Data Literature Review: Final Term Project

GISWR Fall 2013- Maidment

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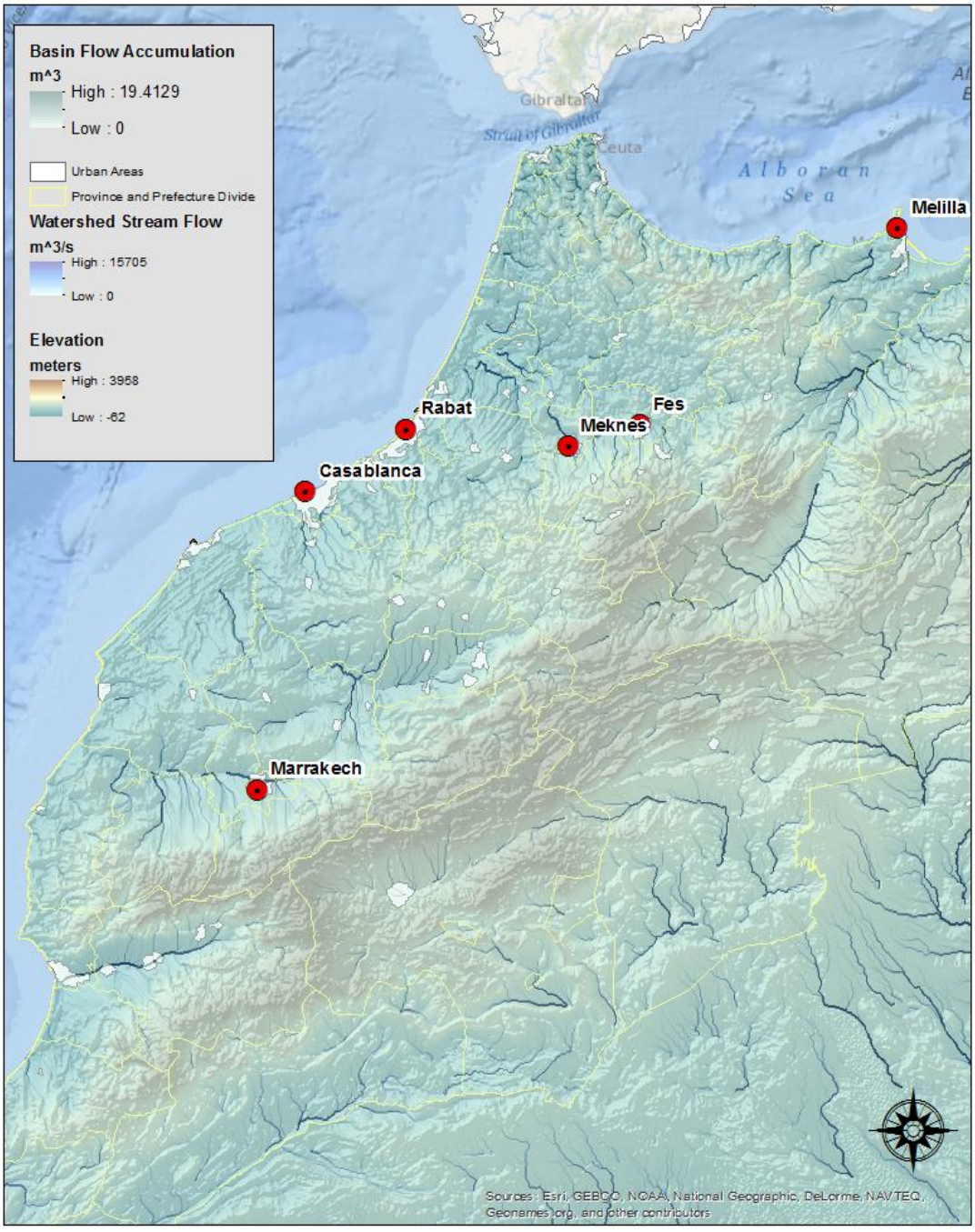
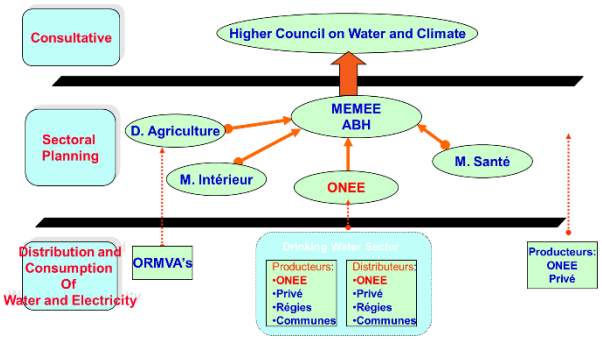
Water Availability and Quality in Morocco



Abstract: This study set out to gather data and conduct a preliminary analysis of water availability and quality in Morocco, and is part of an ongoing project to describe the physical and hydrological landscape of Morocco in real-time. For the purpose of consistency, this study has not focused on including the Western Sahara as part of its analysis. Due to gaps in data, this study will not be able to present a clear picture of the state of water availability and quality in Morocco, but important trends have become clear throughout the data collection and map-making process. **This paper will center around three themes: water management in Morocco and the role of Office Nationale de l'Electricitié et l'Eau ONEP, water quality and human activity, and to the relationship between agricultural and water systems focused-aid and water availability and quality in Morocco.** Future directions will include analyzing indices like the above, and public-health, governance, and socio-economic metrics (including but not limited to: access to clean drinking water, infant and maternal mortality, education, and income) at the municipality and household level. This study could also improve its use of advanced statistical and geo-statistical methods to forecast water availability and quality in highly populated basins. These ideas tie into the larger issues plaguing water management in Morocco, which include climate change, soil erosion, and an imbalance of water supply between north and south.

Part One: Water Management Systems in Morocco

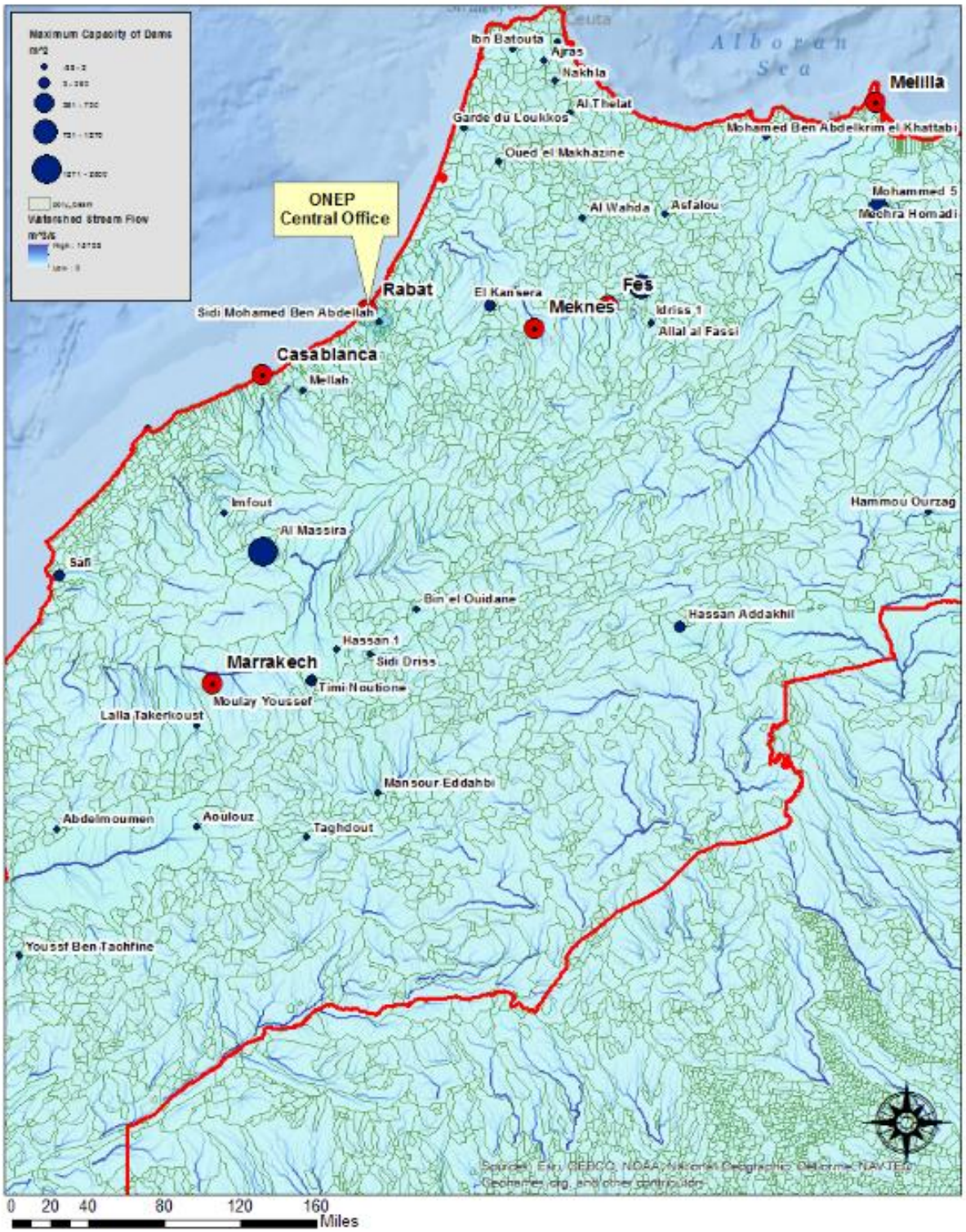


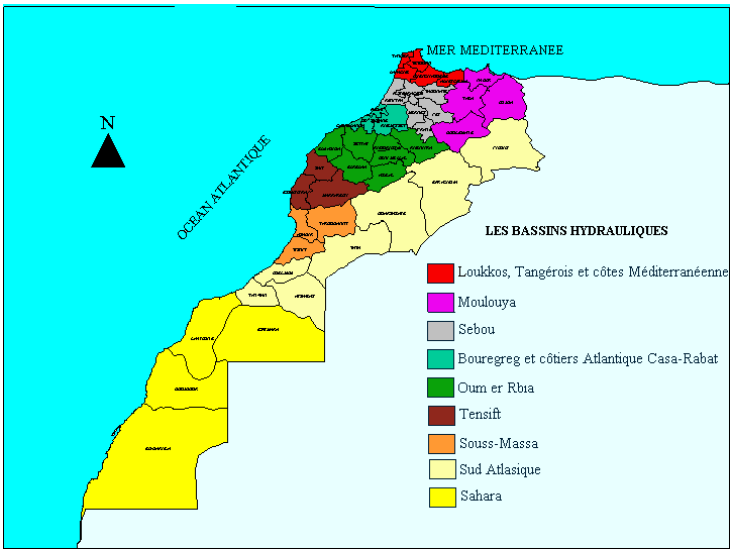
Water management in Morocco is divided politically among three different levels of governmental and non-governmental agencies. Specifically, the Higher Council on Water and Climate (*Conseil Supérieur de l'Eau et du Climat*) overseas the work of the Ministry of Energy, Mining, Water, and the Environment, or MEMEE (*Ministère de l'Energie, des mines, de l'eau et de l'environnement*). MEMEE is split into the sub-Ministries of Agriculture, the Interior, Health, and Office Nationale de l'Electricitiee et l'Eau (ONEE), and these agencies serve as the primary planning elements in the water management policy process. ONEE then further divides into ONEP and ONE (Electricity), and ONEP is responsible for locating and supplying water to users in the public and private sectors.

The complex nature of water management in Morocco and the highly specialized role that ONEP plays within it reflect the country's not-so-recent past as a colony of France. After Morocco achieved independence from France in 1956, the public sector took ownership of water utilities, and the Office National de l'Eau Potable (ONEP) was created in 1972 to join *Société Marocaine de Distribution d'eau, de gaz et d'electricité* (SMD) to management water resources outside of the Oum Er Rbia river basin and Casablanca.

This map provides a geographic context for ONEP operations, which spring from Rabat.

Watershed and Streamflow Delineation Using Publicly Available Data

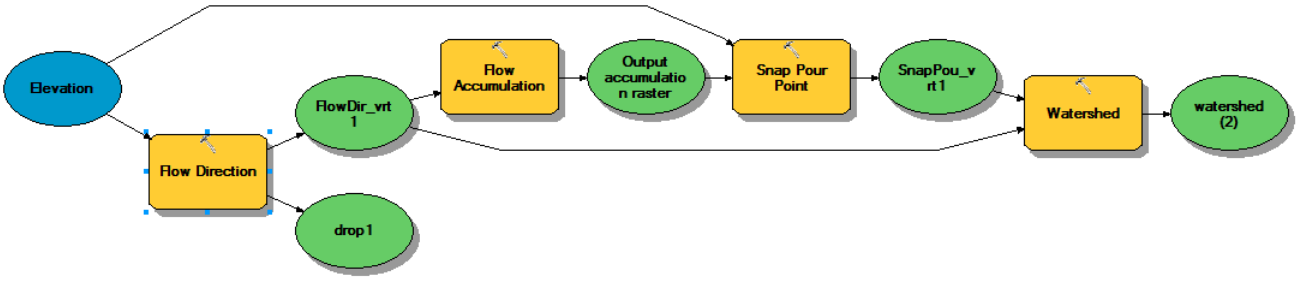


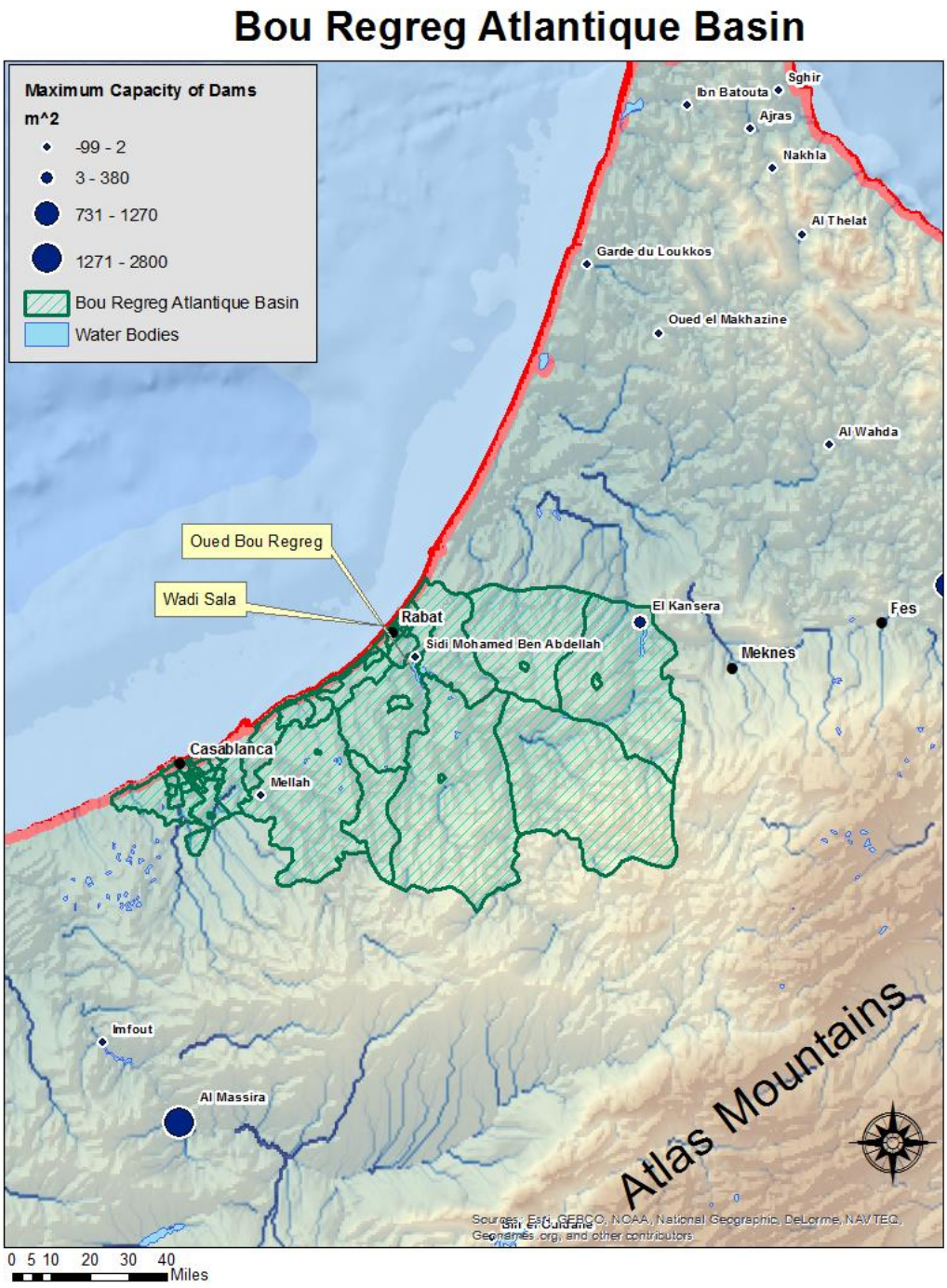


In 1995, water policy in Morocco shifted from supply expansion to demand management through the aspirations of the Water Law (Loi 10-95). From 1996-2000, the Oum Er Rbia, Loukkos, Tangerois, Côtes Mediterranenne, Moulouya, Sebou, Bouregreg-Cotiers Atlantique Casa-Rabat, Tensift, Souss-Massa, Sud Atlantique, and Sahara river basin authorities were created, but were never given substantial implementing power.

Water management became privatized in 1997 when the Moroccan government awarded LYDEC, a consortium of water supply companies, a 30-year contract to manage water supply within the Casablanca province, which spread to other urban areas in Morocco. Under this system, ONEP supplies28% of urban water supply, while private concessionaires provide 38%, municipal utilities provide 31% indirectly, and 3% directly. In terms of supply, ONEP also produces 80% of Morocco's water supply and then sells it to other providers and directly to consumers. In 2000, ONEP also included sanitation under its mandate. This new responsibility for sanitation, coupled with the PAGER program that extends ONEP's mandate to rural communities, has played an important role in improving rural access to clean drinking water.

*Additionally, the streams in all of the maps were produced using stream flow delineation, which was part of a more expansive workflow that derives hydrologic information from a digital elevation model. In order to produce watershed, basin, and stream flow accumulation, I used the following model:



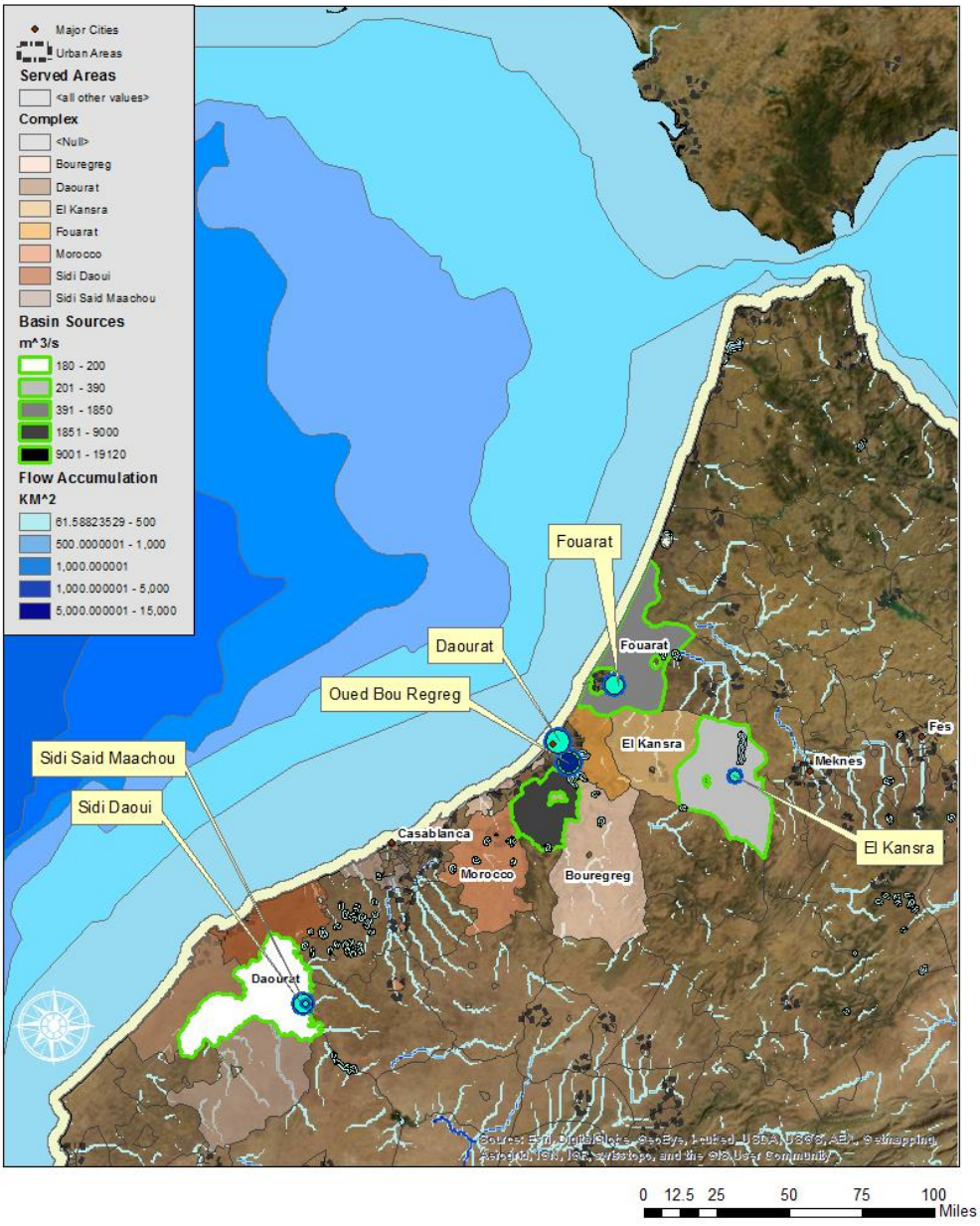


In order to examine the seasonal and regional fluctuations in water availability in a policy context, this paper will take a scenario described by a presentation made by a senior official at ONEP, Dr. Mustapha Hajji. Additionally, this skills and data sets accumulated through the course of this project will feed into work with ONEP on the use of GIS in planning and information dissemination in the future (Inchallah).

In the early part of 2010, ONEP faced a predicament in terms of supplying water to users in the Bou Regreg Atlantique Basin, based on deficits faced in 2009. The Bou Regreg Atlantique Basin extends over the Rabat and Casablanca provinces, and the Rabat-Salé-Zemour region. The estuary of this basin is the Wadi Sala, which is 240 km in length and with an average discharge of 23 m^3/s.

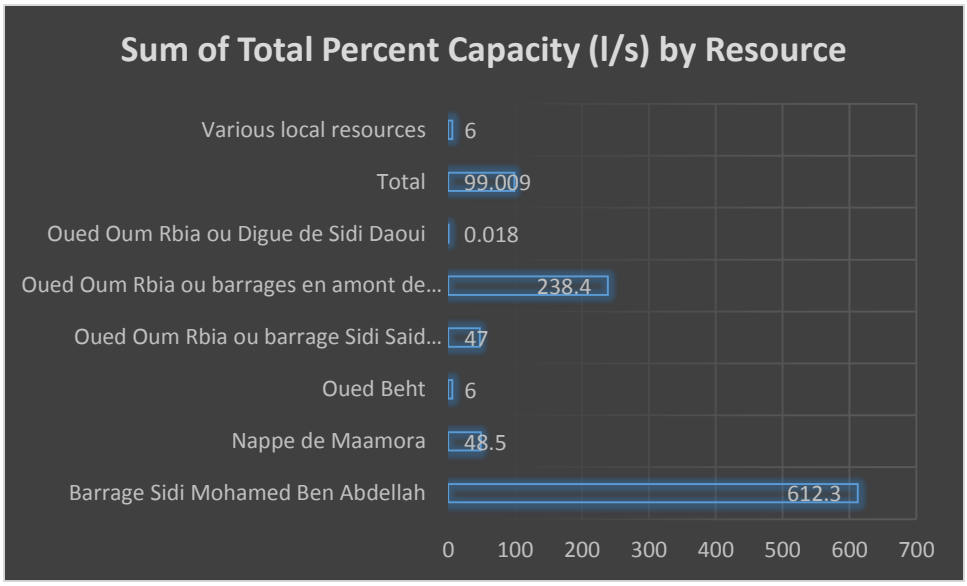
Based on 2009 figures, approximately six production centers provide users in the Bou Regreg Atlantique basin with water, and they include, but are not limited to the following, along with what percent of production they are responsible for: Bou Regreg (47.1), Daourat (29.8), Sidi Said Maachou (9.4), Faourat 9.7), El Kansara (2), Sidi Daoui (0.9), and other various local resources (1).

Water Supply in the Bou Regreg/ Atlantique Basin

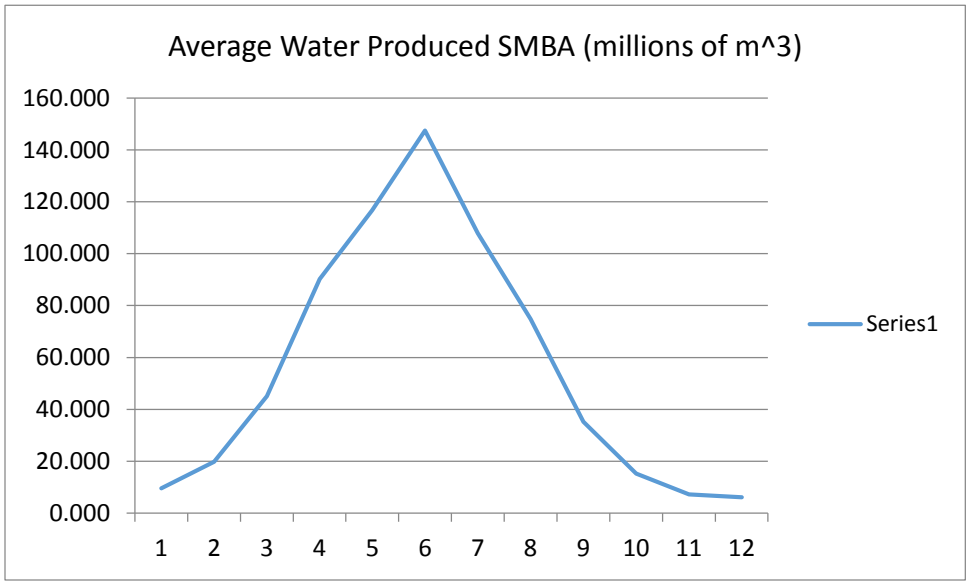


Total production capacity within the Bou Regreg basin was 19,120 litres per second in 2009. During the summer, production was lower than average for Bou Regreg and Daourat, or 87.40% and 78.20% of total production capacity, respectively.

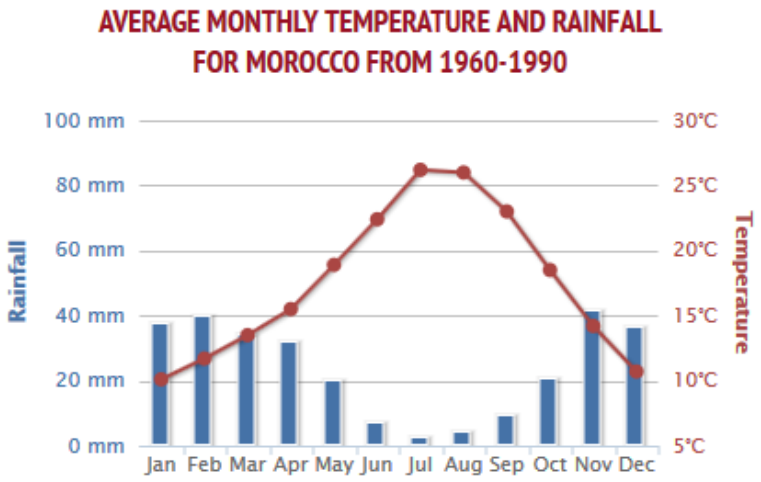
The following table illustrates the breakdown of production capacity by sub-resource within the Oued Bou Regreg and Daourat complexes. The dam or barrage at Sidi Mohammed Ben Abdullah (SMBA) sits at the largest capacity water source by far.



In fact, the gage point at SMBA is one of the best-maintained gage points in the country. Data on annual water intake and reservoir levels exists by month and as an annual average, and span from 1939 to 2012. The following graph illustrates average water production levels at SMBA over the course of the year:

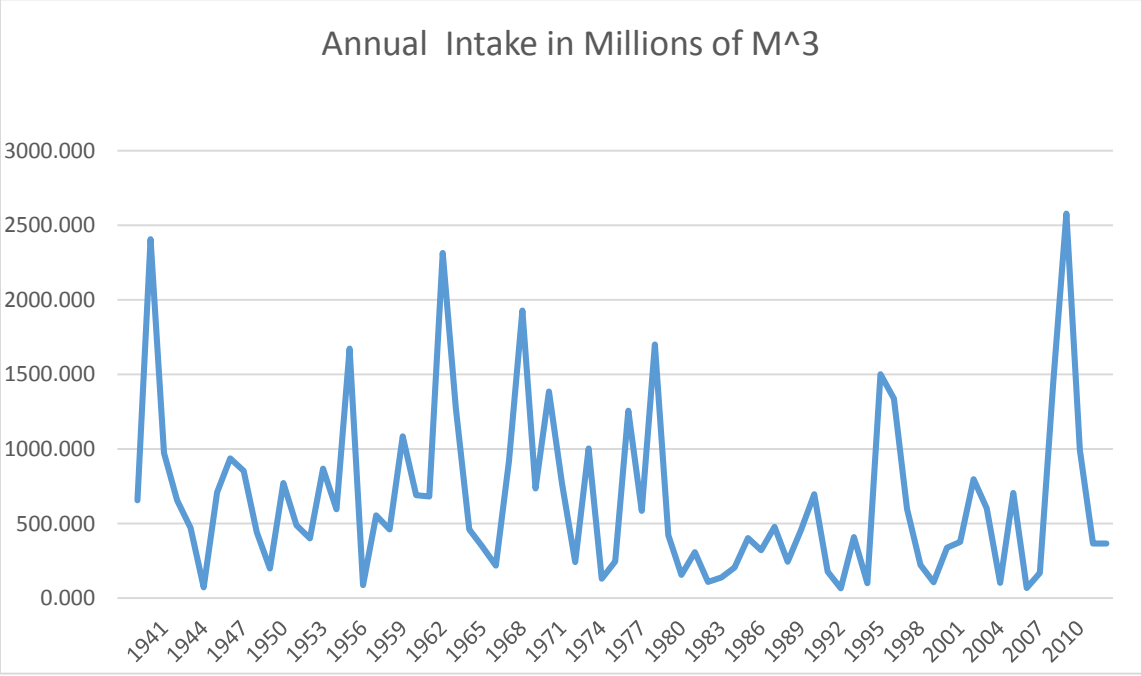


This graph of average water produced by month shows a nearly 120 million m^3 increase in water production or demand in the summer months, when rainfall is more intermittent, to the winter months, when rainfall is more plentiful.



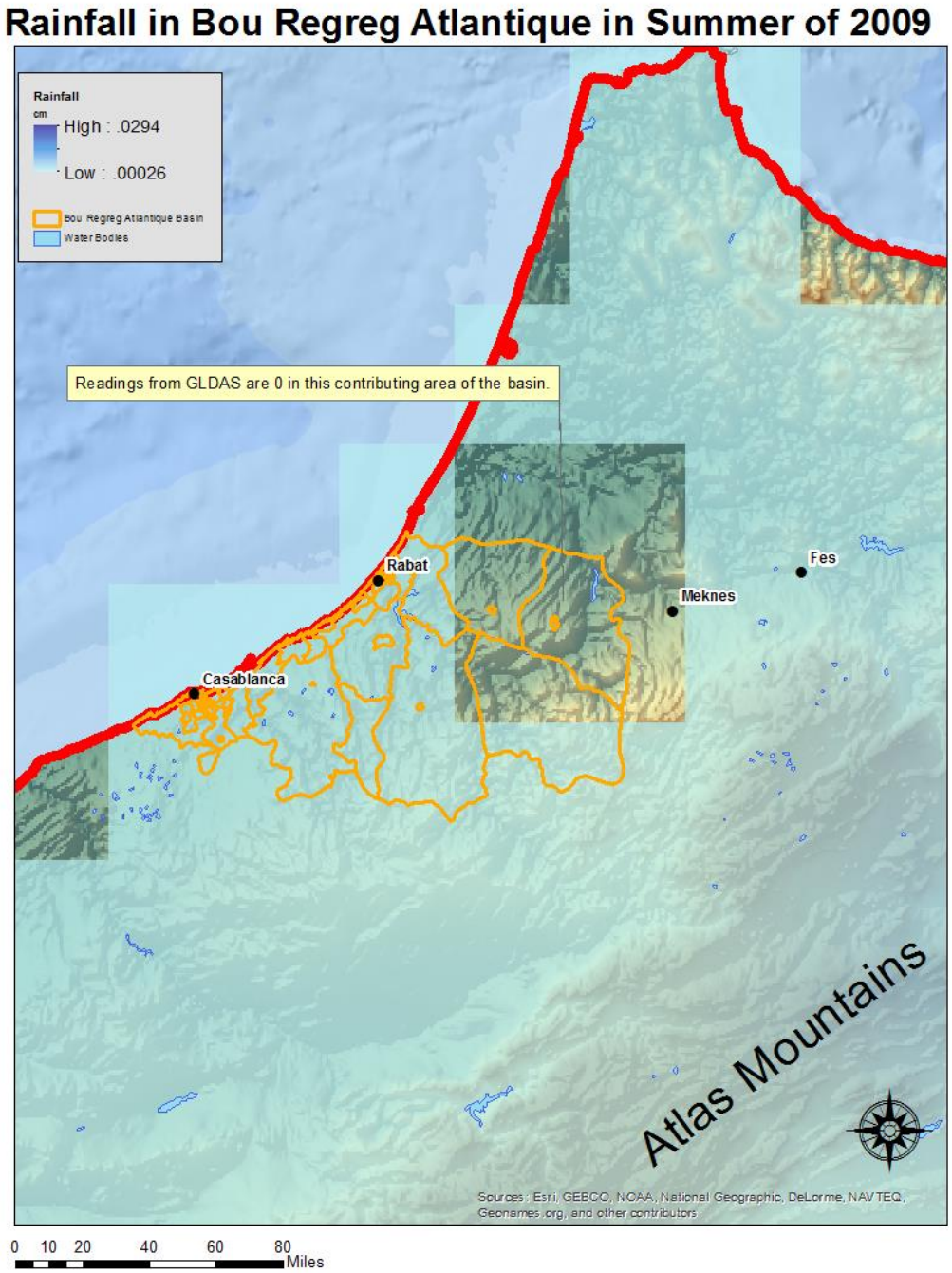
Understanding how to cater to a growing base of consumers as a water supplier can be difficult, especially in a country where achieving water balance is so precipitous by season and by region. Below is a graph from the World Bank displaying average rainfall and temperature in Morocco by month for the period of 1900-2009. [1]

Although this graph is an average of temperatures over a number of years and more importantly, over areas experiencing diverse water challenges across Morocco, we can infer that the SMBA point is at least somewhat representative of water trends in Morocco. The value of demand that it depicts could be read as an inverse of water availability. A historic picture of water demand change is given by this data from SMBA by year:



[1] http://sdwebx.worldbank.org/climateportal/index.cfm?page=country_historical_climate&ThisRegion=Africa&ThisCCode=MAR

In this graph we can see fairly regular fluctuations in demand over time, but this only represents one very small point on the land surface belonging to Morocco, and more data would make analysis of water availability more complete and meaningful. It will be very exciting to see how water use management and planning progresses in countries like Morocco, where real-time data is not readily available (or in existence). Although institutional and technological capacities are developing, there are inputs for geospatial analysis through low-bandwidth open source geo-spatial platforms like Hydroshare.[2]

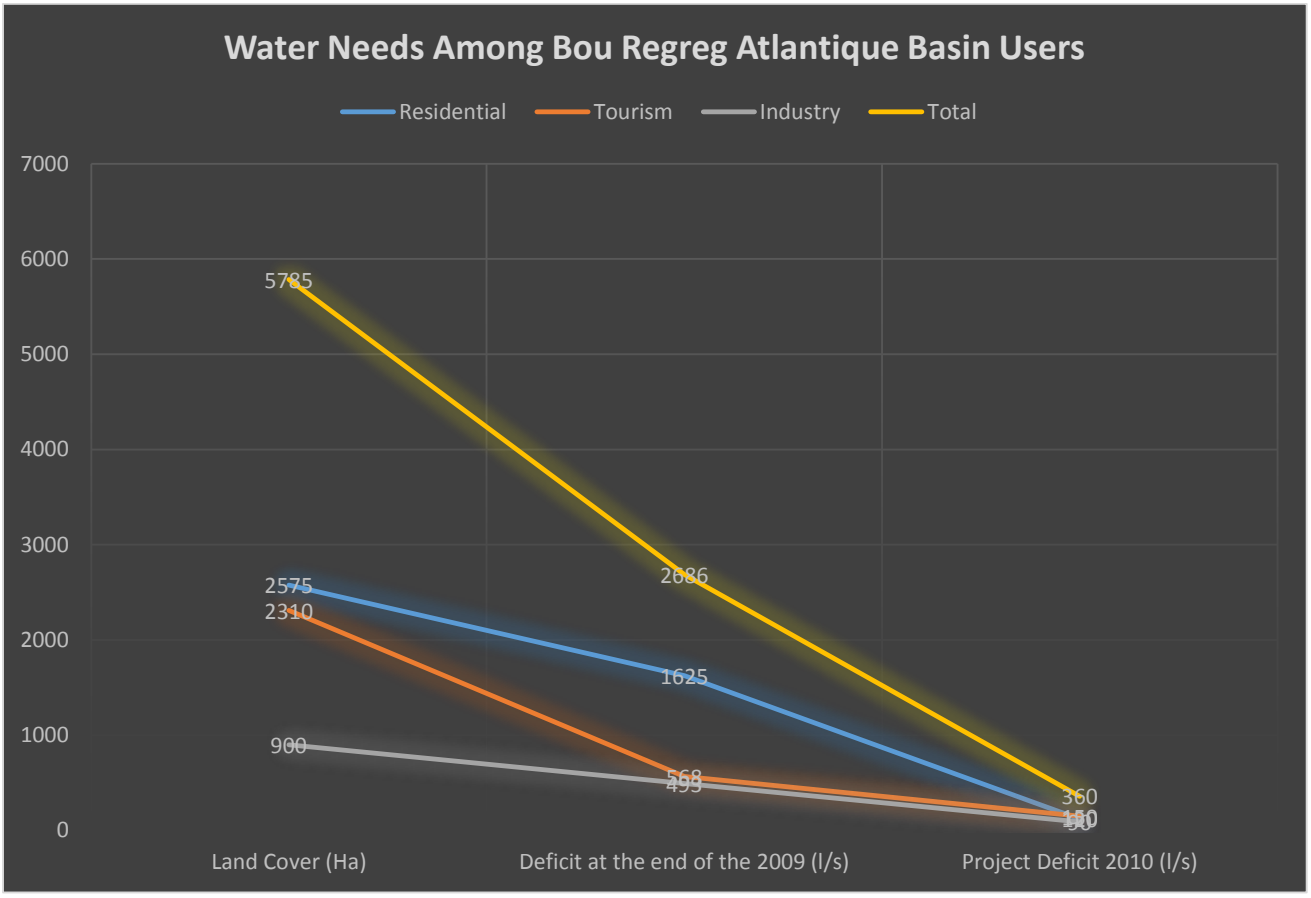


[2] http://www.cuahsi.org/mod.aspx#HydroShare

Climate change is something that Morocco is very sensitive to as a country with a water-intensive economy based heavily in agriculture. Nearly 40 % of Moroccans work in agriculture,[3] and this is a sector which consumes between 75 and 90% of freshwater resources globally.[4]

Due to increased demand from Casablancan and Mohammedian users in the summer of 2009, LYDEC-governed areas of the Bou Regreg basin were projected to experience a 10% deficit in water supply. This deficit would not be due to a lack of water, but a failure of infrastructure and rapid shifts in surface and ground water reserves and increasingly unreliable precipitation levels. GLDAS data extracted from World Water online also supports that this was a dry summer for Bou Regreg:

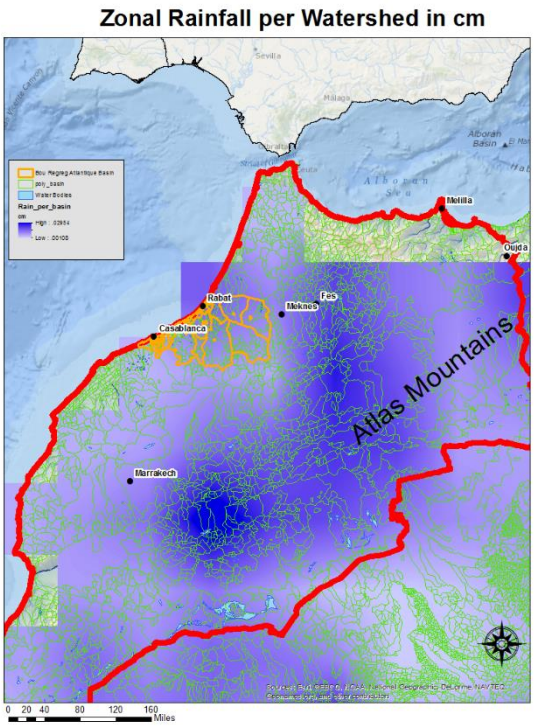
Transit lines became oversaturated in the midst of all of this, and ONEP and other water suppliers worked to help LYDEC meet user demand, which spans not only the residential needs, but the needs of industry and tourism as well. The following table provides a good illustration of needs within Bou Regeg Atlantique among users, by sector.



ONEP officials postulated that this hiccup in service would increase in the following year, especially in the summer. This meant that a total 2686 l/S deficit at the end of 2009 would put Bou Regreg users behind 360 l/s in flow at the beginning of 2010.

[3] http://ag.arizona.edu/oals/ALN/aln45/rhodes.html

[4] T. Roe et al. / Journal of Policy Modeling 27 (2005) 905–928



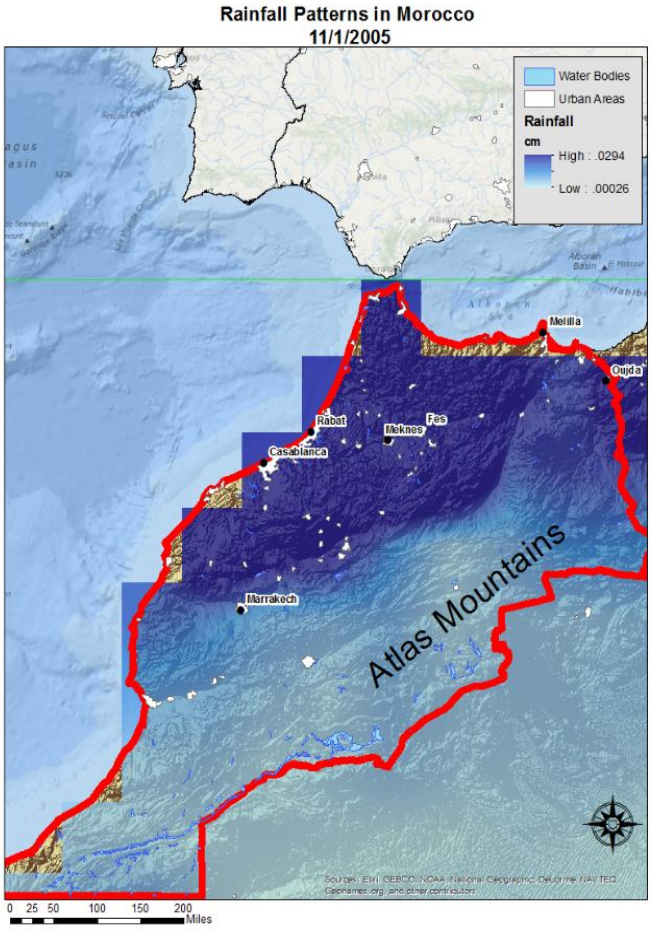
Imbalances in water supply between water suppliers, regions of Morocco, and season play an important part in the interest that ONEP has taken in climate change adaptation projects like the Center for Climate Change and African Political Stability (CCAPS) and the Robert S. Strauss Center for International Security and Law.

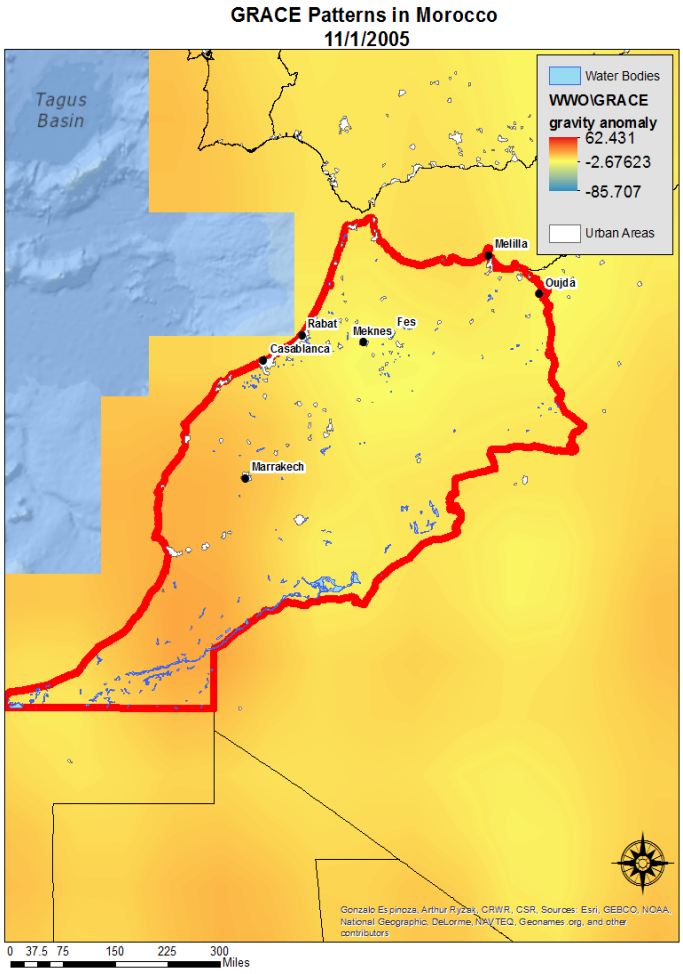
The adjacent map displays zonal averages for rainfall derived from the Global Land Data Assimilation Systems service provide through WWO. It depicts a very difference picture of rainfall in Morocco than EMODIS and USGS. The majority of rainfall does not fall in the coast north, but rather near the Atlas Mountains. This visual trend could be linked to the tendency of the Atlas Mountains to prevent rain from traveling south.

It should be noted that rainfall is not plentiful in these maps (between .001 and .03 cm on average), but this is returns to the manner in which it was collected, which is monthly.

Previous data examined in this paper relied on data derived from the summer months in Morocco, when temperatures are high and precipitation is minimal. The two maps on the following page provide a look at rainfall patterns and water availability during the winter months, or November of 2005 specifically. Here, it is interesting to not only compare between GRACE and GLDAS data to infer water availability, but also to include the water bodies shapefile[5] into the equation. This shapefile does not contain any identifying information about the water bodies depicted, unfortunately. However, important patterns between Here, it seems that water bodies are more concentrated in the north, and rainfall is less prevalent. It is also clear that the north, while receiving larger volumes of rain than the southern or Souss part of the country, does not have the same degree of surface water resources that the south does. This may be part of the reason that there are so many water works that are maintained well in the north, and especially the Bou Regreg Atlantique basin. The GRACE data lends some support for this statement- while having considerably less rain, the southwest corner of the country has relatively more water than the northeast, where rainfall is most concentrated. Further, the northeastern part of the country near Tangiers, as a whole, is relatively less well off in water availability compared to the Souss and western regions.

[5] http://www.diva-gis.org/datadown





The use of these data sets across these two different contexts highlights the importance of triangulating data with diverse methods, data detailed in the sense of both time and space, and how much more progress might be made through collaboration.

Part Two: Water Quality in Morocco

The next series of maps will look at water quality indicators like phosphorus, alkalinity, lead, mercury, iron, and magnesium. The data used in the following maps was downloaded from GEMstat.org, which is a data repository site for the United National Environmental Program (UNEP) Global Environmental Monitoring (GEM) System, which collects water quality indicators from sites all over the world.

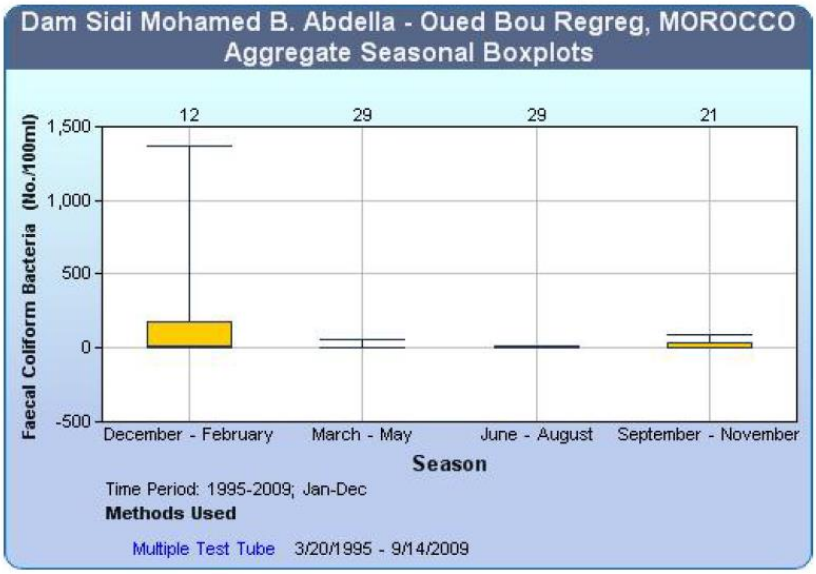
Gage points included all 8 points that were available: the Lala Aicha Dam site at the Sebou River, SMBA at Oued al Regreg, Dam Al Massira at Oum Er Rbia River, Mamora Well, Artesian Well 4/125, the Sebou River at Kenitra, the Moulaya River, and Oum Er Rbia River at Sidi Daoui.

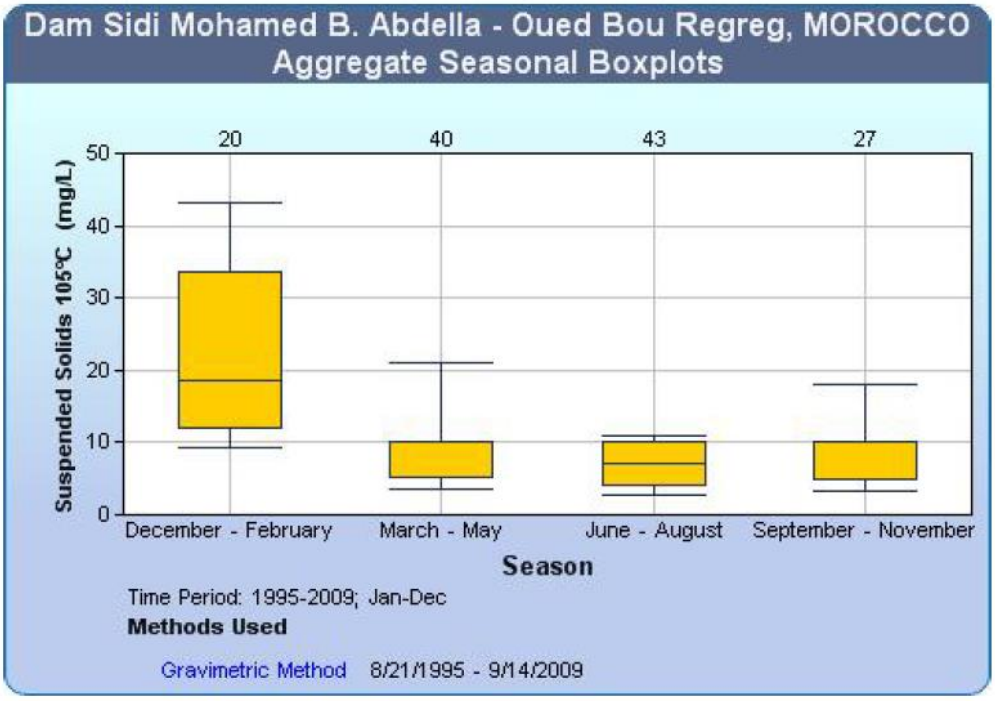
These sites are primarily located in the north central and northwestern part of the country. Due By virtue of their location along the coast, as is depicted in the following maps, they sit in the midst of an impressive land-use mix. Due to the fact that this area is so agriculturally intensive, higher levels of phosphorus, organic dissolved nitrogen, dissolved oxygen, and nitrates could be present.

Centers of industry in Rabat and high-volume urban populations centers in the Rabat-Sale-Zemmour region could also evoke higher levels of organic and non-organic toxins like Lead, Iron, Mercury, and Faecal Colliform. Alkalinity and Magnesium could also have concentrations at the gage points around the Rabat-Casablanca area due to the concentration of residential, industrial, and agricultural land uses. Other important indices to investigate include the sodium content or salinity of water, total suspended solids, ph and temperature. Reports of increasing salinity levels in Bou Regreg point to tidal saltwater intrusion. Higher readings of nitrates and mercury within Bou Regreg near Rabat have also been recorded, and may be due to the use of certain pesticides within the drainage basin.

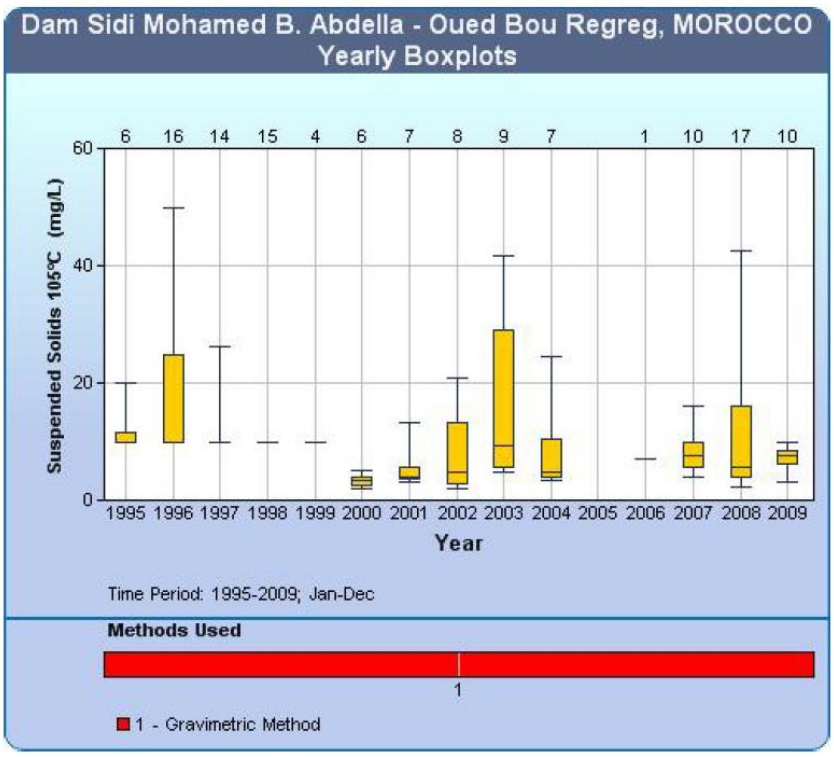
Since Phosphorus, Alkalinity, Magnesium, and metals like Lead, Iron, and Mercury had the most complete data across the stations, they have been chosen for use in the maps, especially in light of secondary source data from the Center for International Earth Science Information Network (CIESN) on phosphorus output from manure in Morocco, and percent cropland use. Other indicators will be depicted through graphs from the SMBA gage point. It is also very important to note that these gage points were not selected randomly, and cannot be used as a representative sample of water quality conditions in Morocco. They do provide a good start to understanding the hydrological landscape of Morocco for the layman, however.

The adjacent graph describes concentrations of faecal coliform bacteria readings at SMBA averaged monthly from 1995-2009. This information depicts higher levels of bacteria in the winter.



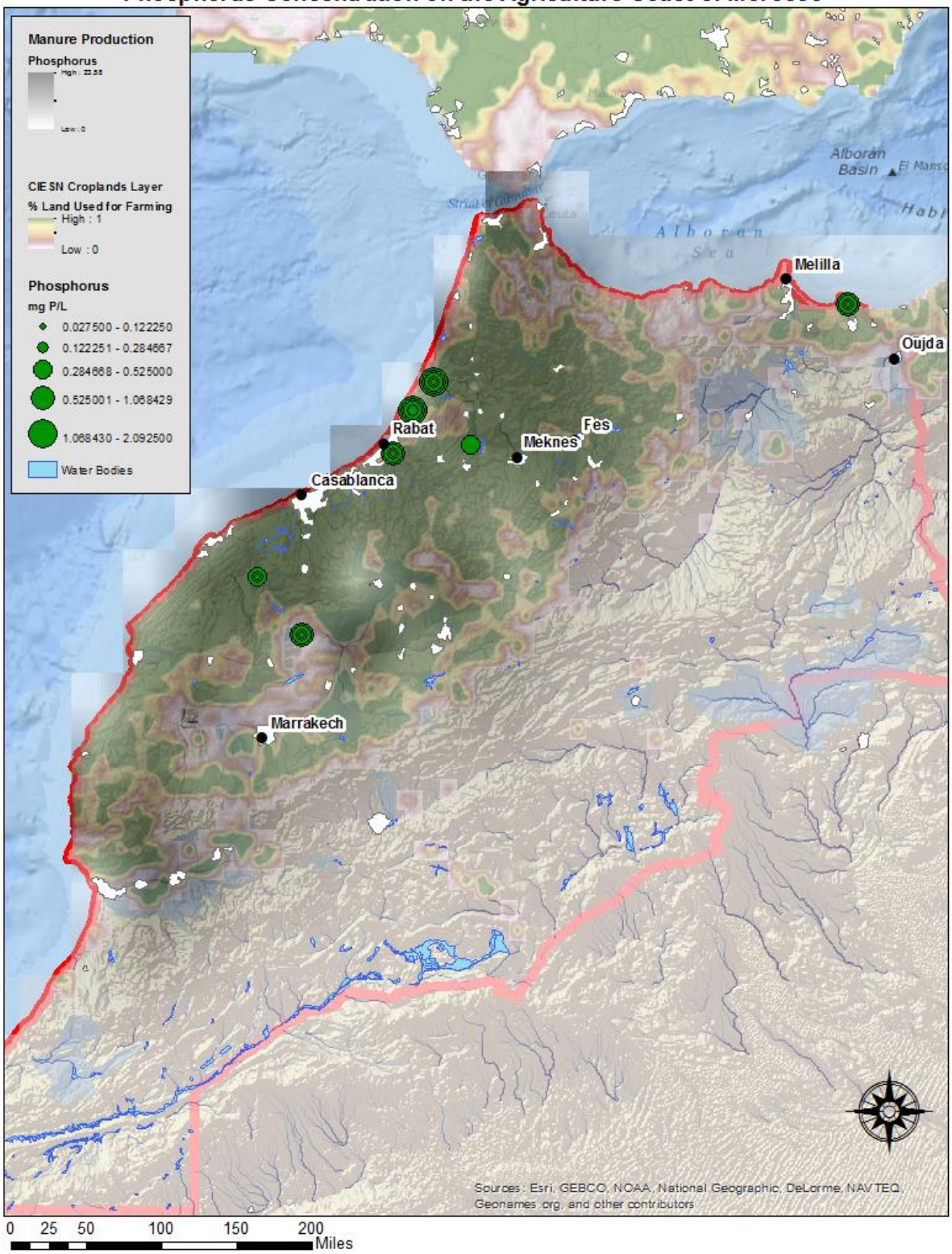


Readings for suspended solids also show similar trends for the same period. What should be kept in mind returns to a point made earlier in this discussion. Precipitation varies substantially seasonally, and sediments, toxins, and other indicators may be present in greater abundance during the start of the rainy season in November.



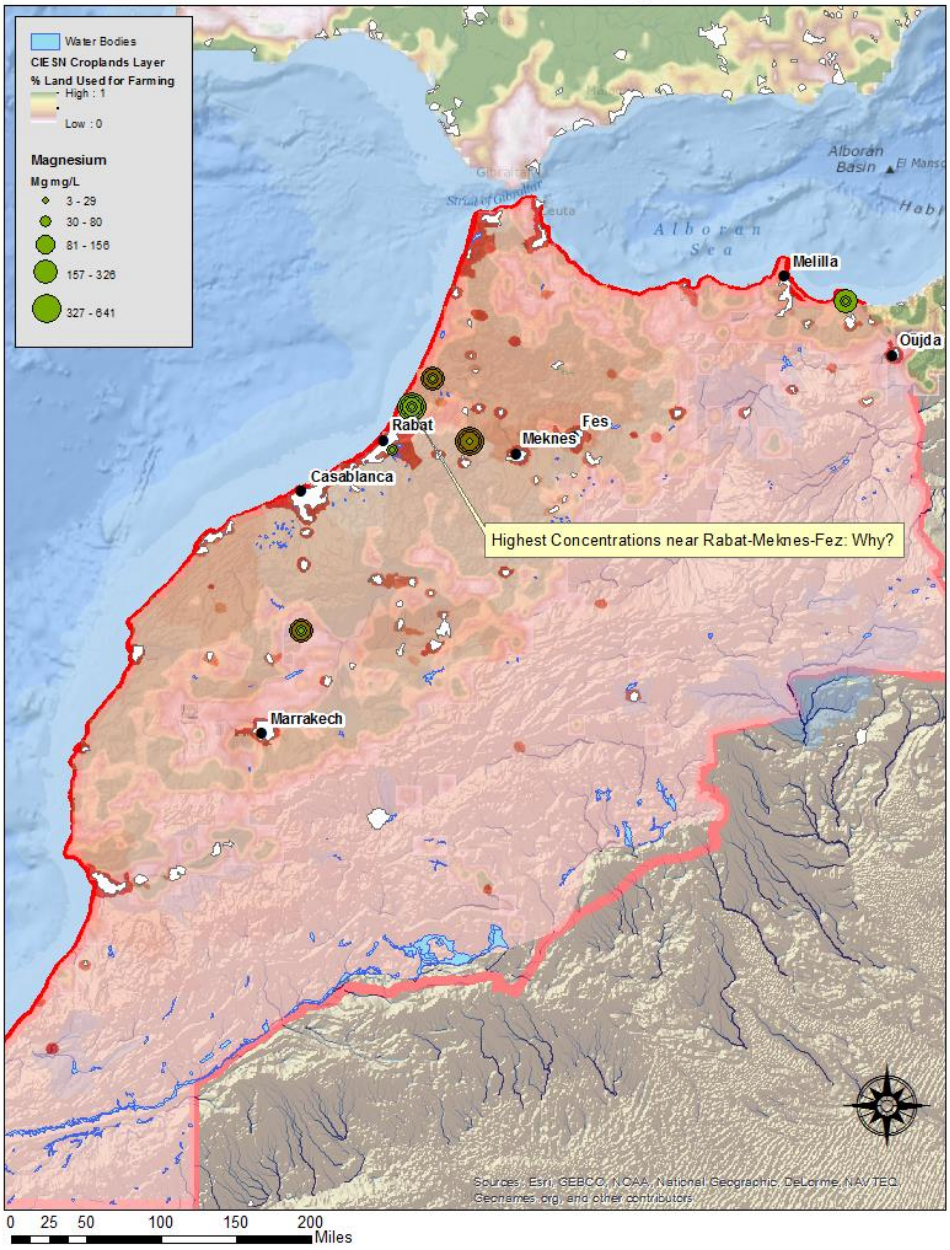
The adjacent graph depicts annual average readings for suspended solids for the same period. Due to population growth, increased investment and productivity in the industrial and agricultural sectors, erosion has been a recurring problem for Morocco. The government currently is looking for ways to mitigate this through soil stabilization measures and the promotion of more sustainable agricultural methods.

Phosphorus Concentration on the Agriculture Coast of Morocco



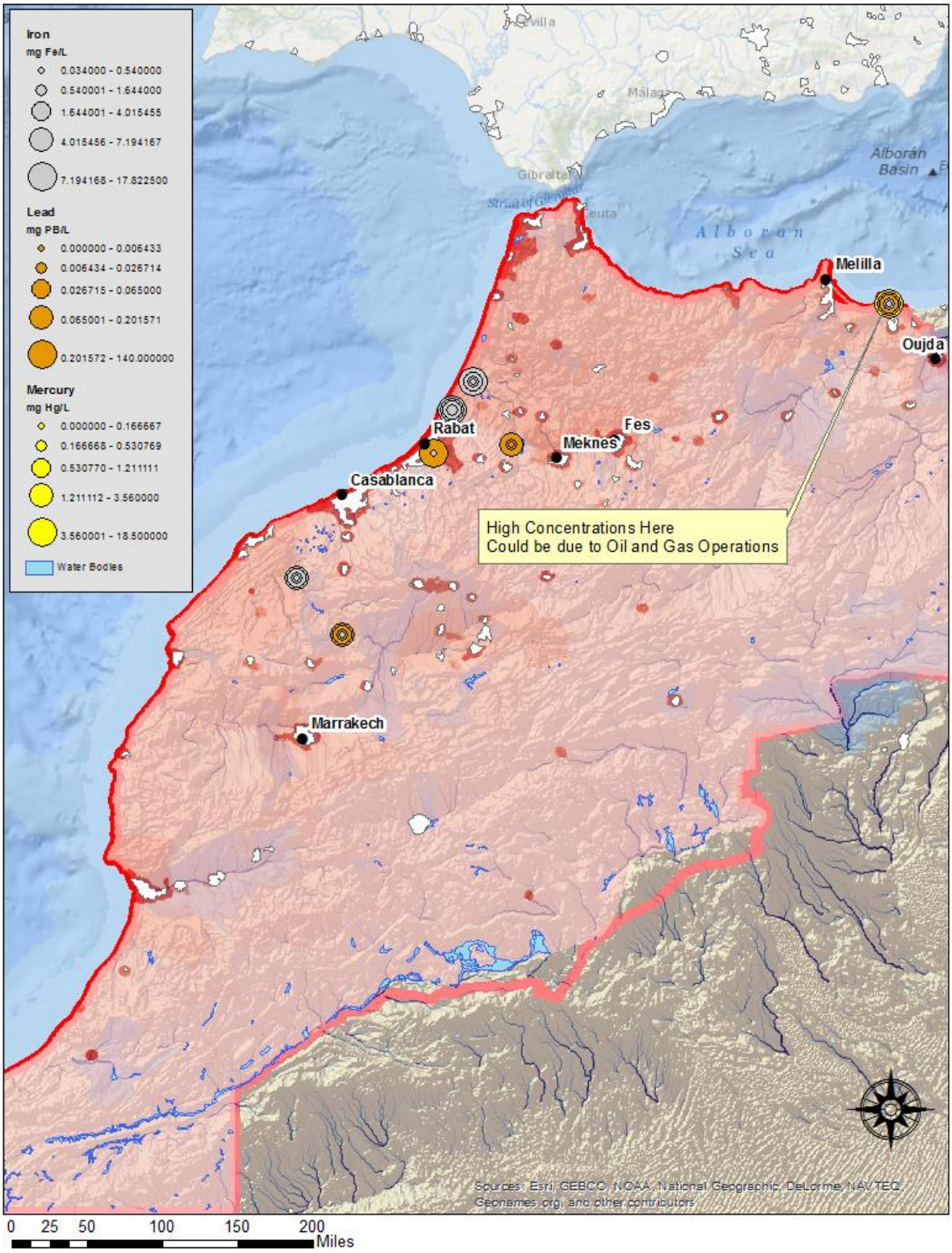
The map on the previous page looks at the relationship between prime farmland, phosphorus readings from the GEMstat gage sites, and phosphorus as a result of manure production. Although the relationship remains visual at this point, higher Phosphorus concentrations in mg P/L coincide with denser concentrations from the CIESN data. Further, both indicators collocate with land that is more likely to be used as cropland.

Magnesium and Alkalinity Levels at Water Gages in Morocco



This map also shows elevated Alkalinity levels and higher concentrations of Magnesium near the Rabat-Salé-Zemmour complex. This could return to its location in a highly diverse land use mix located within a major urban center.

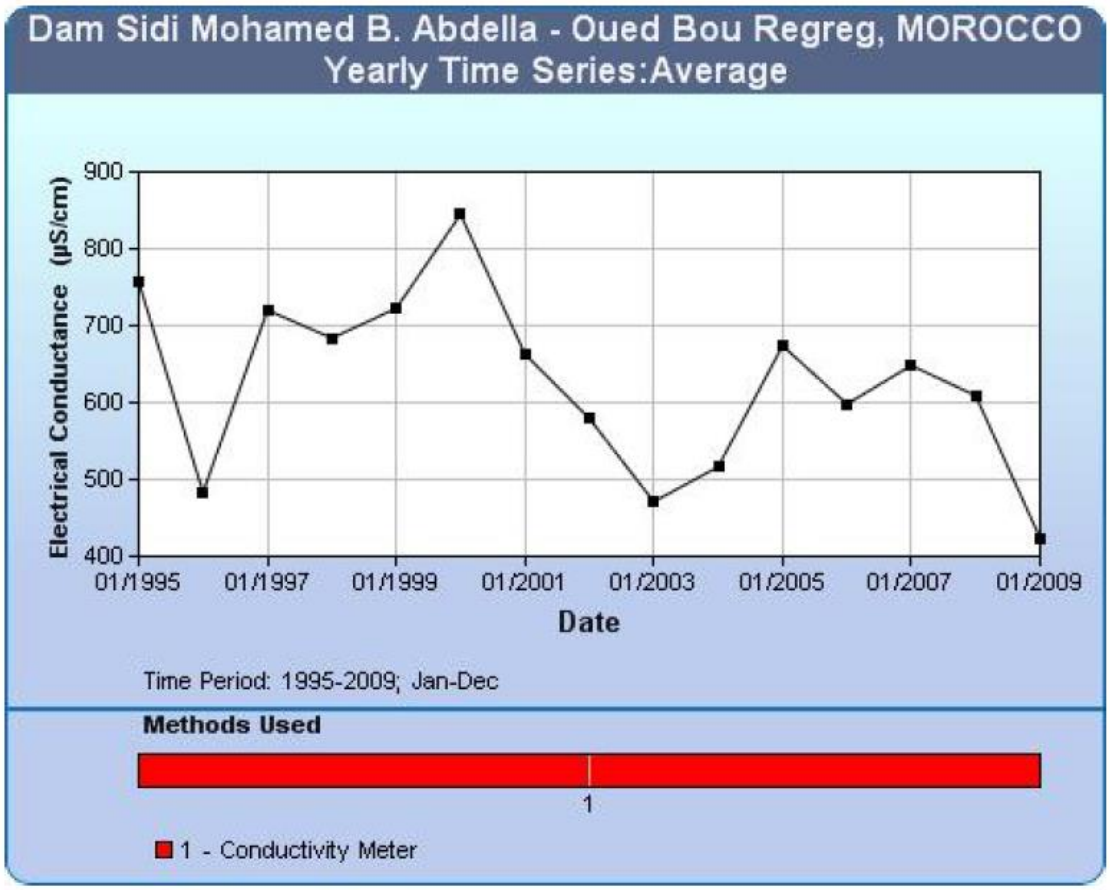
Metals and Pollutants at Water Gage Stations in Morocco



Finally, the previous map depicts concentrations of metals that often coincide with high pollution levels. Higher levels of Lead concentrations are located near Casablanca, Meknes, and Oujda. Casablanca is the largest city in Morocco, and an important port and trading center. Transportation emissions and waste from marine and aviation travel could play a role in this pattern. Further support for this theory rests in the far northeast of Morocco, near Oujda, which lies near the border with Algeria. Algeria contains a substantial amount of oil and gas reserves, and oil and gas production coupled with transportation could be responsible for elevated levels here. Iron, however, shows its highest readings near Rabat, and Mercury levels are also elevated here. These trends may reflect the degree to which industry operates within this basin.

The above geo-spatial representations are static, and do not take the temporal dimension into account. Electric Conductance provides another way to measure the presence of dissolved solids, and it the following graph depicts a decrease in dissolved solids contaminants over time.

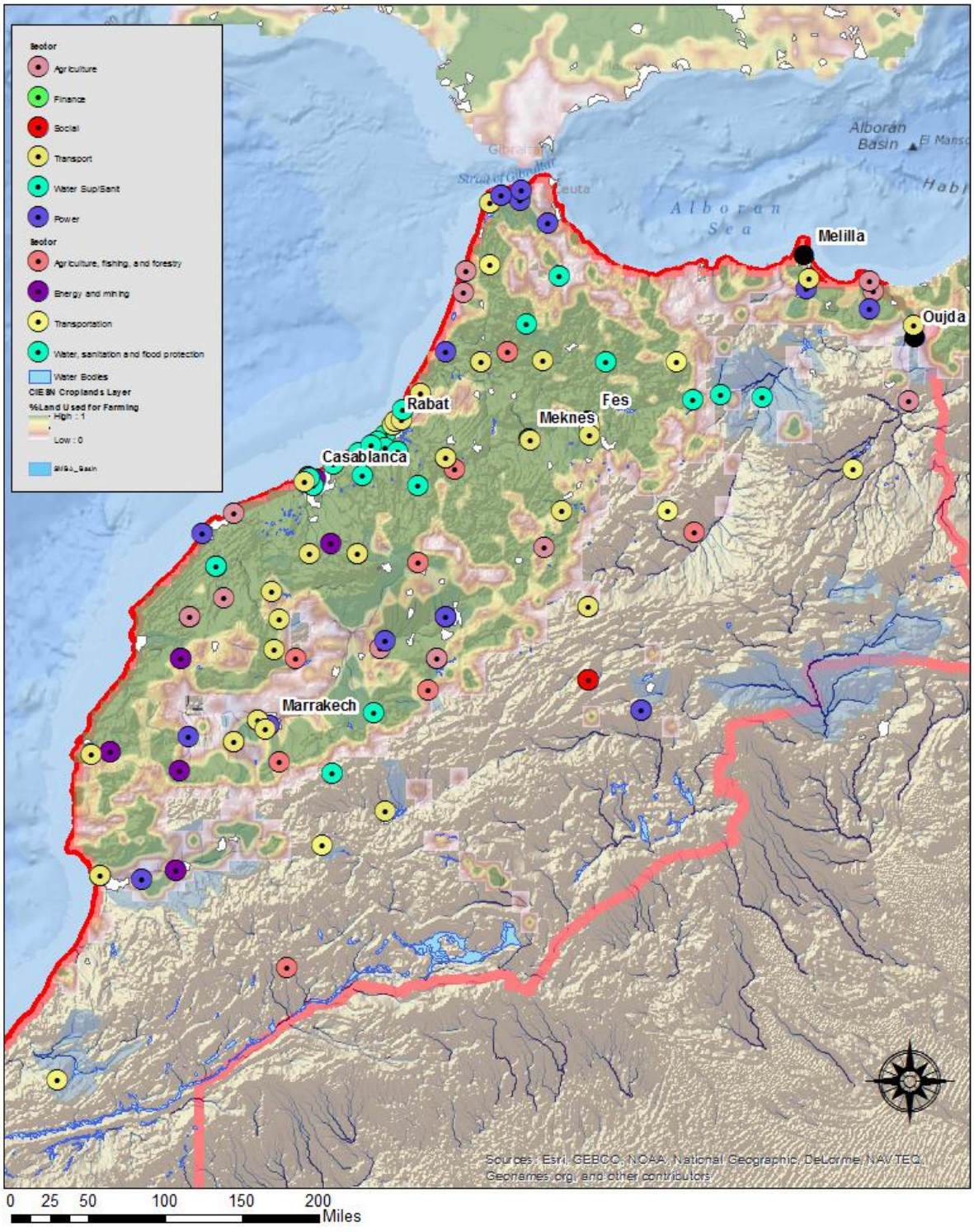
Measuring the quality of drinking water is also important within the context of Morocco, and especially in less economically stable, marginalized, and rural communities where poor drinking water quality wields a large impact in terms of higher infant and maternal mortality from elevated nitrate and faecal coliform concentration levels.



Part Three: What Role does Foreign Assistance Play in all of this?

Aid Project in Morocco - Where is the Money Going for Water and Sanitation?

African Development Bank and World Bank Projects (Up to 2011)



Briefly, the previous map displays World Bank and African Development Bank projects in Morocco by sector. The dataset for World Bank projects is derived from the Mapping for Results dataset, which contains basic information about projects from 2007-2011, and the African Development Bank data ranges from 2009-2010. This data will only present information from two donors, without much context beyond sector and committed aid funding, but it does reveal interesting trends that should be explored, and that may not have been as perceptible without being represented visuo-spatially.

The pattern that emerges here suggests that aid projects may be located in urban areas with a long history of receiving aid, and in areas where business and aid sector are co-located, as in the southern, central, and eastern parts of the country where oil and gas industry is more heavily concentrated. Evidence for this exists in the water and sanitation sector, the agricultural sector, and in the fact that most aid projects from these two donors seem to be industry-related. Water projects are more concentrated in the northern part of the country, which received more rain from the south. Of important note, however, is that specific information about the project is not available, and that agencies implementing aid projects are heavily restricted by donor and home-constituents, and so pairing development and economic goals may be more adaptive within the international community at large and within Morocco, which has historically received a large amount of aid. Water projects may also pertain more to water quality in the North. Aid programs may also work in conjunction or to complement the work of ONEP, which works extensively in water supply procurement.

In the future, it will be important to assign more rigor in analysis of the effectiveness of aid. If geo-spatial location is important, researchers must be thorough and objective in assigning appropriate proxy-variables to human development indicators they are trying to measure and evaluate.

Future Directions and Relevance:

The original intent of the study rested in developing a geospatial and imagery-based inventory of water resources and land use patterns in Morocco, particularly in the coastal Bou-Regreg Atlantique Basin. This study also sought to provide data set that can be used to analyze, at least in a general way, the impact agricultural and water and sanitation aid programs have exerted on Morocco's water resources and topography in terms of both availability and viability. In light of the relative paucity of publicly-available data on basin-level data, this study has made some progress in deriving datasets, and has been very beneficial in terms of learning how to approach water management in a developing context.

It has become very clear that good methods, better connections, a good understanding of the Spatial Analyst and Geospatial toolboxes, and persistence are very useful in overcoming gaps and inconsistencies in data. GIS should not be used, however, without a firm understanding of the data and methods being used, or else it risks falling by the wayside or worse, perpetuating bad information. Markup languages like WatermL, and open source GIS platforms could provide

a huge benefit to agencies in developing countries like ONEP in Morocco, due to the systems-level push that using GIS gives to revamping organizational attitudes in data management, which is a universal problem plaguing NGOs, INGOs, and line ministries in developing countries.

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