Assessing the Potential Impacts of Climate Change on Belize's Water Resources

Preliminary Findings Report

February - July 2013

PROJECT TITLE: Assessing the Potential Impacts of Climate Change on Belize's Water Resources

PROJECT REFERENCE NUMBER: CDKN/RC14

PERIOD OF PERFORMANCE: February 1 - July 31, 2013

DONOR: CARIBSAVE Partnership

SUBMITTED BY: Elma Kay, Principal Investigator and ERI Science Director Terrestrial and Emil Cherrington, Co-PI and Senior Scientist, CATHALAC

The following constitutes the first term performance report regarding implementation of the project, "***Assessing the Potential Impacts of Climate Change on Belize's Water Resources***," implemented by CATHALAC and the ERI, with the support of the CaribSave partnership / Climate and Development Knowledge Network (CDKN). The period of performance to which this report pertains is the first six of the project's eighteen months, spanning February through July 2013.

I. BACKGROUND

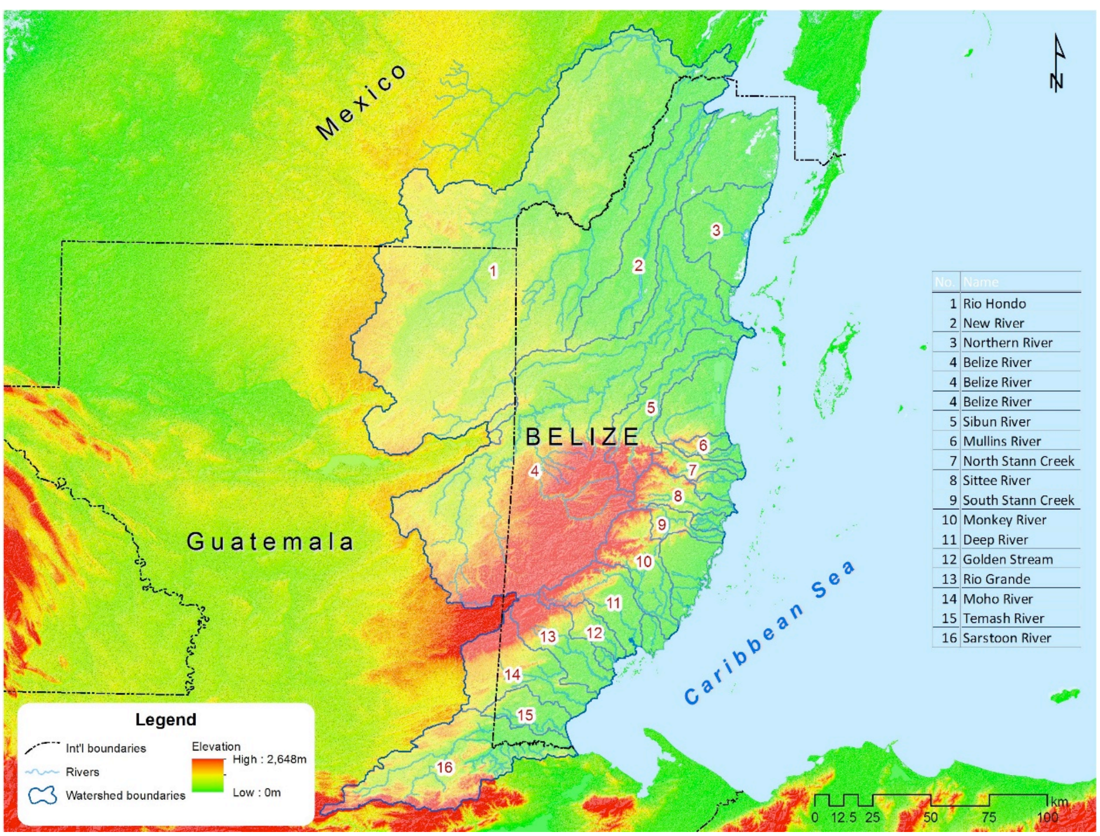

Figure 1: Project geographic domain, showing the 16 major watersheds of Belize

The Assessing the Potential Impacts of Climate Change on Belize's Water Resources project aims to evaluate the potential combined impacts of climate change-driven changes in rainfall and land cover change on Belize's hydrology. The project aims to assess not only the changes in the supply of water resources, but also the potential future changes in demand for those water resources. While the project is focused on the independent Central America and Caribbean nation of Belize, the hydrological modeling that the project entails of necessity also includes portions of neighboring Mexico and Guatemala (see **Figure 1**).

II. PROJECT PROGRESS

The modeling performed to date can roughly be divided into two types of modeling:

- Modeling of the demand for water resources
- Modeling of the supply of water resources

a. Water resource demand modeling

The main input to modeling the demand for water in Belize is data regarding the distribution of populated places and agriculture. Work in modeling the future distribution of population and future agricultural land cover is elaborated in some detail below.

Future population projections

The data from LandScan indicates that in the year 2000, the total population of Belize's watersheds (including the parts of those watersheds in Mexico and Guatemala) totaled some 607,458 persons, while by 2012 that number had grown to 629,225 persons (see **Figures 2-3**). Specifically within Belize, the Statistical Institute of Belize estimated the population to be some 232,111 persons in 2000, growing to 303,422 by 2010. Comparatively, that indicates that in the overall area of interest (AOI), the growth rate was 0.36% per year over the period spanning 2000-2010, while in Belize, the growth rate was almost nine times faster at 3.1% annually. If we extrapolate these rates, then by 2025, the population within the overall AOI would be almost 664,000, while the population of Belize would be almost 478,000. By 2030, the population of the overall AOI would be approximately 676,000, while that of Belize would be approximately 556,000.

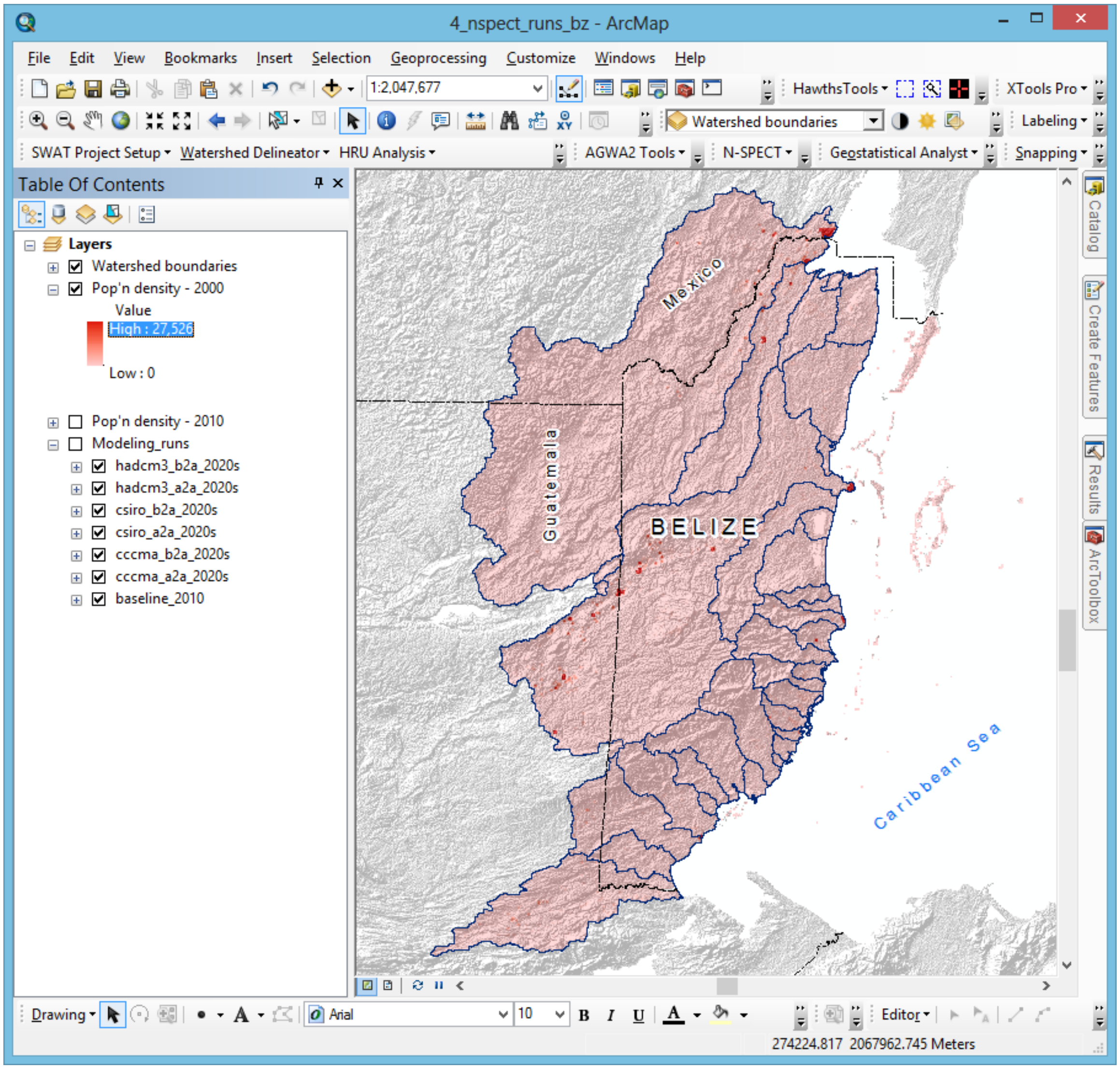

Figure 2: Population density across Belize's watersheds, 2000 (*based on Landscan, 2000*)

As shown in both **Figure 2** and **Figure 3**, some of the major population centers in Belize's watersheds include Belize City in the Belize River watershed, and Chetumal (Mexico) in the Rio Hondo watershed. In the year 2000, the maximum estimated population density was just under 30,000 per km^2, while in 2010, due to urban expansion, that maximum population density had increased to over 33,000 per km^2 (see **Figure 3**).

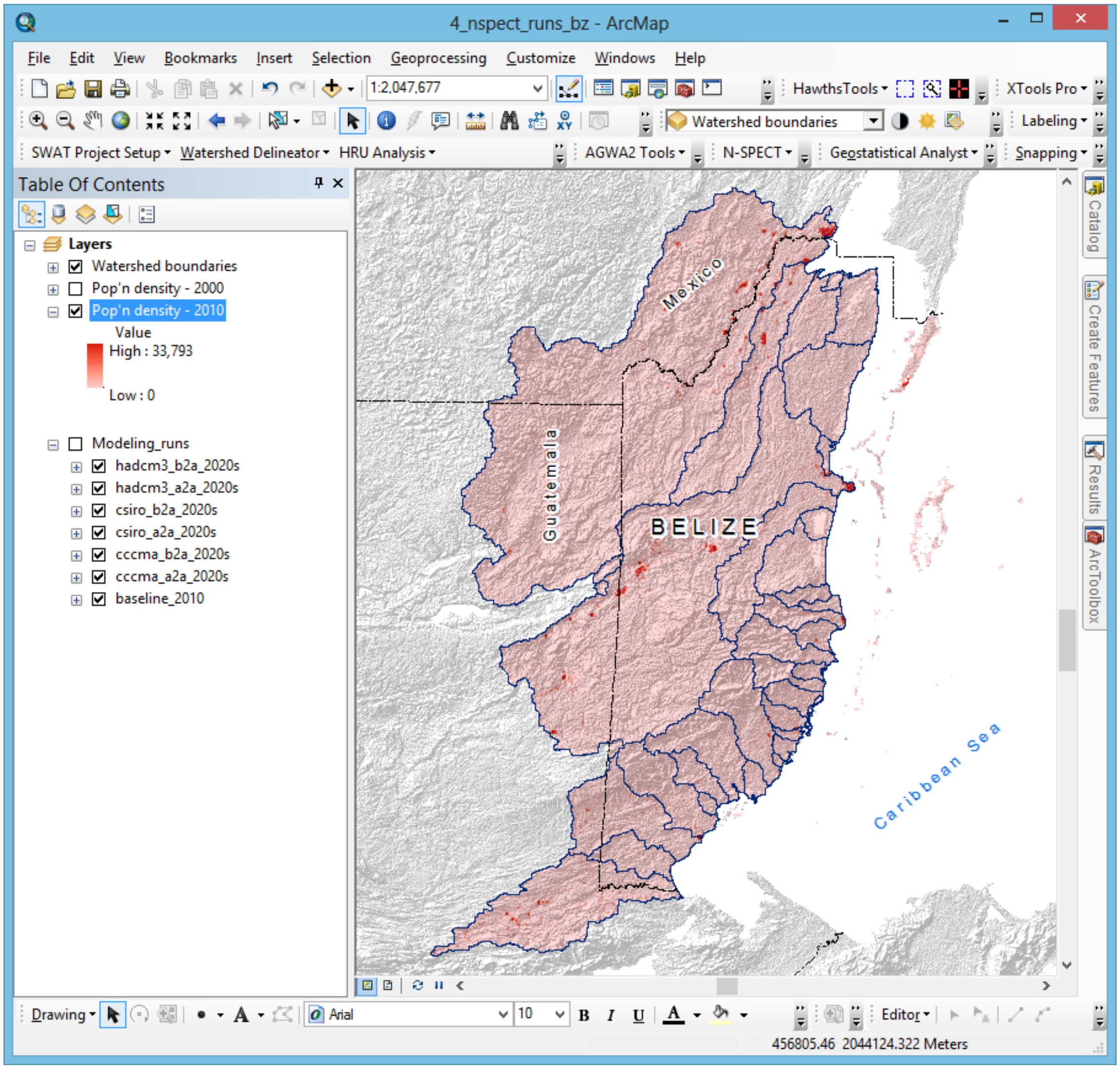

Figure 3: Population density across Belize's watersheds, 2010 (*based on Landscan, 2010*)

Future land use scenarios

Modeling of future land use change is also in process. As shown in **Figure 4** below, the preliminary results also allow us to observe which of the watersheds will likely be impacted by such land use change. As shown in the red circles below, these watersheds include those of the Rio Hondo, the Belize River, the Temash River, and the Sarstoon River. The land use modeling is being done with the software platform IDRISI, and involves doing regressions using a range of factors like the distance to roads, and prior deforestation, among others.

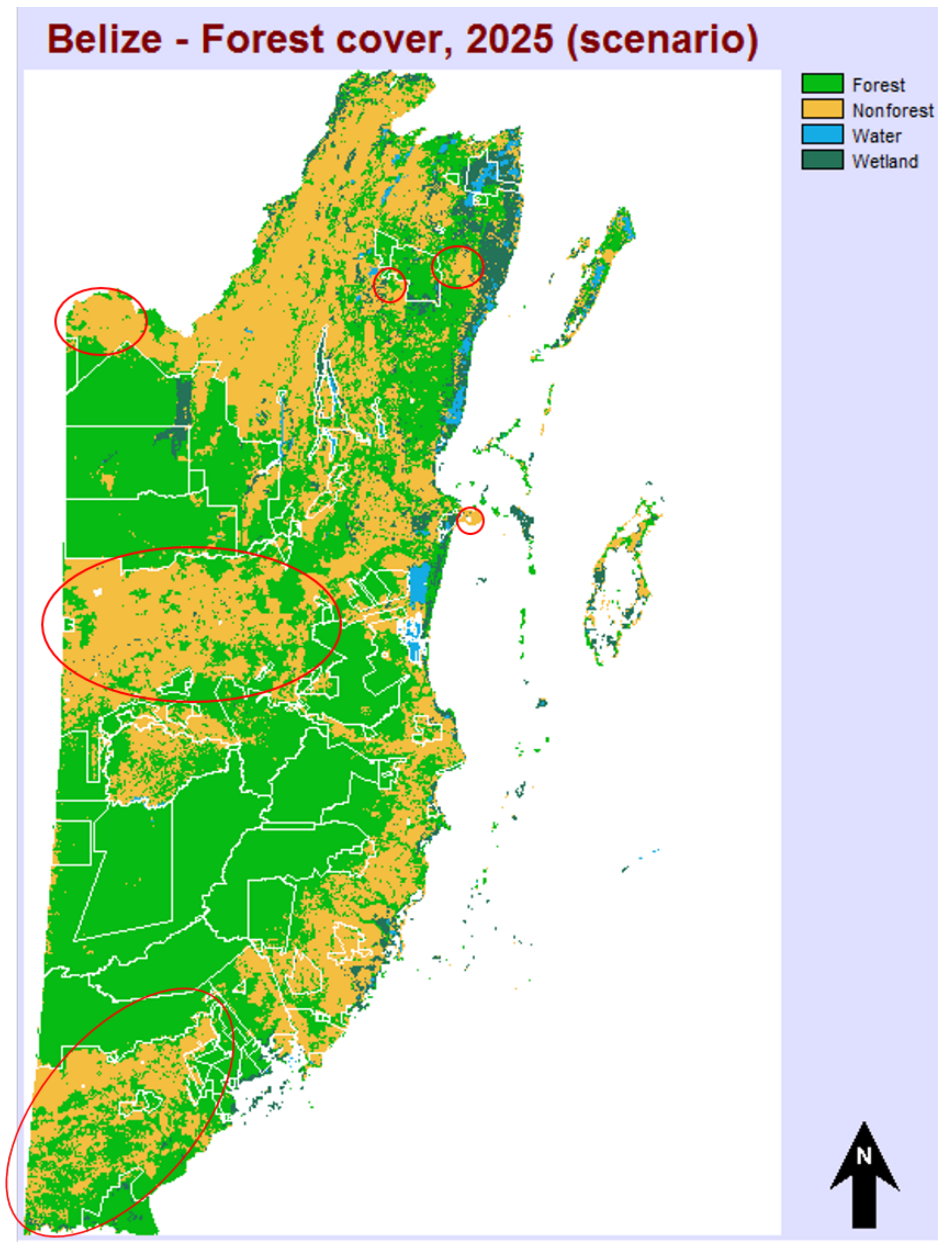

Figure 4: 'Business as usual' land use change scenario for Belize for 2025

b. Water resource supply modeling

Parallel to the modeling of social factors related to the future demand for water resources, a great deal of effort has also been invested in doing hydrological modeling and calibration of those models. The main inputs to that modeling include the following datasets:

i. Elevation
ii. Land use
iii. Rainfall
iv. Soil type

Hydrological modeling across climatic scenarios

Where the modeling will involve changes in hydrology through the 2050s, as part of our sensitivity analysis, we have been examining the preliminary climate change scenario-based model runs for the 2020s prior to continuing the runs out to the 2050s. The project has been using two hydrological modeling frameworks, namely the Soil and Water Assessment Tool for ArcGIS (ArcSWAT) and the Non-point Source Pollution & Erosion Comparison Tool (N-SPECT), and cross-calibrating between these, using data supplied by the National Meteorological Service (NMS) of Belize.

Tables 1-2 present summaries of the modeling using N-SPECT, while **Figures 5-7** show partial results regarding the runoff component of river flow for the Belize River watershed. For instance, we can already see that across the different models of future climate, there is a fairly broad range in terms of anticipated changes in rainfall patterns. For instance, the average annual rainfall for the Belize River watershed is 'forecast' to rise by almost 7% by the 2020s under the B2 scenario of the CCCMA model, while under the A2 scenario of the HADCM3 model, rainfall is 'forecast' to diminish by almost 23% (see **Table 1**). By comparison, the CSIRO model 'forecasts' modest increases in the average annual rainfall.

Table 1: Projected changes in average rainfall in the Belize River watershed, 2010-2020s

No.	**Scenario**	**Detail**	**Period**	**Avg. rainfall (mm)**	**Difference**
0	Baseline	-	~2010	1,804	-
1	CCCMA	A2	2020s	1,811	0.4%
2	CCCMA	B2	2020s	1,924	6.7%
3	CSIRO	A2	2020s	1,835	1.7%
4	CSIRO	B2	2020s	1,826	1.3%
5	HADCM3	A2	2020s	1,393	-22.8%
6	HADCM3	B2	2020s	1,668	-7.5%

In terms of how those changes in rainfall patterns translate to changes in surface runoff, as indicated in **Table 2** below, the potential range of changes in runoff range from an increase of over 14% (CCCMA model, B2A scenario) to a decrease of almost 47% (HADCM3 model, A2A scenario).

Table 2: Projected changes in surface runoff in Belize River watershed, 2010-2020s

No.	Scenario	Detail	Period	Runoff (m3)	Difference
0	Baseline	-	~2010	3,972,104,192	-
1	CCCMA	A2	2020s	3,982,451,016	0.3%
2	CCCMA	B2	2020s	4,545,282,310	14.4%
3	CSIRO	A2	2020s	4,091,308,147	3.0%
4	CSIRO	B2	2020s	4,049,529,471	1.9%
5	HADCM3	A2	2020s	2,152,589,165	-45.8%
6	HADCM3	B2	2020s	3,315,313,672	-16.5%

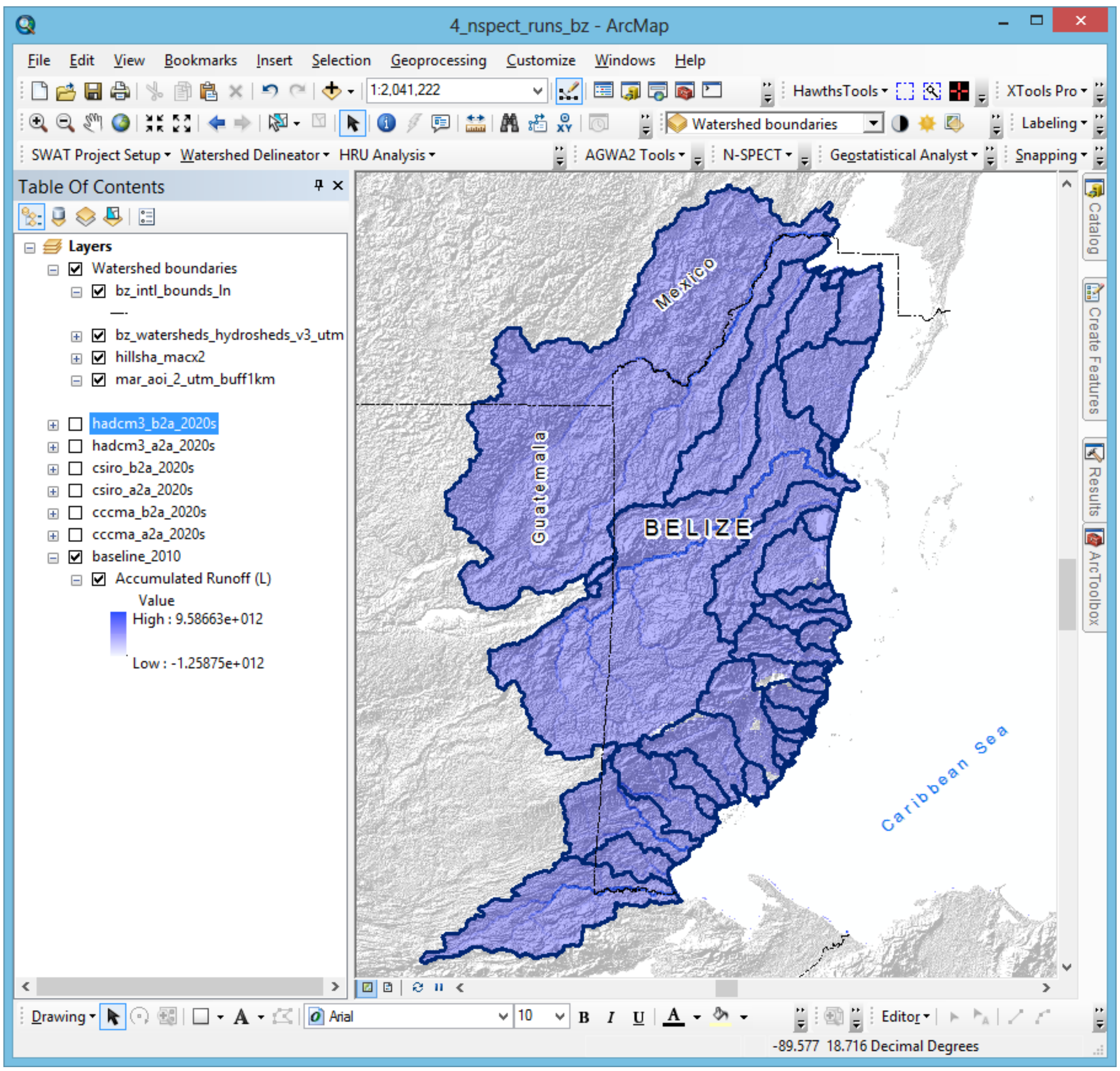

Figure 5: Runoff modeling for the baseline period (circa 2010)

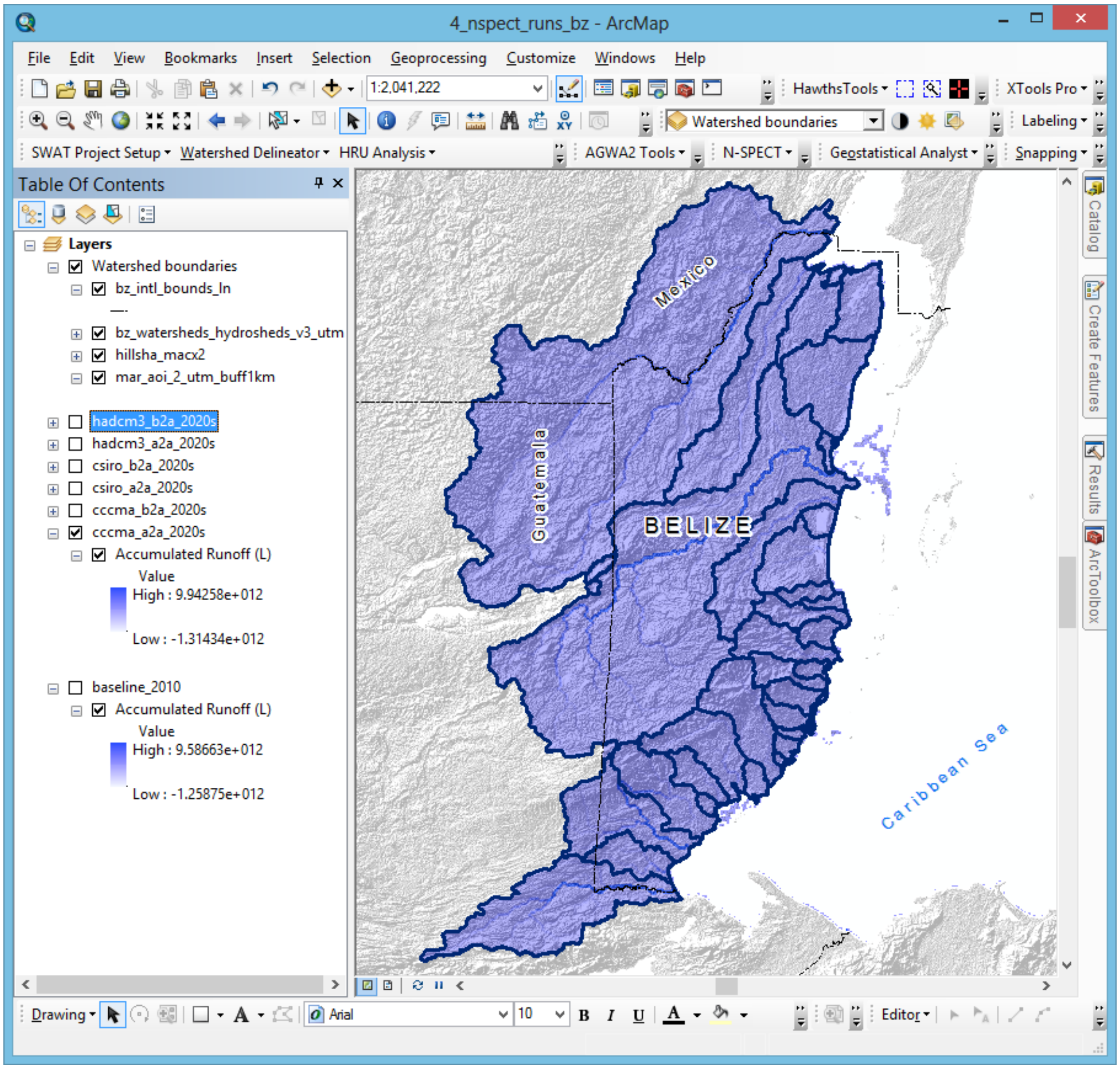

Figure 6: Runoff modeling for the 2020s, based on the A2A scenario / CCCMA model

As illustrated in **Figure 6** above, the maximum runoff actually increases under the A2A scenario of the CCCMA model, as compared with the baseline. And as compared with **Figure 6**, as **Figure 7** following shows, the maximum runoff decreases under the A2A scenario of the HADCM3 model, as compared with the baseline.

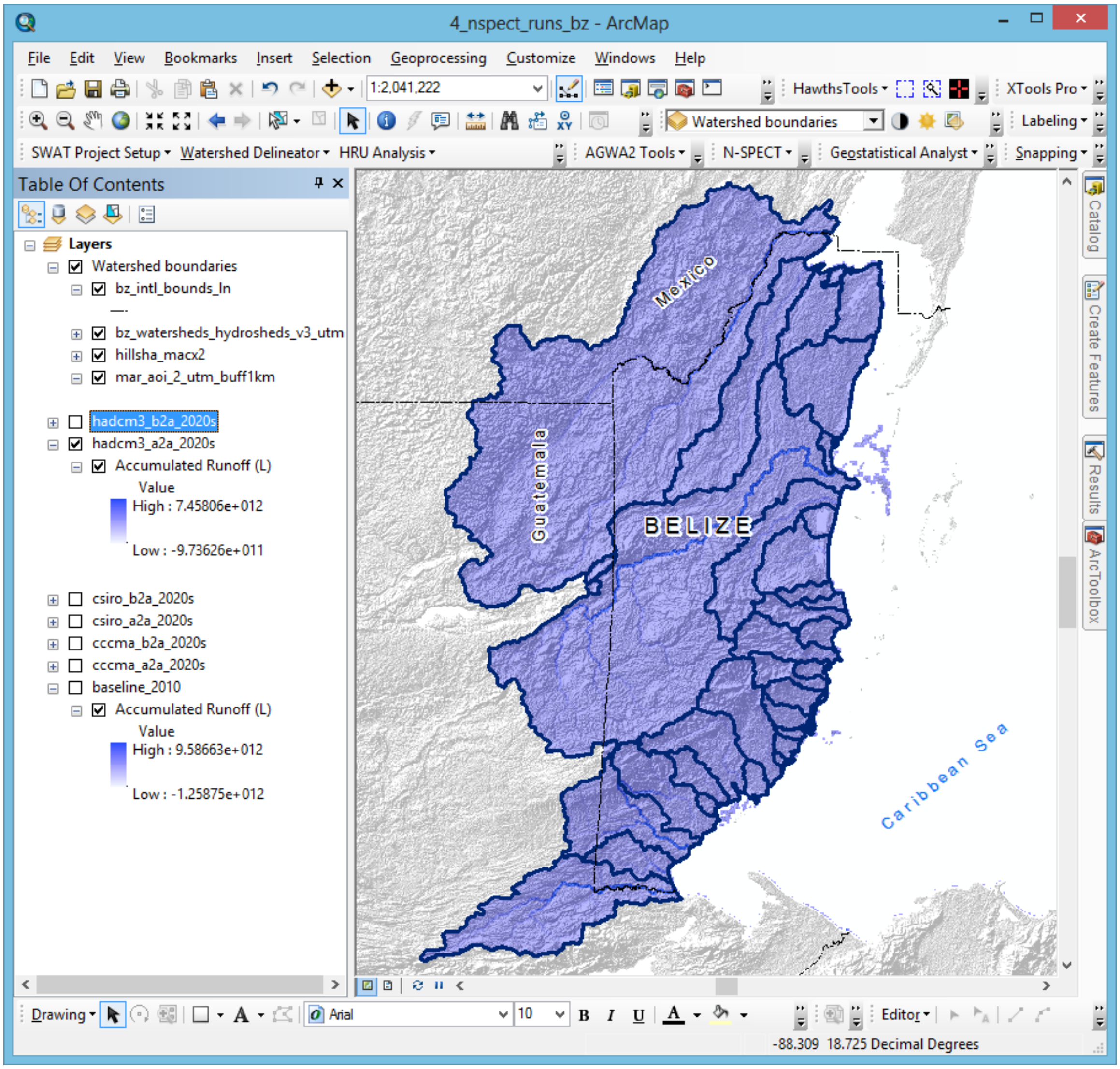

Figure 7: Runoff modeling for the 2020s, based on the A2A scenario / HADCM3 model

Improvements to digital elevation models

As part of the calibration of the process of hydrological modeling, we have noted that some of the data inputs possess systematic errors which require correction. That has been particularly evident in the case of the elevation data input. While the following do not adequately illustrate the impacts on hydrological modeling, **Figures 8-9** do illustrate the errors associated with the different digital elevation models (DEMs). **Figure 8**, for instance, shows how all three remotely sensed DEMs (i.e. ASTER GDEM2, InterMap Star3i, and SRTM v2) inaccurately represent the elevation of the Belize City peninsula probably due to the DEMs representing the heights of vegetation (e.g. mangrove forest). As shown in **Figure 9**, these in turn significantly affect estimates of which areas are at 1m above sea level, and which would potentially be inundated by sea level rise.

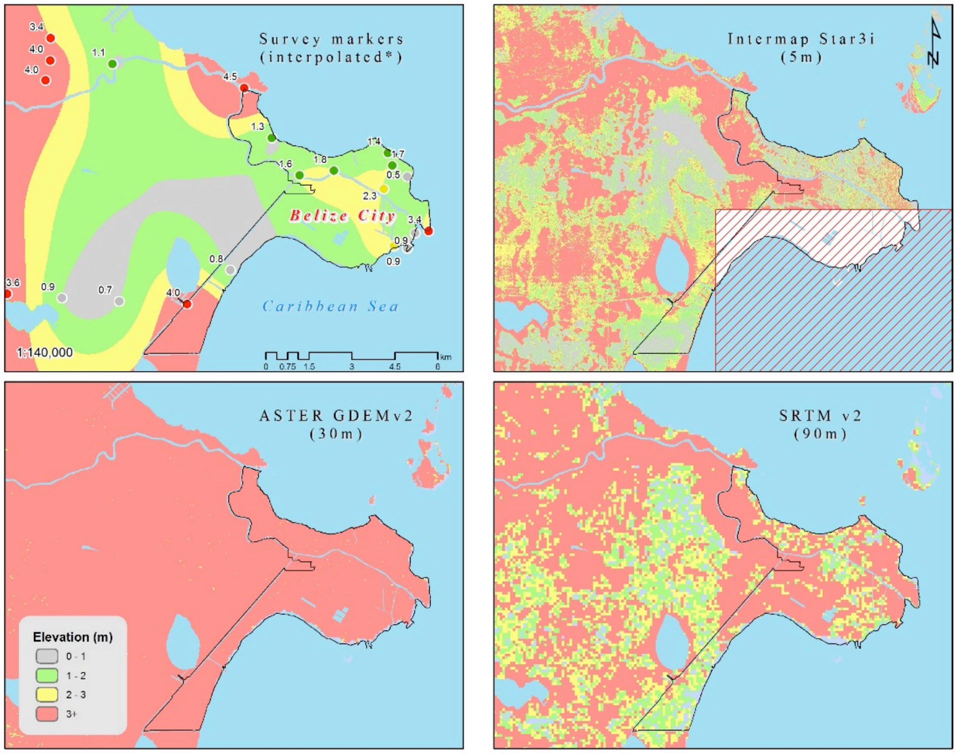

Figure 8: Comparison of digital elevation models for Belize City

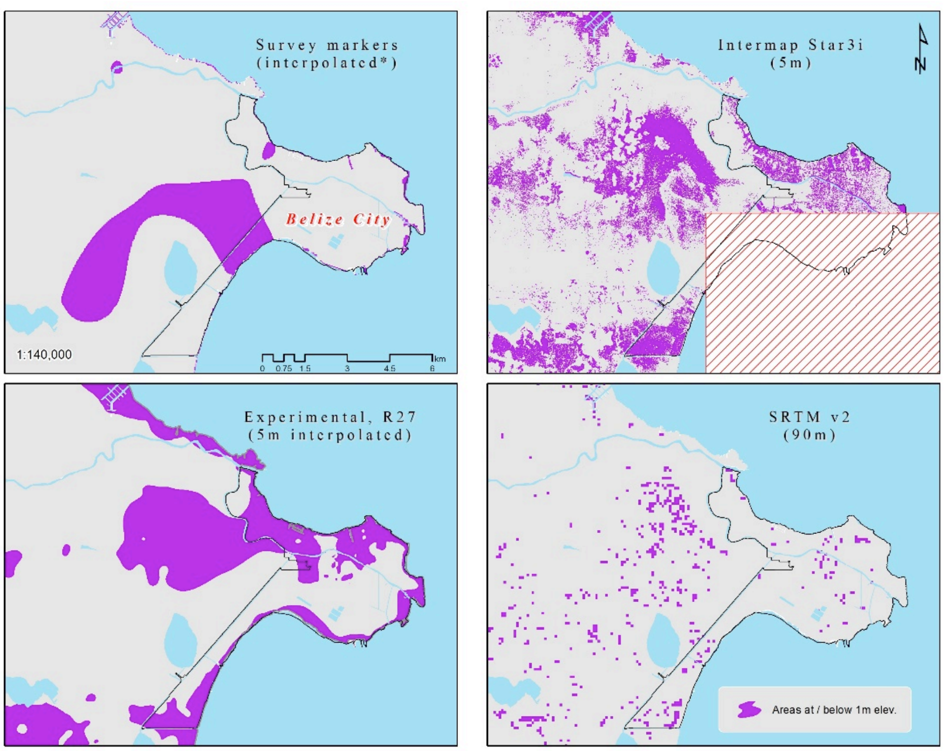

Figure 9: Comparison of derived 1m flood estimates for Belize City

Through a long, intensive process, a DEM of the study area was re-created using principally topographic data from the 1:50,000 topographic sheets for Belize, Guatemala, and Mexico. It is expected that using an improved DEM will in turn significantly improve the hydrological modeling.

IV. SUMMARY

During the first six months of the project, in terms of the technical outputs of the project related to the modeling of future population distribution, future land use, and potential climate change-related changes in rainfall patterns, a great deal of progress has been made. In terms of concrete results, significant progress has been made in terms of calibration of both the hydrological models and the model inputs (e.g. development of an improved digital elevation model for the project area of interest). It is expected that in the following project term (August 2013 – January 2014), the calibration and modeling will be completed, allowing for presentation, discussion, and validation of the project results in the final project term (February – July 2014).