Using ArcGIS to Study the New Lakes in the Toshka Basin in Egypt and Evaluate Egypt's New Valley Project

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Brief Description: In this assignment, students use ArcGIS to analyze the new lakes that have formed in the Toshka Depression, Egypt as a result of overflow from Lake Nasser and use their analyses to evaluate the wisdom of the plan to bypass the Toshka Lakes in developing the New Valley Project for irrigation in the Western Desert of Egypt.

Context: This exercise is part of an introductory geology course called Geology and Human Events in Africa and the Middle East. The course focuses on the underlying influence of geology and geologic processes on human events.

Prerequisite skills: Students must have basic ArcGIS skills and be able to work with DEMs in ArcMap, create and manipulate hillshades, manipulate layers in ArcGIS, and create map layouts.

Where situated in the course: This exercise takes place about half way through the course.

Concept goals: Students will consolidate concepts related to desert hydrogeology, water use in a dry climate, and hydropolicy.

Higher order thinking skills goals: Students will determine what questions they want to have answers to and how to do the GIS analyses to find the answers. Ultimately, they will use the analyses that they have done to independently evaluate Egypt's New Valley Project.

Other skills goals: Students will practice GIS skills learned in previous assignments.

Description: In 1978, the Egyptians constructed a canal known as the Toshka Spillway from Lake Nasser into a low area to the west to allow spillover of Lake Nasser water. Despite the fact that the spillway was created in 1978, it wasn't until the late 1990s that Lake Nasser actually filled up to the level of the spillway canal and the overflow lakes began to form. In November of 1998, US astronauts orbiting in the Space Shuttle noticed the lakes filling for the first time, and they have had water in them ever since.

Egypt has embarked on a long-term and far-reaching irrigation plan to create habitable land away from the Nile River Valley. The Toshka Lakes are not, however, a formal part of the project. One of the main points of the exercise is to have students use both their knowledge of Saharan hydrogeology and GIS analyses to evaluate whether the Egyptians are wise not to use the lakes as part of the proposed system of water distribution.

In this exercise, students download and prepare their own SRTM DEMs and learn how to determine areas and volumes using ArcGIS. They can then ask questions and use ArcGIS to determine the answers. How much water is in the Toshka Lakes? What happens if Lake Nasser rises and more water flows down the canal? Will more lakes form, or will the lakes that are there just get bigger? How much water might be evaporating from the lake surfaces? How much water has to flow down the canal to keep the lakes at a particular level? What might happen as the annual Nile flood fluctuates from year to year?

The document posted for downloading contains two homework assignments, two in-class activities, and a wrap-up assignment.

Evaluation: Students will be evaluated on the basis of the thoroughness and accuracy of their GIS analyses, on the questions they ask and how they answer them using GIS, and on their overall assessments of the Toshka Lakes with respect to the New Valley Project.

NOTE: Occasional blank pages are deliberate and allow the document to be printed double-sided and still have the first page of each assignment start on an odd-numbered page.

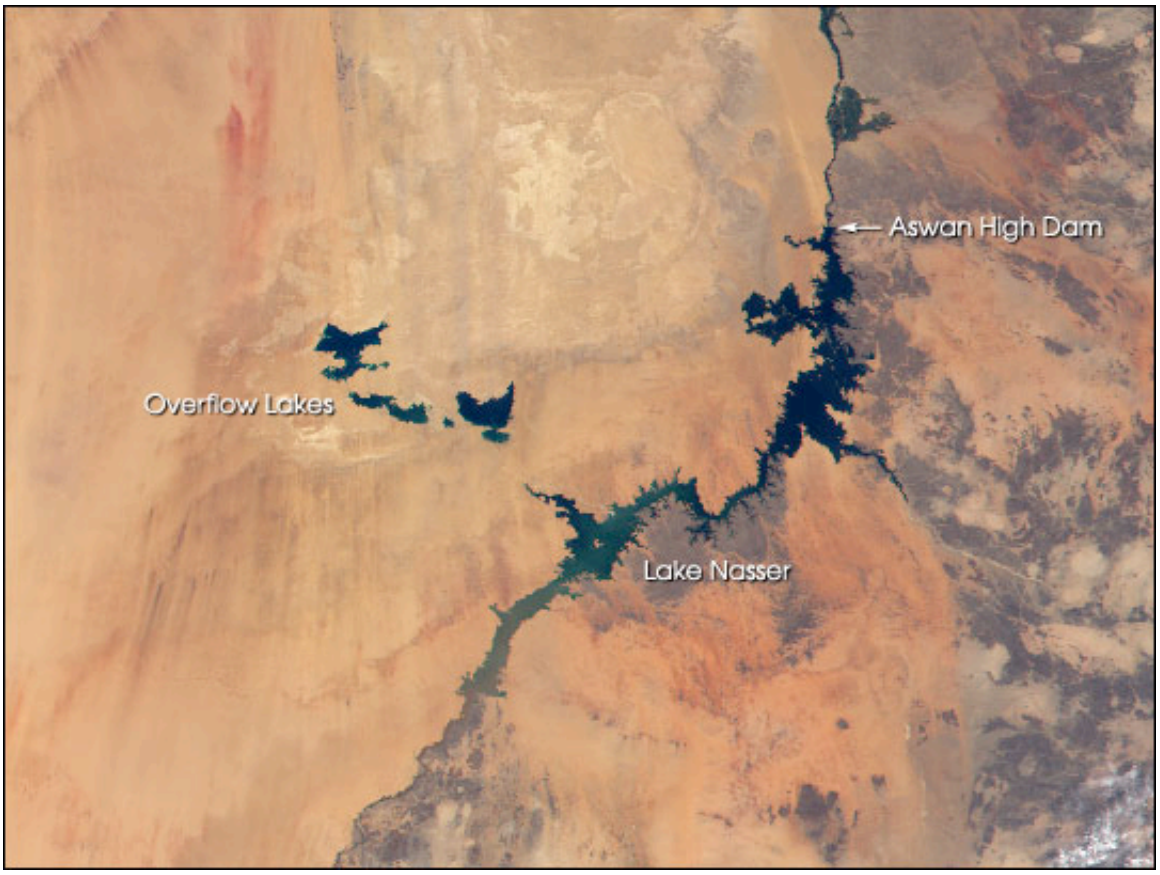
Preparatory Homework Assignment

Name _____ **The Toshka Lakes**

Due Wednesday, Oct. 10

Below, you'll see an October 2000 NASA satellite image of Lake Nasser and the Western Desert of Egypt. What's really striking in the image are the four lakes, known as the Toshka Lakes, that lie west of Lake Nasser. In 1978, the Egyptians constructed a canal known as the Toshka Spillway or Sadat Canal from Lake Nasser into a low area to the west to allow spillover of Lake Nasser water if the reservoir filled above 178 m. Despite the fact that the spillway was created in 1978, it wasn't until the late 1990s that Lake Nasser actually filled up to the level of the spillway canal and the overflow lakes began to form. In November of 1998, US astronauts orbiting in the Space Shuttle noticed the lakes filling for the first time, and they have had water in them ever since.

On the next page, you'll see close-up views of the Toshka Depression in 1987 and in 2004.

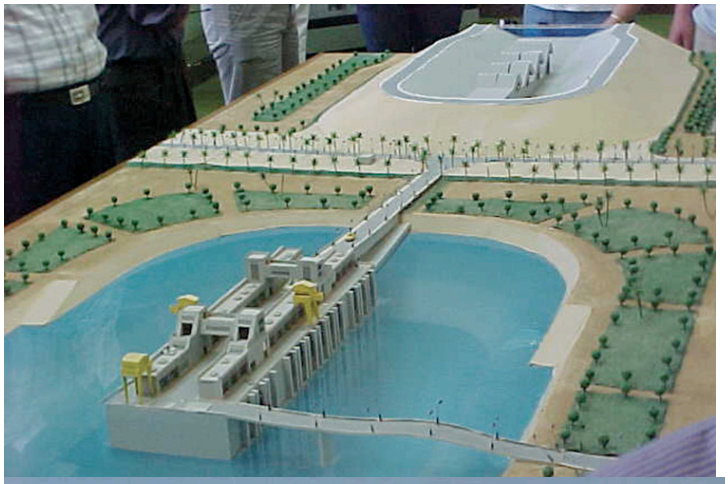


7/9/08 Barbara and Dave Tewksbu

Egypt's New Valley Project

Egypt has embarked on a long-term and far-reaching irrigation plan to create habitable land away from the Nile River Valley. The region involved extends from the western side of Lake Nasser near Toshka Khour (the long arm of Lake Nasser that "points" toward the Toshka Lakes on the satellite image, also labeled on the map on page 5), stretches across the Toshka Depression, and extends north along the old Darb el-Arba'in through the oases of Baris and El-Kharga. All of these places are labeled on the map on page 5. The Darb el-Arba'in, or the Route of the Forty Days, is one of the old trade routes through the Sahara and connects Assiut on the Nile with the Darfur region in the Sudan. The project will ultimately re-direct into the New Valley about 10% of the 55.5 billion m^3 allotted to Egypt out of the flow of the Nile River. The project may eventually extend to the oasis of El-Oweinat on the Egyptian/Libyan border and Dakhla Oasis west of El-Kharga.

The plan has several components and phases:



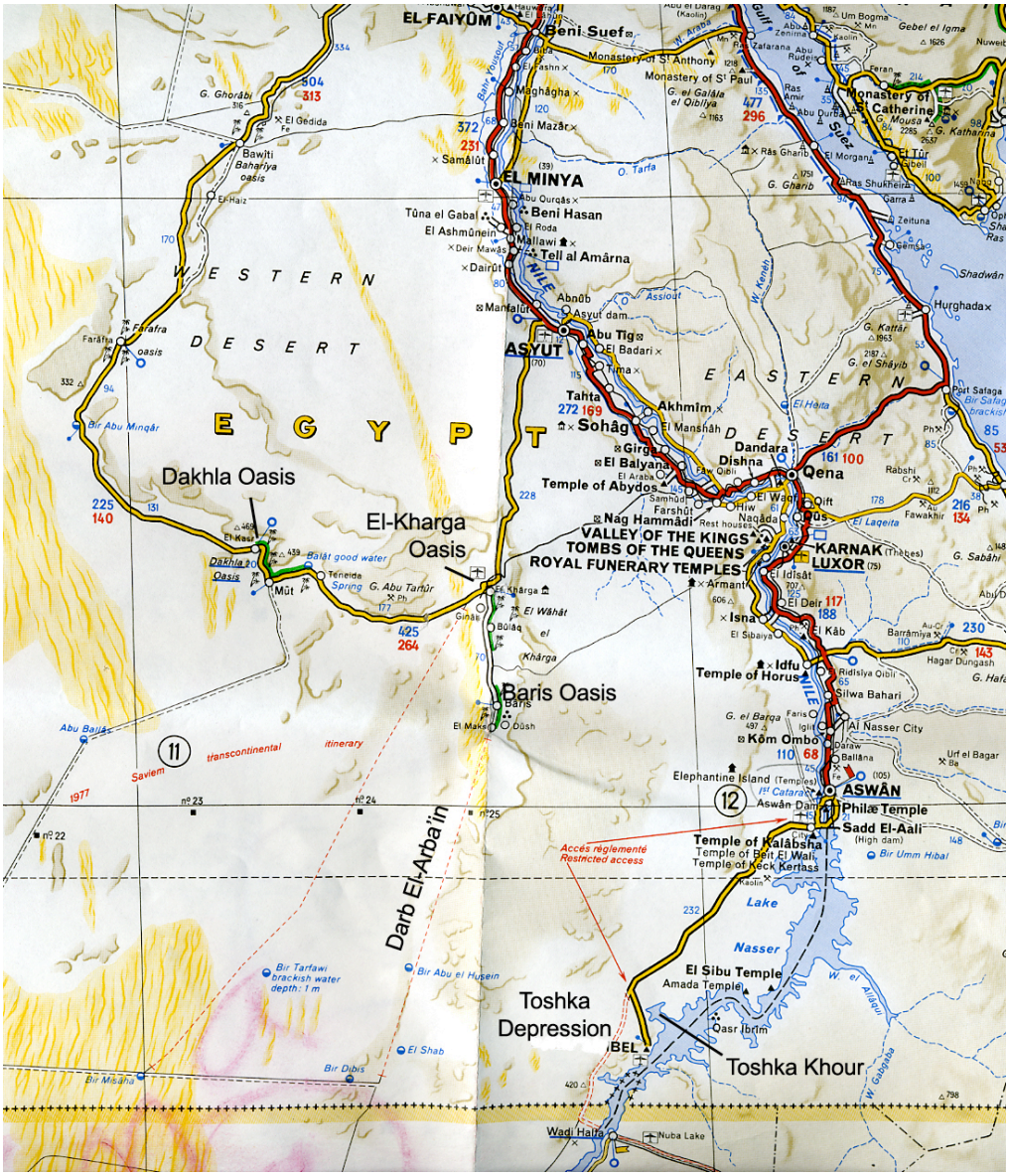
- The Mubarak Pumping Station (right[1]), which went on line in March of 2005 and is currently pumping 14 million m^3/day out of Lake Nasser just north of the Toshka Khour and into a canal system that delivers the water to fields in the Toshka depression.
- The Sheikh Zayed Canal (below right), funded by a $100 million donation by Sheikh Zayed Bin Sultan El Nahayan, president of the United Arab Emirates, through the Abu Dhabi Development Fund. This canal has four branches and is currently carrying irrigation water along a 50 km main transfer canal and feeding it to four 22 km long branches that, in turn, carry water to fields south and east of the Toshka Lakes for irrigation. This part of the project is complete.
- The Toshka Lakes, which are an accident of the overflow of Lake Nasser but will be used to irrigate lake-side agricultural projects.
- A canal that will be built westward from the Sheikh Zayed Canal until it intersects with the route of the old Darb el-Arba'in and then extended northward to bring water to Baris and El-Kharga

[1] Images from http://na.unep.net/digital_atlas2/webatlas.php?id=130

Oases, a distance of several hundred kilometers. As far as I have been able to determine, this phase of the plan is scheduled for completion in about 2017.

- Groundwater wells in Baris and El-Kharga Oases to provide water for irrigation (one figure I read suggested 7.5 billion m^3/year, but that sounds high to me, because the ultimate goal of Libya's entire Great Man-Made River Project is about 6.5 billion m^3/year).
- Recycling of agricultural drainage water in the irrigated areas.

We'll read more about this whole project later, but, for now, we'll use Google Earth to explore the area and use ArcMap to focus on the Toshka Lakes, which are an interesting side light of the New Valley Project.



Google Earth Exploration of the New Valley area

Go to Google Earth, and center the globe on Egypt. Zoom in to southern Egypt, and be sure that you can see the Nile Valley and floodplain as far north as the Qena Bend, Lake Nasser as far south as the Sudanese border, and the Toshka Lakes. If north is not straight up on the screen, click on the "N" to reset north.

Let's start by zooming in on the area of the Toshka Khour. Navigate to the end of Toshka Khour, and zoom in on the Toshka Spillway. In this set of satellite images, it is largely dry, but you can easily trace it into the first of the Toshka Lakes.

Zoom out, and pan to where Toshka Khour widens into Lake Nasser. Just north along the Lake Nasser shoreline, you'll see a distinct area that shows a canal stretching right to the shore. The quasi-circular structure toward the end of the small grayish peninsula (22°38'11.85"N, 31° 51'32.11"E) is the Mubarak Pumping Station under construction. Follow the Sheikh Zayed canal to the west, where it crosses the Toshka Spillway, and ends (this is not 2006 satellite imagery). What struck you as you looked at this area?

Zoom out so that you can see the original area from the Qena Bend to the Sudan border. Let's find El-Kharga Oasis, where the main canal will eventually end. Type the following lat/lon into the "Fly to" box: 25 26 08.17N, 30 33 22.85E), and fly to this spot. Stop the zoom-in when you can see the features of El-Kharga oasis. As you can see, most of the oasis is pretty sandy, except for the irrigated fields (which are dark). What strikes you about the oasis?

Locate the main road out of El-Kharga to the south. scroll along and follow the road to the south. This road follows the old Darb El-Arba'in, the trade and slave route mentioned earlier. Notice the fantastic barchan dunes in the desert on either side of the road. Consult your textbook. What is the prevailing wind direction in this area, based on the horns of the barchan dunes?

Baris Oasis lies at about 24° 39' 16.18"N, 30° 35' 43.78"E. At about 24° 19'N, 30° 38' E, the road swings to the SW. You'll notice that the road has been re-routed in several places along this stretch. What caused the re-routing? Is this fantastic, or what??

Continue following the road south to about 23° 20'N, 30° 00'E. What has struck you along the route?

At this point, zoom out until you can see the Toshka Lakes and the location of the Sheikh Zayed Canal. The New Valley Project will connect the Sheikh Zayed Canal with El-Kharga Oasis along the route of the Darb El-Arba'in. Wow!

What has struck you about your exploration of this entire area?

Downloading Shuttle Radar Topography Mission DEMs

Before class on Wednesday, you need to do two things:

- Go to your folder on the Academic Software server and delete all of your old GIS stuff ***except*** your Nile floodplain/channel stuff. This will give you enough space to do the work we're going to do in Egypt.
- Download and prep a DEM for the Toshka Depression and save it to your folder so that you're ready to work in class on Wednesday night. The following instructions tell you how to download the data and get it ready.

The SRTM (Shuttle Radar Topography Mission) data base is a remarkable worldwide digital elevation data set for about 80% of the Earth's land surface. It took 10 days (only 10 days!!) to collect all of the data! The data set covers all land areas between 60°N and 56°S latitude (higher latitudes were excluded because of the inclination of the Shuttle orbit, which was 56°. The resolution of SRTM data is 30 m/pixel for the highest resolution data. The mission was flown in February of 2000, and one of the mission specialists, Janet Kavandi, was also on the mission that flew in July 2001 that flew the Hamilton College banner that's hanging in the classroom.

The CGIAR/Consortium for Spatial Information has processed Shuttle Radar Topography Data for the world to eliminate any blank pixels, etc. It's much easier to get the data from this site than to go to the

USGS site and deal with the raw data, which you would have to process to remove blank pixels before you could do, for example, a hillshade. If you were doing a research project, you'd want the original data, but, for what we're doing, this is a great and fast way to get SRTM data to work with. Go to the CGIAR site at http://srtm.csi.cgiar.org/

In the left hand link list, click on **SRTM Data Search and Download**

- On the page that comes up, you'll see a map of the world with a grid on it (http://srtm.csi.cgiar.org/SELECTION/inputCoord.asp), This grid outlines tiles of SRTM data. Check to make sure that the **GeoTIFF** radio button is checked. Use the maps and satellite images earlier in this handout to locate which tile likely has the Toshka area on it. Choose your tile(s), and click on the tile(s) that you want.
- You should be able to easily tell from the thumbnail of the DEM whether you have the right area or not. If you've picked the wrong one, click **Clear Area.** Once you're satisfied, click **Search**. Another page will come up with tile details and a location map. If the area isn't what you want, just go back and try again.
- When you're happy, select **Data Download (FTP)**, and save the zipped file to your folder. **Do not save the file to the desktop, because ArcGIS does not like files saved to the desktop. Note**: CGIAR has three servers, one in the US, one in Italy, and one in the UK. If you find that the data are taking a long time to download, go back to the Search page, select a different server, and try downloading again.
- To unzip the data, navigate to the folder, and right click on the folder. Select **Extract all**, and save it to your folder.
- Now, **you must build an attribute table** for the DEM that you have downloaded:
    - The following **must be done in ArcCatalog, not in ArcMap.**
    - Open **ArcCatalog**, and open **ArcToolbox** (the red toolbox icon).
    - Click on **Data Management Tools**, **Raster**, and **Calculate Statistics**. Click the folder next to Input Raster Data Set, and browse to locate your DEM. Leave all the other values as they are, and click OK.
    - Your DEM is now ready to add to an ArcMap.

Projecting your SRTM DEM so that you can create a hillshade

You will need to project your SRTM DEM before you can hillshade it. The locations of pixels in your DEM are specified in decimal degrees. The mathematical equation that ArcMap uses to create a hillshade, however, assumes that pixel locations are specified in meters within a particular projection. If you try to make a hillshade from the unprojected SRTM DEM data, it will be all screwy. So, you need to project the DEM first so that X, Y, and Z are all in meters.

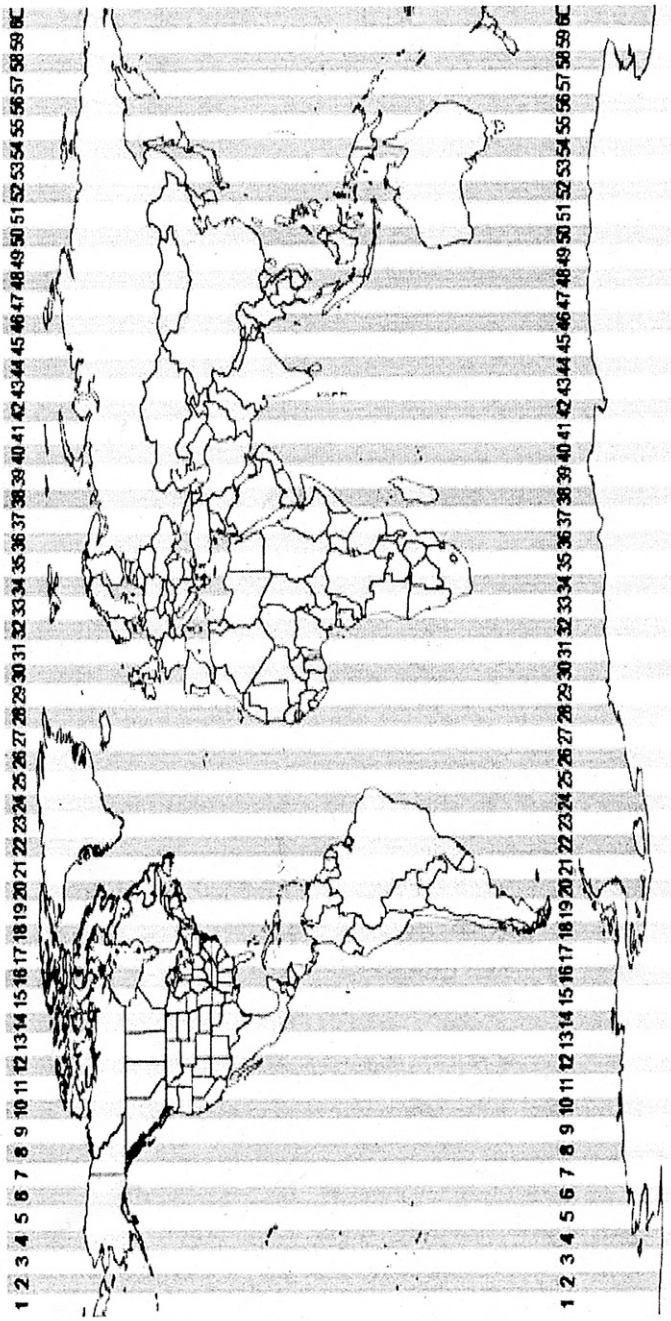
- Open a new ArcMap map, and start by changing the data options to **Save relative pathways** (File/Map Properties/Data Options). **You must remember to do this before you add your first data layer.** Once you've changed to relative pathways, add your DEM.
- Click on **ArcToolbox** (the red toolbox in the menubar) to open up the Tools. Open **Data Management Tools, Projections and Transformations, Raster,** and finally **Project Raster**.

- For **Input Raster**, browse to your SRTM tiff file. You can leave the output raster name as it's automatically put in, although you should check to make sure that the name is **short** and without spaces. If the name is too long, shorten it.
- Click on the button to the right of **Output coordinate system**, and choose **Select**. Select **Projected Coordinate Sytems/Utm/Wgs1984.** Now, you'll need to find the right UTM zone. Use the map on page 9 to determine the UTM zone, and select N, if you are north of the equator, and S if you are south (*e.g.*, Cairo is UTM Zone 36N). Select the correct zone, and click OK, then OK again.
- ****Check the Output Cell Size box.*** If is says **NULL**, type **90** into the box in place of NULL. Click **OK again** for all your selections and again to project the raster. Wait while the **Executing Project Raster** dialog box is busy. Close when done.
- **ArcMap will automatically add your projected raster to the layers in your TOC, and it will store your projected raster in the same folder as the DEM.** Toggling back and forth will show you the difference between the projected raster and the original. Remove the original raster (right-click on the layer, and select remove).

Be sure to copy everything back to your folder on the Academic Software Server. You're now ready for class.

UTM Zone Map

UTM Zone	Central Meridian	Longitude Range
1	177W	180W-174W
2	171W	174W-168W
3	165W	168W-162W
4	159W	162W-156W
5	153W	156W-150W
6	147W	150W-144W
7	141W	144W-138W
8	135W	138W-132W
9	129W	132W-126W
10	123W	126W-120W
11	117W	120W-114W
12	111W	114W-108W
13	105W	108W-102W
14	99W	102W-96W
15	93W	96W-90W
16	87W	90W-84W
17	81W	84W-78W
18	75W	78W-72W
19	69W	72W-66W
20	63W	66W-60W
21	57W	60W-54W
22	51W	54W-48W
23	45W	48W-42W
24	39W	42W-36W
25	33W	36W-30W
26	27W	30W-24W
27	21W	24W-18W
28	15W	18W-12W
29	9W	12W-6W
30	3W	6W-0
31	3E	0-6E
32	9E	6E-12E
33	15E	12E-18E
34	21E	18E-24E
35	27E	24E-30E
36	33E	30E-36E
37	39E	36E-42E
38	45E	42E-48E
39	51E	48E-54E
40	57E	54E-60E
41	63E	60E-66E
42	69E	66E-72E
43	75E	72E-78E
44	81E	78E-84E
45	87E	84E-90E
46	93E	90E-96E
47	99E	96E-102E
48	105E	102E-108E
49	111E	108E-114E
50	117E	114E-120E
51	123E	120E-126E
52	129E	126E-132E
53	135E	132E-138E
54	141E	138E-144E
55	147E	144E-150E
56	153E	150E-156E
57	159E	156E-162E
58	165E	162E-168E
59	171E	168E-174E
60	177E	174E-180E



Technical Reference Guide: UTM Zone Map

In-class activity

Name _____ **The Toshka Lakes**
Class, Wednesday, Oct. 10

Exploring the Toshka area using ArcMap

Open ArcCatalog, and copy the Toshka DEM in your folder on the software server to the C:\ drive.

- Preview the DEM in ArcCatalog to make sure it is the right one.
- Click the metadata tab in ArcCatalog, select the **Spatial** tab, and make sure that, under **Projected Coordinate System**, it says WGS_1984_UTM_36N. If it doesn't call me over.

Toshka DEM and hillshade

- Open ArcMap, and create a new map. As always, go to File, Map Properties, Data Source Options, and select **Store relative path names**. Save your new map to your C:\ drive (remember, **no spaces** in the name).
- Change the data frame name in the TOC to reflect the projection and coordinate system (see above).
- Add the 3D Analyst and Spatial Analyst Extensions (**Tools, Extensions, 3D Analyst**), and make the toolbars active if they aren't already (**View** menu, **Toolbars**, **3D Analyst**). Repeat for **Spatial Analyst**.
- Click the **Add Data** icon, add your Toshka DEM. Remind me that you know what the different shades of gray represent in this DEM:

- Change the display units to **Meters.** [Right click on **Layers** in the TOC, and select **Properties.** Choose the **General** tab, and scroll down to **Meters** in the Display menu. Click OK.]
- Lake Nasser is the large gray feature snaking from the center of the southern edge toward the NE corner of the DEM.
    - Zoom and pan around until you locate the Aswan High Dam.
    - Use the **measure** tool, and determine how long the AHD is: _____ m
    - Use the **identify** tool, and determine the elevation of the water surface of Lake Nasser when the Shuttle Radar Topography Mission was flown (2002): _____ m How does this compare to the level of Lake Nasser during the drought of the 1980s? How does it compare to the optimum operating level? How close is it to the max?

- Use the **identify** tool again to determine the level of the Nile downstream from Aswan: _____ m How much of a drop is there from Lake Nasser to normal river level? _____ m

- Find the long arm of Lake Nasser that extends NW from the west side of Lake Nasser toward the center of the DEM. As you know from the Google Earth part of this assignment, this is Toshka Khour. Zoom in on the NW end of this arm, and find the **Toshka Spillway,** or **Sadat Canal** (described at the start of this assignment).
- Make a hillshade for your DEM, and use a Z factor of 2. Remember to replace "Temporary" with a real file name, and save the hillshade to your data folder.
- What do the different shades of gray represent in this hillshade and how the shades of gray differ in meaning from those on the DEM?

Making a 3D model and flying through it

- Create a 3D model of the area using Arc Scene, and explore the Toshka area. You'll need to set the vertical exaggeration in be able to see much of anything. 10 is actually pretty good.
- Remember that the more clicks, the faster you go. Right clicking slows you down until you stop. Then, right clicking more flies you away from the scene etc. etc. If you get going too fast, click the other button repeatedly until you slow down and stop (the seagull stands on the ground). If all hell breaks loose and you go at warp speed through the model, hit the Esc button on the keyboard. If you've lost your model, just click on the globe tool to center the model again. Moving the seagull right, left, up, and down lets you fly up or down and turn right or left. Play around a bit.
- The major flat plateau north and northeast of the Toshka Lakes consists of Eocene limestones. The sharp, rather straight southern edge of the plateau coincides with the Kalabsha Fault. Fly your model again, and fly along the trace of the Kalabsha Fault. What is the significance of the Kalabsha Fault that you learned a few weeks ago?

- When you're done, close ArcScene, and return to ArcMap.

The Toshka Lakes

How much water is in the Toshka Lakes? What happens if Lake Nasser rises and more water flows down the canal? Will more lakes form, or will the lakes that are there get bigger? How much water might be evaporating from the lake surfaces? ArcMap can help us answer these questions!

Colorizing the hillshade

- We want to colorize our elevation model in ArcMap so that it's easier to visualize the elevations in map view. Should you colorize the hillshade or the original DEM? Explain.

- Colorize your elevation model,[2] and make the hillshade partially transparent. If you've done this correctly, the Toshka Lakes will be easy to see.

Elevations of the Toshka Lakes

- Zoom in on the Toshka Lakes area, and make sure that you can see all four Toska Lakes and the channels that connect them. The Toshka Lakes have not yet been named, so we will just call them Lakes 1 through 4 as follows:
    - Lake 1: at the end of the canal, is shaped like a corset; has a peninsula almost cutting off the waist.
    - Lake 2: the smallest of the lakes, lies west of lake #1.
    - Lake 3: west of lake 2.
    - Lake 4: northwest of lake 3 with a rounded bite out of the SE side.
- Use the **Identify** tool to determine the following elevations. **Remember that you must select your DEM layer in the pulldown menu of the Identify Results dialog box**. If you do not do this, ArcMap will automatically select the topmost layer, which is your hillshade. If you fail to select the DEM, the values that you determine will be gray scale shades on the hillshade, not elevations on the DEM.
    - Elevation of Lake Nasser in the khour (arm) near the canal: _____m
    - Elevation of Lake 1: _____m
    - Elevation of Lake 2: _____m
    - Elevation of Lake 3: _____m
    - Elevation of Lake 4: _____m

    Are the colors of the lakes in this color ramp view consistent with the elevations that you have determined?

[2] Short cuts to getting to properties and the Elevation #1 color ramp: double-click on the layer name in the TOC. Click Symbology, right click on the gray bar and choose **Graphic View**; type an "e". Click OK. If you screw up and colorize the wrong layer, go back and select black to white.

What will happen to the levels of each of the lakes if Lake Nasser continues to add water through the Spillway? Explain your reasoning. Ignore evaporative losses for now.

Lake 1:

Lake 2:

Lake 3:

Lake 4:

Determining the surface areas of the Toshka Lakes

ArcMap can calculate the surface areas of the existing Toshka Lakes, but we need to tell ArcMap what areas to calculate. We'll do this by creating a polygon shape file and tracing the outline of each of the four lakes.

- Make a new shape file for each of your four lakes (page 23 in the Primer). Before you OK each new file, select **Edit**, to define the coordinate system. Select **Projected Coordinate System, UTM, WGS 1984, and UTM 36N** (matching the projection and coordinate system of your ArcMap). Click OK.
- Go back to your ArcMap file, and add your new shape files. Zoom in until Lake 1 fills the entire screen.
- Exract all of the pixels at or below the elevation of Lake #1 (page 31 in the Primer).
- On your shape file for Lake 1, make a polygon that traces the outline of the extracted pixels for Lake 1 (page 26 in the Primer). Be sure to save your edits.
- Extract pixels at the correct elevations for the other three lakes, and make polygons for each of the other lakes on their respective shape files, ignoring the small islands.
- Start by looking at the attribute table for one of your new lakes layers (right click in TOC and select Open Attribute Table). You'll notice that the lake is a polygon listed but that there are no data associated with it. You need to tell arc map to create a new attribute table and calculate the areas
- Calculate the area for each of the four lakes (page 35, starting with the second bullet under **Measuring Areas**). On the next page, write down the areas of your lakes, rounded to the nearest 1000 m^2.

Area of Lake 1: _____ m^2 or _____ km^2

Area of Lake 2: _____ m^2 or _____ km^2

Area of Lake 3: _____ m^2 or _____ km^2

Area of Lake 4: _____ m^2 or _____ km^2

Total surface area of the four lakes: _____ m^2 or _____ km^2

Sum the total areas of these lakes. How does this surface area compare to the surface area of Lake Nasser at the water level you determined on page 1? Use Data Table 20 in your notebook for info on Lake Nasser surface area at various water levels. Are you surprised?

In-class activity

Name _____ **Toshka Lakes GIS class**
Wednesday, Oct. 17

We'll start by finishing what we started on Friday before break.

Evaporation from the Toshka Lakes

How much water evaporates from the Toshka Lakes? ArcMap can help us figure this out. Start by opening the ArcMap you created earlier that has your DEM, hillshade, and lake shape files.

We have calculated annual evaporative losses in m^3 several times in this course. Figure out what formula you would want to use (do you want to multiply lake area by something? divide it by something? if so what?), and write it below:

Check your formula with me, and then use ArcMap to calculate how much water is being lost annually from each of the Toshka lakes by evaporation (Primer page 36). **In the 6th bullet, be sure to change it to read:** Right click the header in the evaporation field (the word **EVAP**). Select **Field Calculator**). What annual evaporative losses have you calculated for each lake?

Est. evaporation, Lake 1: _____ m^3 or _____ km^3 or _____ billion m^3

Est. evaporation, Lake 2: _____ m^3 or _____ km^3 or _____ billion m^3

Est. evaporation, Lake 3: _____ m^3 or _____ km^3 or _____ billion m^3

Est. evaporation, Lake 4: _____ m^3 or _____ km^3 or _____ billion m^3

Total estimated evaporative losses: _____ m^3 or _____ km^3 or _____ billion m^3

Zoom out until you can see the Toshka lakes and Lake Nasser. It is always important to step back and evaluate whether what you have calculated is reasonable or not, or whether you have made an error somewhere along the way (which is easy to do in ArcGIS). Are the numbers you have estimated for evaporation (and the areas you calculated earlier) reasonable relative to numbers you have used and/or

calculated for Lake Nasser as a whole, or do you think something is screwy? Explain, and be specific in your assessment.

Adding Water to the Toshka Lakes

Hopefully, you reasoned out earlier that continuing to add water from Lake Nasser in excess of evaporation losses will not change the levels of Lakes 1, 2, or 3 (except maybe temporarily if there's a sudden influx) but *will* cause the level of Lake 4 to rise. Lake 3 will rise only if Lake 4 becomes as high as Lake 3 and more water is added to the system. Will Lake 4 spill over into yet another lower basin, creating a new lake or lakes as it rises, or will it just fill up and eventually connect with Lake 4? ArcMap can tell us this, plus how much water it will take to accomplish it.

Use the **Identify results** tool to determine the elevation of Lake 4 (remember! you have to select DEM layer in the Identify Results pulldown!!): _____m

Suppose we raised the level of Lake 4 by 2 m. How much bigger would the lake be? Would it spill over into another lower basin? If we could find all of the pixels at and below 134 m, we could see how big the lake will be and whether it connects to other areas that have pixels at or below 134 m. Use ArcMap to select all of the pixels at and below 134 m, as you did earlier (page 31 in the Primer).

Your map now shows all of the pixels across the area that are at or below 134 m in elevation. If you turn this layer off and on, you can see how much Lake 4 has grown in size as the water level has gone up 2 m. It actually hasn't grown all that much, has it? Now let's see if Lake 4 has spilled over into an adjacent basin anywhere along its margins. Zoom in on Lake 4, and examine the lake edges. Is there any point at which the lake pixels connect continuously with pixels leading into an adjacent basin and indicate that Lake 4 can spill over into a new lake?

Repeat the process to make new layers at 2 m intervals from 134 m to the level of Lake 3. Color each extracted pixels layer a different color. When you get it narrowed down, do the intermediate 1 m interval to make sure that you have the minimum elevation for spillover. So, what did you determine about how high Lake 4 would have to rise in order to spill over to create a new lake, Lake 5? _____m Where will that lake be?

How much water would we have to add to the system to cause Lake 4 to overflow and start to fill Lake 5? ArcMap will let us determine that by calculating the volume of the lake basin between the current lake level (132 m) and the minimum overflow elevation that you have just determined.

You'll need your shape file that shows the outline of the current Lake 4 (at 132 m), and you'll need a new shape that shows the outline of Lake 4 at the higher lake level (where Lake 4 starts to spill over into Lake 5 basin).

- In ArcCatalog, create a new shape file, and call it something like lake4hi.
- In ArcMap, add a polygon to your new Lake4hi shapefile the shows the outline of the new, higher Lake 4. Calculate the area of this new lake as you did for your other lakes.

  What is the total area of the higher Lake 4? _____m^2

In order to calculate the volume of water added between the two lake levels, we need to extract elevation pixels from the DEM that lie directly under our new lake. Follow the instructions under **Measuring Volumes** starting on page 36 of the Primer. You don't need to make a new shapefile. Just be sure to use your new lake4hi shapefile.

Once you have extracted the pixels, you can ask ArcMap to calculate the volume above or below a given elevation within the area of the pixels. If you calculate the area below the level of lake4hi, you'll have the amount of water added between your new lake level and the "floor" of the DEM, which will be the old lake level at 132 m plus the surrounding ground surface that lies above 132 m but below your new lake level. Use the instructions on page 37 in the Primer to do this (starting half way down the page).

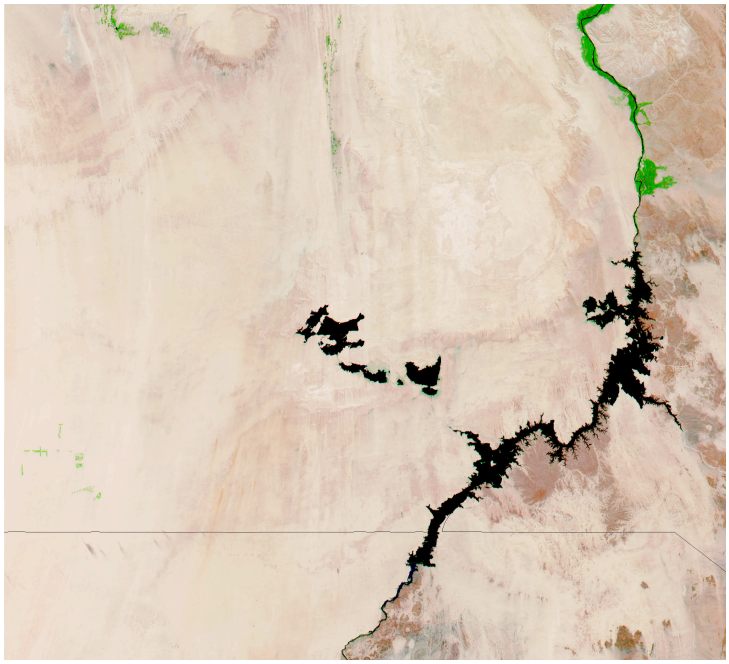
How much water had to be added to raise the lake level to the point at which it spilled over into Lake 5?

_____ m^3 or _____ km^3 or _____ billion m^3

Evaluate whether the numbers you've gotten are reasonable or not. Are you in the right ballpark? How could you independently get a ballpark number for comparison? Make a ballpark comparison, showing how you made your estimate.

Once you are certain you have a reasonable answer, are you surprised by the numbers? Explain.

Below, you'll see a MODIS satellite image of southern Egypt taken on January 26, 2003. If you compare it with the Shuttle image on the first page of your homework, you'll see that, between 1999 and 2003, Lake 4 did, in fact, overflow into a new Lake 5 to the NW! Because the Shuttle Radar Topography Mission was flown in 2000 before Lake 5 formed, we have elevation data for the bottom of the lake.



If we knew the elevation of the Lake 5 surface in early 2003, we could calculate the volume of water in the lake. We don't know what it is for certain, but you can make a pretty good estimate using your ArcMap file in conjunction with the 2003 satellite image.

Here's your task. Make a series of new layers that show pixels at various levels (**Extract by attribute**) until you find an elevation that fills Lake 5 to a level that visually matches the shoreline shape and islands as shown in the satellite image. Then, use ArcMap to calculate the area and volume of the new lake.

lake elevation to match satellite image: _____m

lake area at that elevation_____ m^2 or _____ km^2

lake volume _____ m^3 or _____ km^3 or _____ billion m^3

Are your numbers consistent with what you have determined for the other lakes? Explain.

Are you surprised by the numbers? Explain.

What is the maximum depth of Lake 5? That's easy to find out. Open the attribute table for your masked DEM chunk, and look at the list. The Value column shows elevations, and the Count column shows the number of pixels at that elevation. If you want to see where pixels of a given elevation are on the map, just click the very left hand box next to the row you're interested in, and the pixels at that elevation light up in cyan. If you want to clear all the selected things, just go to the main menu bar at the top of the screen under **Selection**, and choose **Clear Selected Features.**

Minimum elevation of the Lake 5 bottom: _____m

Maximum lake depth at the extent shown in the satellite image: _____m

What other questions might you ask about the Toshka Lakes area that you could use ArcMap to solve? Decide on a question, run it by me via email, and use ArcMap to figure out the answer to your question.

Homework Assignment

Name_____ **Toshka wrap-up and groundwater intro**
due Monday, Oct. 22

Finish your Toshka GIS work.

Read a bit more about the New Valley Project

This project is variously known as the New Valley Project, the Toshka Project, the South Egypt Development Project (Toshka and East Oweinat), and the South Valley Development Project. **On page 2, I've pasted the regional map that you had on a previous homework.** Here are a few web links to articles about the project:

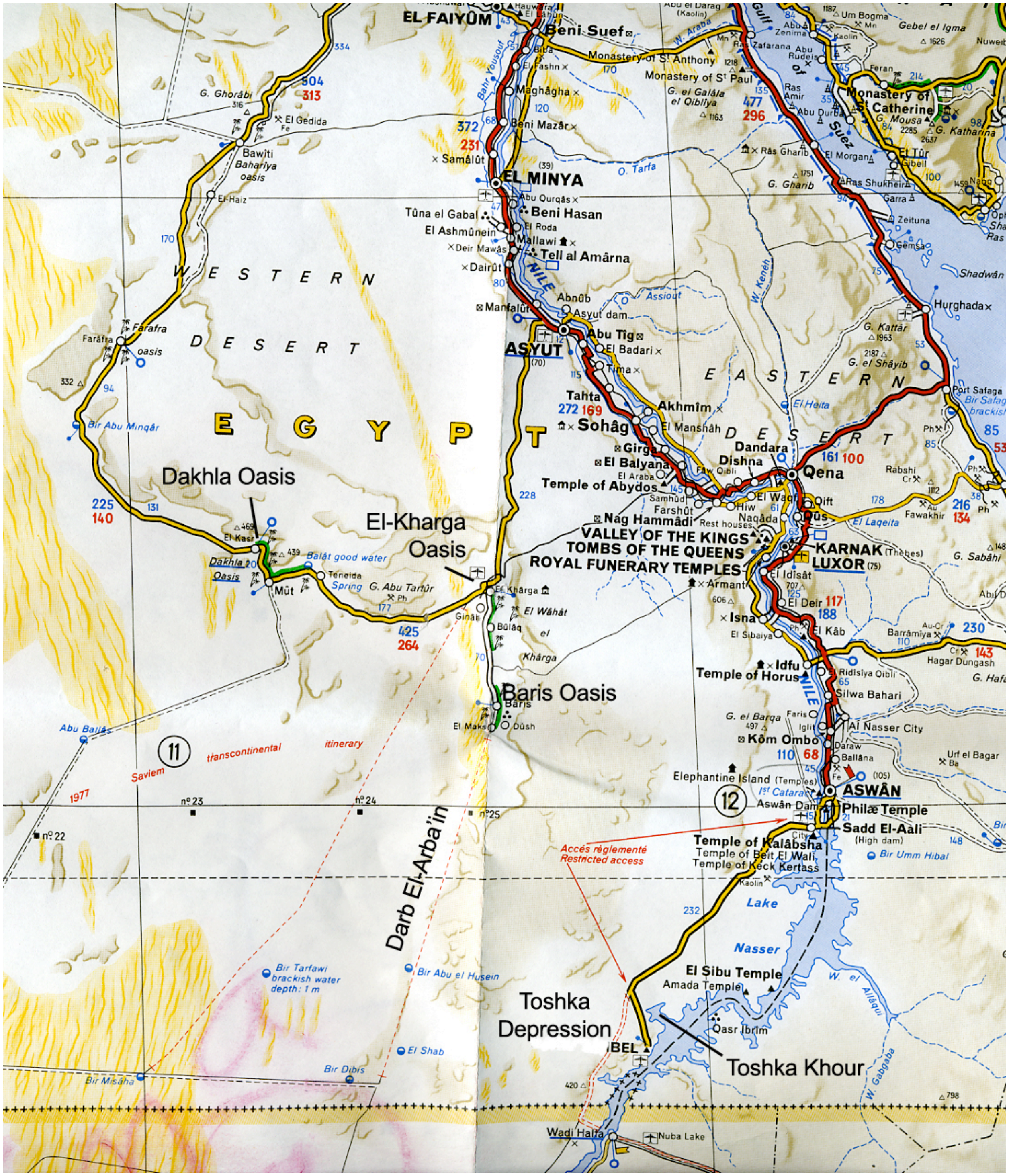
http://www.insnet.org/ins_headlines.rxml?id=4773 (news article, 2007)
http://www.forests.org/articles/reader.asp?linkid=85644 (news article, 2007)
http://www.mwri.gov.eg/english/sinai.asp (Egyptian ministry page)
http://strategis.ic.gc.ca/epic/site/imr-ri.nsf/en/gr114228e.html (Canadian govt, 2003)
http://www.islamonline.net/english/Science/2002/11/article05.shtml (news article, 2002)
http://www.amcham.org.eg/BSAC/StudiesSeries/report20.asp (American Chamber of Commerce in Egypt)

And a cool fly-through of the Toshka area before the lakes were formed (the flythrough goes right down the Kalabsha Fault):
http://www.utdallas.edu/geosciences/remsens/flythrough.html

And, **OMG**, wouldn't it be fab to stay at this place?!?!? http://www.desertlodge.net/ Be sure to browse the "Our Lodge" link and click on the rooms and facilities. And I do love the "how to reach us" options, which includes an 850 km private taxi ride from Cairo. Now, if I can just persuade Dave to go back to Egypt…….

Pros and Cons
What are the pros of the New Valley project?

What are the cons?


Dakhla Oasis
El-Kharga Oasis
Baris Oasis
Darb El-Arba'in
Toshka Depression
Toshka Khour
EL FAIYÛM
Beni Suef
EL MINYA
Beni Hasan
Tell al Amârna
ASYUT
Sohâg
Qena
VALLEY OF THE KINGS
TOMBS OF THE QUEENS
ROYAL FUNERARY TEMPLES
KARNAK (Thebes)
LUXOR
Temple of Abydos
Temple of Horus
Kôm Ombo
Elephantine Island (Temples)
ASWÂN
Philæ Temple
Sadd El-Aali (High dam)
Temple of Kalâbsha
Temple of Beit El Wali
Temple of Keck Kertass
Lake Nasser
El Sibu Temple
Amada Temple
Qasr Ibrim
Wadi Halfa
WESTERN DESERT
EASTERN DESERT
EGYPT
Bawiti Bahariya oasis
Farafra oasis
Mût
Accès réglementé
Restricted access
Saviem transcontinental itinerary
1977
Gulf of Suez
Monastery of St Catherine
Monastery of St Anthony
Monastery of St Paul
Hurghada
Port Safaga
NILE

Final In-class Activity

Name _____ **Toshka Lakes GIS class**
Monday, Oct. 22

What additional questions did all of you ask about the Toshka Lakes area, and what did you find out?

The Toshka Lakes are considered a bonus in the New Valley irrigation scheme and will be used for lakeside irrigation projects as long as Lake Nasser is high enough to have water flowing through the spillway. Think about what you know about the Nile River system. Would you expect that water would necessarily flow through the spillway year round? Explain what conditions would be required for year-round flow through the spillway.

How much water would have to flow down the spillway to keep the lakes at their January 2003 levels, even if none were taken out for irrigation?

In class last Wednesday, Zach wondered why the New Valley Project involves construction of a canal stretching several hundred kilometers around the end of the Toshka Lakes when it would be simpler to let the Toshka Lakes fill and then construct the canal from the farthest extent of the lakes. Are the Egyptians wise to construct the canal (see data on the next page for stats), or should they use the lakes as part of the system of water distribution? Explain, and support your answer with numbers.

Data from the New Valley Project

Dimensions of the Sheikh Zayed Canal and Mubarak Pumping Station:

- intake elevation for pumping station: 147 m
- elevation of max lift at pumping station: 200 m
- max pumping capability: 1.2 million m^3/hour
- current pumping rate: 14 million m^3/day
- canal width: 54 m bank-to-bank, 30 m base
- canal depth: 8 m
- canal length: 139 km in Phase 1; adding an additional 250 km to El-Kharga (with 30 additional pumping stations along the route)
- maximum canal capacity: 30 million m^3/day

Plans for groundwater development in the western desert oases (Baris, El-Kharga, East Oweinat):

- recycled agricultural drainage water: 5 billion m^3/year
- groundwater exploitation: 7.5 billion m^3/year
- groundwater potential of various oases:
    - El-Kharga and Baris: low (prob. <1.5 million m^3/day)
    - El-Dakhla and El-Farafra: medium
    - East Oweinat: high (est. at 4.7 million m^3/day) (this is the irrigated area that shows up as green crop circles to the west of Toshka on the 2003 satellite image.