Appendix E – Equations

Equation 3.1 Plant Water Requirement

Page # 13

$$G/P/D = 0.623 \times ET \times S \times A \times K$$

where:

G/P/D	=	Gallons (U.S.) per plant per day
0.623	=	$\frac{27,152 \text{ gal/ac-in}}{43,560 \text{ ft}^2\text{/acre}}$
ET	=	Peak evapotranspiration rate for location (in/day) (Table 2.1)
S	=	Effective soil water storage factor (decimal) (Table 3.4)
A	=	Plant area (ft^2) – calculated from plant spacing
K	=	Crop coefficient factor (Table 3.5) (decimal)

Two factors that require further explanation are the effective soil water storage factor (S) and the crop coefficient factor (K).

Equation 3.2 Trickle System Design Requirement

Page # 22

$$TC = \frac{G/P/D \times L}{E \times Eu}$$

where:

TC	=	Trickle system design capacity
G/P/D	=	Plant water requirement
L	=	Leaching factor (Table 3.7)
E	=	Application efficiency (decimal) (Table 3.8)
Eu	=	Emission uniformity (decimal)

Equation 4.1 Emitter Flow Rate

Page # 31

$$Q = K_d (P)^X$$

where:

Q	=	Flow Rate (gph)
P	=	Operating pressure (psi)
K_d	=	Constant depending on the emitter and orifice size
x	=	Emitter discharge exponent

Equation 4.2 Emitter Discharge Exponent

Page # 31

$$x = \frac{\log\left(\frac{Q_1}{Q_2}\right)}{\log\left(\frac{P_1}{P_2}\right)}$$

Where Q_1 and Q_2 are emitter flow rates measured at pressures P_1 and P_2 respectively.

Equation 4.3 Emission Uniformity Using Flow Rate

Page # 36

$$Eu = \left(1 - \frac{1.27Cv}{\sqrt{n}}\right)\left(\frac{Qm}{Qa}\right)$$

where:

Eu	=	Emission uniformity as a decimal
n	=	Number of emitters per plant for point source emitters
	=	For line source emitters, the plant spacing divided by the orifice spacing or 1, whichever is greater.
Q_m	=	Minimum emitter flow rate (gph) for the minimum pressure (Hm)
Q_a	=	The average emitter flow rate (gph) for the average pressure (Ha)
C_v	=	Manufacturer's coefficient of variation for the emitter type. (Usually provided by the manufacturer)

The first term bracketed in the formula expresses emitter flow rate variance due to a manufacturing variation (C_v). I t is a measure of the tolerance to which the emitter is manufactured. Table 4.5 indicates a classification of Cv for a new emitter. The formula used to calculate C_v is as follows:

$$C_v = \frac{\text{standard deviation x 100}}{\text{mean}}$$

Equation 4.4 Emission Uniformity Using Pressure

Page # 39

$$Eu = \left(1 - 1.27\frac{Cv}{\sqrt{n}}\right)\left(\frac{Pm}{Pa}\right)^x$$

This can be rewritten for pressure variation as:

$$\left(\frac{Pm}{Pa}\right) = \left(\frac{Eu}{1 - 1.27\frac{Cv}{\sqrt{n}}}\right)^{\frac{1}{x}}$$

The pressure variance (P_m/P_a) is described as the minimum pressure (P_m) divided by the average pressure (P_a). The actual operating pressure range P_{max} to P_{min} will be larger than the pressure variance term used in the Eu formula. P_{max} to P_{min} would normally be computed as two times the difference between P_{ave} and P_{min}. However, because the friction loss is not constant along a lateral and Eu is not calculated using absolute minimum values the allowable pressure variation can be slightly higher than a factor of 2 times the difference between P_{ave} and P_{min}. Equation 4.5 is used to calculate the allowable pressure difference.

Equation 4.5 Allowable Pressure Variation

Page # 39

Allowable Pressure Difference = 2.5 x (P_{ave} - P_{min})

Equation 4.6 Emission Uniformity – Manufacturer's Coefficient

Page # 40

$$Eu_{cv} = 1 - 1.27\frac{Cv}{\sqrt{n}}$$

Equation 4.7 Distribution Uniformity

Page # 42

$$Du = \frac{\text{“minimum” water applied to the plants} \times 100}{\text{average water applied to plants}}$$

Equation 4.8 Lower Quarter Distribution Uniformity

Page # 45

$$LQDU = \frac{\text{Lower Quarter} \times 100}{\text{Average}}$$

where:

LQDU	=	Lower Quarter Distribution Uniformity
Lower Quarter	=	Average of the lower 25% of the sample size
Average	=	Average of the total sample

General criteria for the LQDU are:

> 90%	–	excellent
80 - 90 %	–	good
70 - 80 %	–	fair
< 70%	–	poor

Equation 8.1 Total Dynamic Head

Page # 124

$$H_T = H_s + H_e + H_f + H_P$$

where:

H_S = Static suction head (vertical distance from the water level to the centre of the pump impellor)

H_e = Static discharge head (elevation difference from the centre of the impellor to the highest point of the irrigation system)

H_f = Friction head (total friction loss of all suction and mainline fittings between the pump and the zone pressure control valve)

H_p = Pressure head (the pressure required at the zone pressure control valve)

Equation 8.2 Horsepower

Page # 124

$$H.P. = \frac{Q \times H_T}{3960 \times E}$$

where:

Q = Trickle irrigation system flow rate (gpm)

H_T = Total dynamic head (ft)

E = Pump efficiency at the flow rate and total dynamic head required given as a decimal.

Equation 10.1 Mean Filter Capability – Drip Emitters

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For drip emitters:

$$MFC_d = \frac{\textbf{Emitter Orifice Diameter}}{10}$$

Equation 10.2 Mean Filter Capability – Spray Emitters

Page # 152

For spray emitters:

$$MFC_s = \frac{\textbf{Emitter Orifice Diameter}}{7}$$

Equation 10.3 Screen Open Area

Page # 161

Screen Open Area (ft^2) x 225 = filter capacity in gpm

Equation 10.4 Screen Surface Area

Page # 161

$$SA = \frac{Q(gpm)}{448 \times V(ft/sec) \times \%O_p}$$

where:

SA = Screen surface area (ft^2)

Q = System flow velocity in gpm

V = Flow velocity through the screen (ft/sec)

$\%O_p$ = Open Area of the Screen Mesh (% shown as a decimal)

Equation 11.1 Saturation Index

Page # 181

$$\text{Saturation index} = pH - pHc$$

where:

pH	=	Actual measurement taken from water supply
pHc	=	$p(Ca + Mg + Na + K) + p(Ca + Mg) + p(CO_3 + HCO_3)$ (Table 11.3)

To determine the saturation index a water sample should be analyzed for Ca, Mg, K, Na, HCO_3, CO_3 and pH. All units except for pH must be expressed in meq/L (milliequivalents per litre). Table 11.2 can be used to convert mg/L into meq/L. The pHc terms can be determined from Table 11.3.

Equation 11.2 Chlorination – Iron Treatment

Page # 186

$$Cl_g = \frac{Fe \times Q}{3.15}$$

where:

Cl_g	=	The amount of chlorine to add in g / hr
$Fe_{mg/L}$	=	The concentration of Fe in the water supply in mg/L
Q	=	The irrigation system flow rate in gpm

Equation 11.3 Chlorine Injection Rate – Organic Solid Control

Page # 190

$$I = \frac{Q \times Cl}{1{,}000{,}000} \times 60 \times \frac{100}{(\text{bleach } \%)}$$

where:

I	=	Chlorine injection rate (gph)
Q	=	Trickle system flow rate (gpm)
Cl	=	Desired residual chlorine concentration in the water supply (mg/L) or ppm
Bleach %	=	Chlorine concentration of solution to be injected (% of available chlorine)

Equation 11.4 Chlorine Injection Rate – Metric

Page # 192

$$I = Q \times \frac{Cl}{278} \times \frac{100}{(\%\ bleach)}$$

I	=	Chlorine injection rate (Lph)
Q	=	Trickle system flow rate (Litres per second)
Cl	=	Desired chlorine concentration in the water supply (mg/L) or (ppm)
Bleach %	=	Chlorine concentration of solution to be injected (% available chlorine)

Equation 11.5 Chlorine Gas Injection Rate

Page # 192

$$I = Q \times Cl$$

I	=	Chlorine gas injection rate (lbs / hr)
Q	=	Trickle system flow rate (gpm)
Cl	=	Desired chlorine concentration in the water supply (mg/L) or (ppm)

Equation 11.6 Acid Injection Rate

Page # 196

$$I_a = \frac{A \times Q \times 60}{1000}$$

where:

I_a	=	Acid injection rate L/hr
A	=	Amount of acid (litres) / 1000 gallons of water (Table 11.5 if acid factor known)
Q	=	Trickle irrigation system flow rate (gpm)

Equation 11.7 Sulphuric Acid Injection Rate

Page # 197

$$L_{H2SO4} = \frac{HCO_{3\ meq/L} \times Q}{287}$$

where:

L_{H2SO4} = Litres of sulfuric acid per hour

$HCO_{3meq/L}$ = Amount of HCO3 in the water supply in meq/L

Q = The irrigation zone flow rate in gpm

Equation 12.1 Sodium Adsorption Ratio

Page # 204

$$SAR = \frac{Na}{\sqrt{\frac{Ca + Mg}{2}}}$$

where:

SAR = Sodium Adsorption Ratio
Na = Na ion in meq/L
Ca = Ca ion in meq/L
Mg = Mg ion in meq/L

Equation 14.1 Fertilizer Injection Rate

Page # 242

$$I_c = \frac{Qc \times A}{C \times T}$$

where:

I_c = Rate of chemical injection (L/min)

Q_c = Quantity of chemical to be applied per irrigation cycle (kg/ha)

C = Concentration of injected solution (kg/L)

A = Area (ha)

T = Total time of injection (min)

Equation 15.1 Landscape Plant Water Requirement

Page # 248

$$G/P/D = \frac{0.623 \times A \times K_s \times ET_o}{E \times CE}$$

where:

0.623	=	$\frac{27{,}152 \text{ gal/ac-in (conversion factor)}}{43{,}560 \text{ ft}^2\text{/acre}}$
A	=	Plant root zone area (ft^2)
K_s	=	Crop species factor (Table 15.2)
ET_o	=	Reference evapotranspiration rate for location (in/day) (Table 2.1)
E	=	Application efficiency (Table 3.8)
CE	=	Climate Efficiency (Table 15.1)

Equation 15.2 Evapotranspiration for Landscape Plants

Page # 252

$$ETL = KL \times ETo \text{ (in/day)}$$

where:

ETL	=	Evapotranspiration landscape (in/day)
KL	=	Landscape coefficient
ETo	=	Reference evapotranspiration (in/day)

Equation 15.3 Landscape Crop Coefficient

Page # 254

$$K_L = K_s \times K_d \times K_{mc}$$

Where:

K_L	=	Landscape Coefficient
K_S	=	Species factor (Table 15.2)
K_d	=	Density factor (Table 15.3)
K_{mc}	=	Microclimate factor (Table 15.4)

The landscape coefficient (K_L) is approximated for a known period of time (annual average, monthly, daily or stage of growth). Once determined it is then applied to the reference evapotranspiration (ET_o) to establish the landscape evapotranspiration rate used to calculate plant water requirements using the landscape coefficient method.

Equation 15.4 Number of Emitters Per Plant

Page # 256

$$\text{Number of Emitters} = \frac{\text{Plant root zone area} \times 0.50}{\text{Area wetted by one Emitter}}$$

Equation 15.5 Application Rate for Drip Systems

Page # 260

$$AR = \frac{1.6 \times Q}{A}$$

where:

AR	=	Application Rate of the drip system (in/hr)
Q	=	Flow Rate supplied by the drip system (gph)
A	=	Area to be irrigated (ft^2)

Equation 15.6 Maximum Irrigation Interval for Landscape Systems

Page # 265

$$\text{Maximum Irrigation Interval} = \frac{\text{Maximum Operating Time}}{\text{Calculated Operating Time per Day}}$$