1a) Volume $= 1\ \text{cm} \times A = 0.01\ \text{m} \times A$

$= 182\ \text{m}^3/\text{s} \times \Delta t$

$\Delta t = 6 \times 3600\ \text{s}$

$\therefore\ A = \dfrac{182 \times 6 \times 3600}{0.01} \dfrac{\text{m}^3 \text{s}^{-1} \text{s}}{\text{m}}$

$= 393.1 \times 10^6\ \text{m}^2$

$= 393.1\ \text{km}^2$

b) Runoff due to 2 cm rain is 2 × UH

Runoff due to 3 cm rain is 3 × UH lagged.

Total runoff is the sum. Only evaluate around peak to get peak

t	UH	DRH1	DRH2	TOTAL
0				
6				
12	30.9	61.8		
18	85.6	171.2	92.7	263.9
24	41.8	83.6	256.8	$\boxed{340.4}$ ← PEAK
30	14.6	29.2	125.4	154.6

Peak runoff is $340.4\ \text{m}^3/\text{s}$

c) Total runoff volume = 5 cm × Area

$= 0.05 \times 393.1 \times 10^6 = 19.655 \times 10^6\ \text{m}^3$

Over Area $= 10 \times 10^6\ \text{m}^2$

Depth $= \dfrac{19.655}{10} = 1.97\ \text{m}$

This is change in depth in the reservoir.

2a) $T_{sr} = -7.271$

$12 - 7.271 = 4.729$

$= 4:43:44$

SUNRISE or 4:44 am

OR ON SLOPE

$12 - 6.178 = 5.822$

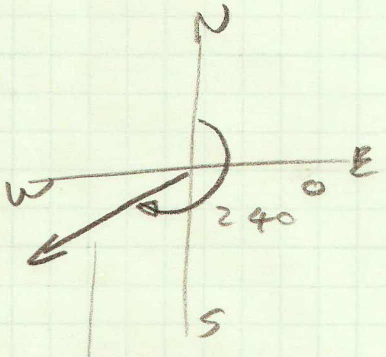
$= 5:49:19$

or 5:49

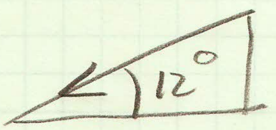
$T_{ss} = 7.271 = 7:16$ pm

SUNSET

b)



AZIMUTH OF SLOPE DIRECTION



SLOPE MAGNITUDE

c) $\Lambda = 0.6458$ rad

$\delta = 0.4091$ rad

at noon $\omega t = 0$

Equation #4

$\cos\theta = \sin\Lambda \sin\delta + \cos\delta \cos\Lambda \cos\omega t$

$= 0.9721$ $\qquad \theta = 0.2367$ rad

$\cos A = (\sin\delta - \sin\Lambda \cos\theta)/(\cos\Lambda \sin\theta)$

$= -0.9999 \simeq -1$

$\therefore A = -\pi = -180^\circ$ Makes sense at noon

$\cos z = \cos\theta \cos\beta + \sin\theta \sin\beta \cos(A - \alpha)$

$A = -\pi$

$\alpha = 4.1888$ $\theta = 0.2367$

$\beta = 0.2094$

$\therefore \cos z = 0.9753$

Close to 1 makes sense of noon

$E_0 = 0.967$

$K_{ET} = 1367 \times 0.9753 \times 0.967$

$= 1289 \quad W m^{-2}$

This does not account for atmospheric attenuation

From spreadsheet

$K_{cs}/K_{et} = \dfrac{29.334}{41.747} = 0.7027$

$\therefore K_{cs} = 1289 \times 0.7027$

$= 905.9 \quad W m^{-2}$

This is noon solar intensity on sloping surface

d) $E = \alpha \dfrac{1}{\rho_w \lambda_v} \dfrac{\Delta}{\Delta + \gamma} R_n$

$\Delta = \dfrac{2508.3}{(T+237.3)^2} \exp\left(\dfrac{17.3T}{T+237.3}\right)$

at $T = 20$ C $\quad \Delta = 0.1454$ kPa K^{-1}

$\gamma = \dfrac{c_a P}{0.622 \lambda_v}$

$\lambda_v = 2.5 - 2.36 \times 10^{-3} T = 2.453$ MJ/kg

$$\gamma = \frac{1 \times 10^{-3} \times 95}{0.622 \times 2.453} \qquad \frac{\cancel{MJ}\ \cancel{kg^{-1}}\ K^{-1}\ kPa}{\cancel{MJ}\ \cancel{kg^{-1}}}$$

$$= 0.06226$$

$$\therefore \frac{\Delta}{\Delta+\gamma} = 0.7002$$

$\alpha = 1.26$ for humid area

For Horizontal

$$R_n = 29.334 \quad MJ\ m^{-2}\ day^{-1}$$

$$\therefore E = \frac{1.26}{1000 \times 2.453} \times 0.7002 \times 29.334$$

$$\frac{\cancel{MJ}\ m^{-2}\ day^{-1}}{\cancel{kg}\ m^{-3}\quad \cancel{MJ}\ \cancel{kg^{-1}}}$$

$$= 10.55 \times 10^{-3}\ m/day$$

$$= 10.55\ mm/day$$

For sloping

$$R_n = 28.860 \quad MJ\ m^{-2}\ day^{-1}$$

$$E = 10.38\ mm/day$$

e) at noon

$$R_n = 905.9\ ~~W~~\ J\,s^{-1}\ m^{-2}$$

$$\times 3600 \times 24\ s/day \times 10^{-6}\ MJ/J$$

$$= 78.27\ MJ\ m^{-2}\ day^{-1}$$

$$E = 28.2 \times 10^{-3}\ m\ day^{-1}$$

$$= 28.2\ mm/day$$

The evaporation on a sloping surface is less due to the radiation being less.
The instantaneous rates of rain are higher than daily averages, because they reflect an instantaneous rate of rain.

3 a) $a = \frac{A}{b} = \frac{250 \times b}{b} = 250 \text{ m}$

b) Wolners model $\lambda = \ln \frac{a}{s}$

$s = \tan(5^\circ) = 0.08749$

$\therefore \lambda = \ln \frac{250}{0.08749}$

$= 7.958$

c) when distance $= x$

$A = bx$

$a = A/b = x$

$\lambda = \ln \frac{a}{s} = \ln \frac{x}{0.08749}$ on left

on right $s = \tan 10^\circ$

$= 0.1763$

$\therefore \lambda = \ln \frac{x}{0.1763}$ on right

d) Saturated implies $D \leq 0$

Equ 83

$D = m\left(\ln T_0 - \ln r - \ln \frac{a}{s}\right)$

Here

$r = \frac{Q_b}{A} = \frac{1.5 \times 10^{-2} \text{ m}^3/\text{s}}{10^6 \text{ m}^2}$

$= 1.5 \times 10^{-8} \text{ m s}^{-1}$

$\times 3600$

$= 5.4 \times 10^{-5} \text{ m hr}^{-1}$

For $D = 0$

$$\ln \frac{a}{S} = \ln T_0 - \ln r$$

$$= \ln 0.2 - \ln 5.4\times10^{-5}$$

$$= 8.217$$

Saturated for $\ln \frac{a}{S} > 8.217$

e) Use wetness index function to determine x where saturated. On the left

$$\ln \frac{x}{0.08749} = 8.217$$

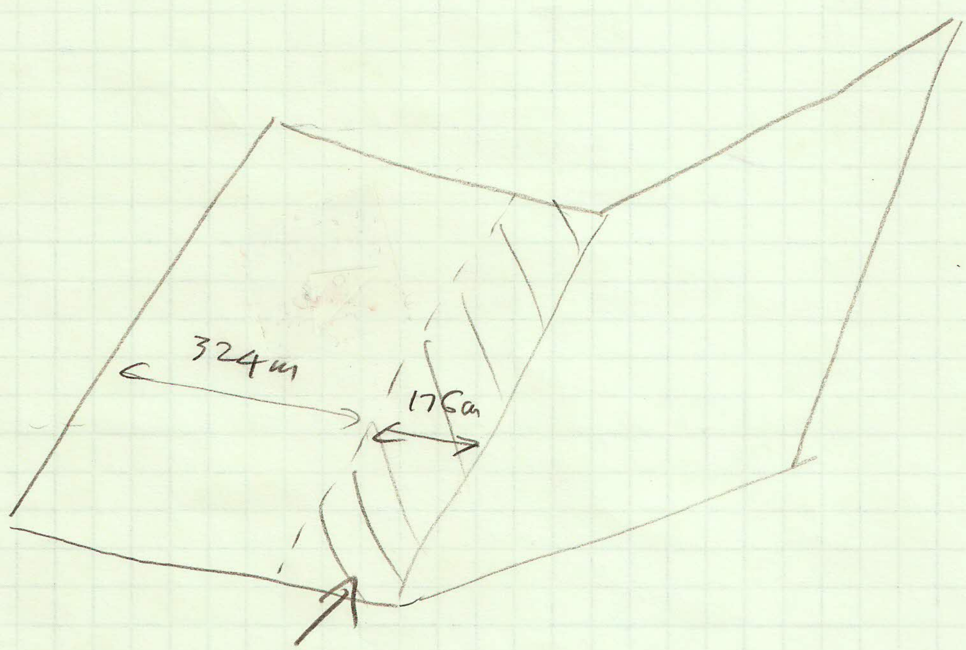
$$\Rightarrow x = 324 \text{ m}$$

So from $x = 324$ to $x = 500$ m is saturated.

On the right

$$\ln \frac{x}{0.1763} = 8.217$$

$$\Rightarrow x = 653 \text{ m}.$$ No saturated as $x > 500$m.



AREA SATURATED BEFORE STORM

e) Saturated area fraction $= \frac{176}{1000} = \underline{0.176}$

f) of P

$$D = m\left(\ln T_0 - \ln r - \ln \frac{q}{s}\right)$$

$0.1 \qquad 0.2 \qquad 5.4\times10^{-5} \qquad \frac{250}{0.08749}$

$= 0.0259$ m

g) Sat area $= 0.176\times10^{6}$ m^2

Vol $= 0.05 \times 0.176\times10^{6}$

$= 8800$ m^3

h) Runoff generated of P is

$0.05 - 0.0259 = 0.0241$ m

$= \underline{2.41 \text{ cm}}$