24 April, 2008

COMPREHENSIVE PLAN SUBMISSION: "ENVIRONMENTAL PROTECTION"

Topic: Protection of County infrastructure from effects of rising sea level

1. Discussion

It is now generally accepted that the earth's climate is changing, and that global temperature is rising. An inevitable result of this is that sea levels are rising around the world, and will continue to do so, at an accelerating rate, for many years to come. James City County is particularly susceptible to rising sea level because of the relatively low elevations above mean sea level of certain parts of the County. In addition to the encroachment of the Atlantic Ocean into the Chesapeake Bay and river estuaries, the changing global climate will give rise to more severe storms, with accompanying storm surges in the County's low lying areas, which will inundate private property and cause damage to public infrastructure. Over the next century, sea level is most likely to rise by about 8 inches along most of the U.S. Atlantic and Gulf Coasts.

The rate of rise in water level in the Chesapeake Bay and adjacent estuarine areas is about a factor of 2 greater than the world wide increase in sea level. Thus, in 50 years, water level can be expected to rise about 8 inches in lower James City County. The result of such a rise in water level will be to increase the extent of flooding due to storm surges. However, as will be seen in Section 2.1 following, it is possible that the rise in mean global sea level may considerably exceed the historical average, as a consequence of accelerated melting of the earth's ice caps.

The recommendations contained in this report relate both to the long term consequences of sea level increase, and the episodic occurrence of storm surges, which are expected to become more frequent and more intense as global climate change progresses.

2. Global Climate Change

Global temperature has risen steadily for at least 100 years, but the rate of increase has accelerated in the last 30 years. A significant part of the increase in sea level has been due to thermal expansion of the ocean water. The remainder has been due to melting of glaciers around the world. Associated with this global warming is a steady increase in the concentration of carbon dioxide in the atmosphere, produced by burning of fossil fuels, which is responsible for most of the global warming. The world's oceans have an enormous capacity for storing heat, and have been doing do since the warming phase began. This is known as the "thermal inertia" of the oceans. The stored heat will be retained, and will continue to increase as long as the global warming persists. The increased level of carbon dioxide will reside in the atmosphere for several decades, so that even in the improbable event that carbon emissions were curtailed immediately, the atmosphere and ocean would continue to warm, glaciers and ice caps to melt, and sea level would continue to rise for decades. The more likely scenario is one in which carbon emissions continue to increase for many years, before gradually declining, thereby greatly exacerbating the climate change. Figure 1 shows the global temperature anomaly since 1880 – i.e., the deviation of the average global temperature from an arbitrary reference year. The black lines and points represent annual mean temperature anomaly, while the red lines represent a 5 year running average temperature anomaly. Global temperature is seen to have increased by about 0.7° C (1.3 ° F) over the interval depicted.

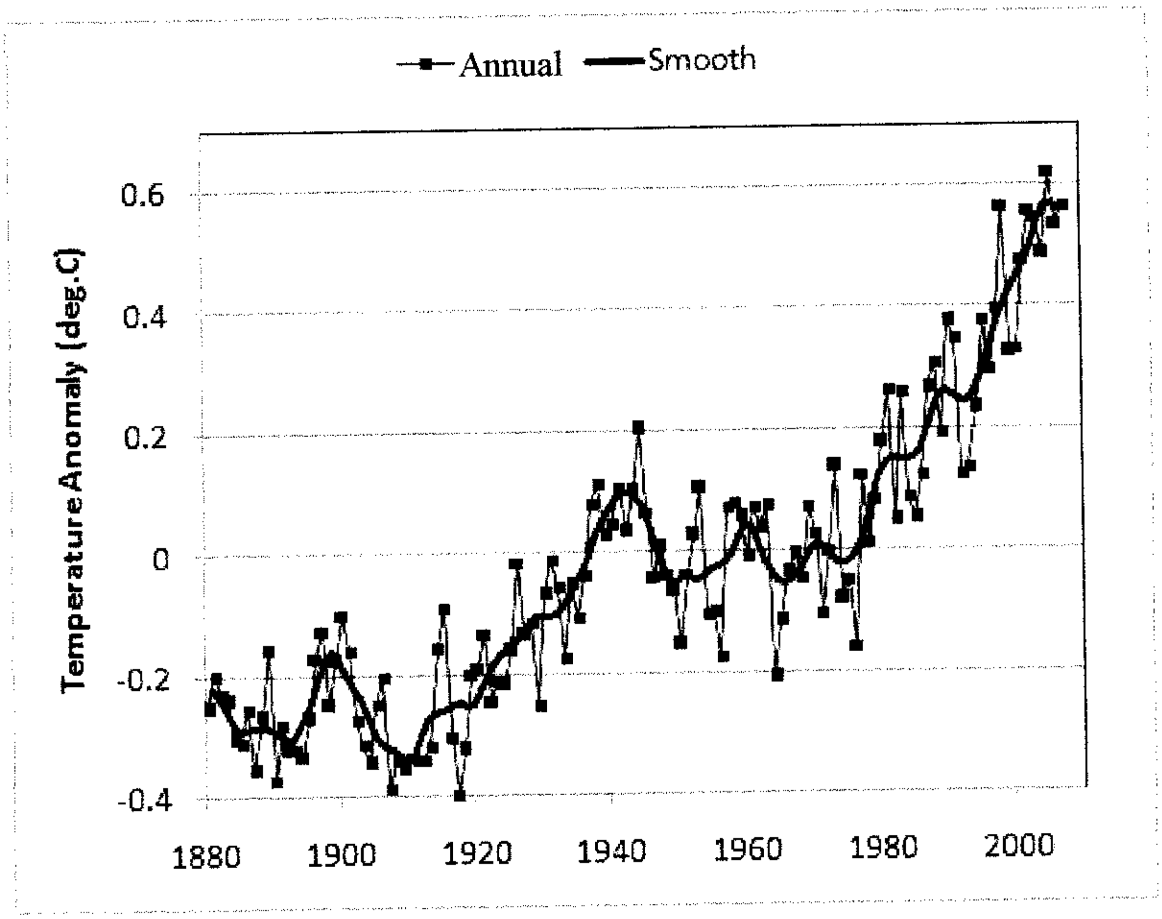

FIGURE 1: Mean Global Temperature Anomaly; Annual and 5-Year Smoothed

2.1 Sea Level Rise

Sea level rise does not occur uniformly over the earth; there are regional differences and climatic differences in the various ocean basins. Among the latter is the response to the

El Nino Southern Pacific Oscillation that occurs at irregular intervals of ~3 – 6 years. The average response of mean global sea level to the global temperature increase has been an increase of about 2 -3 millimeters per year, over the past 100 years or so.[1] Thus, in 50 years at this rate, sea level will increase by 10 -15 centimeters. Even such a modest rise in sea level would substantially increase the risks from erosion and storms in most coastal areas and upset important wetland ecosystems. Recently[2], it has been demonstrated that artificial water impoundment on the world's land surfaces has reduced the global sea level by 30 mm at an average rate of 0.55 mm per year over the past 80 years. The reconstructed rate of increase, allowing for reservoir capture, is 2.46 mm per year. Future reservoir building may decrease due to exhausting of available river sources, which will result in an acceleration of the rate of increase in global sea level.

The estimates provided here for rate of sea level rise assume that the processes that have been contributing to sea level rise will continue to operate as they have done in the past. There is reason to anticipate that this assumption may not be valid: The polar caps are beginning to respond to increasing global temperatures differently than in the past. Thus, there is an accelerating rate of melting of sea ice, ice shelves and glaciers in both Arctic and Antarctic regions. It is at least possible that this will permit the land locked ice sheets to migrate towards the sea, where they will melt and accelerate the rise in global sea level. A rise of one to two meters by the year 2100 is within the bounds of possibility. This is a topic of intense current interest to glaciologists and we can expect that our knowledge in this area will improve rapidly in the next few years. Scientists have found that many of the huge glaciers of Greenland are moving at an accelerating rate - dumping twice as much ice into the sea than five years ago - suggesting that the ice sheet is undergoing a potentially catastrophic breakup. Satellite measurements of the entire land mass of Greenland show that the speed at which the glaciers are moving to the sea has increased significantly over the past 10 years with some glaciers moving three times faster than in the mid-1990s.

This phenomenon may be one of the "tipping points" that have been anticipated by climatologists in recent years, i.e., points in the climate evolution at which non-linear departures from hitherto steady trends may occur and rapid changes proceed practically out of our control. The Greenland ice sheet covers an area of 1.7 million sq km - about four times the size of California - and, in places, is up to 3km thick. It formed over thousands of years by the gradual accumulation of ice and snow but now its disintegration could occur in decades or centuries. If all this ice were to melt, global sea level would increase by 7 meters (23 feet); however, melting on this scale would likely take hundreds of years.

---

[1] Tide gauge measurements indicate 2 mm/yr over ~100 years; satellite altimeter measurements indicate 3.4 mm/year since 1992

[2] B. F. Chao et al,"Impact of Artificial Reservoir Impoundment on Global Sea Level", Science, Vol 320, p212, April 11, 2008

2.2 Altered Weather Patterns

Global climate change brings with it altered weather patterns, including more extreme events such as tropical cyclones (hurricanes), and their associated storm surges in coastal regions. Precipitation is expected to be enhanced due to the increased global temperature, which increases evaporation of water from the ocean and land surfaces. Thus some areas of the globe will experience heavier episodic rainfall – the "50 year" rainstorms may become "20 year" events, for example, or even shorter intervals.

It is possible that the mid-Atlantic coast of the United States may be one of these regions of heavier rainfall, due the Gulf Stream, which carries moist air Northwards from the Gulf of Mexico. Nearby Norfolk, for example, may provide some idea of what may be anticipated: the 5-yr storm currently produces 5 cm (2 in.) of rain in a single hour, whereas the 50-yr storm produces 8 cm (3 in.) in a single hour. According to NOAA[3] analyses, the magnitude of the highest precipitation events has been increasing globally since 1970. A Simple Daily Intensity Index that examines the total precipitation for the United States divided by the number of days with precipitation clearly demonstrates an increase in average intensity from 1970 to 2005. These observed increases in extreme precipitation are not only in keeping with observational analyses but also with model projections for the future. The IPCC AR4[4] (2007) concludes that heavy precipitation events will continue to become more frequent during the coming decades.

Figure 2 shows the frequency of occurrence of tropical cyclones in the North Atlantic since the mid-19th Century, smoothed over intervals of 10 years. It is clear that there has been a noteworthy increase in frequency in the past twenty years.

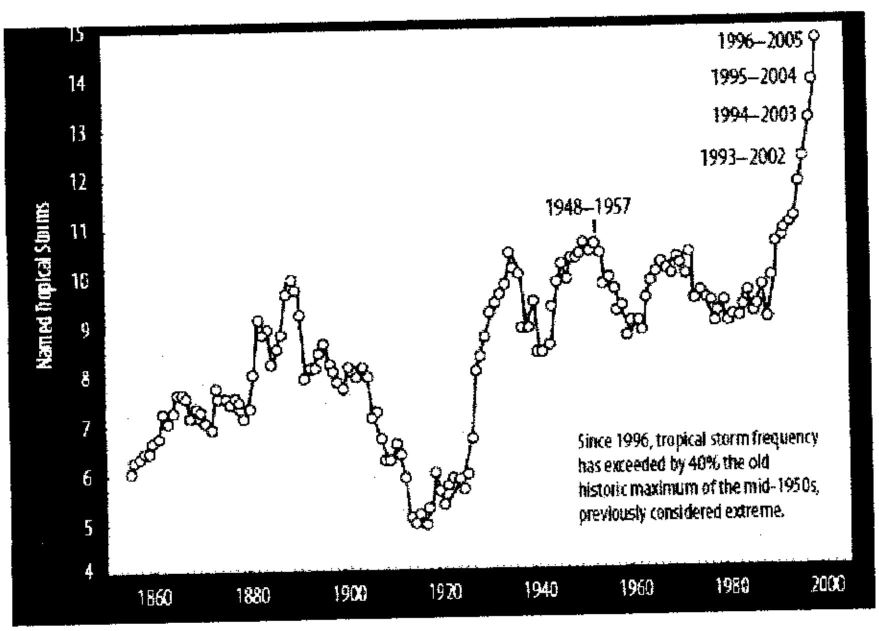

FIGURE 2: Tropical Cyclone Frequency in the North Atlantic (NOAA)

[3] National Oceanographic and Atmospheric Administration (Department of Commerce)
[4] IPCC – Intergovernmental Panel on Climate Change (United Nations); AR4 – 4th Assessment Report

It must be noted that there is presently some disagreement in the scientific community as to whether global warming will contribute to increased frequency of tropical cyclones, or to their intensity, or both. However, if recent experience is any guide, then the damage and loss of life that resulted from Hurricanes Katrina and Rita in 2005 are illustrative of the type of stress that future extreme climate events could produce in the low lying areas of the County.

3. Implications of Sea Level Rise on the Natural Environment of the County

Rising sea level is accompanied by recession the shoreline due to both inundation and erosion. Inundation is the submergence of otherwise unaffected shore, while erosion is the physical removal of beach material. This analysis is mainly concerned with inundation.

Sea level in the lower Chesapeake Bay region has been increasing at approximately 4 mm per year, which is almost double the global increase due to climate change. A contributing factor to local sea level rise is a zone of subsidence of the land along the entire Mid-Atlantic coast, which has been attributed to adjustment of the earth's crust that is still taking place following the removal of glacier ice to the north, during the last ice age, thousands of years ago (a process known as "isostatic" adjustment). An additional contributing factor, that has not been conclusively quantified, is the ground subsidence due to extraction of water from the underground aquifers.

A study[5] in 2002 by the staff of the Center for Watershed Protection investigated the causes for increasing salinity in the Yarmouth Creek and Chickahominy River. It projected a rise in sea level at Hampton Roads of 116 mm (4.5 inches) by 2025 and 234 mm (9 inches) by 2050. Quoting from this study: "The science governing [Sea Level Rise] affecting the salinity in the Chickahominy and Yarmouth explains that the additional elevation of the sea level causes an increase in the upstream push and influence of the saltwater wedge. The additional water elevation will result in approximately 1.6 billion gallons of saline water moving into the Upper Chickahominy and Yarmouth Creek with each tidal cycle by 2050". In general, based on this report's conclusions, it may be predicted that increasing sea level will result in:

- Increase in the salinity of County waterways, especially during drought conditions
- Shift in the biotic community
- Loss or alteration of the wetland plant community

Although the study did not address specifically the issue of groundwater, it can be inferred that increasing sea level will result in increasing salinity of groundwater.

[5] Technical Memo on the Reduced Freshwater Flow in Yarmouth Creek (July 16, 2002), from Paul Sturm to Wayland Bass

A study by Dr. J. Boon[6] of VIMS (Virginia Institute of Marine Sciences) showed that the storm surge accompanying a Category 1 hurricane (Isabel in 2003) was 1.45 m (4.8 ft) at Hampton Roads, approximately equal to that of a much stronger Category 3 hurricane in 1933. This apparent anomaly can be explained by the increase in sea level that has taken place over the intervening 70 years. The sea level at Hampton Roads has increased by 4.25 mm per year over this period. If this rate can be assumed to apply to nearby James City County, it would indicate sea level rise in 20 years of 8.5 cm (3.3 inches) and in 50 years of 21 cm (8.3 inches). The magnitude of storm surges accompanying the anticipated more energetic hurricanes of the future can be expected to be proportionately greater.

4. Implications of Sea Level Rise on County Infrastructure

The infrastructure of the County has been constructed based on historical climate norms, and no consideration has been given to climate conditions that may be far outside these norms. In particular, the steady rise in sea level and the greater frequency of storm surges will likely severely stress buildings, highways, bridges, railroads, electrical distribution systems, sewer and water distribution systems, and others. It is important that we try to anticipate the effects of climate change in terms of future decisions about land use, zoning and public utilities, as well as the probable need for future condemnation and abandonment of some existing structures and facilities. It will be necessary to have in place the ability to provide emergency services to residents in areas impacted by sea level rise. Although it may seem a remote planning horizon, based on the seemingly slow climate trends, it is also apparent that decisions to be made in the next few years will have very direct repercussions within the lifetimes of many current residents. It is incumbent upon us, in this generation, to bequeath to the next generation, a County in which the housing stock, public infrastructure and recreational areas are physically and economically viable. James City County can be a leader among municipalities in proactively planning for an eventuality that appears certain.

5. Water and Sewer Systems

Water and sewer systems that become overtopped by rising sea level become unusable. Ground water systems may be infiltrated by salt or brackish water and gravity fed sewer systems will be rendered inoperative. Septic systems in areas subject to flooding are a potential biological health hazard.

The cost of retrofitting a system in 2050, for example, would be far greater than the cost of designing the system today for an additional 9 inch rise in sea level. It may appear premature to make decisions in the near future that depend on the risk of future sea level rise, but in view of the substantial future costs that could be avoided by cost-effective design modifications made today, it would be prudent to conduct comprehensive drainage

[6] J. D. Boon, in: Hurricane Isabel in Perspective. Chesapeake Research Consortium, CRC Publication 05-160, K.G. Sellner (ed.), (2005), Edgewater, MD.

studies in low lying areas of the County to assess the implications of future sea level rise and climate change.

In the Environmental Protection Agency report "Greenhouse Effect and Sea Level Rise: The Cost of Holding Back the Sea", (lead author James G. Titus), published in Coastal Management (1991), Volume 19, 171-204, the authors state: "To ensure the long-term survival of coastal wetlands, federal and state environmental agencies should begin to lay the groundwork for a gradual abandonment of coastal lowlands as sea level rises". A further quote from this report is: "If state and local governments fail to develop plans to protect the coastal environment as the sea rises, the public will almost certainly call upon engineers to protect their homes in the years to come". The message is clear – if Government fails to anticipate and prepare for the consequences of sea level rise, then future generations will hold our present generation accountable, and potentially severe economic and social disruption may be the future result of our failure to act now.

The consequences of the greenhouse effect are, for the most part still in the future, and until now, there have been few attempts to assess whether the benefits of preparing for that future would justify the costs. Nevertheless, there are many decisions being made today that are sensitive to even the possibility of a rise in sea level, and which cannot wait until current uncertainties are resolved.

6. Flood Control

Episodic flooding due to storm surges will be exacerbated by sea level rise, and may be partially mitigated by upgrading drainage systems. Besides improving drainage systems to prevent flooding, the County might choose to implement a combination of planning and structural measures to adapt to increased flooding. Buildings in low areas can be made flood proof; construction of basements can be avoided; and new buildings and streets can be constructed at higher elevations. At some point it may become necessary to discourage building in increasingly flood-prone areas. Existing coastal management programs that accomplish this objective include reduced government subsidies, zoning measures, and higher flood insurance rates. An extreme scenario may require abandonment of buildings that are most prone to flooding.

7. Suggested Actions by County Government

The County can begin to anticipate the impact of rising sea level and climate change by taking appropriate measures in the near future, rather than waiting for a crisis to develop in the future. It is certainly the case that some, but by no means all necessary measures may be put off until the actual need arises. Anticipatory actions can be implemented at little additional cost beyond that incurred by "business as usual". Reactive actions are those taken in response to an actual climate development as it becomes necessary, but should be included in long term planning.

7.1 Anticipatory Actions

- Examine and, where necessary, modify zoning regulations in low elevation areas that will be affected by future inundation or increased risk of increased storm surges
- Do not subsidize, directly or indirectly, new construction in flood prone areas
- Require all new drainage and sewerage installations to be sized to be adequate for control of predicted water stress; where possible, design and route such systems so that they will be at higher elevation than anticipated water level.
- Require necessary repair and replacement of existing drainage and sewerage systems to conform to the increased standards applicable to new construction

7.2 Reactive Actions

- For drainage and sewerage systems that become permanently or frequently submerged, provide for permanent encasing, pressurization and pumping as necessary
- In special cases, for example for structures having special historic value, raise these to higher elevation, or relocate to another, more protected site

7.3 Data Collection and Modeling

In order to determine which areas of the County are susceptible to flooding due to storm surges, exacerbated by sea level rise, it is desirable to perform high resolution mapping of coastal/estuarine regions, and to undertake modeling and simulation of storm events. Moreover, it is highly desirable to monitor, on a continuous basis, actual water level at least at one location, for the purpose of predicting flooding events. With these objectives in mind, the following actions are suggested:

- Construct highly accurate digital elevation maps of critical areas using high resolution airborne LIDAR[7]. Several companies do this work routinely, at a cost of $100+ per square mile. The maps are valid for a very long period, and the mean shoreline can be updated by long term water level measurements.
- Perform numerical modeling of storm surges, using the high resolution elevation maps. This type of work is presently being done in Virginia at both VIMS and Old Dominion University, and identifies the regions at risk of flooding.
- Perform long term measurements of water level at a permanent location in the County, to develop a model for storm surges combined with tidal variations specific to the County. A tide gauge has recently been installed at Jamestown pier by VIMS, which forms part of a network of such gauges in the lower Chesapeake Bay region. Over time, as experience is gained by continuous monitoring of water level, and other relevant factors such as wind and atmospheric pressure, a predictive capability will be achieved. The meteorological data is available routinely from national sources (e.g., NOAA); a nominal level of funding may be

[7] Laser (Light) Ranging and Detection – analogous to RADAR (Radio Detection and Ranging)

required to maintain the tide gauge. A predictive capability in excess of 12 – 24 hours should be achievable for moderate to large flooding events.

Revised: 25 April, 2008