Appendix E.
Summary of Initial Climate Change Impacts on the Chesapeake Bay Watershed Flows and Loads

The potential effects of climate change have not been explicitly accounted for in the current Chesapeake Bay TMDL allocations, beyond application of a 10-year hydrologic period, because of known limitations in the current suite of Chesapeake Bay models to fully simulate the effects of climate change. A preliminary assessment of climate change impacts on the Chesapeake Bay was conducted, in parallel, using an earlier version of the Phase 5 Chesapeake Bay Watershed Model and tools developed for EPA's BASINS 4 system including the Climate Assessment Tool (CAT). Flows and associated nutrient and sediment loads were assessed in all river basins of the Chesapeake Bay with three key climate change scenarios reflecting the range of potential changes in temperature and precipitation in the year 2030. The three key scenarios came from a larger set of 42 climate change scenarios that were evaluated from 7 Global Climate Models (GCMs), 2 scenarios from the Intergovernmental Panel on Climate Change SRES (Special Report on Emissions Scenarios) storylines, and 3 assumptions about precipitation intensity in the largest events. The 42 climate change scenarios were run on the Phase 5 Watershed Model of the Monocacy River watershed, a subbasin of the Potomac River watershed in the Piedmont region, using a 2030 estimated land use based on a sophisticated land use model containing socioeconomic estimates of development throughout the watershed. The results provide an indication of likely precipitation and flow patterns under future potential climate conditions.

Downscaling of GCM temperature and precipitation data sets were provided by the Consortium for Atlantic Regional Assessment (http://www.cara.psu.edu/). Weather data reflecting each climate change scenario were created by modifying a 16-year period of historical data of precipitation and temperature from 1984 to 2000. The climate change simulation provided for low, medium, and high climate change effects projected out to 2030.

The Susquehanna River Basin covers almost half the Chesapeake watershed and has a major influence on flows and loads to the Chesapeake. The Susquehanna River responses were examined with an annual average time series of flows and loads reported as a percent difference of the 2030 climate scenarios to the 2000 Base Scenario. Generally flows were seen to decrease in the climate change scenarios despite the higher climate change precipitation inputs. Decreased flows were due to the increased estimates in temperature which, in turn, increased the simulated evapotranspiration in the Susquehanna River watershed.

In the Chesapeake Bay watershed, the 2030 estimated temperatures are about 1.5 degrees Celsius higher over the current temperatures. That estimate is relatively consistent in the different GCMs and has a high degree of certainty. Estimated precipitation increases among the seven global climate models are about 2 percent over current conditions, especially at higher rainfall events, and that is estimated with a moderate degree of certainty. How the temperature and precipitation increases affect flow and associated nutrient and sediment loads in the watershed depends on the hydrologic balance between precipitation and evapotranspiration.

Temperature increases tend to increase evapotranspiration in watersheds, and that can offset increases in precipitation. That seems to be the case in the Chesapeake Bay watershed. Current estimates of the medians of the different scenarios run have an annual average flow, nitrogen, and phosphorus load decrease of –6.0 percent, –1.6 percent, and –2.1 percent, respectively. Because sediment loads increase with higher rainfall events, the median of the nine scenario estimates for sediment is for an increase of 4.9 percent. Figures E-1 through E-4 show annual average time series of flow, nitrogen, phosphorus, and sediment loads, respectively, for the three climate change scenarios compared to the 2000 Base Scenario.

For all three scenarios, flow is decreased in the high-flow winter period, although for two of the scenarios, summer flows are higher (Figure E-1). That could be because of the *flash 30%* and *flash 10%* precipitation conditions used in the scenarios as summer precipitation is characterized by short-term, high-precipitation thunderstorm events.

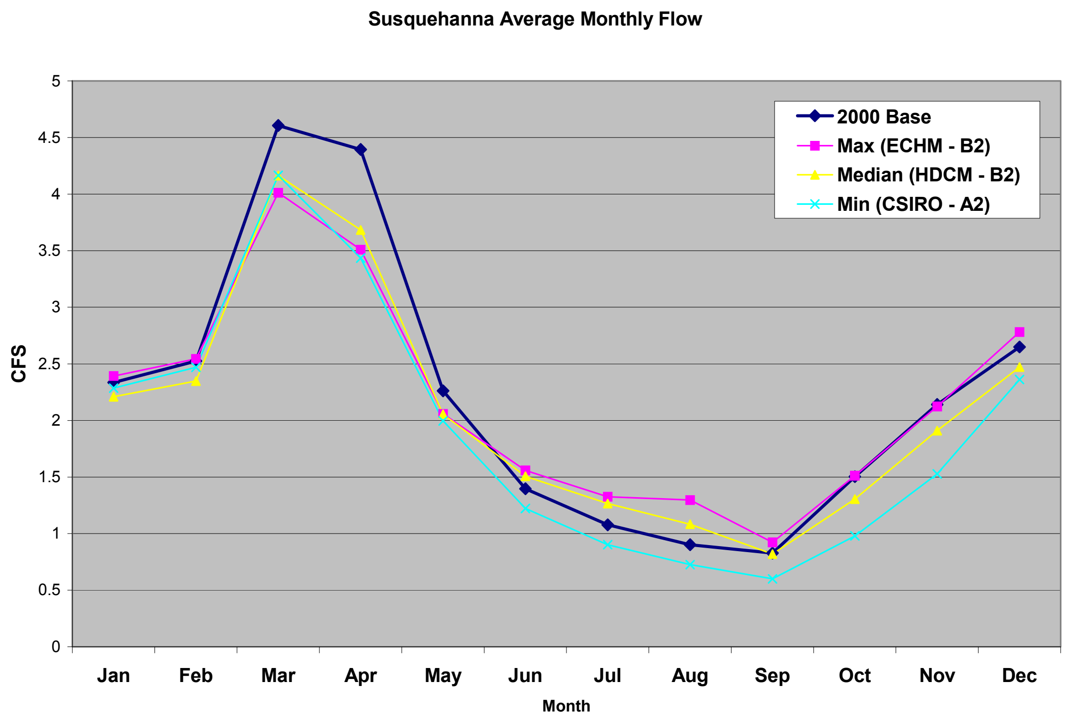

Figure E-1. Average annual time series of flow (cubic feet per second or CFS) for the 2000 Base Scenario and the maximum, median, and minimum climate change scenarios.

Total nitrogen loads follow the overall flow conditions, and they are generally depressed in the winter high-load period of nitrogen (Figure E-2).

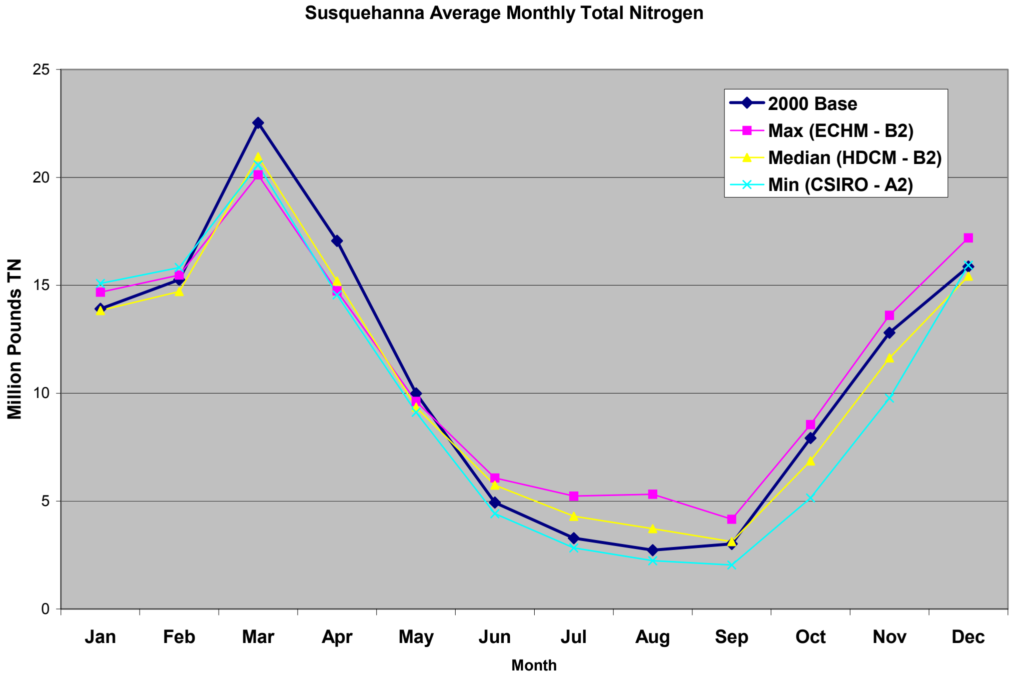

Figure E-2. Average annual time series of total nitrogen loads (millions of pounds per year) for the 2000 Base Scenario and the maximum, median, and minimum climate change scenarios.

The total phosphorus time series is similar to total nitrogen but is somewhat more responsive to episodic high flows in the two flash 10% and flash 30% precipitation conditions (Figure E-3).

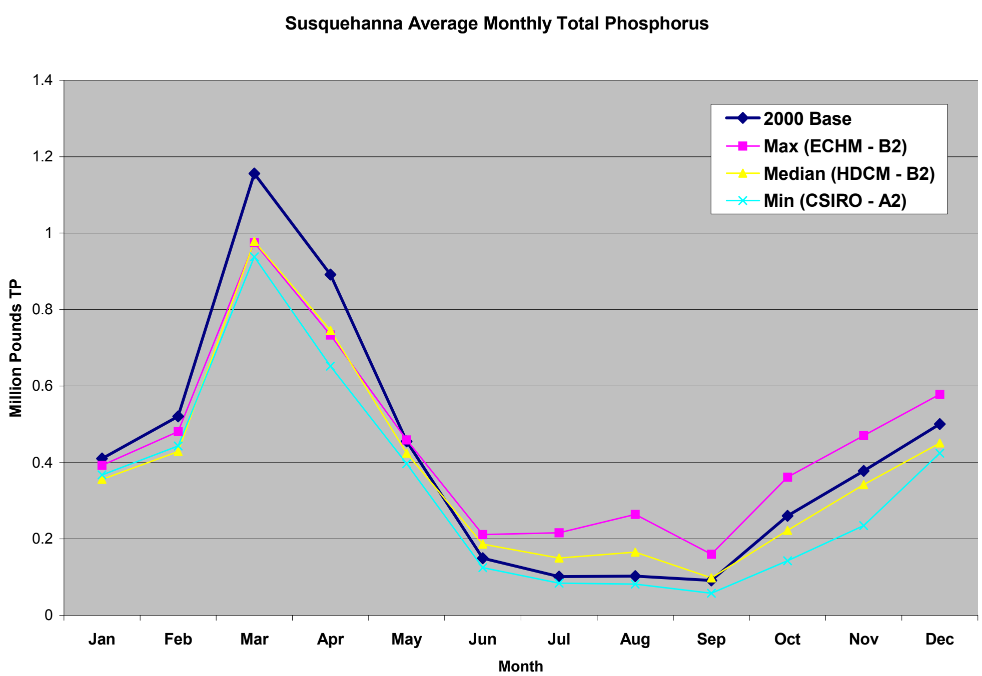

Figure E-3. Average annual time series of total phosphorus loads (millions of pounds per year) for the 2000 Base Scenario and the maximum, median, and minimum climate change scenarios.

In the Chesapeake Bay watershed, the concentration of total suspended solids (TSS) can increase three orders of magnitude from low-flow to extreme high-flow conditions, particularly in the larger rivers. Combined with higher flows, the higher TSS concentrations generate estimates of TSS loads under the flash 10% and flash 30% conditions that are episodic and flashy in nature (Figure E-4).

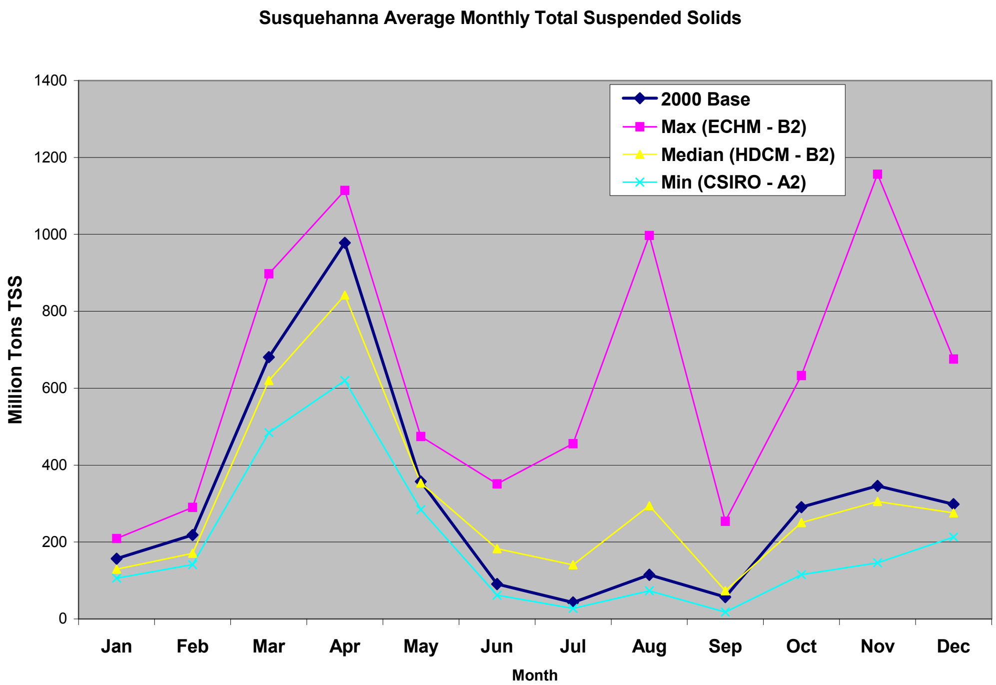

Figure E-4. Average annual time series of total suspended solids loads (millions of tons per year) of the 2000 Base Scenario and the maximum, median, and minimum climate change scenarios

Overall, the model simulation-based findings show the potential range of response of flows and loads to climate change, at least over a relatively short planning horizon of 20 years. If the historic and model trends hold true with respect to precipitation trends increasing in the larger events, and if estimated increases in evapotranspiration with higher temperature outweigh estimated 2030 increases in precipitation, the flow and nutrient loads in the Chesapeake Bay should experience relative declines on an annual average basis. However, the increased precipitation and its related flows could increase sediment loads.