Appendix F

CLIMATE CHANGE DATA

Draft - Bluestone DSMS Future without Action Condition - Potential Future Effects of Climate Change in the Kanawha and New River Watershed

Guidance for Incorporation of Climate Change Effects in Water Resources Planning - Executive Order (E.O.) 13653 and in particular Section 5 (iii) of that EO copied here for reference: *iii. "a description of how any climate change related risk identified pursuant to paragraph (i) of this subsection that is deemed so significant that it impairs an agency's statutory mission or operation will be addressed, including through the agency's existing reporting requirements;"* requires that Federal agencies describe any climate change related risks that may impair an agency's mission or operation, including through that agency's existing reporting requirements. The Bluestone Lake Dam Safety Modification Study Phase 5 report and associated NEPA documents fall under that agency reporting requirement. ECB 2014-10 (May 2014) Section 2.a. specifies that a qualitative analysis of potential effects of climate change for the purpose of enhancing climate preparedness and resilience during hydrologic analyses doesn't apply to dam safety projects.

However, construction of the future without project condition (FWAC) narrative and associated evaluation parameters that would be used to evaluate project alternatives requires an honest assessment of all future conditions. The inclusion of credible (given the levels of uncertainty present in GCM models) modeling outputs for the project area from USACE-vetted climate models that indicate a range of possible climatic conditions extending through the period of analysis is a prudent step in developing the FWAC narrative and merits consideration as a factor in assessing potential project impacts and mitigation options.

Future Without Action Condition (FWAC) – Per ER 1105-2-100 and the Principles, Requirements and Guidelines for Water and Land Related Resources Implementation Studies, the Corps of Engineers is required as part of the Civil Works water resources planning process to forecast future conditions that any formulated alternative including the no action alternative must continue to function within during the period of analysis (typically 50 years from the start of project operation). Evaluation of alternatives requires an assessment of each alternative's performance through an array of hypothetical future conditions in order to prioritize alternative courses of action, including the option of taking no action. The future without action condition is required to be an honest, credible and defensible description of environmental, social, economic, cultural, and climatic conditions that may exist during the period of analysis and that any and all alternatives are evaluated against. Several methods of developing the FWAC are available to Corps planners including simple trend analysis, modeling and scenario building. The Corps of Engineers Guide to Constructing the Without Project Scenario (IWR Report 2012-R-03) describes agency-accepted methods for developing the without project narrative.

With respect to forecasting future climate conditions that may affect the effectiveness and efficiency of formulated alternative(s) during the period of analysis, current climate forecast methods rely on downscaled data from global circulation models (GCM) prescribed by the International Panel on Climate Change (IPCC). The IPCC has issued a series of global climate assessments (since 1990) that include updated modeling data based upon ongoing research results of global atmospheric, land and oceanic interactions, system response values, and global observations of ongoing climate-related changes. Through a process known as downscaling, the global climate models have been restructured for application at finer geographic scales (i.e. ~12 km per grid square side). A number of bias-corrected, downscaled climate models have been archived by a consortium of Federal agencies, private laboratories and academic institutions including USACE, USGS, USBR, and NOAA[1]. Output data is available for mean monthly and daily precipitation and temperature for several emissions scenarios forecasted for multiple future time periods. As discussed below, this climate data has been accessed for several climate change studies of geographic areas that include the entire Kanawha and New River basins. The forecasted results from these studies provide a glimpse of what future with and without project climate conditions may prevail during the 50-year period of analysis during which an array of structural modifications and/or operational changes may be in effect at Bluestone Dam.

Project Area for Addressing Climate Change Effects – The defined project area consists of the area downstream of Bluestone Dam to the juncture of the Kanawha River and the Ohio River at Point Pleasant, WV and upstream from the dam through the boundary of the Federal lands acquired for the project and any flowage easements all the way to the farthest reaches of the New River Watershed in North Carolina. For the purposes of defining climate-induced changes to temperature, stream flow and rainfall intensity, the watershed of Bluestone Dam (4,565 m^2) extending into VA and NC and the downstream New River/Kanawha River to the Kanawha River gage at Charleston is herein identified as the project area. This entire area has been modeled by several climate change studies as discussed below.

Existing Regional Climate - Bluestone Dam and the affected area's mid-latitude position combined with the seasonal undulations of the northern jet stream makes this region susceptible to highly variable weather throughout the year. The watershed's climate is greatly influenced by oceanic (Gulf moisture) and atmospheric (Canadian air mass) interactions. Rhythmic fluctuations in El Niño and La Niña Pacific currents combined with variable North Atlantic Oscillation patterns also affect seasonal weather in the project region. Long-term predictions of weather in such a dynamic system are uncertain at best and model projections of future global climate change further exacerbate those uncertainties.

According to the Köppen climate classification system[2], the New River watershed and areas upstream of Bluestone Dam are located within the zones labeled "Dfb"[3] and "Dfa". These designations refer to a continental location that is fairly moist, and can experience either warm or cool summers depending upon site elevation. There are significant variations in topography and surface elevation within the New River watershed (i.e. Boone, NC at el. 3,333 and Hinton, WV at el. 1,463) that drive differences in seasonal temperatures by several degrees. The New River watershed experiences seasonal weather patterns with climatic conditions typical of all four seasons for the Mid-Atlantic and Southeast Regions of the United States. Variability in weather tends to be greater during the late winter, spring, and fall seasons within the watershed. Past

[1] Climate modeling data for CONUS and territories is accessible by Corps personnel through the USACE Responses to Climate Change Program (IWR) web site.

[2] The Köppen Climate Classification system, established in 1918, is an accepted global climate classification system.

[3] The "Dfb" and "Dfa" designations translate to "D" – continental climate that can be found in the interior regions of large land masses. Total precipitation is not very high and seasonal temperatures vary widely, "f" - moist with adequate precipitation in all months and no dry season, and "a" - hot summers where the warmest month is over 22°C (72°F) and "b" - warm summer with the warmest month below 22°C (72°F), normally associated with C and D climates.

observations of climate data in the Ohio River basin have indicated a slight warming trend (increase in mean annual air temperature) since 1952 and a slight increase in precipitation during the fall season over that time period as well[4].

Climate Change Information - Information on climate change projections for this watershed can be found in three notable resources. The 3rd National Climate Assessment (2014) for the continental United States which is based upon the IPCC's 5th Assessment Report (CMIP5), the Climate Change and Hydrology Literature Synthesis for the US Army Corps of Engineers Missions in the United States (2015)[5] which is a compilation of study findings from multiple climate change studies (since 2004) completed for the HUC 2 Ohio River Basin (Region 05) and the Ohio River Basin Climate Change Impacts and Adaptation Draft Pilot Study (July 2015) sponsored by the USACE Institute for Water Resources (IWR).

Each of these three resources provide climate change projection information derived from ensembles of downscaled GCM models computed for different geographic scales. The finest geographic model scale was a 1/8th degree grid square[6] analysis (covering 698 small watersheds in the Ohio River basin) completed by IWR for the July 2015 Ohio River Basin pilot study. This study applied to the basin ensembles of GCM downscaled models archived by USACE, USGS, USBR, and NOAA that incorporated CMIP3 data[7] based on two emission scenarios (A1b and A2) encompassing three 30-year periods. The Ohio River Forecast Center[8] (OHRFC) used the Community Hydrologic Prediction System (CHPS) in combination with the Sacramento Soil Moisture Accounting Hydrologic Model to produce runoff and stream flow projections for 24 forecast points in the basin (see Figure ____). That stream flow data, presented as percent increases in mean annual and mean monthly[9] stream flow and decadal changes in mean annual air temperature in the Ohio River Basin pilot study, was modeled for the Kanawha River stream gage located downstream of Charleston, WV at Lat. 38°22'17", Long. 81°42'08" (see red star on Figure ____).

Since uncertainty in stream flow projections increases substantially as one moves into smaller watersheds located upstream from the mainstem Ohio River[10], the Kanawha River gage at Charleston was identified by the pilot study team as the optimum forecast point to assess future threats to the four major dams in the basin including Bluestone Dam[11]. Historic data from that gage was included in the base years flow analysis and future flow projections were produced for that gage point as well. The New River is estimated to contribute approximately 49.9% of the total average flow at that gage with the Greenbrier, Gauley and Elk rivers contributing the balance of the total flow.

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[4] NOAA 2013 presentation to USACE Pilot Study team on historic climate trends in Ohio River basin.

[5] USACE (2015). Recent US Climate Change and Hydrology Literature Applicable to US Army Corps of Engineers Missions - Ohio Region 05. Civil Works Technical Report, CWTS 2015-05, USACE, Washington, DC

[6] Each 1/8th grid square measures approximately 12km or 7.45 miles on each side.

[7] Coupled Model Intercomparison Project Phase 3 (CMIP3) data from the IPCC Fourth Assessment in 2007.

[8] The OHRFC is located at Wilmington, OH and is a facility of NOAA, seen at: http://www.weather.gov/ohrfc/

[9] The mean values for annual and monthly forecasts are the mean of the means of each year during the 30-year period and the mean of all mean values for each month over the 30-year period. The mean March maximum values are the mean of each March maximum value during the 30-year period.

[10] The runoff models used by the OHRFC are calibrated using a specific array of gage points; as the number of points feeding data into the model is reduced so likewise is the level of certainty of the forecast.

[11] Those dams include Claytor (HYDRO), Bluestone (FRM), Summersville (FRM) and Sutton (FRM).

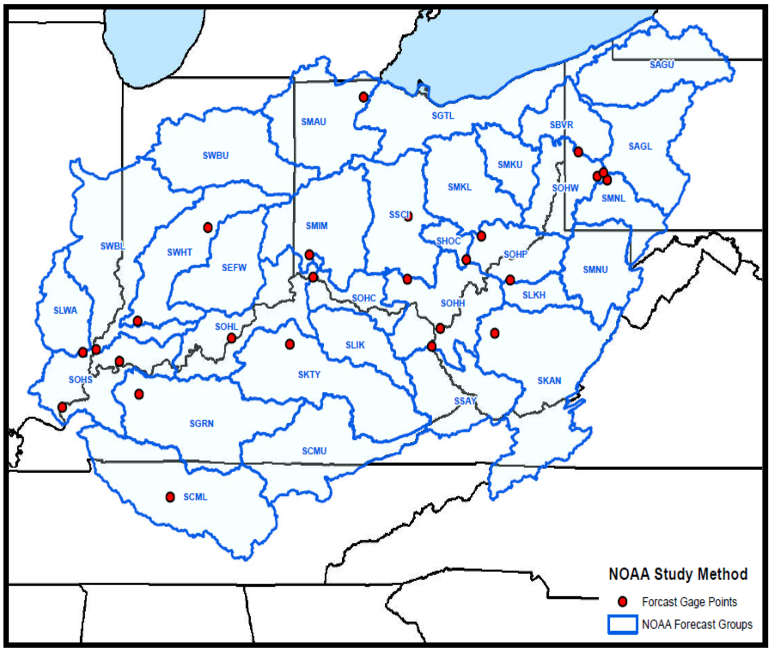

Figure _____ - OHRFC Forecast Points in the Ohio River Basin

<u>Projected Changes in Air Temperature</u> - The three referenced sources indicate the affected area which includes the New River below Bluestone Dam and the watershed above the dam extending into Virginia and North Carolina could generally experience annual mean summer temperatures that range between 3.0^{o} C and 4.0^{o} C higher by 2090 or between 3.9^{o} C and 5.7^{o} C during that same period in a separate study[12]. Information in the 3rd National Climate Assessment estimates that annual mean air temperatures in the Northeast region (includes WV) could rise between 4.5^{o} F and 10.0^{o} F by the 2080's[13]. Temperature projections in the Ohio River Basin Pilot Study suggested that mean annual air temperatures could rise by 0.5^{o} F per decade between 2011 and 2040 and 1.0^{o} F per decade between 2040 and 2099. These projected rates of increase could raise mean annual temperatures at the Kanawha River forecast point from a recorded annual mean of 53.7^{o} F in 2001 to 56.7^{o} F by 2040, 58.9^{o} F by 2070 and 62.3^{o} F by 2099. In each climate study referenced, mean annual temperatures are expected to rise in the project area. Air temperature increases of this magnitude are expected to result in increased water temperatures (more noticeable in lacustrine environments), increased precipitation in the form of rainfall rather than snow in the winter months and higher evaporation rates.

Generally speaking, increased water temperatures could adversely affect indigenous aquatic species that thrive in cool and cold water environments. Warmer waters could cause more frequent algae blooms in lakes receiving higher levels of nutrients – nutrients that provide a growth catalyst for these aquatic biota. Higher air and water temperatures could provide a suitable environment for invasive macro and micro invertebrates in Bluestone Lake and the New River as well as invasive terrestrial/vegetative species on Federal land surrounding Bluestone Lake. Increased likelihood of rainfall rather than snow due to higher winter temperatures (after

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[12] USACE (2015). Recent US Climate Change and Hydrology Literature Applicable to US Army Corps of Engineers Missions - Ohio Region 05. Civil Works Technical Report, CWTS 2015-05, USACE, Washington, DC, pages 21-22

[13] Climate Change Impacts in the United States (2014), 3rd National Climate Assessment, Chapter 16 Northeast, page 374

leaf drop) could result in greater amounts of winter runoff and inflow into reservoirs such as Bluestone Lake (see below). Higher summer air temperatures could result in higher evaporation rates that can affect reservoirs with expansive surface areas like Bluestone Lake. Increasing air temperatures (lengthened growing season), increased rainfall (see below) and higher concentrations of CO^2 could lead to increased vegetation growth (increasing carbon sequestration capacity) in the watershed and associated higher transpiration rates.

Increased Heavier Downpours - Assessing the potential for high intensity storm events in the watershed and affected area requires consideration of the geographic location of the dam and its watershed with respect to the three states WV, VA and NC. Although the dam is located in Summers County, WV only 16% ($730m^2$) of the total catchment area of the dam (total of 4,600 m^2) is located in WV. The remaining 3,870 m^2 or 84% of the total catchment is located in VA (67 %) and NC (17 %).

Current climate change data sources[14] describing recent trends in heavy downpours and future potential for increasing storm intensity divide the continental US into six distinct regions (see Figure ___). Two of those regions, Northeast and Southeast, exhibit decidedly different trends in storm intensity and therefore point to differing expectations of the intensity of future storms that could affect the operation of Bluestone Dam during construction phases associated with the dam safety project and subsequent operations.

As chance would have it, the state of WV is included in the Northeast region and both VA and NC are included in the southeast region – that regional dividing line being located within the flood control pool of the Bluestone Dam project. The Northeast region shows a 71% increase in the past trend of frequency and intensity of heavy downpours since 1958 and the Southeast region exhibits a 27% increase in those downpours over that same period. Realistically for Bluestone Dam that percent increase is necessarily somewhere between those two figures, but in view of the percentages of catchment in each state shown above (WV at 16% verses VA/NC combining at 84%) that historic trend, a trend that influences inflow into Bluestone Dam, probably leans towards the lower end of a continuous scale between the two percentages.

That being said, the 3rd National Assessment (2014) includes data showing increasing trends in frequency and intensity of heavy downpours (defined as the heaviest 1% of all daily events) in many areas including the Northeast and Southeast regions. However, in that same source, future projections of heavier downpours (see Figure 2.19 and its caption) concentrate on a daily rainfall event that now occurs once in 20 years or the 1 in 20 year rainfall event. The 1 in 20 year event addresses shorter-duration, thunderstorm-related, local events rather than intensification of long-duration, high-volume regional storms (1% annual chance, 0.5% annual chance and longer recurrence events) that keep hydrologists awake at night. Figure _____ shows historic trends in regional differences for heavier downpours within several regions of the United States.

[14] Climate Change Impacts in the United States (2104), 3rd National Climate Assessment, Heavier Downpours Increasing, Figures 2.18 and 2.19.

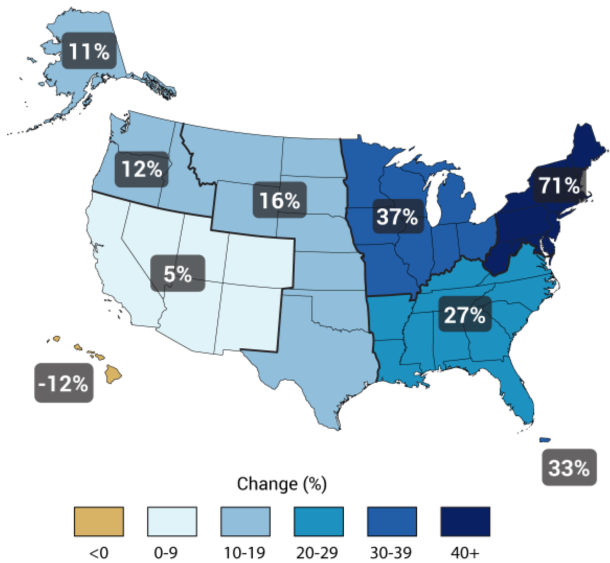

Figure 2.18: The map shows percent increases in the amount of precipitation falling in very heavy events (defined as the heaviest 1% of all daily events) from 1958 to 2012 for each region of the continental United States. These trends are larger than natural variations for the Northeast, Midwest, Puerto Rico, Southeast, Great Plains, and Alaska. The trends are not larger than natural variations for the Southwest, Hawai'i, and the Northwest. The changes shown in this figure are calculated from the beginning and end points of the trends for 1958 to 2012. (Figure source: updated from Karl et al. 2009[21]).

Impacts from intensification of high-frequency storms surface as flash floods in small to moderate-sized urban and desert watersheds where life loss and economic damages are frequent affects. These higher-frequency, flash floods also impact stormwater management measures and facilities whose retention or infiltration capacity is normally designed for the 1 in 10 year or 1 in 20 year storm event. In general, climate models projecting higher air temperatures (warmer air can hold greater amounts of moisture) and increased seasonal (spring) precipitation, lend credence to the potential for heavier rainfall events in the future that would influence operations at the project both during and after construction. However, downscaled global circulation models are based upon global weather patterns and mega-scale atmospheric interactions that cannot predict the occurrence of local thunderstorm convection processes that spawn individual downpours or so called “training” thunderstorms and therefore accurately pinpointing future heavier events to a specific time period or geographic place (i.e. Bluestone Lake watershed) is speculative at best.

<u>Precipitation and Stream Flow</u> – Future changes in precipitation, runoff and resulting stream flow (hydrologic effects) are anticipated in each of the three reference sources. The 3rd National Climate Assessment discusses the potential for increased precipitation in the Northeast perhaps by as much as 5% to 20% greater precipitation (mainly in the winter months) and somewhat wetter in northern portions (including VA and NC) of the Southeast region.[15] Additional modeling studies project that as much as 140 mm (5.5 inches) of additional annual precipitation could fall across Region 5 (Ohio River Basin) during the

[15] Climate Change Impacts in the United States, 3rd National Climate Assessment, page 374.

period between 2071 and 2100 while other modeling completed for the Wabash River sub-basin (IL and IN) predicted changes in precipitation from the base period 1990-1999 to 2051-2060 ranging from -18.6% to 7.25% and between -20% and 16.2% for the future period 2086-2095.[16] Although not directly related to the Bluestone Dam region, this data shows the range of variability in future projections of precipitation. Similar variability (much drier fall and wetter spring) was shown for the Wabash River sub-basin in the following pilot study.

The Ohio River Basin Climate Change Impacts and Adaptation Pilot Study (July 2015), discussed in some detail above, developed a series of projections for future precipitation based upon ensembles of downscaled GCM's (CMIP3) for the basin using two emissions scenarios (A1b and A2) that encompassed three 30-year periods. That precipitation data was subsequently used by the Ohio River Forecast Center (NOAA) to estimate increases in runoff/streamflow for 24 forecast gage points in the basin. The runoff generation models considered soil moisture, air temperature, humidity levels, time of day (precipitation data were produced in 6-hour increments), evaporation and transpiration (leaf-on or leaf off situations) rates and month of year (solar orientation). One of the 24 forecast gage points is the Kanawha River gage at Charleston, WV. At that gage, approximately 49.9% of the water passing derives from the New River flowing out of Bluestone Dam.[17]

The projection results are noted as a percentage increase or decrease from the mean annual and mean monthly flows observed during the base years 1952 to 2001. In the pilot study, identifying threats to operating infrastructure, including those identified as being in poor or unsatisfactory condition[18] was a key objective, therefore projections for flood control structures such as Bluestone Dam concentrated on extreme high flow values normally associated with the spring season. However, for the purposes of the Bluestone DSMS, model projections for mean, minimum and maximum values are being provided on an annual basis and for both the wettest period (March) and the driest period (October) to give a more comprehensive overview of potential future stream flows driven by changed climate conditions. March was selected because of its seasonally high flows across the basin and October because of its seasonally low flows across the basin.

Table ____ shows the projected percent changes in streamflow measured against the base years recorded flows (1952-2001) during the three time periods modeled (2011-2040, 2041-2070, and 2071-2099). Of note in the data are the percentage increases in the October monthly mean and monthly maximum flows over the base years recorded flows. October is historically a very dry month in this region and stream flows are substantially lower during this season. The model projections indicate that future fall season precipitation and resulting flows could be 25% to 50% higher than previously experienced. This dry season increase in flows added to modest increases in the March mean (springtime) flows results in an increase in overall annual mean flows in the watershed above the Kanawha River gage.

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[16] USACE (2015). Recent US Climate Change and Hydrology Literature Applicable to US Army Corps of Engineers Missions - Ohio Region 05. Civil Works Technical Report, CWTS 2015-05, USACE, Washington, DC, pages 25-27.
[17] USACE-LRH Hydrology and Hydraulics estimate.
[18] "Poor" or "Unsatisfactory" performance are categories used in the National Inventory of Dams database and are similar to the USACE Dam Safety Action Categories (DSAC) system for dams.

Table ____ - Projected Percentage Changes in Flow at the Kanawha River gage[19]

Data Category	Model Time Periods		
	2011–2040	2041–2070	2071–2099
Annual Mean[20]	+15% - +25%	+15% - +25%	+15% - +25%
Annual Minimum	+15% - +25%	+5% - +15%	+5% - +15%
Annual Maximum	+15% - +25%	+25% - +35%	+25% - +35%
March Mean	+5% - +15%	+5% - +15%	+5% - +15%
March Minimum[21]	-5% - +5%	-5% - +5%	-5% - +5%
March Maximum	+5% - + 15%	+15% - +25%	+15% - +25%
October Mean	+35% - +50%	+25% - +35%	+25% - +35%
October Minimum	+5% - +15%	-5% - +5%	-5% - +5%
October Maximum	+35% - +50%	+35% - +50%	+35% - +50%

Figure _____ shows the Ohio River Basin map of flood control dams (white and colored dots) having greater than 3,000 acre-feet of storage array across shaded watersheds produced by the Ohio River Forecast Center using climate model data from IWR. The coloration in each watershed represents the projected percent increase in precipitation (see figure legend) that is reflected as flow increases at various forecast points (gages). The Kanawha River gage at Charleston, WV is the forecast point for the mainstem Kanawha/New River watershed. This particular map displays the forecasted March mean maximum flows for the 30-year period of 2071-2099. Similar basin maps for all of the other time periods shown in Table ____ are available. The Bluestone Dam project and the Kanawha River gage (red star) locations have been noted on the map.

[19] Percentages listed are projected values greater than or less than stream flows recorded at the Kanawha River Gage at Charleston, WV between 1952 and 2001 on an annual or seasonal basis.

[20] The data are expressed as the mean of all mean values for each of the annual totals or seasonal totals through the entire time period. In other words the March maximum value is the mean value of all of the March monthly maximum values for each March over a 30-year period.

[21] Values ranging between -5% and +5% in the table represent no substantial change from the base years flow.

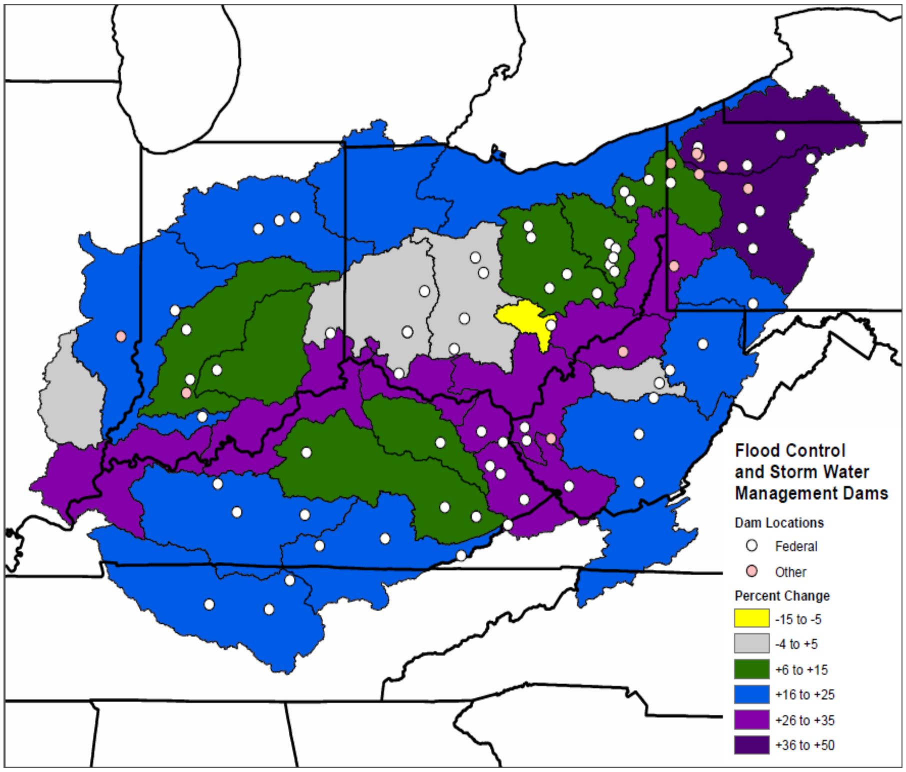

Figure ____ - Forecasted March Maximum Flow Increases 2071-2099

<u>Summary of Anticipated Climate Change Affects;</u>

<u>1)</u> General trends: Meteorologists and climatologists at the Ohio River Forecast Center summarized their findings upon completion of the runoff/streamflow modeling[22] by expressing that despite some warming and increased precipitation in the fall season, climatic conditions during the period between 2011 and 2040 will closely resemble what has been experienced during the historic period 1952 to 2001. There will likely be drought and flood events in the basin as we have seen during those base years, but the consensus opinion was that those conditions wouldn't be more extreme (intensity or duration) than we have seen during the base years (1952-2001). However, after 2040, the Forecast Center indicated that increases in mean annual air temperature and associated increases or decreases in precipitation (depending upon one's location in the basin) may make flood events and drought conditions more extreme with measurable changes in the basin's overall mean annual air temperature and mean annual and seasonal precipitation amounts.

<u>2)</u> Temperatures: Downscaled model projections from current climate change studies indicate increased air temperatures within the affected area and the Bluestone Lake watershed of at least 0.5^{o} F per decade between 2011 and 2040 and at least 1.0^{o} F per decade between 2041 and 2099. At those rates, the mean annual air temperature at the Charleston gage could be 55.3^{o} F by 2020, 56.7^{o} F by 2040, 58.4^{o} F by 2050, 58.9^{o} F by 2070 and 62.3^{o} F by 2099[23]. It is likely this gradual warming will begin to

[22] Modeling completed for the Ohio River Basin Climate Change Impacts and Adaptation Pilot Study (2015)

[23] Recorded mean annual air temperature at the Kanawha River gage in Charleston, WV in 2001 was 53.8^{o} F and 54.7^{o} F in 2011.

raise water temperatures both within Bluestone Lake and downstream New River as well as free-flowing tributary streams (i.e. Greenbrier River and Gauley River). Warming waters may coerce some cool or cold water aquatic species to migrate out of the area enabling warm water species to thrive in the warmer aquatic habitat. Warming waters may also increase the potential for invasive aquatic species to migrate into these waters with increases in both frequency and duration of seasonal algae blooms. Some attenuation of rising New River surface water temperatures downstream of the dam may occur through releases of deeper, cooler water from Bluestone Dam.

3) Precipitation/Runoff and Stream flow: Downscaled model projections for the 2011 though 2099 time frame indicate increases in precipitation in the basin and resulting higher flows in the New River and other major tributaries to the Kanawha River system. Projected increases in stream flow at the Charleston gage indicate that the Bluestone Lake project could experience flows in the New River ranging from 5% to 25% higher in the spring season and between 5% and 50% higher in the fall season by 2070. Overall, the project could experience an increase in mean annual flows in the New River that are between 5% and 35% greater than those experienced between 1952 and 2001.

These stream flow projections for the Kanawha River gage also foretell higher mean annual and mean seasonal flows for the Greenbrier, Gauley, and Elk Rivers (the combination of which account for approximately 50.1% of the water flowing at that gage) under changing precipitation conditions as well. In addition, increases in precipitation within the New River/Kanawha River watershed may result in increased contamination from exposed non-point sources (nutrients, pesticides, herbicides, sedimentation from disturbed soils, contaminants from abandoned mined lands, and other disposal areas) into Bluestone Lake and the other lakes in the system. Due to warming air temperatures, it is likely that more annual precipitation will fall as rain rather than snow in the watershed and both the incidence and thickness of lake ice at Bluestone may steadily decrease throughout the three 30-year periods.

4) Intensification of Precipitation: Various climate change studies have shown a trend in heavier downpours over the last 30 years for the downstream affected area in WV and watershed of Bluestone Dam in VA and NC. These trends show considerable variation between the upper and lower reaches of the affected area. Future projections indicate the potential for more intense rainfall events in the 1 in 20 year event range leading to possible flash flooding on small tributary streams and urban areas in the affected area, but the modeling data from sources investigated does not indicate that longer duration rainfall events – events associated with the 1% annual chance, 0.5% annual chance, or longer recurrence events would be affected by these changes. Local atmospheric convection processes that lead to high-intensity thunderstorm development or "training storms" occur at too fine a geographic scale for downscaled global circulation models to accurately predict.

5) Summary of Forecasted Climate Changes and Associated Effects during FWAC Period of Analysis: In summary, based upon the downscaled modeling completed for the Ohio River Basin Climate Change and Adaptation Study (July 2015), mean annual air temperatures will likely increase throughout the New River and Kanawha River watersheds during the FWAC period of analysis. Forecasted increases in mean annual air temperatures at the Kanawha River gage will likely be 0.6° F by 2020, 2.0° F by 2040, 3.7° F by 2050, 4.2° F by 2070, and 7.6° by 2099[24].

Besides obvious effects of increasing temperatures throughout the four seasons (i.e. potentially more days exceeding 90 degrees in summer, warmer winter temperatures with more precipitation in the form of rain rather than snow and decreasing lake ice), increases in air temperature will begin to warm surface waters in Bluestone Lake, the New River, Claytor Lake and tributaries to the New River during the period of analysis. A shift in aquatic species composition in lakes and rivers within the basin may occur as a result of warming surface waters. Aquatic species commonly associated with cool-water environments would likely migrate upstream into cooler headwater streams at higher elevations in the basin. Warm-water fishes would become the predominant species in the lakes. In addition, warmer water temperatures may encourage invasive aquatic species (macro-invertebrates, fishes, mussels, vegetation, etc.) to migrate into these previously cool-water habitats thus competing with indigenous species for resources and habitat.

The incidence and duration of algae blooms due to combination of warmer water and ongoing introduction of nutrients and other pollutants into the lake from upstream locations (as a result of increased precipitation) could become problematic from a water quality standpoint. Warmer air temperatures could result in a lengthened recreation season at the project but unseasonably higher summer temps may also reduce day-use visitation during the hottest months. Warmer temperatures may also result in gradual shifts in vegetative species composition in the region and the introduction of invasive plants, insect pests and diseases that could be detrimental to the forest community within the 22,000 acres of the project.

The percent changes in mean annual and mean seasonal stream flow forecasted at the Kanawha River gage indicate the likelihood for an increase in stream flow in the New River throughout the FWAC period of analysis. This forecast includes a measure of uncertainty that is displayed as the range of percent of increase (10%) shown in each period of time. The current schedule of construction phases for the Bluestone Lake DSM indicates that the final phase ____ will likely be completed by _____. Based upon that anticipated ending date, the FWAC period of analysis would extend to the year _____ which is within the third 30-year period (2071 - 2099) of the available climate modeling data.

Table ____ displayed the forecasted percent changes in mean stream flow on an annual and seasonal (spring/March and fall/October) basis for the Kanawha River gage in Charleston, WV. That data indicates the annual mean precipitation and resultant runoff and stream flows may increase by as much as 15% to 25% during the two 30-year analysis periods 2041 to 2070 and 2071 to 2099. The table also indicates that much of this increase in annual mean flow may be due to increases in the fall

[24] Degree increases based upon the annual mean of recorded temperatures at that gage in 2011 of 54.7° F.

(mean annual October flows 25% to 35% greater) rather than increases in the spring (mean annual March flows 5% to 15% greater).

Two other series of data show potentially significant increases in stream flow including the forecasted mean value of March (Spring) maximum flows in 2071 to 2099 (15% to 25% higher than the base years flows) and the mean of maximum October (Fall) flows[25] during that same period forecasted to be 35% to 50% greater than the base years recorded flows in that season. Although the increases in the October mean and maximum flows may be welcomed (sustained water supply and hydroelectric power capacity) during an otherwise dry portion of the water year when New River flows are traditionally lower, the 15% to 25% increase in mean maximum March flows (measurably greater that the base years flows) could be problematic during operation of Bluestone Dam, recreation at Bluestone Lake, and for at-risk communities located along the New River and its major tributaries that contribute to readings at the Kanawha River gage.

Although these forecasted mean higher spring flows do not directly affect modeled storms that generate the Probable Maximum Inflow (PMI) or flows that could endanger the stability and integrity of the dam structure in the future, they can have significant impacts on the project resources in the New River above the summer pool and affect lakeside recreation resources in the project. The increased frequency that critical elevations are reached or exceeded at the lake due to these forecasted changes could affect recreation usage and inundation-sensitive ecosystems bordering the lakeshore. Although forecasts of warming temperatures could lengthen the recreation season, higher incoming flows into Bluestone Lake could reduce usage of lakeside campgrounds and boat access points thus affecting visitation. Higher incoming flows could increase erosion of riverbanks and the many islands present within the project both in and upstream of the summer pool elevation. Both the sustainability of sensitive ecosystems and integrity of cultural resources sites existing along the river and on the islands could be at-risk from continued erosion due to these higher forecasted inflows. These additional environmental stressors could compound impacts occurring as a result of construction activities at the dam as well as future operational changes.

[25] As described earlier in this section but repeated here for emphasis, the mean of October maximum flows represents the mean value of all October mean maximum flows for each of the 30 October months during the three 30-year periods.