UNIVERSITI SAINS MALAYSIA

Second Semester Examination
2016/2017 Academic Session

June 2017

EAH422 – Advanced Water Resources Engineering
[Kejuruteraan Sumber Air Lanjutan]

Duration : 3 hours
[*Masa : 3 jam*]

Please check that this examination paper consists of **TWENTY(20)** pages of printed material before you begin the examination.
*[Sila pastikan bahawa kertas peperiksaan ini mengandungi **DUA PULUH (20)** muka surat yang bercetak sebelum anda memulakan peperiksaan ini.]*

Instructions : This paper contains **FIVE (5)** questions. Answer **FOUR (4)** questions.
*[**Arahan** : Kertas ini mengandungi **LIMA (5)** soalan. Jawab **EMPAT (4)** soalan.]*

You may answer the questions either in Bahasa Malaysia or English.
[Anda dibenarkan menjawab soalan sama ada dalam Bahasa Malaysia atau Bahasa Inggeris]

All questions **MUST BE** answered on a new page.
*[Semua soalan **MESTILAH** dijawab pada muka surat baru.]*

In the event of any discrepancies, the English version shall be used.
[Sekiranya terdapat percanggahan pada soalan peperiksaan, versi Bahasa Inggeris hendaklah diguna pakai.]

1. [a] An area of 6500 ha in Bidor, Perak is designated for mixed development. Client specifies for sustainable drainage system to be incorporated in the development and shall be designed based on train of treatment for water quantity control of stormwater. The development area is flat and the infiltration capacity is in the order of 30 mm/hr. Discuss and propose the concept and framework for the sustainable drainage system based on **THREE (3)** approaches of water quantity control. Select **TWO (2)** appropriate devices for each approach to comply with quantity control of the sustainable drainage system.

*Kawasan seluas 6500 ha di Bidor, Perak akan dibangunkan sebagai pembangunan bercampur. Klien telah mengariskan untuk menerapkan sistem saliran mesra alam di dalam pembangunan tersebut dan rekabentuknya adalah berdasarkan kepada rawatan bersiri untuk kawalan kuantiti air ribut. Kawasan pembangunan adalah rata dan keupayaan penyusupan adalah dalam linkungan 30 mm/jam. Bincangkan dan cadangkan konsep dan rangka kerja sistem saliran mesra alam berdasarkan kepada **TIGA (3)** pendekatan kawalan kuantiti air ribut. Pilih sekurang kurangnya **DUA (2)** peranti yang sesuai untuk setiap pendekatan dalam memenuhi kawalan kuantiti untuk sistem saliran mesra alam.*

[10 marks/*markah*]

[b] A catchment in Sungai Petani, Kedah with an area of 28 ha covered with open space/bush, is proposed to be developed for residential consisting of terrace houses. A wet detention pond is planned to control the increased runoff due to the development. An existing streams AB flows to the outlet (B) of the catchment as shown in **Figure 1**. Flow will be directed to the pond through grass channel built on existing stream. The pond has been specified to be designed for 50 year ARI with primary outlets in the riser to control 10 year and 50 year ARIs. Compute the preliminary estimate of the pond volume for 50 year ARI for storm duration equal to t_c. The data for the catchment, existing streams and proposed channels are given in Table 1 and Table 2, respectively. Use Ibu Bekalan Sg. Kulim for IDF station.

Kawasan tadahan di Sungai Petani, Kedah dengan keluasan 28 ha dengan litupan kawasan terbuka/belukar, dicadangkan untuk dibangunkan kawasan perumahan yang terdiri dari rumah teres. Kolam tahanan basah dirancang untuk mengawal pertambahan airlarian disebabkan oleh pembangunan. Kawasan tadahan mempunyai anak sungai AB yang mengalir ke hilir menuju ke alur keluar (B) seperti yang di tunjukan pada ***Rajah 1****. Aliran akan dihalakan ke kolam tahanan basah melalui saluran berumput yang dibina melalui anak sungai sedia ada. Spesifikasi rekabentuk kolam tahanan adalah untuk 50 tahun ARI dengan alur keluar primer berupaya mengawal 10 tahun dan 50 tahun ARI. Hitung anggaran awal isipadu kolam tahanan yang dicadangkan dengan 50 tahun ARI untuk tempoh ribut bersamaan* t_c*. Data kawasan tadahan, anak sungai dan saluran cadangan diberikan dalam Jadual 1 dan Jadual 2. Gunakan Ibu Bekalan Sg. Kulim untuk stesen IDF.*

Table 1 Pre-development catchment and stream properties/
Jadual 1 Kawasan tadahan untuk pra-pembangunan dan ciri anak sungai

Reach/ *Ruas*	Overland/ *Airlarian*			Natural Streams/ *Anak Sungai*			
	L_o (m)	n*	S_o (%)	L_d(m)	n	S_d (m/m)	R (m)
AB	150	0.045	3.50	850	0.05	0.015	0.12

Table 2 Post-development catchment and grass channel properties/
Jadual 2 Kawasan tadahan untuk pasca-pembangunan dan ciri saluran berumput

Reach/ *Ruas*	Overland/ *Airlarian*			Grass Channel/ *Saluran Berumput*			
	L_o (m)	n*	S_o (%)	L_d(m)	n	S_d (m/m)	R (m)
AB	150	0.035	5.0	850	0.035	0.010	0.16

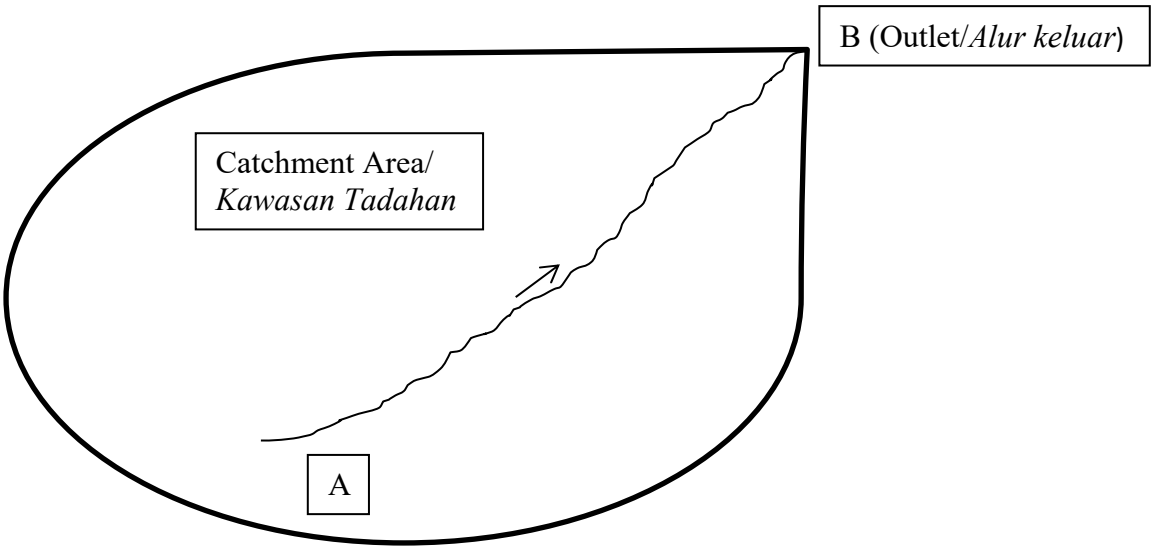


Figure 1/*Rajah 1*

[15 marks/*markah*]

2. [a] Determine the annual pollution loading (in tonnes/yr) generated from a 750 ha mixed development area located in upstream of Sg. Perai sub-catchment shown in **Table 3**. The average annual rainfall for the catchment is 2950 mm. Please refer to **Appendix 2** for annual pollutant loads.

*Tentukan beban pencemaran tahunan (dalam tan/tahun) yang dihasilkan dari 750 ha kawasan pembangunan bercampur yang terletak di hulu Sg. Perai yang ditunjukkan dalam **Jadual 3**. Jumlah purata hujan tahunan bagi tadahan adalah 2950 mm. Sila rujuk **Lampiran 2** untuk beban pencemar tahunan.*

Table 3: Land use pattern in Sg Perai sub-catchment

Jadual 3: Corak gunatanah untuk kawasan sub-tadahan Sg. Perai

Sub Area	Type/*Jenis*	Area (ha)
1	Light Industrial (124 ha)/ *Industri Ringan*	150
2	Residential/*Perumahan*	360
3	Commercial/*Komersial*	140
4	Roads and Highways/*Jalan & Lebuhraya*	100
Total		750

[10 marks/ *markah*]

[b] Estimate the preliminary size of a water quality pond required to meet Pollutant Reduction Target **(Table 1.4; DID 2012- Appendix 2)** according to Manual Saliran Mesra Alam (2012) from the residential area of Taman Pauh Jaya (95.4 ha). The average runoff coefficient of the area is 0.65, which was calculated based on the actual imperviousness of the mixed development residential area (e.g. Bungalow, Link House, Apartment and Open Spaces).

Anggarkan saiz awal kolam kualiti air yang diperlukan untuk memenuhi kriteria Sasaran Pengurangan Pencemaran ***(Jadual 1.4; JPS 2012-Lampiran 2)*** *berdasarkan Manual Saliran Mesra Alam (2012) dari kawasan kediaman Taman Pauh Jaya (95.4 ha). Purata pekali air larian daripada kawasan tersebut adalah 0.65, yang dikira berdasarkan kawasan tidak telap dari kawasan kediaman pembangunan bercampur (e.g Bungalow, Rumah Teres, Apartment dan Kawasan Lapang).*

[15 marks/*markah*]

3. [a] The Seven Step Planning Process is described as a disciplined iterative process, suitable for a water resources project. Discuss in brief the Seven Step Planning Process concept.

Proses Perancangan Tujuh Langkah dinyatakan sebagai satu proses yang teratur, sesuai untuk sesebuah projek sumber air. Bincangkan dengan ringkas konsep Proses Perancangan Tujuh Langkah tersebut.

[5 marks/*markah*]

[b] Kerian District is always affected by floods during the rainy seasons, which had greatly affected the livelihood of the people in the district. The floods also had incurred considerable damages to the economic activities and existing infrastructure. The economic losses during the recent floods were estimated at RM3.5 Million.

It is proposed that a flood mitigation project is planned consisting of a few alternatives as described below.

Daerah Kerian selalu menghadapi masalah banjir semasa musim hujan, yang telah memberi kesan yang amat besar kepada penduduk dalam daerah ini. Banjir juga telah mengakibatkan kerugian kepada aktiviti ekonomi dan juga kepada infrastuktur sedia ada. Kerugian ekonomi semasa banjir baru-baru ini dianggarkan berjumlah RM3.5 Juta.

Dicadangkan satu projek tebatan banjir dirancang untuk pelbagai alternatif berikut:

[i] Alternative 1: A small dam is built upstream, at a cost of RM7.5 Million with an annual operational and maintenance cost of RM120,000. The annual flood damage for this alternative is estimated at RM1.5 Million.

Alternatif 1: Satu empangan kecil dibina di hulu, dengan kos RM7.5 Juta dengan kos operasi dan penyenggaraan tahunan RM120,000. Kerosakan tahunan akibat banjir untuk alternatif ini dianggar sebanyak RM1.5 Juta.

[ii] Alternative 2: A river barrage is built downstream, at a cost of RM6.0 Million with an annual operational and maintenance cost of RM90,000. The annual flood damage for this alternative is estimated at RM1.7 Million.

Alternatif 2: Satu empangan rendah dibina di hilir dengan kos RM6.0 Juta dengan kos operasi dan penyenggaraan tahunan RM90,000. Kerosakan tahunan akibat banjir untuk alternatif ini dianggar sebanyak RM1.7 Juta.

[iii] Alternative 3: Leeves to be built are to regulate water levels along the river built at a cost of RM7.5 Million with an annual operational and maintenance cost of RM180,000. The annual flood damage for this alternative is estimated at RM1.1 Million.

Alternatif 3: Tetambak dibina untuk mengawal aras air sepanjang sungai dibina dengan kos RM7.5 Juta dengan kos operasi dan penyenggaraan tahunan RM180,000. Kerosakan tahunan akibat banjir untuk alternatif ini dianggar sebanyak RM1.1 Juta.

[iv] Alternative 4: A combination of a small dam (Alternative 1) and river barrage (Alternative 2) are built at a cost of RM14.0 Million with an annual operational and maintenance cost of RM250,000. The annual flood damage for this alternative is estimated at RM1.3 Million.
Alternatif 4: Satu kombinasi sebuah empangan kecil (Alternatif 1) dan sebuah empangan rendah (Alternatif 2) dibina dengan kos RM14.0 Juta dengan kos operasi dan penyenggaraan tahunan RM250,000. Kerosakan tahunan akibat banjir untuk alternatif ini dianggar sebanyak RM1.3 Juta.

[v] Alternative 5: A combination of a small dam (Alternative 1) and leeves (Alternative 3) are built at a cost of RM15.0 Million with an annual operational and maintenance cost of RM280,000. The annual flood damage for this alternative is estimated at RM800,000.
Alternatif 5: Satu kombinasi sebuah empangan kecil (Alternatif 1) dan tetambak (Alternatif 3) dibina dengan kos RM15.0 Juta dengan kos operasi dan penyenggaraan tahunan RM280,000. Kerosakan tahunan akibat banjir untuk alternatif ini dianggar sebanyak RM800,000.

[vi] Alternative 6: A combination of a river barrage (Alternative 2) and leeves (Alternative 3) are built at a cost of RM12.5 Million with an annual operational and maintenance cost of RM220,000. The annual flood damage for this alternative is estimated at RM600,000.

Alternatif 6: Satu kombinasi sebuah empangan rendah (Alternatif 2) dan tetambak (Alternatif 3) dibina dengan kos RM12.5 Juta dengan kos operasi dan penyenggaraan tahunan RM220,000. Kerosakan tahunan akibat banjir untuk alternatif ini dianggar sebanyak RM600,000.

[vii] Alternative 7: A combination of a small dam (Alternative 1), river barrage (Alternative 2) and leeves (Alternative 3) are built at a cost of RM20.0 Million with an annual operational and maintenance cost of RM300,000. The annual flood damage for this alternative is estimated at RM300,000.

Alternatif 7: Satu kombinasi sebuah empangan kecil (Alternatif 1), empangan rendah (Alternatif 2) dan tetambak (Alternatif 3) dibina dengan kos RM20.0 Juta dengan kos operasi dan penyenggaraan tahunan RM300,000. Kerosakan tahunan akibat banjir untuk alternatif ini dianggar sebanyak RM300,000.

Given that the rate of return is 5.5%, the life of the small dam and barrage are 100 years. The life of leeves is 60 years.
Determine using the the Incremental Benefit-Cost Ratio Method the most economical alternative for this flood mitigation project.

Di beri kadar pulangan ialah 5.5%, hayat empangan dan empangan rendah adalah 100 tahun. Hayat tetambak ialah 60 tahun.
Tentukan alternatif paling ekonomik dengan menggunakan Kaedah Nisbah Tokokan Faedah-Kos untuk projek tebatan banjir ini.

[10 marks/*markah*]

[c] A hydroelectric dam project is being developed where the project engineers are determining the optimal scale of power in MW. The project engineers has drawn up several project alternatives and the corresponding benefits are shown below;

Sebuah projek empangan hidroelektrik sedang dibangunkan di mana jurutera projek sedang menentukan skala optima kuasa dalam MW. Jurutera Projek telah menggariskan beberapa alternatif projek dan faedah bersamaan seperti dibawah;

Scale/*Skala* (MW)	Benefits/ *Kelebihan* RM Million/*Juta*	Costs/Kos RM Million/*Juta*
50	18.0	15.0
60	21.0	17.4
70	26.7	21.0
80	28.0	22.5
90	29.8	23.4
100	32.7	26.0
110	35.0	30.0
120	38.5	32.5
130	42.5	37.5
140	50.0	45.0
150	55.0	48.0

Determine the optimal scale of the hydroelectric project using the benefit-cost analysis.

Tentukan skala optima projek hidroelektrik ini dengan menggunakan analisa faedah-kos.

[10 marks/*markah*]

4. [a] Define crop period and base period of a crop.

Berikan definisi tempoh tanaman dan tempoh asas untuk satu tanaman.

[4 marks/*markah*]

[b] Define duty D and delta Δ of a crop. Therefore, if a crop base period is B days derive the relationship between duty D and delta Δ of a crop.

Berikan definisi duti D dan delta Δ tanaman. Sekiranya tempoh asas tanaman tersebut ialah B hari, terbitkan hubungan di antara duti D dan delta Δ.

[10 marks/*markah*]

[c] Design a trapezoidal concrete lined channel to carry a discharge of 150 cumec. The longitudinal slope of the channel is 1:5000. The side slope of the channel is taken as 1.5:1 (H:V). The value of Manning's n for concrete lined channel is 0.013. Assume limiting depth of the flow in the channel as 4.5 m. In your design, use the condition that the flow velocity is 2.0 m/s.

Rekabentuk sebuah saluran konkrit trapezoid untuk aliran 150 cumec. Kecerunan saluran adalah 1:5000. Sisi saluran trapezoid mempunyai cerun 1.5:1 (H:V). Nilai pemalar Manning n untuk saluran konkrit ialah 0.013. Anggap bahawa had kedalaman air dalam saluran ialah 4.5 m. Dalam rekabentuk anda, anggap bahawa halaju aliran ialah 2.0 m/s.

[11 marks/*markah*]

5. A culvert is to be built to pass 100 m^3/s of flow under a road embankment. The ground level is 18.00 m RL (RL is reduced level), and the design flood level is 20.00 m. Both levels are at the centreline of the embankment which has a 30 m wide base. The gradient of the flood plain is 3.5 m/km. By using precast concrete box-culvert of size 2.2 m high and 2.0 m wide (assume square-edged inlet, k_e=0.5), and neglecting the thickness of the wall between adjacent box-culvert cells, answer the following questions.

Satu sistem pembentung diperlukan untuk aliran merentasi tambak jalan. Aliran tersebut mempunyai kadar alir 100 m^3/s. Aras tanah ialah 18.00 m RL manakala aras banjir rekabentuk ialah 20.00 m RL. Kedua-dua aras ini diambil di garis tengah tambak tersebut yang mempunyai lebar tapak 30 m. Kecerunan lembah banjir di kawasan tersebut ialah 3.5 m/km. Dengan menggunakan pembentung konkrit pra-tuang yang bersaiz 2.2 m (tinggi) dan 2.0 m (lebar) (anggap pinggir masuk pembentung ialah segi empat, k_e=0.5) dan abaikan ketebalan dinding di antara dua pembentung, jawab soalan berikut.

[a] Design the box-culvert with the invert set at ground level to carry the flood flow without causing any increase in flood level upstream and the culvert is operating under inlet control. Based on the design, determine the number of culvert boxes required.

Rekabentuk kotak pembentung untuk membawa aliran tanpa menyebabkan kenaikan paras air di hulu pembentung dan pembentung berfungsi dalam keadaan 'kawalan alur masuk'. Pembentung akan disusun supaya aras dasar adalah sama dengan aras tanah. Berdasarkan rekabentuk, tentukan bilangan kotak pembentung yang diperlukan.

[8 marks/*markah*]

[b] If the number of culvert boxes are reduced to 4 boxes, determine the following:

Sekiranya bilangan pembentung dikurangkan kepada 4 kotak, tentukan perkara berikut:

[i] Calculate the percentage of change in capacity for the flood level to remain unchanged.

Kira peratus perubahan kapasiti sekiranya aras banjir rekabentuk tidak berubah.

[6 marks/*markah*]

[ii] Calculate the change in flood level if the design discharge remains unchanged assuming inlet control.

Kira perubahan aras banjir sekiranya kadar alir rekabentuk tidak berubah dan pembentung berfungsi dalam keadaan kawalan alur masuk.

[6 marks/*markah*]

[iii] Therefore, check whether inlet control is the correct assumption in question (ii). Assume that the tailwater depth is lesser than the culvert height.

Justeru itu, semak sama ada anggapan keadaan kawalan alur masuk di soalan (ii) adalah benar. Anggap bahawa kedalaman air ekor adalah kurang dari tinggi pembentung.

[5 marks/*markah*]

Appendix (3) is provided to assist the design.

Lampiran (3) *disediakan untuk membantu rekabentuk.*

APPENDIX 1/*LAMPIRAN 1*

Selected Equations for Pond Volume Estimation

$t_o = \frac{107 n^* L^{1/3}}{S^{1/5}}$
$i = \frac{\lambda T^{\kappa}}{(d+\theta)^{\eta}}$
$V_s = dQ_i - 0.5 t_i Q_o$
$V_s = 0.5 t_i (Q_i - Q_o)$
$A_t = \frac{V_w}{n d_t + f_d T_f}$

Fitting Constant for Design Rainfall Estimation (Ibu Bekalan Sg. Kulim Station)

λ	κ	θ	η
57.832	0.188	0.245	0.751

Runoff Coefficient

Landuse	Runoff Coefficient (C)	
	For Minor System (≤10 year ARI)	For Major System (> 10 year ARI)
Residential		
Bungalow	0.65	0.70
Semi-detached Bungalow	0.70	0.75
Link and Terrace House	0.80	0.90
Flat and Apartment	0.80	0.85
Condominium	0.75	0.80
Commercial and Business Centres	0.90	0.95
Industrial	0.90	0.95
Sport Fields, Park and Agriculture	0.30	0.40
Open Spaces		
Bare Soil (No Cover)	0.50	0.60
Grass Cover	0.40	0.50
Bush Cover	0.35	0.45
Forest Cover	0.30	0.40
Roads and Highways	0.95	0.95
Water Body (Pond)		
Detention Pond (with outlet)	0.95	0.95
Retention Pond (no outlet)	0.00	0.00

APPENDIX 2/*LAMPIRAN 2*

Table 1.4: Pollutant Reduction Targets

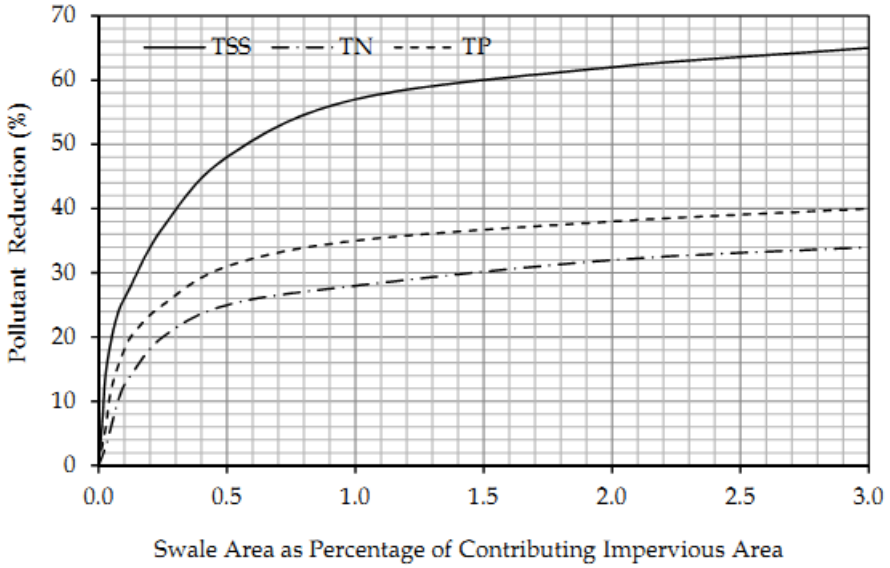
Pollutant	Reduction Targets (%)
Floatables/Litters	90
Total Suspended Solids (TSS)	80
Total Nitrogen (TN)	50
Total Phosphorus (TP)	50

Note: Relevant local regulatory authorities may set higher (stringent) targets depending on the sensitivity and level of pollution in the surrounding areas.

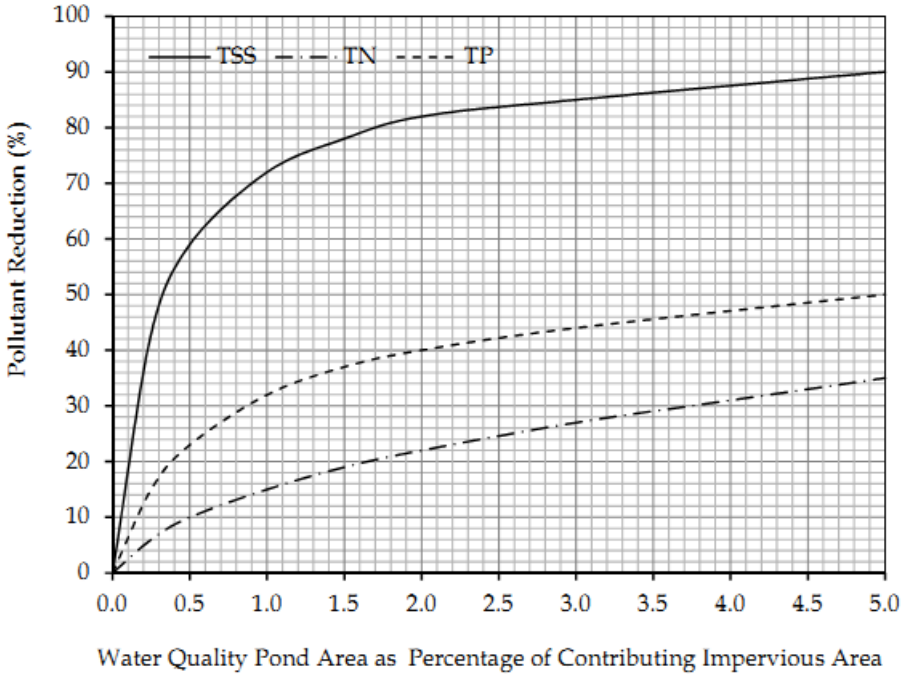
Table 3.2: Mean EMC Values for Selected Landuses

Pollutants		Landuses			
Parameter	Unit	Residential	Commercial	Industrial	Highway
TSS	mg/L	128.00	122.00	166.00	80.00
Turbidity	NTU	122.00	96.00	147.00	69.00
TDS	mg/L	131.00	43.00	137.00	38.00
pH	-	6.46	6.77	6.66	6.57
BOD	mg/L	17.90	22.90	19.30	14.90
COD	mg/L	97.00	134.00	140.00	81.00
AN	mg/L	0.73	0.85	1.00	0.44
TKN	mg/L	2.38	2.53	4.25	1.43
TN	mg/L	4.21	4.84	5.00	2.25
TP	mg/L	0.34	0.32	0.49	0.16
O&G	mg/L	2.00	4.00	NA	3.00
Zn	mg/L	0.19	0.34	0.43	0.21
Pb	µg/L	6.00	22.00	12.00	20.00
Cu	µg/L	28.00	37.00	42.00	28.00
Cr	µg/L	4.00	32.00	31.00	11.00
Ni	µg/L	10.00	17.00	30.00	15.00
Cd	µg/L	6.00	26.00	5.00	10.00

Source: Local stormwater studies conducted by DID in Malacca, Damansara, Penang and Kajang

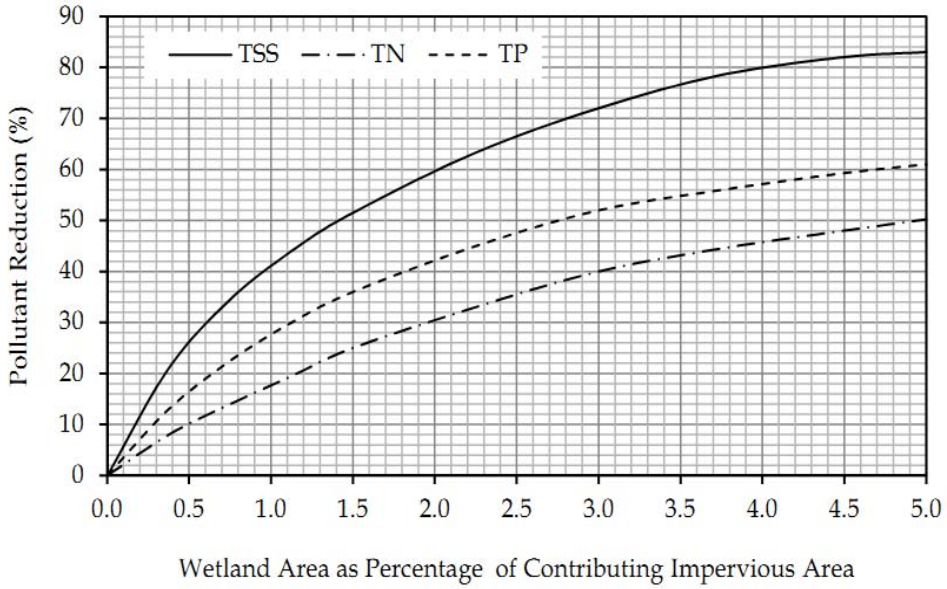


a) Swale



b) Water Quality Pond

Figure 3.1: Pollutant Reduction Curves (Adapted from Melbourne Water, 2005 and Darwin Harbour, 2009)



c) Wetlands

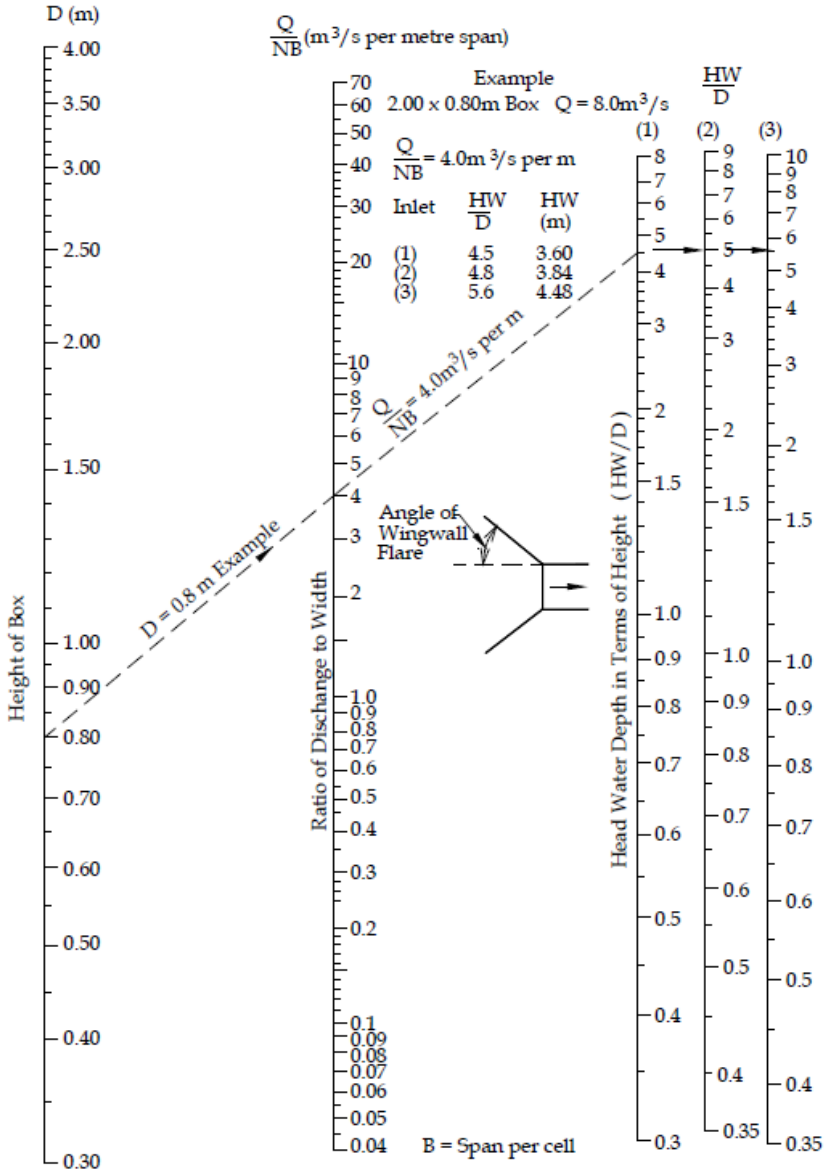
Figure 3.1: Pollutant Reduction Curves (Adapted from Melbourne Water, 2005 and Darwin Harbour, 2009)

Table 3.4: Classification of Treatment Targets for Individual BMPs (Adapted from Melbourne Water, 2005)

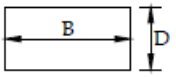
Pollutant	Target of Treatment		
	Low	Medium	High
TSS	Less than 40% of particulates greater than 0.125mm retained.	40-70% of particulates greater than 0.125mm retained.	More than 70% of particulates greater than 0.125 mm retained.
Nutrients (TN & TP)	Less than 10% reduction	10-40% reduction	More than 40% reduction

Note: There is insufficient data available to give firm guidance on gross pollutants. The level of treatment chosen has an effect on the area required for the BMPs. However, in all situations, the overall pollutant reduction by any BMPs or treatment train (at least) ***must comply*** with the criteria given in Table 1.4.

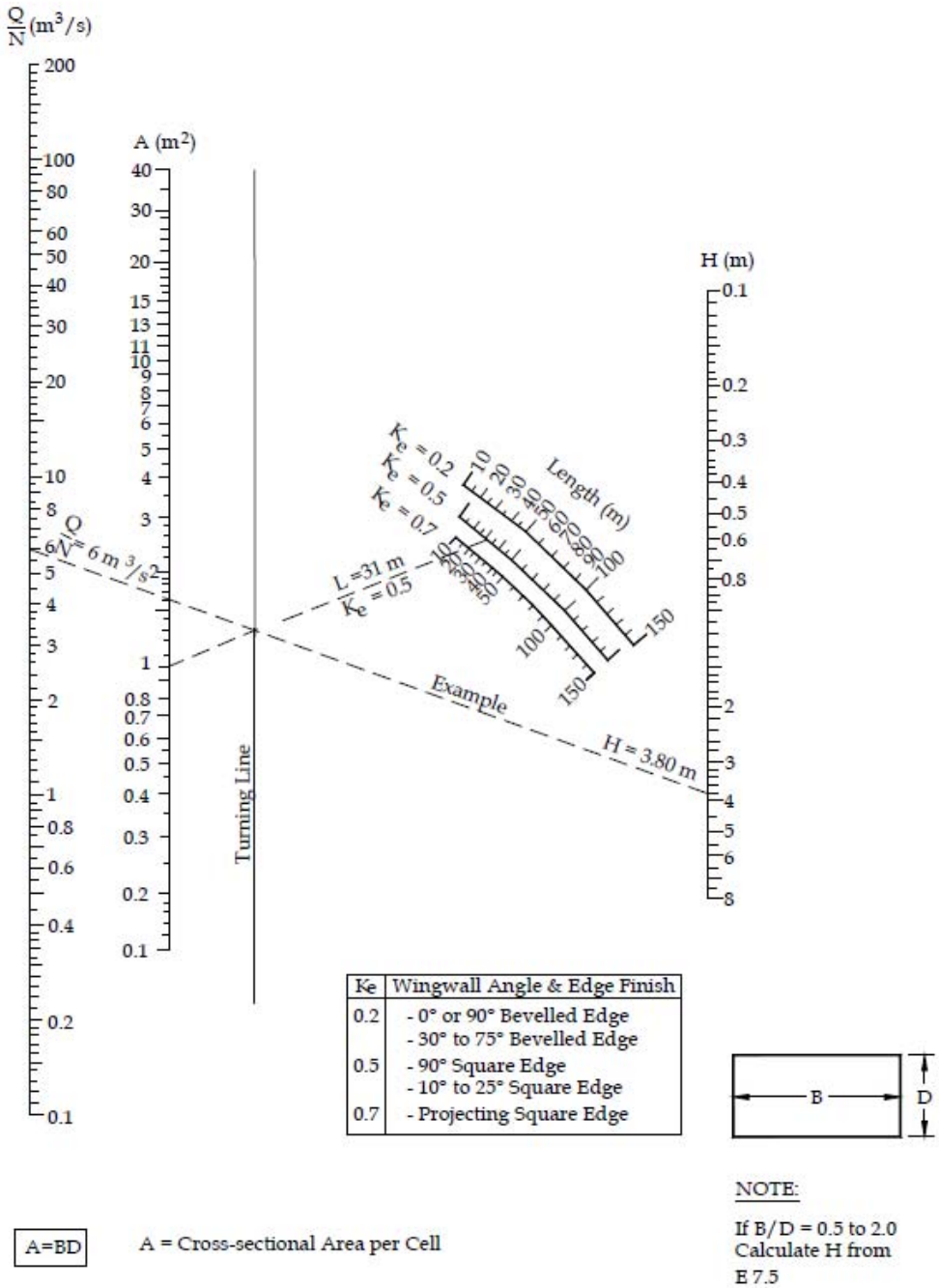
APPENDIX 3/*LAMPIRAN 3*



Wingwall Flare	HW/D Scale
30° - 75°	1
90° (headwall)	2
0° (parallel)	3



Inlet control nomograph for concrete box culvert.



Outlet control nomograph concrete box culvert flowing full.

- oooOooo -