TO: **FDOT**
FROM: **HDR, Inc.**
DATE: **August 2009**
PROJECT: **St Johns River Crossing**
FPID No: 208225-3-21-01
Clay, Duval, and St. Johns Counties; Florida

1. Introduction

The Florida Department of Transportation (FDOT) identified the need for an improved highway corridor and bridge crossing in the area of the St. Johns River between Clay and St. Johns Counties. The St. Johns River Crossing Project is an effort to decide the best solution, while trying to minimize the adverse effects that solution might have on the communities and the environment in the two counties.

Three goals were established to guide the FDOT in developing potential solutions to existing transportation problems in the project area (further defined below):

- Provide additional capacity to improve current and future transportation network deficiencies
- Promote and support employment and economic development
- Improve efficacy of emergency evacuation

These goals were then consolidated into a statement of purpose to be used to evaluate alternatives and identify the one that would best serve the area's transportation needs:

To address population growth and resulting traffic by providing additional capacity that meets the area's transportation, economic, employment and safety needs while avoiding, minimizing, and/or mitigating effects on the affected communities and the environment.

Rapid population growth in the project area has resulted in additional traffic and congestion on local roads, a situation that is expected to worsen in the future. Providing additional capacity to improve current and future transportation network deficiencies in the near term would help alleviate the congestion while providing access for residents to local employment centers, thus promoting and supporting economic development. Perhaps most important, an improved crossing of the St. Johns River would result in more efficient emergency evacuation, thus potentially saving lives.

2. Methodology

FDOT's technical team for climate assessment included atmospheric scientists who have reviewed extensive literature on this subject, including reports produced by a United Nations agency known as the Intergovernmental Panel on Climate Change (IPCC), journal papers, and various publications by a variety of governmental agencies. The intent in this section is to describe the current science as it relates to climate change and to provide the team's conclusions regarding the potential effects of global climate change on the Build Alternatives.

3. Project Impacts on Climate Change

Global climate can be affected by many factors, and in recent years, concerns have been expressed that mankind's emissions of greenhouse gases (GHGs) may warm the climate, possibly affecting precipitation patterns as well.

The proposed project's main potential contribution to global climate change would be through the emission of GHGs, primarily carbon dioxide (CO_2). As shown in the Energy section of the Draft EIS, all alternatives would use less energy for project operation than the No Build Alternative. Therefore, from a climate change standpoint, whatever impact the project's GHG emissions would have on climate change is less than the No Build Alternative's GHG emission impact.

This analysis does not consider the GHG emissions due to the production of construction materials such as steel and concrete for the Build Alternatives, or the construction equipment engine CO_2 emissions. However, if amortized over the life of the project, these emissions are expected to be minimal compared to operation-related emissions.

As shown in **Table 1**, the net annual change in CO_2 emissions due to the proposed project would be a minor fraction of the total CO_2 emissions in the world. Depending on the alternative, the project would contribute between 0.0005 percent and 0.0007 percent (Purple and Pink 1 & 2 Alternatives, respectively) to the global CO_2 emissions in 2030, assuming no increases in total world annual GHG emissions between 2005 and 2030. Over time periods of a year or longer, it can be assumed that CO_2 is essentially evenly distributed throughout the atmosphere across the globe. Because CO_2 is a minor contributor to the greenhouse effect in comparison to water vapor and clouds, and because mankind's emissions of CO_2 are a minor fraction of total CO_2 in the atmosphere, the project's possible contribution to manmade global climate effects would be much smaller than even the very small percentages stated above.

Table 1: **Annual Million Metric Tons of Carbon Dioxide**

Category	Emissions
World Total [a, b]	28,193
U.S. Total [a, b]	5,957
U.S. Power Plants Total [a, c]	2,514
U.S. Transportation Total [a, d]	1,191
2030 – No Build [e]	0.21
2030 – Pink 1 & 2 Build Alternatives [e]	0.19
2030 – Purple Build Alternative [e]	0.14

Sources:
Energy Information Administration, 2008, “Converting Energy Units 101, ” Energy Information Administration, retrieved on January 8, 2009, http://www.eia.doe.gov/basics/conversion_basics.html.

Notes:

a Emissions data are for year 2005.

b From Energy Information Administration (2008). Includes CO2 emissions from the consumption and flaring of fossil fuels. Data for most recent year (2005) are preliminary.

c From Energy Information Administration (2008). Includes CO2 emissions from energy consumption at conventional power plants and combined heat and power plants.

d From EPA (2008a), FHWA (2006). Includes CO_2 emissions from the operation of gasoline-powered highway vehicles. CO_2 emissions from non-gasoline powered private and commercial highway use vehicles is not included. CO_2 emissions per gallon of gasoline were calculated using 8.81x10-3 metric tons of CO2 per gallon of gasoline. Data are for most recent year (2005).

e From EPA (2008b). Carbon dioxide emissions per gallon of gasoline were calculated using 8.81x10-3 metric tons of CO2 per gallon of gasoline.

4. Climate Change Impacts on Project

While there are many viewpoints regarding human-caused effects on global climate, there are three primary positions on global climate change science with respect to GHG emissions:

(1) The effect of anthropogenic, or man-made, emissions of greenhouse gases (those other than water vapor) is the dominant driver of recent climate change and will continue to be for decades to come, barring elimination of a vast majority of the emissions.

(2) The effect of anthropogenic emissions of greenhouse gases on climate is not negligible, but is not the dominant driver of global climate change.

(3) The effect of anthropogenic emissions of greenhouse gases on climate is negligible, in part because water vapor and clouds provide a negative feedback to greenhouse gas “forcing.”

4.1 Model Projections

The committee that developed the IPCC's "Summary for Policymakers" (IPCC 2007) has concluded that the first position noted above is the most supportable. In support of this conclusion, the IPCC has used computer-based mathematical models called "global circulation models" (GCMs) to simulate the climate's response to a wide range of GHG emissions scenarios. Carbon dioxide (CO_2), the primary anthropogenic GHG, is used as the basis for these IPCC scenarios. **Figure 1** shows the results of some IPCC simulations using GCMs to project future global average temperature for various CO_2 emissions and concentrations scenarios.

The four projection curves in **Figure 1** represent emissions scenarios that are assumed to result in Year 2100 concentrations of 370 ppm (Year 2000 Constant Concentration curve), 600 ppm (B1 curve), 850 ppm (A1B curve), and 1250 ppm (A2 curve). The lowest curve represents CO_2 concentrations reverting to the year 2000 level and remaining steady until the year 2100. The other three curves reflect increases in CO_2 concentration of approximately 2.3 ppm per year, 4.8 ppm per year, and 8.8 ppm per year, corresponding to the year 2100 concentrations of 600, 850, and 1250 ppm, respectively. For the two most recent years (2007 vs. 2006) of complete CO_2 monitoring data (at Mauna Loa, Hawaii), the average rate of CO_2 increase has been approximately 1.87 ppm per year (NOAA 2008). Thus, the IPCC's scenarios range from a modest increase over this recent rate of 1.87 (2.3 ppm per year) to an increase of nearly 5 times the recent rate of CO_2 increase (8.8 ppm per year). Note that the shaded areas around each curve represent the IPCC's estimates of uncertainty for each emissions scenario simulation.

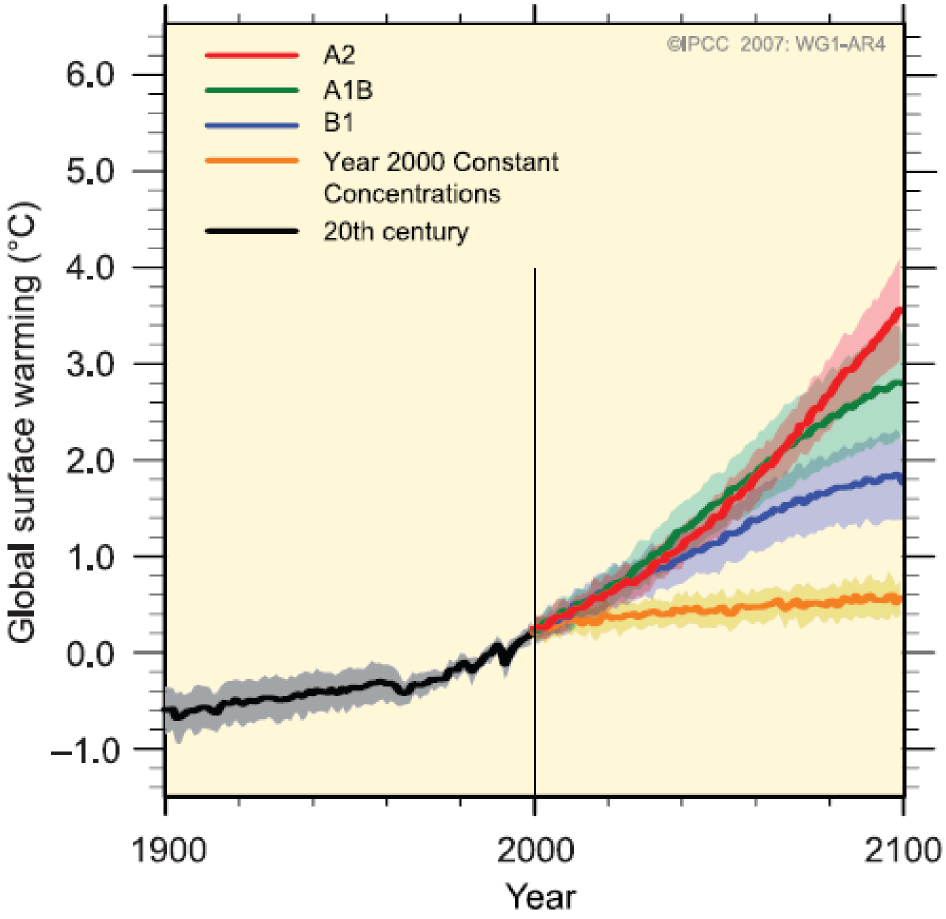
A GCM "is a simplification and simulation of reality, meaning that it is an approximation of the climate system. The first step in any modeled projection of climate change is to first simulate the present climate and compare it to observations. Projections of future climate change depend on how well the computer climate model simulates the climate and on our understanding of how forcing functions will change in the future" (NOAA 2008).

4.2 Observational Data

Observations of global temperature and increasing greenhouse gas concentrations provide a basis for comparison with the IPCC's modeled projections. Given the many problems with surface station records, including limited numbers of stations over oceans, Urban Heat Island issues which can bias local temperature observations, and instrumentation siting issues in non-urban areas, the satellite record may be the best way to monitor global temperatures. Unfortunately, there is only a 30-year record of satellite data, which are used to estimate temperature in a layer of the lower atmosphere, or troposphere. However, a 30-year record is sufficient to see some trends as well as short-term fluctuations.

Figure 2 compares the trends of nearly 30 years of global temperature, measured via satellite (UAH 2008), with atmospheric CO_2 concentration, measured at Mauna Loa, Hawaii (NOAA 2008). The CO_2 measurements are done on the island of Hawaii because it is removed from large anthropogenic influences, so the measurements should be representative of global, rather than local, trends. As shown on the table, there has been a steady rise in CO_2, and much of the rise is due to fossil fuel use and deforestation. The regular up and down pulsing of CO_2

Figure 1: **IPCC Projections of Global Warming for Several CO2 Emissions Scenarios**



Source: IPCC 2007

Solid lines are multi-model global averages of surface warming (relative to 1980-1999) for the scenarios A2, A1B, and B1, shown as continuations of the 20th century simulations. Shading denotes the ± 1 standard deviation range of individual model annual averages. The orange line is for the experiment where concentrations were held constant at year 2000 values. The grey bars at right indicate the best estimate (solid line within each bar) and the likely range assessed for the six Special Report on Emission Scenarios (SRES) markers. The assessment of the best estimate and likely ranges in the grey bars includes the AOGCMs in the left part of the figure, as well as results from a hierarchy of independent models and observational constraints.

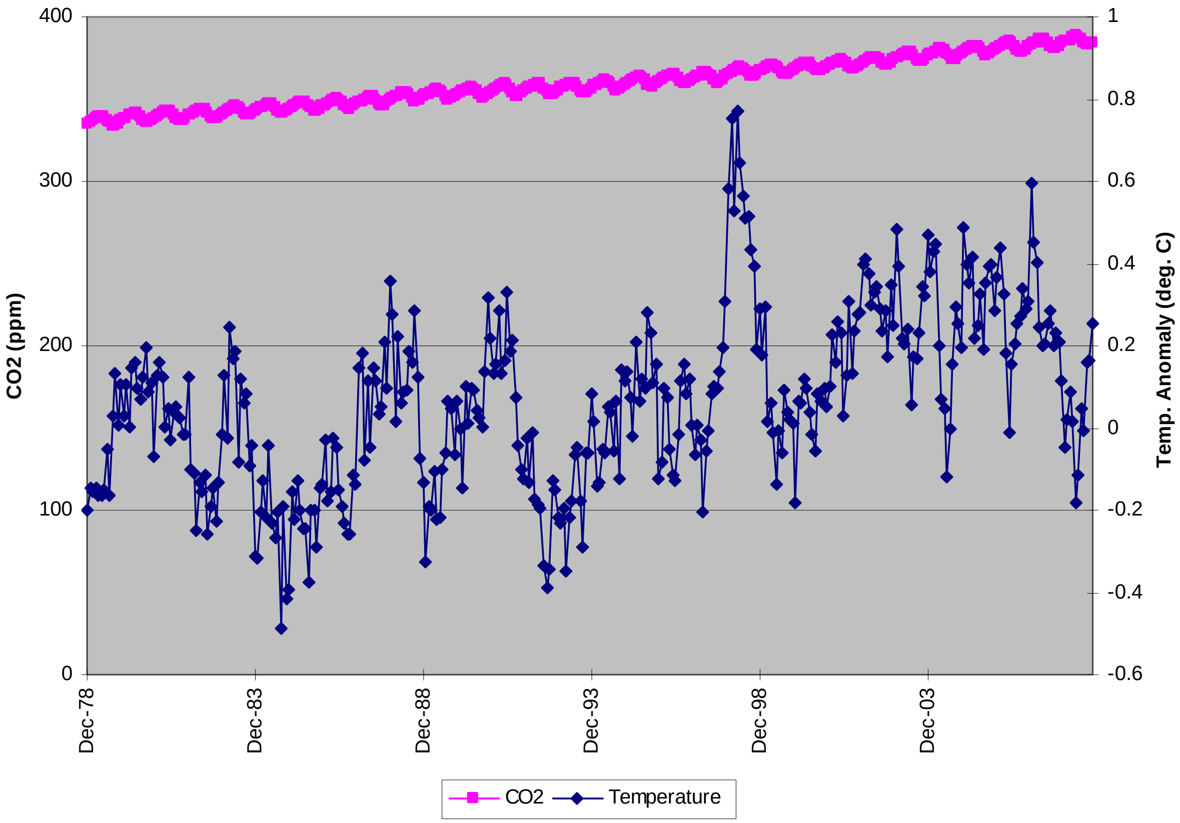
represents annual variation, as the northern hemisphere biosphere removes CO_2 from the atmosphere during the growing season and releases it in the winter.

The temperature data shown in **Figure 2** are based on data collected by satellites, using an instrument called a microwave sounding unit (MSU). The satellite data presented are those analyzed by the University of Alabama at Huntsville (UAH), and represent the lower layer portion of the troposphere (http://vortex.nsstc.uah.edu/public/msu/t2lt/tltglhmam_5.2). Because they represent an average over a vertical layer, and are also averaged across the globe, the data are not as likely to be influenced by station siting issues. They provide much better coverage over oceans as compared to the primarily land-based surface measurement sites. The "temperature anomaly" plotted on the right side of the graph represents the temperature deviation of any given month of data from the mean value based on averaging the data collected from the start of monitoring in December 1978 through December 1999. While this is a somewhat arbitrary period to use as a baseline, it is long enough to average out the short-term fluctuations in the record, and is generally consistent with analyses of these data presented in other forums.

The average temperature trend represented in the UAH data analysis is an increase of approximately 0.13 degrees Celsius (C) per decade, or 1.3 degrees C per 100 years. This value is somewhat lower than the IPCC scenario B1 shown in Figure 1 which represents a CO_2 average rate of increase of 2.3 ppm per year through 2100, corresponding to an IPCC-projected increase over the current century of approximately 1.5 degrees C. If GHG emissions are the primary driver of recent climate trends, then the IPCC's temperature projections, for Scenario B1 at least, are not at great odds with the past 30 years of satellite observations. However, if a significant portion of the observed warming over the past 30 years is due to natural effects, this could mean that the models are significantly overestimating effects of GHG emissions.

Some natural factors are evident in the temperature record displayed in **Figure 2**. The most obvious is a very strong El Niño episode in December 1998, which created a spike in global temperatures. El Niño is characterized by higher than normal sea surface temperatures in the eastern equatorial Pacific Ocean; it is widely recognized that these episodes can affect global average temperatures. The opposite of the El Niño effect is La Niña, in which cooler than average sea surface temperatures occur in the same region. This happened in late 2007 and early 2008, and its effects can be seen in the temperature trend in **Figure 2**.

Figure 2. **Global Temperature (via Satellite) and CO2 Trends Since 1978**



A longer-term Pacific Ocean cycle, considered to affect temperatures globally, is the Pacific Decadal Oscillation (PDO). The PDO cycle is approximately 60 years in length, with approximately 30 years of cool phase followed by 30 years of warm phase and so on. The PDO last switched to a warm phase around 1978, near the time that satellite temperature measurements began. In April 2008, the National Aeronautics and Space Administration (NASA) announced that the PDO had recently switched to a cool phase (NASA 2008). Given that the PDO does affect global average temperatures, it is possible that a significant part of the past 30 years of warming could be influenced by this cycle.

4.3 Global Circulation Models (GCM) Models and Climate Change Uncertainties

A recent paper by NASA and other researchers to document the performance of NASA's GCM demonstrates the difficulties it has in predicting the known, past climate conditions (Lynn, et al. 2007). In the subject study of summertime (June through August) temperature and precipitation conditions covering nearly the entire eastern half of the US, NASA's model estimated the daily maximum temperatures as an average across the modeled region. The NASA model under-predicted daily maximum temperature by an average of 8.5º F compared to actual observed daily maximum temperatures for the five-year study period (1993-1997). For precipitation, observations indicate approximately 52 centimeters (cm) of precipitation fell on average per summer, with measurable precipitation occurring on approximately 25 percent of the days. NASA's model predicted only 25 cm of precipitation—less than 50 percent of the actual total, and predicted it would fall on approximately 67 percent of the days.

The above findings highlight an uncertainty associated with all current GCMs, due to their inability to successfully simulate the hydrologic cycle. This is in large part due to limitations of the models that cannot properly simulate scales of clouds in general, especially convective cloud systems, which perform most of the vertical moisture distribution in the atmosphere. Water vapor is not only the dominant greenhouse gas in the atmosphere; it also has a major effect on climate through precipitation and clouds, which reflect sunlight to keep the earth's surface cool, and trap infrared radiation that would otherwise escape to space, thus keeping the earth's surface warm. While the Sun provides the energy for Earth's climate, water in all its forms is the primary thermostat that moderates temperature. In the case of deserts where water is nearly absent, temperature is not substantially moderated by water vapor or clouds, because of their relative absence.

The authors of the study using the NASA model state: "Unrealistic features of the AOGCM [NASA's GCM] simulation of some climate fields compromise the accuracy of the projections of climate change. However, mindful of the validations of its performance, the AOGCM's simulation of the IPCC A2 climate change scenario [see Figure 2 and the discussion above] is as plausible as simulations from other IPCC models…" While the NASA study points out substantial problems with its model, the authors say that, while it is not very good, it is as good as the other GCMs used by the IPCC.

Currently, uncertainties remain surrounding the science of climate change. These uncertainties will remain unless and until advancements in science can be made in the understanding of natural climatic variations, changes in the sun's energy, land-use changes, the warming or cooling effects of pollutant aerosols, and the effects of changing humidity and cloud cover. The relative contribution to climate change of human activities and natural causes must still be determined (EPA 2008). Other uncertainties include the projection of future greenhouse gas emissions and how the climate system will respond, and the reasons behind past abrupt climate changes and potential for future such changes (EPA 2008).

The U.S. Climate Change Science Program (CCSP 2008) is developing twenty-one synthesis and assessment products to advance scientific understanding of these uncertainty areas by the end of 2008. The first product, SAP-1.1 (CCSP 2006), which to date is the only product that has been made final, addresses identified conflicts between observations and simulations of surface and atmospheric temperature trends. The goals of the CCSP include summarizing what is known about climate change, what is uncertain, and what areas should be recommended for further study.

In addition to the current uncertainties discussed above, there are many longer-term natural factors that affect temperature trends both up and down. These include the natural factors that caused the major ice ages, the Medieval Warm Period, and the Little Ice Age. Some natural factors include:

- Longer-term deep-sea ocean circulations
- Volcanic activity
- Variations in the strength and characteristics of solar output
- Orbital variations of the earth

These factors, to the extent that they could be affecting climate trends, create additional uncertainty because it is not clear which of the natural factors are the dominant influences on climate change.

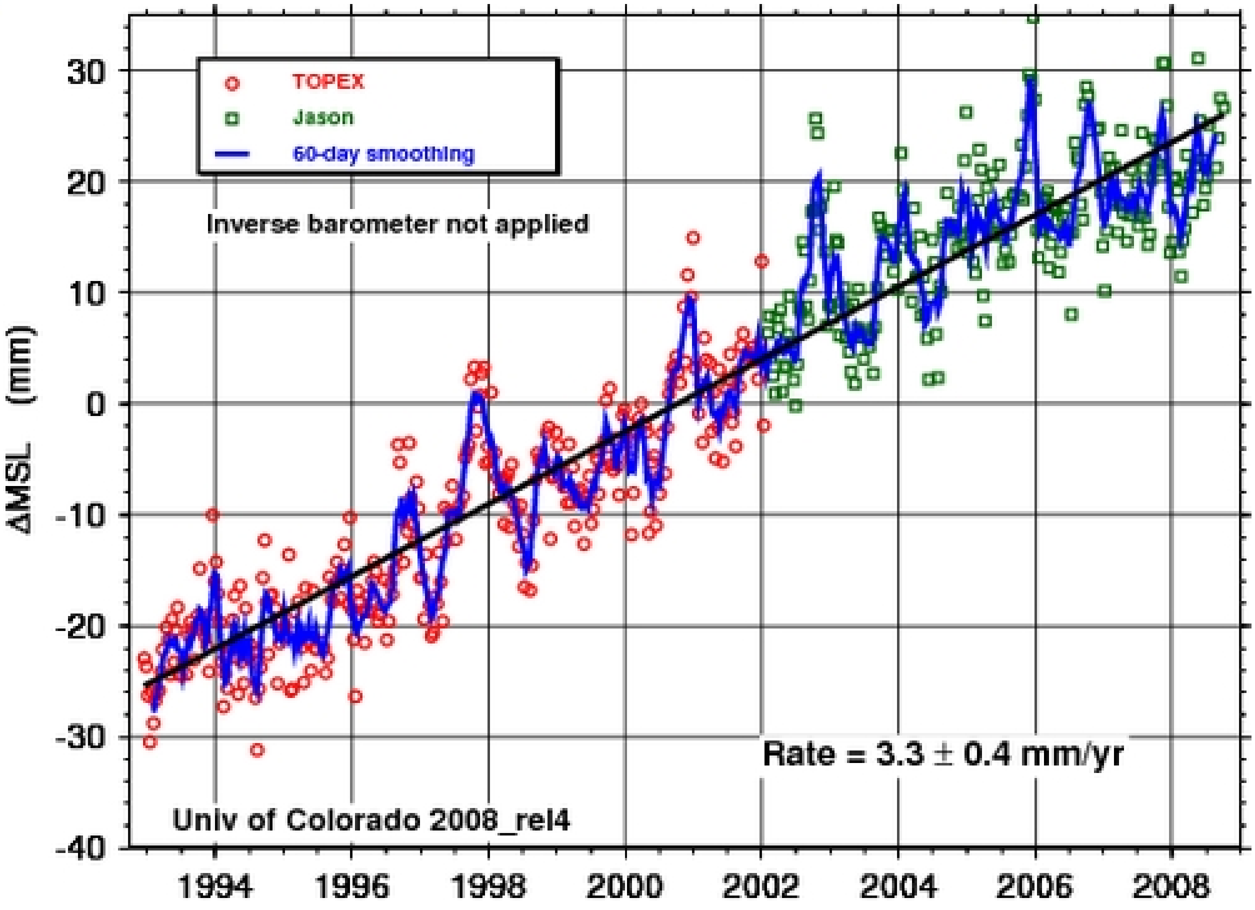
4.4 Global and Regional Sea Level Changes

The variation in mean sea level as a result of global climate change is of considerable interest in coastal regions. While observations of long-term changes in mean sea level can provide corroboration of global warming predictions by climate models, uncertainties in sea level change projections as a result of carbon cycle feedbacks, which impact the climate, limit the ability to specify a best estimate of sea level change.

Sea level variations are primarily determined with two different methods: long-term averaging of tide gauge measurements, and satellite altimeter measurements combined with spacecraft orbits. The latter of these methods, in place since 1992, has measured sea level on a global basis, and concurrent tide gauge calibrations are used to estimate the satellite altimeter drift. The TOPEX/POSEIDON (TOPEX) satellite (1992 to 2005) and the Jason-1 satellite (the successor to TOPEX, launched in 2001) provide observations of sea level change and are presented in **Figure 3**. The Jason-1 satellite currently records an estimate of global sea level every 10 days with an uncertainty of 3-4 mm (http://sealevel.colorado.edu). Prior to 1992, eight different tide gauge estimate studies indicate a long-term annual sea level rise from 0.9 to 3.3 mm/yr, depending on the range of error, the record length used (datasets chosen in sets between 1807 and 1988), and the tide gauges selected (http://sealevel.colorado.edu). Generally, the long-term annual sea level rise during the period 1880 to 1980 is 1.8 mm/yr (Douglas, 1991).

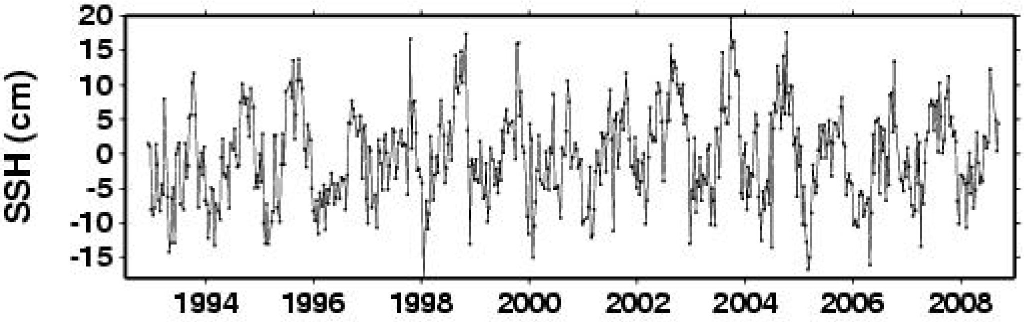
Regional changes in sea level can be different from the global average due to regional variations in oceanic level change and geological uplift/subsidence (Nicholls et al., 2007). **Figure 4**, which was generated using the University of Colorado's online interactive sea level wizard, shows the sea surface height anomaly (relative to the average) measured by satellite at 279 degrees longitude and 30 degrees latitude, or approximately the mouth of the St. Johns River at the Atlantic Ocean. The period of record (1992 to present) indicates no noticeable trend from the average. However, given the relatively short period of record, and the height scale represented, it is possible there could have been a slight increase in sea level that is not obvious in the figure. Note that at the rate of global rise measured from satellite data in **Figure 3**, there should have been approximately 5 centimeters of sea level rise over the period of record shown in **Figure 4**.

Figure 3. **Global Sea Level Changes (via Satellite) Since 1992**



Source : http://sealevel.colorado.edu

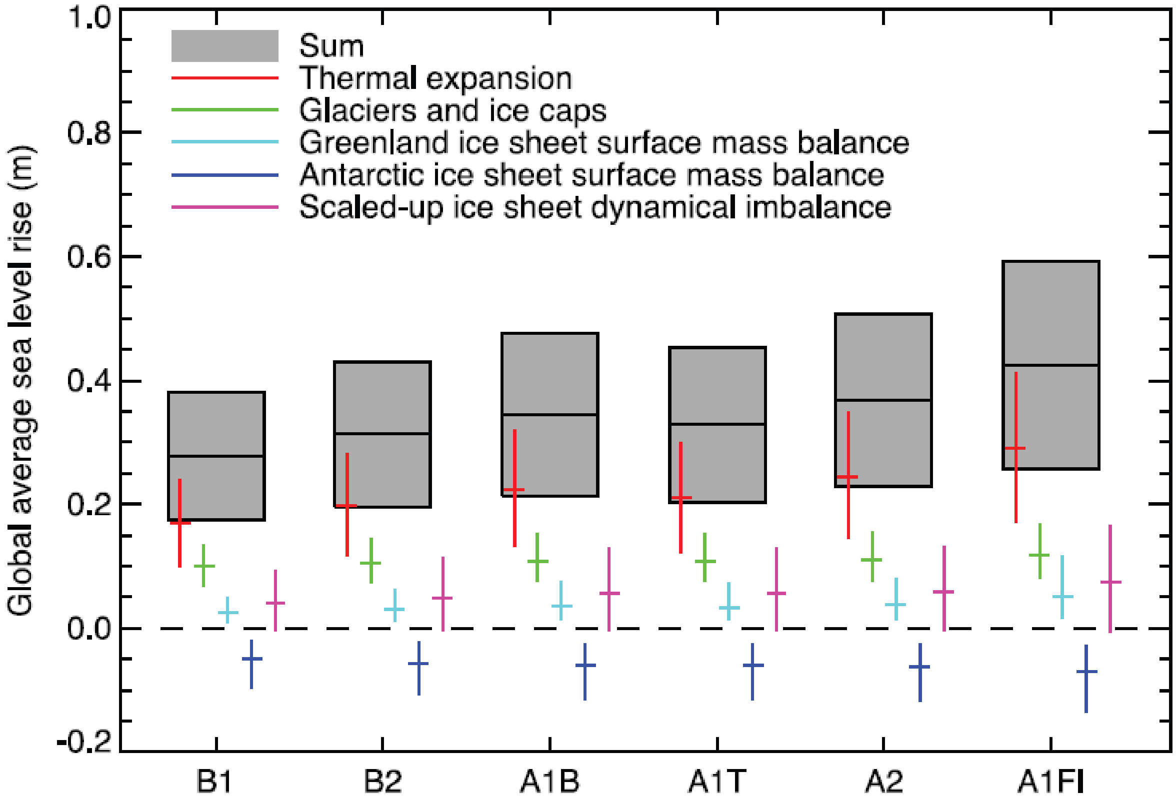
Figure 4. **Sea Surface Height Anomaly (via Satellite) at the Mouth of the St. Johns River**



Source: http://sealevel.colorado.edu/wizard.php?dlon=279&dlat=30&map=v&fit=n&smooth=n&days=60

As shown in **Figure 5**, the IPCC Fourth Assessment Report (TAR) (2007) projected an increase of 0.18-0.59 m (7.1-23.2 inches) global average sea level by year 2100, under the Special Report on Emission Scenarios SRES markers for the 21st Century due to thermal expansion and land ice changes based on Assessment Report 4 (AR4) atmosphere-ocean general circulation model (AOGCM) results (Meehl et al. 2007). Due to uncertainties in sea level rise projections, a best estimate cannot be made. Given the lack of departure from the average for the local area as shown above, the IPCC projections provide a reasonable range of potential sea level rise for use in the project area. However, very recent trends in both sea level (past 3 years) and global temperatures (past 2 years) indicate a potential for leveling-off or even a decrease in global sea level and temperatures, so it is not a foregone conclusion that both will continue to rise over the life of the project.

Figure 5. **IPCC Projections of Sea-Level Rise for Several CO2 Emissions Scenarios**



Source: IPCC 2007

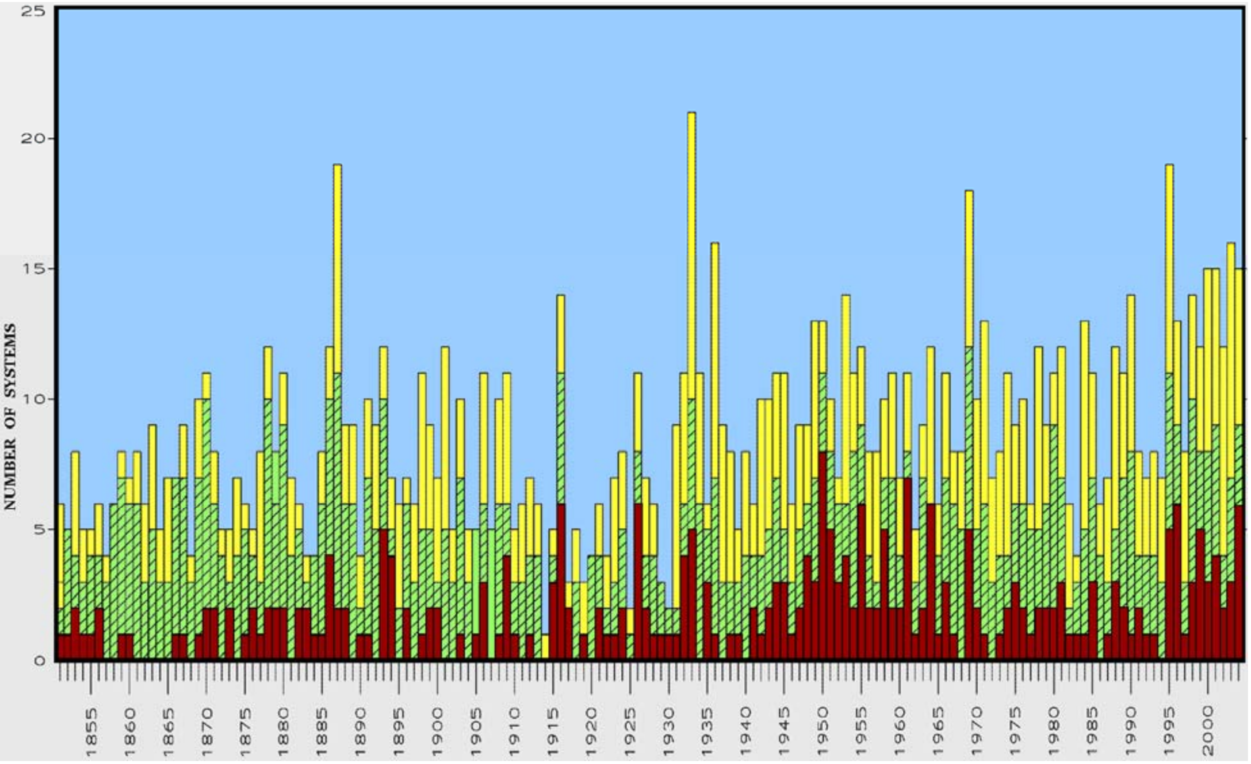
Projections and uncertainties (5 to 95% ranges) of global average sea level rise and its components in 2090 to 2099 (relative to 1980 to 1999) for the six SRES marker scenarios. The projected sea level rise assumes that the part of the present-day ice sheet mass imbalance that is due to recent ice flow acceleration will persist unchanged. It does not include the contribution shown from scaled-up ice sheet discharge, which is an alternative possibility. It is also possible that the present imbalance might be transient, in which case the projected sea level rise is reduced by 0.02 m. It must be emphasized that we cannot assess the likelihood of any of these three alternatives, which are presented as illustrative. The state of understanding prevents a best estimate from being made.

4.5 Storm Surge Change

The St. Johns River is a shallow river which is under the influence of the Atlantic Ocean tides. It is also subject to storm surge resulting from hurricanes. Storm surge occurs as a result of water being pushed onshore by winds swirling around a storm. Storm surge is highest to the right of the center of an approaching storm, and when coinciding with normal high tide. The National Hurricane Center's Sea, Lake and Overland Surges from Hurricanes (SLOSH) models indicate the region's coastal counties could potentially experience storm surges in excess of 19 feet during a Category 5 event, while some areas of the inland counties along the St. Johns River could receive surges up to 10 feet (FDOT 2008).

Under the IPCC sea level rise scenarios, the added sea level rise could potentially add on the order of 10 to 20 percent to maximum anticipated hurricane storm surge levels. There is speculation that global warming could increase the frequency and intensity of hurricanes, also exacerbating the effects of storm surges. However, data from the National Hurricane Center (NOAA 2008) summarized in **Figure 6** indicate that while there seems to be multi-decadal cycles in hurricane frequency and intensity, there is no clear trend toward greater hurricane intensity with the slight global temperature increase of the past 30 years.

Figure 6. **North Atlantic Hurricane Activity**



Source: http://www.nhc.noaa.gov/pastprofile.shtml
Bars depict number of North Atlantic named systems (open/yellow), hurricanes (hatched/green), and Category 3 or greater (solid/red), for the years 1850 to 2004.

4.6 Effects & Conclusions

Any of the Build Alternatives is expected to add a very small amount of CO_2 emissions to local, regional, national and global emissions of CO_2, in comparison to total anthropogenic emissions, and any of the alternatives would contribute less CO_2 emissions than the No Build Alternative. Therefore, if global climate change occurs as a result of anthropogenic GHG emissions, any of the Build Alternatives would have less of an impact on climate change compared to the No Build Alternative.

The existing Shands Bridge has a vertical clearance of 45 feet from the mean high water mark of the St. Johns River. Under the Pink 1 & 2, Green 1 & 2, Orange 1 & 2, and Brown 1 & 2 Alternatives, the proposed project would result in a new bridge with a vertical clearance of 65 feet. The IPCC has projected a sea level increase of 0.18-0.59 m (7.1-23.2 inches) between 1980 to 1999 and 2090 to 2099. Assuming that a rise in sea level elevation would result in an equivalent rise in the St. Johns River, the 20-foot difference in bridge height is sufficient to allow for a potential two-foot increase in sea level elevation due to climate change for any of the Pink, Green, Orange, and Brown Alternatives compared to the No Build Alternative. For the Black and Purple Alternatives, the new bridge crossing of the St. Johns River would also be constructed with a 65-foot vertical clearance, again sufficient for a potential two-foot increase in sea level elevation.

Storm surge effects could increase slightly due to continued sea level rise. However, the modest projected increases in sea level over the present century are not expected to be enough to substantially affect the levels of storm surge such that the proposed bridge Build Alternatives would be dysfunctional.

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