
# Measuring Water Resources Unit 1: Introduction to the hydrological cycle student exercise

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*Unit 1 introduces the hydrological cycle but gives special focus on those portions of the cycle that take place on land and thus form the basis for water used by society. The unit will emphasize quantitative approaches to describing critical portions of the hydrological cycle that humans have access to - surface water and shallow ground water. You will calculate residence times and fluxes between reservoirs, track water particles on an annual basis, and also explore available data sets for specific reservoirs such as snowpack and rivers. To place this work in a societal context you will be asked to create a water budget for one of the various water stakeholder groups (e.g. households, rancher/farmers, conservation/ecological) and analyze the relative status and basis for establishing allocation priorities.*

## Introduction

Water is critical for life as well as serving as a transport agent for energy around the Earth. Water and its various phases and reservoirs have been organized into the hydrological cycle (Figure 1). As can be seen in the figure, there are a number of reservoirs and fluxes between reservoirs. These are typically defined on an annual basis. It is easily noted that the largest of these reservoirs are the oceans, followed by ground water, glaciers and surface waters. What is of particular relevance to society is that portion of the total water volume that is usable by terrestrial life. This is a much smaller fraction of the total, and also distributed with a much greater spatial and temporal variability – and is the focus of this unit.

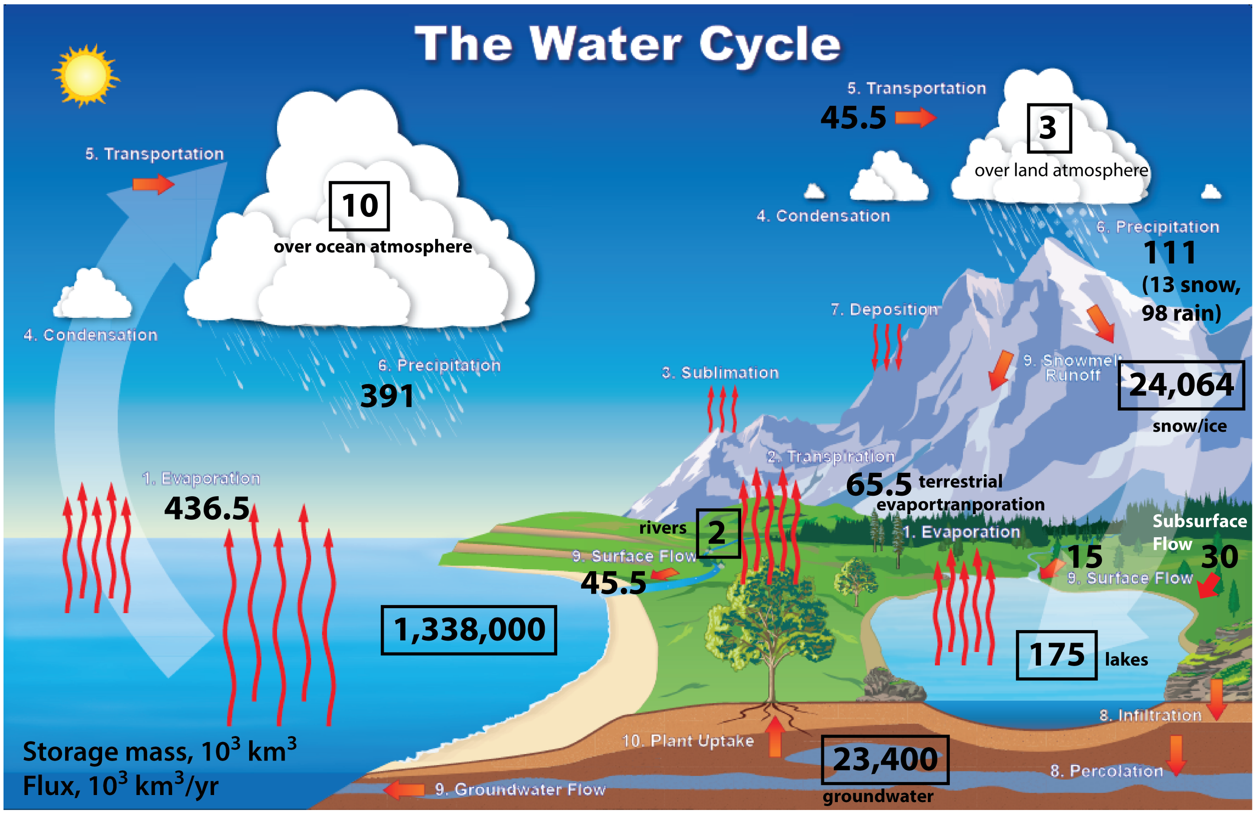
## Exercises

This unit is composed of a series of exercises to familiarize you with the reservoirs, fluxes, and residence times for the various components of the hydrological cycle. This information is critical for establishing a framework within which to place the competing societal demands on the fresh water reservoirs that are accessible for use.

### A. Reservoirs, fluxes, and residence time

For any given reservoir one can consider that the fluxes and residence times are expected to have a variation that reflects local conditions such as the position, relative to global circulation patterns of the atmosphere and oceans as well as its location with respect to the margins or interior of the continents. It needs to be recognized that residence time within any given reservoir is going to be an average and not the minimum or maximum period that a single water molecule might spend in any given reservoir. It must also be recognized that there are fluxes both into and out of, all reservoirs and that variations in these fluxes also can have an impact on residence time. Additional information is available from online resources such as those of the USGS [http://water.usgs.gov/edu/watercyclesummary.html]

1. Based on the information provided in Figure 1, create a table that shows the reservoirs, fluxes and residence times for the various reservoirs in the hydrological cycle. Include calculations using both fluxes out of, and into, the various reservoirs. Show examples of your calculations. Hint: it may be easiest to create this table in a spreadsheet so you can embed the required calculations within the table.




Terrestrial water balance does not include Antarctica

Figure 1. Schematic representation of the hydrological cycle with reservoirs (in black boxes; given as mass, in $10^3$ km$^3$) and fluxes (given as $10^3$ km$^3$/year). The main reservoirs are, in decreasing amount: oceans, ice, ground water, lakes, atmosphere, and rivers. Many assumptions go into determining these fluxes and reservoir masses. Although other studies may give somewhat different numbers, the overall scale of the different residence times give a reasonable idea of where water resides for mere days-weeks or millennia. For simplicity, not all fluxes are included. Fluxes and reservoir masses taken from Oki & Kanae (2006). Base diagram from NOAA [http://www.noaa.gov/resource-collections/water-cycle]

2. Discuss the assumptions that were required to calculate the residence time and include specific comments about which reservoirs are most likely to have the highest uncertainty in the input parameters and how this impacts your calculated residence times.

3. Discuss how the location of any particular terrestrial reservoir is going to be dependent on the position of the region within the global atmospheric circulation cells, oceanic circulation, and orographic considerations. Discuss how specific locations might be connected or be influenced by adjacent regions.

## B. Reservoir storage variations

When considering terrestrial reservoirs one of the important aspects to remember is that these reservoirs have the potential to be highly variable on a seasonal basis. When this variation is coupled with inherent uncertainties in determining the storage capacity of these reservoirs the possibility of large uncertainties must be taken into account.

4. Create a list of the terrestrial reservoirs and discuss what variables probably control the storage capacities of each one.

5. For many localities in the western portions of the United States one of the principle reservoirs for water is snow. This reflects the fact the much of the precipitation occurs during the winter months. For this reason the NRCS has installed a network of snow monitoring sites referred to as SNOTEL sites. Eventually a portion of the snow will melt, the amount will depend on how much snow was added, the amount of residual snow from previous seasons, and the conditions during spring thaw. An example of a SNOTEL site that is situated within a watershed that also has a stream gaging station in reasonably close proximity is the Albro Lake SNOTEL site (NRCS Station ID: 916) and the Willow Creek gaging station near Harrison, MT (USGS 06035000) (Figure 2). Links are given below. Download the data for five years of data for these two sites and create a plot of the data from each site. It will probably be easiest to copy and paste all data into a single spreadsheet (possibly two different tabs) for plotting purposes.

- http://www.wcc.nrcs.usda.gov/nwcc/site?sitenum=916
  - Select Report Content
    - Snow Water Equivalent
    - Daily
    - cvs
    - View Historic: Year of interest (download 1 year at a time), Water Year, All days
- http://waterdata.usgs.gov/mt/nwis/uv/?site_no=06035000
  - Select: Gage height, Tab-separated, and appropriate begin and end dates.

6. Discuss the patterns that can be observed in both data sets.

7. What other reservoirs might be receiving water from the snowmelt that is taking place from the region around the Albro Lake site?

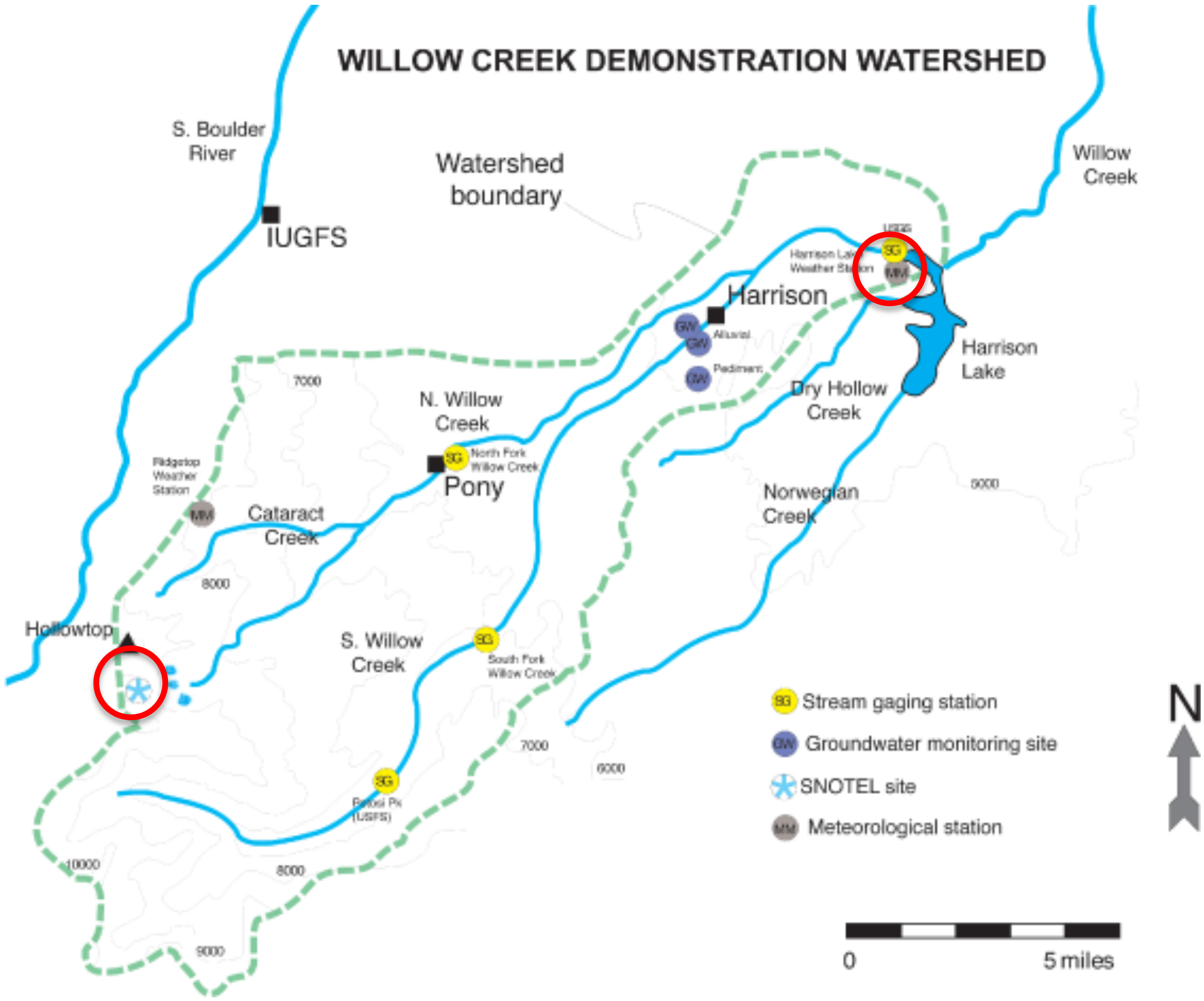



Figure 2. Willow Creek Demonstration Watershed. The watershed starts along the ridge crest of the Tobacco Root Mountains and extends down to the primary inflow into Harrison Lake, also known as the Willow Creek Reservoir. Red circles indicate the SNOTEL station and river gaging station that you will be analyzing data from. Details about the instruments within the watershed can be found on the WCDW website [http://www.indiana.edu/~iugfs/research_WC.html]

C. Water Budget Stakeholders

*Many different people and groups—stakeholders—affect and are affected by water resources. You will work with your classmates to do a water resources stakeholder analysis for the case study region that you read about.*

## Stakeholder Analysis

According to the Project Management Institute (PMI), the term *project stakeholder* refers to "an individual, group, or organization, who may affect, be affected by, or perceive itself to be affected by a decision, activity, or outcome of a project." The *purpose* of a Stakeholder Analysis is "to identify and understand different persons, groups, and institutions who will be positively or negatively impacted."

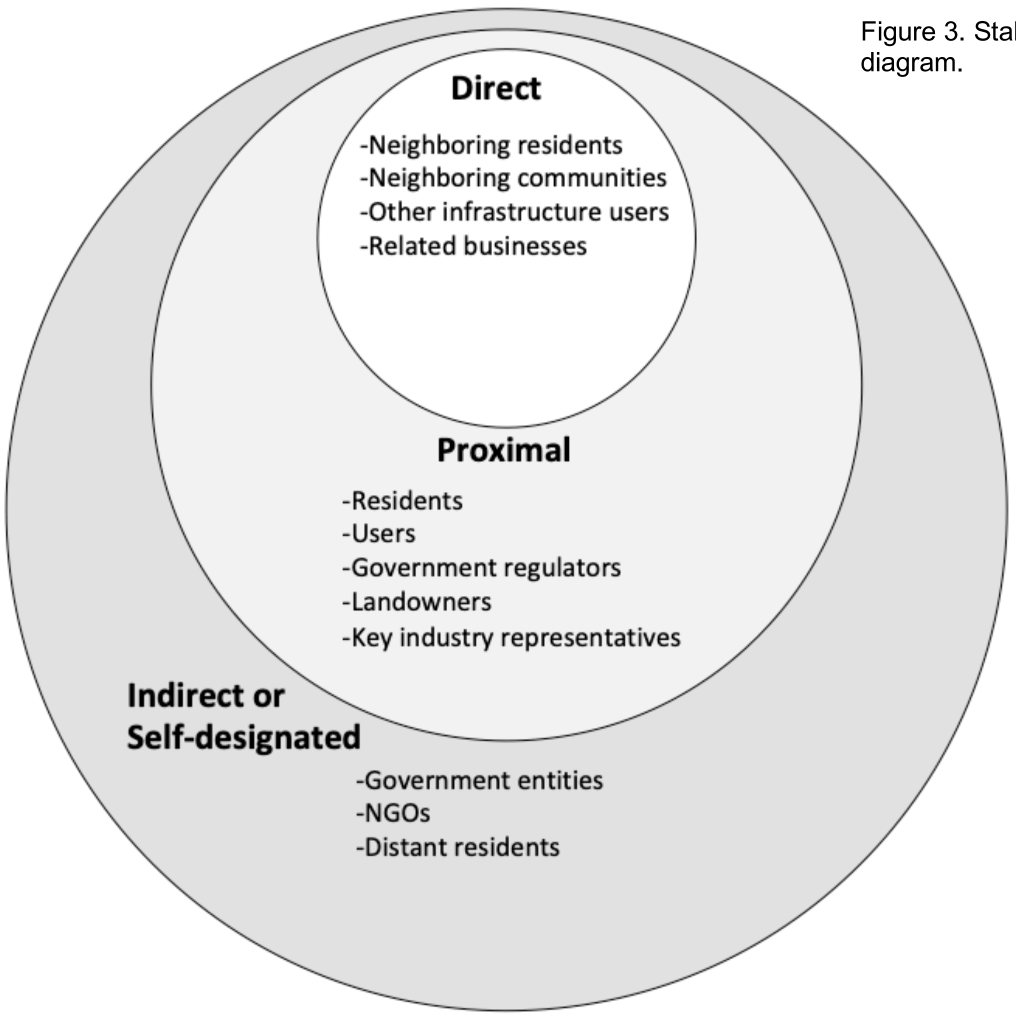



Figure 3. Stakeholder concept diagram.

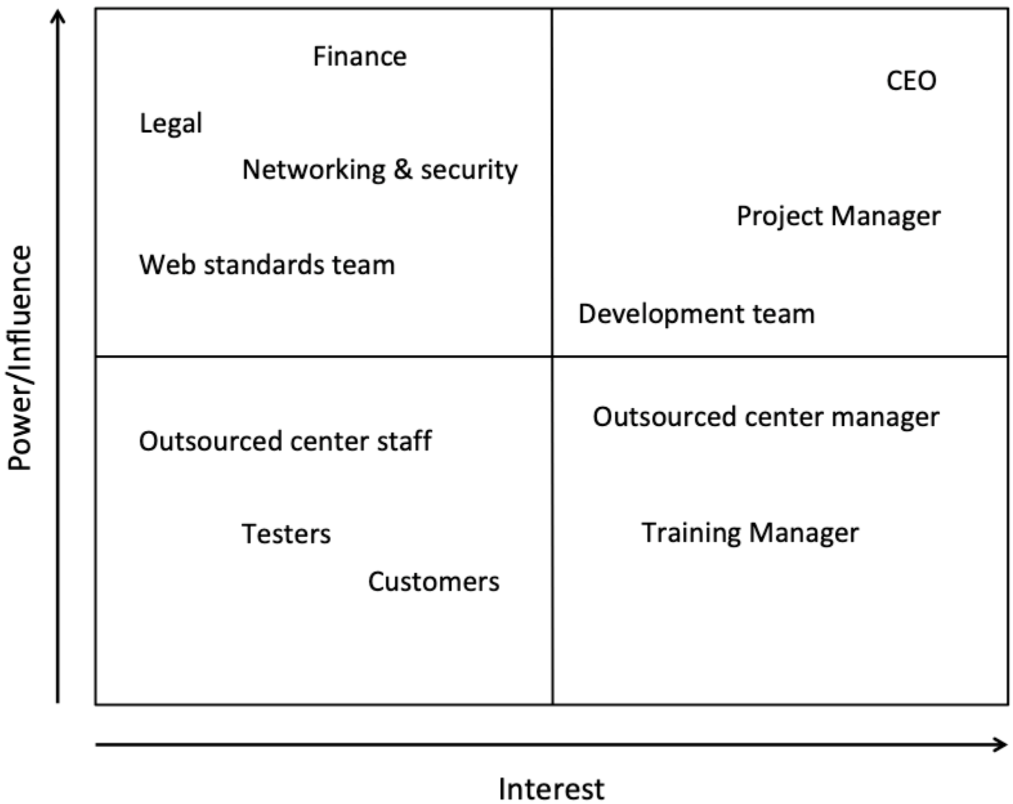



Figure 4. Example Stakeholder Cross Plot of Interest vs. Power/Influence.

Power/Influence can pertain to the ability to take action to adapt to and/or mitigate changes in water resources. Interest reflects the potential impacts of water resource changes on the stakeholder (how much could it affect them).

## Conducting a Stakeholder Analysis

Your groups will eventually be assigned to one of the stakeholder groups determined by the class. List the stakeholders decided on by the class.

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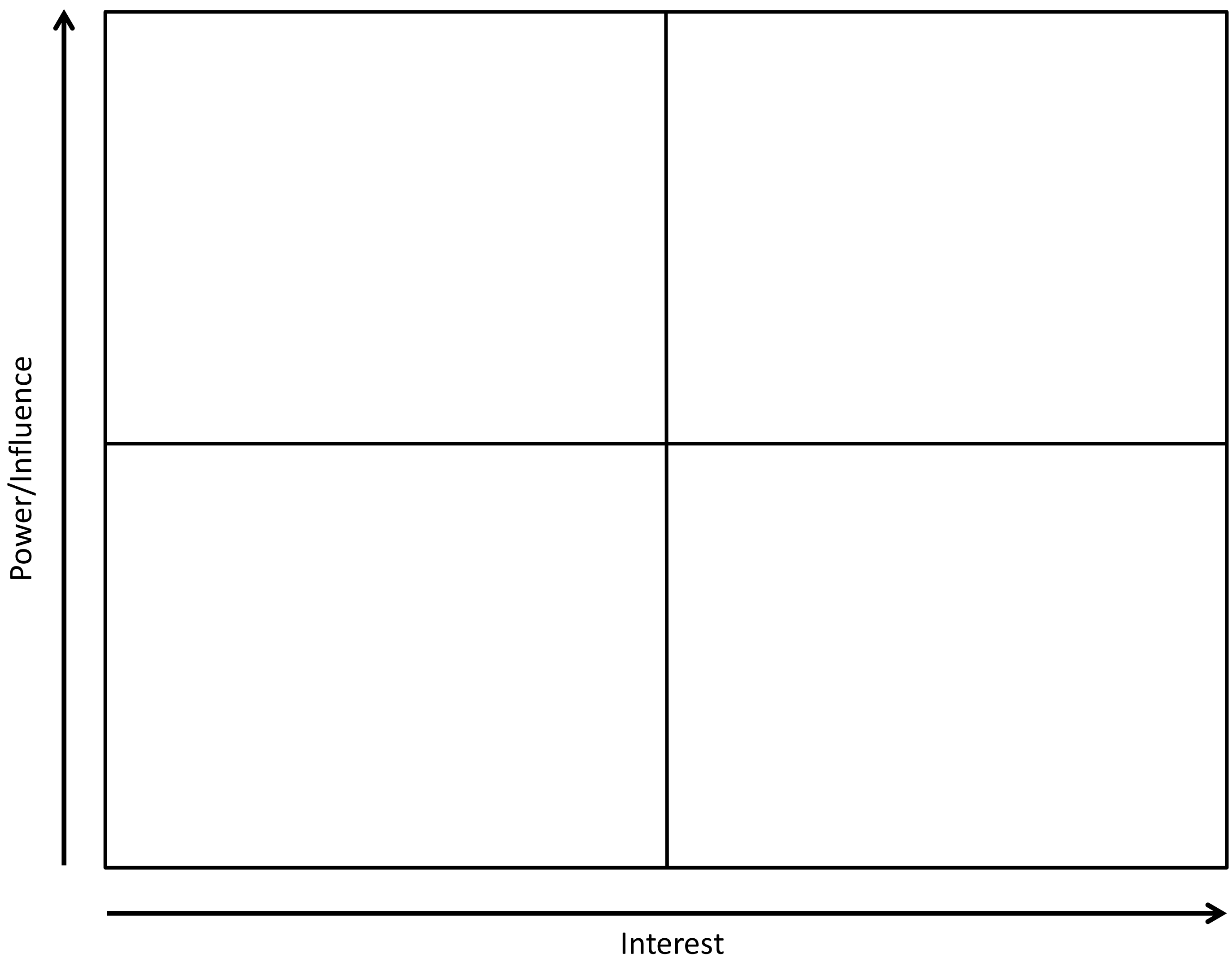


A) Discuss with your group and fill in the chart above based on the stakeholder list your class determines.

B) On the following page fill in a row of the chart for the stakeholder group that your team has been assigned.

C) Reflect on your experience doing a Stakeholder Analysis by completing one of the following questions:

- How has undertaking a stakeholder analysis affected your perspective on water resources and why?
- What surprised you most in undertaking a stakeholder analysis and why?
- What would you like to know more about regarding the societal impact of water resources?

| Stakeholders | Involvement in Issue | Impact of Issue on Stakeholder (high-med-low) | Interest in Issue (high-med-low) | Influence/Power (high-med-low) | Resources for Action or Ways to Engage |
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