On-site Wastewater Management Training Course

# Evapotranspiration Systems and Sizing by Water Balance



## Terminology

Evapotranspiration Systems referred to as:

- Evapotranspiration Absorption Systems ETA – Australia (unlined)
- Evapotranspiration Seepage Systems ETS – New Zealand (unlined)
- Or simply Evapotranspiration Systems ET, if lined



## Purpose

ETA/S Systems designed to:

- Maximise evapotranspiration
- Reduce absorption (drainage) in unlined systems
- Avoid absorption in lined systems
- Provide alternative to conventional trenches/beds in areas of low permeability soils (<0.5-1.5 m/d) e.g. clay loams, light, medium and heavy clays



## AS/NZS 1547:2012

- Table L1 gives recommended DLRs of between 12 mm/d (CL) and 5 mm/d (LC/MC) based on soil texture
- Not necessary for annual evaporation to exceed annual precipitation
- Can use plant transpiration and void space storage to manage hydraulic load throughout seasons



## AS/NZS 1547:2012

- DLRs are conservative values
- Any variation to be justified by full water balance for 12-month cycle (Appendix Q)
- No higher DLRs for Secondary treated effluent (may be better to use conventional trench or bed)
- Plant with grasses and shrubs which tolerate wet conditions and have high evapotranspiration capacity
- Construction outlined in Appendix L



## Water Balance Design

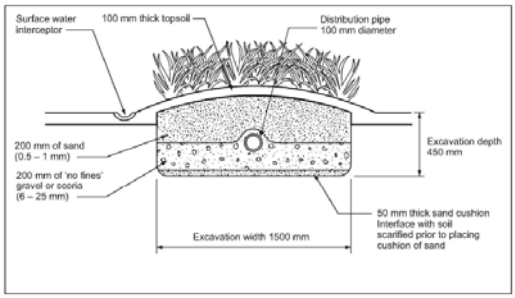
- Background outlined in Appendix Q in AS/NZS1547:2012
- Main factors:
  - Effluent largely disposed of through deep infiltration, interflow and evapotranspiration
  - Evapotranspiration is significant but may not dominate water balance
  - Some deep infiltration is required to prevent salt build up
  - Not suited to shallow water tables unless using a lined system

## Important Components of ET Bed Design

- Crop Factors (Cf), Evaporation (E) and Evapotranspiration (ET) – explained further in water balance example later
- Capillary Water – movement of water laterally and upwards under surface tension
- Field Capacity (FC) – upper limit of available water storage in soil / medium
- Void Ratio (*n*) – proportion of bed available for water/air storage



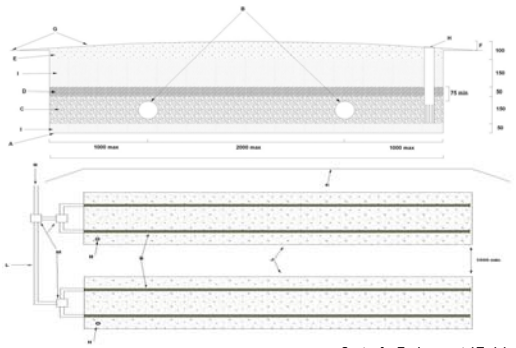
## AS/NZS 1547:2012 ETA Bed Design Detail




(Source: Standards Australia 2012)



## 'Typical' ETA Bed Layout





## ETA Bed Installed



## Raised ETA Bed



## Consideration of Climatic Data

- Pan evaporation (E)
  - From nearest climatically similar meteorological station
- Rainfall (R)
  - From nearest climatically similar meteorological station
- Or use SILO data:
- https://www.longpaddock.qld.gov.au/silo/

## ‘Class A’ Evaporation Pan

Total historical station coverage nationwide:

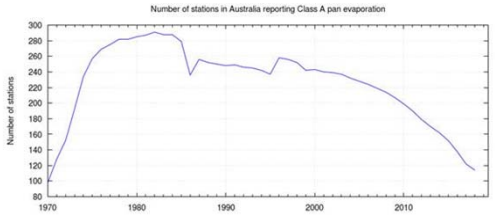
- 17,875 rainfall stations
- Only 601 evaporation stations


(Source: BoM)



## ‘Class A’ Evaporation Pan

- Diminishing number of evaporation stations
- Move to SILO data (5km x 5km intersections)




(Source: BoM)



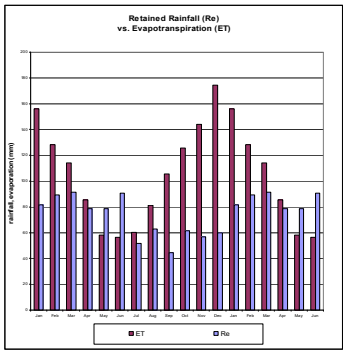
## Nominal Monthly Area Requirement

| Month | Pan evaporation E mm | Evapotranspiration ET ET=0.75E mm | Rainfall R mm | Retained rainfall R, R,=0.75R mm | LTAR per month mm | Disposal rate per month mm | Effluent applied per month L | Size of area m² |
|---|---|---|---|---|---|---|---|---|
| Jan | 207.7 | 155.8 | 109 | 81.75 | 0 | 74.01 | 27900 | 376.90 |
| Feb | 170.8 | 128.1 | 119 | 89.25 | 0 | 38.85 | 25200 | 648.65 |
| Mar | 151.9 | 113.9 | 122 | 91.50 | 0 | 22.43 | 27900 | 1244.15 |
| Apr | 114.0 | 85.5 | 105 | 78.75 | 0 | 6.75 | 27000 | 4000.00 |
| May | 77.5 | 58.1 | 105 | 78.75 | 0 | -20.63 | 27900 | -1352.73 |
| Jun | 75.0 | 56.3 | 121 | 90.75 | 0 | -34.50 | 27000 | -782.61 |
| Jul | 80.6 | 60.5 | 69 | 51.75 | 0 | 8.70 | 27900 | 3206.90 |
| Aug | 108.5 | 81.4 | 84 | 63.00 | 0 | 18.38 | 27900 | 1518.37 |
| Sep | 141.0 | 105.8 | 59 | 44.25 | 0 | 61.50 | 27000 | 439.02 |
| Oct | 167.4 | 125.6 | 82 | 61.50 | 0 | 64.05 | 27900 | 435.60 |
| Nov | 192.0 | 144.0 | 76 | 57.00 | 0 | 87.00 | 27000 | 310.34 |
| Dec | 232.5 | 174.4 | 80 | 60.00 | 0 | 114.38 | 27900 | 243.93 |

Table 3. Calculation of area for each month (disregarding storage of effluent).



## Inputs (Re) vs. Outputs (ET)




- ET dominates the WB, but not completely
- Excess rainfall can be managed for periods of the year provided that there is storage available in the system



## Depth of Stored Effluent

| Month | First trial area m² | Application rate (3) mm | Disposal rate per month (4) mm | (3) - (4) mm | Increase in depth of stored effluent mm | Depth of effluent for month (K - 1) mm | Increase in depth of effluent mm | Computed depth of effluent month (K) mm |
|---|---|---|---|---|---|---|---|---|
| Dec | 1000 | | | | | | | |
| Jan | | 27.9 | 74.01 | -46.11 | -153.70 | 0 | + -153.70 | = 0 |
| Feb | | 25.2 | 38.85 | -13.65 | -45.50 | 0 | + -45.50 | = 0 |
| Mar | | 27.9 | 22.43 | 5.47 | 18.23 | 0 | + 18.23 | = 18.23 |
| Apr | | 27.0 | 6.75 | 20.25 | 67.50 | 18.23 | + 67.50 | = 85.73 |
| May | | 27.9 | -20.63 | 48.53 | 161.77 | 85.73 | + 161.77 | = 247.50 |
| Jun | | 27.0 | -34.50 | 61.50 | 205.00 | 247.50 | + 205.00 | = 452.50 |
| Jul | | 27.9 | 8.70 | 19.20 | 64.00 | 452.50 | + 64.00 | = 516.50 |
| Aug | | 27.9 | 18.38 | 9.52 | 31.73 | 516.50 | + 31.73 | = 548.23 |
| Sep | | 27.0 | 61.50 | -34.50 | -115.00 | 548.23 | + -115.00 | = 433.23 |
| Oct | | 27.9 | 64.05 | -36.15 | -120.50 | 433.23 | + -120.50 | = 312.73 |
| Nov | | 27.0 | 87.00 | -60.00 | -200.00 | 312.73 | + -200.00 | = 112.73 |
| Dec | | 27.9 | 114.38 | -86.48 | -288.27 | 112.73 | + -288.27 | = 0 |

Table 4. Depth of stored effluent.



## The Use of Water Balances

- Will work through an example of an unlined ETA bed
- Have provided templates for water balances for beds and also irrigation areas
- Once you have practiced the skills required in doing water balances longhand they lend themselves to setting up spreadsheets to speed calculation

## Water Balance Exercise

- Calculate the minimum area and depth of an evapotranspiration-absorption/seepage area for a three bedroom / five person dwelling
- BoM rainfall and pan evaporation data

| | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DAILY PAN EVAPORATION (mm) | 6.3 | 5.4 | 4.4 | 3.3 | 2.1 | 1.8 | 2.0 | 3.1 | 4.3 | 5.4 | 5.9 | 7.0 |
| MEAN MONTHLY RAINFALL (mm) | 93.3 | 99.6 | 92.1 | 70.3 | 58.8 | 56.4 | 35.9 | 45.8 | 40.2 | 64.1 | 76.1 | 71.7 |



## Water Balance Exercise

- Three test pits excavated on the proposed disposal area indicate that the soils are 475 mm weakly structured clay loam overlying moderately structured light clay to a depth of 2,000 mm. Use the recommended design loading rate derived from Table L1 of AS/NZS 1547:2012 (see the Field Workshop and Design Exercise section of these Course Notes)



## Water Balance Exercise

- Calculate the evapotranspiration-absorption/seepage area using the worksheets provided on the following pages
- The evapotranspiration-absorption area is to be constructed of imported aggregate, is to have a maximum depth of 400 mm with a minimum of 50 mm freeboard (i.e. maximum depth of stored effluent is 350 mm)
- Conventional beds may have between 300 mm and 600 mm of aggregate, ETA/ETS beds 400 mm of aggregate and sand



Calculation of evapotranspiration-absorption area size by water balance method

Size of area for each month

| (1) Month | (2) Pan evaporation E mm | (3) Evapo transpiration ET ET = 0.75E mm | (4) Rainfall R mm | (5) Retained rainfall $R_r$ $R_r$ = 0.75R mm | (6) DLR per month mm | (7) Disposal rate per month (3)-(5)+(6) mm | (8) Effluent applied per month L | (9) Size of area (8)/(7) $m^2$ |
|---|---|---|---|---|---|---|---|---|
| Jan | | | | | | | | |
| Feb | | | | | | | | |
| Mar | | | | | | | | |
| Apr | | | | | | | | |
| May | | | | | | | | |
| Jun | | | | | | | | |
| Jul | | | | | | | | |
| Aug | | | | | | | | |
| Sep | | | | | | | | |
| Oct | | | | | | | | |
| Nov | | | | | | | | |
| Dec | | | | | | | | |
| | | | | | | First trial area = average monthly area = | | $m^2$ |



Depth of stored effluent (first trial)

| (1) Month | (2) First trial area $m^2$ | (3) Application rate (8)/(2) mm | (4) Disposal rate per month (7) mm | (5) (3) - (4) mm | (6) Increase in depth of stored effluent (5)/n mm | Depth of effluent for month (X - 1) mm | (7) Increase in depth of effluent + (6) mm | Computed depth of effluent month (X) mm |
|---|---|---|---|---|---|---|---|---|
| Dec | | - | - | - | - | 0 | | |
| Jan | | | | | | | | |
| Feb | | | | | | | | |
| Mar | | | | | | | | |
| Apr | | | | | | | | |
| May | | | | | | | | |
| Jun | | | | | | | | |
| Jul | | | | | | | | |
| Aug | | | | | | | | |
| Sep | | | | | | | | |
| Oct | | | | | | | | |
| Nov | | | | | | | | |
| Dec | | | | | | | | |

n = effective void space factor. For imported durable aggregate, n = 0.3



## Conclusions and Discussion

- Can use water balances to size/check size of all land application areas
- Previous example of unlined bed
- Slight modification for lined bed or trench (LTAR/DLR = 0)
- Similar water balance used for sizing irrigation areas but considers soil as an infinitely thin store (i.e. no soil storage) for conservative sizing

## References


- Patterson RA, (2006). Evapotranspiration Bed Designs for Inland Areas. Septic Safe Technical Sheet Reference 05/15. NSW Department of Local Government, July 2006

| Month | Pan evapo-ration E mm | Evapotran-spiration ET ET=0.75E mm | Rainfall R mm | Retained rainfall $R_r$ $R_r$=0.75R mm | LTAR per month mm | Disposal rate per month mm | Effluent applied per month L | Size of area $m^2$ |
|---|---|---|---|---|---|---|---|---|
| Jan | 207.7 | 155.8 | 109 | 81.75 | 0 | 74.01 | 27900 | 376.90 |
| Feb | 170.8 | 128.1 | 119 | 89.25 | 0 | 38.85 | 25200 | 648.65 |
| Mar | 151.9 | 113.9 | 122 | 91.50 | 0 | 22.43 | 27900 | 1244.15 |
| Apr | 114.0 | 85.5 | 105 | 78.75 | 0 | 6.75 | 27000 | 4000.00 |
| May | 77.5 | 58.1 | 105 | 78.75 | 0 | -20.63 | 27900 | -1352.73 |
| Jun | 75.0 | 56.3 | 121 | 90.75 | 0 | -34.50 | 27000 | -782.61 |
| Jul | 80.6 | 60.5 | 69 | 51.75 | 0 | 8.70 | 27900 | 3206.90 |
| Aug | 108.5 | 81.4 | 84 | 63.00 | 0 | 18.38 | 27900 | 1518.37 |
| Sep | 141.0 | 105.8 | 59 | 44.25 | 0 | 61.50 | 27000 | 439.02 |
| Oct | 167.4 | 125.6 | 82 | 61.50 | 0 | 64.05 | 27900 | 435.60 |
| Nov | 192.0 | 144.0 | 76 | 57.00 | 0 | 87.00 | 27000 | 310.34 |
| Dec | 232.5 | 174.4 | 80 | 60.00 | 0 | 114.38 | 27900 | 243.93 |

**Table 3. Calculation of area for each month (disregarding storage of effluent).**

| Month | First trial area | Application rate (3) | Disposal rate per month (4) | (3) - (4) | Increase in depth of stored effluent | Depth of effluent for month (X - 1) | Increase in depth of effluent | Computed depth of effluent month (X) |
|---|---|---|---|---|---|---|---|---|
| | $m^2$ | mm | mm | mm | mm | mm | mm | mm |
| Dec | 1000 | | | | | | | |
| Jan | | 27.9 | 74.01 | -46.11 | -153.70 | 0 | + -153.70 | = 0 |
| Feb | | 25.2 | 38.85 | -13.65 | -45.50 | 0 | + -45.50 | = 0 |
| Mar | | 27.9 | 22.43 | 5.47 | 18.23 | 0 | + 18.23 | = 18.23 |
| Apr | | 27.0 | 6.75 | 20.25 | 67.50 | 18.23 | + 67.50 | = 85.73 |
| May | | 27.9 | -20.63 | 48.53 | 161.77 | 85.73 | + 161.77 | = 247.50 |
| Jun | | 27.0 | -34.50 | 61.50 | 205.00 | 247.50 | + 205.00 | = 452.50 |
| Jul | | 27.9 | 8.70 | 19.20 | 64.00 | 452.50 | + 64.00 | = 516.50 |
| Aug | | 27.9 | 18.38 | 9.52 | 31.73 | 516.50 | + 31.73 | = 548.23 |
| Sep | | 27.0 | 61.50 | -34.50 | -115.00 | 548.23 | + -115.00 | = 433.23 |
| Oct | | 27.9 | 64.05 | -36.15 | -120.50 | 433.23 | + -120.50 | = 312.73 |
| Nov | | 27.0 | 87.00 | -60.00 | -200.00 | 312.73 | + -200.00 | = 112.73 |
| Dec | | 27.9 | 114.38 | -86.48 | -288.27 | 112.73 | + -288.27 | = 0 |

Table 4. Depth of stored effluent.

# WATER BALANCE ANALYSIS WORKSHOP SESSION

## Calculation of evapotranspiration-absorption/seepage area size by the water balance method.

Using the following information using your Course Notes, calculate the minimum area and depth of an evapotranspiration-absorption/seepage area for a three bedroom / five person dwelling.

Bureau of Meteorology rainfall and pan evaporation data for the nearest station is provided below.

| | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **DAILY PAN EVAPORATION (mm)** | 6.3 | 5.4 | 4.4 | 3.3 | 2.1 | 1.8 | 2.0 | 3.1 | 4.3 | 5.4 | 5.9 | 7.0 |
| **MEAN MONTHLY RAINFALL (mm)** | 93.3 | 99.6 | 92.1 | 70.3 | 58.8 | 56.4 | 35.9 | 45.8 | 40.2 | 64.1 | 76.1 | 71.7 |

Three test pits excavated on the proposed disposal area indicate that the soils are 475 mm weakly structured clay loam overlying moderately structured light clay to a depth of 2000 mm. Use the recommended design loading rate derived from Table L1 of AS/NZS 1547:2012 (see the Field Workshop and Design Exercise section of these Course Notes).

Calculate the evapotranspiration-absorption/seepage area using the worksheets provided on the following two pages.

The evapotranspiration-absorption area is to be constructed of imported aggregate, is to have a maximum depth of 600 mm with a minimum of 50 mm freeboard (i.e. maximum depth of stored effluent is 550 mm).

**Calculation of evapotranspiration-absorption area size by water balance method**

**Size of area for each month**

| (1) Month | (2) Pan evaporation E mm | (3) Evapo transpiration ET ET = 0.75E mm | (4) Rainfall R mm | (5) Retained rainfall $R_r$ $R_r$ = 0.75R mm | (6) DLR per month mm | (7) Disposal rate per month (3)-(5)+(6) mm | (8) Effluent applied per month L | (9) Size of area (8)/(7) $m^2$ |
|---|---|---|---|---|---|---|---|---|
| Jan | | | | | | | | |
| Feb | | | | | | | | |
| Mar | | | | | | | | |
| Apr | | | | | | | | |
| May | | | | | | | | |
| Jun | | | | | | | | |
| Jul | | | | | | | | |
| Aug | | | | | | | | |
| Sep | | | | | | | | |
| Oct | | | | | | | | |
| Nov | | | | | | | | |
| Dec | | | | | | | | |
| First trial area = average monthly area = | | | | | | | | $m^2$ |

Depth of stored effluent (first trial)

| (1) Month | (2) First trial area $m^2$ | (3) Application rate (8)/(2) mm | (4) Disposal rate per month (7) mm | (5) (3) - (4) mm | (6) Increase in depth of stored effluent (5)/n mm | Depth of effluent for month (X - 1) mm | (7) Increase in depth of effluent + (6) mm | Computed depth of effluent month (X) mm |
|---|---|---|---|---|---|---|---|---|
| Dec | | - | - | - | - | 0 | | |
| Jan | | | | | | | | |
| Feb | | | | | | | | |
| Mar | | | | | | | | |
| Apr | | | | | | | | |
| May | | | | | | | | |
| Jun | | | | | | | | |
| Jul | | | | | | | | |
| Aug | | | | | | | | |
| Sep | | | | | | | | |
| Oct | | | | | | | | |
| Nov | | | | | | | | |
| Dec | | | | | | | | |

n = effective void space factor. For imported durable aggregate, n = 0.3

Minimum Area Method Water Balance and Wet Weather Storage Calculations

| | | | |
|---|---|---|---|
| Design Wastewater Flow | (Q) | L/day | |
| Design Percolation Rate | (R) | mm/wk | |

| Parameter | Symbol | Formula | Units | J | F | M | A | M | J | J | A | S | O | N | D | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Days in month | (D) | - | days | | | | | | | | | | | | | |
| Precipitation | (P) | - | mm/month | | | | | | | | | | | | | |
| Evaporation | (E) | - | mm/month | | | | | | | | | | | | | |
| Crop factor | (C) | - | - | | | | | | | | | | | | | |
| **Outputs** | | | | | | | | | | | | | | | | |
| Evapotranspiration | (ET) | E x C | mm/month | | | | | | | | | | | | | |
| Percolation | (B) | (R/7) x D | mm/month | | | | | | | | | | | | | |
| Outputs | | (ET+B) | mm/month | | | | | | | | | | | | | |
| **Inputs** | | | | | | | | | | | | | | | | |
| Precipitation | (P) | - | mm/month | | | | | | | | | | | | | |
| Possible Effluent Irrigation | (W) | (ET + B) -P | mm/month | | | | | | | | | | | | | |
| Actual Effluent Production | (I) | H/12 | mm/month | | | | | | | | | | | | | |
| Inputs | | (P + I) | mm/month | | | | | | | | | | | | | |
| Storage | (S) | (P+I) - (ET+B) | mm/month | | | | | | | | | | | | | |
| Cumulative storage | (M) | - | mm | | | | | | | | | | | | | |
| **Irrigation Area** | **(L)** | **365 x Q/H** | **$m^2$** | | | | | | | | | | | | | |
| **Storage** | **(V)** | **largest M** | **mm** | | | | | | | | | | | | | |
| | | **(V x L)/1000** | **$m^3$** | | | | | | | | | | | | | |

Monthly Water Balance used to Determine Wet Weather Storage for a Medium Rainfall Region with a Nominated Irrigation Area

| | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Design Wastewater Flow | (Q) | L/day | | | | | | | | | | | | | | | |
| Design Percolation Rate | (R) | mm/wk | | | | | | | | | | | | | | | |
| Land Area | (L) | $m^2$ | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | |
| **Parameter** | **Symbol** | **Formula** | **Units** | **J** | **F** | **M** | **A** | **M** | **J** | **J** | **A** | **S** | **O** | **N** | **D** | **Total** |
| Days in month | (D) | - | days | | | | | | | | | | | | | |
| Precipitation | (P) | - | mm/month | | | | | | | | | | | | | |
| Evaporation | (E) | - | mm/month | | | | | | | | | | | | | |
| Crop factor | (C) | - | - | | | | | | | | | | | | | |
| **Inputs** | | | | | | | | | | | | | | | | |
| Precipitation | (P) | - | mm/month | | | | | | | | | | | | | |
| Effluent Irrigation | (W) | (Q x D)/L | mm/month | | | | | | | | | | | | | |
| Inputs | | (P+W) | mm/month | | | | | | | | | | | | | |
| **Outputs** | | | | | | | | | | | | | | | | |
| Evapotranspiration | (ET) | E x C | mm/month | | | | | | | | | | | | | |
| Percolation | (B) | (R/7) x D | mm/month | | | | | | | | | | | | | |
| Outputs | | (ET+B) | mm/month | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | |
| Storage | (S) | (P+W) - (ET+B) | mm/month | | | | | | | | | | | | | |
| Cumulative storage | (M) | - | mm | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | |
| **Storage** | **(V)** | **largest M** | **mm** | | | | | | | | | | | | | |
| | | **(V x L)/1000** | **$m^3$** | | | | | | | | | | | | | |