2020 ESS 132: Terrestrial Hydrology Homework 4

You are welcome to work together on this homework to understand the concepts but your answers must be in your own words. Group answers are not acceptable. Please show your workings wherever relevant. Your completed homework is due by 11.59p.m. on Tuesday 12/8 (Week 10).

Part A: Calculations related to streamflow/runoff modelling

1. SCS Method for Rainfall Excess (12)

a) A rainstorm occurs resulting in 4.8 inches of rainfall over the watershed. Fill in the yellow boxes in the table below using the formulae from class to calculate how runoff (Q) would change when an area is developed from forest into an area of mixed forest, landscaping, and housing. Give your answers to 2 decimal places. (6)

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Land Type | CN | S (in) | Ia (in) | Q (in) | Acres before | Acres after | Volume before (acre-ft) | Volume after (acre-ft) |
| Forest | 55 | 8.18 | 1.64 | 0.88 | 54 | 9 | 3.97 | 0.66 |
| Developed | 98 | 0.20 | 0.04 | 4.56 |  | 36 |  | 13.69 |
| Landscaping | 70 | 4.29 | 0.86 | 1.89 |  | 9 |  | 1.42 |
| Sum |  |  |  |  | 54 | 54 | 3.97 | 15.77 |

b) What percentage change is there between the volume of runoff before and after the development? What implications will this have for the local region and flood control? (3)

The runoff will increase by 3 times what it was before development. This will result in more frequent and severe floods in the region.

c) If you were city planners, suggest possible ways that you could reduce flood risk when planning and developing the next area of housing? (3)

I will limit paved surfaces and encourage as much landscaping as possible so that the reduction in infiltration won’t be as much as if I don’t limit paved surfaces. If possible, I want to build as many parks as possible too.

2. Unit hydrograph method (26)

a) A rainstorm occurs over a watershed with an area of 324,000,000 m2. The period of excess rainfall (runoff) lasts for 2 hours. Assuming that the baseflow remains constant for the whole time period, use the following streamflow data to find the unit hydrograph for this watershed. Show your unit hydrograph as a table of data and a graph vs time. (You may find it easier and quicker to use excel! Show your working so that we can award partial credit if necessary.) (10)

|  |  |  |  |
| --- | --- | --- | --- |
| Time (hrs) | Streamflow (m3/sec) | Event flow (m3/sec) | Unit hydrograph (m3/sec for 1cm of rainfall) |
| 0 | 50 | 50 – 50 = 0 | 0/5cm = 0 |
| 1 | 50 | 0 | 0/5cm = 0 |
| 2 | 250 | 200 | 200/5cm = 40 |
| 3 | 500 | 450 | 90 |
| 4 | 1000 | 950 | 190 |
| 5 | 1200 | 1150 | 230 |
| 6 | 1050 | 1000 | 200 |
| 7 | 700 | 650 | 130 |
| 8 | 150 | 100 | 20 |
| 9 | 50 | 0 | 0 |
| 10 | 50 | 0 | 0 |

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b) Another storm is forecast to occur in the same watershed a few weeks later and its projected intensity is shown in the table below. In this basin it is known that about 50% of the total precipitation is lost due to infiltration and we will assume that the infiltration rate over the course of the storm is constant. You are in charge of producing a flood forecast for the watershed. Assuming that the baseflow is 50 m3/s and using the unit hydrograph from part a):

- complete the first table to find the effective rainfall for each 2 hour increment

- complete the table to calculate the streamflow for each hour

- include a graph of streamflow vs time (10)

|  |  |  |  |
| --- | --- | --- | --- |
| Time (hrs) | Rainfall rate (cm/hr) | Total rainfall (cm) | Effective rainfall (i.e. runoff) (cm) |
| 0-2 | 0.1 | 0.1\*2 = 0.2 | 0.2 – 0.2 = 0 |
| 2-4 | 0.2 | 0.2\*2 = 0.4 | 0.4 – 0.2 = 0.2 |
| 4-6 | 0.4 | 0.8 | 0.8 – 0.2 = 0.6 |
| 6-8 | 0.1 | 0.2 | 0.2 – 0.2 = 0 |

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Time (hrs) | Pulse 1 (m3/s) | Pulse 2 (m3/s) | Pulse 3 (m3/s) | Pulse 4 (m3/s) | Total event flow (m3/s) | Streamflow (m3/s) |
| 0 | 0 |  |  |  | 0 | 50 |
| 1 | 0 |  |  |  | 0 | 50 |
| 2 | 0 | 0 |  |  | 0 | 50 |
| 3 | 0 | 0 |  |  | 0 | 50 |
| 4 | 0 | 8 | 0 |  | 8 | 58 |
| 5 | 0 | 18 | 0 |  | 18 | 68 |
| 6 | 0 | 38 | 24 | 0 | 62 | 112 |
| 7 | 0 | 46 | 54 | 0 | 100 | 150 |
| 8 | 0 | 40 | 114 | 0 | 154 | 204 |
| 9 | 0 | 26 | 138 | 0 | 164 | 214 |
| 10 | 0 | 4 | 120 | 0 | 124 | 174 |
| 11 |  | 0 | 78 | 0 | 78 | 128 |
| 12 |  | 0 | 12 | 0 | 12 | 62 |
| 13 |  |  | 0 | 0 | 0 | 50 |
| 14 |  |  | 0 | 0 | 0 | 50 |
| 15 |  |  |  | 0 | 0 | 50 |
| 16 |  |  |  | 0 | 0 | 50 |

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c) How and why would a stream hydrograph shape and lag time might change if:

i) the storm occurred in spring before significant crop growth on agricultural lands rather than in fall when crops were at their maximum size (2)

Lag time would decrease and the peak of the hydrograph would be narrower and taller. Because there is a lack of crop growth during spring, there is less interception and infiltration, making it more likely for the soil, especially the surface of the soil, to be saturated, resulting in more runoff. Runoff reaches streams more quickly than subsurface flow. As a result, the stream receives the same amount of water over a much shorter period of time, producing a shorter lag time and narrower and taller peak in its hydrograph.

ii) infiltration rates are not constant but begin high and decrease over time (as it does in reality!) (2)

If the initial infiltration rate is higher than the constant infiltration rate in part b), then the lag time would be initially higher, as more infiltration than runoff occurs initially and so most of the initial stream flow comes from subsurface flow and if there is any initial overland flow, then it would be in the form of Dunne overland flow – where the entire soil horizon is saturated and so requires more time – than Hortonian flow. However, as the infiltration rate decreases, more and more water reaches the stream as runoff and so reaches the stream faster, which might lead to a higher peak than the hydrograph in part b).

d) Why might it not be a good assumption that baseflow does not change over time? (2)

Because in actuality, base flow can change after a storm, and base flow can change depending on whether a stream is gaining or losing. If a stream is losing, then it constantly leaks water to infiltration, and so base flow might decrease until some time after a storm began when the soil saturates enough to prevent this decrease in base flow.

**Part B – Flooding and ARkStorms (12)**

I think that everyone is very aware of the consequences and occurrence of drought in California. But not as many people are familiar that California is also at risk of very severe flooding. Two reports from the USGS on ARkStorms are available on the class website. The first document is a handout summarizing the report and should be read first. The second document is the full USGS report which I posted to provide more background information – in particular the “Abstract” and pages 1-10 will help with the questions below. I also posted it because I thought you might be interested to read more – I think this scenario is fascinating!

a) Use the handout to explain how ARkStorms compare to large earthquakes on the basis of: (2)

* Likelihood to occur/frequency

ARkStorms are just as likely to occur as the “ShakeOut” earthquake.

* Economic damage

Economic damage is $725 billion, roughly 3 times that of the ShakeOut earthquake.

* Area affected

The entire state would be affected, with floods as far north as San Francisco and as far south as Los Angeles and Orange County. Coastal and riverine communities would both be affected. This is as opposed to the ShakeOut earthquake, which only affects southern California.

* Predictability

It is somewhat more predictable than the ShakeOut earthquake, allowing for some preparation before the storm hits. However, predicting it still remains a difficult challenge.

b) Use the “ARkStorm Meteorology” section of the full USGS report to explain what an ARkStorm is? How frequently do they occur and how do we know about their past occurrences? (2)

An ARkStorm (Atmospheric River 1000) is a storm that comes about due to an atmospheric river bringing vast amounts of precipitation that, in parts of California, reaches levels that are only seen every 500-1000 years. They occurred 6 times in the past 1800 years and we know about their past occurrences through geologic evidence.

c) Describe which broad areas are likely to experience severe flooding. Give at least one reason why it was difficult to produce local-scale detailed maps of flooding at this time. (2)

Southern California (Los Angeles County and Orange County), the Central Valley, and the Sacramento region (including San Francisco and San Jose) are likely to experience severe flooding.

One reason that explains why local-scale detailed maps are difficult to produce is that most current models are small-scale and uses different inputs and produces different outputs, making them difficult to be compared to each other and to be combined together into local-scale flood maps.

d) Apart from flooding, what other hazards are likely to occur due to the ARkStorms? (2)

Another hazard are landslides. The study found that an ARkStorm can cause tens of thousands of landslides along the coast of the entire state with damages of roughly $3 billion.

e) Important services such as power supply, water supply, sewage systems, and transportation are all likely to be affected by such an event. Choose ONE of these and use the relevant section of the USGS report (P.24-57) to explain their vulnerability, how long it might take to restore them after the ARkStorm, and what could be done to make them more resilient. (4)

Highway impacts fall under 4 categories: (1) flooding; (2) debris flow; (3) a combination of floods and erosion; and (4) landslides. It takes 3 days for most of southern California to restore most of its highway capacity, although restored highways can only be used for transport within the region rather than from southern California to northern California. Traffic between northern and southern California would begin roughly 1-2 weeks after the storm, and would gradually be restored with time, taking much longer to restore than traffic within each region.

Some resiliency efforts center around increased monitoring, with suggestions including networks of webcams or CCTV cameras to monitor road networks in real-time and methods of monitoring deep-seated landslides such as using strain gauges. The report also suggests consideration of early evacuation efforts, and monitoring efforts can help predict whether early evacuation is necessary.