CHAPTER 5

Present and Future Potential Flash Floods.

5.1: Introduction.

The potential flash floods for present and future can be explained under four scenarios listed below.

1-Free flow condition with tidal gates fully open. This represents the best case scenario.

2-Mean high tide condition lasting for three hours with tidal gates shut completely. Pumps are assumed not to be operating. This represents the worst case scenario.

3-Mean high tide condition with tidal gates fully shut. Pumps are assumed to be operating at full capacity. This represents a moderate scenario.

4-Mean tide condition with tidal gates fully opened but submerged. Tidal gates are discharging under pressure. Pumps are assumed not to be operating. This represents a moderate scenario.

For each scenario, three conditions are considered. These conditions are stated below.

1-Rainfall intensity of 25mm/hr. Return period of 1 in 1 year.

2-Rainfall intensity of 60mm/hr. Return period of 1 in10 years.

3-Rainfall intensity of 85mm/hr. Return period of 1 in 50 years.

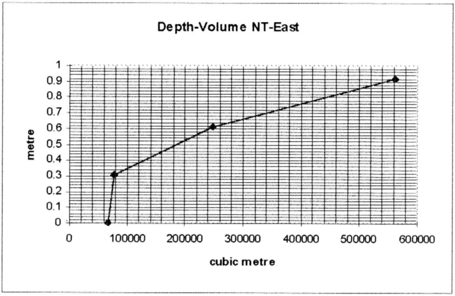
For all cases, the rainfall duration is assumed to be 1 hour. Initial degree of soil moisture saturation (Se) is assumed to be at 0.5 or 50% for all types of soil. Rainfall distributions are assumed to be uniform in time and space. Drains are assumed to be uniform in their respective sections. For all cases, the peak flows or discharges are accumulated peak flows traced from one design point (DP) to another for each drainage network. Overflows are taken into account for each case.

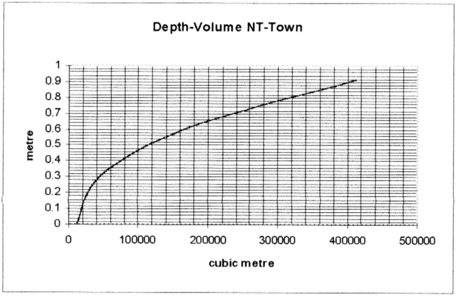
Note: Please refer to Chapter 2 for more details on the various scenarios. For drainage networks and design points, refer to Chapter 3. The term 'unit' refers to drainage unit for this whole chapter.

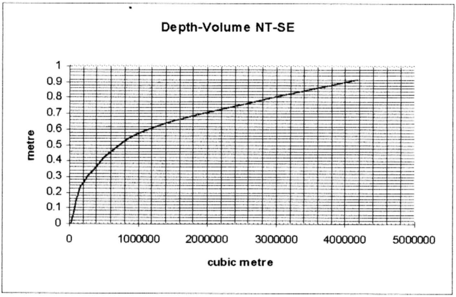
All estimates of flood depths and extent are based on the Depth-Volume Curves constructed for Nibong Tebal --East (covering Sang Lang Village, Air Lintas and Jalan Bukit Panchor), Nibong Tebal --Town (covering town area including Victoria and Caledonia) and Nibong Tebal -- South East (covering Telok Ipil, Tanjung Berembang and Byram Road). These curves are shown in Chart 5.1.

Chart 5.1

Depth-Volume Curves for Nibong Tebal.






Depth-Volume NT-SE
metre
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
1000000
2000000
3000000
4000000
5000000
cubic metre

5.2: Present potential flash floods.

5.2.1: Scenario 1.

Scenario 1 represents free flow condition with tidal gates fully open (best case scenario). The potential flash floods within each drainage networks consisting of a cluster of related drainage units were computed under rainfall intensities of 25, 60 and 85 mm/hr and their results are stated below.

Rainfall intensity : 25 mm/hr.

Units A1-A2	-No flooding.
Units B13-41/42-B5	-No flooding.
Units CA1-CA6	-Drain overflowed at unit CA1 and CA2, causing a minor flash flood . No flooding occurs at any design points.
Units CC1-CC8	-Drain overflowed at DP1, DP2 and DP3. Their accumulated peak flow exceeded their drain capacities by 1.95, 1.35 and 2.35 cumecs or by factors of 2.78, 0.75 and 0.85 respectively. Drain capacities at these design points are 0.7, 1.8 and 2.75 cumecs. -The time of occurrence for these peak flows are at the 26th, 37th and 57th minutes from the beginning of rainfall. The accumulated peak discharge at the outlet or DP4 is 5.125 cumecs (58th minute),

	but it did not exceed its drain capacity. -The resulting flash floods at DP1, DP2 and DP3 are minor.
Units CB1, CB2	-No flooding.
Units CD1-CD4	-Drain overflowed at all design points. Their accumulated peak flow exceeded their drain capacities by 1.478, 0.242, 2.6 and 0.375 cumecs or by factors of 2.83, 0.355, 1.26 and 0.06. Drain capacities at these design points (DP1 to DP4) are 0.52, 0.68, 2.059 and 6 cumecs. -The time of occurrence for these peak flows are at the 115th, 126th, 141st and 162nd minute from the beginning of rainfall. -Peak discharge at outlet 6.375 cumecs (162.5th minute). -The resulting flash floods are minor except at DP3.
Units E1-E4	-No flooding.

Rainfall intensity: 60mm/hr.

Units A1-A2	-No flooding.
Units B13-41/42-B5	- Drain overflowed at unit 41/42 by 8.3 cumecs. -No flooding occurs at DP1 and DP2. Minor flash flood occurs at DP3, drain capacity exceeded by 6.8 cumecs. -Time of occurrence for accumulated peak discharge (13.3cumecs) at outlet (DP3) is at the 173rd minute since the beginning of rainfall.
Units CA1-CA6	-Drain overflowed at unit CA1 and CA2.

	-Minor flooding at DP1. No flooding at DP2. More serious flash flood occurs at DP3 area, its drain capacity exceeded by 19.43 cumecs during peak discharge at the 58th minute. However, its depths and extend are insignificant. -Accumulated peak flow at outlet (DP4) is 5.97 cumecs, arriving at the 157th minutes. However, the drain capacity at the outlet is not exceeded. -Overall, the resulting flash floods are minor.
Units CC1-CC8	-Drain overflowed at DP1, DP2 and DP3. Their accumulated peak flows exceeded their drain capacity by 6.928, 5.59 and 9.66 cumecs or by factors of 9.89, 3.1 and 3.51 respectively. Drain capacities at the design points are 0.7, 1.8 and 2.75 cumecs. -The time of occurrence for these peak flows are at the 23rd, 35th and 54th minute from the beginning of rainfall. -The accumulated peak discharge at the outlet is 10.675 cumecs (56th minute). It did not exceed the drain capacity. -The effects of overbank flow or flash flood are comparatively more serious at Tong Hai Village, Methodist Secondary School and Taman Nibong Tebal. Approximately 0.2 sq.km. of land area could be flooded to the depths of 0.05m to 0.2m. Assumed discharge at DP3 equals to 2.75 cumecs, then flood duration will be about 2.5 hours.
Units CB1, CB2	-No flooding at unit CB1. As for unit CB2, the resulting flash flood

	is minor.
Units CD1-CD4	-Drain overflowed at all design points. Their accumulated peak flows exceeded their drain capacities by 6.178, 0.942, 10.00 and 7.7 or by factors of 11.8,1.4, 4.9 and 1.3. Drain capacities at these design points (1-4) are 0.52, 0.68, 2.059 and 6 cumecs. -The time of occurrence for these accumulated peak flows are at the 102nd, 113th, 129th and 148th minute from the beginning of rainfall. -The accumulated peak discharge at the outlet is 13.7 cumecs (148.5th minute). -The resulting flash floods are more serious at DP1, DP3 and DP4.
Units E1-E4	-No flooding.

Rainfall intensity: 85mm/hr.

Units A1-A2	-Minor flash flood occurred at outlet. Its drain capacity exceeded by 2.8 cumecs.
Units B13-41/42-B5	- Drain overflowed at unit B41/42 by 10.6 cumecs. -Flooding occurs at all design points. Minor flooding occurs at DP1, its drain capacity exceeded by 5.635 cumecs. -The accumulated peak discharge at the outlet (DP3) is 20.95 cumecs, arriving at the 172nd minute from the beginning of rainfall. It exceeds its drain capacity by 15.79 cumecs or by factor of 3

	(drain capacity is 5.15 cumecs). -Assuming discharge at outlet equals to 5.15 cumecs, maximum flood volume at the outlet is 52,704 m^3. The maximum flood depth could reach 0.15m on average, covering approximately 0.35 sq.km. of land area for 3 hours.
Units CA1-CA6	-Drain overflowed at unit CA1 and CA2, exceeding their drain capacities by 5.77 and 2.02 cumecs respectively. -All design points are flooded by their accumulated peak discharge. -Minor flooding occurs at DP1. Its drain capacity exceeded by 3.45 cumecs. -Minor flooding occurs at DP2. Its drain capacity is exceeded by 4.86 cumecs. -More serious flooding occurs at DP3 area. Its drain capacity exceeded by 33.27 cumecs or by factor of 10 during peak discharge at the 109th minute. Assuming the discharge capacity at DP3 equals to 3.37 cumecs, the maximum flood volume at DP3 will be 103,467 m^3 , flooding 0.26 sq.km. of land area up to an average depth of 0.4m for 8.5 hours. -DP3 is actually a 'bottle neck'. The upstream drain capacity is about 9 times larger than at DP3 and the accumulated peak discharge upstream of DP3 is 36.3 cumecs at full bank. This constriction at DP3 causes the storm runoff to overflow, flooding low lying areas along this section.

	-The accumulated peak discharge at the outlet (DP4) is 8.23 cumecs, arriving at the 137th minutes. Its drain capacity is slightly exceeded by 0.64 cumecs.
Units CC1-CC8	-Drain overflowed at DP1, DP2 and DP3. Their accumulated peak discharges exceeded their drain capacities by 9.96, 8.6 and 14.41 cumecs or by factors of 14.2,4.8 and 5.24 respectively. Drain capacities at these design points are 0.7, 1.8 and 2.75 cumecs. Their time of occurrence are at the 23rd, 34th and 54th minute from the beginning of rainfall. -The accumulated peak discharge at the outlet is 10.675 cumecs (54.5th minute). It did not exceed its drain capacity. -The resulting flash floods are serious at Tong Hai Village, Methodist Secondary School, Pinang Village, Taman Sri Nibong and Taman Nibong Tebal. -Assuming the discharge at DP3 is 2.75 cumecs, approximately 0.17 sq.km of land area could be flooded to the depth of 0.36m for 3.6 hours.
Units CB1, CB2	-No flooding occurred at unit CB1. as for unit CB2, the resulting flash flood is minor.
Units CD1-CD4	-Drain overflowed at all design points. Their accumulated peak flows exceeded their drain capacities by 9.178, 0.842, 17.699 and 12.13 or by factors of 17.65, 1.3, 8.6 and 2.05 respectively. The drain capacity at these design points (1-4) are 0.52, 0.68, 2.059 and

	6 cumecs. -The time of occurrence for these peak flows are at the 100th, 110th, 124th and 145th minute from the beginning of rainfall. -The accumulated peak discharge at the outlet is 13.7 cumecs (occuring at the 146th minute). -The resulting flash floods are more serious at DP1, DP2 and DP4. -The maximum flood volume is 141,600 m^3 at DP4. Assuming discharge at DP4 is 6 cumecs, 0.708 sq.km. of land area couldl be flooded up to 0.2m for 3.5 hours.
Unit E1-E4	-No flooding.

Unit E1, E2, E3 and E4 are not susceptible to flash flood in any case. The town areas are prone to flooding. These flood prone areas are Tong Hai Village, Methodist Secondary School, Pinang Village, Taman Nibong Tebal, Taman Sentosa and near the former Post Office. Other units are only susceptible to flooding at higher rainfall intensities. The potential flood depths are shallow, ranging from 0.1m to 0.35m. This is because this area is generally very flat, causing the flood water to be distributed over a vast area.

The potential flood duration ranged from 1 to 4 hours and total extent could reach 1.6 sq.km.

The time of arrival for accumulated peak discharges at various design points are generally short. This is an important point to note for flash flood risk management. Shorter time of arrival would mean that in the event of a major flood (i.e., in the magnitude of 1:50 years), the time available to minimize flood damages would be little.

5.2.2: Scenario 2.

Scenario 2 represents mean high tide condition lasting for three hours with tidal gates shut completely and pumps are assumed not to be operating (worst case scenario). Results were computed under rainfall intensities of 25, 60 and 85 mm/hr. The results are as stated below.

Table 5.1
Maximum flood volume and depth (present potentials).

Drainage Units.	Case V1	DE1	Case V10	DE10	Case V50	DE50
A1-A2 B13-B5 CA1-CA6	124,180	0.44** 0.28	550,342	0.91 0.6	883,199	1.1 0.80
CB1,CB2 CC1-CC8	35,184	0.24 0.146	96,860	0.45 0.22	140,950	0.55 0.27
CD1-CD4	78,258	0.05 0.6	218,688	0.28 0.78	321,553	0.32 1.0
E1-E4	14,095	-	37,548	-	54,575	-

Note: Cases V1..50-maximum flood volume for rainfall intensities of 1 in 1,10 and 50 years return period in m^3, DE1...50- average depth (metre) and extend (sq.km.) for rainfall intensities 1 in 1,10 and 50 years return period. **First figure is flood depth, second is extent.

Case V1 or rainfall intensity equals to 25mm/hr:

The total flooded area is 0.82 sq. km. The average flood depths ranged from 0.05m to 0.44m. The town area is flooded up to 0.22m, effecting all the flood prone areas. Parts of Sang Lang village and areas located near Gate B are affected. The effects on the South Eastern side of Nibong Tebal are minimal.

Case V10 or rainfall intensity equals to 60 mm/hr:

The total flooded area is 1.6 sq. km. The average depths ranged from 0.25m to 0.9m. This is more serious than case V1. Flooded areas are extended to parts of Victoria, Taman Sri Maju-Bahagia, Chanda Sherif Road and Pengkalan Rawa Road or the old town (town area). On the Eastern side, flooded areas include parts of Air Lintas (near the Veterinary Department) and Sang Lang village. The flash flood that occur on South Eastern side is more serious than in case V1.

For case V50 or rainfall intensity equals to 85 mm/hr:

The total flooded area is 2.1 sq.km. The average flood depths ranged from 0.31m to 1.1m. The effects are severe. Flooded areas are extended to almost half of the old town (Ooi Kar Seng Road and sections of High Road area), Telok Ipil, parts of Taman Sri Maju-Bahagia, Victoria (including Sri Sentosa Primary School), Shaik Adam Village and the Southern Pipe factory. Flood depths for these areas ranged from 0.1m to 0.5m (maximum will be at flood prone area). As for the Eastern side of Nibong Tebal, the flooded areas are extended from Gate A to Sang Lang village, parts of Taman Verrapan, Taman Penting, Taman Grand and Air Lintas. At the South Eastern side, about 40% of Victoria Estate will be flooded.

In all cases, units E1, E2, E3 and E4 are not affected. Their existing drains are able to handle the discharges. Moreover, Mati and Daun River have the capacity to take in about 101,250 m^3 of water without overflowing. For all the cases above, the flood duration is between 6 to 12 hours.

5.2.3: Scenario 3.

Scenario 3 represents mean high tide condition with tidal gates fully shut and pumps are assumed to be operating at full capacity (moderate scenario). Only Units CA1-CA6 and CC1-CC8 were considered, others not relevant. The maximum excess flood volumes for pumping rate equaled to 2 cumecs are shown below. These results were computed under rainfall intensities of 25, 60 and 85 mm/hr.

Table 5.2
Maximum excess flood volume.

Return period.	Maximum excess volume (m^3).	Head water depth (m).	Time of occurrence (minutes)*
Units CA1-CA6			
1**	7,560	1.06	250th
10	39,600	1.78	260th
50	64,584	2.13	280th
Units CC1-CC8			
1	18,750	1.44	130th
10	67,860	2.63	140th
50	112,050	3.35	150th

Note: * since the begining of rainfall. ** rainfall intensities of 1, 10 and 50 years return period, they represent case 1, 2 and 3.

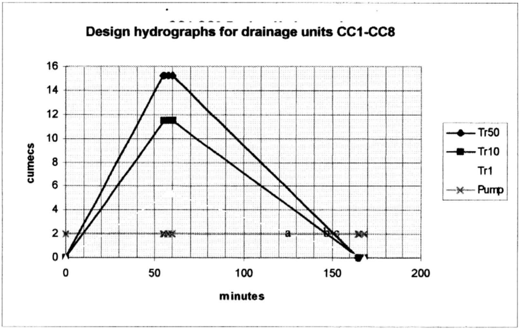
The accumulated excess water causes the head water level (maximum water depth at outlet) to rise to the depth stated above. The normal flow depths are 0.52m and 0.11m for discharge rate equals to pumping rate. Overbank flow is taken into account in the final accumulated peak discharge at their respective outlets.

The accumulation of flood water occurs when the discharge rate exceeds pumping capacity. This excess flood volume creates a backwater effect. The backwater raises water level in the drains. This in turn will aggravates the effects of overbank flow.

Comparing the time of occurrence for the backwater effects and accumulated peak discharge at various design points, it is clear that both phenomena occurred at different time period. For units CC1-CC8, the accumulated peak discharge at DP1 to DP4 occurred within the 22nd to 58th minutes, whereas the maximum backwater effects occured within the 130th to 150th minutes. For units CA1-CA6, the accumulated peak discharge occurred within the 60th to 157th minutes, wherelse the maximum backwater effect occurred within the 250th to the 280th minutes. These differences simply means that the flood depth which was expected to decrease after the overbank flow had achieved its maximum (after peak flow had been reached at a particular design point) will be offseted by the increasing backwater. As a result, under this scenario, the resulting flash floods will be aggravated.

At the point where maximum excess flood water is reached, the discharge rate is equal to pumping rate. Therefore, the normal depths are based on the pumping rate at this equilibrium. This is shown in the design hydrographs for units CC1-CC8 (Chart 5.2).

Chart 5.2



Note: a, b, c are points where maximum excess flood volume is reached. Note that at this point, the discharge rate is equal to pumping rate.

The effects of backwater to the normal flow depths for various return periods (Tr) of rainfall intensities are shown in Table 5.3. The backwater effect on the town drainage are more severe than units CA1-CA6. The whole drainage network for the town is effected by it. Backwater causes overflow to occur at the outlet of units CC4-CC8. For both drainage networks, the backwater effects are more severe at their outlets and at higher rainfall intensities. This is indicated by the offset figures in Table 5.3.

Table 5.3
Backwafer effects on water depth (main drains).

Drain Section.	Section (distance from outlet) in m.	Backwater elevation from bed level or maximum water depth(m).	Normal depth (m)*.	Offset.
Units CA1-CA6				
Tr=1	0	1.06	0.52	0.54
	2730	0.56	0.52	0.04
Tr=10	0	1.78	0.52	1.26
	2782	1.28	0.52	0.76
	5460	0.76	0.52	0.24
Tr=50	0	2.13	0.52	1.61
	2886	1.63	0.52	1.11
	5278	1.11	0.52	0.59
Units CC4-CC8				
Tr=1	0	1.44	0.11	1.33
	1248	0.94	0.11	0.83
Tr=10	0	2.63*	0.11	2.52
	1251	2.13	0.11	2.02
	2500	1.63	0.11	1.52
Tr=50	0	3.35*	0.11	3.24
	1251	2.85	0.11	2.74
	2516	2.35	0.11	2.24

Note: Rullmann's equation assumes uniform flow. Normal depth is based on discharge rate or pumping rate. * -Drain overflowed (maximum drain depth for unit CC8's outlet is 2.00m).

5.2.4 Scenario 4.

The tide level is assumed to be at 0.479m LSD. Therefore, all drainage outlets are submerged. The discharge rate (under pressure) for each outlet is given in Table 5.4. The results were computed under rainfall intensities of 25, 60 and 85 mm/hr.

Overbank flow was taken into account in computing the final accumulated peak discharge. The total volume of flood water accumulated at peak flow will raise the head water level. The head water level had to reach a critical depth before discharge is possible. The critical depth and volume required are given in Table 5.4. for each drainage network. This requirement pose a problem because when of head water rises it will create backwater condition. As mentioned earlier, backwater aggravates the effects of overbank flow or flash flood.

Table 5.4
Discharge rates for submerged outlets.

Return Period. (Tr)*	Accumulated flood volume (m^3).	Maximum head water depth (m).	Elevation of head water surface (m LSD).	Discharge rate ** (cumecs).
	Units A-A1			
1	2,872.7	0.99	-0.11	-
10	28,848.6	3.123	2.053	7.58
50	32,324.5	3.333	2.23	7.58
	cv=9,990.04	hc=1.8506	qc=5.063	
	Units B13-B5			
1	24,032.4	1.21	-0.29	-
10	86,024	2.3	0.8	8.89
50	168,702	3.22	1.72	9.77
	cv=43,706	hc=1.637	qc=5.08	
	Units CA1-CA6			
1	16,314	0.8	-0.5	-
10	31,012	1.11	-0.19	-
50	42,250	1.69	0.39	-
	cv=133,402.5	hc=2.307	qc=14.713	
	Units CC1-CC8			
1	9,532	0.66	-0.254	-
10	20,630	0.98	-0.066	-
50	28,310	1.15	0.236	-
	cv=42,076	hc=1.99	qc=14.304	

	Units CD1-CD4			
1	30,504	1.42	0.44	-
10	74,493	2.22	1.24	13.74
50	80,769	2.32	1.34	13.74
	cv=46,464	hc=1.759	qc=10.447	

Notes: cv-critical volume, hc-critical depth, qc-critical discharge. * Return periods for rainfall intensities of 25, 60 and 85 mm/hr, these represent case 1, 2 and 3. **Maximum discharge is calculated at maximum allowable head (equal to drain depth at the inlet) for cases where the head water exceeds drain's maximum depth (overflow).

Units A-A2: Except for case 1 (Tr=1), discharge is possible for the other two cases. The critical volume (9,990 m^3) that need to be accumulated at the inlet of the tidal gate is small and does not pose any serious flood problem. Its discharge rates ranged from 5.063 to 7.58 cumecs.

Units B13-B5: Except for case 1 (Tr=1), discharge is possible for the other two cases. The critical volume (43706 m^3) that need to be accumulated at the inlet of the tidal gate does not posed any serious flood problem. Its discharge rate ranged from 5.08 to 9.77 cumecs. However for case 3, the excess volume at peak flow could reach 91,900 m^3. This could flood an area of 0.24 sq.km. to a depth of 0.38m for approximately 4 hours.

Units CA1-CA6: No discharge is possible for all cases under mean tide condition. The critical volume needed is higher than accumulated volume at peak flow. The required volume is 133,402 m^3 and head water depth needed is 2.3 m (higher than maximum depth at inlet). As a result, flooding could occur at the outlet. A more severe flooding could be expected for case 2 and 3. This required critical volume could flood 0.3 sq.km. of land area up to 0.44m deep for approximately 2.5 hours and aggravate the effect of overbank flow upstream (especially at units CA51/52 and CA2). The tidal gate need to be upgraded in order to mitigate this potential flooding.

Units CC1-CC8: No discharge is possible for all cases under mean tide condition. The critical volume required is higher than the accumulated volume at peak flow. The needed volume is 42,000 m^3 and head water depth is 1.98m. As a result, flooding could occur on flood prone areas located near to the outlet. A more severe flooding could be expected for case 2 and 3. This critical volume would flood 0.15 sq.km. of land area up to 0.28m deep for approximately 0.8 hours. The effect of overbank flow on the upstream flood prone areas will be aggravated. The tidal gate need to be upgraded in order to mitigate this potential flooding.

Units CD1-CD4: Except for case 1 (Tr=1), the other two cases discharges are possible. The critical volume (46,464 m^3) that need to be accumulated at the inlet of the tidal gate is moderate and does not pose any serious flood problem. The discharge rate for this outlet ranged from 10.44 to 13.74 cumecs. For case 2 and 3, only minor flooding would occur as discharge rate is high after the critical volume is reached.

Units CB1-CB2: No floodings are expected for all cases. Unit E1 to E4 are not relevant for this scenario.

5.3: Future conditions.

5.3.1: Scenario 1.

Scenario 1 represents free flow condition with tidal gates fully open (best case scenario). The future potential flash floods within each drainage networks consisting of a cluster of related drainage units were computed under rainfall intensities of 25, 60 and 85 mm/hr and their results are stated below.

Rainfall intensity : 25 mm/hr.

Units A1-A2	-No flooding.
Units B13-41/42-B5	-No flooding.
Units CA1-CA6	-Drain overflowed at CA1 and CA2. -No flooding occurred at any design points.
Units CC1-CC8	-Drain overflowed at DP1, DP2 and DP3. Their accumulated peak flows exceeded their drain capacities by 2.47, 1.52 and 3.04 cumecs or by factors of 3.5, 0.84 and 1.1 respectively. Their drain capacities at these design points are 0.7, 1.8 and 2.75 cumecs. -The time of occurrence for these peak flows are at the 26th, 37th and 57th minute from the beginning of rainfall. -The accumulated peak discharge at the outlet is 5.4 cumecs (58th minute). It did not exceed its drain capacity.

	- Overall, the resulting flash floods are minor.
Units CB1, CB2	-No flooding.
Units CD1-CD4	-Drain overflowed at all design points. Their accumulated peak flow exceeded their drain capacities by 4.048, 0.272, 5.069 and 7.66 or by factors of 7.78, 0.4, 2.46 and 1.27 respectively. Drain capacities at these design points (1-4) are 0.52, 0.68, 2.059 and 6 cumecs. -The time of occurrence for these peak flows are at the 101st, 112th, 127th and 147th minute from the beginning of rainfall. -The accumulated peak discharge at the outlet is 7.66 cumecs (147th minute). -Overall, the resulting flash floods are minor except at DP1 and DP3.
Units E1-E4	-No flooding occurred except for minor flooding at DP1 of unit E4.

Rainfall intensity: 60mm/hr.

Units A1-A2	-Minor flooding at DP1.
Units B13-41/42-B5	- Drain overflowed at unit 41/42 by 10.2 cumecs. -No flooding occurred at DP1 and DP2. -Flooding occurred at the outlet (DP3). Its drain capacity (6.44 cumecs) is exceeded by 19.685 cumecs. The accumulated peak discharge is 26.125 cumecs, arriving at the 172nd minute from the beginning of rainfall. The maximum excess flood water is 118,110

	m^3 (at 340th minute). This could flood 0.29 km.sq. of land area to a depth of 0.4m for approximately 5 hours.
Units CA1-CA6	-Drain overflowed at unit CA1 and CA2. -Flooding occurred at all design points except DP4. Their drain capacities are exceeded by 5.8, 2.91 and 35.92 at DP1,2 and 3. -Serious flooding occurred at DP3 area. Its drain capacity is exceeded by a factor of 10.6 during peak discharge at the 60th minute. The maximum excess flood volume at DP3 (at the 122nd minute) is 107,760 m^3. This could flood 0.28 sq.km. of land area (Units CA51/52 and B2) to a depth of 0.38 m for 8.9 hours. The 'bottle neck' effect at DP3 was explained in previous section. -The accumulated peak flow at the outlet (DP4) is 6.28 cumecs, arriving at the 136th minutes. However, its drain capacity is not exceeded.
Units CC1-CC8	-Drain overflowed at DP1, DP2 and DP3. Their accumulated peak flows exceeded their drain capacities by 8.068, 6.132 and 11.038 cumecs or by factors of 11.5, 3.4 and 4.01 respectively. Drain capacities at these design points are 0.7, 1.8 and 2.75 cumecs. -The time of occurrence for these peak flows are at the 18th, 35th and 55th minute from the beginning of rainfall. -The accumulated peak discharge at the outlet is 11.51 cumecs , arriving at the 56th minute. It did not exceed its drain capacity. -The resulting flash floods are serious at the flood prone areas

	(Tong Hai Village, Methodist Secondary School and Taman Nibong Tebal). Approximately 0.12 km.sq. of land area could be flooded to a depth of 0.25m. Assuming discharge at DP3 equals to 2.75 cumecs, the flood duration will be about 3 hours.
Units CB1, CB2	-No flooding occurred at unit CB1. As for unit CB2, only a minor flash flood is expected.
Units CD1-CD4	-Drain overflowed at all design points. Their accumulated peak flows exceeded their drain capacities by 11.648, 1.472, 16.069 and 17.8 cumecs or by factors of 22.4, 1.05, 7.8 and 2.9 respectively. -The time of occurrence for these peak flows are at the 95th, 105th, 120th and 140th minute from the beginning of rainfall. -The accumulated peak discharge at the outlet is 17.8 cumecs, arriving at the 140th minute. -The resulting flash floods are serious at DP1, DP3 and DP4. The maximum excess flood volume is 140,967 m^3. Assuming discharge at outlet is 6 cumecs, this could flood 0.41 sq.km. of land area to a depth of 0.34m for 3.5 hours.
Units E1-E4	-Flooding occurred at DP1 of unit E4. Its drain capacity exceeded by 7.2 cumecs.

Rainfall intensity: 85mm/hr.

Units A1-A2	-Minor flooding occurred at the outlet. Its drain capacity is exceeded by 10 cumecs.
Units B13-41/42-B5	-Flooding occurred at all design points. - At DP1 and DP2, their drain capacities are exceeded by 8.35 and 8.65 cumecs respectively. -Flooding occurred upstream at the entrance of unit 41/42. Its drain is overflowed by 11.45 cumecs. -The accumulated peak discharge at the outlet (DP3) is 26.125 cumecs, arriving at the 165th minute from the beginning of rainfall. It exceeded its drain capacity (5.15 cumecs) by 20.975 cumecs or by a factor of 4.1. Assuming the discharge at the outlet is 5.15 cumecs, the maximum excess flood volume will be 188,775 m^3. This could flood 0.36 sq.km. of land area to a depth of 0.52m for 10 hours.
Units CA1-CA6	-Drain overflowed at unit CA1 and CA2, exceeding their drain capacities by 6.87 and 2.0 cumecs respectively. -All the design points are flooded. - Serious flooding occurred at DP1 and DP2. Their drain capacities are exceeded by 12.8 and 15.76 cumecs respectively. -Severe flooding occurred at DP3 area. Its drain capacity is exceeded by 45.12 cumecs or by a factor of 13.4 during peak

	discharge at the 106th minute. Assuming discharge capacity at DP3 equals to 3.37 cumecs, the maximum excess flood volume will be 162,432 m^3. This could flood 0.32 sq.km.of land area up to a depth of 0.5m for 13 hours. -The accumulated peak discharge at the outlet (DP4) is 24.6 cumecs, arriving at the 134th minute. Its drain capacity is exceeded by 17.06 cumecs. The maximum excess flood volume at DP4 is 133,095 m^3. This could flood 0.3 sq. km. of land area to the depth of 0.44m for 4.8 hours.
Units CC1-CC8	-Drain overflowed at DP1, DP2 and DP3. Their accumulated peak flows exceeded their drain capacities by 12.02, 9.3 and 19.28 cumecs or by factors of 17.7, 5.16 and 7.0 respectively. Drain capacities at these design points are 0.7, 1.8 and 2.75 cumecs. -The time of occurrence for these peak flows are at the 23rd, 34th and 54th minute from the beginning of rainfall. -The accumulated peak discharge at the outlet is 15.275 cumecs (54.5th minute). It did not exceed its drain capacity. -The resulting flash floods are serious at Tong Hai Village, Methodist Secondary School, Pinang Village and Taman Nibong Tebal. Assuming discharge at DP3 is 2.75 cumecs, approximately 0.14 km.sq. of land area could be flooded to a depth of 0.34m for 6 hours.
Units CB1, CB2	-No flooding occurred at unit CB1. As for unit CB2, only a minor

	incident is expected.
Units CD1-CD4	-Drain overflowed at all design points. Their accumulated peak flows exceeded their drain capacities by 18.45, 2.95, 24.4 and 24.5 cumecs or by factors of 33.4, 4.34, 11.8 and 4.08. -The time of occurrence for these peak flows are at the 90th, 100th, 116th and 136th minute from the beginning of rainfall. -The accumulated peak discharge at the outlet is 24.5 cumecs (136.5th minute). -The resulting flash floods are serious at DP1, DP2 and DP4. The maximum excess flood volume is 232,650 m^3. Assuming discharge at DP4 is 6 cumecs, 0.68 sq.km. of land area could be flooded up to a depth 0.34m for 10 hours.
Units E1-E4	-All design points are flooded except for unit E2. Serious flooding occurred at DP1 of unit E4. Its drain capacity is exceeded by 11.1 cumecs.

Unit E2 is not susceptible to flash flood in any case. The town areas are very susceptible to flooding. Flood prone areas are Tong Hai Village, Methodist Secondary School, Pinang Village, Taman Nibong Tebal, Taman Sentosa and near the former Post Office. Other units are only susceptible to flooding at higher rainfall intensities.

Flood depths ranged from 0.1m to 0.6m. The flood depths for present and future potential flash floods do not differ much. This is because this area is generally very flat, causing the flood water to be distributed over a vast area.

Time of arrival for the accumulated peak discharges at various design points are generally short. The differences between present and future potential condition are within 2 to 15 minutes only. However, the peak discharge is higher for future potential condition because of the increase in surface runoff.

The extend and duration of flash flood for future potential condition is larger and longer under this scenario. Further comparison will be made at the end of this chapter.

5.3.2: Scenario 2

Scenario 2 represents mean high tide condition lasting for three hours with tidal gates shut completely and pumps are assumed not to be operating (worst case scenario). Results were computed under rainfall intensities of 25, 60 and 85 mm/hr. The results for the future conditions are as stated in Table 5.5.

Table 5.5
Maximum flood volume and depth (future potentials).

Drainage Units.	Case V1	DE1	Case V10	DE10	Case V50	DE50
A1-A2 B13-B5 CA1-CA6	215,506	0.56** 0.38	74,7921	1.2 0.62	1,141,428	1.4 0.82
CB1,CB2 CC1-CC8	40,073	0.26 0.15	109,531	0.49 0.22	158,955	0.58 0.27
CD1-CD4	95,562	0.05 0.6	264,929	0.28 0.95	387,544	0.35 1.11
E1-E4	43,164	-	117,981	-	165,217	-

Note: V1..50-maximum flood volume for rainfall intensities of 1,10 and 50 years return period in metre cube, DE1...50- average depth (metre) and extent (sq.km.) for rainfall intensities of 1,10 and 50 years return period. **First figure is flood depth, second is extent.

Case V1 or rainfall intensity equals to 25 mm/hr:

The total flooded area is 1.13 sq. km (40% more than present potential condition). The average depths ranged from 0.05-0.56m. The town area is flooded up to 0.26m, effecting all the flood prone areas. There is a slight increase in depth and extend compared to the present potentials. Large portion of Sang Lang village and areas located near Gate B are effected. The resulting flash flood on the South Eastern side of Nibong Tebal is minor.

Case V10 or rainfall intensity equals to 60 mm/hr:

Total flooded area is 1.8 sq. km (increased by 11% compared to the present potential condition). The average depths ranged from 0.35m to 1.4m. They are more serious than compared to the present condition. Flooded areas include the flood prone areas and parts of Taman Sri Nibong and Taman Sri Maju-Bahagia, Victoria, Chanda Sherif Road, Telok Ipil, Pengkalan Rawa Road and sections of the old town. On the

Eastern side, flooded areas are Sang Lang village, areas located near to Gate B and parts of Air Lintas (near the Veterinairy Department). The resulting flash flood on South Eastern side is more serious compared to case V1.

For case V50 or rainfall intensity equals to 85 mm/hr:

Total flooded area is 2.2 sq.km (4 % increase compared to present potential condition). The average depths ranged from 0.31 to 1.1m. The effects are severe. Flooded area are extended to the old town, Ooi Kar Seng Road, sections of High Road, Bahru Road, Chanda Sherif Road, Telok Ipil, parts of Victoria including Sri Sentosa Primary School, Shaik Adam Village, parts of Taman Bahagia-Sri Maju and the Southern Pipe factory. The flood depths for the town area ranged from 0.1m to 0.58m (maximum will be at flood prone areas). On the Eastern side, flooded areas are extended from Gate A to the whole Sang Lang Village, parts of Taman Verrapan, Taman Penting, Taman Grand and Air Lintas. On the South Eastern side of Nibong Tebal, about 50% of Victoria Estate will be flooded.

In all cases, unit E2 is not effected. Its existing drains is able to handle the discharge. Mati and Daun River have the capacity to take in about 101250 metre cube of water without overflowing. As a result, in case V10 and V50, the flood volume would only flood the Mati-Daun basin to a depth not more than 0.05m. This is insignificant.

For all the cases, the flood duration is between 6 to 12 hours.

5.3.3: Scenario 3.

Scenario 3 represents mean high tide condition with tidal gates fully shut and pumps are assumed to be operating at full capacity (moderate scenario). Only units CA1-CA6 and CC1-CC8 were considered, others not relevant. The maximum excess flood volumes for pumping rate equaled to 2 cumecs are shown below. These results (future conditions) were computed under rainfall intensities of 25, 60 and 85 mm/hr.

Table 5.6
Maximum excess flood volume (future potentials).

Return period.	Maximum volume (m^3).	Head water depth (m).	Time of occurrence (minutes)*
Unit CA1-CA6			
1**	11,934	1.21	220th
10	42,120	1.82	280th
50	200,000	3.348	300th
Unit CC1-CC8			
1	21,270	1.53	130th
10	79,884	2.85	140th
50	117,705	3.43	150th

Note: * since the begining of rainfall. ** rainfall intensities of 1, 10 and 50 years return period, they represent case 1, 2 and 3.

The maximum excess flood volumes occurred later than the accumulated peak discharges at their respective final design points or outlets. For units CC1-CC8, the accumulated peak discharge at DP1 to DP4 occurred within the 22nd to 58th minutes. Whereas their maximum backwater effect (indicated by the maximum excess flood volume) occurred within the 130th to 150th minutes. For units CA1-CA6, the accumulated peak discharge at DP1 to DP4 occurred within the 60th to 157th minutes. Whereas their maximum backwater effect occurred within the 220th to 300th minutes. Flood depths are expected to decrease after thè overbank flow had achieved its maximum (after peak flow had been reached for a particular design point), but they are offseted by the increasing backwater effect. Consequently, the resulting flash floods are aggravated.

The whole drainage network of units CC4-CC8 are effected by backwater. As for units CA1 to CA6, the backwater effect reaches until the mid section of unit CA31. Thus, all the design points are affected.

The backwater offset margins for the future potential conditions are higher than the present potential conditions. They indicate a more serious backwater effect for the future. Comparatively, the effects of backwater are more serious for the town area or units CC4-CC8. In case 2 and 3 (return periods of 10 and 50 years) for the town area, the whole section of their trunk drain is overflowed by backwater. As a result, the areas that are located along this trunk drain (Taman Nibong Tebal, Taman Sentosa, Taman Maju-Bahagia, Pinang village, Methodist Secondary School, parts of Taman Sri Nibong, Tong Hai village and Shaik Adam village) will remain flooded for a longer period. These backwater offset margins are shown in Table 5.7.

Table 5.7.
Backwater effects on water depth -future potentials (main drains).

Drain Section.	Section (distance from outlet) in m.	Backwater elevation from bed level or maximum water depth(m).	Normal depth (m)*.	Offset.
Units CA1-CA6				
Tr=1	0	1.06	0.52	0.54
	2,730	0.56	0.52	0.04
Tr=10	0	1.78	0.52	1.26
	2,782	1.28	0.52	0.76
	5,460	0.76	0.52	0.24
Tr=50	0	2.13	0.52	1.61
	2,886	1.63	0.52	1.11
	5,278	1.11	0.52	0.59
Unit CC4-CC8				
Tr=1	0	1.44	0.11	1.33
	1,248	0.94	0.11	0.83
Tr=10	0	2.63*	0.11	2.52
	1,251	2.13*	0.11	2.02
	2,500	1.63*	0.11	1.52
Tr=50	0	3.35*	0.11	3.24
	1,251	2.85*	0.11	2.74
	2,516	2.35*	0.11	2.24

Note: Rulhmann's equation assumes uniform flow. Normal depth is based on discharge rate. *Overflow-maximum drain depth for drainage unit CC8 outlet is 2.00m.

5.3.4: Scenario 4.

The tide level is at 0.479m LSD, higher than all the outlets. Therefore, all the outlets are submerged. The discharge rate(under pressure) for each outlet is given next page. Overbank flow is taken into account when computing the accumulated final peak discharge. The total volume of flood water accumulated at peak flow will raise the head water level. Head water level have to reach a critical depth before discharge is possible. The critical depth and volume required for each outlet is given in table 5.8. The rise of head water creates backwater effects. As mentioned earlier, backwater aggravates the resulting flash flood.

Table 5.8.
Discharge rates for submerged outlets -future potentials.

Return Period. (Tr)*	Accumulated flood volume (m^3).	Maximum head water depth (m).	Elevation of head water surface m LSD.	Discharge rate.
	Units A-A1			
1	10470	1.899	0.799	5.37
10	31793	3.31	2.21	7.58
50	62836	4.78	3.9	7.58*
	cv=9,990.04	hc=1.8506	qc=5.063	
	Units B13-B5			
1	37,188	1.5	0	-
10	133,253	2.86	1.36	9.77
50	132,618$^+$	2.83	1.33	9.77
	cv=43,706	hc=1.637	qc=5.08	
	Units CA1-CA6			
1	17,753	0.71	-0.59	-
10	32,126	1.28	-0.02	-
50	99,976	1.99	0.69	-
	cv=133,402.5	hc=2.307	qc=14.713	
	Units CC1-CC8			
1	10,044	0.68	-0.234	-
10	22,244	1.02	0.106	-
50	29,932	1.18	0.266	-
	cv=42,076	hc=1.99	qc=14.304	
	Units CD1-CD4			
1	35,067	1.52	0.54	-
10	72,659	2.2	1.22	13.74
50	105,730	2.65	1.67	13.74
	cv=46,464	hc=1.759	qc=10.447	

Note: cv-critical volume, hc-critical depth, qc-critical discharge. * Return periods for rainfall intensities of 25, 60 and 85 mm/hr, these represent case 1, 2 and 3. **Maximum discharge is calculated at maximum allowable head (equal to drain depth at the inlet) for cases where the head water exceeds drain's maximum depth (overflow). +-lower peak flow because a portion of its volume was lost as overbank flow upstream.

Units A-A2: The critical volume (9,990 m^3) that need to be accumulated at the inlet of the tidal gate is small and does not pose any serious flood problem. The discharge rates ranged from 5.063 to 7.58 cumecs.

Units B13-B5: Except for case 1 (Tr=1), discharge is possible for the other two cases. The discharge rates ranged from 5.08 to 9.77 cumecs. The critical volume (43,706 m^3) that need to be accumulated at the inlet of the tidal gate do not pose any serious flood problem. However for case 2, the excess flood volume at peak flow would be 112,439 m^3. This could flood 0.28 sq.km. of land area to a depth of 0.2m and for approximately 4.3 hours and aggravates the effect of overbank flow upstream. For case 3, the excess volume is slightly lower because a large portion of it is lost as overbank flow upstream.

Units CA1-CA6: No discharge is possible for all cases. The critical volume needed is larger than accumulated volume at peak flow. The required volume is 133,402 m^3 and the head water depth needed is 2.3m (higher than maximum depth at inlet). This critical volume could flood 0.3 sq.km. of land area up to 0.44m deep for approximately 2.5 hours and aggravates the effect of overbank flow upstream (especially at units 51/52 and CA2). As a result, a more severe flooding would occur for case 2 and 3.

Units CC1-CC8: No discharge is possible for all cases. The critical volume needed is larger than accumulated volume at peak flow. The needed volume is 42,000 m^3 and head water depth is 1.98m. This critical volume could flood 0.15 sq.km. of land area up to 0.28m deep for approximatėly 0.8 hours. The resulting flash floods on the flood prone areas will be aggravated. As a result, a more severe flooding would occur for case 2 and 3.

Units CD1-CD4: Except for case 1, discharge is possible for the other two cases. In Case 1, the critical volume that need to be accumulated at the inlet of the tidal gate is moderate and does not pose any serious flood problem. As for Case 2 and 3, only minor flooding would occur as their discharge rates are high after the critical volume is reached. The discharge rates range from 10.44 to 13.74 cumecs.

Units CB1-CB2: No flooding are expected. Units E1-E4: Not relevant for this scenario.

5.4: Summary.

The effects of urbanization on peak discharges in the study area were summarized by comparing the changes in the accumulated peak discharges between present and future potential conditions. The results are shown in Table 5.9.

Unit CB1 and CB2 , no significant change is expected in the future. Units CC1-CC8 showed no significant change in peak discharge except at return periods of 1 in 50 years, where there was 43% increase in discharge. This is because most of their land area are already urbanized.

Table 5.9

Accumulated peak discharges/flows for the present and future potential conditions at their final design point.

Present.	2.5*	t	6	t	8.5	t
A1-A2**	1.31	73.097	14.06	68.394	16.09	69.966
B13-B6	4.42	181.24	16.625	172.48	32.81	171.38
CA1-CA6	3.79	143.49	7.646	138.5	10.28	137
CC1-CC8	5.125	58	14.425	54.58	10.675	55.58
CD1-CD4	6.375	159.5	17.125	145	18.13	148.5
CB1	0.433	11.396	1.254	9.64	1.86	9.09
CB2	0.25	7.66	0.677	5.4	0.983	4.69
E1	0.8	35.0428	2.2	31.992	3.25	31.0462
E2	1.875	45.7256	5.0625	41.2417	7.375	39.8515
E3	1.875	81.7076	4.975	76.5738	7.3	74.9822
E4	2.25	92.6898	6	87.1246	8.75	85.3993
Future	2.5	t	6	t	8.5	t
A1-A2	4.86	71.37	20.45	67.16	31.8	65.86
B13-B6	7.18	172.65	26.165	170.02	26.125	169.21
CA1-CA6	4.21	140.56	7.85	136.42	24.66	135.14
CC1-CC8	5.4	58	11.51	55.58	15.275	54.68
CD1-CD4	7.66	152.6	17.16	141.14	24.5	143.85
CB1	0.51	5.96	1.4	4.19	2.03	3.65
CB2	0.25	7.68	0.68	5.4	0.98	4.7
E1	1.4	18.5224	3.875	16.5475	5.625	15.9386
E2	3	24.4497	8.125	21.547	11.8125	20.6521
E3	3.5	42.0835	9.5	38.7602	13.75	37.7356
E4	4.425	47.5956	12.075	43.9931	17.5	42.8823
Change	2.5	t	6	t	8.5	t
A1-A2	3.55	-1.727	6.39	-1.234	15.71	-4.106
B13-B6	2.76	-8.59	9.54	-2.46	-6.685	-2.17
CA1-CA6	0.42	-2.93	0.204	-2.08	14.38	-1.86
CC1-CC8	0.275	0	-2.915	1	4.6	-0.9
CD1-CD4	1.285	-6.9	0.035	-3.86	6.37	-4.65
CB1	0.077	-5.436	0.146	-5.45	0.17	-5.44
CB2	0	0.02	0.003	0	-0.003	0.01
E1	0.6	-16.52	1.675	-15.444	2.375	-15.108
E2	1.125	-21.276	3.0625	-19.695	4.4375	-19.199
E3	1.625	-39.624	4.525	-37.814	6.45	-37.247
E4	2.175	-45.094	6.075	-43.132	8.75	-42.517

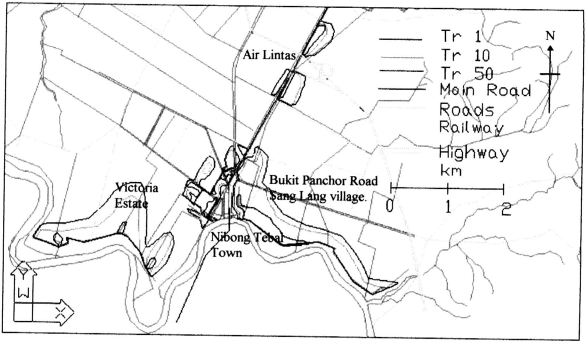
Note: * 2.5, 6.0 and 8.5 rainfall intensities of 1,10,50 years return period for duration of 1 hour. t- time of concentration. **- drainage units.

Other units indicated significant change. Units A1-A2 had the highest increase of peak discharge, ranged from 97 to 270%. Units B13-B6 had moderate increase, ranged from 57 to 62%. However, for return period of 1in 50 years, the peak decreased by 20%. This is because a more severe flooding could occur upstream. Units CA1-CA6 had a very significant change for return period of 1 in 50 years, where there was 140% increase. Units CD1-CD4 had an increase of 20% to 35 %. Units E1-E4 had an increase of 73% to 101%.

As a whole, the peak discharges for future are higher than present potentials. Their time of concentration are shorter. Urbanization changes the surface characteristic of the drainage units from permeable to impervious. Their surface roughness is reduced by the smoother concrete and tarmac surfaces. Impervious surfaces increase the surface runoff. Interception storage is lowered by smaller vegetated area. The roof and gutter system are efficient in collecting and transporting rain water. This decreases overland flow time.

The extent, depth, duration and location of flash floods have been discussed under the different scenarios. The potential flood boundaries are mapped out in Map 5.1 and 5.2. These boundaries are based on scenario 2 (worst case), indicating the maximum extent of potential flooded area. The flooded areas are more extensive in the future. However for the town area and units CD1-CD4, their flood boundaries do not differ much. Potential future flood boundaries for return periods of 10 and 50 years, covered 40 to 50% of the total urbanized area. Therefore, the potential floods are expected to be severe in the future as a result of urbanization.

Map 5.1
Present potential flood boundaries.



Note: Tr = 1,10,50 return periods of rainfall intensity (25, 60, 85 mm/hr for 1 hour).

Map 5.2
Future potential flood boundaries.