Technical Feasibility for Kampong Chhnang Flood Protection[1]

[1] Prepared by the projection preparation technical assistance (TA 7986-CAM) consultant team.

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A. Introduction

1. This report provides the detailed analysis and technical justification for the flood protection works in Kampong Chhnang.

2. It provides a description of the existing situation and impact of inundation in the town. Section C forms the options and strategies for flood mitigation, while Section D develops the design and levels of service and standards for the flood protection works. A detailed project description with maps and plans is at Section E with costs contained in the next section. Benefits and risks are described in Section 0 and arrangements for implementation and procurement are at Section H. Project sustainability through improved operation and maintenance is covered in the next and final Section.

3. This report aims to provide the technical feasibility for the proposed project, it only considers to environmental or resettlement issues where they relate to the project design and impacts as these aspects are comprehensively covered in their own sections of the report. Similarly while risks have been assessed, the cost-benefit analyses are also covered in their own sections of the report.

4. An overview of Kampong Chhnang is provided in Section Three of the main report. As such this appendix deals only with the proposed flood protection intervention in Kampong Chhnang.

B. Background to Flooding

1. Existing Situation

5. Kampong Chhnang lies about 100kms North-West of Phnom Penh on National Highway 5 which is the main route to Poipet on the Thai Border. It is a provincial capital and serves as an administrative center and market town. It was created as a municipality in 2008. Of the six provincial capitals surrounding the Tonle Sap, Kampong Chhnang is the closest to the lake and is the only municipality which has the Tonle Sap forming part of its boundary.

6. The current municipality comprises four Sangkats, or communes, with a total population of 40,000, although the total urban population is around 56,000 as areas outside the municipal limits are also being urbanized. By the end of the proposed project implementation period, 2020, the urban population is estimated to be between 66,000 to 72,000.[2]

7. This proximity to the Tonle Sap has been a benefit in providing much of the economic base of the town as a port and fishing settlement. However, the annual cycle of the water level fluctuation in the Tonle Sap means that high water levels often leads to the town being inundated. Flooding is also caused from run off from the hills to the West of the town during heavy rainfall.

8. However it is the Tonle Sap that invariably causes the most flooding. Data provided by the Ministry of Water Resources and Meteorology (MoWRaM) shows the difference between annual high and low water levels in the Tonle Sap at Kampong Chhnang over the last 30 years, averages at just under eight meters. This is shown in Figure B.2. Trend lines applied to this chart show only a marginal increase in the average highest water levels over this period, but reveal that the lowest annual levels have been decreasing with a slight recent recovery. In some ways this lower trend is of more concern as it could imply a reduction in total water flow in

[2] Source – PPTA 7986-CAM consultants developed from census data.

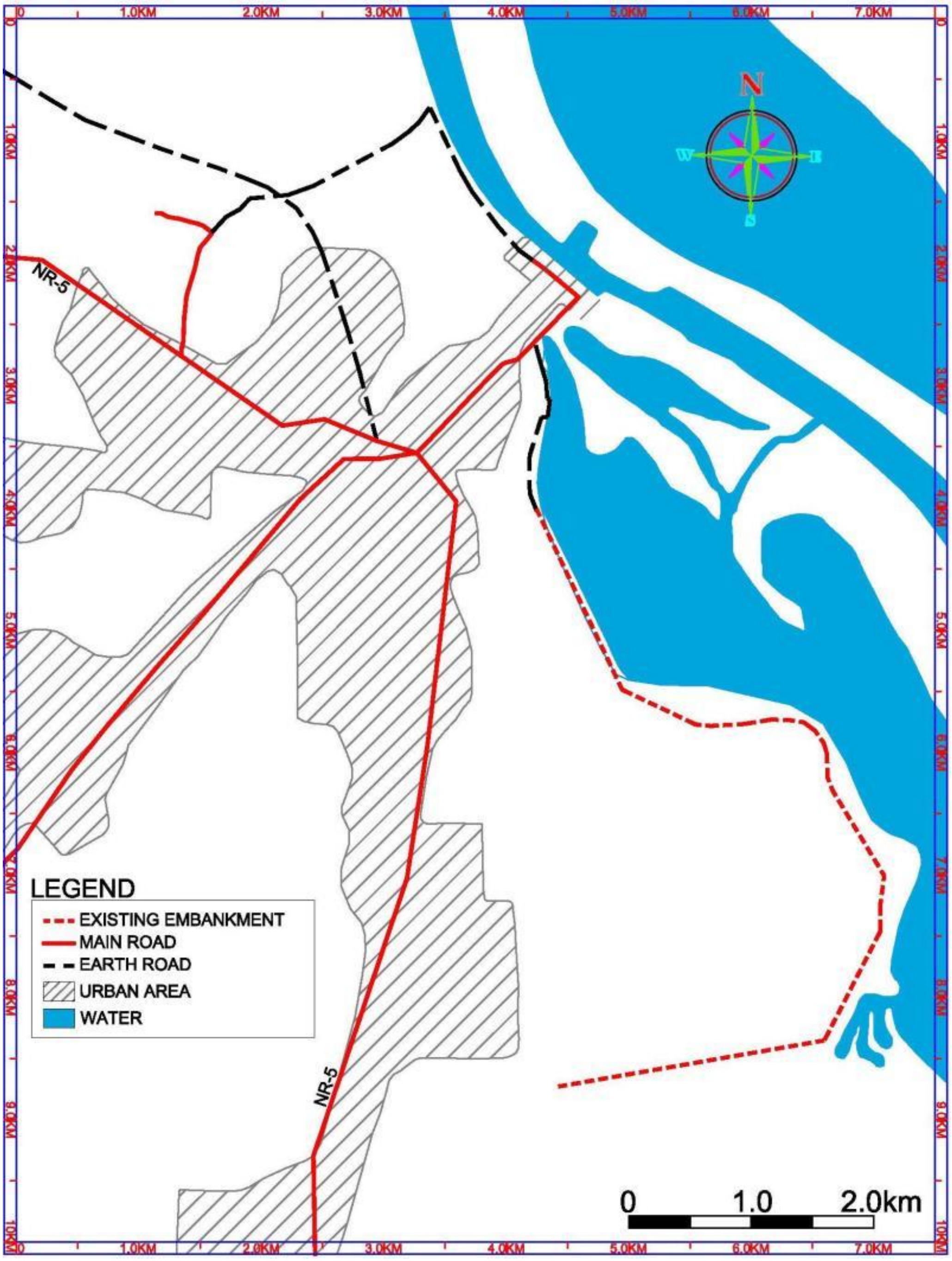
the Tonle Sap which corresponds with the Lower Mekong Basin 20-year development plan[3] which estimates a decrease of the dry season river flow by 7 to 17 per cent.

1 9. This range in water levels is demonstrated by the fact that during the dry season area directly adjacent to the Tonle Sap serves as a market as well as a port. Once the level begins to rise, this market is abandoned and the structures dismantled. Other areas adjacent to the lake are used for agriculture during the dry season. This change is shown in

[3] Basin Development Strategy, Mekong River Commission, 2011

Figure B.3.

Figure B.1 Map of Kampong Chhnang

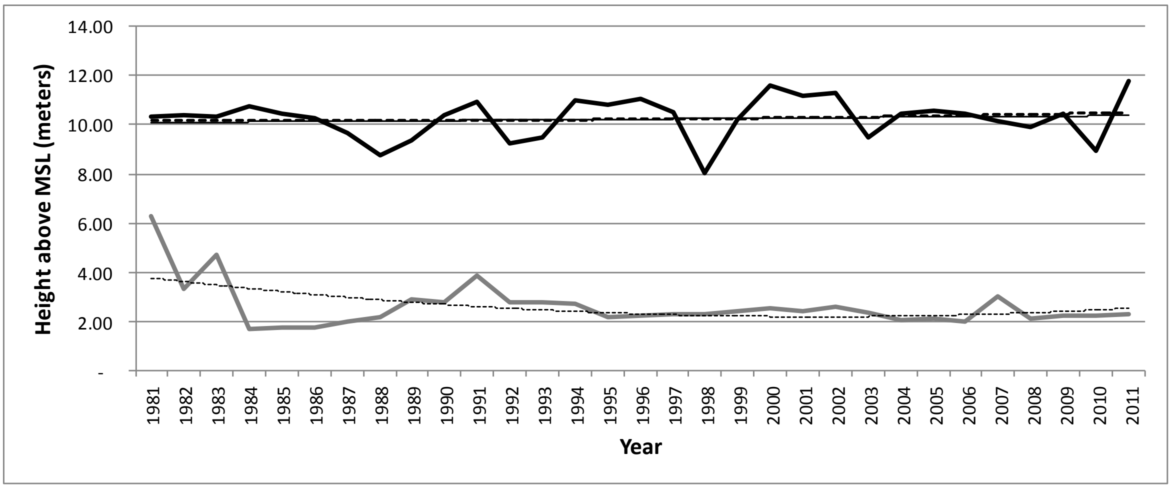


Source: TA 7986-CAM Consultants

2 10. As is shown in Figure B.1 Kampong Chhnang can be divided into various drainage areas. The area of the town towards the Tonle Sap that is prone to flooding is mainly used for agriculture and there is little settlement. The bulk of the town's population live in the town center and in ribbon development along NH5, areas that are on higher land. While the town is growing mainly to the West, away from the river, there is increased development along the roads leading to Tonle Sap. In particular, a provincial highway that cuts through the town is fully developed. The photograph at

Figure B.3 has been taken at the end of this road. The houses in these areas are raised on stilts to avoid flooding during the wet season and many of these houses lack permanent road access for months of the year.

Figure B.2 Annual Highest and Lowest Water Levels in the Tonle Sap at Kampong Chhnang



Source MoWRaM (MSL – Mean Sea Level)

Figure B.3 Seasonal Market Adjacent to Embankment

Source: TA 7986-CAM Consultants

11. Close by this area, the Municipality estimates that around 1,000 households actually live on the river with another 500 households residing on the riverbanks. They are mainly fisher folk, and around 80% are ethnic Vietnamese who settled there in the 1960s, were forced out in the 1970s and then returned in 1980. As can also be seen from Figure B.4, solid and liquid waste management is a particular problem in the area with much of the area severely environmentally degraded. A 2010 proposal to relocate this community failed as the proposed site which is six kilometers away and inland from the river was not acceptable to the community. The houses on the river banks that are not on stilts, are fixed on dry land and float during the wet season.

Figure B.4 Riverside Dwellers and Floating Community in Kampong Chhnang

Source: TA 7986-CAM Consultants

2. Flooding and Drainage Issues

a. Flooding Impacts

12. The town is frequently inundated during the wet season with the last major flooding occurring in 2011, when the existing embankment was overtopped and flooded up to National Highway 5 which passes through the town. This is shown in Figure B.5.

3 13. The flood water rose to a level of 11.78 meters above mean sea level (MSL), 180 millimeters above the previous highest level in 2000. The level of the embankment shown in

Figure B.3 is around 11.6 to 11.7 meters above MSL, thus this new road and the surrounding properties and markets were inundated for a few weeks. Similarly much of the urban area at the town center also suffered flooding.

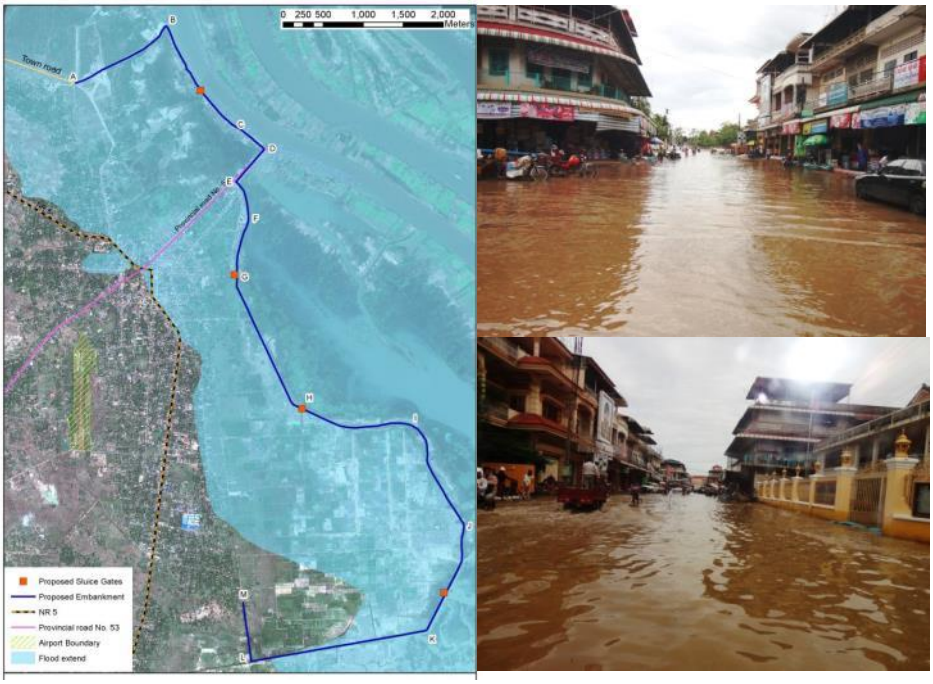
Table B.1 Flooding Impacts in Sangkats of Kampong Chhnang

Sangkat	Area (Ha)	Population	Population Affected	Per cent Affected	Area Flooded (Ha)	
					Urban	Agricultural
Chrey Bak	4,499	11,251	1,430	13	0	310
Phsar Chhnang	1,060	17,489	17,489	100	120	70
Khsam	1,262	5,899	4,872	83	140	320
B'er	231	6,154	2,593	42	20	0
K Chhnang	2,111	10,818	2,274	21	90	560
Total	**9,163**	**51,611**	**28,658**	**56**	**370**	**1260**

Source: TA 7986-CAM Consultants

14. Neither the Municipality, nor the Department of Water Resources and Meteorology have an estimate of the cost of the damage, but around 55% of the population living in the flood-affected Sangkats were inundated while approximately 370 hectares of urban, and over 1,200 hectares of agricultural, land was also inundated.

Figure B.5 Impact of Flooding in Kampong Chhnang in 2011



15. As well as inundating the center of the town, all of the commercial areas around the port were inundated that severely affected the livelihoods of around 800 shops, 300 temporary small traders and all the market stall holders[4]. The river dwellers, while not suffering any flooding, were also affected as access to vital services on the shore, plus their ability to market their fish produce, were lost for a period of nearly a month.

[4] PPTA consultant's estimates.

16. In Kampong Chhnang, from the social survey carried out as part of the project preparatory technical assistance (TA 7986-CAM), 87% of households said that their village floods. So flooding is perceived as a major issue across the town.

b. Existing Flood Protection and Drainage

17. Some flood protection work has been carried out, mainly in raising the embankment at the end of Provincial Highway 53 where it extends up to the Tonle Sap and functions as a perennial port. This was done in 2006 by a private concession under the Provincial Government who recouped costs from local businesses and from operating the seasonal market and port in this area. Some new embankments have also been built to the North of the town to prevent flooding. In the agricultural areas to the East of the town, many small private embankments have been built to protect crops from flooding.

18. An old damaged weir provides dry season access to around 300 families living outside the embankment. During the wet season, these families have no fixed links to the town as the road is flooded and boats have to be used for any transport.

19. There is a drainage system in the town center that was built in the 1960s and extended in the 1980s. Details of its lengths are shown in Table B.2. The system mainly comprises piped drains with some surface drains that are covered, particularly in the market area. The system receives both rainwater and also sullage and wastewater from houses, although it is unclear whether the system was originally designed for the latter. However, as it receives both storm and wastewater, it functions as, and should really be termed, a sewerage system.

20. The other main drains and ponds that intercept run-off and shield the town center from inundation originating from the hills to the West of the town. However, many of these ponds are being encroached, and, to a lesser extent, the drains which increases run-off and potential for flooding.

21. The sewerage system has multiple discharge-points that drain towards the Tonle Sap and flow into drainage canals with much of the wastewater being used for irrigation. The central market has its own sewer and outfall that also drains towards the Tonle Sap, but via an open channel. During the dry season, the base flows at these discharge points will comprise mainly wastewater from houses, commercial and institutional buildings, and even some from the industries in the town. There is no treatment but as the wastewater flows into the Tonle Sap it is substantially diluted.

22. Many of the road-side inlets on the sewerage system are blocked with solid waste and there do not seem to be enough inlets to accommodate runoff during heavy rainfall. The provincial department of public works and transport (PDPWT) has an operational sludge pump for cleaning blocked sewers. Table B.2 provides a summary of the existing drainage system.

Table B.2 Summary of Stormwater Drainage in Kampong Chhnang

Drain Type	Length Surface[5] Drains (meters)	Length Piped Drains (meters)	Total
Lined		9,110 (PDPWT-2013)	9,110
Unlined	3,272 (PDPWT-2013)		3,272
Total	3,272	9,110	12,382

Source: Kampong Chhnang provincial department of public works and transport.

[5] These are drains that have been constructed along the surface, usually at the edge of the road. They can also be referred to as open drains, but as they are often covered, particularly in market areas, the term surface drain has been used.

23. Exact numbers are not known, but PDPWT and the municipality estimate that only around 10 to 20 per cent of the town is connected to the system despite connections not requiring any permission from the Municipality, or PDPWT, who maintain the system. Most connections are made by the householder who joins the household waste pipe, either directly or via a septic tank, to the sewer. Usually this is at a manhole, but not always. Without any monitoring by PDPWT, invariably there will be leaks at various places in the system, while sewers may even be damaged.

24. Importantly, the Municipality estimates that only around 50% of the town's families have access to latrines making human waste disposal a major issue. With around 1,500 households living on, or adjacent to, the Tonle Sap, plus the many houses on stilts that do not have latrines, this could even be an underestimate.

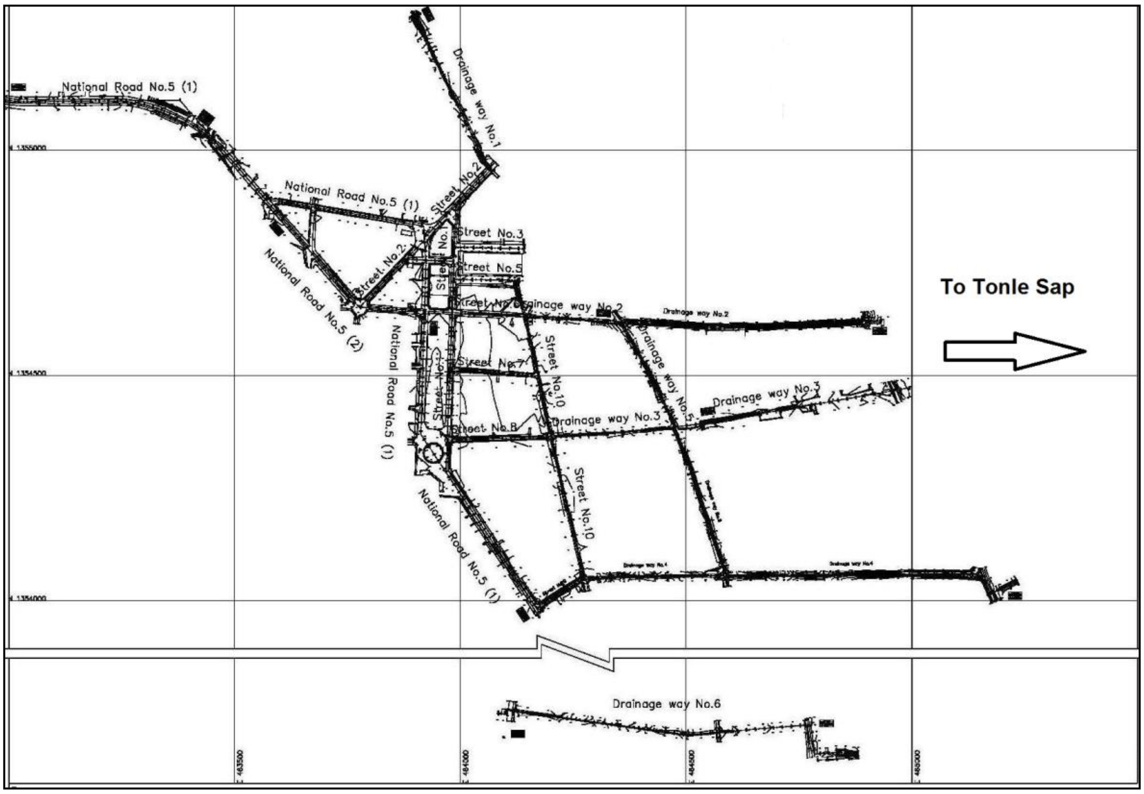
25. During the Khmer Rouge era in the late 1970s, a 14 kilometer long earth embankment was built around the North and east of the town to provide flood free irrigable land. This embankment varies between two to four meters in height depending upon adjacent ground levels. While the embankment has been breached in several places, it still provides a relatively large flood free area that has encouraged permanent settlements along parts of its length, particularly near Provincial Highway 53.

3. Ongoing and Planned Activities

26. The Japan International Cooperation Agency (JICA) is rehabilitating selected drains and some roads in the city center. The construction work started in January 2013 and should be completed by the end of 2014. As the intention is to create a separate stormwater drainage system, detailing of each sewer and drain requires extensive consultation with local communities and PDPWT. JICA will fund the construction of some surface drains, but mostly piped drains sized between 300 millimeters and 1,500 millimeters diameter will be built. JICA has included removal of unexploded ordinance (UXO) costs for pre-excavation work in the cost estimates.

27. There is a proposal from the municipality to clean up one of the streams that runs through town and some of its retention ponds. However there does not seem to be a major flooding issue with the drain and stream, it mainly needs better maintenance and removal of blockages caused by solid waste and other material.

Figure B.6 Plan of Ongoing JICA Drainage Improvements



Source: Amended by TA 7986-CAM Consultants from "Preparatory Survey Report For Flood Disaster Rehabilitation and Mitigation", JICA. 2012 (online: http://libopac.jica.go.jp/images/report/P1000006480.html)

28. The Province and Municipality propose to upgrade and rehabilitate the long embankment circling the town to the North and East, by raising the embankment level and improving the road in certain areas.

C. Flood Mitigation Strategy

1. Objectives and Guiding Principles

29. The annual hydrological cycle of the Tonle Sap is the main cause of flooding in Kampong Chhnang. While minor flooding can also be caused by run-off from the adjacent hills, this is much less of an issue and is being addressed by the current JICA interventions discussed in paragraph 0 above. Addressing the Tonle Sap flooding, should thus be the main target of any intervention in Kampong Chhnang. The main aim of the flood protection interventions in Kampong Chhnang is thus to minimize damage caused by flooding.

30. To develop the drainage strategy, some guiding principles have been developed. The objective of a town's flood prevention strategy should be:

- Drains should not be built in an ad hoc manner, this tends to just move the problem elsewhere – develop a master plan for the drainage system with prioritized routes and levels, thus the system can be built as funds become available, but will be an integrated functioning system;
- Aim to reduce not just the frequency of flooding, but also the length of time that any floods occur;

- Recognize that greater urbanization will increase run-off, and introduce actions to accommodate this – planning should importantly avoid reducing drain sizes or filling in retention areas either intentionally or by allowing them to be encroached upon;
- Develop a hierarchy of flood damage based upon minimizing the cost of damage – details on this are provided in paragraph 0 below;
- Aim to use topography as much as possible to minimize costs and any pumping;
- Aim to use any existing drainage system and any flood protection works as much as possible;
- Design the drainage system to accommodate both storm flows and wastewater coming from houses – if a combined system is used, then grades must allow for minimum velocities to avoid solids settling in the sewers and blocking them.
- Accommodate climate change scenarios by translating the variables and options into practical, tangible, and importantly, cost effective, figures that can be built into the design.

31. The aim of any flood prevention strategy should be to avoid floods and the damage they cause. However, this can be very expensive to achieve and in reality a “hierarchy of potential damage” is usually developed. This aims to ensure that the costs and impacts of any flooding damage are limited and only gradually move up the scale with more severe conditions. The hierarchy can be described as guiding any flooding to first impact on:

- Main drains and retention areas; then
- Open land – recreation areas and fields; after which
- Roads; and then,
- Non-structural property such as gardens.
- The aim is to completely avoid any flooding inside, and any structural damage to, buildings and most importantly, any human casualties.

2. Options

32. The flooding from the Tonle Sap is a non-point source of flooding that initially originates from water backing up the many channels flowing through the town towards the Tonle Sap, and then continues to flood more land as the water levels rise. Apart from building some sort of barrier to prevent this flow of water reaching the town, there are limited options to address this. However there are many options for the barriers, particularly in type and location.

4 33. Cost considerations imply that an embankment would invariably be the least cost solution. Although this might not always be possible as there may not be sufficient land available to build an embankment, thus necessitating some other type of barrier, such as retaining wall. The option of building the whole barrier as a retaining wall is not viable as retaining wall of four to six meters height would be very expensive (about three to four depending on height[6]) and much less resilient to floods. Another advantage of an is that, if needed its height can be raised, plus it provides easier access for maintenance inspections. During the Khmer Rouge era in the late 1970s, a 14 kilometer long earth embankment was built around the north and east of the town to provide flood free irrigable This embankment varies between two to five meters in height depending upon adjacent levels. While the embankment has been breached in several places, it still provides a large flood free area that has encouraged permanent settlements along parts of its length,

[6] See Section 2 on Capital Costs.

particularly near Provincial Highway 53. It has already endured 35 years of annual flooding. Parts of it have been upgraded by adding a concrete embankment and bitumen road. This is the concrete embankment shown in

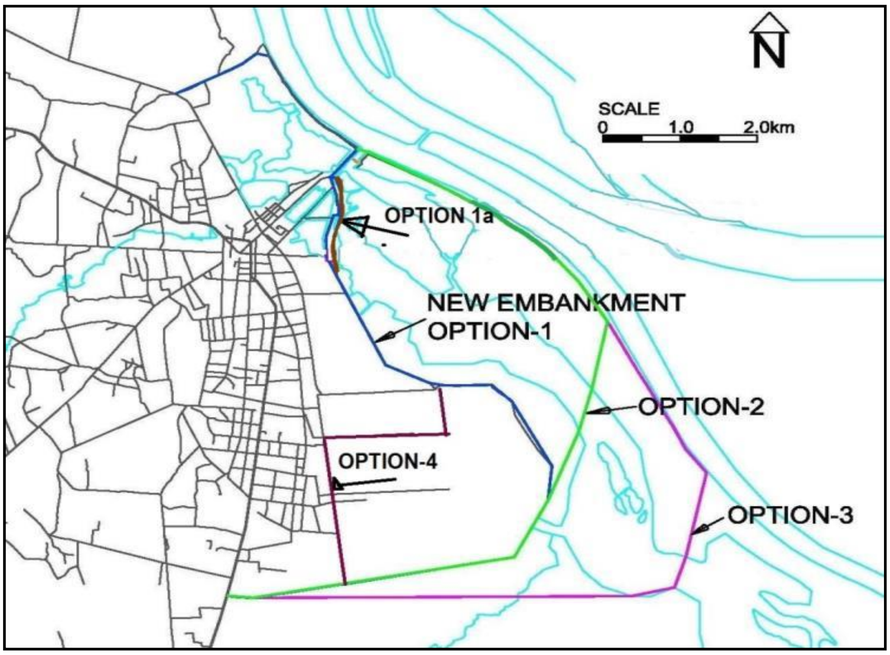
Figure B.3. Inspection of the embankment shows that parts of it are reasonably well built, although other sections would need replaced. Thus, the main options have been designed around using this embankment.

34. As the embankment was built to create agricultural land it covers a longer distance than required to protect the town. Thus there are shorter routes that could reduce lengths and thus costs. However, to maximize the benefits the embankment could be extended and thus provide perennial access to the 300 houses across the old weir described in paragraph 0, although this would require at a minimum, a high level footbridge. The options are shown in

Figure C.1 below.

- Option 1 follows the route of the existing embankment;
- Option 1a follows the same route, except at the points highlighted in brown. This section of the embankment is narrow with many houses on either side, thus a new embankment will be built on the Tonle Sap side at this point.
- Option 2 only uses the first part of the existing embankment and is a new embankment for most of the route shown in green.
- Option 3 is a larger scale version of option 2 to create more flood free land.
- Option 4 places the embankment much closer to the town to shorten its length.

Figure C.1 Options for Embankment



Source: TA 7986-CAM Consultants.

Table C.1 Advantages and Disadvantages of Embankment Options

Option	Advantages	Disadvantages
1	Lower capital costs as it follows the existing embankment.	Beneficiaries' housing adversely affected by construction. Construction difficult in some areas. Limited road width and options for expansion.
1a	Avoids beneficiaries being affected during construction. Construction easier as access is better. Greater flexibility in designing road widths and accommodates future expansion. Government land available for construction	Requires new embankment in one section.
2	Accommodates the 1.5 kms of embankment to floating community. Provides around 700 hectares more flood free land for agriculture. Construction easier as access is better.	More expensive to construct Loss of wetland and marchland. Possible reduction of retention.
3	Accommodates the 1.5 kms of embankment to floating community. Provides1,100 hectares more flood free land for agriculture. Construction easier as access is better.	Even more expensive to construct Greater loss of wetland. Possible reduction of Tonle Sap retention.
4	Shorter distance and thus possibly less cost, but large section of wholly new embankment,	Requires substantial land acquisition and resettlement. Less retention area, may require pumps to be installed.

Source: TA 7986-CAM consultants

35. These advantages and disadvantages are compared in Table C.2 below to evaluate the preferred option using option 1 as a base.

Table C.2 Selection of Preferred Embankment Option

Option	Approximate Cost (USD)	Benefits	Environmental Impact	Land Acquisition & Resettlement	Total
1	+	+	+	+	+4
1a	+	++	+	++	+6
2	-	++	--	+	0
3	--	++	---	+	-2
4	++	+	-	---	0

Source: TA 7986-CAM consultants

36. While the above table is subjective it does show that option 1a is the most suitable, particularly from land acquisition and resettlement considerations.

3. Preferred Strategy

37. Thus the strategy for flood protection in Kampong Chhnang is to prevent flooding from the Tonle Sap by raising[7] and strengthening the existing embankment to:

- Prevent flooding in the main town;
- Provide improved access to services for those living adjacent to, or on, the Tonle Sap;
- Complement the ongoing drainage works in the town;
- Minimize flooding of agriculture land; and
- Improve the overall environment and aesthetics of the town.

D. Project Design

1. Design Objectives and Process

38. The major factor in the design of the embankment is fixing the elevation of its crest (or crown) level. Clearly, this level has to be constant along the whole length of the embankment and be contiguous with the ground levels at either end of the embankment to ensure it cannot be outflanked by flood water. Secondary factors to be considered are the design life of the embankment, plus the need to accommodate stormwater and sewage run-off from the town towards the Tonle Sap.

39. Figures from the Ministry of Water Resources and Meteorology (MOWRAM) show that over the last 30 years, the maximum Tonle Sap water level at Kampong Chhnang first reached over 11.00 meters in 1996 and since then it has passed this level four more times. This is shown graphically in Figure B.2., with actual flood levels listed in the table below. There is currently no data for 2012.

[7] The calculations for the embankment height are contained in Section E Project Description.

Table D.1 Annual High Water Levels of Tonle Sap at Kampong Chhnang

1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
10.320	10.370	10.330	10.780	10.430	10.250	9.670	8.770	9.350	10.380	10.940	9.240	9.510	11.000	10.840	11.050
1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	
10.540	8.030	10.200	11.600	11.160	11.280	9.480	10.450	10.550	10.450	10.150	9.890	10.460	8.940	11.780	

Source MOWRAM – Gauge station at Phsar Krom in Kampong Chhnang (12°16' 05.84" N, 104°40' 53.09" E)

40. Drainage design is usually based upon a statistical analysis of rainfall or discharge, or in this case, Tonle Sap flood levels. This develops *return periods* which estimate the likely recurrence interval between levels of floods. Return periods are statistical measurements denoting the average recurrence interval over an extended period of time. For drainage and flood control the return period is given in years, such that a drainage system might be designed for a 20 year flood return period. This implies that there is a probability of the drainage system's capacity not being able to deal with floods every 20 years. However, it is a purely statistical calculation and it is possible that the stormwater system's capacity could be overcome during storms in two consecutive years, or even twice in the same year. Conversely, the drainage system could cope for 50 years or longer.

41. The greater the return period, implies a larger and more expensive drainage system. For Kampong Chhnang, the greater the return period considered, the higher the embankment level should be. Return periods are usually based on historic data so there is also a need to consider climate change which, through more intensive rainfall, could cause the Mekong and the Tonle Sap to rise more over the design life of the embankment. Climate change could possibly be the reason that, over the recording period, between 1981 and 1995 the Tonle Sap did not rise to more than 11.00 meters above sea level, but since then has passed this level five times. Table D-2 shows typical design return periods for various land use types.

Table D-2 Typical Annual Return Period Values for Flooding

Land Use	Range - (Years)
Town Center and Commercial Area	20 – 100
Industrial Areas	10 - 50
Urban Residential High Density >20 dwellings/ha	20 - 50
Urban Residential Low Density >5<20 dwellings/ha	10 - 20
Rural Villages	2 – 10
Agricultural Land	1 – 10
Recreation areas	1 - 5

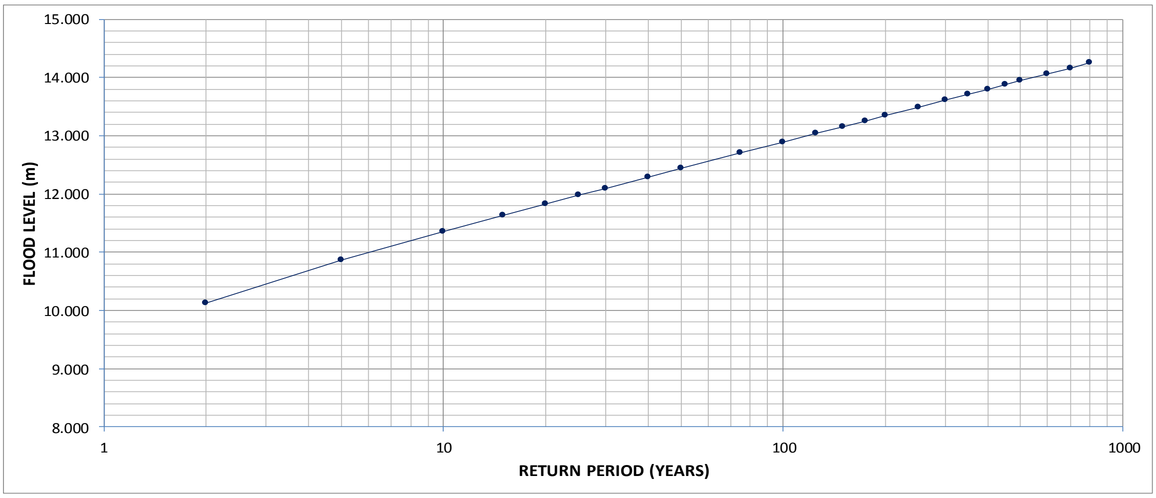
Source: TA 7986-CAM Consultants amended from Andhra Pradesh Urban Services for the Poor, Infrastructure Planning and Design Guidelines for Municipal Engineers, GHK International Consortium, March 2003.

42. As topography also plays a major factor in the costs of drainage and flood control structures, return periods for areas that can be protected more easily, such as areas on higher ground or slopes, can have a much longer return period at a lower cost.

7 43. Using the data from

Table D.1, the chart below which shows return periods against water levels was developed.

Figure D.1 Annual Return Period Chart for Tonle Sap at Kampong Chhnang



Source: TA 7986-CAM Consultants

a. Selected Return Period and Design Life

44. The design life of the embankment has been taken as 30 years. Earthen structures, if constructed of correct material and compacted properly can last longer than this, but to ensure the continued protection of the town, much of the embankment should be rebuilt and the slopes reconstructed at this time. Climate changes impacts may also be better quantified by this time and it may be necessary to raise the crest level. The sluice gates will need to be replaced after 15 years.

45. The construction of such a large and expensive embankment that aims to protect a medium sized town and substantial agricultural land from inundation, requires a commensurate return period. Thus a 50 year return period has been taken.

2. Climate Change Considerations

46. Climate change could also have an impact on the flood levels of the Tonle Sap. An overview of the expected consequences of climate change between 2020 and 2050 has been carried out by the Mekong River Commission (MRC)[8]. The main predictions relating to flood levels and river flows in Cambodia are the following:

- The mean annual rainfall in Cambodia will be unchanged or even decrease by up to eight per cent. The largest increase is expected in the wet season, but will also occur in the dry season in Upper Mekong
- The Mekong's flow is expected to increase by four to 13 per cent in the wet season and by 10 to 30 per cent in the dry season. The largest increases will appear from the Chinese border to Kratie in Cambodia.
- The snow melt contribution from the Upper Mekong is expected to increase and to start earlier due to increased temperatures.
- The increased flow in the Mekong will improve water availability in the dry season, but also increase the risk of flooding in the wet season. The low-lying areas downstream

[8] Impacts of climate change and development on Mekong flow regimes. First assessment – 2009, Mekong River Commission Technical Paper No. 29, June 2010

of Kratie including the Tonle Sap area are expected to be particularly at risk. The areas affected by flooding due to rainfall and upstream flow from Mekong are estimated to increase by nine per cent, not including effects of a possible sea level rise. Areas with flooding depths higher than two meters are estimated to increase by almost 40 per cent.

- The storage capacity of hydropower installations may potentially reduce impacts of flooding in some areas. The Lower Mekong Basin 20-year development plan alone estimates a decrease of the wet season river flow by 7 to 17 per cent, while the climate change scenarios for this season estimate a flow increase of between two to 11 per cent. The combined effect is expected to vary between a decrease of 13 per cent to an increase of three per cent.

47. Importantly, the report states that there is a high degree of uncertainty related to both the climate change scenarios and the different development plans in the basin.

48. However, another 2010 study "Modeling climate change impacts on the flood pulse in the Lower Mekong floodplains"[9] indicates that by 2050 the average water levels in the Tonle Sap may increase by 0.2m and peak water levels may increase by up to 0.3m. This study estimated flood durations to be nine per cent longer under anticipated climate change conditions and therefore the probability of coincidence with river floods is likely to increase. However, the 2010 study also considers the development of water infrastructure along the Mekong River and its impact on reducing downstream flood impact under climate change conditions. It concludes that while the two phenomena may balance each other, further detailed studies are required.

b. Climate Change Resilience Measures

49. Despite the impact of climate change being difficult to quantify at this stage, various climate change resilience measures have been developed for the embankment. As can be seen in Section F, this does increase the costs. However, another major benefit of these measures is that they reduce maintenance costs and should prolong the overall life of the embankment.

50. The main measures taken are:

- Taking a return period of 50 years, rather than 20 years and building in a factor of safety for the embankment's crest level as described in paragraph 0 below – this means the embankment design height is 13.00 meters above MSL rather than 12.10 meters; Note that 12.10 is 300 millimeters above the highest flood level of 11.78 meters[10].
- Using concrete revetment for the slopes on the embankment's Tonle Sap side in areas where there is settlement and will be used by boats, rather than gabions.
- Constructing the crest road of concrete rather than bitumen. Concrete roads are much more expensive to construct than bitumen roads, but they are more robust and require much less maintenance.

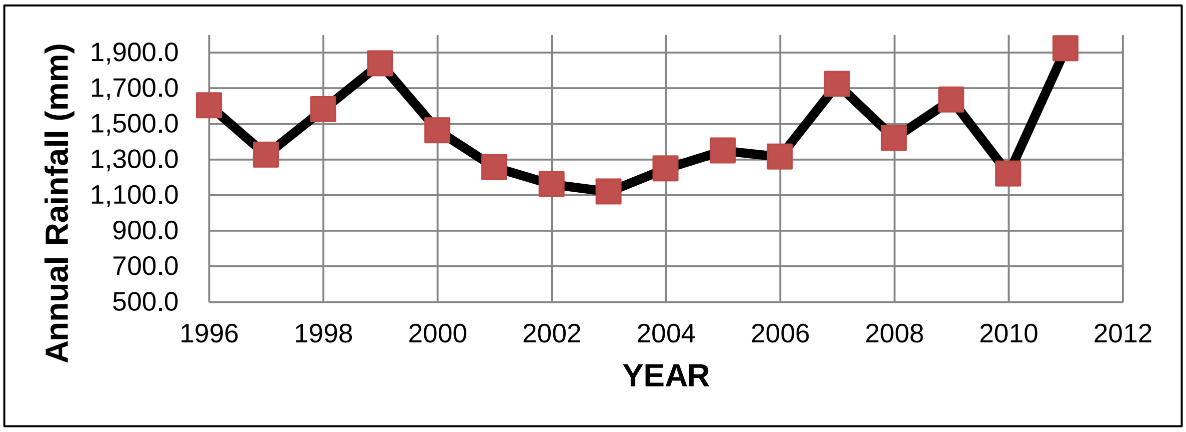
[9] Vastila et al, 2010, Modeling climate change impacts on the flood pulse in the Lower Mekong floodplains, Journal of Water and Climate Change.

[10] The cost of the embankment is not very sensitive to changes in its height. It is the other climate change measures, particularity using concrete rather than gabions and bitumen that increases the cost. See paragraph 0.

3. Rainfall Data for Kampong Chhnang

51. A review of rainfall data in Kampong Chhnang (Table D-3) shows that rainfall over the last 15 years has been variable, but does seem to be increasing since 2006. 2011 saw the greatest rainfall and this coincided with the flooding in the town when the existing embankment was overtopped. However, long term change could cause the Mekong River levels to rise with more intensive precipitation. There are also quite a few river control structures being built or planned in China and Laos, but only around 25 per cent of the Mekong's wet weather and less than 50 per cent of its dry weather flow originates from China[11]. These structures could have a substantial impact on both the Mekong's hydraulic regime. Irrigation schemes will increase infiltration or possibly even drain to other catchments, while dams will also alter the total and seasonal sediment loads of the river which can have an impact on aquatic life and erosion as well as water levels.

Figure D.2 Annual Rainfall in Kampong Chhnang



Source: TA 7986-CAM Consultants

[11] Annual Flood Report and Yearbook, MRCS, Vientiane, 2008.

Table D-3 Monthly Rainfall Data for Kampong Chhnang, 1996 to 2012

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	TOTAL
1996	Total:	0.2	6.0	0.0	118.6	97.7	236.3	334.4	162.4	266.5	201.7	148.0	30.4	1,602.2
	Max.:	0.2	6.0	0.0	57.0	23.3	84.2	61.1	54.0	77.5	42.8	35.0	28.2	469.3
	Avg.:	0.2	6.0	0.0	16.9	10.9	18.2	23.9	14.8	24.2	22.4	16.4	10.1	164.0
	#RD.:	1	1	0	7	9	13	14	11	11	9	9	3	88
1997	Total:	0.0	25.7	18.8	99.0	159.8	142.0	242.7	262.5	145.8	192.2	37.0	0.0	1,325.5
	Max.:	0.0	21.6	18.8	41.5	63.5	35.4	50.0	50.8	22.2	33.5	20.5	0.0	357.8
	Avg.:	0.0	8.6	18.8	33.0	17.8	17.8	16.2	15.4	9.1	13.7	18.5	0.0	168.8
	#RD.:	0	3	1	3	9	8	15	17	16	14	2	0	88
1998	Total:	0.0	10.2	0.0	42.5	75.8	87.0	257.8	252.8	482.5	261.0	111.3	0.0	1,580.9
	Max.:	0.0	10.2	0.0	35.0	20.5	18.0	46.0	65.0	130.0	62.5	35.0	0.0	422.2
	Avg.:	0.0	10.2	0.0	14.2	15.2	7.3	17.2	25.3	32.2	29.0	18.6	0.0	169.0
	#RD.:	0	1	0	3	5	12	15	10	15	9	6	0	76
1999	Total:	3.2	3.0	3.0	99.8	312.2	240.6	153.1	156.8	186.3	463.8	154.1	63.0	1,838.9
	Max.:	3.2	3.0	3.0	41.7	38.3	46.2	42.0	42.0	30.3	130.0	40.0	32.0	451.7
	Avg.:	3.2	3.0	3.0	11.1	20.8	16.0	15.3	14.3	11.0	35.7	19.3	21.0	173.6
	#RD.:	1	1	1	9	15	15	10	11	17	13	8	3	104
2000	Total:	0.0	0.0	2.5	135.8	184.7	220.8	286.5	238.7	150.4	243.6	0.0	0.0	1,463.0
	Max.:	0.0	0.0	2.5	32.0	34.2	43.0	43.0	56.9	34.8	60.3	0.0	0.0	306.7
	Avg.:	0.0	0.0	2.5	19.4	15.4	17.0	13.6	13.3	12.5	17.4	0.0	0.0	111.1
	#RD.:	0	0	1	7	12	13	21	18	12	14	0	0	98
2001	Total:	55.1	0.3	207.6	16.3	161.5	153.0	89.2	253.6	122.1	174.7	17.0	5.0	1,255.4
	Max.:	44.9	0.3	72.1	16.3	20.3	36.0	32.5	25.8	22.5	28.5	10.0	3.5	312.7
	Avg.:	27.6	0.3	26.0	16.3	11.5	10.9	9.9	12.7	8.7	10.3	5.7	2.5	142.3
	#RD.:	2	1	8	1	14	14	9	20	14	17	3	2	105
2002	Total:	0.0	0.0	21.8	0.0	53.8	136.2	241.4	244.2	284.4	48.7	117.7	12.0	1,160.2
	Max.:	0.0	0.0	21.8	0.0	19.7	43.0	40.4	61.0	42.0	12.0	32.3	9.0	281.2
	Avg.:	0.0	0.0	21.8	0.0	6.0	11.4	14.2	16.3	15.0	4.9	9.8	4.0	103.3
	#RD.:	0	0	1	0	9	12	17	15	19	10	12	3	98
2003	Total:	0.0	0.0	31.2	41.7	193.4	190.1	192.4	119.4	207.5	122.4	20.6	0.0	1,118.7
	Max.:	0.0	0.0	13.5	13.6	40.5	31.0	35.0	24.5	64.7	34.0	17.0	0.0	273.8
	Avg.:	0.0	0.0	7.8	10.4	12.9	17.3	11.3	9.2	10.9	11.1	10.3	0.0	101.3
	#RD.:	0	0	4	4	15	11	17	13	19	11	2	0	96
2004	Total:	10.0	0.0	0.0	4.5	114.8	246.7	193.5	240.3	293.7	138.0	7.7	0.0	1,249.2
	Max.:	10.0	0.0	0.0	4.5	52.5	63.2	47.0	46.6	83.0	36.0	7.7	0.0	350.5
	Avg.:	10.0	0.0	0.0	4.5	19.1	14.5	14.9	13.4	19.6	19.7	7.7	0.0	123.4
	#RD.:	1	0	0	1	6	17	13	18	15	7	1	0	79
2005	Total:	0.0	0.0	0.0	17.4	217.0	96.7	141.5	222.5	299.5	233.5	120.5	0.0	1,348.6
	Max.:	0.0	0.0	0.0	11.5	87.0	28.5	41.0	55.0	50.5	98.5	30.0	0.0	402.0
	Avg.:	0.0	0.0	0.0	4.4	18.1	12.1	11.8	20.2	16.6	16.7	15.1	0.0	114.9
	#RD.:	0	0	0	4	12	8	12	11	18	14	8	0	87
2006	Total:	0.0	0.0	13.0	32.0	76.0	118.8	306.5	364.5	157.5	220.5	6.0	20.0	1,314.8
	Max.:	0.0	0.0	13.0	22.0	25.0	44.0	174.0	53.0	34.0	72.0	6.0	20.0	463.0
	Avg.:	0.0	0.0	13.0	16.0	19.0	17.0	27.9	21.4	19.7	18.4	6.0	20.0	178.3
	#RD.:	0	0	1	2	4	7	11	17	8	12	1	1	64
2007	Total:	0.0	0.0	61.0	103.5	232.5	126.5	248.0	177.0	481.0	265.0	29.0	0.0	1,723.5
	Max.:	0.0	0.0	61.0	50.0	52.0	59.0	36.0	35.0	85.0	45.0	16.0	0.0	439.0
	Avg.:	0.0	0.0	61.0	25.9	23.3	18.1	20.7	14.8	34.4	17.7	7.3	0.0	222.9
	#RD.:	0	0	1	4	10	7	12	12	14	15	4	0	79
2008	Total:	0.0	11.0	2.6	25.0	259.3	97.1	170.6	92.0	326.0	169.2	267.0	0.0	1,419.8
	Max.:	0.0	11.0	2.6	13.0	40.0	31.0	30.0	20.0	58.0	30.0	55.0	0.0	290.6
	Avg.:	0.0	11.0	2.6	12.5	19.9	12.1	12.2	9.2	21.7	12.1	22.3	0.0	135.6
	#RD.:	0	1	1	2	13	8	14	10	15	14	12	0	90
2009	Total:	0.0	0.0	64.0	73.5	195.8	164.6	275.6	273.0	299.1	289.0	0.0	0.0	1,634.6
	Max.:	0.0	0.0	23.0	27.0	63.0	58.0	72.8	54.0	70.0	76.0	0.0	0.0	443.8
	Avg.:	0.0	0.0	16.0	10.5	15.1	11.8	18.4	22.8	19.9	26.3	0.0	0.0	140.7
	#RD.:	0	0	4	7	13	14	15	12	15	11	0	0	91
2010	Total:	26.2	22.1	148.6	40.5	191.6	80.8	126.5	147.4	147.4	236.8	51.7	0.0	1,219.6
	Max.:	24.0	22.1	103.1	32.1	83.1	19.4	35.3	30.0	30.0	63.1	18.4	0.0	460.6
	Avg.:	8.7	22.1	49.5	13.5	17.4	6.7	12.7	8.7	8.7	18.2	10.3	0.0	176.6
	#RD.:	3	1	3	3	11	12	10	17	17	13	5	0	95
2011	Total:	0.0	0.0	73.0	178.0	138.0	249.0	259.7	265.0	301.0	237.0	210.5	11.0	1,922.2
	Max.:	0.0	0.0	55.0	118.0	34.0	35.0	55.0	67.0	68.0	40.0	105.0	8.0	585.0
	Avg.:	0.0	0.0	24.3	59.3	11.5	17.8	17.3	20.4	21.5	21.5	2.0	3.0	198.7
	#RD.:	0	0	3	3	12	14	15	13	14	11	4	2	91
2012	Total:	94.0	17.0	24.0	96.0	123.1								354.1
	Max.:	49.0	12.0	20.0	43.0	34.5								158.5
	Avg.:	3.0	5.0	12.0	12.0	12.3								44.3
	#RD.:	4	2	2	8	10								26

(Total: Total monthly precipitation, Max: Maximum precipitation on any one day during the month; Avg: Average daily precipitation for that month; #RD: Number of days with precipitation during the month). Source MOWRAM.

4. Proposed Level of Flood Protection

52. Thirty years' data is slightly limited in allowing a detailed prediction of flood levels, 50 years' data would be preferable, but it does provide enough data to allow an analysis. Applying a Gumbel Analysis[12] to the historical annual flood level records gives the following flood levels. This analysis was used to determine the return periods at Figure D.1.

Table D-4 Determination of Return Periods for Flood Protection in Kampong Chhnang

Year	Lowest (m) Date	Lowest (m) Level (x)	Highest (m) Date	Highest (m) Level (y)	*Return Period* (Years)	*Flood Level* (m)
1981	07/07/1981	6.30	23/09/1981	10.32	2	10.127
1982	20/06/1982	3.31	14/10/1982	10.37	5	10.866
1983	08/08/1983	4.72	23/10/1983	10.33	10	11.356
1984	24/05/1984	1.70	23/09/1984	10.78	15	11.632
1985	26/04/1985	1.75	03/10/1985	10.43	20	11.826
1986	01/04/1986	1.73	06/10/1986	10.25	25	11.975
1987	30/04/1987	2.00	06/10/1987	9.67	30	12.096
1988	01/06/1988	2.16	27/10/1988	8.77	40	12.286
1989	14/06/1989	2.91	09/10/1989	9.35	**50**	**12.434**
1990	01/06/1990	2.77	08/10/1990	10.38	60	12.554
1991	01/07/1991	3.85	14/10/1991	10.94	70	12.655
1992	25/06/1992	2.75	04/10/1992	9.24	80	12.743
1993	20/06/1993	2.77	10/10/1993	9.51	90	12.820
1994	09/05/1994	2.68	05/10/1994	11.00	**100**	**12.889**
1995	29/04/1994	2.19	17/10/1995	10.84	***120***	***13.009***
1996	28/04/1996	2.22	14/10/1996	11.05	**150**	**13.155**
1997	15/05/1997	2.26	09/10/1997	10.54	170	13.237
1998	10/05/1998	2.30	03/10/1998	8.03	**200**	**13.343**
1999	18/04/1999	2.40	08/10/1999	10.20	250	13.489
2000	18/04/2000	2.54	27/09/2000	11.60	300	13.608
2001	15/05/2001	2.38	30/09/2001	11.16	350	13.709
2002	09/04/2002	2.60	05/10/2002	11.28	400	13.796
2003	13/05/2003	2.37	06/10/2003	9.48	450	13.873
2004	11/04/2004	2.05	04/10/2004	10.45	500	13.942
2005	17/05/2005	2.10	08/10/2005	10.55		
2006	24/05/2006	2.00	21/10/2006	10.45		
2007	12/05/2007	3.00	22/10/2007	10.15		
2008	08/04/2008	2.08	08/10/2008	9.89		
2009	02/04/2009	2.20	15/10/2009	10.46		
2010	24/03/2010	2.20	25/10/2010	8.94		
2011	16/04/2011	2.30	22/10/2011	11.78		

Source: TA 7986-CAM Consultants.

12 This is a statistical tool used to model the distribution of the maximum (or the minimum) of a number of samples of various distributions. It is used here to represent the probability of maximum river levels over time, based upon historical data.

53. A 50-year return period gives a flood level of 12.434 meters above mean sea level. This is around 600mm above the highest level of the existing embankment and about eight meters above areas where there is no existing embankment.

54. Climate change reports, while extensive in analysis, are understandably vague in quantifying tangible figures that can be used for designs. For climate change it is difficult to predict an exact level for the Tonle Sap in the future. However, in Kampong Chhnang, the overtopping of the embankment could have a disastrous impact. Consideration of the findings of the climate change reports, plus the relative paucity of river level data, indicates the need to build in a factor of safety for the height of the embankment crest level. This can be included within the freeboard. Freeboard is the area above the designed highest water level and the top of the embankment. Where flood events can be reasonably accurately predicted, freeboard can be taken as 300 mm. However, to accommodate the unknown factors of climate change and the limited river flow data, 500 mm has been taken. This will take the design crest level to 12.934 meters. For ease of construction, this level will be **13.000 meters above mean sea level**. This level provides a 120 year return period based on historical data in Table D-4.

55. The embankment height can also be raised by up to half a meter in the future by constructing a wall on the Tonle Sap side where there are existing settlements and by constructing a higher, but narrower, road on the embankment elsewhere. The wall would be disruptive to those living or working on the Tonle Sap side of these settlements, so should only be constructed if river levels are seen to rise significantly and hydrologists predict the possibility of flood levels over 13.000 MSL. This would then cover a current return period of 200 years.

56. It should be noted that the existing embankment levels were surveyed through a topographical survey subcontract issued by the PPTA consultants. This limited survey aimed to establish the alignment and levels of the existing embankment. Levels were fixed using two existing national benchmarks one which has been fixed by the MoWRaM in 2007 and another has recently been established by the JICA-assisted drainage project (see paragraph 0). As the survey did not take place until July, it was hindered by the rising levels of the Tonle Sap which is amply demonstrated in Figure D.3 below. The detailed design will require another survey to be carried out in the dry season when all of the proposed construction site is above the Tonle Sap water level.

Figure D.3 Surveying Existing Embankment Base in Kampong Chhnang

Source: TA 7986-CAM Consultants

5. Selection of Embankment Type

57. Unsurprisingly, there do not seem to be any national standards for embankment design in Cambodia. Recent projects[13] that designed flood protection measures, including embankments, used international standards. For the IUEMTSB PPTA, European Standards have been used. Protection will also be provided against erosion. However, it is the quality of construction that will be important in ensuring the effectiveness and longevity of the embankment.

58. Most of the embankment will be constructed of earth. This will use locally sourced earth, particularly clay, as it is impervious. This will be placed in layers to allow compaction. All the main materials for filling and protecting the embankment, such as earth, sand, gravel and rock, are available near to Kampong Chhnang. Only the geotextile lining and the mesh for the gabions are not available locally.

59. The table below provides information on the approach to selecting the type of embankment.

Table D-5 Selection of Embankment Type

Existing Embankment	Type of Embankment
No embankment, no settlement	New on best route available
No embankment with settlement	New on Tonle Sap side of settlement. If not possible, then on land side of settlement. If still not possible, then raise existing right of way using retaining walls
Upgraded embankment with settlement	Raise embankment by constructing concrete or brick wall. If not possible, then construct new embankment as for (2) above.
Existing embankment with settlement	New embankment on Tonle Sap side of settlement. If not possible, then on land side. If still not possible, raise existing right of way with retaining walls
Existing embankment no settlement	Raise and rebuild existing embankment.

Source: TA 7986-CAM Consultants

a. Erosion Protection

8 60. The embankment needs to be protected from erosion that will occur from the water level changes in the Tonle Sap and also from heavy rainfall. At Kampong Chhnang, Tonle Sap acts more as a river, so there is little effect from waves, apart from those by river traffic. However, over time earthen embankments can deteriorate and need to be protected. Three options were considered for this protection: (i) concrete revetment; (ii) rock riprap; and (iii) gabion mattress. All of these options include the use of geotextiles to strengthen the embankment soil and control seepage. Concrete revetment is similar to upgraded existing embankment shown at

[13] For example, TA 7644-REG, Cambodia: GMS Corridor Towns Development Project, Nov 2012, used Norwegian Standards.

Figure B.3. Armor rock riprap is formed by grading strong rock and placing it on the embankment. Gabions also use rock, but enclose them in a galvanized iron cage to provide greater strength. For areas of the embankment next to existing settlements, concrete revetment is proposed as these areas will most likely be used by boats that will need moorings that could damage the wire on the gabions. In other areas gabions will be used as they are less expensive encourage the growth of grass and other flora due to the silt build-up in the rock voids and thus integrate better with the local ecosystem.

9 61. All of the proposed embankment will be earth filled with compacted soil. Along its length the earthworks will be protected by gabion revetments on the Tonle Sap side grass embankment on the inland side. All slopes will be a minimum of 1 vertical unit to 2 horizontal units to reduce gradients and will contain berms to maintain compaction and slope stability. In areas adjacent to settlements the Tonle Sap side of the embankment will be concrete revetment. In sections where the right of way for the embankment is limited, retaining walls will be constructed as shown in

Figure E.4.

62. The inside slope of the embankment also needs to be protected from rain, and the foot of the slope from any flash floods. Grass will be sown on these slopes to stabilize them and a drain will be built at the foot of the slope to deflect stormwater and divert it to the natural drainage channels.

b. Sluice Gates

63. Sluice gates will be provided at six locations on the embankment as shown on Figure E.1. These will be constructed on existing drainage channels. The sluice gates will be typical screw type and manually operated. Sizes will vary depending upon the sizes and slopes of the existing channel. With the extensive retention areas behind all of the sluice gates, the size of these gates is not critical, but double gates will be provided on each channel similar to standard designs for irrigation schemes in the country.

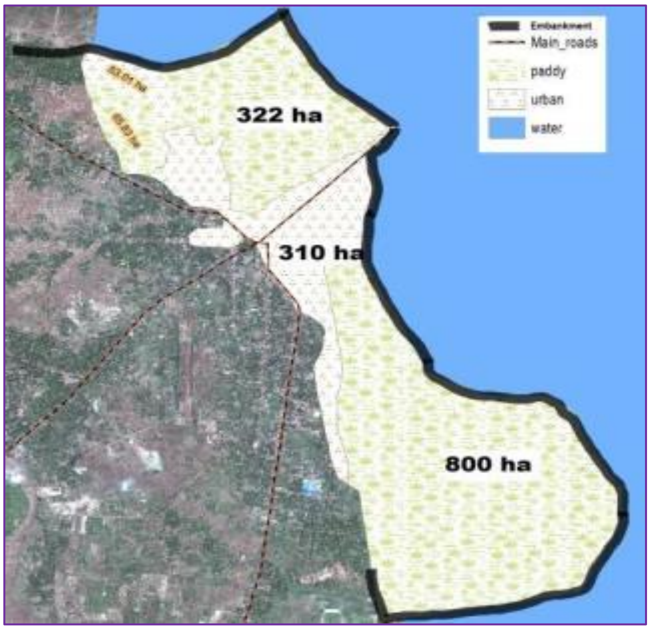
64. While there is no current need for pumping, the creation of flood free land behind the embankment may encourage future development and reduce the retention areas. Thus the sluice gates and embankment will be designed to accommodate the future provision of pumps and associated pumping stations.

c. Accommodating Stormwater Flow

10 65. The construction of the embankment will prevent flow from the Tonle Sap into Chhnang. It will also prevent drainage from Kampong Chhnang into the Tonle Sap. As discussed in paragraph 0, there are several streams that flow through the town, thus the embankment will have to include outlets for these streams. During the dry season, when Tonle Sap level is low, the outlets can drain naturally to the Tonle Sap, but to avoid into the town as the Tonle Sap rises, sluice gates will have to be fitted. During the wet water from the streams will accumulate behind the embankment, but, as shown in

Figure D.4, there is substantial vacant land to retain these flows, particularly to the South of the town.

Figure D.4 Potential Stormwater Retention Areas Behind the Embankment



Source: TA 7986-CAM consultants.

66. The area to the north of the embankment does receive substantial storm flows and has a smaller retention area. Calculations show that even with more intensive rainfall this area is still adequate to retain the wet season flows without the need for pumping. There is a potential to train these streams to allow them to better drain the area. However, as most of the land is privately owned this would be best carried out by the Provincial Government in conjunction with the land owners.

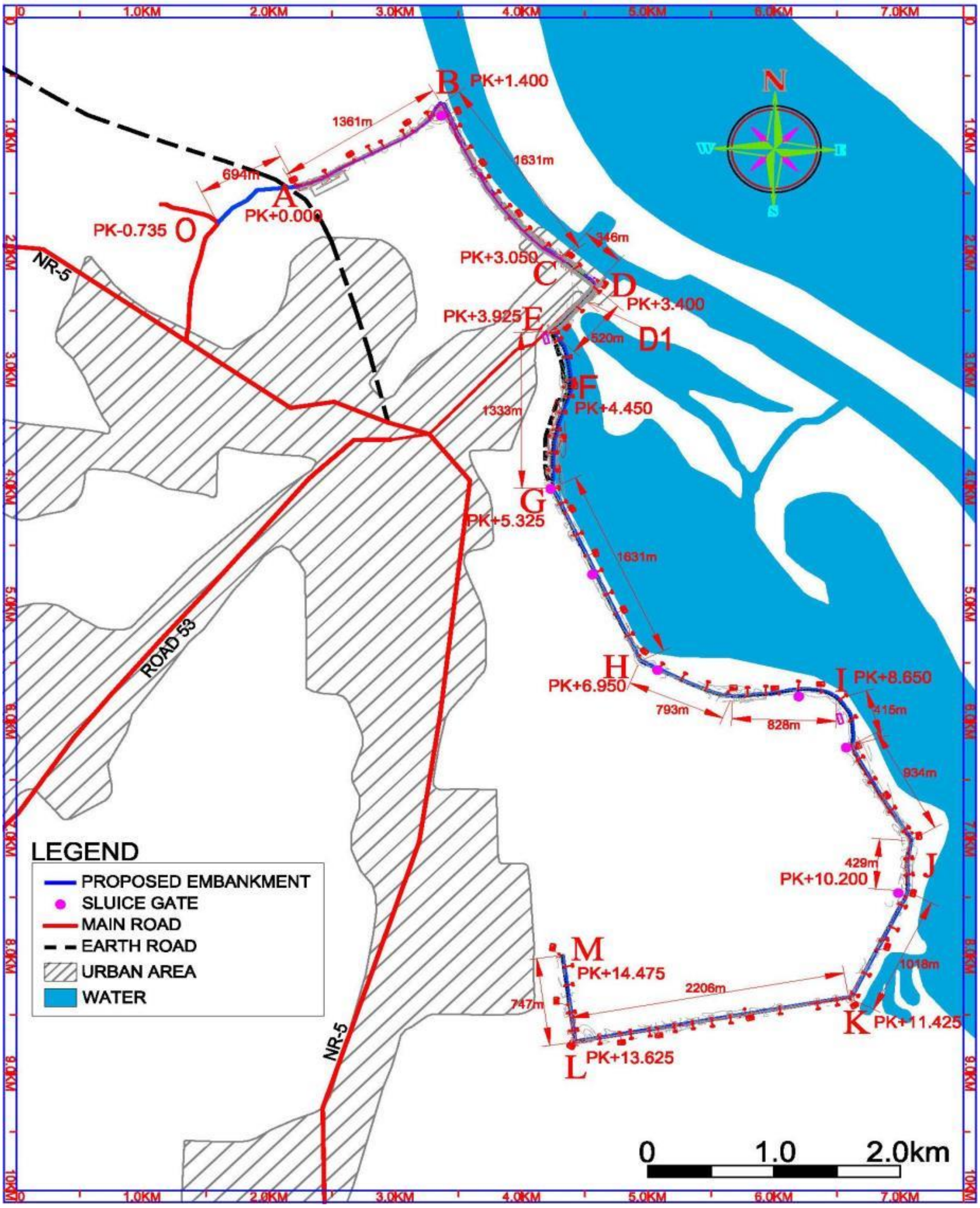
E. Project Description

1. Proposed Works

11 67. The previous chapter set out the various design criteria and fixed the level of the embankment. This chapter provides a detailed description of the proposed embankment works. Figure E.1 shows a plan of the proposed embankment and its various sections, while

Table E-1 and Table E-2 provide a summary description of each section.

Figure E.1 Proposed Embankment Showing Sections



Source: TA 7986-CAM Consultants

68. The works proposed for the embankment can be summarized as:

- Reinforcing and raising the level of the existing embankment where required;
- Rebuilding and raising the existing embankment where it is damaged or construction is poor;
- Building a new embankment in areas where there is no current embankment;

- In areas where raising the existing embankment would severely impact on adjacent properties but where land is available adjacent to the settlement, building a new embankment;
- In areas where raising the existing embankment would severely impact on adjacent properties and where land is not available, building retaining walls to support the embankment;
- Providing sluice gates to allow stormwater to flow to the Tonle Sap.

2. Alignment Considerations

a. Settlement Patterns

Table E-1 Existing Settlements along the Proposed Embankment

<table>
<tr><th>Section</th><th>Length (m)</th><th>Flooding</th><th>Settlements</th><th>Access*</th><th>Planned Embankment</th></tr>
<tr><td>O – A</td><td>735</td><td rowspan="2">None</td><td rowspan="2">None, only water treatment plant</td><td rowspan="2">Perennial</td><td>New</td></tr>
<tr><td>A – B</td><td>1,380</td><td>Replace and raise existing</td></tr>
<tr><td>B – C</td><td>1,650</td><td>1 in 1 year</td><td>Many fixed (on stilts), seasonal and floating properties</td><td>Seasonal</td><td>New using concrete retaining walls</td></tr>
<tr><td>C – D</td><td>350</td><td rowspan="3">1 in 10 years</td><td rowspan="3">Embankment already upgraded, many permanent structures and huts.</td><td rowspan="5">Perennial</td><td>Raise existing wall</td></tr>
<tr><td>D – D1</td><td>125</td><td>Build new wall outside settlements</td></tr>
<tr><td>D1 – E</td><td>400</td><td rowspan="3">New embankment outside existing embankment</td></tr>
<tr><td>E – F</td><td>540</td><td rowspan="3">1 in 1 year</td><td rowspan="2">Permanent houses on both sides of existing narrow embankment</td></tr>
<tr><td>F – G</td><td>860</td></tr>
<tr><td>G – H</td><td>1,630</td><td rowspan="5">None, one temple</td><td rowspan="5">Seasonal</td><td rowspan="5">Reconstruct and raise existing embankment. Temple will be by-passed on Tonle Sap side and better protected and not affected during construction.</td></tr>
<tr><td>H – I</td><td>1,670</td><td rowspan="4">1 in 1 year at low points</td></tr>
<tr><td>I – J</td><td>1,800</td></tr>
<tr><td>J – K</td><td>1,000</td></tr>
<tr><td>K – L</td><td>2,200</td></tr>
<tr><td>L – M</td><td>750</td><td>1 in 20 years</td><td>A few houses</td><td>Perennial</td><td>New, houses not affected</td></tr>
<tr><td>Total</td><td>15,090</td><td></td><td colspan="3">* Means access to the town</td></tr>
</table>

Source: TA 7986-CAM Consultants.

69. Once the proposed embankment is built, all houses along its length will have perennial land access.

70. The Southern section of the embankment from G to M has practically no existing settlements. It is the sections between B to G that require consideration of both the alignment and type of embankment to minimize any adverse impacts on adjacent settlements.

12 71. A section of the embankment (C to E) has already been incrementally upgraded. existing road level at the section is 11.8 meters above MSL and a 500 mm wall has been constructed on the Tonle Sap side of the road bringing the flood protection level to 12.3 above MSL. As there is substantial property already built in this area, even in some areas

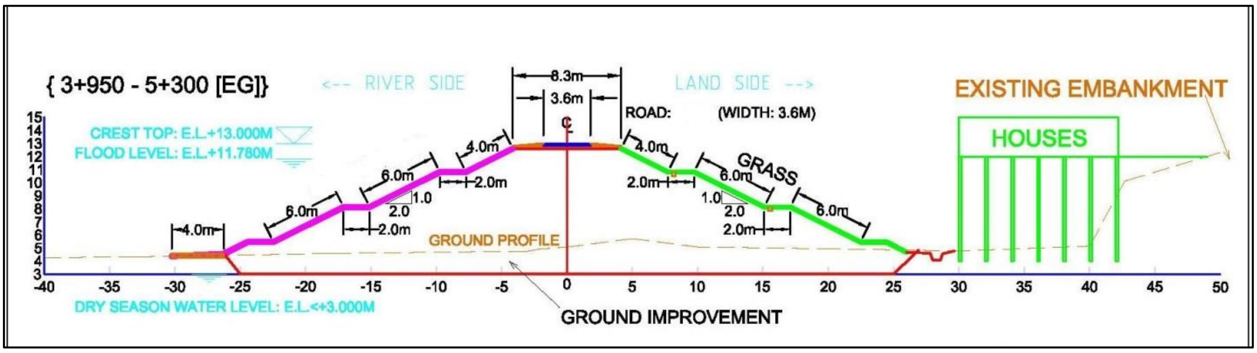
flood annually, the existing wall on the embankment will be raised by around 500 mm to above MSL. During the wet season, boats use this area to moor and unload produce, the dry season the area underneath where the boats moor is used as a market and also unloading produce (see

Figure B.3). To ease access across the new higher, 1.2 meter wall, steps will also be provided.

72. There are also many simply constructed shops and houses along this section that are provided six monthly recurring contracts by the Municipality. Although considered temporary, many of the inhabitants have been living and working in these properties for over five years. It was initially intended to continue the wall down to point E, but placing an 800 mm barrier in front of these shops would affect their access. Thus a new embankment will be built behind this area.

73. In other areas where settlements already exist, either on or close to the existing embankment, existing rights of way are too narrow to allow construction. In most of these areas, the solution is to propose the construction of a new embankment on the Tonle Sap side of the existing settlement. While this could be more expensive, it will ease construction as any disturbance to existing settlements will be avoided while it will mean that all houses on both sides of the existing embankment will be protected from flooding. The required land is below the current high water mark, and has been confirmed as state land. Thus from point D1 to G, a cross section of the embankment will typically look like that in Figure E.2.

Figure E.2 Typical Cross Section of Proposed Embankment beside Existing Settlements



Source: TA 7986-CAM Consultants.

Figure E.3 Plan View of Proposed Embankment beside Existing Settlements

Source: TA 7986-CAM Consultants.

74. In some areas, it is not possible to construct an embankment on the Tonle Sap side of these settlements as the water is too deep. The alignment of the embankment from point B to C also required substantial field and documentation investigation. This was hindered by the Tonle Sap water levels already being well above much of the existing road level which had many houseboats moored above it. The municipality states that there are approximately 250 permanent properties along this section of the embankment. Thus around 1.6 kilometers of this new section of embankment will be built using concrete retaining walls with a reduced road width of 6.5 meters. The road height will be constructed to same level (11.8 meters above MSL) as the already upgraded section (C to E) and protected by a wall as shown in

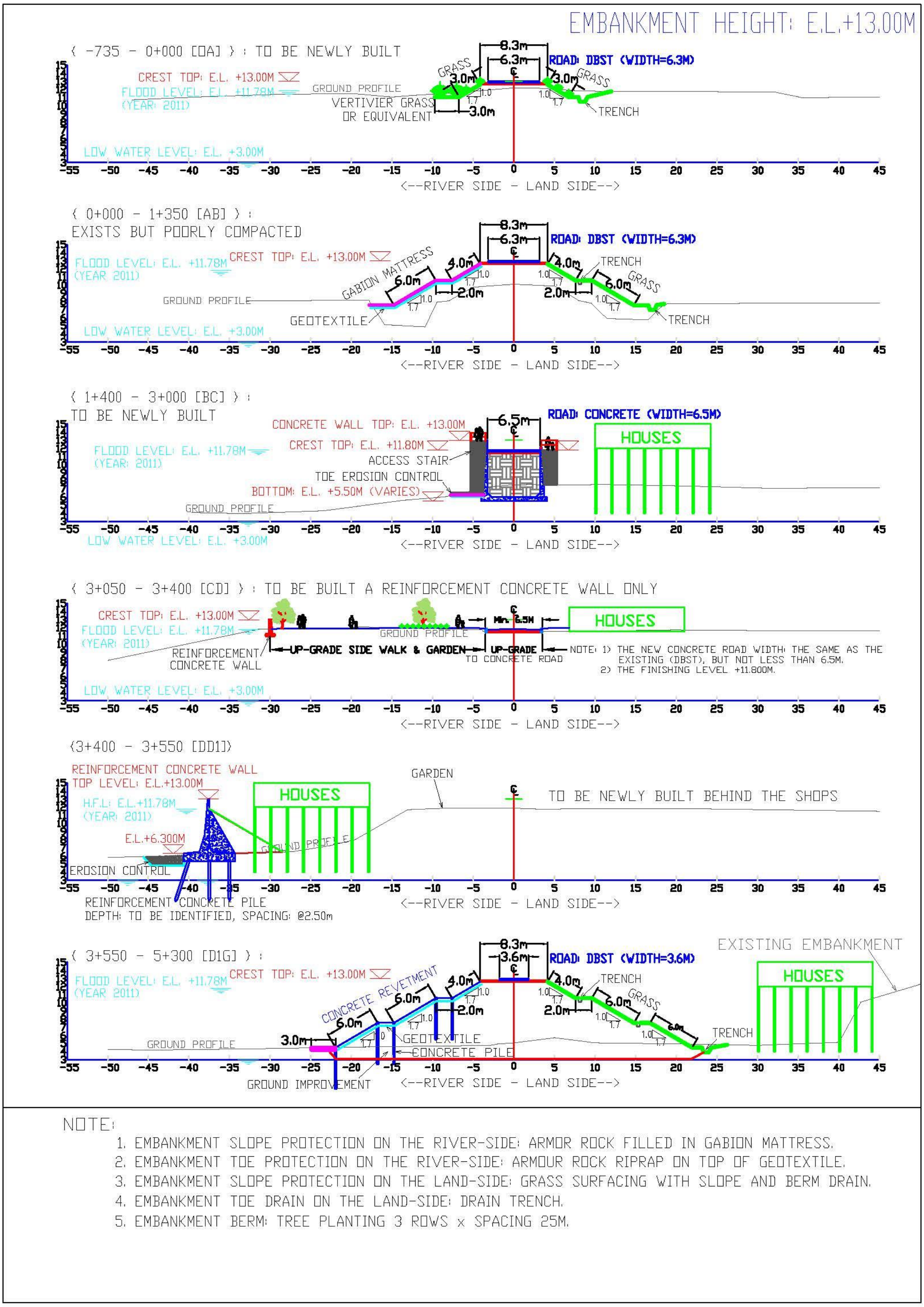
Figure E.4. The construction of the embankment along this section will also provide a permanent waterfront along the Tonle Sap that provides potential for an improved market and port as well as improving the overall environment of the area. All of the land along the route of the proposed embankment belongs to government.

b. Safety Considerations

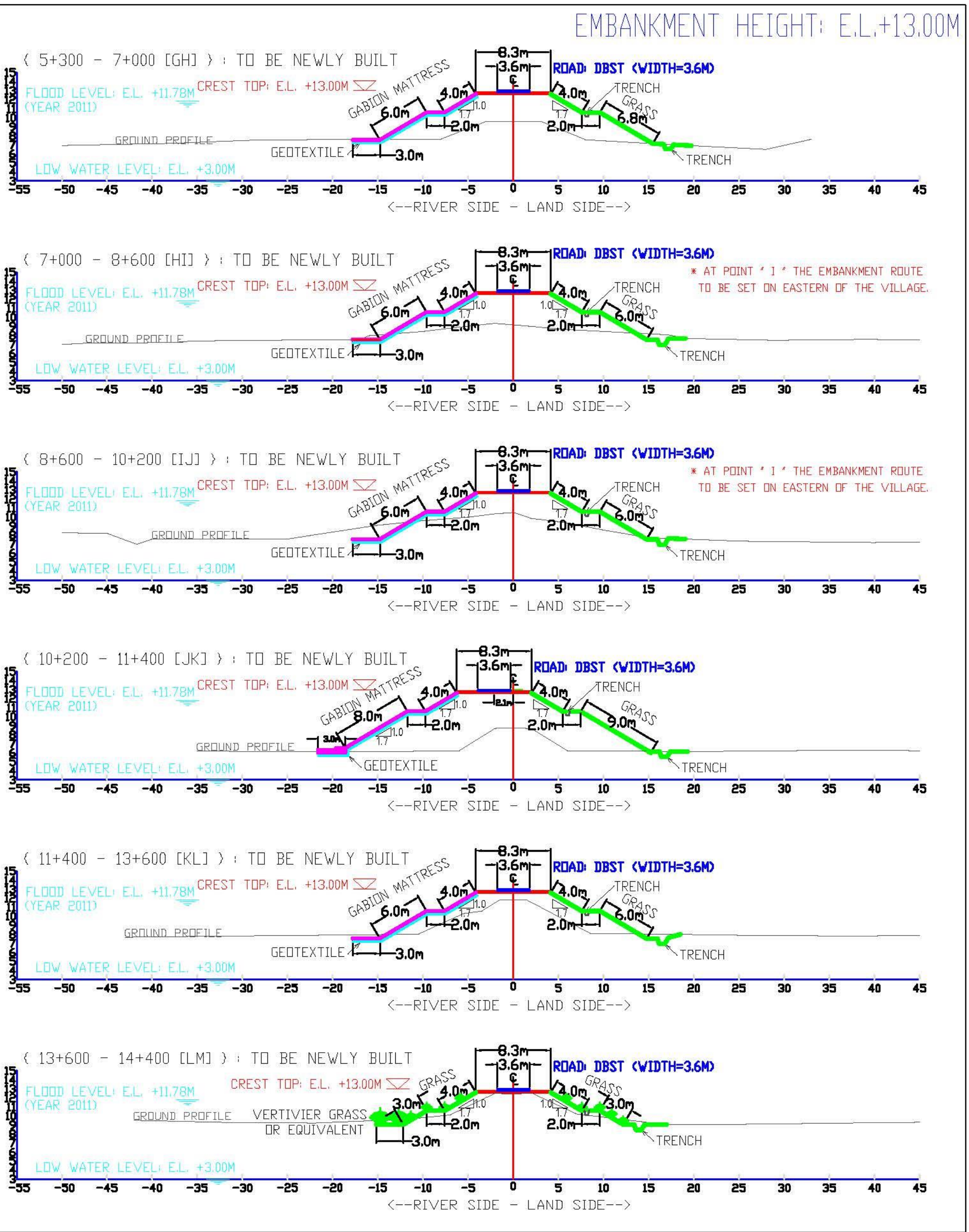
75. The construction of an embankment of the scale proposed could pose a safety issue both during construction and in its long term use. The potential safety issues that could arise during construction and are covered in the IEE for Kampong Chhnang. The IEE has been discussed and shared with the Ministry of Environment, Ministry of Water Resources and Meterology and the Tonle Sap Authority and a summary has been presented at TA 7986-CAM consultation workshops with government officials and residents. The main issues during operation are the potential for cars to drive off the embankment and for people to fall into the water. The list provides the safety measures that are included in the design and its costs. These should be reviewed with local residents again prior to detailed design to ensure it reflects the needs of the local community. These costed features, and other recommendations, should be incorporated during detailed design by future project implementation consultants.

- All roads on the embankment are lower than the edge parapets. In particular, where the road is built upon concrete walls with perpendicular sides, the road is at least 1.2 meters below the top of the embankment. Where there are grass slopes by the edge, normal 100 mm high curbs are proposed, although at bends and passing places, barriers should also be erected.
- In places where the embankment passes through or alongside inhabited areas, pedestrian sidewalks are also proposed.
- Maximum speed should be limited to 30 km per hour on the embankment and speed breakers and other speed control measures will be implemented as required to reduce speeds.
- Solar powered lamps to be used at 35 meter intervals.
- Floatation assistance devices, such as lifebelts, and alarm buzzers are to be provided every 200 meters along the embankment for child and woman safety.
- The embankment structure needs to be inspected after and before ever wet season and the maintenance measures described in Section 0 implemented.

Figure E.4 Typical Cross Section of Embankment at Each Section



Source: TA 7986-CAM Consultants



NOTE:

1. EMBANKMENT SLOPE PROTECTION ON THE RIVER-SIDE: ARMOR ROCK FILLED IN GABION MATTRESS.
2. EMBANKMENT TOE PROTECTION ON THE RIVER-SIDE: ARMOUR ROCK RIPRAP ON TOP OF GEOTEXTILE.
3. EMBANKMENT SLOPE PROTECTION ON THE LAND-SIDE: GRASS SURFACING WITH SLOPE AND BERM DRAIN.
4. EMBANKMENT TOE DRAIN ON THE LAND-SIDE: DRAIN TRENCH.
5. EMBANKMENT BERM: TREE PLANTING 3 ROWS x SPACING 25M.

Source: TA 7986-CAM Consultants

3. Embankment Sections

Table E-2 Summary Description of Proposed Embankment Sections

Section	Existing: Length (m)	Existing: Average Height (above MSL)	Existing: Ground Level (above MSL)	Existing: Embankment Condition	Proposed (Crest Level 13.00 m): Embank-ment to be built	Average Height from Base (m)	Base Width (m)	Crest Width (m)	Crest Finish	Road Width (m)	Outer Revetment[14]: Slope	Outer Revetment: Toe	Inner Revetment: Slope	Inner Revetment: Toe
O – A	735	12.0	12.0	None	New	1.00	15	8.3	Road	6.3	Grass	Grass	Grass	Grass
A – B	1,380	10.0	8.0	Poorly compacted	Replace	5.00	30	8.3	Road and wall		Rock riprap[15]	Apron	Grass	Trench
B – C	1,650	7.5	7.0	None	New retaining wall type	4.00	9	6.5			Concrete			
C – D	350	11.5	11.5	Good, paved & outer slope protected with concrete	Existing side wall to be raised	1.50	2	0.2 (top of wall only)	Wall at top of embank-ment	Use existing road	Existing to be used			
D – D1	125	11.5	11.5	Good, paved		8.20	6				Concrete			
D1 – E	400	11.5	11.5	Good, paved & slope protected, but encroachments	New, soft soil base	8.20	45	8.3	Road	6.3	Rock riprap	Apron	Grass	Trench
E – F	540	8.0	4.8			8.20	45	8.3						
F – G	860	4.8	4.8			8.20	30	8.3						
G – H	1,630	9.0	7.0	Low	Recon-struction of existing	6.00	30	8.3		3.6 with passing places				
H – I	1,670	8.0	7.0	Good quality breached in places		6.00	30	8.3						
I – J	1,800	10.0	8.0			5.00	30	8.3						
J – K	1,000	10.0	7.0			6.00	33	8.3						
K – L	2,200	11.0	8.0			5.00	30	8.3						
L – M	750	13.0	11.0	None	New	2.00	24	8.3			Grass	Grass		Grass
Total	15,090													

Source: TA 7986-CAM Consultants.

[14] Channel bank lining designed to prevent or halt bank erosion.
[15] Well-graded mass of stones, or other material, designed to provide protection from flow induced erosion and used on slopes.

4. Preliminary Quantity Estimate

76. For each of these sections, preliminary quantities have been developed as shown in Table E-3. This shows that the quantities are substantial. Nearly two million cubic meters of backfilling will be required, along with 23 hectares of geotextile lining. Twenty hectares of turf will be required and the roads will cover an area of around eight hectares.

Table E-3 Preliminary Quantities for Embankment Sections

Item \ Section	Unit	OA	AB	BC	CD	DD1	D1E	EG	GH	HI	IJ	JK	KL	LM	TOTAL
Length	m	735	1,350	1,650	375	175	350	1,400	1,700	1,600	1,600	1,200	2,200	800	15,135
Cross-Section	m	10	109	35.1	2	10.78	212	212	100	108	53	100	54	10	-
Base Width	m	15	30	9	2	6	45	45	30	30	30	33	30	24	-
Top Width	m	8.3	8.3	6.5	0.2	0.2	8.3	8.3	8.3	8.3	8.3	8.3	8.3	8.3	-
Road Width	m	6.3	6.3	6.5	6.5	-	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	-
Slope	m	4	12	-	-	-	20	20	12	12	12	17	12	9	-
Toe Apron Width	m	3	3	3	-	4	3	3	3	3	3	3	3	3	-
Backfilling Soil	1,000m^3	9.92	198.65	78.19	1.01	4.73	100.17	400.68	229.50	233.28	114.48	162.00	160.38	10.80	1,703.8
Concrete Wall	1,000m^3	-	-	15.0	0.3	1.9	1.1	4.2	-	-	-	-	-	-	22.4
Geotextile	1,000m^2	-	20.25	4.95	-	1.14	8.05	32.20	25.50	24.00	24.00	24.00	33.00	-	197.1
Gabion Mattress	Unit	-	1,350	-	-	-	-	-	1,700	1,600	1,600	1,700	2,200	-	10,150
Armor Rock	1,000m^3	-	6.4	1.6	-	1.0	2.5	1.3	1.6	7.6	7.6	7.6	10.4	-	47.4
Grass	1,000m^2	5.15	16.20	-	1.50	-	7.00	28.00	20.40	19.20	19.20	20.40	26.40	9.60	173.0
Toe Trench	m	735	1,350	-	-	175	350	1,400	1,700	1,600	1,600	1,200	2,200	800	13,110.0
Road Base-course	1,000m^2	6.10	11.21	10.73	0.08	-	2.91	11.62	14.11	13.28	13.28	9.96	18.26	6.64	118.2
Road Pavement	1,000m^2	4.63	8.51	10.73	2.44	-	1.26	5.04	6.12	5.76	5.76	4.32	7.92	2.88	65.4
Sidewalk	1,000m^2	1.5	2.7	-	9.0	-	1.6	6.6	8.0	-	-	-	-	-	29.4
Solar Street lamps	Unit	25	45	55	13	6	12	47	57	53	53	40	73	27	506
Tree Planting	Unit	89	162		30	7		168	204	192	192	144	264	96	1,548

Source: TA 7986-CAM Consultants

F. Cost Estimates

1. Sources and Development of costs

77. Costs were obtained from the PDPWT in Kampong Chhnang in July 2013 for various ongoing works. Costs not available in Kampong Chhnang, such as geotextile linings, were obtained from Phnom Penh. Costs have been reviewed and modified to reflect costs in Kampong Chhnang in September 2013as shown in Table F-1 below.

Table F-1 Unit Costs for Kampong Chhnang

Item	Names and Description	Unit	Unit Price (USD)
I.	EARTH WORKS		
1.1.	Excavation	m^3	0.60
1.2.	Compaction (soil)	m^2	0.20
1.3.	Normal Soil	m^3	1.70
1.4.	Laterite Soil	m^3	15.60
1.5.	Sand for backfilling	m^3	8.40
II.	STONE, ROCK, AGGREGATE WORKS		0.00
2.1.	Mixed Aggregate - M30/M40	m^3	12.90
2.2.	Compaction (M30/M40)	m^2	0.40
2.3.	Stone 15cmx25cm (riprap)	m^3	9.00
2.4.	Stone 4cmx6cm	m^3	23.40
III.	CONCRETE WORKS / REBAR WORKS		
3.1.	Concrete Cylinder 30Mpa	m^3	102.00
3.2.	Mortar	m^3	90.00
3.3.	Cement (K-Cement)	ton	114.00
3.4.	Reinforcement Steel Bar (V steel, SD390)	ton	900.00
3.5.	Plywood Formwork	m^3	614.70
3.6.	Brick (Solid/Hollow)	pcs	0.10
IV.	PAVEMENT		
4.1.	Laterite Soil (Thk200mm)	m^2	4.40
4.2.	Mixed Aggregate, M30 (Thk200mm)	m^2	3.80
4.3.	RC concrete, DB12@175 (Thk175mm)	m^2	38.90
4.4.	Double Bituminous Surface Treatment (DBST)	m^2	15.90
4.5.	Paving Block / Tile	m^2	9.10
4.6.	Concrete curb (Standard H350mm)	l.m.	7.00
4.7.	Surface drain (V-drain)	l.m.	15.70
4.8.	Grass and Plating	m^2	1.80
4.9.	Galvanized Wire Mesh for capping the stone	m^2	3.00

Item	Names and Description	Unit	Unit Price (USD)
V	RC PIPE (DRAINAGE)		
5.1.	Concrete Pipe 300mm	pcs	10.90
5.2.	Concrete Pipe 600mm	pcs	32.70
5.3.	Concrete Pipe 800mm	pcs	75.70
5.4.	Concrete Pipe 1,000mm	pcs	110.80
5.5.	Concrete Pipe 1,200mm	pcs	151.10
5.6.	Concrete Pipe 1,500mm	pcs	226.20
5.7.	Concrete Pipe 1,750mm	pcs	289.70
VI.	GEOSYNTHETIC		
6.1.	Geotextile, Polyfelt TS30	m^2	1.40
6.2.	Geotextile, Polyfelt TS50	m^2	2.00
6.3.	Geotextile, Polyfelt TS80	m^2	3.20
6.4.	Galvanized Gabion Box 2.0mx1.0mx1.0m	pcs	54.00
6.5.	Galvanized Gabion Box 2.0mx1.0mx0.5m	pcs	44.40
6.6.	Galvanized Mattress Box 6.0mx2.0mx0.3m	pcs	144.00
C	Unskilled Labor (1 person/day)	Day	3.70
	Skilled Labor (1 person/day)	Day	7.30

Source: Department of Public Works and Transport (Kampong Chhnang) and modified by TA 7986-CAM consultants.

2. Capital Costs

78. Capital costs have been developed for each individual section. This allowed both comparison of options and flexibility where the design has to be altered. The costs presented are base costs and include materials, labor, plant and equipment plus contractors overheads. They do not include any physical or price contingencies.

79. The total base cost of the embankment is USD 21.255 million. This is detailed at Table F-2 below.

3. Recurrent Costs

80. The main recurrent costs will be for maintaining the road and slope of the embankment and for operation of the sluice gates. This is detailed in Section I on Operation and Maintenance. This estimates an annual recurrent cost of USD 150,000. This cost is for annual maintenance and does not include major items such as road resurfacing or gabion replacement. Equipment costs are shown in Table 6-4.

4. Climate Change

81. As can be seen from Table F-2 and Table F-3, the additional cost of the climate change measures is USD 6.10 million. Most of this increase is attributable to using concrete revetment on the slopes on the Tonle Sap side rather than gabions (USD 2.2 million) and a concrete road instead of bitumen (USD 1.5 million). Raising the level by 0.9 meters to 13.00 accounts for the balance USD 2.4 million. This increase in cost is justified in two ways. The overtopping of the embankment would be disastrous and with the unknown climate change consequences a return

period of 50 years and a freeboard of 500 millimeters is justifiable. The use of concrete for the road and slopes will increase the longevity of the embankment and reduce maintenance costs.

Table F-2 Cost Summary of Embankment Works

All costs in thousand US Dollars

Item	Section													Total Cost
	OA	**AB**	**BC**	**CD**	**DD1**	**D1E**	**EG**	**GH**	**HI**	**IJ**	**JK**	**KL**	**LM**	
Length(m)	735	1,350	1,650	375	175	350	1,400	1,700	1,600	1,600	1,200	2,200	800	15,135
Site Clearance Works	8.8	30.8	8.9	0.5	0.6	10.9	43.7	40.8	38.4	28.8	28.8	39.6	9.6	290.2
Foundation Works	20.9	73.1	21.2	1.1	42.0	398.6	1,594.3	96.9	91.2	68.4	68.4	94.1	22.8	2,592.9
Earth Works	28.3	623.3	222.8	2.9	13.0	316.5	1,265.8	752.2	769.5	369.4	531.0	550.2	30.8	5,475.5
Concrete Wall Structure	-	-	3,492.3	79	401.0	414	1,725.9	-	-	-	-	-	-	6,111.5
Geotextile,TS50	-	50.8	9.8	-	2.6	18.0	74.8	70.7	66.5	47.5	49.9	65.3	-	456.0
Gabion Mattress, 6x2x0.3m	-	259.2	-	-	-	-	-	367.2	345.6	230.4	259.2	316.8	-	1,778.4
Armor-Rock	-	72.7	14.0	-	9.4	25.8	11.9	14.5	95.3	68.0	71.4	93.6	-	476.6
Grass Slope Protection	9.3	38.9	-	-	-	14.5	60.5	55.1	51.8	34.6	38.9	47.5	15.8	366.8
Toe Trench Work	1.1	2.0	-	-	-	0.5	2.1	2.6	2.4	2.4	1.8	3.3	1.2	19.4
Road Base-Course, M30	23.2	42.6	40.8	-	-	11.0	44.2	53.6	50.5	50.5	37.8	69.4	25.2	448.7
Road Pavement, RC	180.0	330.6	416.9	-	-	49.0	195.9	237.9	223.9	223.9	167.9	307.8	111.9	2,445.6
Sidewalk	13.3	24.5	-	-	-	14.9	59.7	72.4	-	-	-	-	-	184.8
Lighting & Safety	6.5	11.7	14.3	3.4	1.6	3.1	12.2	14.8	13.8	13.8	10.4	19.0	7.0	131.6
Tree Planting & Safety	7.1	13.0	-	2.4	-	3.4	13.4	16.3	15.4	15.4	11.5	21.1	7.7	126.6
COST (no sluice gate)	298.5	1,573.1	4,240.9	88.9	470.3	1,279.7	5,104.5	1,794.9	1,764.2	1,153.0	1,277.0	1,627.7	232.1	20,904.8
Cost per meter (no sluice gate)	0.406	1.165	2.570	0.237	2.687	3.656	3.646	1.056	1.103	0.721	1.064	0.740	0.290	1.381
Sluice Gate 7 Locations	-	-	50.0	-	-	-	50.0	50.0	100.0	50.0	50.0	-	-	350.0
TOTAL COST	**298.5**	**1,573.1**	**4,290.9**	**88.9**	**470.3**	**1,279.7**	**5,154.5**	**1,844.9**	**1,864.2**	**1,203.0**	**1,327.0**	**1,627.7**	**232.1**	**21,254.8**

NOTE: RC: Reinforced Concrete
Source: TA 7986-CAM Consultants.

Table F-3 Cost Summary without climate change measures

	OA	**AB**	**BC**	**CD**	**DD1**	**D1E**	**EG**	**GH**	**HI**	**IJ**	**JK**	**KL**	**LM**	**TOTAL**
TOTAL COST / SECTION	159.6	1012.7	4045.3	176.8	94.6	106.5	4113.7	1234.1	1195.1	807.1	896.9	1172.1	138.7	**15,153.2**

NOTE: RC: Reinforced Concrete
Source: TA 7986-CAM Consultants.

Table F-4 Embankment Maintenance Equipment

Item	Unit	Quantity	Rate	Amount (USD)
Tool Set for Gabion maintenance				
Heavy Duty Pliers	Number	50	30	1,500
Wire Cutters	Number	20	40	800
Mesh Welder	Set	4	250	1,000
Wheelbarrows	Set	30	150	4,500
Industrial Protection Gloves	Pair	200	30	6,000
Industrial Protection Boots	Pair	200	80	16,000
Mobile Scaffolding	Set	2	5,000	10,000
Total				**39,800**

G. Benefits and Risks

1. Direct and Indirect Benefits

82. These are fully described in sections 12 and 13 of the main reports and the appendices containing the financial and economic analyses.

2. Risks

83. A risk assessment of the river embankment was completed. The risk matrix is given in the table below with mitigation measures.

Table G-1 Risk Matrix

Risk	Probability	Impact	Mitigation Measures
Overtopping of embankment	Very Low	Very damaging	Design – includes factor of safety. Operations – need to ensure all sluice gates are closed when necessary. Monitoring – Plan to raise embankment more if water levels show continued annual rise.
Failure of embankment	Low	Very damaging & dangerous	Design – Includes strong embankment protection to increase resilience and minimize maintenance. Construction – Ensure adequate supervision of contractor. Operation – Annual maintenance and inspection required.
Poor construction	Medium	Damaging	Ensure effective contractor supervision, including materials and compaction. Include one-year contractor defect liability period.
Construction delayed due to increased flooding	Medium	Minimal	Plan implementation carefully with factor of safety. Introduce advance action to ensure topographical surveys can be carried out next dry season.

Flooding behind the embankment increases for run-off	Medium	Medium	There are adequate retention areas behind the embankment at present. If these areas are urbanized, then pumps may have to be installed. The design allows for this.
Climate change accelerates the rising level of the Tonle Sap	Medium	Medium	Design – accommodates climate change in factor of safety and the design allows for be further raising of the embankment.

Source: TA 7986-CAM Consultants.

a. Potential Negative Impacts of the Projects

84. The embankment will create substantial flood free land. There is a risk that this will encourage more urban development in the area and reduce the retention areas. However, a new by-pass road is proposed to be built about five kilometers to the West of the town center. This should pull future growth of the town away from the Tonle Sap towards the West of the Town, particularly for industrial development. However, the development of better access to the port on the Tonle Sap could also encourage more development in this area, particularly if many of the boat population decide to relocate to permanent structures but maintain fishing as their main source of income.

85. The Provincial Disaster Management Committee (DMC), which is chaired by the Deputy Provincial Governor in charge of environment, should develop a contingency plan to deal with the unlikely, yet potentially disastrous, overtopping of the embankment.

H. Implementation

1. Existing Responsibilities and Issues

86. The land along the length of the embankment belongs to the Provincial Government and the Provincial Department of Water Resources and Meteorology (PDRAM) is currently responsible for looking after most of the existing embankment, while the Municipality maintains the upgraded area.

2. Implementation Arrangements

a. Implementation Responsibilities

87. In Kampong Chhnang the management of the embankment construction will be by the Provincial Department of Works and Transport (PDPWT) with oversight provided by the Municipality as PDPWT has greater capacity for managing this type of work, while the Southernmost 2.9 kilometers of the embankment lies outside of the Municipality in Rolea Phaer District.

88. The PDWRAM will also need to be involved, as it will be responsible for some of the operation of the sluice gates. This will be done through the local steering committee.

b. Implementation Program

89. Technically, the embankment will be relatively straightforward to construct, but there is one major challenge with respect to construction period. Apart from the section on the already upgraded embankment (C to D1), construction can only take place during the dry season when there is access to the embankment base. This means that there is really only a **five to seven month annual construction window**, depending upon the Tonle Sap levels. Although this is the responsibility of the civil works contractor, the construction work will have to be carefully planned around this constraint. The main technical constraint is that the soil is silty and soft in

some areas, particularly where the embankment is on new land, and will need to be excavated and replaced, probably with impermeable laterite which is available locally.

90. Any section of the embankment will have to be constructed and protected within one dry season which implies, at a minimum the following:

- Excavation as required including removing parts of the existing embankment where necessary;
- Placing and compacting the earthworks;
- Providing the required protection – geotextile sheets, rock formed gabions, or concrete revetment and grass on internal slopes.
- Finishing the crest to avoid any damage during the wet season.

91. The road section can be constructed later and may be better done this way to allow for any settlement, particularly on the higher parts of the embankment and where the existing soil is soft.

92. This dry season window will affect the whole critical path for construction. If the detailed topographical and soil surveys are not carried out during the next dry season in 2014, the detailed design might not be able to commence until the following year. As such, the implementation plan has been designed around this and assumes that the detailed topographical surveys will be completed with the next dry season.

93. Other assumptions for implementation are that the project period will be six years, but that some advanced action will be applied to establish the Project Management Unit (PMU) and ensure surveys are carried out. Plus only one contractor will be used (see Section 3 below) and that the construction will have to be done over three, or even four, dry seasons. Table H-1 below only contains the implementation items related to the embankment construction in Kampong Chhnang. The table is dated, rather than just indicating years, as the timing of the dry season combined with the timing of low water in the river and Tonle Sap lake are critical to the construction of the embankment. An accurate assessment of the time windows available for construction will be undertaken during detailed engineering design.

94. Similarly, as very little construction work will be carried out during the wet season, supervision will also be intermittent.

Table H-1 Indicative Implementation Schedule

Item	2015	2016	2017	2018	2019	2020	2021	2022
1.1 Improved, Reinforced and Raised River Embankment								
Conduct topographical and soil surveys								
Update feasibility study and prepare appraisal report for ADB and government approval.								
Issue ICB bids, evaluate bids and submit to ADB for no objection								
Submit external resettlement M&E report to ADB (continuous, as per agreed RPs)								
Award contract and construct embankment from sections O to A, and C to D (Possible during higher lake levels)								
Transfer of O&M responsibilities for drainage and flood control systems to urban service unit (USU)								
Dry season 1, construct embankment from section A to C								
Dry season 2, construct embankment from section D to I								
Construct embankment from section I to M (Possible during higher lake levels)								
Road surfacing and supervision intermittent								
Final handover of works								
Internal monitoring of safeguards, including RPs and EMPs (continuous, as per agreed safeguard								

Note: Lighter shaded area indicates the approximate period when the embankment base cannot be accessed.
Source: TA 7986-CAM Consultants

95. Assuming that the first year of project implementation is 2015, estimated expenditure over the six years of construction is:

- Year 1: 0%
- Year 2: 5%
- Year 3: 15%
- Year 4: 40%
- Year 5: 30%
- Year 6: 10%

c. Implementation Support

96. The PDPWT in Kampong Chhnang has limited capacity and has never carried out design or construction management of such a large scale project and also lacks the capacity to procure contractors for such works. The ongoing JICA drainage project, which is being implemented by PDPWT, was designed by consultants appointed by JICA who also appointed the contractor and supervision consultants.

97. Assistance will be required in project design, procurement and supervision. In particular this will require the following expertise:

- Surveying;
- Soil mechanics;
- Drainage engineering;
- Roads' engineering;
- Cost engineering and estimation;
- Procurement;
- Construction management including supervision.

98. This expertise overlaps with the type of expertise required for the other infrastructure interventions under the Project and clearly there are efficiencies in combining inputs. Thus much of the design and procurement work will be carried out in the PMU. However, supervision will need to be done locally and will require extensive field-based work. While an important secondary objective of providing implementation support should be to develop local level capacities. Details of implementation are contained in Section 14 and relevant appendices of the main report.

3. Procurement

99. All procurement to be carried out using ADB loan or grant funds, will be carried out in accordance with ADB's Procurement Guidelines (2007, as amended from time to time). Full details of procurement are contained in Section 14 of the Main Report and in relevant supporting annexes.

100. The work will mainly be all civil work, of which earthworks will comprise the greatest component. There will be very little equipment procurement, only the sluice gates. Hence only a civil works contracts will be procured. The options for contractor selection are whether to use one or more contractor. The large size of the civil works contract implies that International competitive bidding (ICB) procedures will be used for major civil works contracts estimated to cost over $1.0 million. The recent ADB-assisted Greater Mekong Subregion Southern

Economic Corridor Towns Development Project which has the same executing agency as that proposed for the Kampong Chhnang embankment works also used this value. If three contracts are awarded of approximately the same value, then all would still be ICB.

101. The other considerations for the number of contractors are:

- Project management – it is much simpler for the PMU to manage and supervise one contractor, but more importantly, only one contractor is responsible for all the works – Conversely, if the embankment construction is divided into sections along its length, with one contractor for each section, responsibility for any poor quality work could still be easily ascertained, although clear instructions for joining sections would need to be developed;
- Speed of work – this is very important given the intermittent construction window. Multiple contractors could speed up the work, but one large contractor with adequate resources, could also ensure construction deadlines are met.
- Impact on local area during construction – many contractors working independently could cause disruption to local areas with multiple large dump trucks hauling earth and compactors using the small roads in the area. This would be better managed by one contractor.
- Availability of plant – the large and long embankment will require substantial equipment, particularly for compacting, plus the intermittent nature of the construction work will mean that each dry season there will be long periods when equipment is not required. Again this might be better managed by one contractor.

102. It would seem that appointing one large contractor with the technical and financial capacity to construct the embankment in the required time period is the preferred option. However, cost is also one of the major considerations for procurement and to allow a comparison of the options, a slice and package system could be used. This is permitted under the ADB procurement guidelines. However, ICB clearly encourages cost competitiveness while MPWT has not procured contractors using this method before thus introducing a possible delay.

103. It is recommended that a one year contractor's defect liability period be used. This is standard practice in Cambodia. This will span one wet season and if there is any failure or weaknesses in the embankment during this period, the contractor will be responsible for its repair. Ten per cent of the contract value payment is withheld to cover this period.

104. It is envisaged that the design and supervision consultant will be appointed by the PMU or MPWT if advanced action is approved and the PMU is not yet established.

I. Operation and Maintenance

1. Responsibilities and Costs

105. Overall management of the embankment including the road on its crest will be by PDPWT, but operation and maintenance will need to be shared with PDRAM for operation of the sluice gates who will, in turn, need to liaise with the Department of Agriculture, Forestry and Fisheries to maximize agricultural yields.

106. The embankment has been designed to minimize any maintenance. However routine and periodic maintenance will ensure that the embankment remains functional for a longer period. Routine maintenance will mainly be seasonal and involve grass cutting, cleaning the toe-drains on the embankments, etc, while periodic maintenance will involve replacing damaged

gabions or resealing roads every few years. Maintenance costs for large static civil works structures, such as roads and embankments, tend to be variable over time. For example, bitumen roads need resurfacing every four or five years, while concrete walls should be plastered every ten years. However, annual operation and maintenance budgets usually do not cover these items. The cost of these larger maintenance items is best covered by including them in the annual capital budgets. As such the table below only includes the annual costs for maintenance. It also does not include any incremental administration costs by government.

107. Table I-1 below provides a description of the annual operation and maintenance costs. As this is a very broad estimate, the quantities and amounts have been rounded.

Table I-1 Annual Operation and Maintenance Costs

Description	Unit	Quantity	Rate (USD)	Amount
Seasonal				
Clean toe-drains, maintenance of sluice gates (oil, scraping, etc) and cleaning of outlet channels	Lump Sum			1,000
Replacing grass on embankment (about 3%)	m2	5,000	2	10,000
Repair compacted earth and toes (about 1%)	m2	10,000	8	80,000
Inspection and repair of gabions (about 3%)	m2	5,000	8	40,000
Minor repairs of road (about 1%)	m2	1,000	12	12,000
Solar Lamp Maintenance (about 5%)	LS			7,000
Total				**150,000**

108. While this amount is around 0.5 per cent of the capital cost, it is still a large amount that may be difficult for the Provincial Government to assign or spend effectively. However, the maintenance of a large embankment 15 kilometers in length is expensive, even if it is designed to be “maintenance free”. It is difficult to obtain direct cost recovery from the embankment construction, but the creation of flood free agricultural and urban land should be reflected in higher land and property values with part of this increase being captured by the local government for embankment maintenance. This should be the goal, but within the current urban institutional arrangements, is maybe still not possible.

109. To assist with maintenance, a budget of USD 40,000 will be provided to purchase simple maintenance equipment such as tools to cut grass and trim trees and hedges. Tools and spare mesh for gabion repair will also be purchased.