Stormwater Runoff and Hydraulics

A Solidify Understanding Task

Purpose:
Main purpose is to determine if an existing drainage system is sufficient to handle the extra rainwater runoff from a new 5-acre construction to prevent an adjacent road from flooding. After determining the existing system is not big enough and by how much is it short, determine an engineered ditch that will handle the excess water runoff from the new 5-acre construction site.

Career Field:
Civil Engineering
NC DOT – Hydraulics Unit

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NC Math 4 Standards:
AF.1 Apply properties of function composition to build new functions from existing functions.
AF.1.1 Execute algebraic procedures to compose two functions.
AF.1.2 Execute a procedure to determine the value of a composite function at a given value when the functions are in algebraic, graphical, or tabular representations.

Unit Alignment:
NC Math 4 - Unit 2: Functions
MAT 121 - Unit 1: Functions (however, Pythagorean theorem and trapezoid area formula are applied)
MAT 121 - Unit 2: Geometry

Common Core State Standards for Mathematical Practice

1. Make sense of problems and persevere in solving them.
2. Reason abstractly and quantitatively.
3. Construct viable arguments and critique the reasoning of others.
4. Model with mathematics.
7. Look for and make use of structure.

Prerequisite Skills

- Sum notation ∑
- Unit conversions
- Compare and analyze mathematical findings
- Pythagorean theorem
- trapezoid area and perimeter

Time Required
The time required to complete this activity is approximately 200 minutes.

Materials Needed

- Excel or any spreadsheet
- If a spreadsheet is not available, then a calculator

The Teaching Cycle:

Launch:

Assign the Teacher Desmos Activity as an individual student assignment. This Desmos includes the Launch Video and questions on ∑, unit conversations, slope, and trapezoidal area and perimeter and all these are applied in the student tasks sheet. One option is to watch the video in class, which can generate several good points of discussion. This video will introduce to the student just how broad Civil Engineering is and what type of tasks Hydraulics units actually do in keeping our roads passable during heavy rains. It also introduces the idea that "new construction" will usually create more water runoff onto our roads, which could cause the existing drainage piping network to be too small to handle the new added amount of water caused by the construction.

Explore:

Task 1 primarily deals with runoff coefficients and amounts of runoff from the new construction site. You may want to have a class discussion about the runoff charts. For example, for pavements, C = 0.7 to 0.9, which means that about 70% to 90% of the rainfall onto pavements will runoff and for woods, C = .1 to .2, which means that about 10% to 20% of the rainfall onto wooded area will runoff. The current instructions ask the students to use the midpoint of these intervals, but there could be an argument to utilize the maximum endpoint of the interval in the design. Also, a table of rainfall rates based on the storm occurrence and duration is given. 95% confidence intervals or the rainfall rates are also listed. A 100-year storm is a storm that has a 1% chance of occurring in a given year and a 10-year storm has a 10% chance of occurring in a given year. The rainfall rates are based on historical data. The duration of the rainfall also is related to the rainfall rate. Heavy rains will usually last for shorter periods and lighter rains will usually last a longer amount of time. The rainfall rates are in inches per hour. These are all good topics for discussion. Try NOT to give answers to groups that are asking you questions as they explore these tasks, but rather ask them questions that will bring their everyday experiences into their thought.

After finding the amount of water runoff from the new construction site using the 10-year 10-minute rainfall design rate, now we need to determine if the existing pipe system is large enough to handle the additional rainwater. Manning's Equation will tell us the amount of water a pipe can carry based on the slope, size, and smoothness of the pipe. A large, smooth, steep sloped pipe can carry and move a lot of rainwater. Best practice here is to create an excel spreadsheet where each input parameter is in a cell. This will allow students to explore changes in the flow rate by making changes in the inputs. Also, this formula can be used for circular pipes as well as trapezoidal ditches. One common student mistake is to determine the total amount of flow possible in the existing pipe without taking into account the drain inlets. Use the drain inlets already in the existing design to determine the current rainwater rate coming into the large 24 in pipe going under the roadway. Then add the "new construction runoff" to determine the rainfall needed to be drained.

Task 3 is exploring engineered trapezoidal ditches and various size riprap (large rocks in ditches to slow the water and decrease erosion) that also will help carry off runoff rainwater.

Task 4 will go back to the Manning's Equation excel spreadsheet. You can change the slope of the pipe and determine the steepness that would result enough flow rate to handle the new turning lane. If you know how to use "goal seek" in excel, you can find the exact slope needed. If the needed slope is too large, then you could increase the pipe diameter to handle the new flow rate. Again, goal seek will help, but be realistic on your size pipe. Maybe research what are the various sizes of existing pipe that are commonly used is road drainage systems.

Discuss:

Students will share their results and compare what they arrived at compared to other groups. Groups can explain their process they used at arriving at their result. You could have groups trade their answers and have groups compare their results with the results of the paper they are reviewing. Again, time is a factor in how you handle the discussion part of the activity. Do at least have each group explain to some degree how they arrived at some part of their results.

OnLine Class Option: Below find the blackboard post for this activity assignment for an online class. The discussion part of this schematic could be assigned as the Discussion part of an in class face to face class.

Project Steps

YOUR FINAL PROJECT GRADE IS 10% DESMOS, 80% PROJECT SOLUTIONS WITH DOCUMENTATION, AND 10% GROUP VIDEO UPLOAD!!!

Step 1: **GOAL COMPLETION BY FRIDAY, 6/2 at 11:59pm.**

- Watch the launch video https://www.youtube.com/watch?v=RtiPQ8BHf4Q&list=PLBdwIq8dHqDrmfaF2eESXyZlT9bBYyoYB&index=22
- Complete the Launch Desmos Activity (This part individually): "Stormwater Runoff - NCDOT Hydraulics"   Desmos Link: https://student.desmos.com/join/marm8n

Step 2: **MUST BE COMPLETE BY MONDAY June 5 @ 11:59 pm. One group member upload the group's project solutions.**

- Explore the task as a group.
- This does not mean dividing up the tasks into individual pieces but as a group, discuss the problem and agree on the best solution to the problem.
- As part of the explore phase, your group will be expected to solve the problems and upload one complete solutions and supporting work document on blackboard.
- Please number your solutions corresponding to the numbers on the student activity sheet and include your supporting math / excel work to support your results.
- I strongly encourage you to set up several teams meetings to work through this as a group.

Step 3: **MUST BE COMPLETE BY TUESDAY June 6 @ 11:59 pm.**

- Meet in TEAMS in your private group and record your group explaining solutions to task 2 and upload your group's recording.
- Make sure someone shares their screen in the recording showing your solutions and everyone has a speaking part.

Exit Ticket:

Use Manning's Equation, $Q = \frac{1.49}{n} * A * \left(\frac{A}{P}\right)^{\frac{2}{3}} * (S)^{\frac{1}{2}}$, to determine the slope of a 20 inch diameter pipe needed to handle a flow rate of 32 cfs if the manning's coefficient for the pipe is .012.

Ans: Using the spreadsheet generated in the activity, n = 0.012, the radius is 10 inches (=10/12 ft), then goal seek back to the slope using 32 cfs for Q. Result = 4.5%. Of course, a student could solve this algebraically for S.

Two example assessments for testing:

1. Use Manning's Equation, $Q = \frac{1.49}{n} * A * \left(\frac{A}{P}\right)^{\frac{2}{3}} * (S)^{\frac{1}{2}}$, to determine the maximum flow rate for a trapezoidal ditch whose cross section has a base of 1.5 feet, sloped sides with ratio of 2:1, and water is 8 inches deep. Also, the ditch has a Manning's roughness coefficient of .028 and is sloped at 6.5%.

Ans: Using the spreadsheet generated in the activity, n = 0.028, the trapezoidal cross section area is .5*(1.5 + (1.5+8/3))*(2/3) = 1.889 sq ft and the wetted perimeter is 1.5 + 2*(sqrt(20/9) = 4.481 ft. Substituting these values into Manning's Equation results 14.41 cfs .

2. For the trapezoidal ditch in question 1 above, determine the shear stress and the size riprap required in the ditch.

where

Table 1. Permissible Shear Stress

Liner	d50 (in)	τ_p (lb/ft^2)
Class A riprap	4	1.6
Class B riprap	8	3.2
Class I riprap	10	4.0
Class II riprap	12	4.8

Ans: $\tau = 62.41 * \frac{8}{12} * 6.5\% = 2.704$ which would result Class B riprap needed.