The goal of this project is to improve the usage of available rainfall in the arid region of Tunisia through the installation of a storm water collection reservoir. These structures store rainwater to be used for irrigation and increase groundwater recharge. Current and indigenous water harvesting practices will be studied and local data compiled to be used in deriving and evaluating a suitable model for water harvesting structures in Tunisia. Due to the low rainfall in this area, the placement of these water harvesting structures is critical. Criteria for evaluating the site selection for these structures include: amount of runoff, storage potential, soil conditions, sediment accumulation, and impact of water use. We will use several hydrologic modeling programs, such as HEC-1 (hydrologic model) and WEPP (erosion prediction model, in order to predict runoff, sedimentation, and storage that are needed for the design. We will use the modeling applications to simulate the current water-harvesting structures in the watershed and their impact on the hydrology, sedimentology, and water use. Using the results of our simulation, we can determine the environmental impacts on the watershed as a whole by looking at runoff and sediment upstream and downstream of the reservoirs. The method developed for the evaluation of the water harvesting structures will be able to be applied to other watersheds. We will also evaluate the impacts on the local community in order to optimize cost and effectiveness of these structures. After designing and creating a viable model of the structure using the aforementioned software, we will compare our results with available data provided by the local research institute (IRA) to determine the effectiveness of our design.

A general overview of our design process begins with the local site and hydrologic data including soil types and infiltration rates. This allows us to compare the soil infiltration rates in relation to the topography of the watershed. This relationship will then allow us to study the amount of erosion that will occur in different areas of the watershed. Sediment distribution prediction is important because the sediments that are carried down the watershed will affect the permeability of the soil at the base of the structures as well as the storage potential of the structures. We will need to determine the effects of sediment buildup and determine how much clogging will occur.

GIS Data Acquisition and Modeling

The first step we took for our project was to use the sub-delineation tool in ArcView GIS in order to divide the watershed into sub-basins. The sub-delineation tool uses the topography of the land and determines the direction of flow of the runoff through the watershed. Once the flow direction was determined, the areas of accumulation were then determined. The areas of flow accumulation were then linked together using a stream representation. Once these layers were formed in the GIS project, we were able to create 17 sub-basins within the Hallouf watershed. These sub-basins allow us to associate properties such as the land use curve number to each sub-basin with more accuracy. The distribution of each land use and soil type in each sub-basin was also determined using the GIS software.
Once the sub delineation was done in GIS, we were able to follow the stream layer and determine the path of water flow through the watershed from the first sub-basin to the outlet. The path allows us to connect each of the sub-basins in HEC-1 and determine the cumulative runoff through the watershed. This linkage will be used along with the time of concentration to determine the time to peak flow for the entire watershed.

After the sub delineation was complete, the next step was to determine the appropriate values for the input parameters for each sub-basin. The first parameter was determined using the GIS software and excel to calculate a weighted curve number for each sub-basin. The original curve number data we received is defined using both land use and soil type and divides the year into three “seasons”. The weighted curve number was then calculated for the 17 sub-basins for all three seasons. Two of the seasons’ final curve numbers were found to be very close to one another for each sub-basin. The difference was minimal so the average was able to be taken and the varying curve numbers were reduced to two seasons for each sub-basin.

The second parameter we determined was the outlet elevation for each sub-basin. When using the GIS software, the cell input size was too large to be determined accurate if you simply choose the farthest downstream cell of the sub-basin. In order to increase the accuracy of our project, the average elevation was taken from the appropriate amount of cells at the outlet of each sub-basin.

**Calculation of Rainfall Input Data**

When using HEC-1, single storm information can be entered to determine the amount of runoff that occurs in a watershed. The storm input data we will use is based on a Type II rainfall event. The Type II rainfall event was chosen based off the fact Tuscan, Arizona is in the Type II region. This correlation had to be since we are using the SCS rainfall distribution method and this method was developed in the United States. We received the weather data for our watershed for six years. Included in this data were all measurements taken for any storm event within that time. The amount of rain for each event was determined and then ranked based on the amount of rain. The size of storm that you would have a 10%, 50% and 90% probability of experiencing in a 6 year period was then determined. These three amounts were then applied to the Type II storm event curve to determine the expected rainfall depth at any hour increment in a 24 hour time period. These three storm events will be inputted separately into HEC-1 in order to compare the amount of runoff that will be experienced throughout the watershed for each storm.

We will use the pond option in HEC-1 to represent the gabion structures. The dimensions of the pond will be determined by the topography of the land directly upstream from the gabions. This part will be completed once we receive additional information from our contacts in Tunisia.

The table below summarizes the simulations that will be completed: These simulations were chosen to represent the three existing gabions in the watershed and the possible runoff outcomes that may occur. This combination was sent to our contacts in Tunisia for verification and may be altered before the project is completed.
<table>
<thead>
<tr>
<th>Simulations</th>
<th>Included Gabions</th>
<th>Storms</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-3</td>
<td>No gabions included</td>
<td>One for each storm, using the Oct-June Curve Number</td>
</tr>
<tr>
<td>4</td>
<td>No gabions included</td>
<td>10% probability storm, since it’s the largest with the July-Sept Curve Number</td>
</tr>
<tr>
<td>5-7</td>
<td>Farthest downstream gabion</td>
<td>One for each storm, using the Oct-June Curve Number</td>
</tr>
<tr>
<td>8</td>
<td>Farthest downstream gabion</td>
<td>10% probability storm, since it’s the largest with the July-Sept Curve Number</td>
</tr>
<tr>
<td>9-11</td>
<td>Two furthest downstream gabions</td>
<td>One for each storm, using the Oct-June Curve Number</td>
</tr>
<tr>
<td>12</td>
<td>Two furthest downstream gabions</td>
<td>10% probability storm, since it’s the largest with the July-Sept Curve Number</td>
</tr>
<tr>
<td>13-15</td>
<td>All three existing gabions</td>
<td>One for each storm, using the Oct-June Curve Number</td>
</tr>
<tr>
<td>16</td>
<td>All three existing gabions</td>
<td>10% probability storm, since it’s the largest with the July-Sept Curve Number</td>
</tr>
</tbody>
</table>

The methodology for our entire senior design project is included on the following page. In order to fully understand the scope of the project we felt it was necessary to include the other design elements. Using the HEC-1 program will be an integral part of our capstone design project as this will allow us to better evaluate the overall impacts of the gabion structures on the surrounding watershed.

The next steps for the input parameters for each sub-basin included determining the area, time of concentration, the mean slope, and the length of each sub-basin. The time of concentration will be calculated twice for each sub-basin using the two different curve numbers, and then the length and average slope of the sub-basin. We will also need to determine the dimensions of the area that will be used as the pond representation for each of the existing gabions.

**WEPP Sedimentology Analysis**

In addition to the hydrologic analysis, we will construct a representative model of the watershed in the WEPP modeling software program. Before the simulations can be run, it will be necessary to define specific local parameters within the program including soil profiles and local climate from the Hallouf watershed. The soil profiles can be created within the program using provided soil data from our Tunisian contacts including soil properties such as the percentage of sand, silt and clay, and the depth of each soil layer. Next, the provided storm data will need to be transformed to fit the WEPP climate template. It will be necessary to consolidate the storm data by reducing the recorded rainfall times to one reading per minute as the WEPP software only recognizes hours and fractions of hours. Then, the daily temperature data provided will need to be averaged to produce one year of maximum and minimum temperature data. Using this climate and temperature data, the values can then be applied to the WEPP climate template to develop a weather system specific to Tunisia. Any climate information not provided by our contacts in Tunisia will be supplemented with climate data from Tucson, Arizona.
After the soil profiles and local climate data are generated for the software, we can begin the method to represent the watershed within WEPP. The representation will be done using the watershed interface in WEPP. We will represent the sub-basins using an equivalent area rectangle in the software. These rectangular sub-basins will then be connected by channels to route the water to each of the gabions. The gabions will also be represented by a channel in the WEPP program. After modeling is complete, the software will yield the calculated soil loss and sediment yield for the watershed.

Our analysis will include benefits of the gabion at the watershed level compared to the cost of implementing the project. Comparison of the watershed-scale gabion costs and benefits with the costs and benefits to the local scale water harvesting structure, known as the jessour, will also be made. The outcome of this work will be documented and shared with the local sponsors in order to quantify the benefits and costs of building water harvesting structures in the Hallouf Watershed in Tunisia.
Figure 1: Schematic of Design Methodology

Gabion Design Methodology

HEC-1 Modeling: Hydrologic modeling software tool
- Used for determination of runoff volumes

Economic Analysis
- Considerations:
  - Cost of water
  - Cost of structure
  - Cost of labor/maintenance

WEPP Modeling: Sedimentology modeling software
- Used to determine sediments lost
  - Considerations:
    - Varying soil types and respective conductivity values
    - Volume of water contained

Upstream Watershed Sub-basins
- Use weighted CN from land use data within each sub-basin considering area of each type

Area directly upstream of gabion
- Considerations:
  - Pond representation
  - Varying soil types
  - Use land elevations for pond dimensions

Economically feasible gabion design such that it maximizes infiltration, minimizes sediment loss, and permits water flow downstream of structure
HEC-1 Hydrologic Analysis for Hallouf Watershed

Gathering Inputs for simulations from GIS software

Sub-delineation of Watershed

Average Slope for Each sub-basin

Exit Elevation for Each sub-basin

Total Area for Each Sub-basin

Maximum length of sub-basin to outlet

Weighted CN for each Sub-basin using Land use

Analysis

Simulation Combinations that Will be completed

1-3 No gabions Included, one for each storm, using Oct – June Curve Number

5-7 One gabion Included, one for each Storm, using Oct – June Curve Number

9-11 Two gabions Included, one for each Storm, using Oct – June Curve Number

13-15 Three gabions Included, one for each Storm, using Oct – June Curve Number

4 No gabions Included, 10% Prob. Storm, using July – Sep Curve Number

8 One gabions Included, 10% Prob. Storm, using July - Sep Curve Number

12 Two gabions Included, 10% Prob. Storm, using July – Sep Curve Number

16 Three gabions Included, 10% Prob. Storm, using July – Sep Curve Number

Characteristics to be considered

Effect on watershed’s Time of concentration By adding a gabion

Total Volume of Runoff for each Sub-basin

Determine the appropriate Amount of runoff that needs To be left for use

Determine the effect Of adding a fourth Gabion to the watershed

Final Recommendations

Figure 2: Schematic outline of HEC-1 Hydrologic Analysis
Figure 3: Schematic of WEPP Modeling: Sedimentology Analysis

- Gathering inputs from storm and temperature data
- Gathering inputs for simulations from GIS software
  - Sub-delineation of Watershed
    - Determination of the area of each sub-basin
    - Weighted curve number for each
  - Analysis
    - Create watershed sub-basins in sequential order connected by
    - Run 3 simulations: Each including sub-basins upstream of gabion
      - Compare soil loss to calculated USLE for comparison
Literature List:


Oussser, Mohamed, and Gabriels, Donald. “Soil and Water Management in the Dry Regions of Tunisia: Prospects of Building on Traditions.”


