | 2049 | 0 | 59 | 59 | 6,506 | 6,447 |
| Total | | 19,788 | 2,785 | 22,573 | 294,603 | 272,030 |

| | | | |
|---|---|---|---|
| OMR cost = | 0.3% | EIRR | 25.16% |
| Rate of growth of benefit until 2010 | 7.2% /year | B/C | 2.76 |
| Discount rate : 10%/year | | NPV ($10^3$$) | 29,475 |

## TableF4-1 Cost Benefit Stream for Priority Projects (Compnent 3) (2/3)

| No. | Year | Component 3 | | | | |
|---|---|---|---|---|---|---|
| | | Construction Cost | OMR Cost | Total | Benefit | B-C |
| 1 | 2000 | 800 | 0 | 800 | 0 | -800 |
| 2 | 2001 | 6,424 | 4 | 6,428 | 58 | -6,370 |
| 3 | 2002 | 8,229 | 36 | 8,265 | 566 | -7,699 |
| 4 | 2003 | 4,406 | 77 | 4,483 | 1,298 | -3,185 |
| 5 | 2004 | 6,713 | 99 | 6,812 | 1,788 | -5,024 |
| 6 | 2005 | 6,713 | 133 | 6,846 | 2,565 | -4,281 |
| 7 | 2006 | 6,954 | 166 | 7,120 | 3,445 | -3,676 |
| 8 | 2007 | 7,451 | 201 | 7,652 | 4,464 | -3,188 |
| 9 | 2008 | 0 | 238 | 238 | 5,672 | 5,433 |
| 10 | 2009 | 0 | 238 | 238 | 6,080 | 5,842 |
| 11 | 2010 | 0 | 238 | 238 | 6,518 | 6,280 |
| 12 | 2011 | 0 | 238 | 238 | 6,518 | 6,280 |
| 13 | 2012 | 0 | 238 | 238 | 6,518 | 6,280 |
| 14 | 2013 | 0 | 238 | 238 | 6,518 | 6,280 |
| 15 | 2014 | 0 | 238 | 238 | 6,518 | 6,280 |
| 16 | 2015 | 0 | 238 | 238 | 6,518 | 6,280 |
| 17 | 2016 | 0 | 238 | 238 | 6,518 | 6,280 |
| 18 | 2017 | 0 | 238 | 238 | 6,518 | 6,280 |
| 19 | 2018 | 0 | 238 | 238 | 6,518 | 6,280 |
| 20 | 2019 | 0 | 238 | 238 | 6,518 | 6,280 |
| 21 | 2020 | 0 | 238 | 238 | 6,518 | 6,280 |
| 22 | 2021 | 0 | 238 | 238 | 6,518 | 6,280 |
| 23 | 2022 | 0 | 238 | 238 | 6,518 | 6,280 |
| 24 | 2023 | 0 | 238 | 238 | 6,518 | 6,280 |
| 25 | 2024 | 0 | 238 | 238 | 6,518 | 6,280 |
| 26 | 2025 | 0 | 238 | 238 | 6,518 | 6,280 |
| 27 | 2026 | 0 | 238 | 238 | 6,518 | 6,280 |
| 28 | 2027 | 0 | 238 | 238 | 6,518 | 6,280 |
| 29 | 2028 | 0 | 238 | 238 | 6,518 | 6,280 |
| 30 | 2029 | 0 | 238 | 238 | 6,518 | 6,280 |
| 31 | 2030 | 0 | 238 | 238 | 6,518 | 6,280 |
| 32 | 2031 | 0 | 238 | 238 | 6,518 | 6,280 |
| 33 | 2032 | 0 | 238 | 238 | 6,518 | 6,280 |
| 34 | 2033 | 0 | 238 | 238 | 6,518 | 6,280 |
| 35 | 2034 | 0 | 238 | 238 | 6,518 | 6,280 |
| 36 | 2035 | 0 | 238 | 238 | 6,518 | 6,280 |
| 37 | 2036 | 0 | 238 | 238 | 6,518 | 6,280 |
| 38 | 2037 | 0 | 238 | 238 | 6,518 | 6,280 |
| 39 | 2038 | 0 | 238 | 238 | 6,518 | 6,280 |
| 40 | 2039 | 0 | 238 | 238 | 6,518 | 6,280 |
| 41 | 2040 | 0 | 238 | 238 | 6,518 | 6,280 |
| 42 | 2041 | 0 | 238 | 238 | 6,518 | 6,280 |
| 43 | 2042 | 0 | 238 | 238 | 6,518 | 6,280 |
| 44 | 2043 | 0 | 238 | 238 | 6,518 | 6,280 |
| 45 | 2044 | 0 | 238 | 238 | 6,518 | 6,280 |
| 46 | 2045 | 0 | 238 | 238 | 6,518 | 6,280 |
| 47 | 2046 | 0 | 238 | 238 | 6,518 | 6,280 |
| 48 | 2047 | 0 | 238 | 238 | 6,518 | 6,280 |
| 49 | 2048 | 0 | 238 | 238 | 6,518 | 6,280 |
| 50 | 2049 | 0 | 238 | 238 | 6,518 | 6,280 |
| Total | | 47,690 | 10,732 | 58,422 | 286,658 | 228,236 |

| | | | |
|---|---|---|---|
| OMR cost = | 0.5% | | |
| Rate of growth of benefit until 2010 | 7.2% /year | EIRR | 11.69% |
| Discount rate : 10%/year | | B/C | 1.17 |
| | | NPV ($10^3$S) | 5,909 |

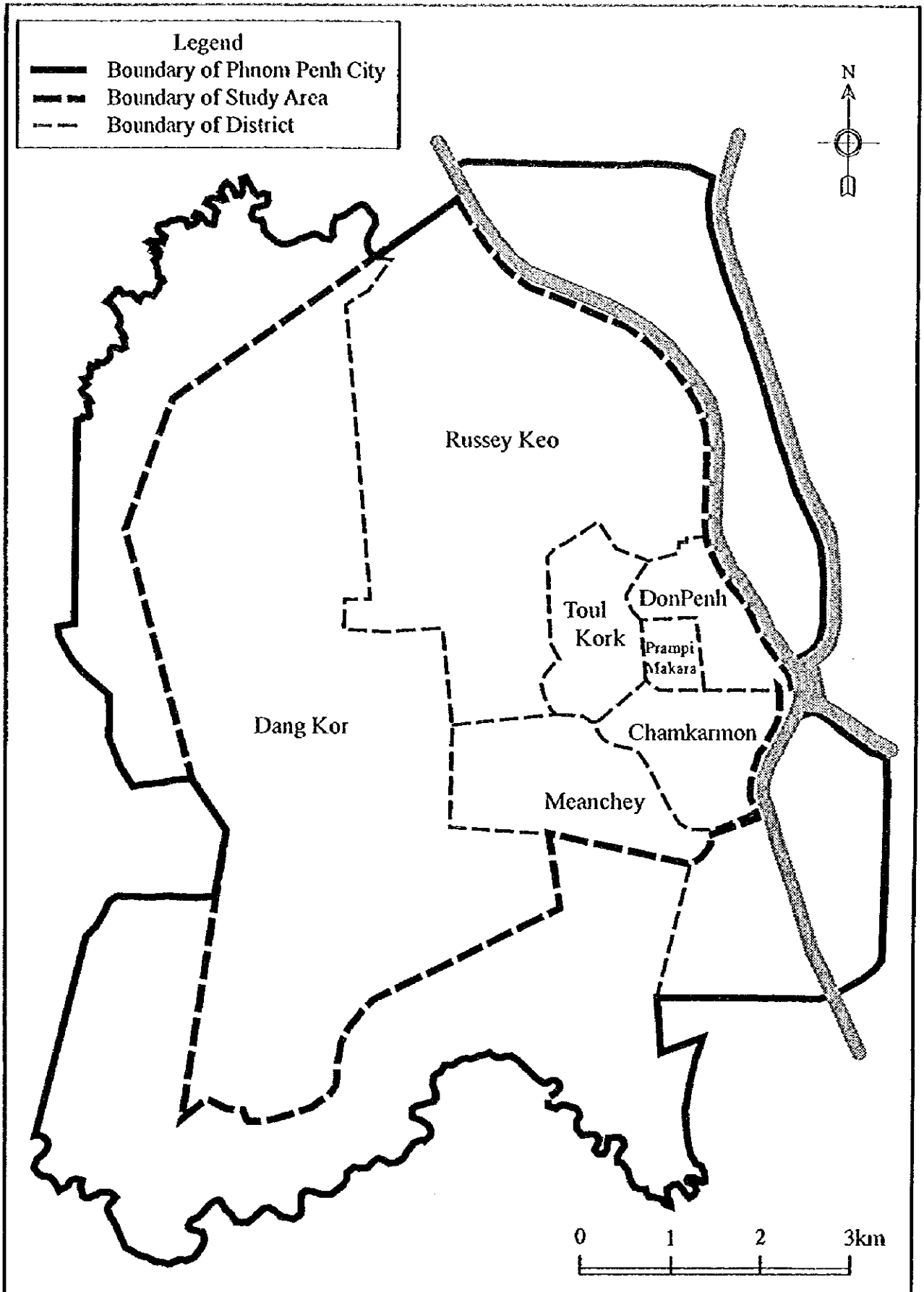
**TableF4-1 Cost Benefit Stream for Priority Projects (Compnent 2 plus 3) (3/3)**

| No. | Year | Component 2 plus 3 | | | | |
|---|---|---|---|---|---|---|
| | | Construction Cost | OMR Cost | Total cost | Benefit | B-C |
| 1 | 2000 | 964 | 0 | 964 | 0 | -964 |
| 2 | 2001 | 12,549 | 4 | 12,553 | 87 | -12,466 |
| 3 | 2002 | 13,459 | 55 | 13,514 | 1,752 | -11,762 |
| 4 | 2003 | 12,675 | 112 | 12,787 | 3,626 | -9,161 |
| 5 | 2004 | 6,713 | 159 | 6,872 | 6,075 | -796 |
| 6 | 2005 | 6,713 | 192 | 6,905 | 7,161 | 256 |
| 7 | 2006 | 6,954 | 226 | 7,180 | 8,371 | 1,191 |
| 8 | 2007 | 7,451 | 261 | 7,712 | 9,745 | 2,034 |
| 9 | 2008 | 0 | 298 | 298 | 11,333 | 11,035 |
| 10 | 2009 | 0 | 298 | 298 | 12,149 | 11,851 |
| 11 | 2010 | 0 | 298 | 298 | 13,024 | 12,726 |
| 12 | 2011 | 0 | 298 | 298 | 13,024 | 12,726 |
| 13 | 2012 | 0 | 298 | 298 | 13,024 | 12,726 |
| 14 | 2013 | 0 | 298 | 298 | 13,024 | 12,726 |
| 15 | 2014 | 0 | 298 | 298 | 13,024 | 12,726 |
| 16 | 2015 | 0 | 298 | 298 | 13,024 | 12,726 |
| 17 | 2016 | 0 | 298 | 298 | 13,024 | 12,726 |
| 18 | 2017 | 0 | 298 | 298 | 13,024 | 12,726 |
| 19 | 2018 | 0 | 298 | 298 | 13,024 | 12,726 |
| 20 | 2019 | 0 | 298 | 298 | 13,024 | 12,726 |
| 21 | 2020 | 0 | 298 | 298 | 13,024 | 12,726 |
| 22 | 2021 | 0 | 298 | 298 | 13,024 | 12,726 |
| 23 | 2022 | 0 | 298 | 298 | 13,024 | 12,726 |
| 24 | 2023 | 0 | 298 | 298 | 13,024 | 12,726 |
| 25 | 2024 | 0 | 298 | 298 | 13,024 | 12,726 |
| 26 | 2025 | 0 | 298 | 298 | 13,024 | 12,726 |
| 27 | 2026 | 0 | 298 | 298 | 13,024 | 12,726 |
| 28 | 2027 | 0 | 298 | 298 | 13,024 | 12,726 |
| 29 | 2028 | 0 | 298 | 298 | 13,024 | 12,726 |
| 30 | 2029 | 0 | 298 | 298 | 13,024 | 12,726 |
| 31 | 2030 | 0 | 298 | 298 | 13,024 | 12,726 |
| 32 | 2031 | 0 | 298 | 298 | 13,024 | 12,726 |
| 33 | 2032 | 0 | 298 | 298 | 13,024 | 12,726 |
| 34 | 2033 | 0 | 298 | 298 | 13,024 | 12,726 |
| 35 | 2034 | 0 | 298 | 298 | 13,024 | 12,726 |
| 36 | 2035 | 0 | 298 | 298 | 13,024 | 12,726 |
| 37 | 2036 | 0 | 298 | 298 | 13,024 | 12,726 |
| 38 | 2037 | 0 | 298 | 298 | 13,024 | 12,726 |
| 39 | 2038 | 0 | 298 | 298 | 13,024 | 12,726 |
| 40 | 2039 | 0 | 298 | 298 | 13,024 | 12,726 |
| 41 | 2040 | 0 | 298 | 298 | 13,024 | 12,726 |
| 42 | 2041 | 0 | 298 | 298 | 13,024 | 12,726 |
| 43 | 2042 | 0 | 298 | 298 | 13,024 | 12,726 |
| 44 | 2043 | 0 | 298 | 298 | 13,024 | 12,726 |
| 45 | 2044 | 0 | 298 | 298 | 13,024 | 12,726 |
| 46 | 2045 | 0 | 298 | 298 | 13,024 | 12,726 |
| 47 | 2046 | 0 | 298 | 298 | 13,024 | 12,726 |
| 48 | 2047 | 0 | 298 | 298 | 13,024 | 12,726 |
| 49 | 2048 | 0 | 298 | 298 | 13,024 | 12,726 |
| 50 | 2049 | 0 | 298 | 298 | 13,024 | 12,726 |
| Total | | 67,478 | 13,517 | 80,995 | 581,260 | 500,266 |

| | | | |
|---|---|---|---|
| OMR cost = | 0.5% | | |
| Rate of growth of benefit until 2010 | 7.2% /year | EIRR | 16.67% |
| Discount rate : 10%/year | | B/C | 1.69 |
| | | NPV ($10^3$S) | 35,384 |

## Table F4-2 O/M Cost of Priority Projects Compared with DDS's Revenue Since 2008

| | | | |
|---|---|---|---|
| a. Operation and maintenance costs since 2008 | | | |
| a-1 Investment cost | | | |
| Component 2 | 20.80 | US$ million | |
| Component 3 | 50.80 | US$ million | |
| Total | 71.60 | US$ million | |
| a-2 Proportion of OM costs | | | |
| Component 2 | 0.30% | | |
| Component 3 | 0.50% | | |
| a-3 Operation and maintenance costs since 2008 | | | |
| Component 2 | 0.06 | US$ million/year | |
| Component 3 | 0.25 | US$ million/year | |
| Total | 0.32 | US$ million/year | |
| b. Revenue for DSD | | | |
| b-1 DSD's revenue | | | |
| 1997 | 0.09 | US$ million/year | |
| 2010 | 0.39 | US$ million/year | |
| 2008 | 0.34 | US$ million/year | |
| b-1 Revenue from wastewater surcharge | | | |
| PPWSA's revenue in 1996 | 13.5 | Riel billion | |
| PPWSA's revenue in 2007 | 53.1 | Riel billion | |
| PPWSA's revenue in 2008 | 54.8 | Riel billion | (An increase of 3.2% over 2007) |
| Wastewater surcharge for DSD in 2008 | 5.5 | Riel billion | (10% of PPWSA's water sale) |
| | 1.41 | US$ million | ($: 3,880 Riel) |
| c. Comparison in 2008 | | | |
| DSD's revenue by government budget | 0.34 | US$ million | |
| Wastewater surcharg revenue | 1.41 | US$ million | |
| **DSD's total revenue** | **1.76** | **US$ million** | |
| **Total OM cost required since 2008** | **0.32** | **US$ million** | |
| **Balance** | **1.44** | **US$ million** | |




| | |
|---|---|
| The Study on Drainage Improvement and Flood Control in the Municipality of Phnom Penh<br>JICA - CTIE International Co., Ltd. - Nippon Koei Co., Ltd. | Figure F2-1<br>Boundaries of Phnom Penh City, Study Area and Districts |

## Appendix 1 (1/5)
## Settlement Densities by Land Use Type

| Land use type | | 1998 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Household | | Factories | | Shops | | Offices | |
| | | Number of meshes in 1998 | Number in a mesh | Total number | Number in a mesh | Total number | Number in a mesh | Total number | Number in a mesh | Total number |
| 0 | Out of study area | 4,922 | - | - | - | - | - | - | - | - |
| 1 | Dense activities | 89 | 3.2 | 285 | 2.00 | 178 | 2.0 | 179 | 0.2 | 22 |
| 2 | Dense urban center | 151 | 500.0 | 75,500 | 0.50 | 76 | 11.9 | 1,792 | 2.6 | 391 |
| 3 | Dense residential | 278 | 160.0 | 44,480 | 1.00 | 278 | 3.2 | 896 | 0.1 | 22 |
| 4 | Loose residential | 827 | 16.0 | 13,232 | 0.00 | 0 | 0.4 | 358 | 0.0 | 0 |
| 5 | Loose activities | 190 | 3.2 | 608 | 0.00 | 0 | 0.9 | 179 | 0.0 | 0 |
| 6 | Agriculture land, unused land | 2,917 | 3.0 | 8,751 | 0.00 | 0 | 0.1 | 179 | 0.0 | 0 |
| 7 | Green space, park | 44 | 0.0 | 0 | 0.00 | 0 | 0.0 | 0 | 0.0 | 0 |
| 8 | Fish pond | 14 | 3.0 | 42 | 0.00 | 0 | 0.0 | 0 | 0.0 | 0 |
| 9 | Lakes, pond, river | 396 | 0.0 | 0 | 0.00 | 0 | 0.0 | 0 | 0.0 | 0 |
| Sum of 1 to 9 | | 9,828 | - | 142,898 | - | 532 | - | 3,584 | - | 438 |
| Total derived from survey and statistics | | | | 143,000 | | 535 | | 3,584 | | 438 |

| Land use type | | 1998 | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | Warehouse | | School | | Hospital | |
| | | Number of meshes in 1998 | Number in a mesh | Total number | Number in a mesh | Total number | Number in a mesh | Total number |
| 0 | Out of study area | 4,922 | - | - | - | - | - | - |
| 1 | Dense activities | 89 | 0.08 | 7 | 0.002 | 0 | 0.000 | 0 |
| 2 | Dense urban center | 151 | 0.80 | 121 | 0.368 | 55 | 0.079 | 12 |
| 3 | Dense residential | 278 | 0.02 | 7 | 0.118 | 33 | 0.043 | 12 |
| 4 | Loose residential | 827 | 0.00 | 0 | 0.012 | 10 | 0.000 | 0 |
| 5 | Loose activities | 190 | 0.00 | 0 | 0.002 | 0 | 0.000 | 0 |
| 6 | Agriculture land, unused land | 2,917 | 0.00 | 0 | 0.002 | 6 | 0.000 | 0 |
| 7 | Green space, park | 44 | 0.00 | 0 | 0.000 | 0 | 0.000 | 0 |
| 8 | Fish pond | 14 | 0.00 | 0 | 0.000 | 0 | 0.000 | 0 |
| 9 | Lakes, pond, river | 396 | 0.00 | 0 | 0.000 | 0 | 0.000 | 0 |
| Sum of 1 to 9 | | 9,828 | - | 134 | - | 105 | - | 24 |
| Total derived from survey and statistics | | | | 134 | | 105 | | 24 |

## Appendix I (2/5)
## Settlement Densities by Land Use Type

| Land use type | | 2010 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Household | | Factories | | Shops | | Offices | |
| | | Number of meshes in 1998 | Number in a mesh | Total number | Number in a mesh | Total number | Number in a mesh | Total number | Number in a mesh | Total number |
| 0 | Out of study area | 4,922 | - | - | - | - | - | - | - | - |
| 1 | Dense activities | 134 | 3.5 | 468 | 2.2 | 290 | 2.1 | 284 | 0.3 | 39 |
| 2 | Dense urban center | 178 | 546.0 | 97,188 | 0.5 | 96 | 12.5 | 2,227 | 3.1 | 556 |
| 3 | Dense residential | 453 | 174.7 | 79,148 | 1.1 | 491 | 3.4 | 1,539 | 0.1 | 43 |
| 4 | Loose residential | 1,407 | 17.5 | 24,583 | 0.0 | 0 | 0.5 | 643 | 0.0 | 0 |
| 5 | Loose activities | 416 | 3.5 | 1,454 | 0.0 | 0 | 1.0 | 414 | 0.0 | 0 |
| 6 | Agriculture land, unused land | 1,869 | 3.3 | 6,123 | 0.0 | 0 | 0.1 | 121 | 0.0 | 0 |
| 7 | Green space, park | 44 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 |
| 8 | Fish pond | 14 | 3.3 | 46 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 |
| 9 | Lakes, pond, river | 391 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 |
| Sum of 1 to 9 | | 9,828 | - | 209,010 | - | 878 | - | 5,227 | - | 638 |
| Total derived from survey and statistics | | | | 209,000 | | 878 | | 5,225 | | 639 |

| Land use type | | 2010 | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | Warehouse | | School | | Hospital | |
| | | Number of meshes in 1998 | Number in a mesh | Total number | Number in a mesh | Total number | Number in a mesh | Total number |
| 0 | Out of study area | 4,922 | - | - | - | - | - | - |
| 1 | Dense activities | 134 | 0.09 | 12 | 0.003 | 0 | 0.000 | 0 |
| 2 | Dense urban center | 178 | 0.95 | 170 | 0.400 | 71 | 0.096 | 17 |
| 3 | Dense residential | 453 | 0.03 | 13 | 0.128 | 58 | 0.038 | 17 |
| 4 | Loose residential | 1,407 | 0.00 | 0 | 0.013 | 18 | 0.000 | 0 |
| 5 | Loose activities | 416 | 0.00 | 0 | 0.003 | 1 | 0.000 | 0 |
| 6 | Agriculture land, unused land | 1,869 | 0.00 | 0 | 0.002 | 4 | 0.000 | 0 |
| 7 | Green space, park | 44 | 0.00 | 0 | 0.000 | 0 | 0.000 | 0 |
| 8 | Fish pond | 14 | 0.00 | 0 | 0.000 | 0 | 0.000 | 0 |
| 9 | Lakes, pond, river | 391 | 0.00 | 0 | 0.000 | 0 | 0.000 | 0 |
| Sum of 1 to 9 | | 9,828 | - | 195 | - | 153 | - | 34 |
| Total derived from survey and statistics | | | | 195 | | 153 | | 35 |

# Appendix I (3/5)
# Settlement Densities by Land Use Type (Assumptions)

(Household)

The number in a mesh for 2, 3. And 6. are derived from data collected.

Densities for the other land uses are assumed as follows.

1. : assumed same as loose activities

4. : assumed at .10% of dense residential

5. : Assumed at 20% of loose residential

7 and 9. : no household assumed

8. : assumed same as agriculture area

143,000 in 1998 = $(1{,}000*10^3/872*10^3)*(151*10^4)*82\%$

The number of household in a mesh is assumed to rise by :

9.2% per year

to control for the total of all land use types to become consistent with the total estimated based on Socio-Economic Framework.

(The remaining growth in the number of total households will result from the change in land use of a mesh.)

Annual average growth rate of household:

3.2% per year between 1998 and 2010.

(consistent with the population growth rate in the Socio-Economic Framework.)

(Factories) (Total number of factories in 1998)

| | Phnom Penh | Share of study area | Study area | |
|---|---|---|---|---|
| Those with equal or more than 10 workers : | 181 | 100% | 181 | * (only in 1. Dense activities) |
| Those with less than 10 workers : | 432 | 82% | 354 | (in 2. Dense urban activities and 3. Dense residential activities) |
| Total : | 613 | - | 535 | |

* The number of factories with equal or more than 10 workers in 1998 is estimated based on the number in 1993 at 123 and the following annual growth rates of the GRDP's industrial sector.

1993-94 : 15.3%, 1994-95 : 9.5%, 1995-96 : 15.0%, 1996-97 : 0.6%, 1997-98 : 0.6%. -> 1993-98 : 8.0%/year on average

The number of factories in all meshes are assumed to rise by : 0.67%

(Shops) Total number of shops in 1998 :

| | |
|---|---|
| Phnom Penh | 4,371 |
| Share of Study Area | 82% |
| Number of shops in the Study Area | 3,584 |
| Assumed allocation to land uses : | |
| Dense activities | 5% |
| Dense urban center | 50% |
| Dense residential | 25% |
| Loose residential | 10% |
| Loose activities | 5% |
| Agriculture land, unused land | 5% |
| Green space, park | 0% |
| Fish pond | 0% |
| Lakes, pond, river | 0% |
| Total | 100% |

The number of shops in all meshes are assumed to ri 0.44% per year

to control for the total of all land use types to become consistent with the total estimated based on Socio-Economic Framework.

# Appendix I (4/5)
# Settlement Densities by Land Use Type (Assumptions)

**(Offices)** Total number of offices in 1998:

| | |
|---|---|
| Phnom Penh | 534 |
| Share of Study Area | 82% |
| Number of offies in the Study Area | 438 |

Assumed allocation to land uses :

| | |
|---|---|
| Dense activities | 5% |
| Dense urban center | 90% |
| Dense residential | 5% |
| Loose residential | 0% |
| Loose activities | 0% |
| Agriculture land, unused land | 0% |
| Green space, park | 0% |
| Fish pond | 0% |
| Lakes, pond, river | 0% |
| Total | 100% |

The number of offices in all meshes are assumed to rise by :

1.5% per year

to control for the total of all land use types to become consistent with the total estimated based on Socio-Economic Framework.

**(Warehouses)**

Total number of warehouses :

| | |
|---|---|
| Phnom Penh | 164 |
| Share of Study Area | 82% |
| Number of warehouses in the Study Area | 134 |

Assumed allocation to land uses :

| | |
|---|---|
| Dense activities | 5% |
| Dense urban center | 90% |
| Dense residential | 5% |
| Loose residential | 0% |
| Loose activities | 0% |
| Agriculture land, unused land | 0% |
| Green space, park | 0% |
| Fish pond | 0% |
| Lakes, pond, river | 0% |
| Total | 100% |

The number of warehouses in all meshes are assumed to rise b 1.5% per year to control for the total of all land use types to become consistent with the total estimated based on Socio-Economic Framework.

# Appendix I (5/5)
# Settlement Densities by Land Use Type (Assumptions)

(Schools) Assumed allocation to land uses (in proportion to household distribution):

| | (1998) | (2010) |
|---|---|---|
| Total number of schools : | | |
| Phnom Penh | 128 | 187 |
| Share of Study Area | 82% | 82% |
| Number of schools in the Study Area | 105 | 153 |
| Dense activities | 0.2% | 0.2% |
| Dense urban center | 52.9% | 46.5% |
| Dense residential | 31.1% | 37.9% |
| Loose residential | 9.3% | 11.8% |
| Loose activities | 0.4% | 0.7% |
| Agriculture land, unused land | 6.1% | 2.9% |
| Green space, park | 0.0% | 0.0% |
| Fish pond | 0.0% | 0.0% |
| Lakes, pond, river | 0.0% | 0.0% |
| Total | 100.0% | 100.0% |

Annual growth rate of schools :

3.2% %/year between 1998 and 2010. (consisten with the population growth rate set in the Socio-Economic Framework.)

(Hospitals) Allocation to land uses (in proportion to household distribution):

| | (1998) | (2010) |
|---|---|---|
| Total number of hospitals | | |
| Phnom Penh | 29 | 42 |
| Share of Study Area | 82% | 82% |
| Number of hospitals in the Study Area | 24 | 34 |
| Dense activities | 0.0% | 0.0% |
| Dense urban center | 50.0% | 50.0% |
| Dense residential | 50.0% | 50.0% |
| Loose residential | 0.0% | 0.0% |
| Loose activities | 0.0% | 0.0% |
| Agriculture land, unused land | 0.0% | 0.0% |
| Green space, park | 0.0% | 0.0% |
| Fish pond | 0.0% | 0.0% |
| Lakes, pond, river | 0.0% | 0.0% |
| Total | 100.0% | 100.0% |

Annual growth r

3.2% %/year between 1998 and 2010. (consistent with the population gorwth rate set in the Socio-Economic Framework.)

## Appendix II
## Summary of Results of Asset and Flood Damage Survey (AFDS)

| Item | Unit | Type of interviewees | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Household | Shop | Office | Factory | Warehouse | School | Hospital | Farm | Livestock | Fishpond |
| Number of samples surveyed | | 416 | 121 | 11 | 16 | 10 | 17 | 9 | 102 | 30 | 20 |
| Number of household members/ employees/students/patients | | 6.5 | 6.2 | 22 | 5 | 3 | 2,624 | 132 | 6.6 | 6.9 | 4.4 |
| Annual income in 1997 | $ | 1,091 | 1,268 | 6,000 | 23,832 | 39,673 | - | n.a | 873 | 1,929 | 6,823 |
| Size of land | $m^2$ | 177 | 64 | 1,536 | 511 | 317 | 6,962 | 6,696 | 13,802 | 1,360 | 4,724 |
| Floor area | $m^2$ | 105 | 32 | 424 | 239 | 205 | 2,154 | n.a | - | - | - |
| Frequency of flood | | | | | | | | | | | |
| No flood | % | 0.2 | 0.0 | 27.3 | 18.8 | 21.6 | 0.0 | 62.5 | 46.1 | 93.3 | 80.0 |
| Once a year | % | 59.6 | 59.5 | 18.2 | 50.0 | 32.4 | 11.8 | 0.0 | 37.3 | 3.3 | 20.0 |
| two to five times a year | % | 19.0 | 27.3 | 0.0 | 6.3 | 5.4 | 11.8 | 0.0 | 1.0 | 3.3 | 0.0 |
| More | % | 21.2 | 13.2 | 54.6 | 25.0 | 40.5 | 76.5 | 37.5 | 15.7 | 0.0 | 0.0 |
| Height of floor level | meter | 0.54 | 0.29 | 0.39 | 0.18 | 0.12 | 0.72 | n.a | - | - | - |
| Water depth at inundation | | | | | | | | | | | |
| 1995 | meter | 0.62 | 0.39 | 0.41 | 0.52 | 0.36 | 0.57 | 0.57 * | 1.1 | 0.55 | 1.12 |
| 1996 | meter | 0.60 | 0.35 | 0.39 | 0.57 | 0.34 | 0.53 | 0.57 * | 1.2 | 0.55 | 0.00 |
| Duration of inundation | | | | | | | | | | | |
| 1995 | days | 22 | 18 | 3 | 14 | 10 | 13 | 6 * | 80 | 23 | 38 |
| 1996 | days | 21 | 14 | 3 | 8 | 7 | 10 | 6 * | 80 | 23 | 0 |
| Suffer from flood | | | | | | | | | | | |
| No answer | % | 9.6 | 0.0 | 9.1 | 0.0 | 0.0 | 0.0 | 0.0 * | 46.1 | 0.0 | 80.0 |
| Severely | % | 23.3 | 37.2 | 63.6 | 56.3 | 40.0 | 94.1 | 100.0 * | 10.8 | 6.7 | 10.0 |
| Lightly | % | 41.8 | 43.0 | 9.1 | 37.5 | 60.0 | 5.9 | 0.0 * | 24.5 | 0.0 | 5.0 |
| No | % | 25.2 | 19.8 | 18.2 | 6.3 | 0.0 | 0.0 | 0.0 * | 18.6 | 93.3 | 5.0 |
| Damage in utility/infrastructure in 1996 | | | | | | | | | | | |
| Power | % | 1.2 | 0.0 | 0.0 | 6.3 | 0.0 | 0.0 | 0.0 | - | - | - |
| Telephone | % | 0.0 | 0.0 | 0.0 | 6.3 | 0.0 | 0.0 | 0.0 | - | - | - |
| Water | % | 32.5 | 21.5 | 0.0 | 18.8 | 10.0 | 0.0 | 12.5 | - | - | - |
| Transportation | % | 31.3 | 17.4 | 45.5 | 12.5 | 10.0 | 82.4 | 25.0 | - | - | - |
| Flood damage in monetary value | | | | | | | | | | | |
| 1995 | $ | 341 | 235 | 1,077 | 2,153 | 914 | 3,067 | n.a | 230 | n.a | 9,245 |
| 1996 | $ | 143 | 107 | 10,050 | 517 | 1,054 | 6,571 | n.a | 104 | n.a | 0 |
| Expectation for flood mitigation | | | | | | | | | | | |
| Strongly support | % | 51.7 | 48.8 | 100.0 | 68.8 | 40.0 | 94.1 | 28.6 * | 24.5 | 16.7 | 10.0 |
| Support | % | 44.5 | 47.1 | 0.0 | 25.0 | 60.0 | 5.9 | 0.0 * | 75.5 | 83.3 | 0.0 |
| No need | % | 3.9 | 4.1 | 0.0 | 6.3 | 0.0 | 0.0 | 71.4 * | 0.0 | 0.0 | 90.0 |
| Other | | | | | | | | | | | |
| Closure of shop/stop operation in 1996 | days | - | 6 | 0 | 16 | 0 | n.a | 0 | - | - | - |
| Total number in Phnom Penh | No. | - | 4,371 | 534 | 613 | 164 | 128 | 29 | - | - | - |

Note :
(1) The values above are all average values except for percentages.
(2) The values with * are the averages of the samples with effective information only.
Source : Asset and Flood Damage Survey conducted by TEAM Consulting Engineers Co.,Ltd.

# Appendix III (1/7)
## Average Value of Assets Owned in 1998 (Household)

| Asset | Rate of prevalence (%) | Number of assets per household | Average number per household | Surveyed prices (US$) | | | | | Average asset value per household |
|---|---|---|---|---|---|---|---|---|---|
| | | | | New | | Used | | 50% of average of "new" | |
| | | | | Low | High | Low | High | | |
| Carpet (1) | 2.16 | 1 | 0.02 | 40 | 60 | n.a. | n.a. | 25 | 0.5 |
| Desk/table | 80.29 | 2 | 1.61 | 22 | 281 | 75 | 110 | 76 | 121.6 |
| Chairs | 80.29 | 6 | 4.82 | 3 | 18 | n.a. | n.a. | 5 | 25.1 |
| Cupboard | 54.57 | 1 | 0.55 | 16 | 85 | n.a. | n.a. | 25 | 13.8 |
| Chest or drawers (2) | 27.16 | 2 | 0.54 | 46 | 250 | n.a. | n.a. | 74 | 40.2 |
| Bed | 90.87 | 5 | 4.54 | 9 | 70 | n.a. | n.a. | 20 | 89.7 |
| Television | 68.27 | 1 | 0.68 | 275 | 1,050 | 350 | 600 | 331 | 226.1 |
| Radio | 59.13 | 1 | 0.59 | 4 | 100 | n.a. | n.a. | 26 | 15.4 |
| Refrigerator | 4.81 | 1 | 0.05 | 130 | 330 | 170 | | 115 | 5.5 |
| Motorcycle | 66.59 | 1 | 0.67 | 950 | 1,400 | 250 | 850 | 588 | 391.2 |
| Car (3) | 7.21 | 1 | 0.07 | n.a. | n.a. | 1,200 | 7,500 | 2,175 | 156.8 |
| Bicycle | 44.47 | 2 | 0.89 | 85 | 97 | 17 | 35 | 46 | 40.5 |
| Computer | 0.00 | 1 | 0.00 | 450 | 2,500 | n.a. | n.a. | 738 | 0.0 |
| | | | | Average total asset value per household : | | | | | $1,126 |
| | | | | Average number of stories : | | | | | 1.4 |
| | | | | Asset value to be damaged by inundation : | | | | | $805 |
| | | | | | | | | (rounded) | $800 |

Note :
(1) 10m² assumed for a carpet
(2) Prices checked as wardrobe/cabinet
(3) Average price of used cars applied.
Source :
(1) Ownership of assets : Asset and Flood Damage Survey by TEAM Consulting Engineers Co.,Ltd.
(2) Prices of assets : surveyed by JICA study team in June 1998 in Phnom Penh

## Appendix III (2/7)
## Average Value of Assets Owned in 1998 (Shop : only independent shop)

| Asset | Rate of prevalence (%) | Number of assets per shop | Average number per shop | Surveyed prices (US$) | | | | | Average asset value per shop |
|---|---|---|---|---|---|---|---|---|---|
| | | | | New | | Used | | 50% of average of "new" | |
| | | | | Low | High | Low | High | | |
| Carpet (1) | 1.90 | 1 | 0.02 | 40 | 60 | n.a. | n.a. | 25 | 0.5 |
| Desk/table | 88.90 | 2 | 1.78 | 22 | 281 | 75 | 110 | 76 | 135 |
| Chairs | 88.90 | 3 | 2.67 | 3 | 18 | n.a. | n.a. | 5 | 14 |
| Cupboard | 38.90 | 1 | 0.39 | 16 | 85 | n.a. | n.a. | 25 | 10 |
| Chest or drawers (2) | 31.50 | 1 | 0.32 | 46 | 250 | n.a. | n.a. | 74 | 23 |
| Bed | 90.70 | 1 | 0.91 | 9 | 70 | n.a. | n.a. | 20 | 18 |
| Television | 79.60 | 1 | 0.80 | 275 | 1,050 | 350 | 600 | 331 | 264 |
| Radio | 75.90 | 1 | 0.76 | 4 | 100 | n.a. | n.a. | 26 | 20 |
| Refrigerator | 5.60 | 1 | 0.06 | 130 | 330 | 170 | | 115 | 6 |
| Motorcycle | 66.70 | 1 | 0.67 | 950 | 1,400 | 250 | 850 | 588 | 392 |
| Car (3) | 5.60 | 1 | 0.06 | n.a. | n.a. | 1,200 | 7,500 | 2,175 | 122 |
| Bicycle | 61.10 | 2 | 1.22 | 85 | 97 | 17 | 35 | 46 | 56 |
| Computer | 0.00 | 1 | 0.00 | 450 | 2,500 | n.a. | n.a. | 738 | 0 |
| | | | | Average total asset value per shop : | | | | | $1,059 |
| | | | | Average number of stories : | | | | | 1.3 |
| | | | | Asset value to be damaged by inundation : | | | | | $815 |
| | | | | | | | | (rounded) | $800 |

Note :
(1) 10m² assumed for a carpet
(2) Prices checked as wardrobe/cabinet
(3) Average price of used cars applied.
Source :
(1) Ownership of assets : Asset and Flood Damage Survey by TEAM Consulting Engineers Co.,Ltd.
(2) Prices of assets : surveyed by JICA study team in June 1998 in Phnom Penh

## Appendix III (3/7)
## Average Value of Assets Owned in 1998 (Office)

| Asset | Rate of prevalence (%) | Number of assets per office | Average number per office | Surveyed prices (US$) | | | | | Average asset value per office |
|---|---|---|---|---|---|---|---|---|---|
| | | | | New | | Used | | 50% of average of "new" | |
| | | | | Low | High | Low | High | | |
| Building | 100.00 | - | - | - | - | - | - | - | - |
| Merchandise | 45.45 | - | - | - | - | - | - | - | - |
| Documents | 81.82 | - | - | - | - | - | - | - | - |
| Car (3) | 63.64 | 2 | 1.27 | n.a | n.a | 1,200 | 7,500 | 4,350 | 5,537 |
| Truck (4) | 45.45 | 1 | 0.45 | 23,300 | 109,350 | 2,250 | 7,500 | 4,875 | 2,216 |
| Motorcycle | 36.36 | 3 | 1.09 | 950 | 1,400 | 250 | 850 | 588 | 641 |
| Bicycle | 18.18 | 5 | 0.91 | 85 | 97 | 17 | 35 | 46 | 41 |
| Forklift | 9.09 | 1 | 0.09 | 45,500 | 45,500 | n.a | n.a | 22,750 | 2,068 |
| Computer | 63.64 | 2 | 1.27 | 450 | 2,500 | Depend on quality. | | 738 | 939 |
| Copy Machine | 36.36 | 1 | 0.36 | 1,299 | 6,973 | n.a | n.a | 2,068 | 752 |
| Other office documen | 63.64 | - | - | - | - | - | - | - | - |
| Carpet (5) | 36.36 | 3 | 1.09 | 80 | 120 | n.a | n.a | 50 | 55 |
| Desk and table | 81.82 | 30 | 24.55 | 22 | 281 | 75 | 110 | 76 | 1,859 |
| Chair | 81.82 | 30 | 24.55 | 3 | 18 | n.a | n.a | 5 | 129 |
| Cupboard | 81.82 | 5 | 4.09 | 16 | 85 | n.a | n.a | 25 | 103 |
| Chest and drawers | 72.73 | 5 | 3.64 | 46 | 250 | n.a | n.a | 74 | 269 |
| Bed | 45.45 | 5 | 2.27 | 9 | 70 | n.a | n.a | 20 | 45 |
| TV | 54.55 | 1 | 0.55 | 275 | 1,050 | 350 | 600 | 331 | 181 |
| Radio | 54.55 | 3 | 1.64 | 4 | 100 | n.a | n.a | 26 | 43 |
| Refrigerator | 27.27 | 1 | 0.27 | 130 | 330 | 170 | 171 | 115 | 31 |
| Power generator | 18.18 | 1 | 0.18 | 500 | 100,000 | 2,500 | 2,500 | 25,125 | 4,568 |
| Jar | 0.00 | - | - | n.a | n.a | - | - | - | - |
| | | | Total assets value: | | | | | | 19,476 |
| | | | Average number of stories : | | | | | | 2.2 |
| | | | Asset value to be damaged by inundation : | | | | | | $8,853 |
| | | | | | | | (rounded) | | $8,800 |

Note :

(1) The numbers of commodities per office are assumed based on the average number of employees at 22 and the average total floor area at 423 $m^2$.

(2) In the event that only one figure for price is available, that figure is shown both for high and low price.

(3) Average price of used cars applied.

(4) Average price of used trucks applied.

(5) 20 $m^2$ assumed

Source :

(1) Ownership of assets : Asset and Flood Damage Survey by TEAM Consulting Engineers Co.,Ltd.

(2) Prices of assets : surveyed by JICA study team in June 1998 in Phnom Penh

# Appendix III (4/7)
# Average Value of Assets Owned in 1998 (Factory)

| Asset | Rate of prevalence (%) | Number of assets per factory | Average number per factory | Surveyed prices (US$) | | | | | Average asset value per factory |
|---|---|---|---|---|---|---|---|---|---|
| | | | | New | | Used | | 50% of average of "new" | |
| | | | | Low | High | Low | High | | |
| Building | 100.00 | - | - | - | - | - | - | - | - |
| Merchandise | 62.50 | - | - | - | - | - | - | - | - |
| Machinery | 75.00 | 3 | 2.25 | 5,000 | 9,000 | n.a | n.a | 3,500 | 7,875 |
| Documents | 43.75 | - | - | - | - | - | - | - | - |
| Car | 37.50 | 1 | 0.38 | n.a | n.a | 1,200 | 7,500 | 4,350 | 1,631 |
| Truck | 12.50 | 1 | 0.13 | 23,300 | 109,350 | 2,250 | 7,500 | 4,875 | 609 |
| Motorcycle | 87.50 | 2 | 1.75 | 950 | 1,400 | 250 | 850 | 588 | 1,028 |
| Bicycle | 31.25 | 3 | 0.94 | 85 | 97 | 17 | 35 | 46 | 43 |
| Forklift | 0.00 | 1 | 0.00 | 45,500 | 45,500 | n.a | n.a | 22,750 | 0 |
| Computer | 6.25 | 1 | 0.06 | 450 | 2,500 | Depend on quality. | | 738 | 46 |
| Copy Machine | 6.25 | 1 | 0.06 | 1,299 | 6,973 | n.a | n.a | 2,068 | 129 |
| Other office document | 37.50 | - | - | - | - | - | - | - | - |
| Carpet | 0.00 | 2 | 0.00 | 80 | 120 | n.a | n.a | 50 | 0 |
| Desk and table | 75.00 | 5 | 3.75 | 22 | 281 | 75 | 110 | 76 | 284 |
| Chair | 75.00 | 5 | 3.75 | 3 | 18 | n.a | n.a | 5 | 20 |
| Cupboard | 62.50 | 1 | 0.63 | 16 | 85 | n.a | n.a | 25 | 16 |
| Chest and drawers | 56.25 | 1 | 0.56 | 46 | 250 | n.a | n.a | 74 | 42 |
| Bed | 87.50 | 2 | 1.75 | 9 | 70 | n.a | n.a | 20 | 35 |
| TV | 68.75 | 1 | 0.69 | 275 | 1,050 | 350 | 600 | 331 | 228 |
| Radio | 62.50 | 2 | 1.25 | 4 | 100 | n.a | n.a | 26 | 33 |
| Refrigerator | 37.50 | 1 | 0.38 | 130 | 330 | 170 | 171 | 115 | 43 |
| Power generator | 6.25 | 1 | 0.06 | 500 | 100,000 | 2,500 | 2,500 | 25,125 | 1,570 |
| Jar | 12.50 | 1 | 0.13 | n.a | n.a | - | - | - | - |
| | | | | Total asset value : | | | | | $13,631 |
| | | | | Average number of floor : | | | | | 1.2 |
| | | | | Asset value to be damaged by inundation : | | | | | $11,359 |
| | | | | | | | (rounded) | | $11,300 |

Note :

(1) The numbers of commodities per factory are assumed based on the average number of employees at 5.3 and the average total floor area at 239 m² based on the source (1)

(2) In the event that only one figure for price is available, that figure is shown both for high and low price.

(3) Average price of used cars applied.

(4) Average price of used trucks applied.

(5) Asset values to be damaged for factories with equal or more than 10 workers are derived as follows.

| | |
|---|---|
| Average number of workers : | 34 workers/factory (4,122 workers working in 123 factories in 1993*) |
| Ratio between large/small factories : | 6.4 (34/5.3, ratio of number of workers) |
| Total asset value : | $87,239 ($13,631 * 6.4) |
| Average number of floor : | 1.2 |
| Asset value to be damaged by inundation : | $72,699 |
| (rounded) | $72,600 |

* Survey of Industrial Establishments 1993, National Institute of Statistics

Source :

(1) Ownership of assets : Asset and Flood Damage Survey by TEAM Consulting Engineers Co.,Ltd.

(2) Prices of assets : surveyed by JICA study team in June 1998 in Phnom Penh

# Appendix III (5/7)
## Average Value of Assets Owned in 1998 (Warehouse)

| Asset | Rate of prevalence (%) | Number of assets per warehouse | Average number per warehouse | Surveyed prices (US$) | | | | | Average asset value per warehouse |
|---|---|---|---|---|---|---|---|---|---|
| | | | | New | | Used | | 50% of average of "new" or | |
| | | | | Low | High | Low | High | | |
| Building | 100.00 | - | - | - | - | - | - | - | - |
| Merchandise | 90.00 | - | - | - | - | - | - | - | - |
| Documents | 50.00 | - | - | - | - | - | - | - | - |
| Car (3) | 70.00 | 1 | 0.70 | n.a | n.a | 1,200 | 7,500 | 4,350 | 3,045 |
| Truck (4) | 20.00 | 1 | 0.20 | 23,300 | 109,350 | 2,250 | 7,500 | 4,875 | 975 |
| Motorcycle | 70.00 | 1 | 0.70 | 950 | 1,400 | 250 | 850 | 588 | 411 |
| Bicycle | 30.00 | 1 | 0.30 | 85 | 97 | 17 | 35 | 46 | 14 |
| Forklift | 10.00 | 1 | 0.10 | 45,500 | 45,500 | n.a | n.a | 22,750 | 2,275 |
| Computer | 0.00 | 1 | 0.00 | 450 | 2,500 | Depend on quality. | | 738 | 0 |
| Copy Machine | 0.00 | 1 | 0.00 | 1,299 | 6,973 | n.a | n.a | 2,068 | 0 |
| Other office document | 50.00 | - | - | - | - | - | - | - | - |
| Carpet | 0.00 | 1 | 0.00 | 80 | 120 | n.a | n.a | 50 | 0 |
| Desk and table | 100.00 | 3 | 3.00 | 22 | 281 | 75 | 110 | 76 | 227 |
| Chair | | 3 | 0.00 | 3 | 18 | n.a | n.a | 5 | 0 |
| Cupboard | 80.00 | 1 | 0.80 | 16 | 85 | n.a | n.a | 25 | 20 |
| Chest and drawers | 90.00 | 1 | 0.90 | 46 | 250 | n.a | n.a | 74 | 67 |
| Bed | 70.00 | 2 | 1.40 | 9 | 70 | n.a | n.a | 20 | 28 |
| TV | 40.00 | 1 | 0.40 | 275 | 1,050 | 350 | 600 | 331 | 133 |
| Radio | 40.00 | 1 | 0.40 | 4 | 100 | n.a | n.a | 26 | 10 |
| Refrigerator | 20.00 | 1 | 0.20 | 130 | 330 | 170 | 171 | 115 | 23 |
| Power generator | 0.00 | 1 | 0.00 | 500 | 100,000 | 2,500 | 2,500 | 25,125 | 0 |
| Jar | 0.00 | 1 | 0.00 | n.a | n.a | - | - | - | - |
| | | | Total asset value : | | | | | | $7,228 |
| | | | Average number of floor : | | | | | | 2.1 |
| | | | Asset value to be damaged by inundation : | | | | | | $3,442 |
| | | | | | | (rounded) | | | $3,400 |

Note :
(1) The numbers of commodities per warehouse are assumed based on the average number of employees at 3.1 and the average total floor area at 205 $m^2$.
(2) In the event that only one figure for price is available, that figure is shown both for high and low price.
(3) Average price of used cars applied.
(4) Average price of used trucks applied.
Source :
(1) Ownership of assets : Asset and Flood Damage Survey by TEAM Consulting Engineers Co.,Ltd.
(2) Prices of assets : surveyed by JICA study team in June 1998 in Phnom Penh

## Appendix III (6/7)
## Average Value of Assets Owned in 1998 (School)

| Asset | Rate of prevalence (%) | Number of assets per school | Average number per school | Surveyed prices (US$) | | | | | Average asset value per school |
|---|---|---|---|---|---|---|---|---|---|
| | | | | New | | Used | | 50% of average of "new" or | |
| | | | | Low | High | Low | High | | |
| Building | 100.00 | - | - | - | - | - | - | - | - |
| Machinery | 5.88 | 0 | 0.00 | 5,000 | 9,000 | n.a | n.a | 3,500 | 0 |
| Documents | 100.00 | - | - | - | - | - | - | - | - |
| Car (2) | 5.88 | 1 | 0.06 | n.a | n.a | 1,200 | 7,500 | 4,350 | 256 |
| Truck (3) | 5.88 | 1 | 0.06 | 23,300 | 109,350 | 2,250 | 7,500 | 4,875 | 287 |
| Other office equipment (4) | 100.00 | 20 | 20.00 | 10 | 10 | - | - | 5 | 100 |
| Carpet (5) | 5.88 | 1 | 0.06 | 80 | 120 | n.a | n.a | 50 | 3 |
| Desk and table (6) | 100.00 | 1,000 | 1000.00 | 22 | 281 | 75 | 110 | 11 | 11,000 |
| Chair (7) | 100.00 | 1,000 | 1000.00 | 3 | 18 | n.a | n.a | 2 | 1,500 |
| Cupboard | 100.00 | 10 | 10.00 | 16 | 85 | n.a | n.a | 25 | 253 |
| Chest and drawers | 76.47 | 10 | 7.65 | 46 | 250 | n.a | n.a | 74 | 566 |
| Bed | 11.76 | 50 | 5.88 | 9 | 70 | n.a | n.a | 20 | 116 |
| TV | 11.76 | 3 | 0.35 | 275 | 1,050 | 350 | 600 | 331 | 117 |
| Radio | 17.65 | 10 | 1.76 | 4 | 100 | n.a | n.a | 26 | 46 |
| Power generator | 5.88 | 1 | 0.06 | 500 | 100,000 | 2,500 | 2,500 | 25,125 | 1,478 |
| | | | Total asset value : | | | | | | $15,721 |
| | | | Average number of stories : | | | | | | 2.0 |
| | | | Asset value to be damaged by inundation : | | | | | | $7,860 |
| | | | | | | (rounded) | | | $7,800 |

Note :
(1) In the event that only one figure for price is available, that figure is shown both for high and low price.
(2) Average price of used cars applied.
(3) Average price of used trucks applied.
(4) $10 assumed for an equipment
(5) 20 $m^2$ per carpet assumed.
(6) Half of new/low price applied.
(7) Half of new/low price applied.
Source :
(1) Ownership of assets : Asset and Flood Damage Survey by TEAM Consulting Engineers Co.,Ltd.
(2) Prices of assets : surveyed by JICA study team in June 1998 in Phnom Penh

## Appendix III (7/7)
## Average Value of Assets Owned in 1998 (Hospital)

| Asset | Rate of prevalence (%) | Number of assets per hospital | Average number per hospital | Surveyed prices (US$) | | | | | Average asset value per hospital |
|---|---|---|---|---|---|---|---|---|---|
| | | | | New | | Used | | 50% of average of "new" or | |
| | | | | Low | High | Low | High | | |
| Building | 100.00 | - | - | - | - | - | - | - | - |
| Medical equipment | 100.00 | 30 | 30.00 | 1 | 180 | - | - | 45 | 1,358 |
| Merchandise | 22.22 | 0 | 0.00 | - | - | - | - | - | - |
| Documents | 55.56 | - | - | - | - | - | - | - | - |
| Ambulance | 55.56 | 1 | 0.56 | 25,000 | 25,000 | - | - | 12,500 | 6,944 |
| Car (2) | 66.67 | 2 | 1.33 | n.a | n.a | 1,200 | 7,500 | 4,350 | 5,800 |
| Truck (3)A242 | 11.11 | 1 | 0.11 | 23,300 | 109,350 | 2,250 | 7,500 | 4,875 | 542 |
| Motorcycle | 66.67 | 3 | 2.00 | 950 | 1,400 | 250 | 850 | 588 | 1,175 |
| Bicycle | 11.11 | 10 | 1.11 | 85 | 97 | 17 | 35 | 46 | 51 |
| Forklift | 22.22 | 1 | 0.22 | 45,500 | 45,500 | n.a | n.a | 22,750 | 5,056 |
| Computer | 44.44 | 2 | 0.89 | 450 | 2,500 | Depend on quality. | | 738 | 656 |
| Copying machine | 22.22 | 1 | 0.22 | 1,299 | 6,973 | n.a | n.a | 2,068 | 460 |
| Other office equipment (4) | 33.33 | 20 | 6.67 | 10 | 10 | - | - | 5 | 33 |
| Carpet (5) | 0.00 | 1 | 0.00 | 80 | 120 | n.a | n.a | 50 | 0 |
| Desk and table(6) | 44.44 | 50 | 22.22 | 22 | 281 | 75 | 110 | 11 | 244 |
| Chair A595 | 44.44 | 100 | 44.44 | 3 | 18 | n.a | n.a | 2 | 67 |
| Cupboard | 33.33 | 5 | 1.67 | 16 | 85 | n.a | n.a | 25 | 42 |
| Chest and drawers | 44.44 | 5 | 2.22 | 46 | 250 | n.a | n.a | 74 | 164 |
| Bed | 100.00 | 150 | 150.00 | 9 | 70 | n.a | n.a | 20 | 2,963 |
| TV | 88.89 | 2 | 1.78 | 275 | 1,050 | 350 | 600 | 331 | 589 |
| Radio | 66.67 | 3 | 2.00 | 4 | 100 | n.a | n.a | 26 | 52 |
| Refrigerator | 33.33 | 1 | 0.33 | 130 | 330 | 170 | 170 | 115 | 38 |
| | | | | Total asset value : | | | | | $26,233 |
| | | | | Average number of stories : | | | | | 2.3 |
| | | | | Asset value to be damaged by inundation : | | | | | $11,405 |
| | | | | | | | | (rounded) | $11,400 |

Note :

(1) In the event that only one figure for price is available, that figure is shown both for high and low price.

(2) Average price of used cars applied.

(3) Average price of used trucks applied.

(4) $10 assumed for an equipment

(5) 20 $m^2$ per carpet assumed.

(6) A266Half of new/low price applied.

(7) Half of new/low price applied.

Source :

(1) Ownership of assets : Asset and Flood Damage Survey by TEAM Consulting Engineers Co.,Ltd.

(2) Prices of assets : surveyed by JICA study team in June 1998 in Phnom Penh

# Sector G

# Environment

THE STUDY ON
DRAINAGE IMPROVEMENT AND FLOOD CONTROL
IN THE MUNICIPALITY OF PHNOM PENH

## SECTOR G: ENVIRONMENT

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## G1. Introduction

There is a continuous steady migration of families from the rural areas into Phnom Penh. Squatter settlements have become established along the flood protection levees, over drainage channels and shallow lake foreshores, in road and park reserves, and on unoccupied private land. Unplanned settlements are also developing outside of the central city core into areas, which are very prone to floods.

Further, garbage collection is inadequate and a large part of it ends up in the drains. All this has resulted in restricting drain water flow and in causing sanitation problems. The problems are further aggravated during flooding events directly affecting public health, quality of life and long-term economic growth.

The Study Area defined is the Municipality of Phnom Penh composed of seven districts (Khan), four "inside the dyke" or core districts and three "outside the dyke" or suburban districts. Present environmental conditions of Study Area as determined from analysis of secondary data, site investigations and various interview surveys conducted are described in Chapter 2. Based on this information and other baseline project information presented in other sector reports and main report, an Initial Environmental Examination (IEE) is presented in Chapter 3. This involves environmental baseline evaluation of the study area, and determination of "With" and "Without" project impacts. The last section of Chapter 3 presents the priority projects selected for detailed feasibility study in Phase II. Chapter 4 and Chapter 5 present the environmental impact assessment (EIA) of the selected priority projects.

## G2. Existing Conditions

### 2.1 Natural Environment

The present condition of natural environment is described hereunder.

#### 2.1.1 Topography and Basic Layout of Phnom Penh

Phnom Penh is located on a flat alluvial plain at the western bank of the confluence of the Tonle Mekong, the Tonle Sap, and the Tonle Bassac. The only significant relief is a tiny hill (20 m high) from which the city derives its name. The most important features are:

- High accretion embankments along both sides of the main rivers (altitude above sea level roughly 10 m)
- Low-lying land behind (west) of these embankments which, where not filled by urbanization, presents a series of lakes ("Boeng") and ponds interconnected by streams ("Stuong") and canals ("Preak") and draining eventually back into the Mekong system via small tributary rivers, mainly the Preak Thnot to the south and the Preak Phnov to the north.
- Further west (at roughly 5 to 7 km from the river) the land slowly begins to rise; thus the system of lakes and ponds described above receives the considerable river runoff from the higher land as well as that of the embankments and the urbanized area
- A similar topography and pattern of drainage (but oriented differently) occurs on the peninsulas created by the confluence of the Tonle Sap and Tonle Mekong to the north, and that of the Tonle Bassac and Tonle Mekong to the south. In these areas, as well as across on the east bank of the Tonle Mekong, most non-embankment land is low-lying and flood-prone.

The town center is located on the west bank of the Tonle Sap just north of its confluence with the Tonle Mekong and Tonle Bassac.

#### 2.1.2 Hydro-geology

Phnom Penh lies on young and old alluvium deposits, which overlay weathered rock and clay at a depth of 30 to 50 meters with hard crystalline rock at the base. As far as is known, there are no artesian aquifers and practically no groundwater.

#### 2.1.3 Urban Infrastructure and Environment

Environmental problems in Phnom Penh are widespread and serious. Wastewater mixes with flood drainage and discharges to watercourses, into areas with shallow groundwater where there are dug wells, and into fields where vegetables are cultivated and later eaten raw. The water containing disease-causing organisms is used for washing and swimming, and the pollution is harmful to the aquatic environment. **Table G2-1** summarizes the condition of the existing infrastructure in Phnom Penh. Some important characteristics are as follows:

(1) Drainage

Surface water drainage and the management of monsoon flooding has a fundamental influence on the development of the existing city.

The various elements of the drainage system are explained below.

There are several drainage catchment areas within the study area. However, they all in general encompass three kinds of drainage elements from upstream to downstream:

- A drainage network, comprised of gullies or grids at the collection points, and of buried pipes or open drains (canals, ditches etc.). This network ensures the collection and transport of effluents and storm water out of the elementary zones of the town.
- A storage basin or lake, called "Boeng", at the outlet of the drainage primary network thus receiving all waste and storm water from the catchment areas. Because of their storage capacity, the "Boeng" absorbs the peak storm water flows brought by the network during heavy rains, and prevents upstream flooding by maintaining the "Boeng" water level within acceptable limits at maximum pumping capacity.
- A pumping station, whose sole function is to dispose off waste and storm water accumulated in the Boengs outside the first dyke system surrounding the town.

Difficulties are numerous and affect all components of this drainage system. Disfunctioning of networks mainly results from a general clogging phenomena (silts brought by runoff water, miscellaneous refuse), and from the poor condition of the gullies collecting storm water, many of them being broken or blocked. As a consequence, the drainage network only collects a small part of the storm water, its major part flowing on to the street surface and resulting in frequent flooding during the rainy season.

The problem of "Boengs" mainly lies with their progressive filling by silts and other solids brought in through the drains and direct runoff on street surface during floods. This phenomenon has throughout years without dredging, considerably reduced the "Boengs" storage capacity (at least by 50%). Since emptying out these "Boengs" is limited by the capacity of the pumping stations, they are less and less able to absorb peak discharges during high intensity rainfalls. This results in progressive aggravation of floods. The banks of the "Boengs" are also progressively being colonized by squatters, which worsens the situation.

The pumping stations, the final element of the drainage system, do not operate satisfactorily because of their old age, the lack of spare parts, and shortages in electrical or thermal energy supply (frequent power cuts, inadequate storage and "rationing" of fuel).

These problems are worsened by the town physical context itself: namely, flat natural ground gradients, high rainfall intensities, and external dykes retaining the waters. This leads to a system in which the three types of elements of the drainage system -- networks, "Boengs" and pumping stations are interdependent in their functioning. An awareness and understanding of this hydrological aspect is very important. Indiscriminate filling up of lake and pond systems can cause the breakdown of the natural and manmade drainage, leading to annual floods of larger areas of the town. Further, structural measures like network cleaning operations need to be accompanied by "Boengs" dredging.

(2) Water Supply

The entire raw water source for the piped water supply system in Phnom Penh was originally from the rivers Tonle Mekong, Tonle Sap, and Tonle Bassac; but in the

1970s wells were dug and linked to the system to augment supply. In the peri-urban areas within the municipal boundaries UNICEF has had a well digging program since the early 1980s. There are about 1,500 open wells in Phnom Penh. It is however reported that in the environs of Phnom Penh, no artisan aquifers have been found and the availability of groundwater is very low. Among the several hundred wells, which have been dug, only about one per cent is reported to have an average yield of about 91 ℓ/min. Their average depth is about 35 m and range of the depth varies from 10 to 290 m. The remaining wells are more or less non-productive.

Thirty percent of total households in Phnom Penh have piped water or water from the PPWSA. Water treatment works in Phnom Penh include sedimentation, filtration and chlorinating. Almost 44% purchase water for drinking and cooking purposes. The piped water supply as well as water from wells is used for bathing, washing and watering plants. The piped water supply is available only 11-12 hours a day. Every house has covered storage tanks, uncovered clay jars and buckets for storing water.

Water distribution system is in a poor state of repair with high leakage rates. Only the four central districts of the seven in the city receive more or less continuous supplies. Rest of the city supply is limited to a few hours per day due to insufficient electrical supply to operate pumps. The networks in the three outer districts are no longer supplied due to limited capacity. Private water sellers are common who buy water from the waterworks and deliver to unconnected households.

The status, however, is steadily being improved by the projects implemented under the Japan's grant aid program and under a loan from ADB.

(3) Sewage

In Phnom Penh, untreated sewage and industrial wastewater is discharged directly into the rivers. A variety of undesirable effluents are washed into the watercourses directly. Combined systems for sewage and surface water drains mostly by gravity are common. Developed in colonial times, the sewerage system is designed to work as follows: domestic wastewater is held on plot in septic tanks (regulations specify that each building has to have a three-compartment septic tank). Overflow effluent from the septic tank runs through pipes into the combined system that also collects surface water runoff. There is no treatment of wastewater before final outfalls, other than what occurs in septic tanks and holding ponds.

As the combined sewage/drainage system is in a poor state of repair with pipes and collectors sometime blocked and canals/ponds partially filled in, drainage is ineffective. It was estimated in 1995 that this system handles on the average between 60,000 to 100,000 $m^3$ of domestic wastewater daily. At the present time, no law regulates domestic wastewater disposal, no fee is collected for the sewerage connections, and it is the household's responsibility to carry out such works.

All urban housing (Villas and Chinese shop houses) is supposed to be equipped with three compartment septic tanks. However, there are many instances of institutional users discharging wastewater directly into the network. It is important to recognize that only a small fraction of households in central Phnom Penh are actually connected to the sewerage network. The majority of the population either use latrines (water sealed pit latrines or dry pits) or septic tanks/soak-aways. The 1993-94 Socio-

economic Survey of Cambodia found that 22% of households in Phnom Penh had no facilities while nearly 60% had water sealed type toilets.

Outside the dike, in the peri-urban area, there is virtually no sewerage system. All domestic wastewater is either disposed off on-site (septic tanks or pit latrines) or in the very common case of embankment housing on stilts, via privies in which all wastes are directly dropped into the lake, pond or stream. As domestic water supplies are limited in the peri-urban areas (reliance is totally on vendors, wells, ponds or collected raw water), it is only in a few instances where off-site disposal of wastewater is necessary. In these cases, the overflow is discharged into existing drains natural or manmade.

(4) Roads

The large number of unsealed roads in Phnom Penh results in grit being washed into the drains and sewers. This blocks all but the largest diameter drainpipes. Naturally high river levels and rainfall intensities are responsible for the extensive flooding in Phnom Penh during the monsoon season.

(5) Urban Solid Waste

Central area of Phnom Penh is served by semi-regular curbside pick-up of household solid wastes. The system requires residents to deposit waste at communal collection points in their vicinity. The waste is collected from these points and transported to the municipal dumpsite. The communal collection points are generally in unconfined areas within the road reserves. Waste is often poorly packaged and not picked up properly. As a result, debris is scattered by animals, scavengers or the wind, and consequently fails to be collected.

Receptacles are uncommon, though some premises do have customized refuse bins with wheels and hinged lids. These are supplied to customers whose monthly fee is US$ 5 or more. Many of the trucks used by contractors are of the tipper/dump truck type, which are open. When transporting waste from the collection points to the dumpsites, light wastes such as paper, plastic etc. can be blown away from the vehicles.

Phnom Penh has two waste dumpsites: Phum Damnak and Stung Meanchey. The former is a large open area of low-lying flood prone land where semi-controlled dumping takes place over a wide area. The site is also a sand and gravel quarry. The quarry is owned by the quarrying company that does not charge for dumping on the site, but sells gravel to empty trucks. Quarry excavations at the site reach depth of 10 m before hitting the underlying clay layer. The quarry excavations are to be in-filled with waste once quarrying is completed.

There are apparently no precautions planned to protect groundwater from "leachate" pollution before "in-filling" is carried out. Dumping has spawned a recycling industry at the site. The road to the site is lined with yards dedicated to the recycling business. A colony of scavengers live on or around the Phum Damnak site. Garbage or urban solid waste collection is inefficient in the peri-urban area and in squatter settlements scattered all over and contributes to drainage pipe blockages.

(6) Markets

Market places particularly are very poorly drained resulting in unsanitary working and shopping conditions in the wet season. The walkways between the stalls are often flooded and muddy with decaying organic matter spread on the ground. Such unhygienic conditions pose significant health risks.

(7) Industries

There is no industrial park or delineated industrial zone in Phnom Penh. Industry has tended to locate logically where it can function best. Historically, and until today, most manufacturing and warehousing has located along the embankments of Tonle Sap north of town or the Tonle Bassac south of town, mixed in with the commercial and residential land uses. Such locations allowed direct access to river transport and, for large consumers of water such as tobacco and beverages, a direct and uninterruptable source of raw water.

Smaller industries, workshops, and artisan establishments are common in Phnom Penh and represent considerable production capacity and employment generation. These tend to concentrate on the radial highways heading out of town or along the outer dike embankments, especially the southwest arc.

One area of industrial concentration is along and beside the access road to the current city landfill located in Sanghat Stung Meanchey. Factories, recycling sheds, and warehouses are all found in this area, mixed with housing. It is also seen that medium and large lot factories and warehouses are being set out on apparent random fashion, practically anywhere along a vast arc of land west of the presently urbanized area. There seems to be a degree of concentration in three locations, namely, along the Boeng Tompun embankment, north and south of the Pochentong road, and around the airport in Chan Chao Sanghat.

Along the right bank of the Tonle Sap and the Tonle Bassac, in addition to human habitation, industries, ports, floating hotels and restaurants are also found. A part of the untreated wastewater from this area is directly discharged into these two rivers. The right bank of the Tonle Mekong is also inhabited and occupied by some industries. Tourism is also taking place there. Between the Chrouy Changwar treatment plant and the Cham treatment plant, there is a harbor and an army barrack. Development of the entire Chrouy Changwar is expected in the future and a very high pollution potential for the Mekong river is foreseen if remedial action is not taken.

It has been determined that most industries do not have any specific treatment system and divert their wastewater directly to the nearest drain, river or lake. A few neutralize the wastewater before discharge. State hospitals too do not treat their wastewater before discharge. No fee is collected from the industries for disposal of the wastewater into the public drainage system.

### 2.1.4 Water and Benthic Material Quality

(1) General

It is necessary to know the quality of surface waters of lakes and rivers since they are important raw water sources for Cambodia. However, the quality of the surface water

is affected mainly by domestic wastewater, industrial wastewater, garbage and road/soil erosion. It is also important to know the quality of benthic material deposits that may be excavated to decide proper disposal and reuse options.

(2) Water Quality Standards and Soil Contaminant Standards

The Ministry of Environment (MOE) is in the process of drafting a sub-decree on Water Pollution Control, to supplement the general provisions of the Law on Environmental Protection and Natural Resources Management. It is expected that this sub-decree will provide for:

- the setting of receiving water quality standards and guidelines
- Rights for MOE and local representatives to inspect, take samples etc., and demand cooperation from owners in the process of monitoring.
- MOE's role, responsibilities and means to implement compliance with standards
- penalties for non-compliance

In the absence of water quality standards (effluent, receiving or drinking), the appropriate minimum standards proposed by the World Health Organization (WHO) is considered in this Study.

A literature survey was conducted and selected multimedia goals for solid waste and soil by contaminant class as proposed by L.W.Canter in his 1996 Second Edition of book titled 'Environmental Impact Assessment' is proposed to be used as guideline standards for soil and/or sediment. These are elaborated upon later in this chapter.

(3) Existing Water Quality Data

Water quality data of Tonle Mekong, Tonle Sap and Tonle Bassac are summarized in **Table G2-2**. These were to determine the location of water treatment systems and the intake for the water. The raw water for the Phnom Prek treatment plant is from Tonle Sap, for the Chamcar Mom treatment plant from the Tonle Bassac, and for the Chrouy Changwar treatment plant – the Tonle Mekong. The three rivers have quite similar water quality characteristics. The distinguishing feature is the turbidity, which ranges between 5 NTU and 10 NTU during the dry season. During the rainy season, the high turbidity (greater than 200 NTU) continues for two to three months.

It is seen that the intake water quality at the three treatment plants is in conformity with the WHO Guidelines for drinking water with respect to all measured parameters except turbidity and microbiological aspects. It is reported that the distributed treated water sampled at taps in some areas, is in conformity with the WHO's guidelines for drinking water with respect to all measured parameters except free chlorine and fecal coliform.

Within the existing information, no data is available concerning water quality in the drains, canals, and lakes. No data is available concerning benthic material deposits.

(4) Water and Benthic Material Quality Survey

Water and benthic quality survey has been conducted in the Study, since there is no sufficient existing data. Methods and results of the survey are presented hereunder.

(a) Methods

Twenty locations at the concerned rivers, channels, lakes and groundwater wells were selected for water and benthic material quality sampling. **Table G2-3** and **Figure G2-1** gives the names and locations of these sampling stations, respectively. Sampling has been conducted four times as follows:

- First sampling period (water quality only); 27-28 April, 1998 (dry season)
- Second sampling period (water quality and benthic material); 20-21 May, 1998 (dry season)
- Third sampling period (water quality only); 19-20 October, 1998; (rainy season)
- Fourth sampling period (water quality only); 5-6 November, 1998; (rainy season).

At each sampling station, water samples were collected at mid-depth by use of a water sampler. The water was transferred for analysis to the laboratory (either at the Department of Research and Extension, General Directorate of Irrigation, Meteorology and Hydrology, or the laboratory of the Ministry of Environment). Temperature, pH and dissolved oxygen (DO) were measured on-site. The collection, preservation and analytical methods were as per the Standard Methods of the American Water Works Association (AWWA).

The concerned parameters for determination of water quality included pH, Suspended Solids (SS), Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), DO and Fecal Coliform Count.

The Benthic material quality parameters included Total Cyanide, Organic Phosphate, Lead (Pb), Chromium ($Cr^{+6}$), Arsenic (As), Total mercury (Hg), and Alkyl Hg, Poly-Chloro-Benzene (PCB).

(b) Results

**Table G2-4** to **Table G2-7** present the results of the water quality at each sampling station as conducted in April, May, October and November 1998 respectively. **Table G2-8** presents a descriptive summary of the results along with general site description and water utilization near each site.

Only the groundwater wells exhibit good water quality (station 18 to 20). All lakes and drainage channels have very poor quality due to direct discharge of sewage and garbage into them. This is clear from the extremely high values of COD, SS and Fecal Coliform Counts at all these locations (Stations 6 to 17). The rivers (Stations 1 to 5) also seem polluted by untreated sewage to a lesser degree.

The analyses were made for nine contaminants in benthic material samples from 20 stations around the project study area. Concentration of pollutants deposited in the sediments is primarily influenced by the source and deposition and flushing rates at each particular water-body. Therefore, four categories of water-bodies were applied for this study, i.e., natural waterway, lake/swamp, drainage channel, and well, as designated in **Table G2-9**.

The average concentration of contaminants was calculated for each category of water-body as shown in **Table G2-10**. It is clear that lake/swamp, especially Boeng Kak and Boeng Tompun lakes that collect wastewater from northern and southern sections of Phnom Penh municipality, show relatively higher concentration of pollutants, e.g., Cd, CN, Pb, $Cr^{+6}$ and organic phosphorus. These findings correlated well with water quality data. These lakes serve as an oxidation pond for the city. Thus, deposition of metals and other contaminants can be found in these lakes.

Concerning the natural waterways, most of the concentrations were lower than the average except for Phum Svay Pak. This stream receive wastewater from industrial area near Boeng Poungpeay which made concentration of Cd, CN, organic phosphorus and Pb higher than other stream in the study area. Another aspect that should be noted is the relatively high organic phosphorus concentration at Tonle Sap (Phnov river confluence). This station was close to aquaculture activities, which may be contributing to high phosphorus level in the sediment.

An attempt was made to compare the level of contaminants with international standards to determine the severity of these problems. Table G2-10 also presents selected multimedia environmental goals (MEGs) for solid waste and soil, and drinking water quality standards by contaminant tested for in sediment samples collected in this study. The MEGs have been proposed for use in the United States while the water quality standards are those used in Japan. Discharge MEGs (DMEGs) represent approximate concentration maxima in source emissions to receiving water, atmosphere, or soil (through solid waste) which should be tolerable for short term exposures. Values based on acute human health effects and short-term (reversible) effects on natural biological communities are specified. The use of DMEGs in evaluating emissions is ultraconservative in that no dilution of contaminants in the environment is assumed prior to exposure. "Ambient Level MEGs" (AMEGs) are approximate levels of contaminants in water, air, or soil below which unacceptable negative effects in human populations or in natural biological communities should not occur, even with continuous exposure.

MEGs for terrestrial environments (expressed in milligrams per kilogram) in Table G2-10 are based on a simple leachate model for solid waste (in this case DMEGs) and for contaminated soil (here, AMEGs are used). They are equal to the liquid emission MEGs (expressed in micrograms per liter) for the chemical of concern, multiplied by a factor of 0.2. This model assumes that all contaminants in 1 kg of soil or solid waste would be leached by 2L of water. The major human exposure route to contaminants from soil or solid waste is assumed to be consumption of contaminated drinking water. Similarly, the major exposure route for aquatic life is through leaching of contaminated soil or solid waste by surface waters. It is further assumed that the concentrated leachate entering a body of water (groundwater or surface water) will be diluted almost instantaneously by an arbitrary factor of 100. While this model is simplistic and in most situations very conservative (e.g. it considers almost no retention or attenuation of contaminants before reaching surface water), it does provide a set of rough guideline limits for a broad range of contaminants, without the need to consider hydro-geological and other environmental variables in detail. In the

present master plan study, the quality of the dredged materials from channels and lakes needs to be judged to decide its safe disposal site. The basic issue of concern is associated with precipitation and other runoff waters that might move through the disposal site and thus appear as leachate in the subsurface (soil and groundwater) environment.

Comparing the values in **Table G2-10** and **Table G2-11**, it is seen that the site selection for safe land disposal of dredged sediment deposits from various water bodies needs to be carefully done. This is because the amount of dredged material especially from channels and Boengs could be very large and also has high concentration levels of toxic contaminants.

**Table G2-12** presented the concentrations of heavy metal in various polluted (all other than Solway Firth) and non-polluted estuaries (Solway Firth) and average concentration for nearshore sediment in UK. These values are reported in milligram per liter. The values of Lead, Chromium and Cadmium contaminants concentration in the sediment of water bodies of Phnom Penh (reported in milligram per dry kilogram and/or parts per million if converted to milligram per liter assuming the same simple assumptions of model mentioned above in deriving MEGs) are higher than in unpolluted Solway Firth but lower than in case of other polluted estuaries. They can thus be judged to be not drastically high. The release of these toxic contaminants in the sediment to the surrounding water environment would occur only under very acidic conditions which are not present in any of the water bodies in Phnom Penh.

### 2.1.5 Flora and Fauna

There is no information concerning terrestrial flora and fauna within the study area. The study area consists of the central urbanized areas and the peri-urban rural suburbs where paddy cultivation is common. There are a number of lakes or Boengs and natural drainage canals. Aquatic plants and weeds especially water hyacinth, water lily, and duckweed is common. The water hyacinth proliferation is very significant in all drainage channels (natural and manmade) and marshy areas near lakes. It can be concluded that there are no valuable floral species in the study area, which could be negatively affected by flooding.

There are also no reports or information concerning important fauna like migratory birds in the various water bodies or other terrestrial fauna in the study area. Aquatic faunal species especially different kinds of fish are common in various water bodies and the rivers. The inland capture fisheries in or around Phnom Penh and downstream of Phnom Penh is governed by the annual flooding phenomena. The hydrological cycles determine the longitudinal and lateral migration and reproduction of most species of fish found here. The inland fisheries are unique in several aspects. They exploit a large diversity of water bodies (i.e. a natural lake and rivers with their floodplains). The inundation zone provides the spawning and nursery grounds which supply the bulk of the water bodies in the basin. The flooding transfer suspended and dissolved solids into the floodplains. Flooding also release nutrients from the soil, vegetation and inundated organic debris, which in turn supports an expansion of fish. Over 200 fish species inhabit the inland waters of Cambodia most of which are captured and used as food. Most fish species in the Tonle Mekong, Tonle Sap and Tonle Bassac rivers, as well as in the natural lakes are well adapted to a widely fluctuating water level, and have a wide tolerance for temperature, pH, DO and other environmental parameters.

## 2.2 Social Environment

Social environment aspects concern human settlements and their various inter-related characteristics. A summary is presented below.

### 2.2.1 Demography and Urbanization

It is estimated that the population of the Phnom Penh Municipality is approximately one million in 1998 including both registered and non-registered population. Of these, about 60% live in the four central districts (Danh Penh, Chamcar Morn, Prampinkara, and Toul Kork) within the inner-dyke, while the remaining 40% are in the three districts (Dang Kor, Meanchey, and Russey Keo) outside the inner-dyke. Assuming the population growth rate to be 3.8% per annum until 2010, the estimated population in 2010 is around 1,568,000. It is expected that Phnom Penh will maintain its primate city status in Cambodia. At present, Phnom Penh is 16 times larger than the next larger Cambodian town. More than 80% of the residents are literate. Less than 50% of the residents have a declared activity. In 1993, Phnom Penh contained over 41% of all Cambodia's industrial establishments.

### 2.2.2 Land Tenure

Until the end of the 1980s, the Government technically owned all real property in Cambodia and occupiers of buildings and land were given family cards, which recognized the legitimacy of their occupancy. In 1989, the Government began to move towards private ownership, permitting Cambodians to go to local agricultural or land offices to request recognition of ownership of the land they were occupying.

Assuming the office recognized the applicant as the occupant, it would issue a certificate of land use and possession, which was tantamount to a land title. However, quite often occupants stopped the process after they held the receipt for the application of land ownership. This receipt was considered sufficient evidence of their rights, as pursuing a certificate of ownership tended to be costly in terms of making incentive payments to officials. With the arrival of the UNTAC, there was an enormous boom in the rental housing market. Speculation led to inflationary housing prices and created a new class of urban squatters-people with no recognized rights to the lands they occupied.

There is presently a defined land registration procedure with roles of concerned governmental institutions defined. The Land Titles Department in the Municipality of Phnom Penh has made a start in registering properties of the central district of Phnom Penh, but this is not expected to be completed until end 1998. Cadastral mapping is also in progress. Before properties can be properly registered on a cadastral map, the Council of Ministers must approve a parcel map. The unusual history of land ownership in Cambodia with the lack of clarity in the 1992 Land Law has resulted in a large number of land ownership conflicts.

Today, practically all urban land, and particularly vacant land on the city fringes are under private control. This private control can take many forms of possession and ownership, but the result is that, for any land development scheme, Government must purchase or expropriate land or impose development restrictions.

While the right to own private property was only re-established in 1989, the purchase and sale of land today in Cambodia is relatively unrestricted. The price of urban property varies

greatly depending on location. Generally prime land in the central area of town in Phnom Penh can be 10-15 times as much as land on the edge of town.

A substantial amount of residential expansion is occurring on the periphery of lakes or "Boengs" inside the dike in Phnom Penh. In particular, new construction is readily visible in Boengs Slang, Trabek, and Tompun. Though this new development threatens to exacerbate the city's already difficult drainage situation during monsoon season, the economic logic of this activity is undeniable for new builders. Land in central Phnom Penh can cost US$150-400/m$^2$. In contrast, the cost of reclaiming a piece of land that is a part of a "Boeng" involves no initial investment other than the cost of landfill and grading. Preliminary estimates of fill and grading costs for "Boeng" property indicate that land can be reclaimed for as little as US$12/m$^2$. Areas such as Boeng Slang in Central Phnom Penh are witnessing the construction of new concrete buildings. This is evidence that the reclamation of "Boeng" areas is perceived as a "safe" venture. It is also an indication that new development is being undertaken by those with more resources.

### 2.2.3 Urban Housing

**Table G2-13** presents the Housing Indicators for Phnom Penh and other areas of Cambodia. Six types of houses are observed in Phnom Penh: Detached Concrete Villa, Chinese Row Housing, Hybrid Wood Villa, Stilted Khmer Wood House, Stilted Bamboo Wood House, and Thatch Tin House -- each ranging in cost, prevalence and characteristics. The Stilted Khmer Wood House is found mixed in with other housing in linear strip development and on spontaneous urban fringes. The Stilted Bamboo/Wood House is prevalent in linear strip developments, in spontaneous fringe areas, and in squatter communities. The Thatch/ Tin House can only be built on ground where there is no flooding. It is commonly found in squatter areas along embankments, and as a "starter" shelter in urban fringe areas.

### 2.2.4 Urban Social Profiles

The main secondary source of information has been the results as reported in the Socio-Economic Survey of Cambodia (1993-94) conducted by the National Institute of Statistics.

(1) Urban Social Indicators

**Table G2-14** presents a summary of urban social indicators for Phnom Penh and other parts of Cambodia.

(2) Urban Family Incomes

The mean and median urban family household income is reported to be 781,200 Riel/month and 562,000 Riel/ month respectively in Phnom Penh.

(3) The Urban Poor and Disadvantaged

(a) Women

Women significantly outnumber men in Cambodia. 29% of all heads of households are women in Phnom Penh. Women play a very important role in the urban economy of Cambodia; the labor force participation rate for women is over 94% in urban area.

(b) Squatters

It is estimated that there are 120,000 to 150,000 squatters in Phnom Penh. They are mostly food sellers, small traders, cyclo drivers, construction workers, and petty manufacturers. The majority of squatters are located close to work opportunities. Squatters occupy land owned by the government, although there is disagreement over the legal status of many areas, particularly in Toul Kork and Chamcarman. Urban infrastructure services hardly exist and drainage and wastewater disposal have been identified by the residents as their greatest problem.

(c) Minority Ethnic Groups

The Muslim Cham – mainly lower income communities can be found on the outskirts of Phnom Penh (Russey Keo and Chruoy Chang Wa). People of Vietnamese origin can be found in the low-income areas of Russey Keo and Srok Mean Chay, mostly along the riverbanks. Their status is precarious, given past anti-Vietnamese feelings. The minority Chinese community is the ethnic group, which is most integrated and assimilated with the majority Khmers. Because of their success in trade, the Chinese monopolize many areas of business and are the most prominent members of the business community in Phnom Penh.

(d) Seasonal Migrants

Seasonal migration to Phnom Penh is thought to be high from the rural areas. It is suggested that as many as 150,000 peasants come to Phnom Penh to seek casual employment during the dry season (March to June) and between planting/transplanting and harvesting of the rice crop (Nov.-Dec.).

(4) Health

The Ministry of Health Statistics Report of 1994 revealed that water and sanitation related diseases are the leading cause of mortality and morbidity among the Phnom Penh populace especially children aged 5 years or below. Presence of uncovered storage tanks and water jars, improper sewage and solid waste disposal, poor and cramped living conditions, lack of proper hygiene practices, use of unsafe water, and poor state of urban infrastructure especially drainage (which results in stagnant water even after a short rainfall), all contribute to creating ideal breeding grounds for vector carrying insects like mosquitoes

### 2.2.5 Resettlement Issues

It is expected that proposed projects and/or project structural measures proposed in the master plan would result in some temporary or permanent relocation/ resettlement. There is also the possibility of "nudging" of houses to the edge of easements in some locations. It was therefore determined at this preliminary stage of master planning to identify locations in different catchment areas where there is a possibility of temporary or permanent resettlement or nudging due to proposed structural works. These areas are typically encroached areas or illegal squatter settlements. Based on the identified locations, 1,000 samples were selected and a comprehensive questionnaire survey was carried out

concerning various resettlement issues including willingness to move and socioeconomic conditions of the affected persons. The identified areas and approximate sample size were as follows:

- Trabek drainage channel: 104 samples
- Boeng Trabek: 201 samples
- Kop Srov Road: 73 samples
- Boeng Tompun road: 224 samples
- Strung Meanchey drainage channel: 262 samples
- Boeng Salang catchment area: 90 samples
- Boeng Tompun: 54 samples

Results of the survey are as follows:

(1) Social and Economic Characteristics

Average household size is 4.25 persons. Major occupation of respondents is trading (32.4%) followed by wage earning, government employee and taxi driving (26.2%, 18.3% and 11.3%, respectively). A total of 37% of respondents report having a supplementary occupation. The proportion of employed to unemployed members in a household is 1:1.64. It was found that from the interviews there is not much difference in the level of family earning of each group. The average household annual income is US$ 1,309. The average commuting distance for employed persons is about 3.3 km.

(2) Information on Assets Owned by the Family

All households possess a plot of land for house and residence. The average residential area is 365m$^2$/household. Communities around Boeng Salang have small plots with only 110m$^2$/household. About 61% of respondents have some sort of land ownership certificate. Almost half the respondents in Boeng Trabek and Boeng Salang have no land holding certificate as their houses are built over swamps that are public lands. The average value of houses is US$ 7,329. Among assets owned by families, motorcycle (62.4%), television set (48.3%) and radio (17%) are most common followed by bicycle and power generator.

(3) Information on Migration

In the past 10 years, about 2/3 of respondents have never moved. The remaining 1/3rd of the population has migrated to Phnom Penh within the last 10 years (about 59% from within the districts of Phnom Penh and 38.4% from other provinces).

(4) Perception of Existing Living Conditions

The reasons cited commonly for living in present location are good neighbors, close to school, close to work place and available infrastructure/electricity. Perceived problems are inadequate/ no water supply, annual flooding, odor from polluted water, excessive mosquitoes/insects, and excessive garbage. Majority (92%) of the respondents had never heard of the drainage improvement and flood control project. The project is felt to be necessary by all respondents as it may contribute to alleviating existing environmental problems.

(5) Attitude to Relocation

More than half the respondents (56%) showed their cooperation to relocate while 19.4% disagreed and 24.7% gave no opinion. Communities around Boeng Tompun, Boeng Salang and Boeng Trabek are willing to cooperate especially since their houses are built on public lands and are prone to natural hazards like flooding. Significant reason for cooperation is the expectation of being provided better housing, improved environmental conditions and water availability. Residents around Trabek drainage channel do not want to move (38%) as they have been living there for a long time and the location is close to work place and market. The communities expect to be provided as part of the relocation assistance package new residential land, provision of funds for relocation of houses and assets to new place, and provision of supporting facilities at new place.

### 2.2.6 Present Condition of Water Use

In order to supplement available secondary data, a questionnaire survey was carried out on a limited number of samples (100 nos.). These samples were within those who could also be affected by necessary temporary or permanent resettlement.

Surveyed areas are the following:

Urban Area
- Boeng Salang
- Boeng Trabek
- Trabek Drainage Channel

Sub-urban Area
- Boeng Tompun
- Boeng Tompun Dike
- Phum Toul Cha Area
- Meanchey Drainage Channel

It was seen that there are four main sources of water for drinking/ cooking namely, deep well (25%), water supply from private vendors (50%), city water supply system (19%), and water from shallow wells (5.9%). Comparing water consumers in central urban area and the peri-urban area, the main water source for residents in the urban area is from private vendors while residents in sub-urban area utilize groundwater as their main source. The average water consumption is 8,352 liters per household per month. The water consumption in urban area is higher than in sub-urban area (10,300 and 6,850 liters/household/month, respectively). The average expense is 7.43 US$/month/household. This figure is higher for urban area as compared to sub-urban area. From the survey, it was found that only 9.9% of respondents reported suffering from water borne diseases (15.4% in urban area and 6.5% in sub-urban area). The willingness to pay for water supply maintenance is 0.85 US$/$m^3$ on the average.

## G3. Initial Environmental Examination

### 3.1 Objective

The IEE is being conducted to determine and evaluate the significance of the environmental impacts of proposed flood control master plan project measures. More detailed studies if identified as necessary can then be done as part of the environmental impact assessment (EIA) during subsequent project cycle stage and appropriate mitigation, monitoring and management plans can then formulated.

### 3.2 Laws and Guidelines

The IEE is being carried out as per prevailing environmental laws in Cambodia and as per JICA environmental guidelines.

### 3.3 Initial Environmental Examination Matrix

A matrix was prepared to evaluate and identify important environmental components that can be affected by the Project, their present condition, their future condition without the project and the impacts to be generated on them with the project implementation. The cause, effect and time aspect of environmental impacts needs to be understood. The "cause" refers to the Drainage Improvement and Flood Control Project, the "effect" refers to environmental impacts that need to be addressed at various project stages namely – planning, design, construction and operation.

### 3.4 Criteria Used for Environmental Examination

The scale of importance given to the environmental elements is an arbitrary scale to evaluate the importance of each environmental element to the problem of flooding in the study area. The importance rating is given to each environmental element according to the following evaluation criteria:

| Rating | Criteria |
|---|---|
| 1 (not important) | un-related to or un-affected by flooding |
| 2 (important) | affected to some extent by flooding |
| 3 (very important) | affected significantly by flooding |
| x (not clear) | may/ may not be affected by flooding; further study necessary |

The scale of present condition is an arbitrary measure to evaluate the current quality level of each environmental aspect determined to be important or very important in the importance rating above. The judgment is based on a comparison with conditions in the past. The scale of present condition evaluation in IEE Matrix was decided by comparing the present condition with the environmental state of the area 20 years ago as follows:

| Rating | Criteria |
|---|---|
| 1 | worse quality than twenty years ago |
| 2 | almost same as 20 years ago |
| 3 | better quality than 20 years ago |
| X | rating not possible due to lack of data; further study needed |

The next phase of the evaluation comprises an arbitrary scale determining what the future environmental condition would be "without " the proposed project. That is, what the environmental susceptibility to management is. Finally, potential environmental impacts to be generated by the project is predicted to preview the possible future environmental disruptions and benefits from the proposed project. The rating system for the predicted future condition and for the potential impacts in IEE Matrix is as follows:

| Rating | "Without" Project/ Potential Impacts to be generated "With" the Project |
|---|---|
| -3 | high significance (negative) |
| -2 | medium significance (negative) |
| -1 | low significance (negative) |
| 0 | no impact |
| X | impact not clear; further study needed |
| 1 | low significance (positive or beneficial) |
| 2 | medium significance (positive or beneficial) |
| 3 | high significance (positive or beneficial) |

The ratings of these four phases have been judged based on the environmental pre-conditions in the project area presented in previous sections of this report. Those environmental elements receiving an importance rating of 2 or 3 or x, a present rating of 1 or x, and a future "Without" project rating of x or +/- 2 or 3 are important. They are indicative of environmental aspects whose existing conditions are not good and/or which would be affected if the Project were not implemented.

Considering the last phase of the Matrix, a negative rating of any environmental aspect due to a proposed structural alternative/option indicates negative impact caused by the alternative. A positive rating indicates project benefit. Those environmental elements receiving a rating of x or - 2 or -3 due to any proposed physical alternative need further study during subsequent project cycle stage.

### 3.5 Potential Alternatives and Options

Various physical alternative measures either individually or in combination are to be applied in each watershed area in the city core, northeast area, middle area, northwest area, and south area. These alternatives/options are summarized below. Non-physical measures in the form of land use/building control and farm/lake conservation need to be implemented in some watersheds. Their implementation and resulting impacts are positive in nature. Therefore, in the IEE, only impacts of physical measures are considered.

(1) Reinforcement of Ring Dikes

Flood protection dike would be developed by reinforcement the existing ring dikes comprising Kop Srov Dike on the north (length of 9 km) and Tompun Dike on the south (length of 3.8 km). Height of existing Kop Srov dike will be raised to meet design high water level and both dikes will be reinforced as they are determined to be structurally very weak.

(2) Rehabilitation and Installation of Drainage Gates and Sluices

Existing drainage system would be improved. Drainage gates and sluices would be constructed at the existing ring dike as follows:

- 2 drainage gates/sluices at Kop Srov Dike
- 2 drainage gates/sluices at National Road No.5
- 2 drainage gates/sluices at Tompun Dike
- 1 drainage gate/sluice at National road No.4
- 1 drainage gate/sluice at Monireth road.

(3) Rehabilitation & Closure of Existing Outlets

Revetment with stop gates would be rehabilitated on the right bank of the Tonle Sap near Chaktomuk and Royal Palace.

(4) Rehabilitation, Reinforcement, and/or Installation of Pumping Stations

Three pumping stations are expected to be rehabilitated and/or installed to facilitate flood draining from the area to the east of Pochentong Airport including Boeng Tompun and Boeng Trabek areas.

(5) Rehabilitation of Regulation Ponds

Boeng Poungpeay and Boeng Kak would be rehabilitated for higher efficiency in flood regulation and improving water quality.

(6) Rehabilitation and Installation of Main Drainage Pipes

The existing drainage channels within the urban area would be improved for higher efficiency. Main drainage channels are to be constructed along six roads comprising road No.182, road No.215 (Jawaharlal Nerhu), road No.217 (Monireth), road No.245 (Mao Tse Toung), road No.201 and road No.315.

(7) Dredging and Improvement of Drainage Channels and Boengs

Existing drainage channels and Boengs would be excavated, i.e. drainage channels of Boeng Salang, Trabek and Tompun. This alternative needs permanent relocation of 855 households.

## 3.6 Potential Impacts due to the Considered Alternatives/Options

A description of the impacts on each environmental aspect due to each of the proposed structural alternative measures is presented in **Table G3-1**. A "With Project" evaluation is presented in **Table G3-2** for each environmental parameter due to proposed physical alternatives/options. Due to the differences of environmental characteristics, variation of project impacts can be expected (for more details see **Table G3-2**). A descriptive and comparative analysis of the impact of each proposed physical alternative on various environmental aspects is presented below.

(1) Topography & Location

Most of the proposed project physical measures are improvements of existing features, e.g., dike enhancement, boeng and drainage channel excavation, and pump rehabilitation. Therefore, serious alterations of topographic aspects are not expected.

(2) Flow Regime (Water balance)

Construction of flood protection revetment along the bank of the Tonle Sap and rehabilitation/installation of main drainage channel would have no impact on the water balance. Other physical alternatives would cause some impact as they relate with inflow/outflow control, which affects flow regime. The construction of dike, regulators and pumping stations would cause more impact than rehabilitation and dredging of boengs and drainage channel.

(3) Flooding & Surface Runoff

Construction of dike would be better than other alternatives in terms of flood protection since the dike structure would prevent flood and overflow along the total length of 30 km.

(4) Eutrophication

Rehabilitation/installation of main drainage channel and flood protection revetment along the bank of the Tonle Sap would cause no impact since the sites are not within the waterways and water in Sap river would be diluted.

Rehabilitation of boengs and dredging drainage channels and boengs would have positive impact since it would make water quality better. The remaining three alternatives would cause some minor adverse impact during construction phase.

(5) Turbid/Polluted Water

Construction of dike would cause some minor adverse impact during construction phase. Construction of flood protection revetment along the bank of the Tonle Sap and rehabilitation/installation of main drainage channel would cause no impact since water in the Tonle Sap will not be affected and it does not result in any waterway encroachment.

(6) Dissolved Oxygen

Construction of dike would cause some minor adverse impact during construction. Construction of flood protection revetment along the bank of the Tonle Sap and rehabilitation/installation of main drainage channels would cause no impact since water in the Tonle Sap will not be affected and waterways would not be encroached. The other remaining alternatives would also help in improving water quality by increasing DO.

(7) Offensive Odor

Dike construction would cause some minor adverse impact during construction phase while construction of flood protection revetment along the bank of the Tonle Sap and

rehabilitation/installation of main drainage channels would cause no impact in the Tonle Sap and waterways would not be encroached. The other remaining alternatives would help in improving water quality.

(8) Power and Water Supply

Most of alternatives would cause no impact on power and water supply. Construction of dike, rehabilitation of Boeng Poungpeay and Boeng Kak would cause some positive impact since it may induce power and water supply development opportunities in terms of expanding electrical and water supply services. The rehabilitated boengs could be a water source for communities around the boengs. Rehabilitation/installation of main drainage channel would cause some minor adverse impact during construction phase.

(9) Sanitary Facilities

Most of alternatives would cause no impact due to the method and operation pattern. The construction of dike would cause some positive impact since it would induce sanitary development opportunity.

Rehabilitation/installation of main drainage channels would result in improved sanitation due to regular draining of storm sewers.

(10) Drainage Network

Construction of dike, installation of regulators, construction of flood protection revetment along the bank of the Tonle Sap, installation of pumping station and rehabilitation/installation of main drainage channels would cause positive impact since they would improve drainage efficiency. The remaining two alternatives would cause no impact since they do not affect the drainage system.

(11) Solid Waste and/or Dredge Spoil Disposal

The first six alternatives would cause some minor adverse impacts during construction phase concerning which appropriate measures need to be implemented for waste disposal by construction contractors. Alternative seven involving dredging of lakes and canals would result in significant negative impacts in terms safe disposal of large amount of excavated material which has been determined to have high concentration levels of toxic contaminants. This needs to be mitigated by appropriate site selection for disposal of dredging spoil materials.

(12) Spontaneous/Planned Settlements

Rehabilitation/installation of main drainage culverts would cause no impact since there would be no relocation of people. Rehabilitation/installation of main drainage channels would cause some impact since there would be relocation of people. Dike construction would cause medium impact since about 150 households have to be relocated. Dredging of drainage channel/boengs would cause serious impact since around 855 households need to be permanently relocated. The other four alternatives would cause some minor adverse impact since only a few households need to be relocated.

(13) Squatters

The expected impacts are the same as those of spontaneous/planned settlements. Most of the households to be relocated are squatters. They only hope for a better living standard after relocation.

(14) Fishery

Construction of dike would be beneficial in preventing damage to fish culture ponds. Most of the fishponds are within the dike especially near Kop Srov Dike and Boeng Poungpeay. Installation of regulators and pumping stations would also help in preventing damages but to a lesser degree than dikes. Rehabilitation/installation of main drainage channels and construction of flood protection revetment along the bank of the Tonle Sap would cause no impact. Rehabilitation of boeng and dredging drainage channels/boengs would have some positive impact in improving aquaculture within the boengs.

(15) Industry

Construction of flood protection revetment along the bank of the Tonle Sap, dike construction, installation of regulators and pumping station would cause moderate to high positive impact since they will prevent flooding of industrial plants within the project area. Rehabilitation of boeng and dredging drainage channel/boengs would have no impact on industrial plants. Rehabilitation and installation of main drainage channels would cause some minor negative impact during construction since business and transportation would be interrupted due to relocation of transmission line, supporting towers, public water supply pipes and drainage pipes.

(16) Tourism

Construction of flood protection revetment along the bank of the Tonle Sap and rehabilitation/installation of main drainage channels would cause moderate positive impact since they would alleviate flood condition at main tourism sites such as the Royal Palace, the National Museum and the Russian Market. The other five alternatives would not cause any impact on tourism sites.

(17) Land Transportation

Construction of dike would induce more convenience in transportation for people living along Kop Srov and Tompun roads since the road would be reinforced for flood protection resulting in better condition of roads. The other six alternatives would cause some impact on traffic during construction phase due to closing/diversion of traffic lanes, falling of construction material, residues/soil on roads causing traffic jams.

(18) Waterborne Disease

All seven alternatives would be beneficial in decreasing prevalence of waterborne diseases due to control of flooding and drain waters and improvement in water quality. Environmental management of construction wastes and maintenance of sanitation and hygienic conditions during construction phase would result in minimal negative impact.

## 3.7 Conclusion

The main factors differentiating the significance and degree of impact of each proposed physical alternative are the natural environmental aspects comprising topography & location, flow regime (water balance), flooding and surface runoff and social environment aspects relating to spontaneous/planned settlements and squatters.

Each alternative has specific characteristics; e.g. a 30 km. dike and a 1 km flood protection revetment along the bank of the Tonle Sap are different in terms of operation of site and number of households to be evacuated. Another example is the difference between dredging drainage channels and/or Boeng Salang, Boeng Trabek, Boeng Tompun and low lands in Pochentong east area, as compared to installation of main drainage channels. Dredging needs permanent relocation of about 855 households while installation of drainage channel needs no relocation. Dredging material disposal is important as they have significant volume and high levels of toxic contaminants. Appropriate site selection and site design for safe landfill and/or disposal is necessary.

From the point of view of minimizing social impacts due to relocation, dike construction is the most appropriate. Second is construction of regulators, and third is installation of pumping stations. The least preferred option is dredging of drainage channel and boengs as they require permanent relocation of a large number of households.

Dike construction would cause medium impact since 150 households have to be relocated.

The only major significant negative impact is due to the physical alternative, dredging of drainage channel/boengs. This would cause serious impact since 855 households need to be relocated permanently and an appropriate relocation, resettlement and rehabilitation plan for affected persons needs to be formulated and implemented. Dredging spoil disposal site selection and safe disposal methods are also important considerations.

It can be concluded that the proposed project impacts are largely beneficial. Negative impacts of relocation and dredging spoil disposal can be controlled by formulation of mitigation measures. On the other hand, without the proposed project physical and non-physical measures (**Table G3-2**), flooding in Phnom Penh would continue to cause considerable economic disruption and social hardship to a very large proportion of the population. Vulnerable social groups living in flood prone areas like in or near dikes, drainage channels and lakes, would be seriously affected, and could be further marginalised. Risk to health hazards and outbreak of water-borne diseases after floods would be higher.

## G4. Environmental Impact Assessment of Priority Project - Reinforcement of Kop Srov and Tompun Dikes

### 4.1 Existing Conditions

Along the perimeter of the Study Area, there are two dike sections with considerably large height, of more than 3 m: namely, Kop Srov and Tompun Dikes. The features of the two dikes can be summarized as follows:

Features of Kop Srov and Tompun Dikes

| Description | Kop Srov Dike | Tompun Dike |
|---|---|---|
| (1) Length | 9.0 km | 4.4 km |
| (2) Existing Conditions | | |
| (a) Crest Elevation | EL. 10.1 to 10.7 m | EL. 10.0 to 10.4 m |
| (b) Height above Land* | 4 m | 5 m |
| (c) Crest Width* | 10 m | 20 m |
| (d) Formation Width* | 26 m | 40 m |
| (e) Side Slope | Approx. 1:2 | Approx. 1:2 |
| (f) Structural Conditions | • No pavement on the crest, undulated, and marshy in the rainy season.<br>• Many holes found on the dike crest and even on the slopes that should be the traces of piping through the dike body.<br>• Slopes eroded in places. | • No pavement on the crest, undulated, and marshy in the rainy season.<br>• No holes found on the dike crest, however a lot of piping observed in past flood times.<br>• Slopes eroded in places. |
| (g) Social Conditions | • Squatters live on both slopes in the east end portion. | • Squatters occupy on both slopes along the entire stretch. |
| (3) Design Conditions | | |
| (a) High Water Level | EL. 10.4 m | EL. 9.0 m |
| (b) Freeboard | 0.8 m | 1.1 m |
| (c) Hydraulic Gradient of Seepage Water** | 1/8 (1/5) | 1/8 (1/8) |

Remarks;
* At a higher portion in the stretch.
** A value in the bracket shows the existing condition

(1) Kop Srov Dike

As can be seen in the table above, Kop Srov Dike is short in height by 1.1 m at maximum and is judged to be quite weak against seepage phenomenon. Hence, heightening and widening the existing dike should be done.

(2) Tompun Dike

With respect to Tompun Dike, the height is sufficient to confine the high water level (EL. 9.0 m). However, the dike body is supposed to be weak against seepage judging from the fact that piping was reported in past flood events although the formation width of the dike is relatively large even compared to other practices.

(3) Svay Pak Drainage Sluiceway

There exists a sluiceway passing under NR-5 about 2 km southward from the intersection to Kop Srov Dike. The sluiceway was constructed and managed by Department of Agriculture, Forestry and Fishery, MPP with function of:

- To avoid floodwater from entering into the Northeast Area, causing serious inundation over the area; and
- To control the water stage of Boeng Poungpeay area for agricultural purpose.

The sluiceway is provided with wooden gates, which however has lost water-tightness because of lack of maintenance and repair. Moreover, the civil structure itself is heavily damaged in places. Once the gate structure should breach, the Northeast Area would be under floodwater. Taking into account such importance and the existing status, the sluiceway will be re-constructed under the Project.

## 4.2 Projects

### 4.2.1 Reinforcement of Kop Srov Dike

(1) Necessary Measures

From the standpoint of flood protection, measures necessary for the existing Kop Srov Dike are as follows:

a. Heightening of the existing dike, whose crest elevation is EL. 10.1 m at the lowest portion, to confine the design high water level, EL. 10.4 m, throughout the dike stretch;

b. Strengthening of the existing dike body that is damaged in many places by seepage, heavy traffic, etc.; and

c. Pavement of the existing road surface for smooth operation of flood defense activity and easy maintenance of the dike.

The reinforcement by stretch, comprising measures for either dike or road, is as follows:

Measures Applicable by Stretch

| Section | Crest Height of Existing Dike | Measures | |
|---|---|---|---|
| | | For Dike | For Road |
| 0+000 to 0+900 (900 m long) | EL. 10.5 to 10.7 m (higher than the design HWL EL. 10.4 m) | Not to be constructed. | To be paved to connect the following section with NR-5. |
| 0+900 to 7+650 (6,750 m long) | EL. 10.1 to 10.9 m (partly lower than the design HWL 10.4 m) | To be constructed with a crest elevation of 11.2 m. | To be paved. |
| South from 7+650 (9,350 m long) | Above EL. 10.5 (higher than the design HWL EL. 10.4 m) | Not to be constructed. | To be paved to connect the above section with NR-4. |

(2) Dike Reinforcement

A dike will be provided on the outer side of the existing dike road in the section between Station 0+900 and 7+650 (6,750 m in length). This construction method of dike can achieve an about 10 % of cost reduction compared to full-width heightening of the existing dike road, and moreover has the following advantages:

a. To ensure seepage prevention by filling non-permeable soil on the riverside of the existing dike;

b. To secure smooth construction by keeping dike construction area from the existing roadway; and

c. To minimize evacuation of houses that are much more built on the inner side of the dike *.

* Number of existing houses along Kop Srov Dike is as follows:

| Section | Number of Houses | |
|---|---|---|
| | Outer Side | Inner Side |
| 0+000 to 0+900 | 66 | 36 |
| 0+900 to 2+000 | 30 | 26 |
| 2+000 to 4+000 | 3 | 178 |
| 4+000 to 6+000 | 2 | 7 |
| 6+000 to 7+650 | 19 | 42 |
| 7+650 to 9+000 | 0 | 0 |
| Total | 120 | 289 |
| | 409 | |

The dike is 3 m wide on its crest, and slopes down at 1:2 on both sides with sod facing. The material of diking will be of laterite, which is suitable to control seepage so that a land side berm proposed in the Master Plan can be left out.

(3) Road Pavement

The existing road surface will be paved between the junctions with NR-5 and NR-4 (17,000 m in length). The pavement is for the following purpose:

- Easy operation of flood defense and maintenance of the dike;
- Prevention of piping holes made by seepage of rainfall on the dike crest; and
- Protection of the dike body from heavy traffic.

Considering that the road may constitute in future a part of the proposed Outer Ring Road, cross-sectional design of the road should follow Cambodian National Road Standard, namely a carriageway of 7.0 m with 1.5 m shoulders on both sides.

As for the type of pavement, the high quality asphalt is selected in view of durability, cost, easiness of construction and maintenance.

### 4.2.2 Reinforcement of Tompun Dike

(1) Design Dike Height

The design crest elevation of the dike is EL. 10.1 m constantly along the whole stretches (the design high water level, EL. 9.0 m, plus freeboard of 1.1 m to cope with wave setup).

(2) Necessary Measures

The crown elevation of Tompun Dike ranges from EL. 10.0 m to 10.4 m, while the design dike elevation being EL. 10.1 m. No heightening is hence required and necessary measures for the 4.44 km stretch of Tompun Dike are as follows:

a. Strengthening of the existing dike that is damaged in some places by seepage and traffic; and

b. Pavement of the existing road surface for easy operation of flood defense and maintenance of the dike.

(3) Dike Reinforcement

Pavement on the dike crest is recommended to prevent seepage from the crest to the slope surface.

* Number of existing houses along Tompun Dike is as follows:

| Section | Number of Houses | |
|---|---|---|
| | Outer Side | Inner Side |
| 0+900 to 2+000 | 159 | 133 |
| 2+000 to 3+000 | 92 | 60 |
| 3+000 to 4+000 | 92 | 54 |
| 4+000 to 5+300 | 91 | 16 |
| Total | 434 | 263 |
| | 697 | |

(4) Road Pavement

The existing road surface will be paved for the whole stretch of Tompun Dike with a length of 4.44 km. The pavement is for the following purpose:

- Easy operation of flood defense and maintenance of the dike;
- Prevention of piping holes made by seepage of rainfall on the dike crest; and
- Protection of the dike body from heavy traffic.

Likewise with Kop Srov Dike road, considering that Tompun Dike road may constitute in future a part of the proposed Outer Ring Road, cross-sectional design of the road should follow Cambodian National Road Standard, namely a carriageway of 7.0 m with 1.5 m shoulders on both sides. The pavement is of the high quality asphalt type.

### 4.2.3 Re-construction of Svay Pak Drainage Sluiceway

(1) Design High Water Levels

The design high water levels outside and inside the sluiceway site are as follows:

- Outer side (Tonle Sap River) : EL. 10.0 m
- Inner side (Boeng Poungpeay) : EL. 7.0 m

(2) Structure

Structures of the proposed drainage sluiceway are as follows:

(a) Cross-sectional Area

In the following considerations, the total cross-sectional area of the sluiceway is determined 1.5 m wide, 2.0 m high, 3 cells equaling 9.0 $m^2$ in total:

(b) Structural Type

The sluiceway is of the general type of RC gate structure with manually operated steel slice gates.

(c) Construction Method

Cofferdams shall be provided upstream and downstream of the construction site with temporary drains. Further, relocation of NR-5 is necessary during the work, which may be shifted on the upstream cofferdam temporarily.

## 4.3 Summary of Project Features

(1) Reinforcement of Kop Srov Dike

| | | | |
|---|---|---|---|
| (a) | Stretch | : | 7.65 km section southwestwards from the junction with NR-5 plus 9.35 km connecting road |
| (b) | Design High Water Level | : | EL. 10.4 m (30-year return period) |
| (c) | Design Dike Height | : | EL. 11.2 m (adding 0.8 m of freeboard) |
| (d) | Dike Structure | : | Earthfill dike with a 7 m wide asphalt-paved road |

(2) Reinforcement of Tompun Dike

| | | | |
|---|---|---|---|
| (a) | Stretch | : | 4.44 km section between the junctions with the Inner Ring Dike and NR-303 |
| (b) | Design High Water Level | : | EL. 9.0 m (30-year return period) |
| (c) | Design Dike Height | : | EL. 10.1 m (adding 1.1 m of freeboard) |
| (d) | Dike Structure | : | 7 m wide asphalt-paved road |

(2) Svay Pak Drainage Sluiceway

| | | | |
|---|---|---|---|
| (a) | Location | : | Existing Svay Pak Drainage Sluiceway (PK #9) site |
| (b) | Structure | : | 3 lanes box culverts (1.5 m by 2 m) each with a steel-made slide gate |

## 4.4 Environmental Surveys

All environmental surveys were sub-contracted out to TEAM Consulting Engineers Ltd. Results presented herein are summarized from the study reports (TEAM, April 1999). These reports should be referred to for detailed information.

### 4.4.1 Land Use Survey

The study on land use was carried out as follows:

- Study the existing land use patterns of the study area from various sources e.g., the related documents, aerial photo and maps (scale 1:2,000).
- Investigate current land use by field surveys and identify areas of importance in the study area.

The area surveyed are within 20 m strips on both sides of Kop Srov road in an area of about 304,000 $m^2$ and in an area along Tompun road (177,040 $m^2$).

(1) Kop Srov Dike

The results of the investigation revealed that land use pattern along the Kop Srov road comprise of 6 individual categories and 1 mixed category as follows:

Land Use Types along the Proposed Kop Srov Dike Reinforcement

| No. | Land Use Type | Approximate Area ($m^2$) | Percentage (%) |
|---|---|---|---|
| 1. | Resident (U/R) | 21,354.43 | 7.03 |
| 2. | Factory / Industry (U/F) | 13,594.53 | 4.47 |
| 3. | Paddy field (A1) | 754.45 | 0.25 |
| 4. | Orchards (A/O) | 252.68 | 0.08 |
| 5. | Idle land (M/I) | 139,128.01 | 45.77 |
| 6. | Paddy field / Idle land (A/P) | 5,964.71 | 1.96 |
| 7. | Water bodies (W) | 122,951.19 | 40.44 |
| | Total | 304,000.00 | 100.00 |

(2) Tompun Dike

The land use patterns can be classified into 7 categories as presented below:

Land Use Types along the Proposed Tompun Dike Reinforcement

| No. | Land Use Type | Approximate Area ($m^2$) | Percentage (%) |
|---|---|---|---|
| 1. | Resident (U/R) | 86,542.11 | 48.87 |
| 2. | Factory / Industry (U/F) | 9,020.00 | 5.10 |
| 3. | Entertainment / Restaurant / Hotel (U/E) | 848.00 | 0.48 |
| 4. | Orchards (A/O) | 4,600.00 | 2.60 |
| 5. | Aquatic Plants (A/A) | 19,770.10 | 11.17 |
| 6. | Idle land (M/I) | 43,036.46 | 24.31 |
| 7. | Water bodies (W) | 13,223.33 | 7.47 |
| | Total | 177,040.00 | 100.00 |

### 4.4.2 Transportation Survey

In the Study Area, the major transportation network comprises the Kop Srov road, the National road No.4, No.5 and Tompun road. Relevant data on road transportation were collected by field investigation.

Field survey and traffic records were conducted on Kop Srov and Tompun roads during December 27-28, 1998. These roads are expected to be directly affected by transportation of construction materials and equipments to the project site, in terms of traffic congestion and deterioration of road surface during the construction period.

(1) Road Network

**Kop Srov road:** This road is the main transportation route for truck transportation. The width of carriageway is approximately 10 m with laterite pavement and bad surface conditions can be found in many sections. During the rainy season only some sections of this road can be utilized. The road is connected to the National road No.5 on the northeast and with National road No.4 on the south.

**National road No. 4:** It is the main road to Phnom Penh and the important cities near the coast e.g., Sihanoukville (230 km away from Phnom Penh) and Kampot (150 km) etc. It is also the access to the Pochentong International airport. The surface is asphaltic concrete with good condition but some sections need to be improved.

**National road No. 5:** This road is located along Sap river. It is the main transportation route to important cities such as Batambong (325 km from Phnom Penh) and Kampong Chnang (90 km) in the west of the country. This road is also utilized for goods transportation from the Phnom Penh Port near the Cambodian-Japanese Friendship bridge.

**Tompun road:** This road is about 10 m wide with laterite pavement. The good pavement condition can only be found at the section connecting with the road No. 271. The remaining sections are in bad condition. Some sections are flooded. In addition, a lot of dust is generated and many houses have encroached on this road.

(2) Traffic Volumes

**Table G4-1, G4-2 and G4-3** present the traffic volume records during field survey conducted on December 27-28, 1998. It was found that the traffic volumes through the Kop Srov road are almost similar on both days of the survey with 3,115 vehicles and 2,931 vehicles on December 27 and December 28 respectively. Motorcycle is the major type of vehicle found on Kop Srov during the first and second day (2,716 and 2,385 vehicles respectively), followed by Medium Truck (6 wheels; 100 and 127 vehicles on the first and the second day respectively).

Heavy trucks (10 wheels) and trailers, numbered about 65 vehicles and 56 vehicles on the first and second day respectively. In addition, 57 carts hauled by horses were found on the first day (52 were found on the second day).

For Tompun road, the records (Table G4-3) show that total traffic volumes are 4,535 and 3,994 vehicles on the first day and the second day, respectively. Motorcycles were found with the highest volume, 3,770 and 3,028 vehicles followed by bicycles and

tricycles with 433 and 586 vehicles and car and pick-up with 159 and 199 vehicles on the first and second day respectively. Trucks were found to have low numbers such as medium trucks were found with 80 and 117 vehicles followed by heavy truck with 29 and 12 vehicles and light truck with 5 and 6 vehicles respectively. Trailer was only found with 4 vehicles on the first day.

For the bus, light bus (4 wheels) was found with higher volume of vehicles than heavy bus (6 wheels). No heavy buses were found on the two survey days.

### 4.4.3 Survey on Past Flood and Inundation

To clarify the flood and inundation condition in recent major flood years, i.e. 1995 and 1996, an interview survey in the Study Area was carried out. The survey was conducted at 609 points in the City Core and 291 points in the suburban area, totaling 900 points, by using 1:20,000 scale map and a questionnaire form. The interview comprised of the following items:

- Location of sample point;
- Name of informant;
- Maximum flood/inundation depth in the year;
- Duration of the flood/inundation;
- Direction of inflow and outflow;
- Cause of the flood/inundation, and
- Suggestion from the informant for mitigation measures.

The major findings obtained are:

- No over-topping happened along the Outer Ring Dike in both flood years due to the flood defense activity by governmental agencies concerned (**Table G4-4**). So, all the inundation identified through the interview survey was rated as ones caused by local rainfall, except in the South Area where floodwaters from the Prek Thnot river system easily come in and out through openings provided along the Pray Sar road.
- There is no significant difference in the magnitude of inundation in the year 1995 and 1996 (**Table G4-5**). In this case, flood and inundation map was prepared for the year 1996 which has a higher water level of the Tonle Mekong by 0.8 m and had larger local rainfall in the Study Area.
- Interviews cannot specify the exact dates when flood or inundation took place in the year at the locations. This means that the surveyed flood/inundation depths and duration correspond to the maximal ones which occurred in the year.

### 4.4.4 Asset and Flood Damage Survey

Asset and Flood Damage Survey (AFD) was carried out to collect data on the damage caused by flood and inundation and assets owned by households, business organizations and social organizations. The following table summarizes the number of samples surveyed by type of interviewees.

**Table G4-6** summarizes the findings of the AFD Survey.