Master Course Water Footprint Assessment
Solutions to calculation questions

Solution to question 1
Crop water requirement = effective rainfall + irrigation requirement = 180 + 382 = 562 mm
ET_{green} = minimum (crop water requirement, effective rainfall) = minimum (562 mm, 180 mm) = 180 mm/growing period
ET_{blue} = minimum (irrigation requirement, effective irrigation) = minimum (382 mm, 874 mm) = 382 mm/growing period
CWU_{green} = 10 x ET_{green} = 1800 m^3/ha
CWU_{blue} = 10 x ET_{blue} = 3820 m^3/ha
WF_{green} = CWU_{green}/Yield = 1800/50 = <u>36 m^3/t</u>
WF_{blue} = CWU_{blue}/Yield = 3820/50 = <u>76.4 m^3/t</u>

Solution to question 2
Grey water footprint = Effl ∗ $(c_{effl} - c_{act})/(c_{max} - c_{nat})$
= 6×10^4 m^3/yr ∗ (20 mg/l – 2 mg/l) / (3 mg/l – 2 mg/l)
= <u>1.08×10^6 m^3/yr</u>
Grey water footprint per unit of product = Grey water footprint / Production
= (1.08×10^6 m^3/yr) / (10,000 t/yr)
= <u>108 m^3/t</u>

Solution to question 3
In general:
Product WF[*p*] = (Process WF [*p*]+ Σ Product WF[*i*] / product fraction[*p*,*i*]) × value fraction[*p*]

Product fraction = 0.15
Value fraction = 0.89

Green WF of sugar = [0+(45 m^3/ton)/0.15] × 0.89 = <u>267 m^3/ton</u>
Blue WF of sugar = [0+(23 m^3/ton) /0.15] × 0.89 = <u>136.5 m^3/ton</u>
Grey WF of sugar = [0+(18 m^3/ton)/0.15)] × 0.89 = <u>106.8 m^3/ton</u>

Given that 50 g of sugar is used, the total water footprint related to the ingredient sugar is:
Total WF of sugar in 0.5 litre bottle of the soft drink = amount used × (green WF + blue WF + grey WF) = 50/1000 kg × (267 l/kg + 136.5 l/kg + 106.8 l/kg) = <u>25.5 l</u>

Solution to question 4
Value fraction of cocoa paste = 0.97
Product fraction of cocoa paste = 0.80

Water footprint of cocoa paste:
WF_{green} = 19745 l/kg × (0.97/0.80) = 23941 l/kg
WF_{blue} = 4 l/kg × (0.97/0.80) = 5 l/kg
WF_{grey} = 179 l/kg × (0.97/0.80) = 217 l/kg

Value fractions: of cocoa butter = 0.66; of cocoa powder = 0.34
Product fractions: of cocoa butter = 0.47; of cocoa powder = 0.53

Water footprint of cocoa butter:
WF_{green} = 23941 l/kg × (0.66/0.47) = 33619 l/kg
WF_{blue} = 5 l/kg × (0.66/0.47) = 7 l/kg
WF_{grey} = 217 l/kg × (0.66/0.47) = 305 l/kg

Water footprint of chocolate:
WF_{green} = 0.4 × 23941 l/kg + 0.2 × 33619 l/kg + 0.4 × 1176 l/kg = 16771 l/kg
WF_{blue} = 0.4 × 5 l/kg + 0.2 × 7 l/kg + 0.4 × 481 l/kg = 196 l/kg
WF_{grey} = 0.4 × 217 l/kg + 0.2 × 305 l/kg + 0.4 × 107 l/kg = 191 l/kg
WF_{total} = 17158 l/kg

The total water footprint of a 100 g bar of chocolate is thus 1716 l.

Solution to question 5

	January	February	March	April	May	June
WS_{blue}	0.05	0.13	0.20	0.48	1.3	3.4

	July	August	September	October	November	December
WS_{blue}	4.9	4.9	4.8	4.4	2.6	0.34

Discussion may include:
Number of months with

Low WS	Moderate WS	Significant WS	Severe WS
5	1	0	6

Should EFR be set at 80 per cent of R_{nat} under such conditions?
Ways to reduce blue WS in catchment.

Solution to question 6
$R_{act} = R_{nat} - WF_{blue}$

	January	February	March	April	May	June
WF_{grey}	1000	1000	1000	1000	1000	1000
R_{act}	670	1273	3016	1788	775	315
WPL	1.5	0.79	0.33	0.56	1.3	3.2

	July	August	September	October	November	December
WF_{grey}	1000	1000	1000	1000	1000	1000
R_{act}	13	15	21	24	31	149
WPL	77	67	48	42	32	6.7

Discussion may include points regarding:
Assimilation capacity fully consumed during 9 months of the year.
Water quality standards are extremely violated in the period July-November.
Is a constant grey water footprint realistic?
Usefulness of calculating WPL at river basin level?
Restrictions with respect to load?
How does the blue water footprint influence WPL?