Shona and Ben's Water Tank

Shona and Ben are building a house on an acreage property near Beenleigh, just south of Brisbane. There is no town water, so they need a rain water tank to collect the rain that falls on their roof. They have decided to build an in-ground concrete tank. The local concrete tank manufacturer, Kanga's Concrete Tanks, produces four sizes of tank. Shona and Ben need to decide what size tank they want.

Q1. What factors should they consider in making their decision?

When they rang Kanga, they got the manager on his mobile. He was out on a property building a tank. He gave them the following information, but he wasn't sure of the capacity of the large tank and couldn't remember the capacity of the very large tank.

	External height	External diameter	Capacity	Price
Small	2.20 m	3.60 m	16 700 L	$2380
Medium	2.20 m	4.85 m	31 200 L	$3420
Large	2.55 m	5.70 m	53 500 L ?	$4550
Extra large	2.55 m	7.50 m		$7250

Kanga's tanks are cylindrical with 100 mm thick roof and floor and 125 mm thick walls. They have 100 mm diameter inlet and overflow pipes in the top of the wall under the roof. This means that the tanks will only fill to 100 mm from the roof. Any further water will go out through the overflow. The capacity is how much water the tank will hold before water goes out through the overflow.

Q2. Check the capacity of the large tank and find the capacity of the very large tank. Before doing this use the method you plan to use to recalculate the capacity of the small or medium tank to make sure it comes to the same as the quoted capacity. If it doesn't, you might need to check your method.

Rainfall

A typical summer storm might produce 30 mm of rain. This means that if the ground was flat and no water ran away or soaked into the ground, after the storm, the water would be 30 mm deep on the ground. A quick shower might produce about 3mm. On a wet summer day in Tully, there might be 150 mm. In the Brisbane floods of 1974, about 750 mm of rain fell over three days. Rainfall in the coastal mountain ranges like those behind Cairns, Mackay and the Gold Coast can be even higher, sometimes over 1000 mm with the passing of a cyclone.

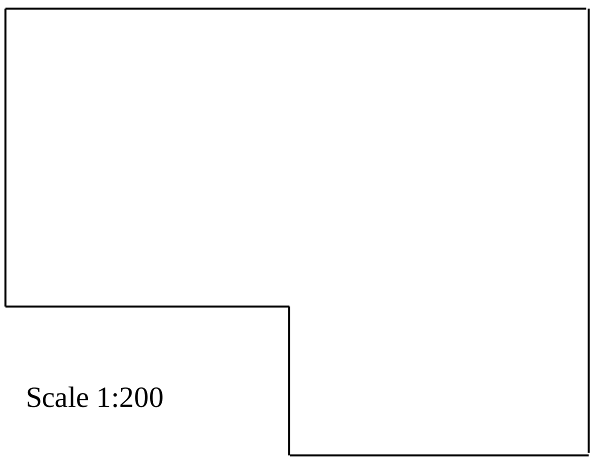
Q3. Water is measured in volume units like litres or cubic metres. Explain why rainfall is measured in length units like millimetres and not in volume units.

Shona and Ben's roof

Shona and Ben's house is going to be L-shaped. The outline of the roof as viewed from above is shown to the right

Q4. Assuming that all the water that lands on the roof goes into the tank and assuming that the roof is flat, how many litres of water would Shona and Ben collect in the tank in a 30 mm storm?

Q5. How many millimetres of rain would it take to fill the Medium tank?



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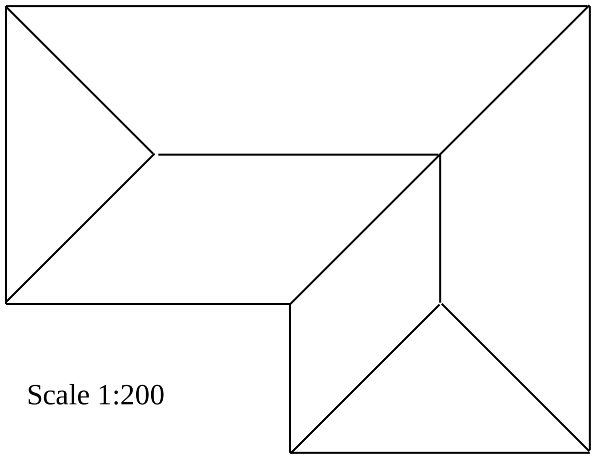
Q6. Their roof is in fact not flat, but slopes 20° towards the gutters as most roofs do. The picture to the right is the view from above showing the ridges and the valley. How will the fact that the roof is not flat affect the amount of water that is caught in the storm? Will it be more or less than what you calculated in Q4? Explain why.



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Water Consumption

Shona and Ben aren't sure how much water they use per day. This is something they need to know before they decide which tank to get. They have two teenage kids so they probably use quite a bit.

Your next task is to find out how much water a typical household with two teenage kids uses in a day.

Q7. Estimate the amount of water your household uses in a day.

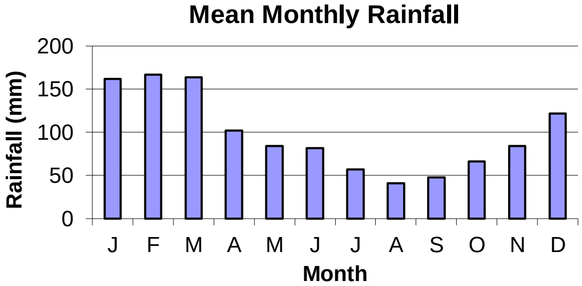
Q8. Find out how much your house uses in a day. There are a few ways to do this. If you have a water meter out the front of your house, go out and read it one day, then read it again at the same time the next day. You might be able to persuade a parent or someone to help you read the meter. If not, with a bit of effort, you should be able to work out yourself how to read it. Another way, if you get charged for water usage by your local council, and if you can find an old water bill, is to find the amount used in the period for that bill and divide by the number of days in the period. If you don't have a water meter, for instance if you are on tank water yourself, your parents may have a reasonable idea of how much you use per day. You can, if you like, measure the drop in the water level in the tank over 24 hours and use that and the diameter of the tank to work out the amount used.

Q9. Collect the data from all those in your class who found out how much water their household uses per day. Express this data in a suitable graph. Then compare your graph with that of others in the class and discuss which is the best type of graph for the job.

Q10. Work out the mean, the median and the mode of the class data. Which of these would be the most suitable to estimate the amount a typical household uses in a day? Take this amount as the amount Shona and Ben will use.

Monthly rainfall

Shona and Ben now know how much water they expect to use per day and how much they will collect from a given amount of rain. They need to know what the typical pattern of rainfall is for the area they live in. They have found this chart on a local map.



Q11. Use the chart to find the mean annual rainfall.

Q12. What size tank would Shona and Ben need if they wish to collect at least as much rain in an average year as they will use in a year?

Q13. This would be the best size if the rainfall was spread nice and evenly throughout the year, but, as you can see, most of the rain occurs in summer. What might happen is the tank might overflow in summer and then run dry in winter. A bigger tank would allow the extra rain to be saved in summer and kept for winter. If Shona and Ben want their water to last through winter, what size tank should they buy?

Q14. The chart shows average rainfall. There is in fact quite a bit of variation from year to year. What difference will this make to their decision?

Q15. Of course the bigger the tank, the more it will cost. It may be more economical to pay for a water delivery now and then than to get a bigger tank. A load of 15kL of water costs $110. They expect to be using the tank for about 20 years. Do an analysis of the overall costs (tank and water deliveries over the 20 years) for the various sizes of tank and decide which size they should buy in order to spend least overall.

Driving Rain

You should have worked out that the slope of the roof makes no difference to the amount of water collected. The area is all that matters.

However, sometimes in a cyclone, the wind blows so hard that the rain falls almost horizontally. If the rain falls more horizontally than the slope of the roof, the amount that hits the roof will be different from what you would calculate from the rainfall and the roof area.

Q16. Will the amount of rain hitting the roof be more or less than that calculated? Explain.

Q17. In a cyclone the rain drops are usually quite large and thus fall fairly fast. 6 vertical metres per second is a typical value. Find the wind speed which would cause the rain to fall at an angle of less than 20° from the horizontal. Express this wind speed in km/h.

A floating tank (challenge – not for the feint hearted)

When Kanga construct an in-ground concrete tank, they start off by digging a hole in the ground a little bit shallower than the height of the tank. This means that the top of the tank sticks out of the ground a bit. They then put a layer of crusher dust in the bottom to get a smooth level base. Then they construct the tank on this base. They then leave the tank for three days to let the concrete set and strengthen. Then they get some water delivered and put into the tank.

The danger during those three days is that there will be heavy rain and the hole will fill with water. Of course the water does not get inside the tank, so the tank stays empty. What can happen then is that the tank can float on the water. When the water in the hole is pumped out, the tank then settles in the wrong place and a large crane is needed to lift it up while workers flatten out the bottom of the hole again and then to put it back in the right place.

Q18. Assuming that Shona and Ben get the tank that you recommended in Q15, how far up the outside of the tank can the water come before the tank will float? For this you will need to know the density of water and the density of concrete. Water has a density of 1 kilogram per litre; concrete (with the steel reinforcing) has a density of about 2.7 tonnes per cubic metre. You also need to know that the tank will float when the mass of the tank is equalled by the mass of the water displaced by the tank. That is the mass of a cylinder of water the same size as the part of the tank that is below the surface of the water. You may have learnt this in Science. It comes from Archimedes' Principle.

Ben's rainfall records

Shona and Ben moved into their new home at Beenleigh, complete with water tank. Having a few acres, Ben decided to get into gardening. He planted trees and shrubs and some vegetable and flower gardens. He was interested in knowing how much rain fell, not only for his tank water supply but also for his garden.

He decided to get himself a rain gauge and kept track of the rain each day.

Below are his records for his first six years at the house. [These are actual records for the six years at a place near Beenleigh.]

1995												
Jan	3-12	4-7	2-25	8-1	10-3	14-4	15-1	17-4	22-1	28-6		
Feb	7-2	11-6	12-88	13-8	14-42	15-53	16-11	18-6	19-2	25-6	26-5	
Mar	7-14	11-1	17-1	25-12	26-17	27-4	29-26					
Apr	5-1	14-4	15-1	16-2	23-1	26-24	27-4	29-26				
May	4-2	8-1	9-6	10-3	11-2	17-12	18-2	21-9	22-1			
June	1-2	6-1	15-12	16-16	28-7							
July	7-4											
Aug	15-32	16-19										
Sep	3-5	21-1	24-2	26-1								
Oct	1-12	3-2	7-2	8-22	9-1	22-3	26-14					
Nov	1-1	5-55	6-11	16-21	17-27	18-4	20-68	21-1	22-20	23-15		
Dec	1-40	6-5	11-43	12-3	16-4	17-24	18-52	19-7	23-69	24-2	28-11	
1996												
Jan	2-4	3-53	4-42	5-4	9-57	10-36	20-1	23-6	27-3	29-2		
Feb	3-20	7-6	9-9	15-7	16-1	18-18	23-5	24-4	25-1	27-1	28-1	29-4
Mar	1-8	10-2	11-2	12-2	23-1	24-5	26-1					
Apr	23-15	24-7	27-61	30-9								
May	1-69	2-144	3-150	4-27	5-110	6-29	7-3	14-3	17-4	18-2	20-3	
June	1-10	2-6	3-7	6-1	7-2	15-19	16-1					
July	12-1	27-2	28-36									
Aug	6-1	16-2	17-2	18-14	30-42							
Sep	20-8	30-18										
Oct	6-8	7-6	20-4	29-4	30-5							
Nov	5-2	6-10	7-5	8-4	17-12	20-9	21-10	22-1	24-76	25-1		
Dec	4-37	7-20	8-6	9-14	10-3	11-11	12-23	18-29	19-2	21-1	31-1	
1997												
Jan	1-1	4-6	5-2	18-22	19-3	25-34	26-24	27-61	28-32	29-2	30-3	31-1
Feb	2-3	14-14	15-35	16-2	18-4	19-7	27-42					
Mar	6-1	7-2	9-3	26-1	31-14							
Apr	3-13	12-1	20-11	26-1	29-11	30-3						
May	1-16	2-1	3-28	4-15	5-29	7-10	8-5	16-8	17-34	30-8	31-12	
June	16-9	21-7	25-3	28-2								
July	12-2	13-15	24-5	25-1	26-1	27-16	28-1	30-1				
Aug	7-1	21-5	24-1									
Sep	2-1	20-19	21-18	24-30	29-3							
Oct	6-3	7-27	8-26	19-8	20-30	29-4	30-5					
Nov	5-6	6-49	7-2	12-3	15-18	16-8	17-3	18-33	19-2	20-4	30-17	
Dec	7-10	8-2	10-42	15-12	24-12	27-12						
1998												
Jan	9-1	14-4	15-1	28-57	31-51							
Feb	1-1	7-18	9-7	10-18	11-5	14-4	16-3	17-1				
Mar	1-3	4-1	8-2	19-25								
Apr	1-1	2-2	3-16	10-5	11-1	14-11	15-22	16-1	17-3	18-2	21-2	23-14
	24-8	28-3										
May	2-18	5-45	14-18	15-8	16-70	17-1	31-1					
June	1-4	16-4	23-2	29-3	30-2							
July	4-4	8--1	19-10	22-3	25-2	26-7	27-2	28-12				
Aug	5-48	6-4	16-3	20-1	21-10	22-18	23-5	24-1	27-9	28-1		
Sep	9-8	10-12	11-61	13-5	14-18	21-3	25-51					
Oct	13-22	25-3	26-1									
Nov	13-28	14-7	17-1	18-20	22-17	24-15	26-4	30-6				
Dec	1-1	5-6	16-12	19-2	20-1	23-5	24-147					

1999												
Jan	1-21	2-27	3-8	5-2	9-32	13-10	20-1	21-11	22-2	28-8	29-2	31-2
Feb	1-31	2-3	4-3	7-12	8-42	9-72	10-10	11-10	12-1	25-4	28-25	
Mar	1-13	2-5	3-36	10-3	12-9	20-44	23-21					
Apr	4-31	10-53	11-26	12-2	15-8	18-5						
May	6-15	7-7	8-27	10-9	11-6	13-8	19-7	20-3	21-16	22-10	23-7	
June	5-52	6-12	9-32	23-17	24-10	26-2	27-32	28-23	29-30			
July	1-32	9-6	10-9	24-34	27-6							
Aug	3-5	23-2	24-13	25-1	27-1	28-13	29-25	31-14				
Sep	2-2	10-3	11-31	27-19	28-9	29-18	30-5					
Oct	1-20	3-7	4-30	14-30	15-2	18-4	24-20	27-20				
Nov	6-1	7-9	8-18	9-11	12-2	17-6	23-10					
Dec	10-26	11-31	18-45	27-21	28-26							
2000												
Jan	5-3	13-2	15-19	17-11	28-25	30-5						
Feb	7-8	13-13	14-1	26-7	28-7	29-12						
Mar	2-2	4-1	8-31	9-25	10-1	18-4	19-2	21-3	22-4			
Apr	2-1	5-1	11-5	15-3	23-2	27-28	28-9	29-3	30-2			
May	1-10	2-28	4-2	24-14								
June	10-7	11-36										
July	12-9	27-10										
Aug	7-2	8-3										
Sep	2-1											
Oct	10-6	11-1	15-15	24-5	25-1	30-11						
Nov	2-9	3-1	4-2	5-1	13-22	15-1	17-24	20-10				
Dec	8-30	26-4	27-3	28-19	29-20	30-4						

There is a lot of data here. Your job now will be to draw some conclusions from this data. As there are a lot of figures to go through, it would be best to work in a group of 3 or 6. That way you can share out the work.

Q1. Work out how Ben recorded the rainfall – what do the various numbers mean?

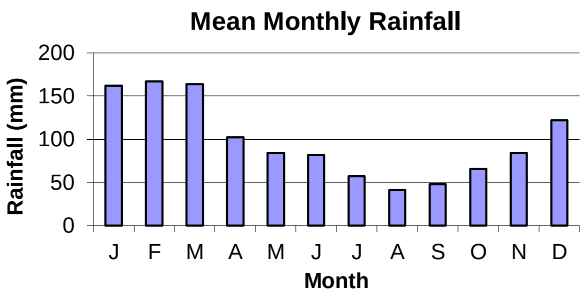
Q2. When was the wettest week (seven day period) of the six years? How much rain fell in the week?

Q3. When was the longest period without rain?

Q4. Ben and Shona had to buy water twice during the 6 six years. When do you think these times were?

Q5. Calculate the total rainfall for each of the 60 months and record the totals in a compact table.

Q6. Draw a graph like the one Ben and Shona found on the local map (shown to the right) for each of the 6 years. Your graphs will be of monthly rainfall, not of mean monthly rainfall.



Q7. Find the mean monthly rainfall for each of the 12 months at Ben and Shona's place for the period 1995-2000. Draw this up as a graph like the one above.

Q8. How different is your graph from Q6 from the one on the map. Would you conclude that the one on the map is right or wrong? Explain.

Q9. Use Ben's data to produce a graph showing the mean number of wet days in each of the 12 months. A wet day is defined as one on which rain was recorded. As Ben rounded his rainfall to the nearest millimetre, days with less than 0.5 mm would not be recorded as wet days.

Q10. Use the graph you produced for Q8 to find the probability that 15 January next year will be a wet day at Ben and Shona's place?

Q11. Use the graph you produced for Q8 to find the probability that 15 October next year will be a wet day at Ben and Shona's place?

Q12. Use the graph you produced for Q8 to find the probability that 1 October next year will be a wet day at Ben and Shona's place? Note that using the October average will give you a rough answer here, but you can do a bit better than that.

Ben noticed that wet and dry days don't seem to come at random, but that you often get a bit of a run of wet days, then a bit of a run of dry days.

Q13. Look at the wet days in February each year and see if you think Ben is right or whether wet and dry days occur at random.

You probably answered Q13 just by looking at the data and forming an impression. This is valid, but there is a more reliable way.

'At random' means that every day has the same probability of being wet irrespective of whether the previous day was wet or not. If the wet days do tend to come in runs rather than just being random, then you should find that the probability of rain on the day after a wet day is significantly greater than the probability of rain on the day after a dry day.

Q14. In this question you will find whether wet days tend to come in runs as explained above. For each dry February day over the 6 years, find out whether the following day was wet or dry, then use this data to find the probability that the day after a dry February day is wet and the probability that it is dry.

Then do the same for every wet February day over the six years.

How significant is the difference in the probabilities?

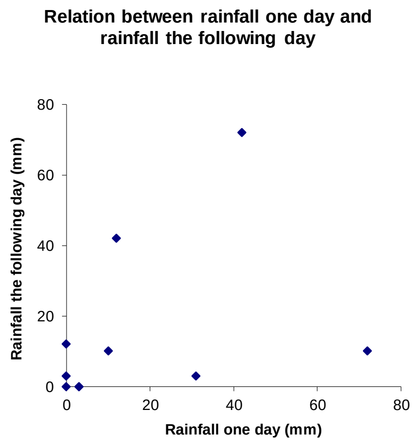
Was Ben right in suggesting that wet days tend to come in runs rather than being random?

Challenge

Ben realised that this fact might be helpful in producing whether forecasts. If today is wet, there is a better than average chance that tomorrow will be wet and vice versa. He wondered whether he could take his theory further. He thought that maybe knowing the amount of rain one day might help predict the amount of rain the next day.

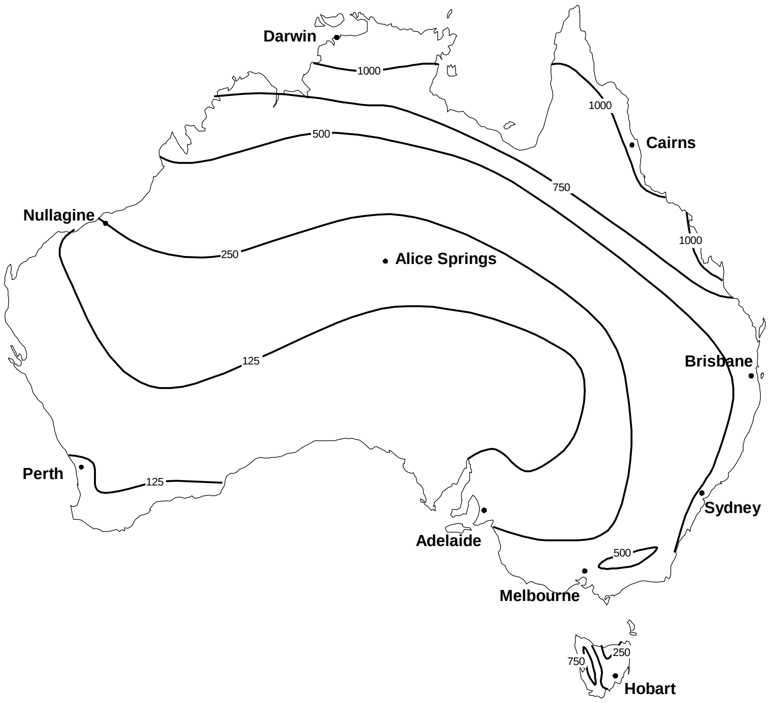
Q15. Produce a scatter plot. Plot the rain one day along the horizontal axis and the rain on the next day along the vertical axis. The first 10 days of February 1999 are plotted on the graph below as an example. A graphics calculator or spreadsheet may make this job easier.

Q16. Does your scatter graph support Ben's idea that the amount of rain one day might help predict the amount of rain the next day? In other words, is it true that the more rain there is one day, the more rain can be expected the next day?



Rainfall across Australia

The mean rainfall for the summer months (November to April) is shown on the map below.



This map uses contours to join places of equal rainfall. All the places along the 125 mm contour have an average of 125 mm of rain in summer. Of course some years they will have more; others they will have less, but the average will be 125 mm. All the places along the 250 mm contour have an average of 250 mm of rain in summer and so on.

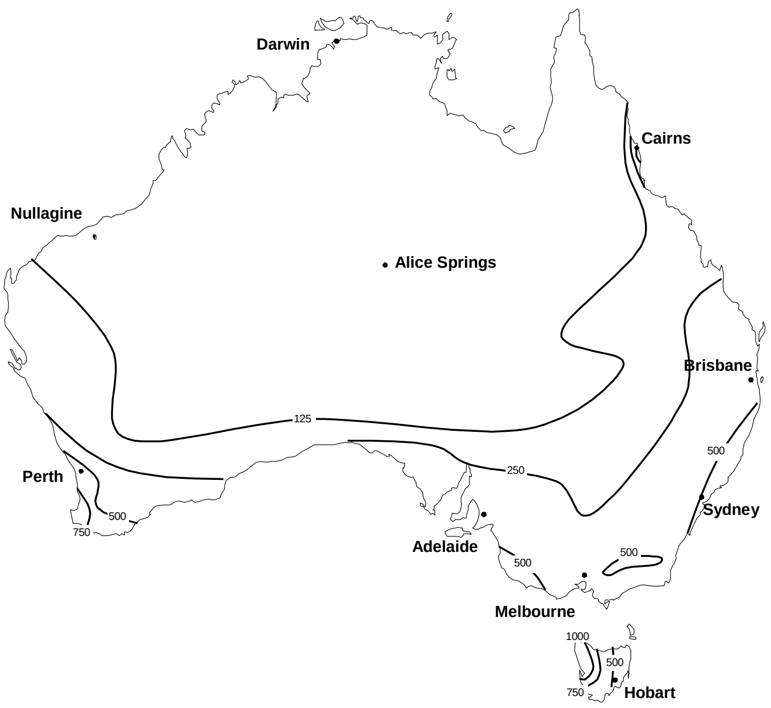
If you look at the map, you will see that Nullagine in Western Australia is right on the 500 mm contour. This means that Nullagine has an average summer rainfall of 500 mm. Alice springs is between the 250 mm and 500 mm contours. So it has between 250 mm and 500 mm of rain in summer. As it is about half way between the two contours, its summer rainfall is probably about half way between 125 mm and 250 mm, ie. about 190 mm. If it were closer to the 250 mm contour, its rainfall would probably be higher than 180; if it were closer to the 125 mm contour its rainfall would probably be closer to 125 mm.

Cairns is near the 1000 mm contour. It is not between that contour and any other contour, so how do we decide what range the Cairns rainfall lies in? Well, the 750 mm contour is on the other side of the 1000 mm contour from Cairns, so rainfall on the other side of the contour must be between 750 mm and 1000 mm. The 1000 mm contour, like all contours, divides the area with less than 1000 mm rain on ones side from the area with more than 1000 mm rain on the other side. As the area with less than 1000 mm is on the left side of the contour, the area with more than 1000 mm must be on the right. As Cairns is in this area, it must have more than 1000 mm of rain. How much more? This is hard to tell, but, as Cairns is close to the contour, probably not much more. Maybe 1100 mm.

Q1. Use the same logic to estimate the mean summer rainfall at each of the towns marked on the map. Think carefully about Perth – is it below or above 125 mm – it is possible to tell!

Q2. Choose a colour scheme and shade in the areas between the contours to show how much rain they have. You might use say brown for <125 mm, yellow for between 125 mm and 250 mm, green for between 250 mm and 500 mm light blue for between 500 mm and 1000 mm and dark blue for over 1000 mm.

The map below shows the average rainfall for the winter months (May to October)

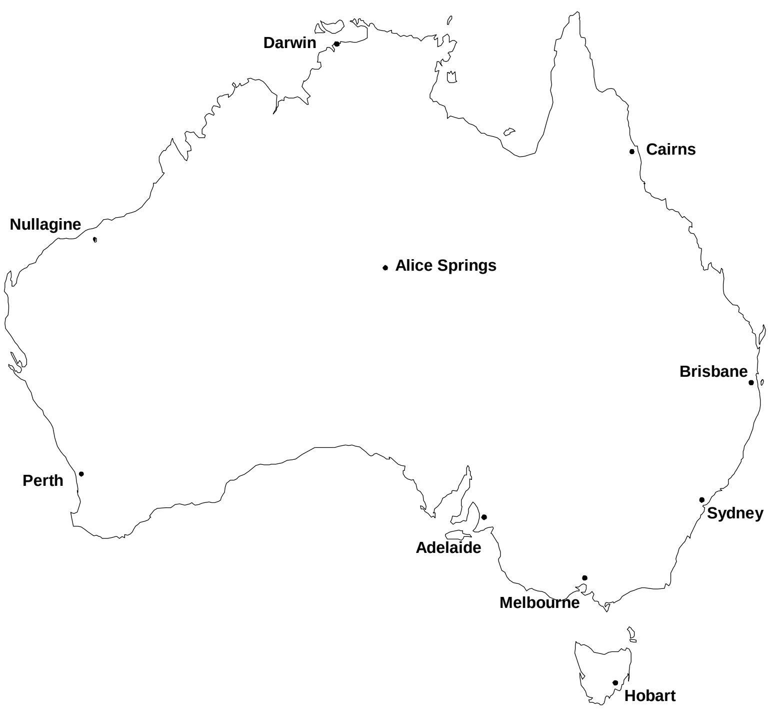


Q3. Estimate the mean winter rainfall for each of the towns shown.

Q4. How reliable is your estimate for Darwin? Explain why.

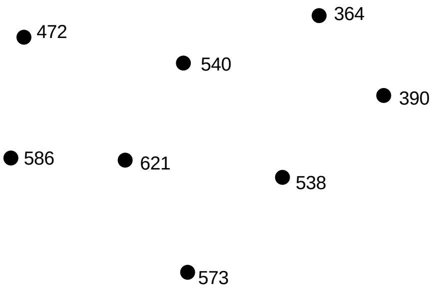
Q5. Which parts of Australia have more rain in summer than winter; which parts have more rain in winter; and which parts have their rain fairly evenly distributed? This might be easier to answer if you shade the winter map with the same colours you used to shade the summer map.

Your next task is to use the blank map below to produce a contour map of the total annual rainfall for Australia, ie. the average rainfall for the whole 12 months.

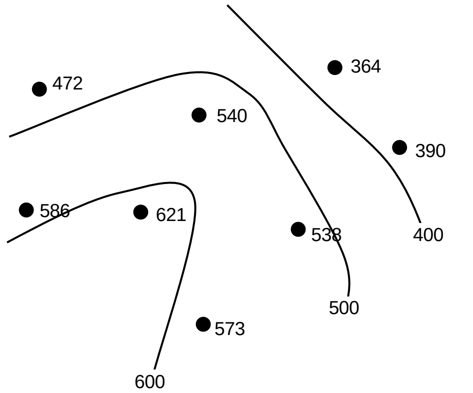


The best way to draw a contour map is to put spot values on the map and then draw the contours between them.

Suppose part of your map had these spot values.



You might draw in the contours like this.

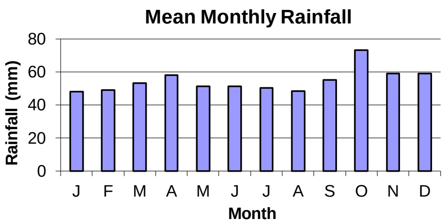


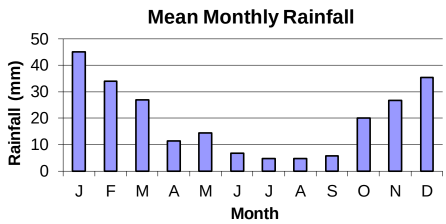
Have a good look at this to see how it was done.

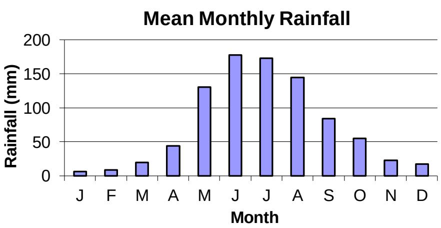
Now to get some spot values, put some dots on the blank map – maybe in a sort of grid pattern. Then copy each dot onto the other two maps, estimate the summer and winter rainfalls at that point, add them together and write the total on the new map.

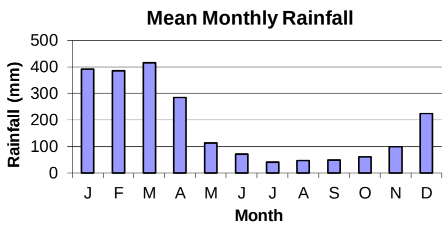
Q6. Produce the mean annual rainfall map using the blank map above.

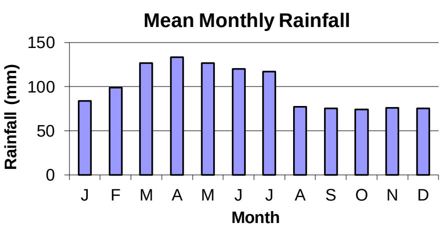
Q7. Below are mean monthly rainfall charts for the 10 towns shown on the maps of Australia. Work out which town corresponds to which chart and write the name of the town below the chart.

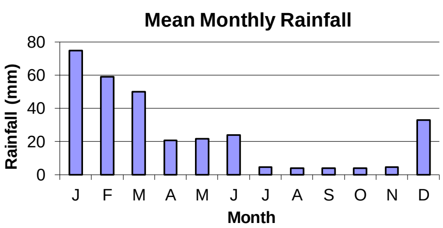


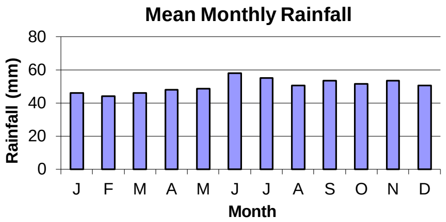


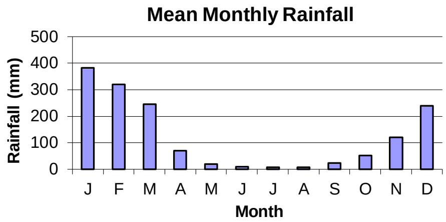


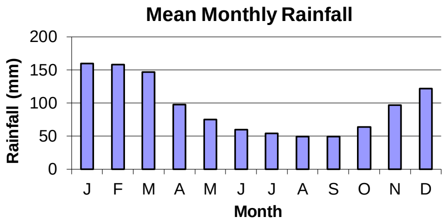


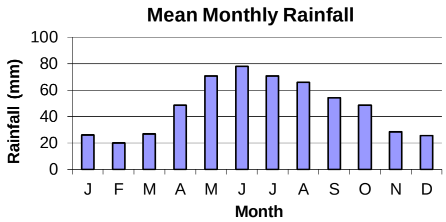












Extremes

Australia's driest place is Lake Eyre in South Australia. It gets about 130 mm of rain a year on average. But this is an average only. Some years it will get 300 mm or more. Other years it gets less than 20 mm.

Lake Eyre is a salt lake. Once every few years it gets water in it. This can happen as a result of rain in the area, but more often happens as a result of rain in North Queensland. When there are floods in inland North Queensland, the water flows down the Rivers (like the Diamantina and Coopers Creek) that run into Lake Eyre. Because the land is so flat, it can take a month or more for the flood waters to reach the lake.

The driest place in the world is Arica in Chile. Arica averages about 1 mm per year and it sometimes doesn't rain for 15 years at a stretch.

There is a small town near Longreach that has never recorded rain. But that in only because they haven't got a rain gauge.

Australia's wettest rain recording station is on top on Mount Bellenden Kerr just south of Cairns. The average annual rainfall here is about 7.5 m. 1979 was a particularly wet year there. The total rainfall on Bellenden Kerr in 1979 was 11.25 m. 5.4 m fell in January 1979, 1140 mm on 4 January 1979.

The wettest place in the world is on Mt Waialeale in Hawaii. The mean annual rainfall there is 12 m. Cherrapungi in the Indian Himalayas is a close second. Cherrapungi received 23 m of rain in one year in 1861.

Creek and dam (Beyond Level 6 – 4 hours)

contour maps
total fall in catchment
volume of dam lake - integration
height of creek flow

Dam