Appendix A: List of Alternatives Considered during Development of the Community Water Supply Plan

Below are all of the prior alternatives considered for the community water supply plan with alternatives that were selected and incorporated into the plan bolded:

- Dredge South Fork Reservoir
- Reduce Sediment Load into SRR
- Alternative Release Scenarios at SRR
- Add 4 ft. crest gates on South Fork Rivanna Dam
- Add 8 ft. crest gates on South Fork Rivanna Dam
- Use SRR as a Pumped Storage Reservoir
- Up to 5 ft. drawdown of Chris Greene Lake
- 20 ft. drawdown of Chris Green Lake
- Use of Chris Greene Lake as a pumped storage reservoir
- Use Beaver Creek Reservoir to Supplement Flows in Mechums River
- Dredge Sugar Hollow Reservoir
- Conversion of Ragged Mountain to Pumped Storage Reservoir
- Pumpback to Mechums River
- Pumpback to Moormans River
- Water Conservation
- Growth Management
- Drought Management-demand side
- Drought Management-supply side
- Leak Detection and Meter Calibration
- Aquifer Storage and Recovery
- Conventional Withdrawal of Groundwater
- Construct Dam on Buck Mountain Creek
- Construct Dam on Preddy Creek
- Construct Dam on Moormans River

- Construct Dam on North Fork Rivanna River
- Construct Dam on Mechums River near Lake Albemarle
- Construct Dam on Mechums River near Midway
- Construct Dam on Buck Island Creek
- James River Withdrawal at Scottsville
- Rivanna River Withdrawal
- Mechums River Withdrawal
- Regional Cooperation with Rapidan Service Authority
- No Action
- Add crest gates at South Fork Rivanna Dam to meet the full deficit
- Use available storage in Lake Albemarle
- Raise Ragged Mountain Reservoir
- Construct new pumped storage facility at Rocky Creek
- Expand Sugar Hollow Reservoir
- Regional Cooperation with Fluvanna and Louisa Counties for a James River withdrawal

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WATER & SEWER AUTHORITY

RWSA Urban System Water Demand Forecast Report

Final
Work Authorization No. 1
Hazen Project No. 31430-000
July 14, 2020

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List of Acronyms

Abbreviation	Definition
ACOCD	Albemarle County Office of Community Development
ACSA	Albemarle County Service Authority
ADD	average day demand
DU	dwelling unit
FTE	Full-Time Equivalent (measure of employment)
FW	Finished water (delivered from water treatment plants)
FY	Fiscal Year (July 1 of prior year to June 30th of the indicated year)
GDS	[Albemarle County Office of] Geographic Data Services
GIS	Geographic information system
gpcd	gallons per capita per day
gped	gallons per employee per day
gpd/DU	Gallons per day per dwelling unit
gpd/ksf	Gallons per day per thousand square feet (of building space)
GSF	Gross Square Footage (measure of building space)
ksf	Thousand square feet
LRTP	Long Range Transportation Plan (see TJPDC and MPO)
MDD	maximum day demand
MF	Multi-family
MG	million gallons
mgd	million gallons per day
MPO	Metropolitan Planning Organization
NDS	[City of Charlottesville] Neighborhood Development Services
NR	Non-residential
RDU	Residential dwelling unit
RW	Raw water (withdrawn from reservoirs prior to treatment)
RWSA	Rivanna Water and Sewer Authority
SF	Single-family
TAZ	Traffic Analysis Zone
TJPDC	Thomas Jefferson Planning District Commission
WTP	Water treatment plant

Introduction and Purpose

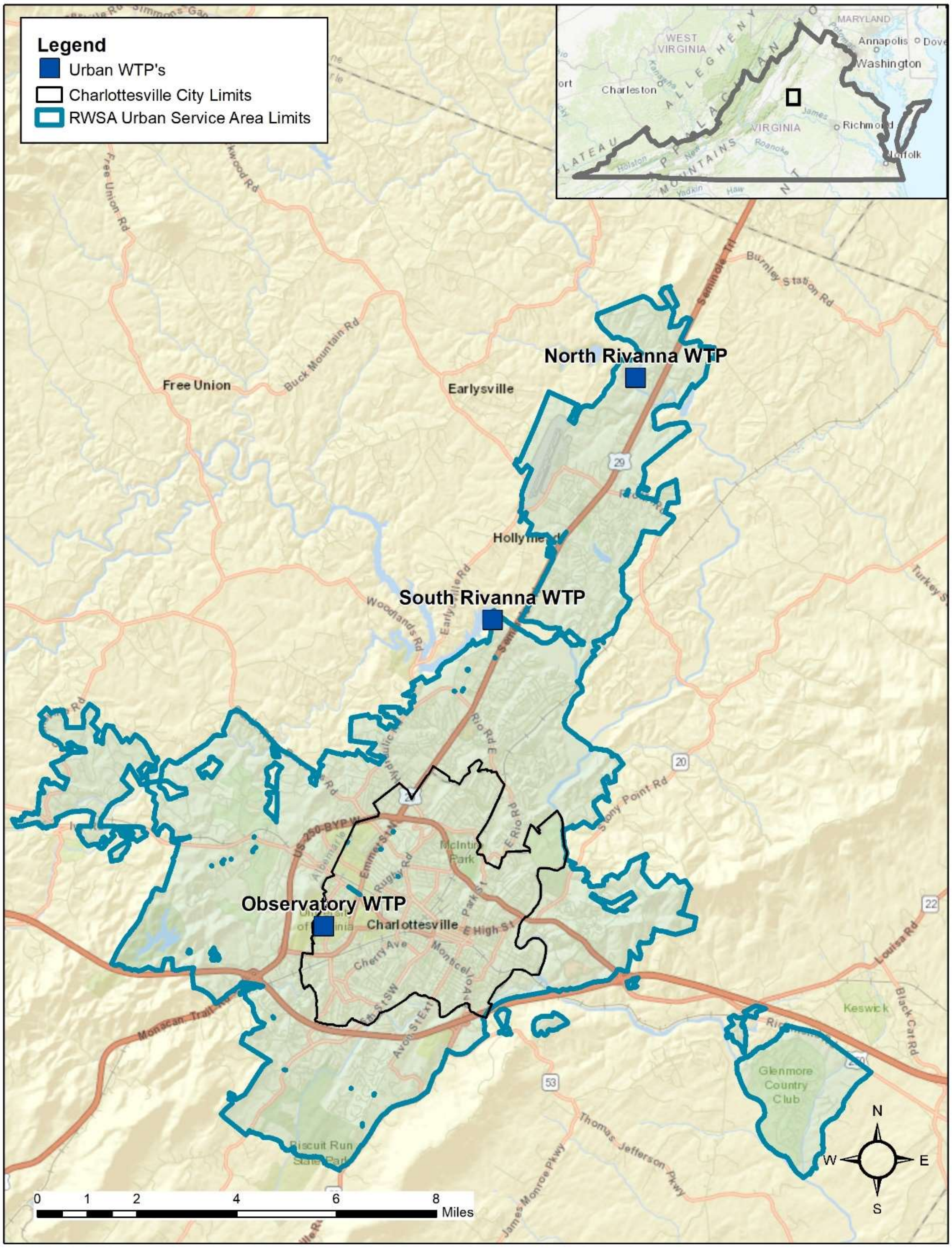
This RWSA Urban System Water Demand Forecast Study was prepared to define the path for implementation of water supply, treatment and distribution improvements necessary to meet the Authority's planning needs for the next 50 years.

Since 1973 the Rivanna Water and Sewer Authority (RWSA) has provided wholesale treated water to several communities in Albemarle County, Virginia as well as the City of Charlottesville. The largest contiguous water system served by RWSA is known as the Urban System or Urban Service Area. The RWSA has two wholesale customers within the Urban Service Area: The Albemarle County Service Authority (ACSA) and City of Charlottesville (City), which is a part of The City of Charlottesville Department of Utilities. Portions of the water distribution system are managed by RWSA with the remainder operated by the ACSA and the City. The RWSA operates three water treatment plants with a combined treatment capacity of 21 mgd that produce treated water (finished water) for the Urban Service Area. The extent of the Urban Service Area is shown in Figure 1.

Since 2008, the Urban Service Area has experienced a steady annual average finished water demand around 9.5 mgd despite a population growth rate averaging 2.2% per year (for a total increase of about 25% since 2008). Aggregate usage per capita has come down as fast as the population has grown leading to near zero growth in demand. Flat or even declining demand trends have taken many water utilities across the country by surprise over the past 10-15 years and a key question facing the RWSA and utilities in similar situations is to determine whether demand growth will resume, when, and at what rate. Looking to the future, the Urban Service Area does have space to accommodate significant population growth, especially within the areas of the County served by the ACSA. There is also potential for further conservation (i.e. continued reduction in per capita demand), but as one of the most water efficient service areas in the nation it would seem reasonable to assume the RWSA may find the limit of the conservation trend as soon or sooner than peer utilities.

This Urban System Water Demand Forecast Study was developed to help RWSA anticipate water demand decades into the future. The foundation of the plan is a series of finished water demand projections developed based on contemporary planning documents, current zoning regulations, finished water production records, and account-level billing data. These projections identify the amount of raw and finished drinking water needed in the Urban Service Area through the year 2070, broken down into five-year increments which will aid in activities planning needed to maintain a high service quality and meet anticipated changes in demand over the planning horizon.

Figure 1: RWSA Urban Service Area Boundaries



1. RWSA Urban Water System Overview

1.1 General Description of the Service Area

The RWSA Urban System lies approximately 65-70 miles to the northwest of Richmond, Virginia and supplies water to all of the City of Charlottesville and rapidly urbanizing portions of Albemarle County surrounding Charlottesville, including the University of Virginia. Its scenic surroundings and the presence of the state's flagship university have contributed to steady employment and population growth for many decades. The County's rural area policies, designed to preserve the scenic nature of most areas of the County not served by RWSA, also drive growth toward areas in and around Charlottesville's urban core and away from surrounding rural areas. The service area's estimated population in 2010 was 97,300, and in 2018 it was approaching 116,000. The Urban System's water supply is derived from the North Fork Rivanna River, South Fork Rivanna River Reservoir, Ragged Mountain Reservoir, and indirectly from Sugar Hollow Reservoir located 15 miles northwest of Charlottesville in the Blue Ridge Mountains. Raw water derived from those sources is then treated at one of three water treatment plants and distributed throughout the service area shown in Figure 1.

1.1.1 Albemarle County Service Authority

The Albemarle County Service Authority (ACSA) distributes treated water and collects sewage for treatment across the portions of the Urban System that lie within the County's jurisdiction. This includes all areas outside of the City of Charlottesville shown on Figure 1, with the exception of the University of Virginia grounds which overlap City-County jurisdictional borders but is served via a connection with the City of Charlottesville. The ACSA purchases treated water from RWSA for distribution to its customer base and pays the RWSA for treatment of the wastewater it collects. The ACSA currently serves a population of approximately 65,000 persons within the Urban Service Area. The majority of the population growth within the Urban Service Area is taking place in areas served by the ACSA.

1.1.2 City of Charlottesville

The City of Charlottesville distributes treated water and collects sewage for its approximately 50,000 residents as well as supplying water to the University of Virginia main grounds. The City purchases treated water from RWSA for distribution to its customer base and pays the RWSA for treatment of the wastewater it collects. Population growth in the City continues despite the fact there is little developable land remaining within City limits. Most future population growth is expected to occur through redevelopment that will allow for greater population density.

1.1.3 University of Virginia

The University of Virginia (UVA) is the region's largest employer and the Urban System's largest water user. Central grounds receive potable water from The City through a 14-inch meter. The University is also a significant property owner of land and buildings within the Urban Service Area that are not contiguous with central grounds. Those buildings receive water service from the City or the ACSA, depending on location and generally have individual accounts per building or per development. UVA is in a continual process of development and redevelopment, adding, on average, over 200,000 square feet of gross building area per year both on-grounds and to its outlying properties.

2. Forecast Goals and Summary of Prior Planning Documents

2.1 Prior Demand Forecasting Reports

Prior to conducting the various analyses required to develop the current demand forecast, the project team reviewed available reports and other documentation associated with prior demand forecasting efforts conducted for the RWSA's Urban System. These documents were reviewed to provide a baseline understanding of the prior projections, the considerations and methods employed, forecast accuracy and therefore the context in which the present report may be received. The Urban Service Area has been the subject of numerous planning studies over the years. The two most recent studies to focus on water demand forecasting for the Urban System are:

1. Demand Analysis for the Urban Service Area, Gannett Fleming, May 2004
2. RWSA Regional Water Demand Forecasts, AECOM, September 2011

The former employed linear and power law (exponential) curve fitting equations and applied them to historical population and demand data for both City and County areas to produce a demand forecast for the Urban Service Area. They also applied an expectation of 5% reduction in aggregate unit demand, via conservation and efficiency improvements, over the 50-year planning period, based on AWWA M50 guidance from that time. Estimated demand forecasts from the study are shown in Table 2-1.

The latter report utilized population and employment projections from the Virginia Employment Commission (VEC) and U. S. Department of Labor Quarterly Census of Employment and Wages (QCEW). Baseline unit demands were developed for the period of 2006 through 2010 and then additional conservation potential was analyzed and estimated at 3.9% over the 50-year planning period.

Table 2-1: Prior Demand Forecasts

Source	2025	2055	2060
Gannett Fleming, 2004	14.5 mgd	18.7 mgd	-
AECOM, 2011	11.9 mgd	16.2 mgd	17.0 mgd

A review of the assumptions in both forecasts shows that the population estimates have, in aggregate, tracked reasonably well with actual population growth since those forecasts were produced. The unit demands, however, have deviated significantly from the assumptions in those reports (implicit in the 2004 forecast and more explicit in the 2011 forecast) and are the principal source of error despite the fact both methods attempted to account for future conservation. Water use intensity (as measured by unit demand metrics) has declined far faster than was imagined at the time those reports were produced.

2.2 Forecast Planning Horizon and Contemporary Urban Planning Documents

2.2.1 Temporal Forecast Horizon

The RWSA Urban Demand Forecast estimates water demand through the year 2070. The 50-year planning horizon exceeds the range for most population and infrastructure planning processes because major water resource infrastructure projects can require a particularly long time to plan, permit, design, construct, and fill. New reservoirs and reservoir expansions can easily require 2-3 decades to move from permitting studies through the construction and filling steps and so it is important to assess needs and plan well in advance of those steps. Other infrastructure such as pipeline and pump stations can also take a long time to plan, permit, and construct.

While the goal of the project is a 50-year forecast, and there are good reasons to select that range, the realities of such a forecast period need to be understood. Regional population and employment forecasts are only available through 2045. Furthermore, the accuracy of forecasts decreases for target dates further into the future. For this reason, the RWSA demand forecasting process is updated approximately every 10 years. Given this understanding, the goal of this forecast is to be as accurate as possible at the 2030 horizon, and to match the regional population and employment forecasts at the 2045 horizon. The forecast at the 2070 horizon involves a lot of assumptions as there are no parallel planning documents (i.e. population and employment forecasts) to support a water demand forecast 50 years into the future, but this information can still be used for appropriate long range planning purposes. Estimates regarding 2070 population for the service area were made based on maximum build-out densities estimated by Albemarle County Office of Community Development (ACOCD) and City Neighborhood Development Services (NDS) department staffs.

2.2.2 Contemporary Planning Documents and Information

The Charlottesville/Albemarle Metropolitan Planning Organization 2045 Long Range Transportation Plan (LRTP), dated May 22, 2019, is based upon the most recent and rigorous urban population and employment forecast data produced for the metropolitan region that includes the RWSA Urban System. The Thomas Jefferson Planning District Commission (TJPDC) produced the LRTP and made available the population and employment projections used for the Demand Forecast Study. The LRTP breaks down population projections and estimates into spatial units known as Traffic Analysis Zones (TAZs). TAZs within the RWSA service area ranged from under 4 acres to just over 2300 acres, with a median size of 72.6 acres and were well-suited to the spatial resolution required for the demand forecast and associated analyses. The population and employment projections in the LRTP closely match those available from UVA's Weldon Cooper Center for Public Service, shown in Tables 2-2, 2-3, and 2-4, and were used as benchmark population targets for the Demand Forecast Study. The Weldon Cooper Center is the Commonwealth of Virginia's leading demographic research group and produces the official population projections and estimates for the state's cities and counties.

Table 2-2: City of Charlottesville Population Projections

	Year	
Projection Source	**2015**	**2045**
Weldon-Cooper	48,210	55,969
TJPDC LRTP[1]	48,326	56,770

1- Population estimates for Charlottesville are based on an area-weighted clip of TAZs matched to Charlottesville boundaries

Table 2-3: ACSA Population Projections[2]

	Year	
Projection Source	**2015**	**2045**
TJPDC LRTP	61,629	95,829

2- Population estimates for the ACSA are based on an area-weighted clip of TAZs matched to the ACSA service area

Table 2-4: Employment Projections from TJPDC LRTP[3]

	Year	
	2015	**2045**
Charlottesville	37,045	47,682
ACSA	37,403	46,293

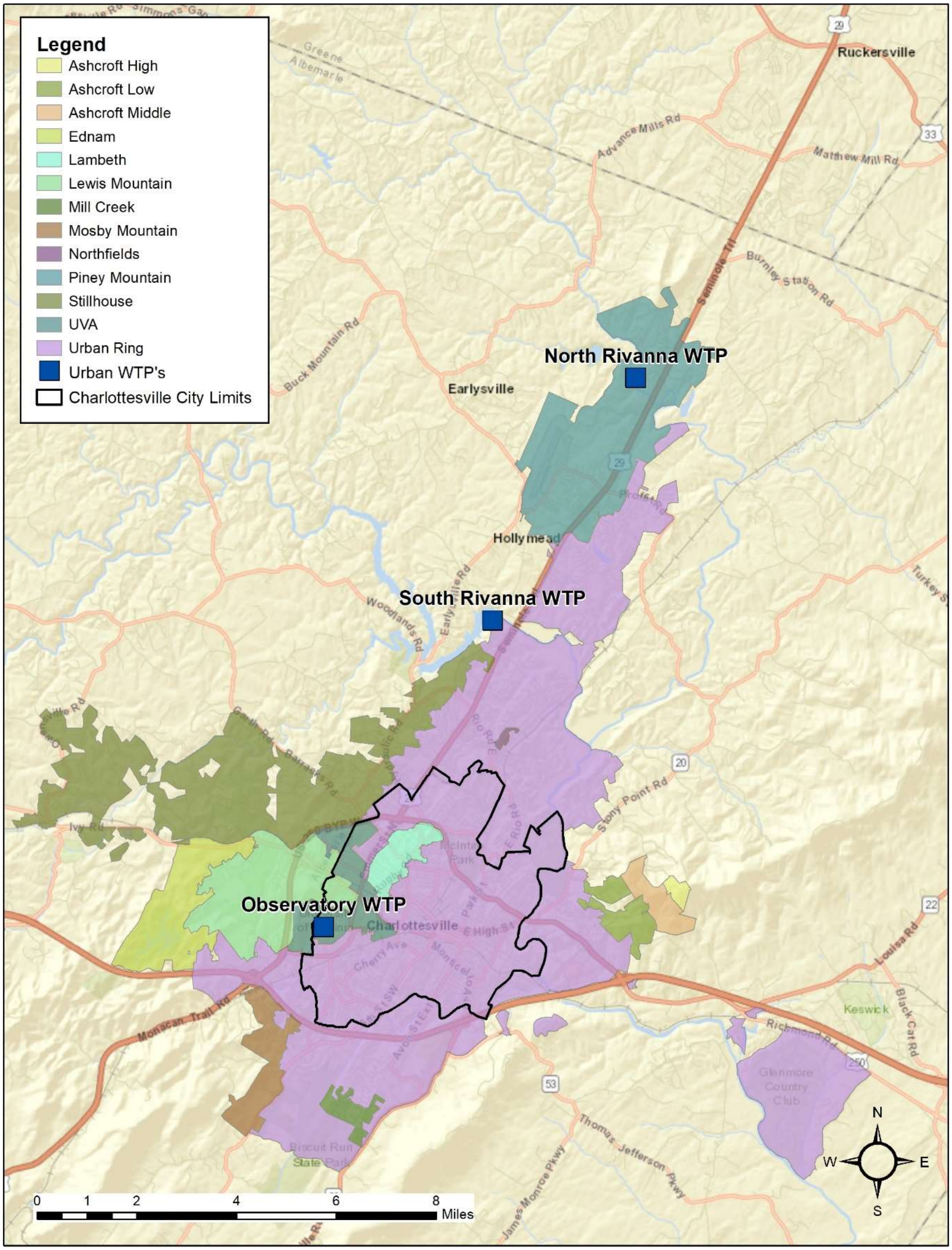
3- Employment estimates for Charlottesville and the ACSA are based on an area-weighted clip of TAZs matched to the ACSA service area

2.3 Geospatial and Water Sectoral Resolution

In addition to developing forecasts for the ACSA, City of Charlottesville, and UVA, the present demand forecasts also allocates the overall demand across twelve distinct pressure zones in the Urban System. The Urban Service Area and demarcations for its 13 pressure zones are illustrated in Figure 2-1 below. For the purposes of the Demand Forecast Study, the small Northfields pressure zone is rolled into the Urban Ring pressure zone forecast. The spatially disaggregate demand forecast was produced using a land use model of development within the Urban Service Area which is described in more detail in Section 3.

In some cases, a demand forecast was developed for specific projects at a finer resolution than the pressure-zone level. Most of these finer scale projections pertain to projects or masterplanned areas owned by the University of Virginia and are described in more detail in Section 3.3. Furthermore, analysis of historical demands and projection of future demands involved assigning billing accounts and future development to one of three water sectors, or class types. Those three class types are single-family residential (SF), multifamily (MF) residential, and non-residential (NR). This is also described in greater detail in Section 3.

Figure 2-1: RWSA Service Area and Associated Pressure Zones

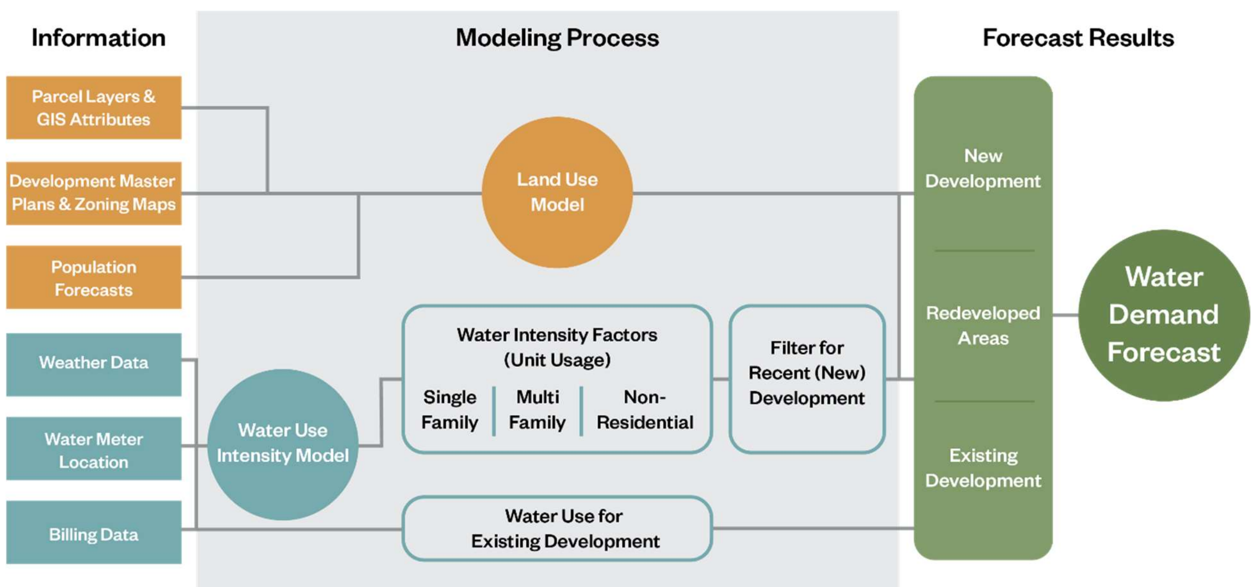


3. Demand Forecast Development

The RWSA Urban System Demand Forecast Study was developed through the application of a land use model and water use intensity model of the service area, together with guidance on population and employment projections from independent agencies to pace the development rate within the land use model. There were many sources of information that went into developing these two models. A simplified schematic, in Figure 3-1, describes the major classes of information and the process flow used to produce the RWSA water demand forecast.

Many of the sources of information used in the modeling process came from local agencies including City Utilities, Charlottesville Open Data, Charlottesville Neighborhood Development Services (NDS), the ACSA, Albemarle County Office of Community Development (ACOCD), Albemarle County Geographic Data Services (GDS), TJPDC, the University of Virginia, the Weldon Cooper Center, and RWSA. The project team held meetings with RWSA, City Utilities, City NDS, ACSA, ACOCD, and UVA during the course of the project to explain the rationale and goals for the project, the proposed forecast development method, request assistance with providing and collecting data, as well as to review the assumptions and results as the demand forecast project began to wrap up.

Figure 3-1: Overview of Demand Forecast Modeling Process



The land use model was used to spatially disaggregate the demands across the RWSA Urban System. Using the general classes of information shown in orange in Figure 3-1, it determines where, how much, and what type of development is likely to occur in the future. The spatially linked information it produces can be used to sum up the number of new single-family homes, multifamily dwellings, and additional non-residential space across a spatial boundary such as a pressure zone. The water intensity model relies on the classes of information shown in blue in Figure 3-1 to determine how much water new single-family homes, multifamily dwellings, and non-residential spaces are likely to use. The information from the two models is combined (along with water demand from existing development) to produce a spatially disaggregate water demand forecast for the Urban Service Area. Sections 3.1 and 3.2 describe the land use and water intensity modeling processes, respectively, in greater detail.

3.1 Land Use Development Model

The purpose behind utilizing a land use model to forecast water demand is to predict the types and densities of development that will take place across the service area and to be able do so in a spatially relevant manner. The type and density of development can then be linked to water demand with the water use intensity model.

The methodology underpinning the land use model involved assigning each parcel to a *partition* according to its pressure zone, zoning or master plan specification, and current development status (built upon or vacant/undeveloped). Together, these characteristics were used to define assumptions about how land will develop in the service area, the assumed rate of development, and the pressure zone to which its water use would be assigned. Partitioning involved grouping parcels into nonoverlapping areas wherein current and future demands were estimated using a consistent set of assumptions within each partition. Thus, each partition in the model represents a group of parcels (an area) within the RWSA Urban Service Area in which the same set of assumptions are applied with respect to the type of development (e.g. residential, non-residential, or mix thereof), timing of development, and density of development expected over the forecast horizon.

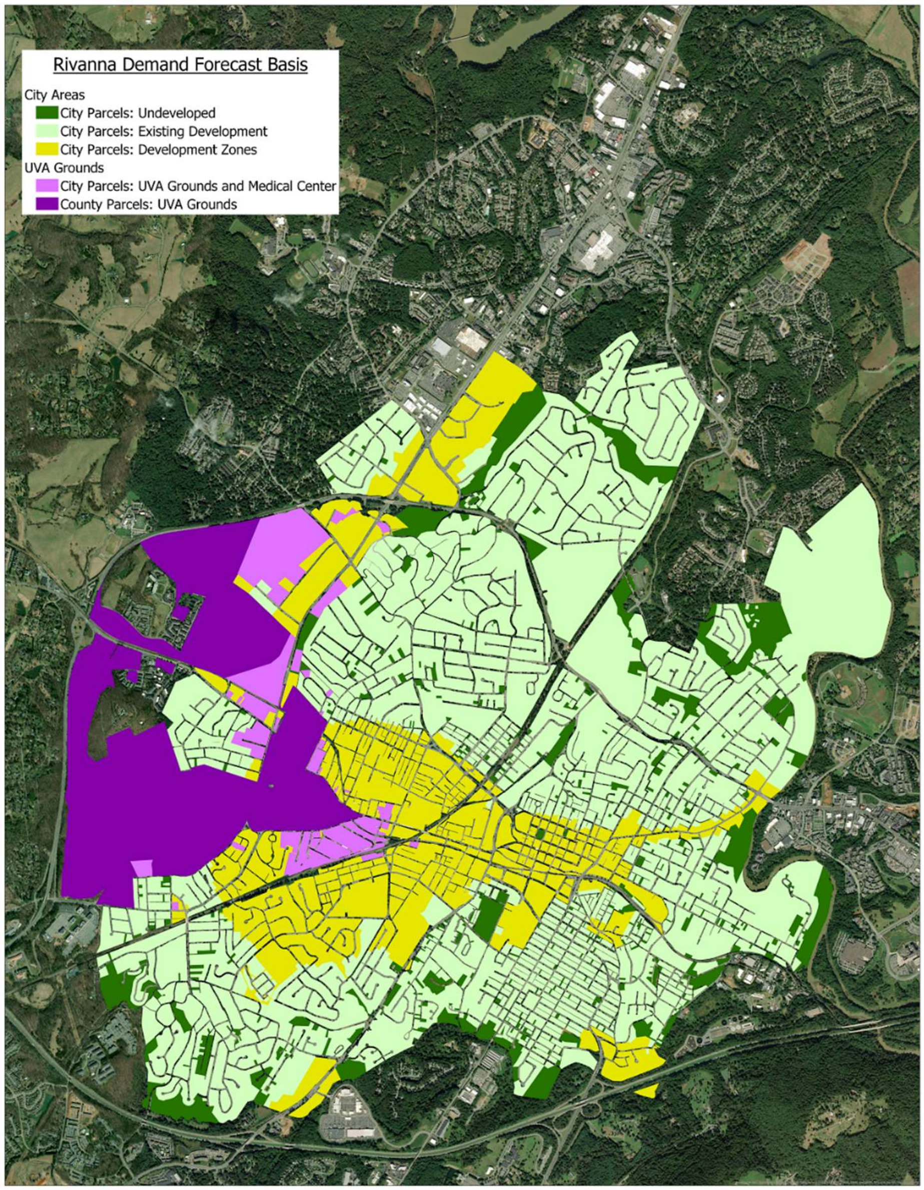
Parcels pertaining to areas of the University grounds that are served by the 14" meter from the City (currently about 90% of the water UVA uses passes through this meter) were excluded from this land use model basis of demand forecasting. The UVA demand forecast was developed independently from the forecast for the City and ACSA service areas. The UVA demand forecast model is described in Section 3.3.

Development within the land model was bounded on the upper end by the maximum densities allowed by current zoning regulations. In the case of the County's small area masterplans, which cover a significant portion of the ACSA service area, the maximum densities proposed under those masterplans superseded the zoning classifications and were used to define the maximum build-out density. Those densities are enumerated in detail in Appendix A and were acceptable to both the ACSA and ACODC. The model generally assumed no adjustments to the existing zoning and masterplan regulations within Albemarle County. Undeveloped parcels were assumed to develop in accordance with their associated zone or masterplanned densities. Parcels with existing development and water meters were assumed to remain as-is throughout the forecast horizon unless they fell within one of the areas where redevelopment was considered within the model.

Some portions of the ACSA service area were assumed to partially redevelop over the forecast horizon regardless of their existing development status. Areas where redevelopment was assumed in the County are shown in Appendix A Figure A-14 and correspond to areas within the County's small area masterplans. Those shown in Figure A-12 are currently part of the County's "development pipeline" and are already slated for development or redevelopment. These assumptions were also met with acceptance by the ACOCD.

Furthermore, some areas within Charlottesville, such as those within a half-mile of the UVA Medical Center and those zoned for mixed use development, were assumed to redevelop to mixed use at higher densities than their zones may currently allow. This assumption is based on the precedence for zoning variances issued in those areas of the City in the recent past. The yellow 'Development Zones' in Figure 3-2 demarcate these areas and City NDS staff reviewed these assumptions.

Figure 3-2: Charlottesville Land Use Forecast Basis



Once the development model was assembled for build-out conditions, the degree of development at target forecast dates was set within the model such that a sufficient number of new housing units and non-residential space would be added to accommodate the anticipated employment growth within the City or ACSA service areas.

Details regarding the partitioning process, build out densities, and other inputs and outputs from the land use model are described in detail in Appendix A.

3.2 Population and Employment Growth

Population growth guidance through 2045 is available from both the UVA Weldon Cooper Center and the Thomas Jefferson Planning District Commission's 2045 Long Range Transportation Plan (LRTP). The projections for both Charlottesville and the ACSA are shown in Tables 3-1 and 3-2, respectively. The values selected for this study for the ACSA represent a growth in population through 2045 equivalent to that projected for the ACSA portion of the service area, but using the ACSA population served estimate from 2015 as a starting point rather than the area-weighted population from the TAZ data for the ACSA. The ACSA's estimate was selected since it was assumed that their estimate based on the number of residential connections might be more accurate than one where TAZs were split to match the service area boundaries, but the two estimates have less than a 1% difference, so they mutually reinforce confidence in the service area population estimate.

The population target for 2070 was based on a rough estimate from City NDS of the maximum population capacity of Charlottesville without any changes to the zoning ordinance, but allowing for redevelopment of currently developed areas. That redevelopment is focused on the portion of Figure 3-2 shaded in yellow and previously discussed in Section 3.1. The 2070 population target for the ACSA is based on the High Development Area Population at buildout from the ACOCD. Figure 3-3 shows these projected populations for the City, ACSA, and total service area.

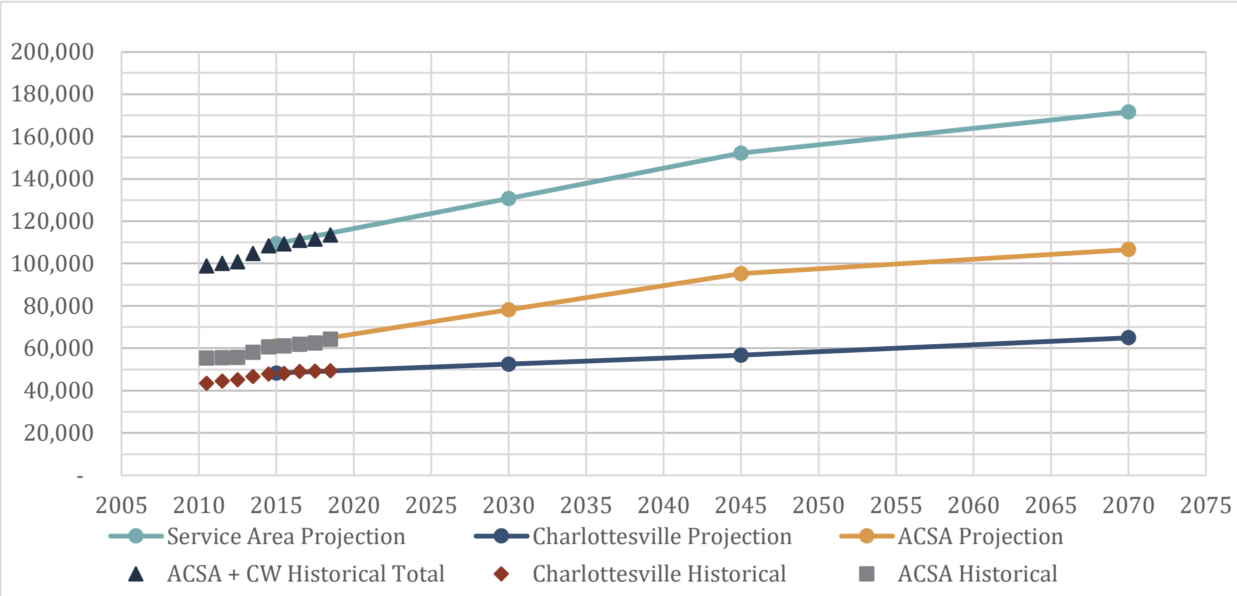
Table 3-1: Charlottesville Population Projections

Source	2015	2045	2070
Weldon-Cooper	48,210	55,969	-
TJPDC LRTP	48,326	56,770 (+17%)	-
This study	48,326	56,770	65,000

Table 3-2: ACSA Population Served Projections

Source	2015	2045	2070
ACSA	61,113	-	-
TJPDC LRTP	61,629	95,829	-
This study	61,113	95,300 (+56%)	106,650

Figure 3-3: Populations Projections for Charlottesville and the ACSA



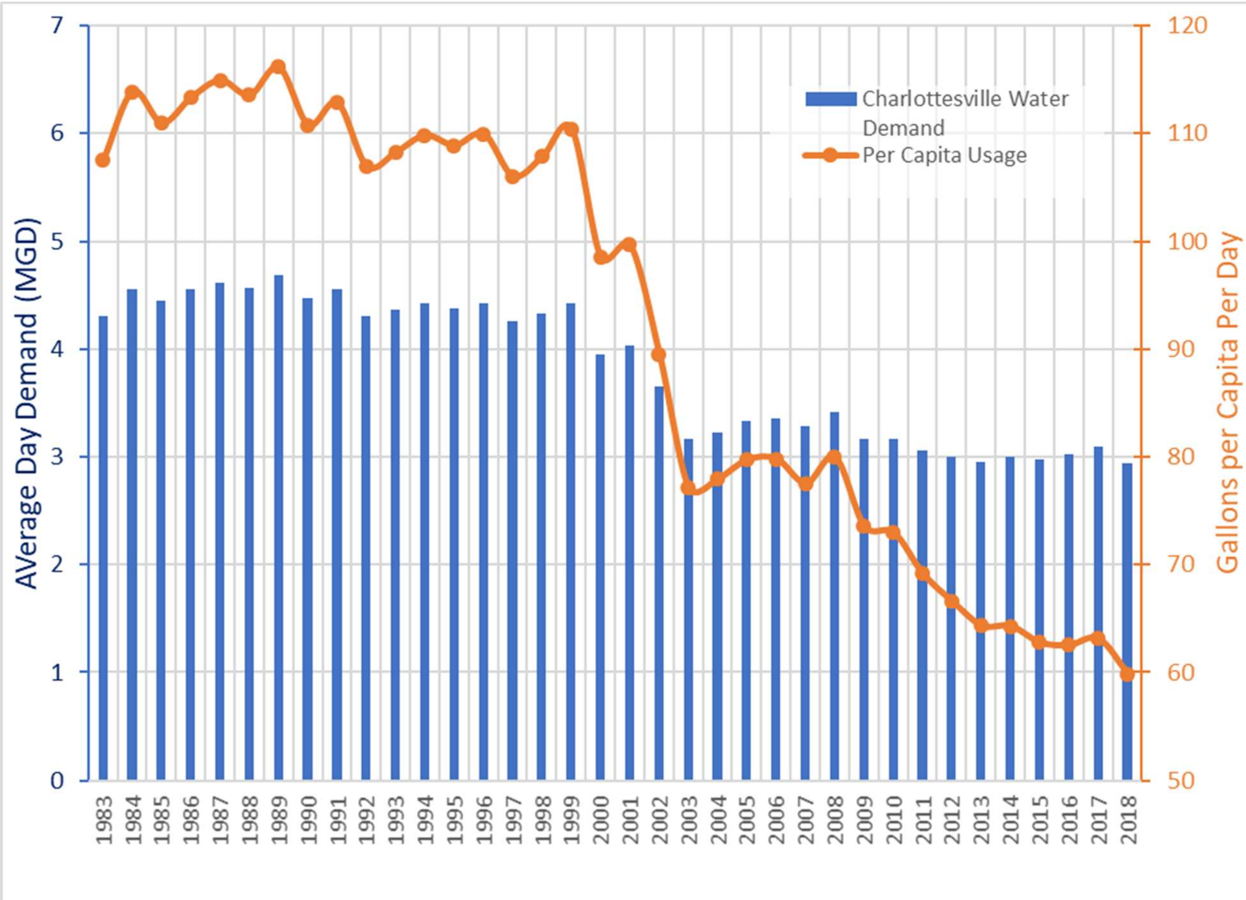
Employment estimates were used as guidance for the addition of new NR space to the service area. At present there is around 500 square feet of NR space in the service area per employee. The amount of new NR space per additional employee through 2045 is closer to 750 square feet, but this figure itself does not account for the replacement or demolition of existing NR space which will often be required to accommodate the new NR structures. There are no employment projections for 2070 available so the ratio of new residential to new NR space was kept fixed after 2045.

3.3 Unit Demand Analysis

Unit demand, also referred to as demand intensity, represents the amount of water used per person, employee, dwelling unit, or per unit area. Developing unit demand profiles is standard practice for water demand forecasting activities[1]. The aggregate per capita unit demand is one water intensity metric often used for comparison. It is calculated as the sum of all water use, not just residentially metered uses, divided by the total service area population. The aggregate per capita unit demand for the Urban Service Area has been declining rapidly over the past two decades as illustrated in Figures 3-4 and 3-5. As shown in Table 3-3, the RWSA service area is among the more efficient in the nation in terms of water use based on this metric.

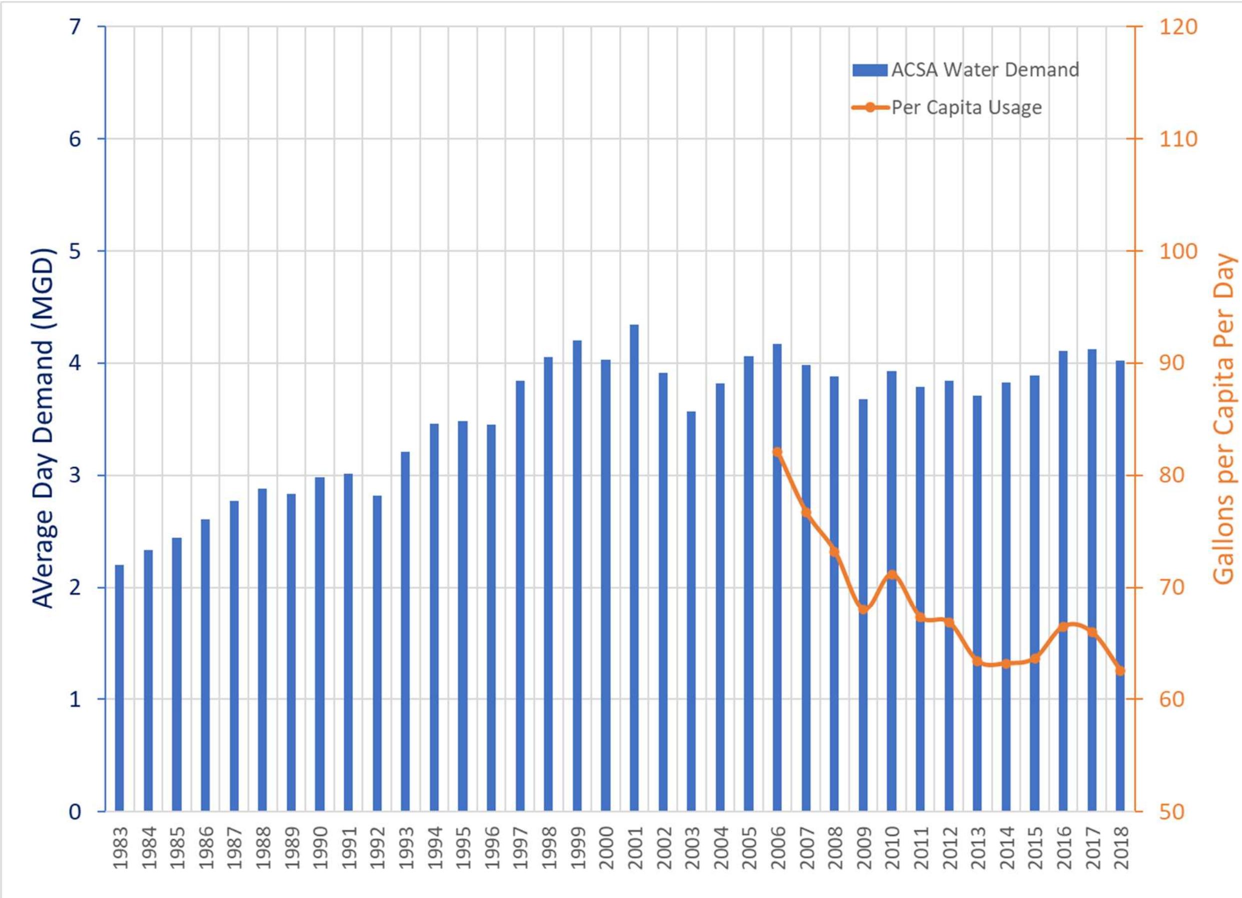
[1] AWWA M50 3rd Edition, Water Resources Planning, Chapter 5, Water Demand Forecasting

Figure 3-4: Charlottesville Average Day and Per Capita Demand Trend[2]



2- University demand removed from Charlottesville totals

Figure 3-5: ACSA Average Day and Per Capita Demand Trend



The unit demands for the City and ACSA portions of the RWSA Urban Service Area have tracked closely as is evident in Figure 3-4 and 3-5, although the population in the ACSA portion of the service area has grown more rapidly than in Charlottesville. The similarities in unit demand profiles provide confidence to support the application of findings from either the City or ACSA to the other in cases where data may be missing from one of the services areas.

Table 3-3: Aggregate Unit Demand Comparison Across Utilities

City / Utility	Aggregate per capita consumption (year)	Raw or Finished Water Basis
RWSA	73 gpcd (2017)[1]	Finished
Loudon Water, VA	80 gpcd	Finished
OWASA (Chapel Hill, Carrboro, UNC)	84 gpcd (2017)	Finished
Raleigh, NC	88 gpcd (2017)	Raw
Durham, NC	105 gpcd (2017)	Raw
Charlotte, NC	120 gpcd (2017)	Raw
Baltimore, MD	109 gpcd (2015)[2]	Unknown
Austin, TX	126 gpcd (2017)[3]	Raw
Santa Cruz, CA	71 gpcd (2015)[4]	Finished
New York City	117 gpcd	Finished

1. Includes UVA consumption and On-grounds population
2. Data from USGS https://waterdata.usgs.gov/md/nwis/wu
3. https://data.austintexas.gov/Utilities-and-City-Services/Austin-Water-Gallons-of-Water-Pumped-per-Capita/wfm8-s7zc
4. http://www.cityofsantacruz.com/home/showdocument?id=55168

The Demand Forecast Study involved further disaggregation of the per capita unit demands among several class types (or use sectors). Each meter or account was assigned to one of three class types. All accounts within a class type were analyzed collectively to develop unit demands for that sector. Of the three class types, two are residential (single-family residential and multifamily residential) and all non-residential (NR) accounts were grouped together into the NR sector. The unit demands for the three sectors were specified as: single-family demand per dwelling unit, multifamily demand per dwelling unit, and nonresidential demand per thousand square feet of building space. The demand intensities in single-family, multifamily, and nonresidential water use sectors were estimated using City and County meter data for FY 2017 and associated information describing structures on parcels from the City from Charlottesville and the Albemarle County Office of Community Development (ACOCD). The results are shown in Table 3-4

Sectoral Classification of Meters. Both the City and the ACSA provided data indicating the type of development (SF, MF, or NR) served by each meter. Visual comparison of meter locations with aerial and street-view imagery indicated that type of development generally agreed with true development characteristics. There were some exceptions, in particular for ACSA meters, that required the accounts to be reclassified for the purposes of this study prior to estimating sectoral unit demands. The account reclassification process used as part of the study is described in detail in Appendix B Section B.1.1.

Single Family Intensity. Following sectoral classification of meters, intensities were estimated for each water use sector using FY 2017 consumption data and estimates of the numbers of dwelling units. Since SF dwelling units (DUs) tend to have their own parcel and also have one account per dwelling unit, the calculation of unit demand for this sector is relatively easy. The average SF unit demand for FY 2017 was estimated to be 120 gal/DU/day. Unit demands were compared across pressure zones and though there were some differences between zones, the dispersion of the data within zones supported the use of a single value for future development across the service area.

Multifamily Intensity. To estimate multifamily (MF) intensity, it was necessary to know the number of dwelling units served by each MF meter used in the estimate. This requirement arises since meters that serve MF structures often serve more than one DU, or even all DUs in those structures. Usually, property appraisers can provide information on the number of dwelling units for MF parcels; then, through a matching of meters to parcels, consumption per MF DU can be estimated. Unfortunately, neither the City nor the ACOCD had this information available for all MF parcels. However, the MF DU count was estimated by working backward from better known quantities. First, the population living in MF DUs was estimated. This was done using the Urban Service Area population estimate (111,600 in FY 2017), the number of SF DUs, and the assumption that 2.54 persons live in the average SF DU. The persons per SF DU figure came from County GDS data and was confirmed with Census Bureau data. The SF population was calculated by multiplying the SF DU count (described in the preceding paragraph) by 2.54. The MF population was then estimated by subtracting the SF population from the service area population. The persons per dwelling unit for MF DUs is 2.01 (also from GDS and Census Bureau) which led to an estimate of 24,934 MF DUs in the service area. The sum of usage across accounts designated as MF divided by this inferred number of MF DUs led to an estimate of 75 gallons per MF DU per day for FY 2017.

Nonresidential Intensity. Nonresidential intensities were estimated from total consumption for NR meters over FY 2017 and then dividing that by total days to produce average gallons per NR sector per day. That number was then divided by the total number of nonresidential building square feet served by those meters. Total building square footage on each parcel was provided by both the City and the ACOCD. The estimated unit demand for the NR sector was 85 gallons per day per thousand square feet (gpd/ksf).

Table 3-4: Estimated FY 2017 Demand Intensity by Sector

Sector	Estimated Intensity
Single-family	120 gal/DU/day
Multifamily	75 gal/DU/day
Nonresidential	85 gal/ksf/day

3.3.1 Demand Intensity Estimates for Future Development

Given the decreasing trend in unit demands across the service area, it became especially important to model how that might change over the forecast horizon. It was assumed that people using future development will use water similarly to newly developed structures compared to older structures. Therefore, an effort was made to discern water use habits of these newer developments. Fortunately, the ACOCD was able to provide parcel-level unit information for housing stock constructed since 2010. These were matched with meter records such that demand intensities for this subset of SF and MF dwellings could be calculated as shown in Table 3-5. These unit demands were assumed reasonable and applied to all future development. Future NR unit demand was estimated at 75 gpd/ksf based on data for University buildings and the expectation of some improvement in efficiency over the present aggregate NR stock (85 gpd/ksf).

Table 3-5: Estimated FY 2017 Demand Intensities for post-2010 Development by Sector

Sector	Estimated Intensity
Single-family	109.4 gal/DU/day
Multifamily	79.5 gal/DU/day
Nonresidential	75.0 gal/ksf/day

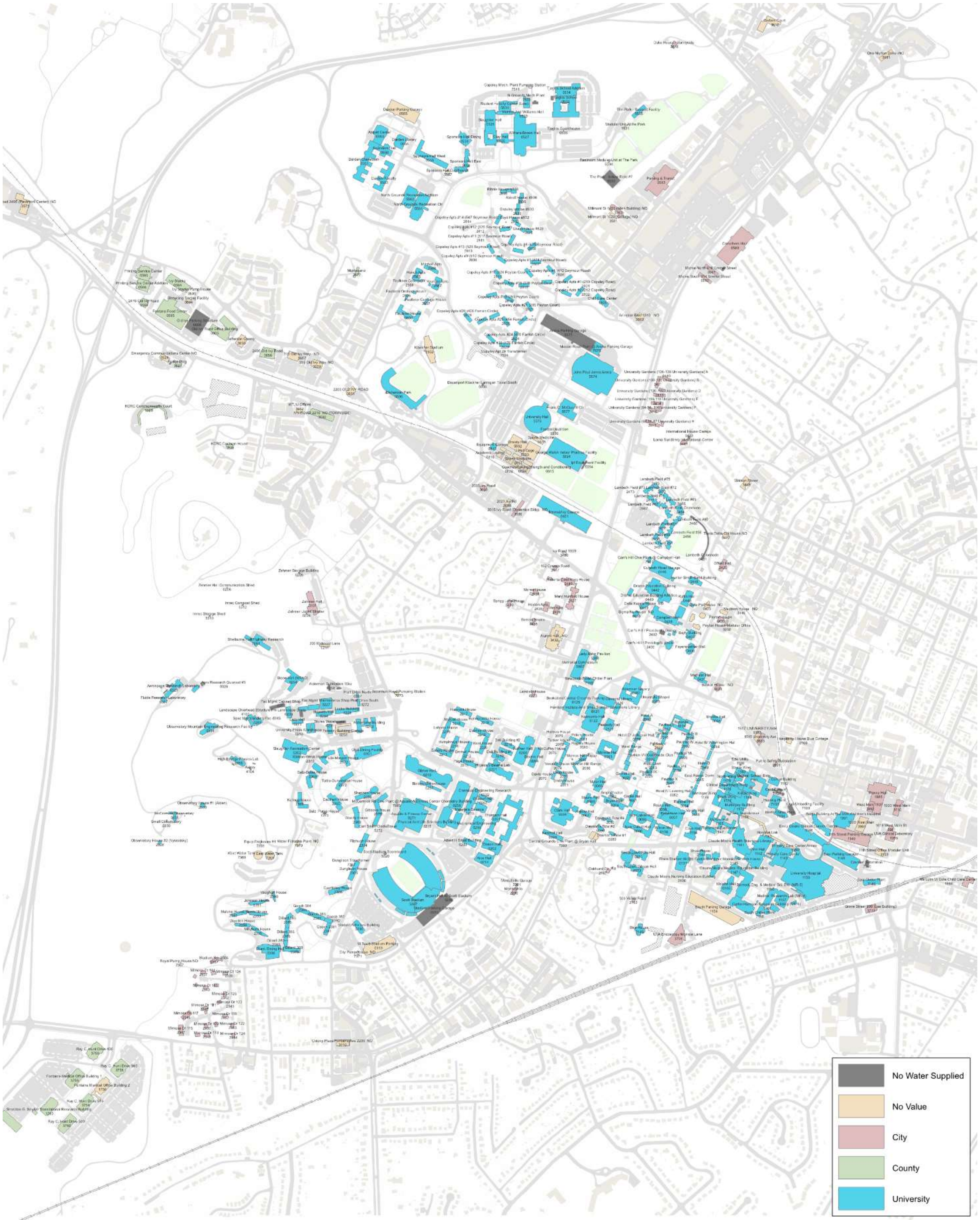
Collectively this set of assumptions produces an aggregate unit demand that continues to decline slightly in the ACSA and remains flat in Charlottesville. These trends are displayed graphically in Section 3.6.2, Figures 3-14 and 3-15.

Details regarding the water intensity modeling covered in this section are described in Appendix B.

3.4 The University of Virginia Demand Forecast

The University of Virginia (UVA) is located on the west side of Charlottesville and has a large influence on water usage in the RWSA service area and is the single largest consumer. UVA has a stated goal of reducing total water use through the year 2035. Currently about 90% of UVA's water is supplied through a single 14-inch meter from the City. UVA buildings not receiving water service via the 14" master meter are supplied by accounts from the ACSA or the City, and are referred to as "direct drops" by University staff. Figure 3-6 is a University produced map and the buildings in blue correspond to those served via the 14-inch line. Predicting demand for UVA using a future land use model would be difficult since the University does not have a comprehensive parcel-based long range plan (not beyond about 10 years), and is not subject to zoning requirements that could guide such a model beyond 10 years into the future. Therefore, a separate forecast method was developed based on University-stated student enrollment projections and historical building development rates together with historical usage data for UVA buildings whose water is supplied by the 14-inch service line. In addition to the demand forecasts for the areas served via the 14-inch service line, forecasts were done for several of the University's masterplanned areas.

Figure 3-6: UVA Building Water Source



Prior to developing the UVA water demand forecast, Hazen reviewed water use data and student enrollment data. In an effort to better understand data sources as well as current planning, Hazen met with University staff in January 2019 to review data and discuss recent trends that could impact Hazen's demand forecasts. The information gathered were used to analyze the University's water use and project water demands for the UVA 14-inch meter area over the 50-year planning horizon. Additionally, Hazen developed specific demand forecasts for UVA masterplanned and several near-term projects and research parks using a similar methodology to that employed for the principal "on-grounds" forecast. The sections below describe the forecast development in more detail.

3.4.1 Determine Building Categories and Demand Drivers for Each Category

The water usage data provided by UVA contained a building use classification which categorized buildings into one of 18 use classifications. The 18 building types were consolidated into four aggregate categories for the areas served by the 14" master meter from the City to simplify the analysis and demand projection. The aggregate categories are University Housing, General University, Care Facilities, and Utilities. Historical water usage for buildings in each aggregate category was correlated with several potential demand drivers for water use and the most well-correlated driver was assumed to remain well-correlated over the forecast horizon. For example, water use within University Housing is well-correlated with the number of students living on grounds while the Utility category is well-correlated with the total university building area since the majority of water usage within this category is from chiller plants which supply the HVAC systems for most of the buildings on grounds. Demand drivers were also assumed to grow and change over time. University staff provided guidance on the expected growth rate of the student body (1% annually) and the growth in building square footage and full-time equivalents for health care facilities were determined from the data provided by staff. University staff reviewed and approved the use of these assumptions in conjunction with this forecast at a meeting on September 16, 2019. Table 3-6 summarizes building types, aggregate categories, water and area footprints, and demand drivers.

Table 3-6: UVA Building Categories and Demand Drivers

Aggregate Building Category	Correlated Water Use Driver	Demand Driver Growth Assumption	Building Use Classification	2018 Water Use (MG)	2018 Area (ksf)
University Housing	Students Housed On-grounds	University will house 1/3 of FT students in on-Grounds housing	Housing	52.8	2178
General University	All students	1% average annual growth until 2070	Athletic	22.2	1430
			Classroom	4.5	484
			Dining	8.9	132
			Landscape	1.1	194
			Library	5.8	817
			Office	35.5	2871
			Public Service	0.1	30
			Research	46.5	2604
			Sports Field	5.2	1247
			Storage	0.3	26
			Support	6.8	601
Care Facilities	Hospital FTE	1% average annual growth until 2070	Child Care	0.4	8
			Patient Care	61.1	1673
Utilities	Total University Building Square Footage	About 190 ksf of net new building square footage per year	Utilities	156.3	91
Not Included in analysis	N/A	N/A	Parking Garage	0.3	1131
			TBD	0.0	0
			Hospital Support (helipad)	0.0	0
Total				**408.0**	**15,518**

3.4.2 Analyze and Project Water Use Intensity, Student Population, and Building Area

After establishing building categories and growth assumptions for the drivers, the historical data were analyzed to determine historical water use intensity for each building category. A water use intensity was calculated by summing the total usage from an aggregate category and dividing by the quantity of each correlated driver (e.g. total students, health care facility FTEs, building GSF). Historical data shows that water use intensity has declined over time for all building types as shown in Figure 3-7. This can be explained by initiatives to reduce water usage and the installation of more water-efficient devices and plumbing fixtures. The rate of decline (i.e. slope) of water use intensities is expected to slow and plateau over time as new water use initiatives and technologies approach their practical efficiency limits, but there is uncertainty with regard to the rate of decline and ultimate efficiency. For this reason, greater efficiency improvement rate and lower efficiency improvement rate scenarios were evaluated for this analysis. The greater efficiency improvement rate results in lower demand and the water use intensity slope from 2018 to 2035 is ½ the historical rate and 1/10 the historical rate after 2035. The lower efficiency improvement rate scenario results in a higher demand and the slope from 2018 to 2035 is ¼ the historical rate and is zero after 2035. Projected water use intensities are shown in Figure 3-8.

Figure 3-7: Historical Water Use Intensity and Trends by Aggregate Building Class

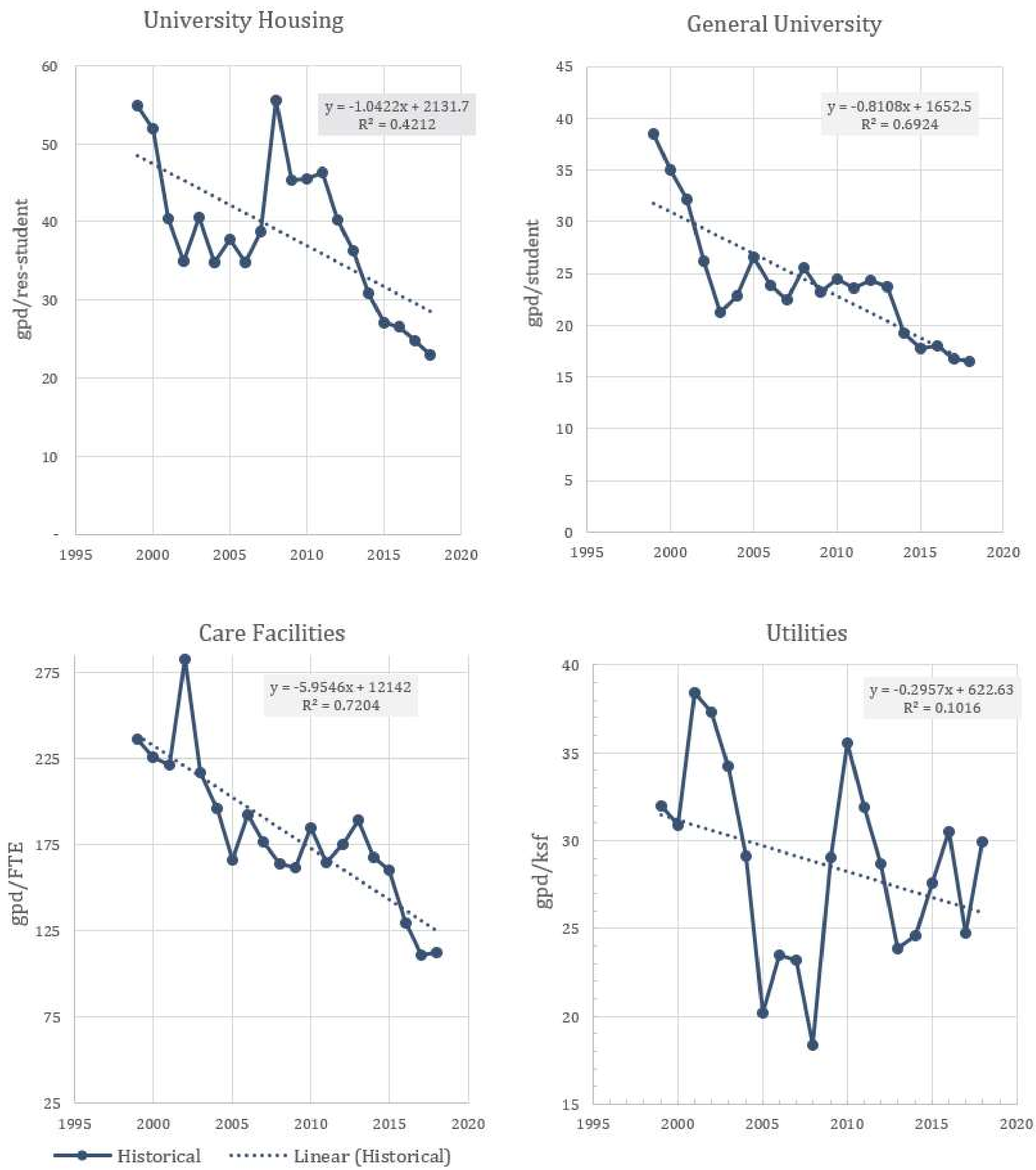
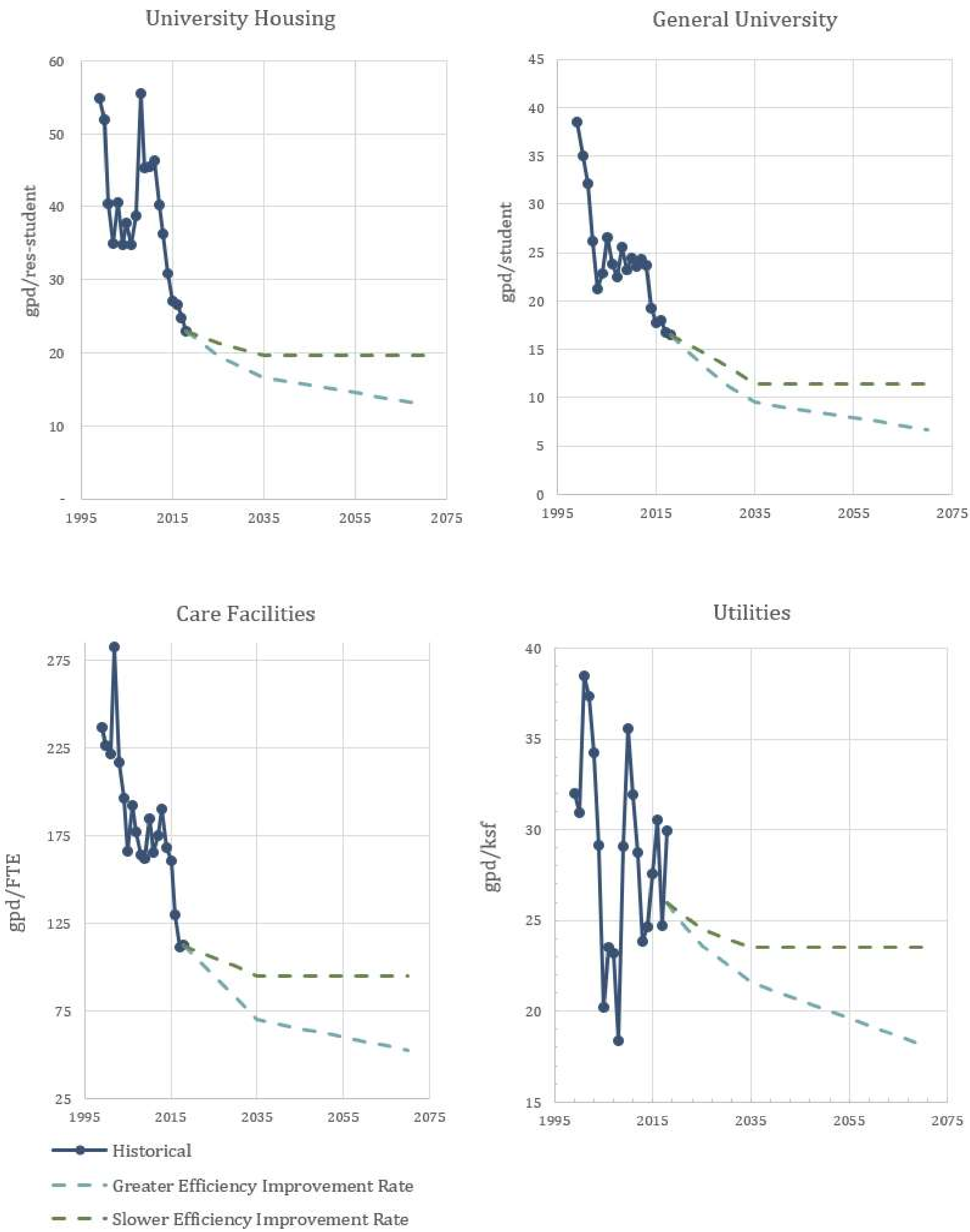
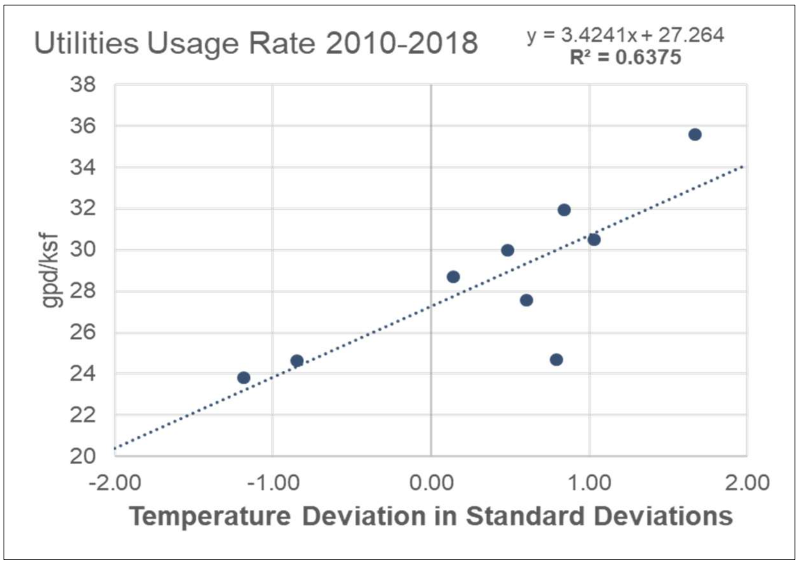


Figure 3-8: Projected Water Use Intensity trends by Building Class



Additionally, it is worth noting that the historical water use intensity for the Utilities category exhibits a dependence on temperature (Figure 3-9). This dependence is expected since the majority of water used in the Utility category is to run water cooled chiller plants which provide cooling for most University buildings on grounds. The utility unit usage rates are also expected to decline and plateau as new buildings with improved thermal efficiency replace older building stock. However, the greater efficiency improvement rate and lower efficiency improvement rate scenarios reflect the usage rate during an average temperature year and do not account for potential variances in temperature. Accounting for weather variation is described in Section 3.6.3 and in Appendix D.

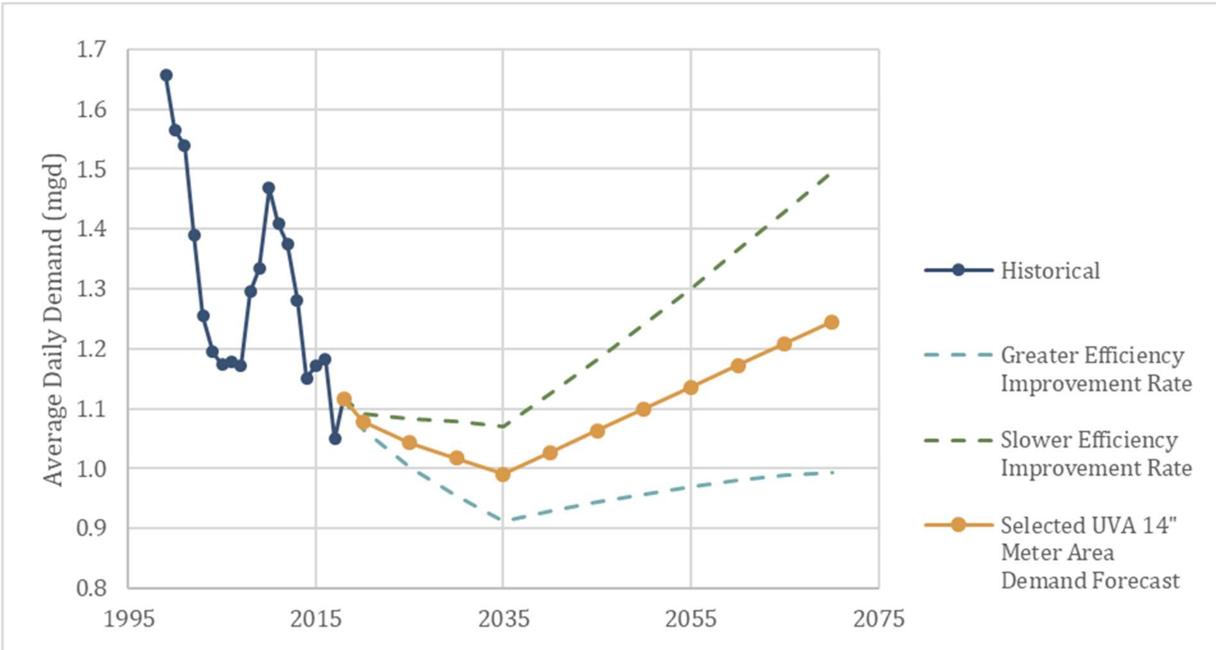
Figure 3-9: Utility Water Use Intensity Temperature Dependence



3.4.3 Project Future UVA Water Use

A water demand forecast for on-grounds areas served by the 14-inch line was developed through 2070 using projected usage rates and projected university growth. Two sensitivity scenarios were developed, one for a greater efficiency improvement rate and another for a lower efficiency improvement rate for each building type. The selected 14-inch meter area demand forecast is an average of the greater efficiency improvement rate and lower efficiency improvement rate projections. As shown in Figure 3-10, the projection predicts that there will be a slight decline (~10%) in UVA water usage until 2035 where demand is forecast to be roughly 1 mgd during an average weather year. Following 2035, a slow increase in demand is projected through 2070. This projection is in line with the UVA planning goal of no increase in water use until 2035. The selected 14-inch meter area demand forecast is incorporated into the RWSA Urban System demand forecast.

Figure 3-10: UVA Demand 14” Meter Area Demand Forecast



3.4.4 Estimates for UVA Masterplanned Areas and Research Parks

Additionally, Hazen provided specific demand forecasts for several UVA masterplanned areas and research parks. Seven (7) future UVA projects were analyzed using a similar methodology as the general UVA projection. First, building categorization and demand drivers were determined through a review of UVA master planning documents. It was determined that three building categories would be considered, a general category, UVA hospital, and research park residential. The general category contains office, research, classroom, and athletic fields. Demand for each category is correlated to planned building square footage.

Second, direct water use intensities (in gpd/ksf) were determined for the general and UVA hospital building types based on historical usage and square footage. Additionally, indirect water use intensities for heating and cooling use were also used for both the general and UVA building categories. Adding the direct and indirect intensities provided a total water use intensity for the new developments. For the research park residential category, water use was estimated by applying the MF water intensity rate that is used in the non-university model described in section 3.3.1, along with the assumption that MF unit size will average 1,000 square feet. The latter assumption was necessary to get a number of dwelling units since the University provided an estimate of residential square footage rather than a count of dwelling units. Table 3-7 below summarizes usage rates used for the demand forecasts for masterplanned areas.

Table 3-7: UVA Masterplanned and Near-term Projects or Special Areas Area Usage Rates

Types	Water Use Intensity
Direct Rate General, gpd/ksf	50
Direct Rate Hospital, gpd/ksf	125
Indirect (Utility/HVAC) Rate, gpd/ksf	25
Research Park Residential, DU/ksf	1
Research Park Residential, gpd/du	79.5

Third, demand projections for the benchmark years 2030, 2045, and 2070 were calculated using the anticipated project square footage and the usage rates stated above. Projected completion time for each project was used to attribute new demand for the benchmark years except for the UVA Research Park project which is assumed to be steadily built over the forecast horizon, building a fixed amount of square footage every year. Table 3-8 summarizes demand projections for the Brandon Avenue, Hospital Bed Expansion, North Grounds / Athletics, Emmet/Ivy Corridor, Ivy Mountain, Fontaine Campus and North Fork (UVA) Research Park Projects. The UVA masterplanned areas and research parks demand forecast is incorporated into the RWSA Urban System demand forecast.

Table 3-8: Demand Forecast for UVA Masterplanned Areas and Research Parks

Assumed Service	Project Name	Total Net Area, ksf	2030 New Use, kgd	2030 Total Use, kgd	2045 New Use, kgd	2045 Total Use, kgd	2070 New Use, kgd	2070 Total Use, kgd
14" Meter Area	Brandon Ave	405	30	30	-	30	-	30
	Hospital Bed Expansion	440	66	66	-	66	-	66
	North Grounds / Athletics	279	21	21	-	21	-	21
	Subtotal	1124	117	117	-	117	-	117
City	Emmet/Ivy Corridor[1]	678	*100*[1]	*100*[1]	-	*100*[1]	-	*100*[1]
ACSA	Ivy Mountain	323	24	24	-	24	-	24
	Fontaine Campus	866	38	38	27	65	-	65
	Near Term Projects	500	38	38	-	38	-	38
	Long Term Projects	366	-	-	27	27	-	27
	UVA Research Park	3150	42	42	61	103	69	172
	Residential	500	9	9	11	21	19	40
	Non-residential	2650	33	33	50	83	50	133
	Subtotal	4339	103	103	89	192	69	261
Total		6141	321	321	97	410	69	479

1 - Based on Table 3-7 and the square footage of the project, the daily average use is projected to be about 50,000 gpd. However, the University of Virginia – Ivy Corridor Redevelopment Phase I Public Realm (issue date September 3, 2019) cited water usage for this site at 248,500 gpd. The latter cited figure is well beyond water usage rates at similar University facilities, but the demand projection for this project was adjusted upward to provide a more conservative estimate.

3.5 Primary Forecast Results by Pressure Zone

Combining the forecast methods used for the ACSA and City as described in Sections 3.1 and 3.2 together with the water demand forecast for the University described above in Section 3.3 produces an overall retail water demand forecast by pressure zone as described in Table 3-9.

Table 3-9: RWSA Retail Demand Forecast by Pressure Zone

Forecast Date Demand in mgd					
Pressure Zone	**2017**	**2030**	**2045**	**2070**	**Demand Change through 2045**
Ashcroft Low	0.045	0.07	0.10	0.12	+ 124%
Ashcroft Middle	0.0044	0.08	0.24	0.34	+ 5300%
Ashcroft High	0.0005	0.002	0.005	0.007	+1050%
Ednam	0.039	0.04	0.04	0.04	-1%
Lambeth	0.184	0.19	0.19	0.20	+3%
Lewis Mountain	0.304	0.45	0.53	0.59	+74%
Mill Creek	0.036	0.04	0.05	0.06	+52%
Mosby Mountain	0.079	0.11	0.16	0.18	+98%
Piney Mountain	0.32	0.52	0.71	0.89	+123%
Stillhouse	0.67	0.70	0.76	0.80	+14%
Urban Ring	5.37	5.96	6.46	7.13	+20%
UVA Pressure Zone (accounts outside 14” meter area)	0.024	0.025	0.026	0.029	+8%
UVA 14" Meter Forecast	1.25	1.13	1.19	1.39	-5%
Total Retail Demand	**8.33**	**9.31**	**10.47**	**11.77**	**+26%**

As can be discerned from the chart, demand growth is not anticipated to be uniform on a percentage basis across pressure zones. Seven of the outlying pressure zones are anticipated to grow faster in their water consumption on a percentage basis than the Urban Zone while four are expected to exhibit little growth (Stillhouse, Ednam, UVA, and Lambeth). Nevertheless, the Urban Ring Pressure Zone demand growth will continue and is expected to account for 60-65% of retail water sales throughout the forecast period.

Table 3-10 summarizes retail, non-revenue, and process water portions of the forecast. It was assumed that non-revenue water will continue to average 12-13% of the retail volume. Non-revenue water refers to water use that does not generate revenue, including that used for line flushing, fire flows, loss to leakage, unauthorized connections, unbilled accounts, or otherwise used at points that are unbilled. While each of these possibilities represent specific ways water can end up in the non-revenue category, not all utilities exhibit each type of non-revenue water and a non-revenue analysis was not conducted for the RWSA as part of the Demand Forecast Study. While it is assumed that non-revenue water will remain a stable fraction of retail demand, there are reasons that it could shift. Some of the more common reasons for changes in the non-revenue fraction include:

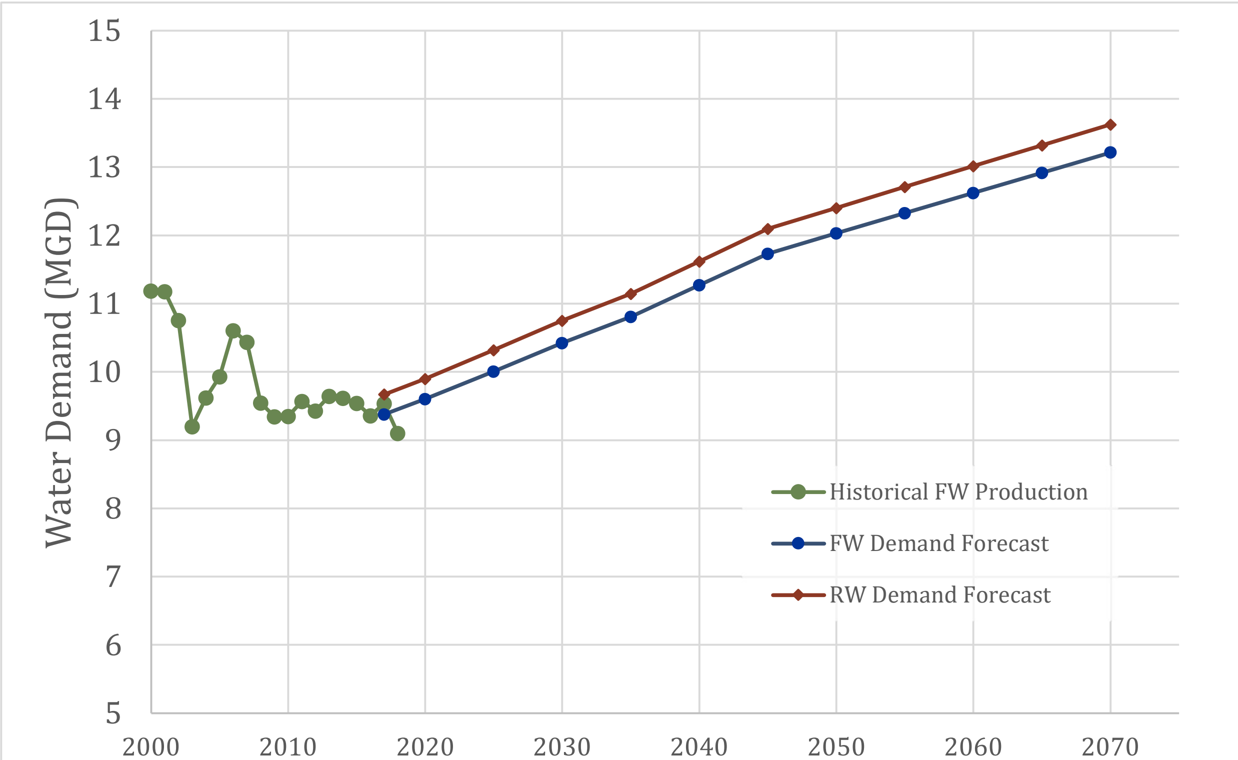
1. Aging infrastructure can result in increasing losses via main breaks and smaller leaks.
2. Leak detection programs are often able to help utilities to noticeably reduce the fraction of non-revenue water.
3. Water quality concerns can force a utility or its customers to increase line flushing to address:
    a. Increased water age in areas of the distribution system with lower demands which, together with reduced retail demand can increase the relative fraction of non-revenue water.
    b. More stringent regulation of disinfection by products or other water quality parameters related to water age.

Process water losses are relatively low system-wide because the South Rivanna WTP, the largest in the system, currently has a very minimal process water loss. Process water loss at South Rivanna WTP is assumed to be 1% for the purpose of calculating raw water demand. Process water losses at Observatory WTP and the North Rivanna WTP are 6% and 3.3% of finished water production, respectively, based on an accounting of the last several years of production data. Figure 3-11 illustrates both raw and finished water demand projections for the primary forecast scenario.

Table 3-10: Raw and Finished Water Forecasts

Forecast Date Demand in mgd					
Demand Component	**2017**	**2030**	**2045**	**2070**	**Change through 2045**
Retail Total	8.33	9.31	10.47	11.77	26%
Non – Revenue Water	1.05	1.17	1.32	1.48	26%
FW Production	9.38	10.49	11.79	13.26	26%
WTP Process Water Loss	0.29	0.33	0.37	0.41	26%
Raw Water Need	9.67	10.82	12.15	13.67	26%

Figure 3-11: RWSA Raw and Finished Water Demand Forecasts



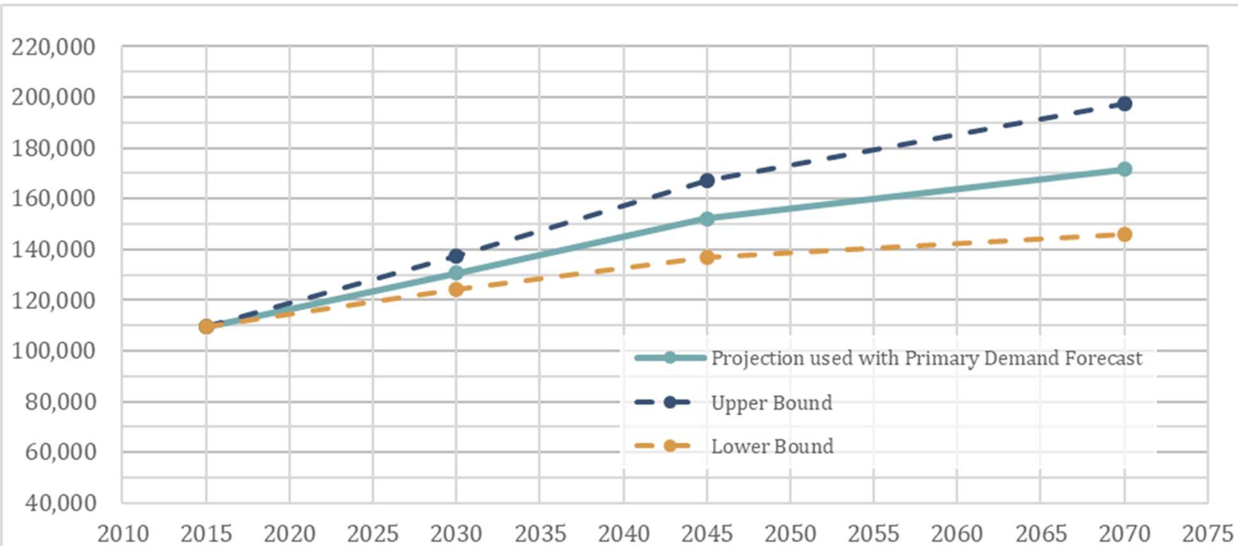
3.6 Forecast Sensitivity Analyses

Prior to about the year 2000, demand forecasting industry wide tended to be a relatively simple exercise that involved calculating a unit demand and multiplying it by a population projection. In many cases even these steps were avoided and a simple linear regression was applied to the historical annual average demand trend to produce the future water demand forecast. Relying on such simple techniques has fallen out of favor as water using behaviors have changed. While urban areas across the country are, in many cases, continuing to exhibit population growth (unlike most rural areas), water demand intensity has been shifting significantly over the past two decades for various reasons. Some of the more commonly cited reasons are that water prices have risen as water utilities shift to full cost-recovery pricing methods, conservation has become more appealing for social and economic reasons, and water using devices have become increasingly efficient. Anticipating the rate of improvement in conservation and efficiency has been difficult for an industry prone to err on the side of caution since a central mission of all water utilities is to provide a high level of supply reliability. However, over-projecting demand can lead to over-investment in infrastructure and associated impacts such as stranding financial resources, water quality concerns, the need to raise customer rates, and higher levels of environmental impact from larger or more infrastructure. Understanding that the primary planning forecast in this report is also intended to be somewhat conservative (more likely to over-project than under-project), some sensitivity analyses were conducted to aid in RWSA's decision making process when facing choices that require anticipating long-range water demands. Many assumptions about future conditions were necessary to produce this forecast. These analyses were conducted to help gauge forecast sensitivity to the principal forecast assumptions which are population growth and water demand intensity (unit demands). In addition, this section also provides an estimate for demand sensitivity to year-to-year fluctuations in weather conditions.

3.6.1 Population Growth

Population growth was assumed to vary by ± 5%, ± 10%, and ± 15%, at the 2030, 2045, and 2070 forecast intervals, respectively. These bounds are less than the full range of potential error in a long-range population forecast according to the Weldon Cooper Center, but were considered sufficient to capture the likely range of forecasting error[2]. The population projection bounds along with the primary projection forecast for the Urban System Service Area are shown in Figure 3-12.

Figure 3-12: Population Forecast Bounds for RWSA Service Area



[2] http://statchatva.org/2017/06/21/how-accurate-are-population-projections/

When the upper and lower bound population projections are factored into the land use and demand forecast model the water demand shifts are somewhat less than the population error bounds on a percentage basis. This is due to the fact that new development (and redeveloped areas) built to accommodate population and employment growth are predicted to be more efficient than the existing building stock. Figure 3-13 illustrates the demand forecast sensitivity to the assumed population range. Table 3-11 contains the demand forecast figures as well.

Figure 3-13: Demand Forecast Sensitivity Range to Population Projection Uncertainty

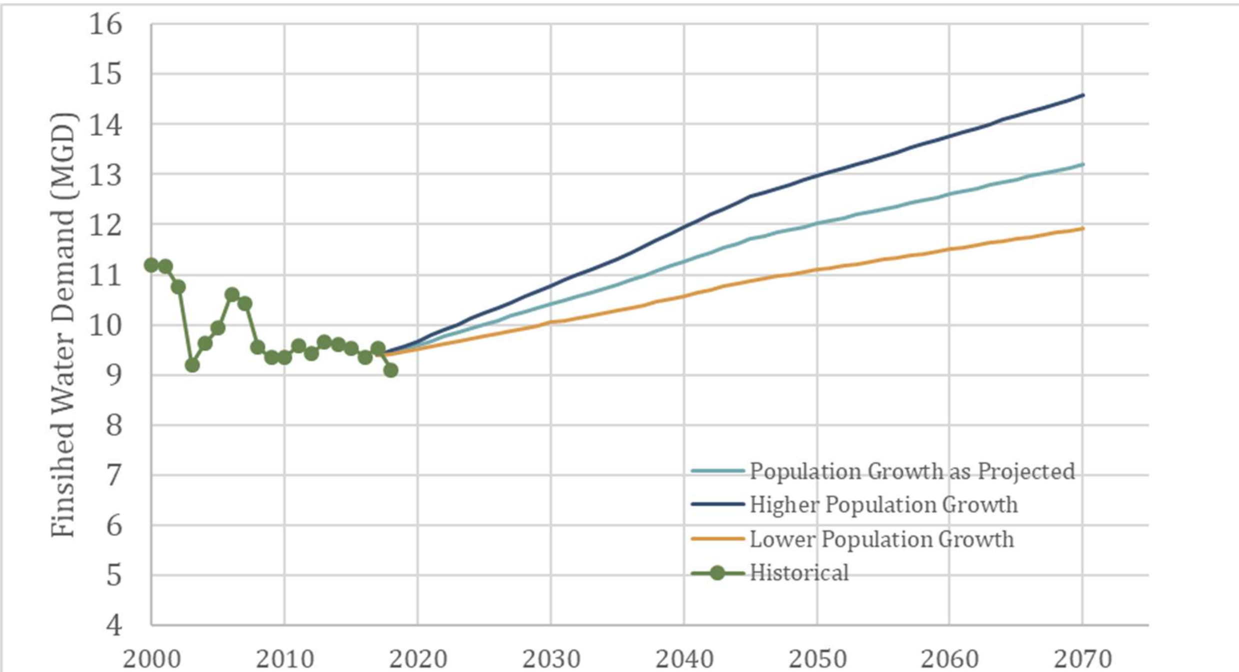


Table 3-11: Demand Forecast by Year and Population Scenario

	Demand in mgd		
	2030	**2045**	**2070**
Lower Bound Population	10.0	10.6	11.9
Primary Population Forecast	10.4	11.3	13.2
Upper Bound Population	10.8	11.9	14.6

3.6.2 Unit Demand Sensitivity

Unit demand assumptions have been the largest source of error in demand forecasts conducted over the past two decades. The primary demand forecast in this report assumes existing structures (other than those on-grounds at UVA) will continue to use water at the same rates as they have historically and that new development will be as efficient as new buildings constructed in the last decade, but no more so. Given the historical trends (see Figures 3-4 and 3-5) in water use intensity within the Urban Service Area, such an assumption is likely to err on the high side of future water use intensity. However, it also seems unlikely that unit demands will continue to fall as rapidly as the have over the past 10-20 years.

A more aggressive conservation scenario was developed under the assumption that per capita unit demand could continue declining at about 0.5 gpcd/yr through 2045, which is about half the rate of decline exhibited in the ACSA since 2007 and about one-third the rate of decline observed in Charlottesville over the same period. These rates were selected knowing that the RWSA Urban Service Area is already amongst the most efficient water using areas in the nation based on the per capita metric, and has probably already achieved much of the readily attainable conservation and efficiency gains given the state of water use technology at present. After 2045 the rate of additional decline in per capita water use is assumed to be 0.15 gpcd/yr. Figures 3-14 and 3-15 illustrate the unit demand rates in the primary forecast, the more aggressive conservation sensitivity scenario described above, as well as illustrating unit demand assume din the 2011 Urban Demand Forecast Study for comparison for both the ACSA and Charlottesville portions of the service area.

Figure 3-14: ACSA Unit Demand Sensitivity Scenarios

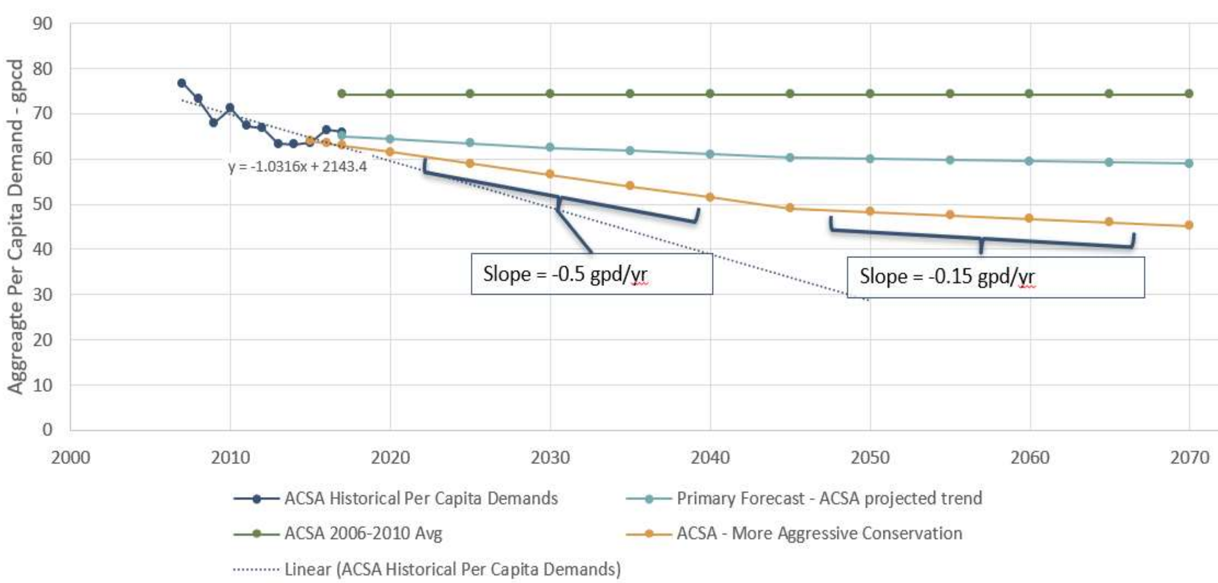
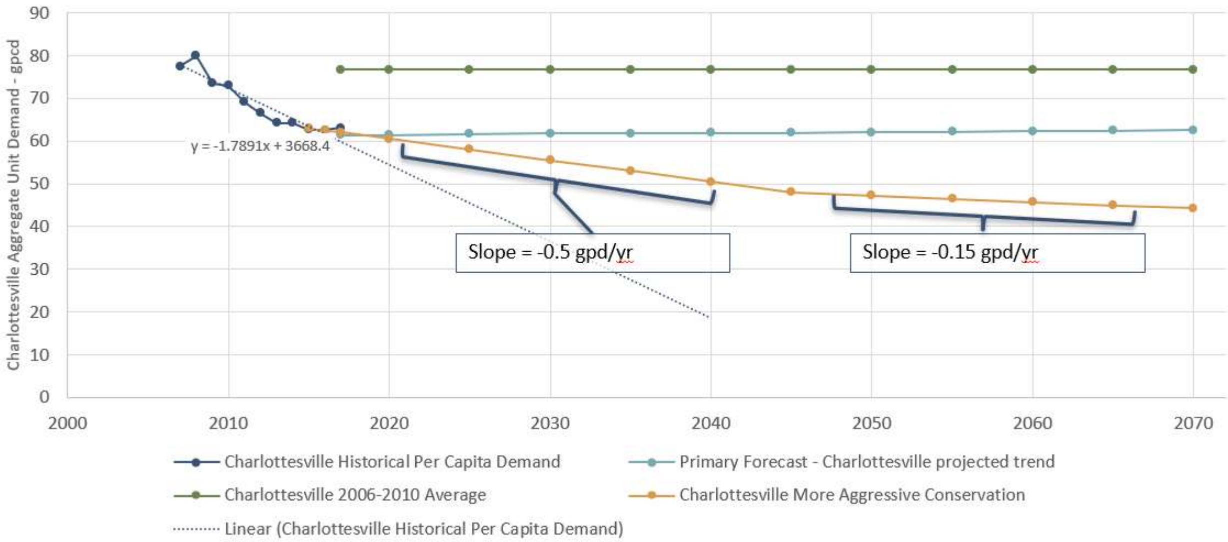


Figure 3-15: Charlottesville Unit Demand Sensitivity Scenarios



When these unit demand scenarios are combined with the primary population forecasts for the City and the ACSA, as well as the UVA demand forecast, the results show an upper and lower bound forecast for unit demand sensitivity. For planning purposes, the Primary Forecast and More Aggressive Conservation scenarios form a plausible upper and lower forecast bound based on uncertainty with respect to future water use intensity (unit demand). The series employing the 2006-2010 average unit demand is shown for comparative purposes to illustrate what water demands might look like if not for the conservation and efficiency measures adopted over the past decade. However, this series is not to be considered a plausible projection bound at present as there is no reason to believe unit demands would revert to pre-2010 usage rates. Table 3-12 contains the demand forecast numbers associated with the scenarios displayed in Figure 3-13. The More Aggressive Conservation scenario includes the Greater Efficiency Improvement forecast demand scenario for UVA whereas the Primary Forecast scenario utilizes the Selected UVA 14” Meter Area Forecast scenario. The respective UVA forecast scenarios for the area served by the 14” meter are described in section 3.4.3 and displayed in Figure 3-10.

Figure 3-16: Demand Forecast Sensitivity Range to Unit Demand Uncertainty

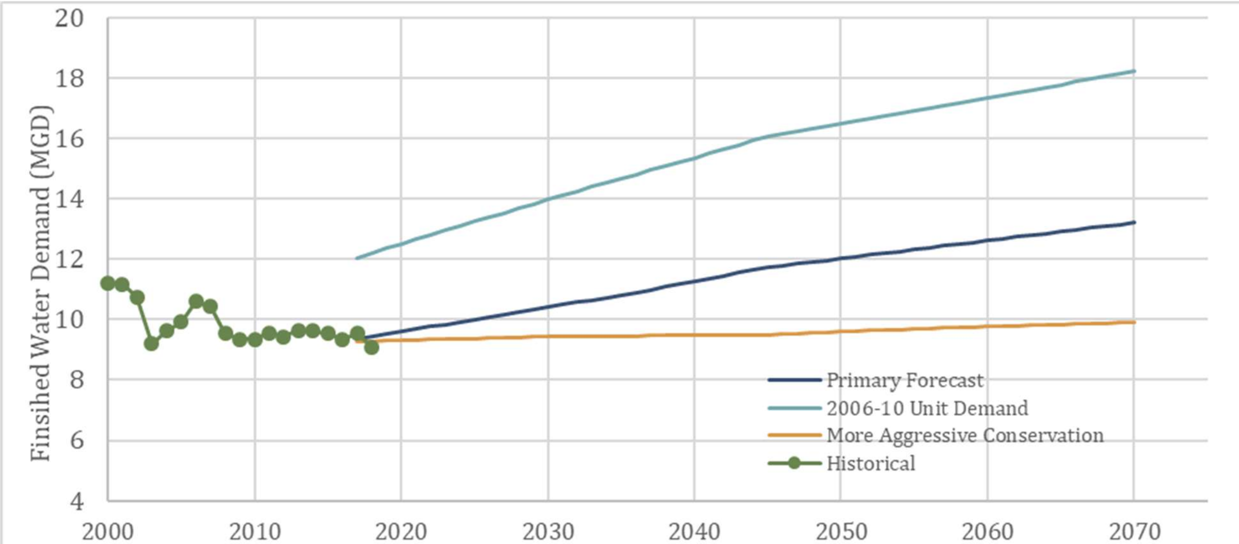


Table 3-12: Demand Forecast by Year and Unit Demand Sensitivity Scenario

Scenario	Demand in mgd		
	2030	2045	2070
2006-2010 Avg. Unit Demand (For comparative purposes only – not a plausible projection)	14.0	16.1	18.2
Primary Forecast	10.4	11.3	13.2
More Aggressive Conservation	9.4	9.5	9.9

3.6.3 Weather Sensitivity (Annual)

Of the manifold influences on water demand, weather is among the most variable over short time scales. Weather can move from one extreme to the opposite in a relatively brief period, though the fluctuations tend to average out over longer periods. Nevertheless, at time scales as long a year, weather can vary enough to noticeably influence water demand and cause it to deviate from that expected under average conditions. Since weather is simultaneously influencing the hydrology of RWSA's reservoir system and water demand, it is important for the purposes of risk management and long-range planning to understand how much demand might increase (or decrease) during these periods. Year-to-year variability in water demand will correspond well with the temporal scale at which RWSA's reservoir system reliability exhibits the greatest sensitivity to weather driven hydrologic variation.

To estimate demand response with respect to annual weather variability, weather data for this region was collected over a 39-year period from 1980-2018. A multiple linear regression model was fit to water demand from 2007 – 2018 (response variable) using annual temperature and precipitation conditions as the explanatory variables. The modeling process was carried out with City, ACSA, and UVA demands considered independently. As expected, the models demonstrate that water demand is positively correlated with temperature and inversely correlated with precipitation. The demand-response coefficients for the three service regions are described in Table 3-13. The coefficients represent the expected demand response per standard deviation from the mean annual temperature and precipitation conditions.

Table 3-13: Expected Demand Response

RWSA Service Region	Temperature Response[1]	Precipitation Response[1]
ACSA	+2.45%	-2.17%
Charlottesville	+0.83%	-0.88%
UVA Grounds (14" meter area)	+3.30%	-2.29%

1 – response per standard deviation from mean, Temperature std dev =1.5°F, Precipitation std dev =7.2 inches

The ACSA portion of the service area exhibits a sensitivity to weather variability that is very typical of the mid-Atlantic region of the United States. Charlottesville's sensitivity to weather is quite low and may reflect a high ratio of commercial and multi-family residences as compared to single family homes which typically have a greater proportion of outdoor and seasonal water use that is weather dependent. The University of Virginia's 14" meter area is fairly sensitive to weather fluctuations and is likely due to the use of water-cooled chiller facilities to produce cooling for buildings on grounds. Furthermore, as the University becomes more water efficient in other building categories, the utility category may make up a greater fraction of water use leading to even greater sensitivity to weather in the future.

The demand response coefficients were used to model water demand variability over 5,000 simulated years in which weather conditions were varied using a statistical model based on 1980-2018 weather conditions using a technique known as Monte Carlo Simulation. This number of simulations is more than sufficient to produce a statistical distribution that is both reproducible, unlikely to change significantly with a greater number of simulations and is time-efficient to execute with present computing capabilities. More detail on the weather-demand modeling is provided in Appendix C. The weather bounds used for planning purposes are displayed in Figures 3-17 through 3-20 and show the 99th percentile (upper bound) and 5th percentile (lower bound). The 5th percentile was chosen for the lower bound rather than the 1st percentile because experience indicates that the demand response to weather is attenuated at the low end of the spectrum. This is especially true with respect to precipitation when a threshold is reached such that additional rainfall does not lead to further reduction in demand once turf watering needs are met by sufficient precipitation. At the upper end of the spectrum, it is possible to have events hotter and drier than the 99th percentile conditions. However, imposing mandatory conservation measures is an available tool RWSA can employ to curtail the upper end demand response to such weather events. Furthermore, there is little evidence that the uncurtailed demand response would remain linear beyond the 99th percentile as this type of model assumes.

Figure 3-17: RWSA Finished Water Demand Forecast Sensitivity to Annual Weather Variability

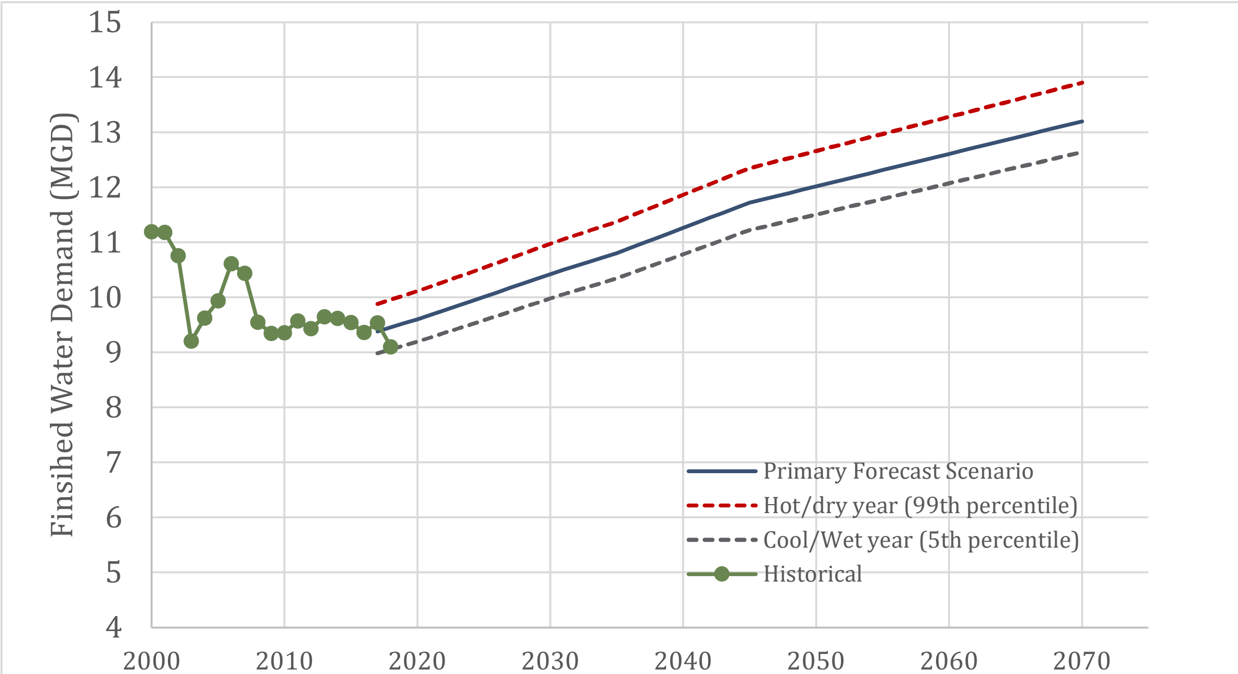


Figure 3-18: ACSA Demand Forecast Sensitivity to Annual Weather Variation

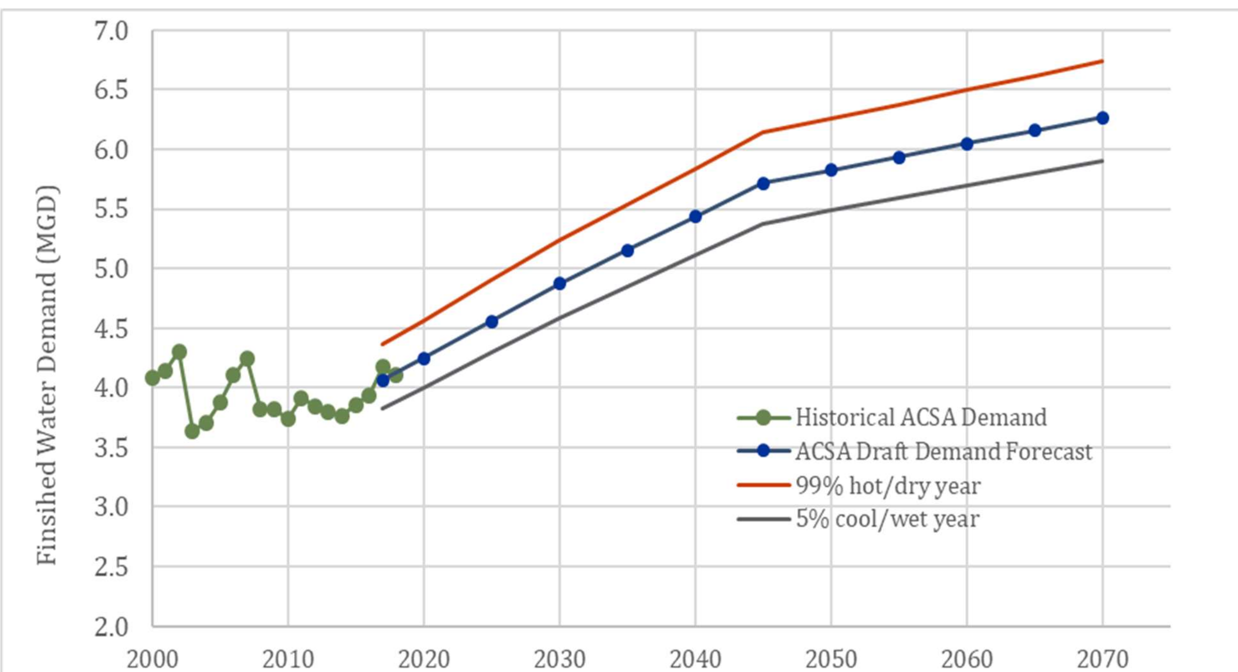


Figure 3-19: Charlottesville Demand Forecast Sensitivity to Annual Weather Variation

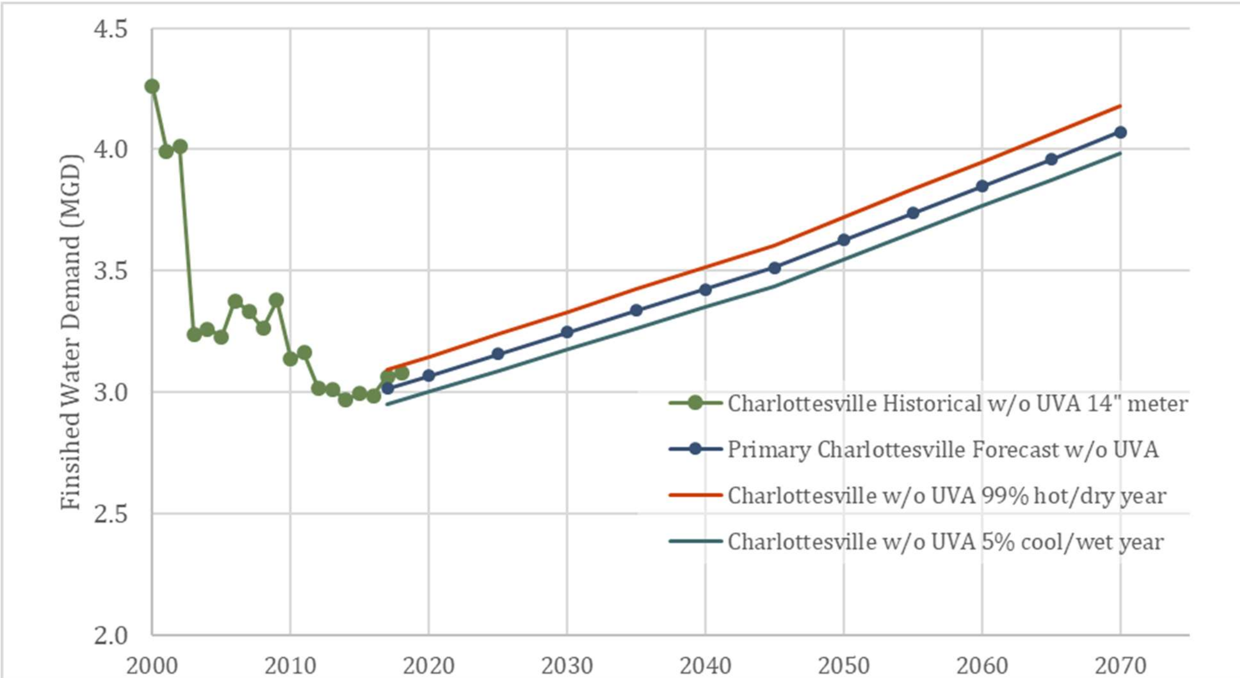


Figure 3-20: University Demand Forecast Sensitivity to Annual Weather Variation

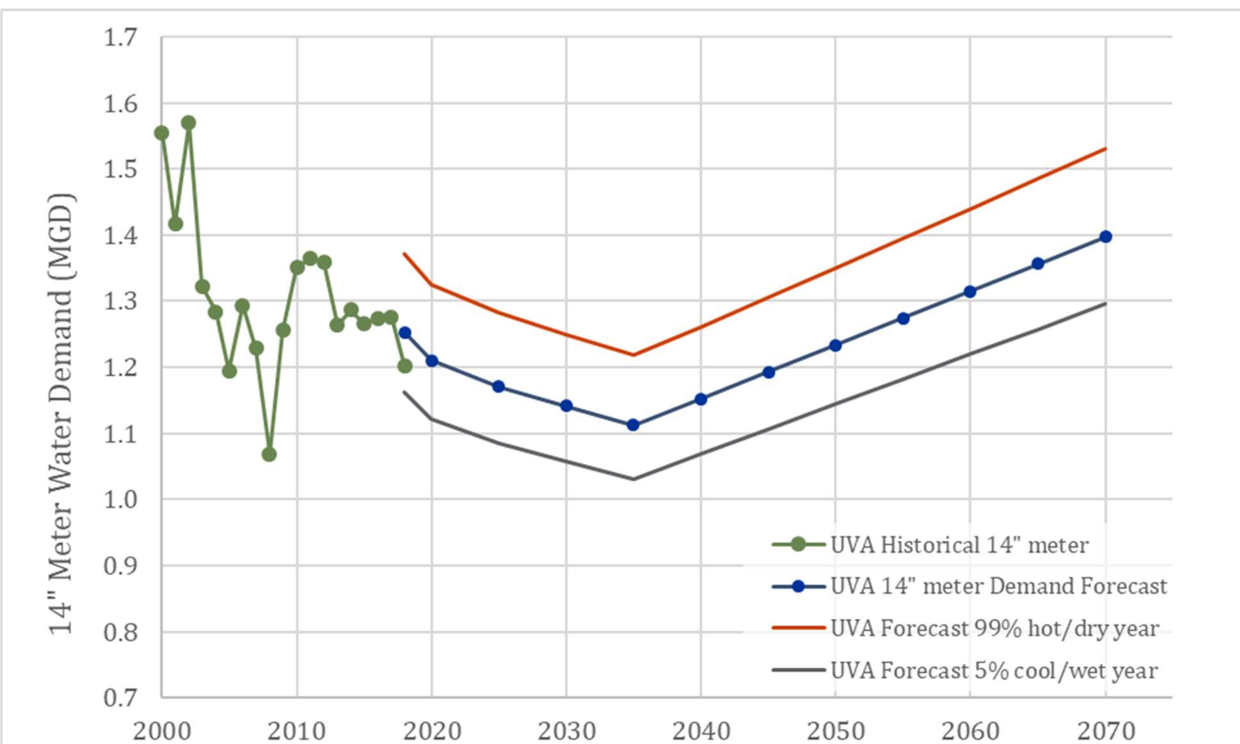


Table 3-14: Finished Water Weather Variability Bounds (mgd)

Forecast Horizon	ACSA		Charlottesville		UVA		RWSA Total[1]	
	5th %tile	99th %tile	5th %tile	99th %tile	5th %tile	99th %tile	5th %tile	99th %tile
2017	3.82	4.36	2.95	3.09	1.16	1.37	8.99	9.88
2030	4.59	5.23	3.18	3.33	1.06	1.25	9.99	10.98
2045	5.38	6.14	3.44	3.61	1.11	1.31	11.24	12.36
2070	5.90	6.74	3.98	4.18	1.30	1.53	12.66	13.92

1 – RWSA Totals also include non-revenue finished water not included in ACSA, Charlottesville and UVA Totals

Finally, one additional feature afforded by the weather variability analysis is that using response described in Table 3-13 to remove the weather influence should make it easier and more reliable to identify the updated direction of the overall unit demand trend (driven by socioeconomic factors).

3.6.4 Compound Sensitivity Bounds

A PowerBI file is provided to navigate the many permutations resulting from the interactions of the three sensitivity analyses described in Sections 3.6.1 through 3.6.3

4. Peak Day Factor Analysis and Maximum Day Demand Forecast

Peak day demand, also referred to as maximum day demand (MDD) is the highest daily demand that occurs in a given year. Water treatment plants, as well as raw and finished water pump stations, are typically sized with peak day criteria in mind and as such it is important to estimate these demands over the water demand forecast horizon. Section 3 described the development of average day demand forecasts and maximum day demand forecasts are typically estimated with a peak to average day ratio (or MDD:ADD ratio).

Two methods were used to approach the peak to average day ratios for RWSA. The primary peak factor analysis (WTP Production Method) estimated peaking factors using RWSA's historical daily finished water pumping data for North Rivanna WTP, South Rivanna WTP, and Observatory WTP (including non-revenue water) for 2010 to 2018. This is the method typically used to determine MDD:ADD ratios. The second method (Mass Balance Method) made use of available distribution pumping records from 2013 to 2018. This method is described in Appendix D.

The primary peak factor analysis used a daily sum of the 3 WTPs' (North Rivanna, South Rivanna, and Observatory) finished water flows from January 2010 through November 2018. The highest day for each year was divided by the average production for that year to get an annual MDD peak factor. Figure 4-1 illustrates the variability in peaking factors over the past nine years. Peaking factors averaged 1.37 over this period. The maximum and minimum peaking factor was 1.50 in 2017 and 1.22 in 2014, respectively. In the last four years the peaking factor has been greater than 1.30.

Figure 4-1: WTP Production Method – Historical Maximum Day Peaking Factors

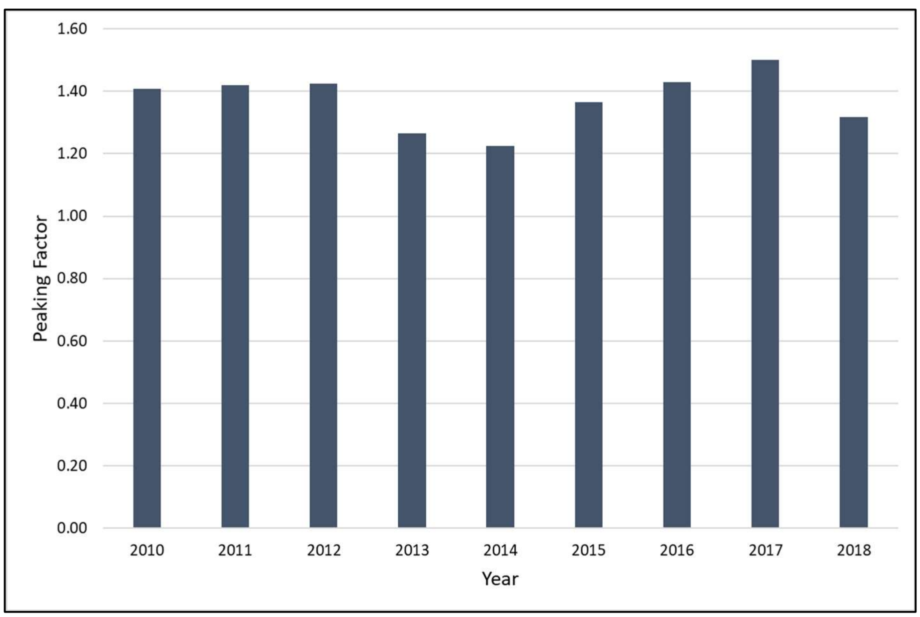
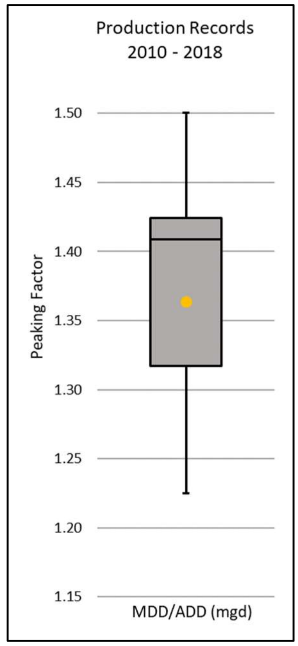


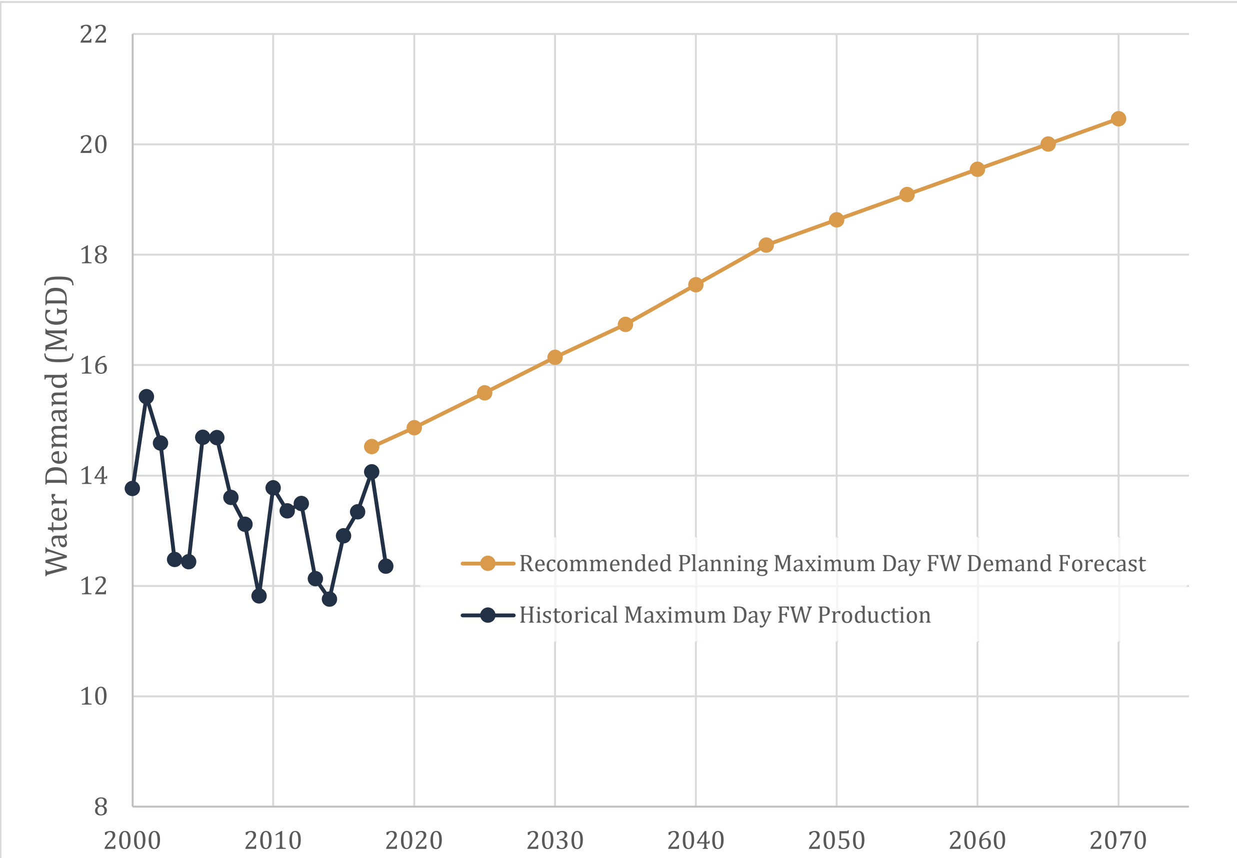
Figure 4-2 illustrates a box and whisker plot of peaking factors for the WTP Production Method. RWSA staff agreed that the 95th percentile of recent historical peaking factors should be used for planning facilities that need to be sized for maximum day demands. The 95th percentile of this dataset was 1.47.

Figure 4-2: Peaking Factors – WTP Production Method



Finally, there was no statistically significant relationship between the average day demand and the annual peak factor in a given year. This means a high (or low) peaking factor is roughly as likely to occur in a year in which the average demand itself is below, near average, or above the trend in annual demands. Therefore, it is recommended that a peaking factor of 1.47 times the hot/dry year average day demand forecast be used as a planning value for infrastructure capacities that are designed to handle maximum day demand within the RWSA Urban System. Figure 4-3 illustrates the maximum day FW demand projection for the Urban Service Area.

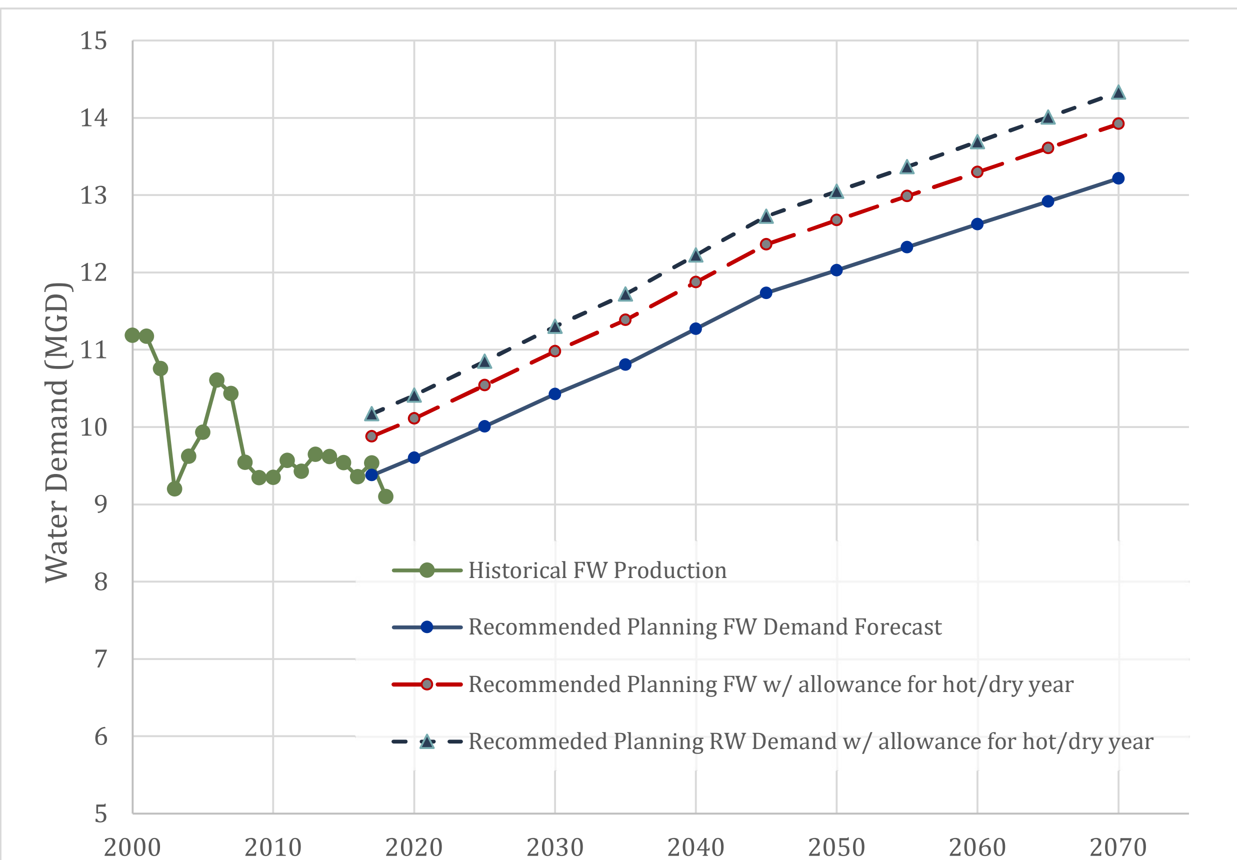
Figure 4-3: Maximum Day Demand Forecast for Primary Demand Forecast



5. Recommendations and Conclusions

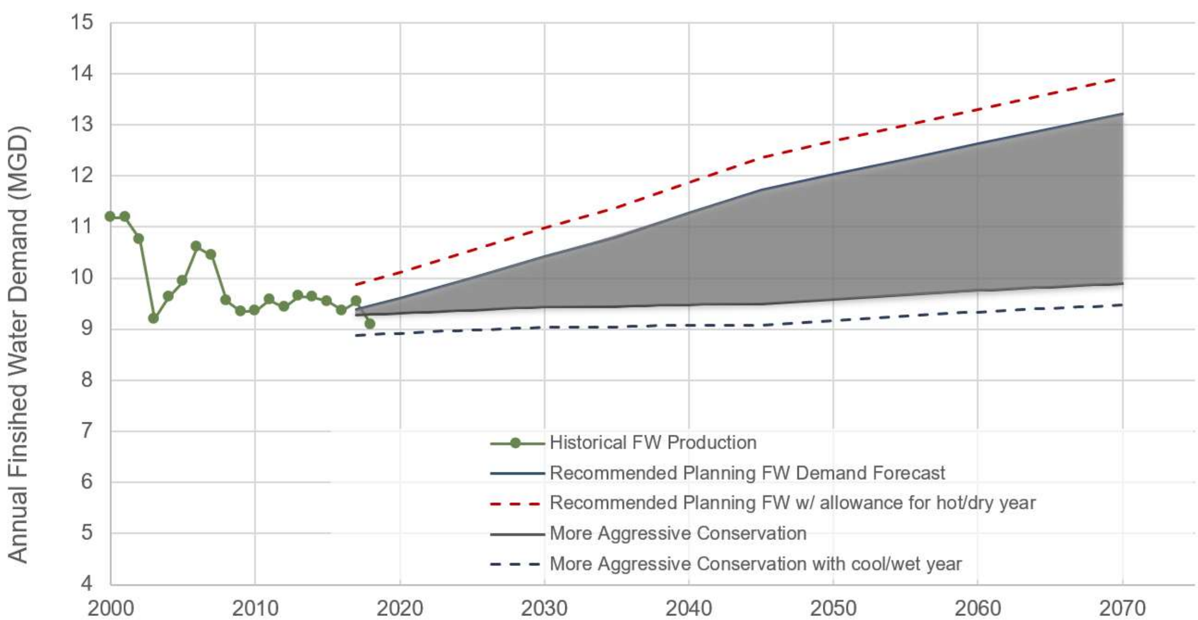
Chapter 780 of the Virginia Administrative Code covers local and regional water supply planning and states that plans shall be designed to "ensure adequate and safe drinking water is available" and to "promote conservation". The primary forecast developed for this report was developed with the principal goal of ensuring that RWSA plans for an adequate supply to meet future needs and is therefore the recommended forecast for infrastructure planning. The primary forecast also assumes that future development will continue to be as efficient as the development over the past 9 years which has led RWSA to be among the most water efficient utilities in the nation. Furthermore, the RWSA should provision for sufficient finished water (FW) to satisfy the increased annual average demand under sustained hot dry conditions that exceed the primary forecast (which assumes near average historical weather conditions) as shown in Figure 5-1. This additional demand may be met by either assuring sufficient additional supply during hot/dry years or imposing mandatory conservation such that demand can be curtailed to a level no greater than the reliable supply, or a combination of the two. Finally, in making these plans, RWSA should also ensure that raw water supplies are not only sufficient and reliable to meet the FW demand, but also account for process water loss, which at present is a low percentage of overall treatment plant production.

Figure 5-1 Recommended Infrastructure Planning Forecasts for Annual Average Demand



Nevertheless, the recommended infrastructure planning forecast is likely to err on the high side. The RWSA Urban Service Area has experienced steadily declining water intensities over the past two decades and this trend may continue for some time into the future until the most efficient plumbing devices and conservation practices fully penetrate the service area. Figure 5-2 illustrates a recommended planning bound, in gray, that the RWSA should prepare for. The lower end of the planning bound is formed using the 'More Aggressive Conservation' scenario described in Section 3.5.2. Should demand trend toward this lower bound, revenue from sales will be less than if financial planning is based on the demands from the recommended infrastructure planning forecast. Furthermore, individual years may fall outside of the gray shaded area due to weather variation. Weather bounds extended above and below the recommended planning bounds are indicated by the dashed series outside of the gray shaded planning bound. The expectation is that individual years may fall between the gray planning region and the dashed bounds, but that longer term trends would remain within the gray-shaded region.

Figure 5-2: Recommended Planning Bounds for Annual Trends



The population forecast uncertainty was not included in the planning bounds, though it is a factor that, combined with other uncertainties, could potentially push water demand outside the planning bounds shown in Figure 5-2. However, service area population is a relatively discernable quantity and does not tend to fluctuate rapidly from year to year. If population does track closer to the higher or lower population growth scenarios (described in Section 3.5.1) then the bounds shown in Figure 5-2 can be adjusted by selecting for the appropriate population forecast in the electronic deliverable (PowerBI format) that accompanies this report. Population can be tracked prior to the next water demand forecast by checking in with annually updated population figures provided by the Weldon Cooper Center (for Charlottesville) and by tracking the number of new residential connections for the ACSA multiplied by upcoming 2020 Census estimates for persons per household in the relevant block groups.

Maximum day demands drive the sizing of water treatment plants, which in turn influence supply intakes, raw water pump stations, and to some extent finished water pumping and conveyance pipelines. It is critical that capacity for these facilities is planned for with an appropriate engineering safety factor and are operational ahead of these events to meet expectations for service reliability. However, unlike fluctuations in the average day demand for a year, fluctuations in the peak day (or MDD:ADD ratio) from year to year typically do not have repercussions for utility revenue. Nevertheless, both low and high forecast ranges for maximum day demand are illustrated in Figure 5-3 for both the recommended planning forecast as well the more aggressive conservation scenario. As with the planning bounds for average annual demand described above, peak day sensitivity to population growth is not incorporated into the figure, but variance in service area population should be tracked prior to conducting the next water demand forecast.

Figure 5-3: Maximum Day Demand Ranges for Selected Scenarios

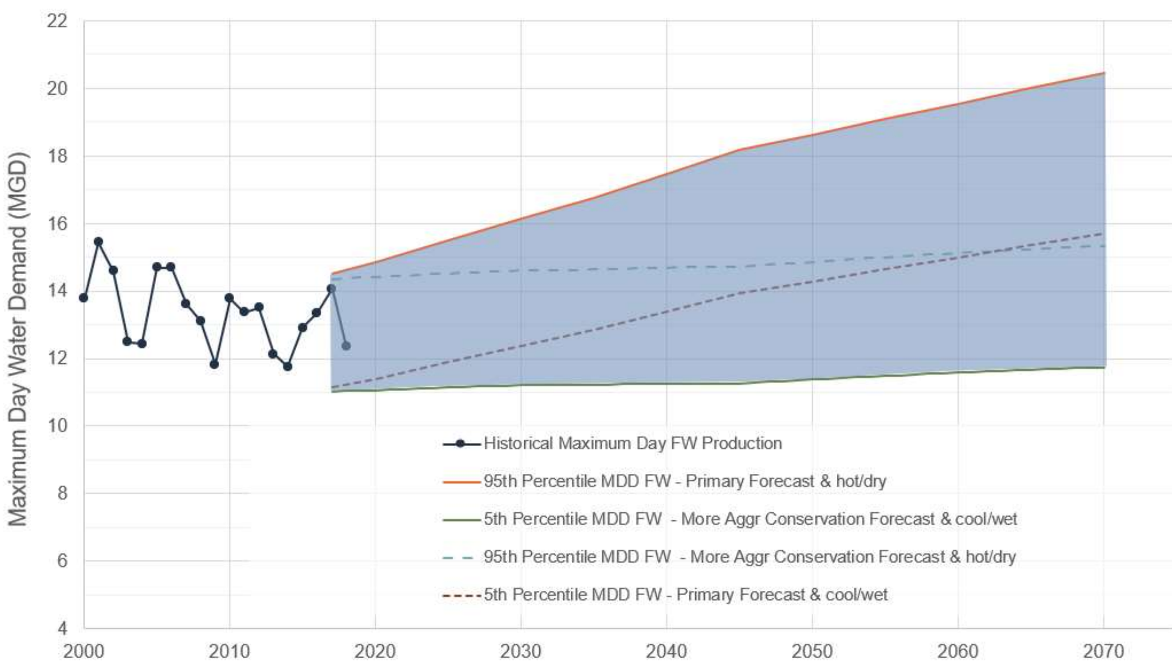


Table 5-1 provides average day demand values for the series shown in Figures 5-1 and 5-2 as well as the higher and lower population growth scenarios described in Section 3.6.1. Unless otherwise indicated, it is assumed the forecast values are for average year weather conditions, the unit demand used with the recommended planning forecast[3], and expected population growth.

Table 5-1: Average Day Demand Forecast for Key Scenarios (mgd)

	Year					
Forecast Scenario	**2020**	**2030**	**2040**	**2050**	**2060**	**2070**
Recommended Planning FW Demand	9.6	10.4	11.3	12.0	12.6	13.2
Recommended Planning FW Demand Hot/Dry Extreme	10.1	11.0	11.9	12.7	13.3	13.9
Recommended Planning RW Demand Hot/Dry Extreme	10.4	11.3	12.2	13.1	13.7	14.3
More Aggressive Conservation FW Demand	9.3	9.4	9.5	9.6	9.8	9.9
More Aggressive Conservation FW Demand Cool/Wet Extreme	8.9	9.0	9.1	9.2	9.3	9.5
Higher Population Growth FW Demand	9.7	10.9	12.0	13.1	14.0	14.9
Lower Population Growth FW Demand	9.5	10.0	10.5	10.9	11.2	11.4

Similarly, Table 5-2 provides maximum day demand values for the recommended planning forecast conditions as well as a set of scenarios that generally form upper and lower bounds for peak day conditions over the forecast horizon. However, in addition to the combination of sensitivity scenarios used above, a low range (5th percentile [1.24 x average day]) and high range (95th percentile [1.47 x average day]) peak day factor was assumed depending on whether a low or high bound would be accentuated under that scenario.

[3] Single-family demand 109.4 gpd/DU; multi-family demand 79.5 gpd/DU; Non-residential 75.0 gpd/ksf from Section 3

Table 5-2: Peak Day Demand Estimates for Key Scenarios (mgd)

Forecast Scenario	Peak Day Factor	Year					
		2020	2030	2040	2050	2060	2070
Recommended Planning FW Demand	1.47	14.1	15.3	16.6	17.7	18.6	19.4
Recommended Planning FW Demand Hot/Dry Extreme	1.47	14.9	16.1	17.5	18.6	19.6	20.5
Recommended Planning RW Demand Hot/Dry Extreme	1.47	15.3	16.6	18.0	19.2	20.1	21.1
More Aggressive Conservation FW Demand	1.47	13.7	13.9	13.9	14.1	14.3	14.5
Higher Population Growth FW Demand Hot/Dry Extreme	1.47	15.0	16.8	18.6	20.3	21.7	23.1
More Aggressive Conservation FW Demand Cool/Wet Extreme	1.24	11.1	11.2	11.3	11.4	11.6	11.7
Lower Population Growth FW Demand Cool/Wet Extreme	1.24	11.3	11.9	12.5	13.0	13.3	13.6

Demand forecasts for each pressure zone are also provided in the PowerBI deliverable for each combination of the sensitivity scenarios described in Section 3.6. However, a note of caution is that there should be an expectation that development by pressure zone is subject to greater variability than is the service area as a whole.

Appendix A: Land Use Model Detail

The principal activities carried out under the land use modeling was the partitioning of the service area and the developing the set of assumptions that tell the model how to treat each partition. This involves assigning each unit of land (in this case the units were property parcels from City and County GIS data) to a partition. Each partition is treated with individual sets of rules based on its jurisdiction (city/county), current development status and zoning or masterplan guidelines. The sections below describe this process, first for the City of Charlottesville and then for the portion of the Urban System served by the ACSA.

A.1 City Partitioning

City land use partitions were based on adjusted zoning attributes of the City parcel layer as well as indicators of occupancy or vacancy for certain zoning classes.

Table A-2 how zoning and occupancy values were used to assign parcels to partitions. Partitions included the following:

- UVA Grounds – omitted from the City forecast
- Medical Center – demand assumed to not change
- Parks and Cemeteries – demand assumed to not change
- Mixed-Use Redevelopment Areas – Neighborhood Plan Zones and an area ½ mile around the Medical Center, all assumed to redevelop towards dense mixed-use characteristics
- Other Areas currently occupied – demand assumed to not change
- Other Areas currently vacant – assumed to develop towards zoned land use

Zoning attribute adjustments. Zoning attributes were contained in the *ZONE* field of the parcel_area_11_06_2018 layer. Prior to partitioning, *ZONE* attributes for some parcels were first adjusted as follows.

- **'MTLP', 'MLTPC', and 'MLTPH' ZONE values**. A total of 57 parcels initially contained 'MLTP', 'MLTPC', or 'MLTPH' in their ZONE fields, neither of which is a true zoning classification defined by the City. By visually cross-referencing the shapes and locations of these parcels in GIS with the City of Charlottesville Zoning District Map, it was established that each of these parcels was partially overlain by multiple zoning districts, though the specific classifications involved in these cases varied. Therefore, for each parcel having an 'MTLP', 'MLTPC', or 'MLTPH' in its ZONE field, that value was replaced to the true zoning classification covering the largest amount of the parcel's area. Figure A-1 shows the parcels having 'MLTP', 'MLTPC', and 'MLTPH' zone values, while Figure A-2 shows an example of an 'MLTP' parcel and its corresponding overlain zoning districts.

Table A-1: Data Source Files for the Demand Forecast

Source	Type	Original Filename	Description
A	Shapefile	*CVL_METERS.shp*	Point layer of retail meters with identifiers for associating consumption records
	Excel	*Water 6-1-16 to 5-31-17.xlsx*	Consumption records by meter (6-1-16 to 5-31-17)
	Excel	*Water Invoicing 7-1-17 to 6-30-18. xlsx*	Consumption records by meter (7-1-17 to 6-30-18)
	Shapefile	*parcel_area_11_06_2018.shp* [H]	Parcel delineations with zoning
	Text	*Real_Estate_Base_Data.csv*	Comma-delimited files containing records, by parcel, of State Tax land use codes, City land use codes, descriptions as well as residential building characteristics
	Text	*Real_Estate_Residential_Details.csv*	
	Text	*Real_Estate_Commercial_Details.csv*	
B	Shapefile	*URbanRingMetersBaker.shp*	Point layer of retail meters with FY 2017 consumption records in attribute table
C	Shapefile	*ParcelsStacked_current.shp* [I]	Polygon layers of parcel delineations with parcel identifiers • ParcelsStacked_current: all parcel shapes including overlapping parcels in same location (e.g. multi-story condominiums) • Parcels_Current: overlapping parcels consolidated into single shapes • Zoning_Current: parcel shapes with identifiers and zoning designations
	Shapefile	*Parcels_Current.shp* [I]	
	Shapefile	*Zoning_Current.shp* [I]	
D	Shapefile	*places29MP_landuse_current.shp* [I]	Polygon layers of development areas from the OCD's neighborhood master plans with future land use designations (these areas are drawn independently of, and do not necessarily align with, parcels)
	Shapefile	*pantopsMP_landuse_current.shp* [I]	
	Shapefile	*village_of_rivannaMP_current.shp* [I]	
	Shapefile	*southern_and_western_urban_ neighborhoods_landuse_current.shp* [I]	
	Shapefile	*Development_RWSA.lpk*	Package of polygon layers for areas currently at various stages of development approval and construction with planned values for SF and MF dwelling units and NR square footage
	Shapefile	*COs_2019_01_02.shp*	Polygon layer of building footprints for new construction since 1991 (mostly since 2000), with certificates of occupancy listing residential type and number of dwelling units in each building.
	Text	*GIS_CardLevelDataNew_20190318.csv*	Comma-delim file containing records, by parcel, of County land use codes and building characteristics
E	Shapefile	*2015_2045_Pop_Empl_Estimates.shp*	Polygon layer of Traffic Analysis Zones with associated 2015 population and employment estimates and 2045 population and employment projections
F	Shapefile	*cb_2017_51_bg_500k.shp* [J]	Block Group polygons covering the entire State of Virginia (subsequently filtered to Albemarle County)
	Excel	*ACS_2015_2017_BG_5YR_B25032.xlsx* [K]	Block Group estimates of total number of housing units in single-unit and multiunit structures.
G	Shapefile	*Pressure_Zones-2016.shp*	Contains city and county pressure zones composing the RWSA service area (including Crozet and Red Hill, both of which were removed before any use of the layer).

A - City of Charlottesville B – ACSA C - Albemarle County Office of Geographic Data Services D - Albemarle County Office of Community Development E - Thomas Jefferson Planning District Commission
F - US Census Bureau's American Community Survey 5-year Estimates (2013-2017) G – RWSA H - Downloaded from http://www.charlottesville.org/online-services/maps-and-gis-data/download-gis-data
I - Downloaded from https://www.albemarle.org/department.asp?department=gds&relpage=3914 J - Downloaded from https://www2.census.gov/geo/tiger/GENZ2017/shp/
K - Downloaded from US Census American FactFinder: https://factfinder.census.gov/faces/nav/jsf/pages/searchresults.xhtml?refresh=t

Table A-2: Zoning and Occupancy Values Used to Create City Land Use Partitions

Partition Priority Level	Partition(s)	ZONE values	UseCode values	Sub-partitioning?	Future demand
1	UVA Grounds	'UVA Grounds' [A]	NA	Pressure zone only	Forecasted Separately
2	Medical Center	'MedCenterCore' [A]	NA	Pressure zone only	No change from current
3	Parks and Cemeteries	'Park/Cem' [A]	NA	Pressure zone only	No change from current
4	Medical Center Half-Mile	'MedCenterHalfMile' [B]	NA	Pressure zone only	Change with redevelopment towards mixed-use characteristics
5	Neighborhood Plan Zones	'CC', 'CCH', 'CDH', 'CH', 'CHH', 'D', 'DE', 'DEH', 'DH', 'DN', 'DNC', 'DNH', 'HS', 'HSC', 'HW', 'NCC', 'NCCH', 'SSH', 'URB', 'URBH', 'WME', 'WMEH', 'WMNH', 'WMW', 'WMWH', 'WSH'	NA	ZONE value and pressure zone	Change with redevelopment towards mixed-use characteristics.
6	Other Areas currently vacant	All 'B-1', 'B-2', 'B-3' variants All 'R-1', 'R-2', 'R-3' variants 'ES', 'IC', 'ICH', 'M-I', 'MR', 'PUD', 'PUDH', 'U', 'UMD', 'UMDH'	'Vacant Land', 'Vacant Commercial (B1-B3)', 'Vacant Industrial (M1,M3,PMD)'	ZONE value and pressure zone	Change with new development towards residential or nonresidential characteristics specific to each ZONE type.
7	Other Areas currently occupied		Any other than those above	Pressure zone only	No change from current

A – Parcels identified visually and initial *ZONE* values changed to 'UVA Grounds', 'MedCenterCore', or 'Park/Cem'
B – Parcels identified in GIS as all those within ½ mile of 'MedCenterCore' parcels that were not already assigned to 'UVA Grounds', 'MedCenterCore', or 'Park'

Figure A-1: Locations of City Parcels with ZONE = 'MLTP', 'MLTPC', or 'MLTPH'

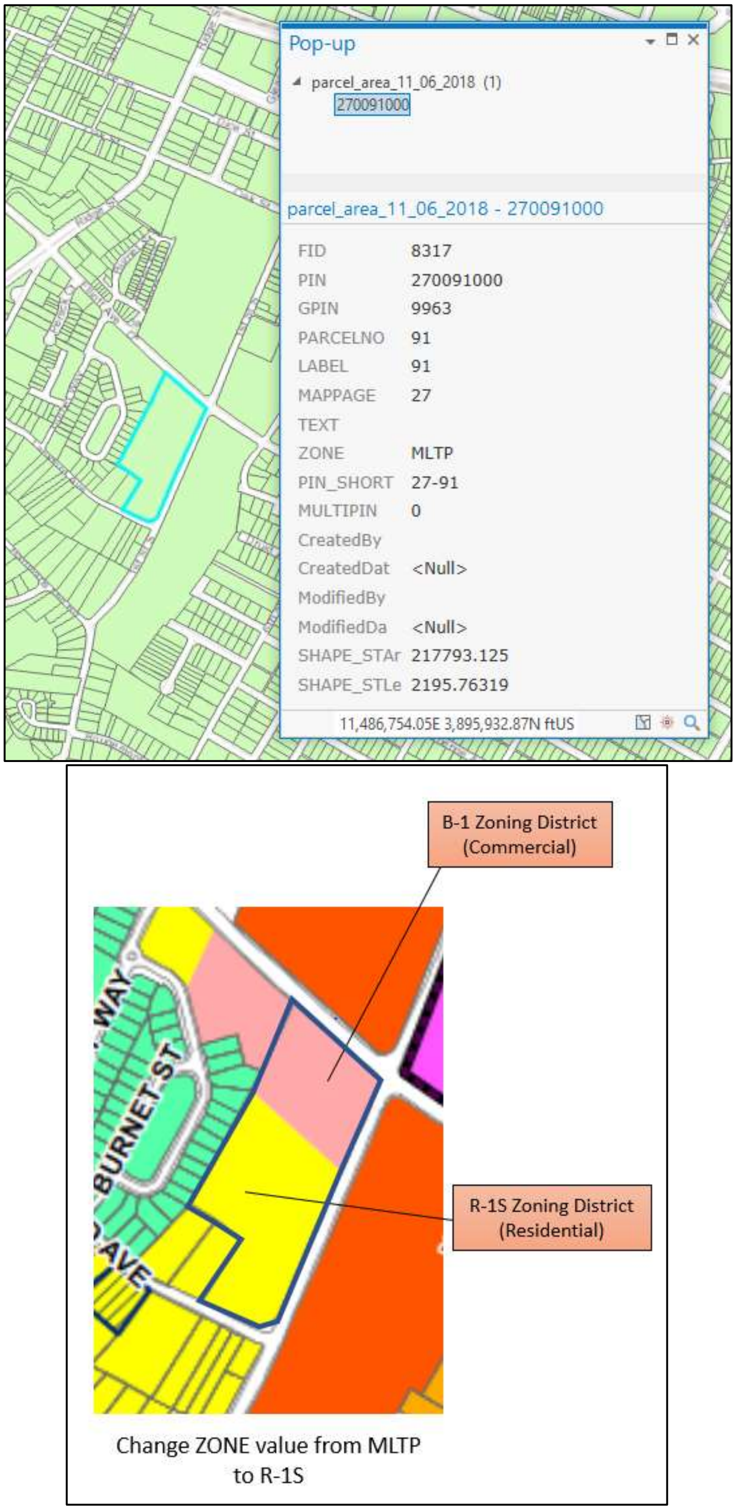


Figure A-2: Example of parcel with original *ZONE* = 'MLTP' (reassigned to *ZONE* = 'R-1S': larger proportion of area than 'B-1')

- **Parks and Cemeteries.** It was desired to ensure that the forecast would never imply redevelopment of current parks and cemeteries in any way. Nevertheless, most parcels containing parks and cemeteries (identified by comparing parcel boundaries to the World Street Map basemap in ArcGIS Pro) had *ZONE* values reflecting some sort of residential, commercial, or neighborhood development plan. To denote that these parcels were ineligible for development in the forecast, a special *ZONE* classification of 'Park/Cem' was assigned to these parcels. Figure A-3 shows an example of a parcel containing a cemetery and the corresponding parcel in GIS with its original *ZONE* value.

- **Medical Center and UVA Grounds.** It was also desired to ensure that the forecast would never imply redevelopment of UVA Grounds by the City. Online maps showing UVA boundaries[4] generally aligned closely with parcel boundaries, such that parcels contained within UVA Grounds could be identified clearly by visual inspection. Furthermore, many of these parcels contained buildings that are part of UVA as indicated by the *UVA_Buildings* layer. Nevertheless, these parcels generally had *ZONE* values reflecting some sort of residential, commercial, or neighborhood development designation by the City. To denote that these parcels were ineligible for development in the forecast, a special *ZONE* classification of 'UVA Grounds' was assigned to these parcels. In addition, ten parcels were visually identified as containing major buildings for the UVA Medical Center. To denote ineligibility for redevelopment, these parcels were given a special *ZONE* classification of 'MedCenterCore'. Figure A-4 shows the locations of 'UVA Grounds' and 'MedCenterCore' parcels.

- **Half-Mile Medical Center.** Discussions with stakeholders including RWSA Staff and City staff indicated that, regardless of zoning or neighborhood plans, the area around the Medical Center (not including UVA Grounds) is valuable real estate and a portion of it could reasonably be expected to redevelop into mixed-commercial-residential uses over the forecast horizon. To explicitly include this redevelopment potential in the forecast, all parcels located within a half-mile distance of 'Medical Center' parcels (excluding 'UVA Grounds' parcels) were given a special *ZONE* classification of 'MedCenterHalfMile'. Figure A-5 shows the locations of 'MedCenterHalfMile' parcels. The MedCenterHalfMile was treated as an additional Mixed-Use Redevelopment Area along with Neighborhood Plan areas.

Occupancy and Vacancy. Following the above adjustments to the *ZONE* field, all City parcels were joined with their corresponding land use codes (the column *UseCode* in the real estate attribute tables *Real_Estate_Residential_Details.csv* and *Real_Estate_Commercial_Details.csv*). Parcels were then flagged as "Vacant" if their *UseCode* value was either 'Vacant Land', 'Vacant Commercial (B1-B3)', or 'Vacant Industrial (M1,M3,PMD)' and their updated *ZONE* value was anything but 'Park/Cem'; parcels that did not meet these criteria were flagged as "Nonvacant".

[4] For example, the UVA SMART Transportation map - https://www.fm.virginia.edu/docs/ges/Bike_Map.pdf

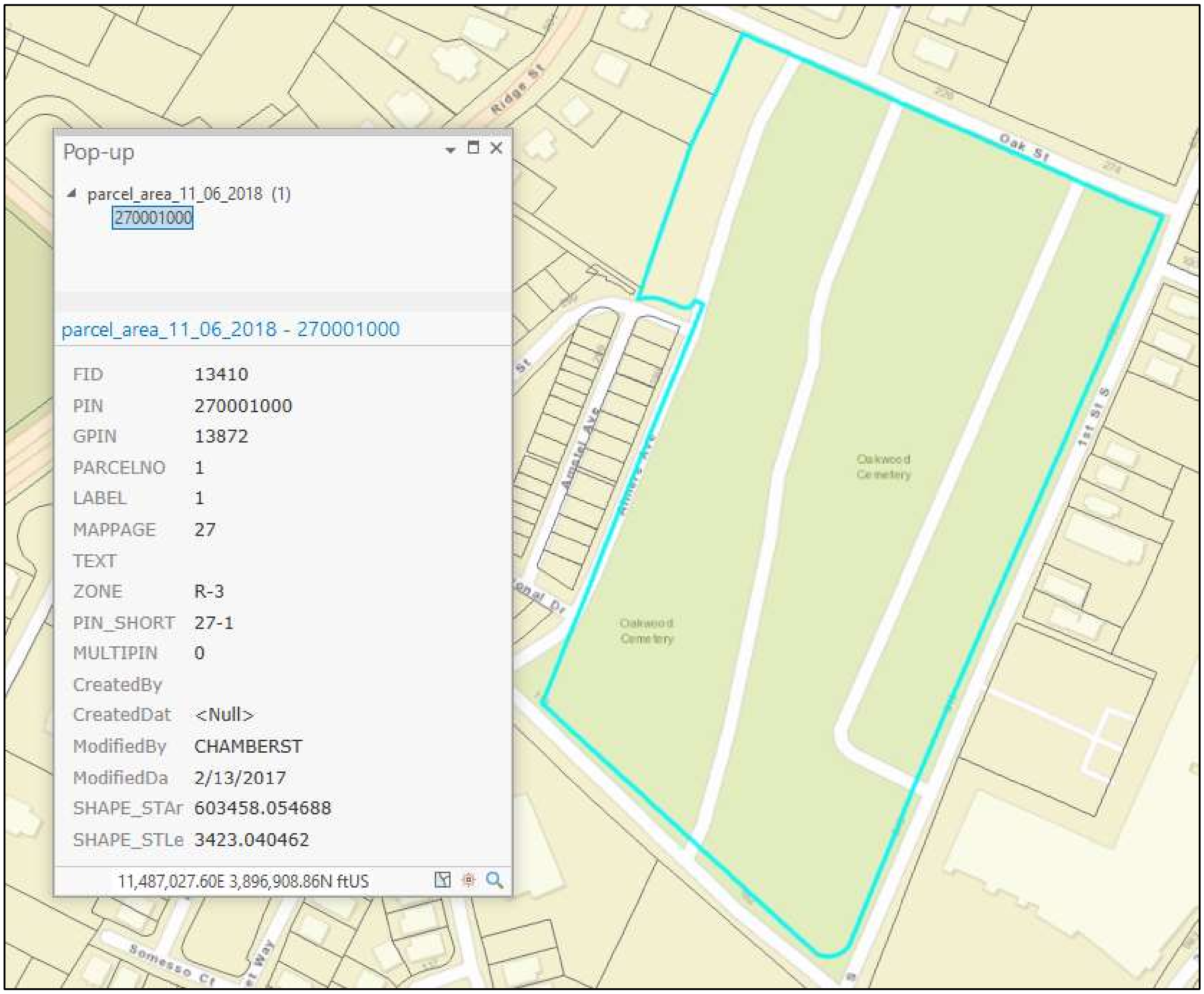


Figure A-3: Example of parcel containing a cemetery with *ZONE* = 'R-3' (Oakwood Cemetery, reassigned to *ZONE* = 'Park/Cem')

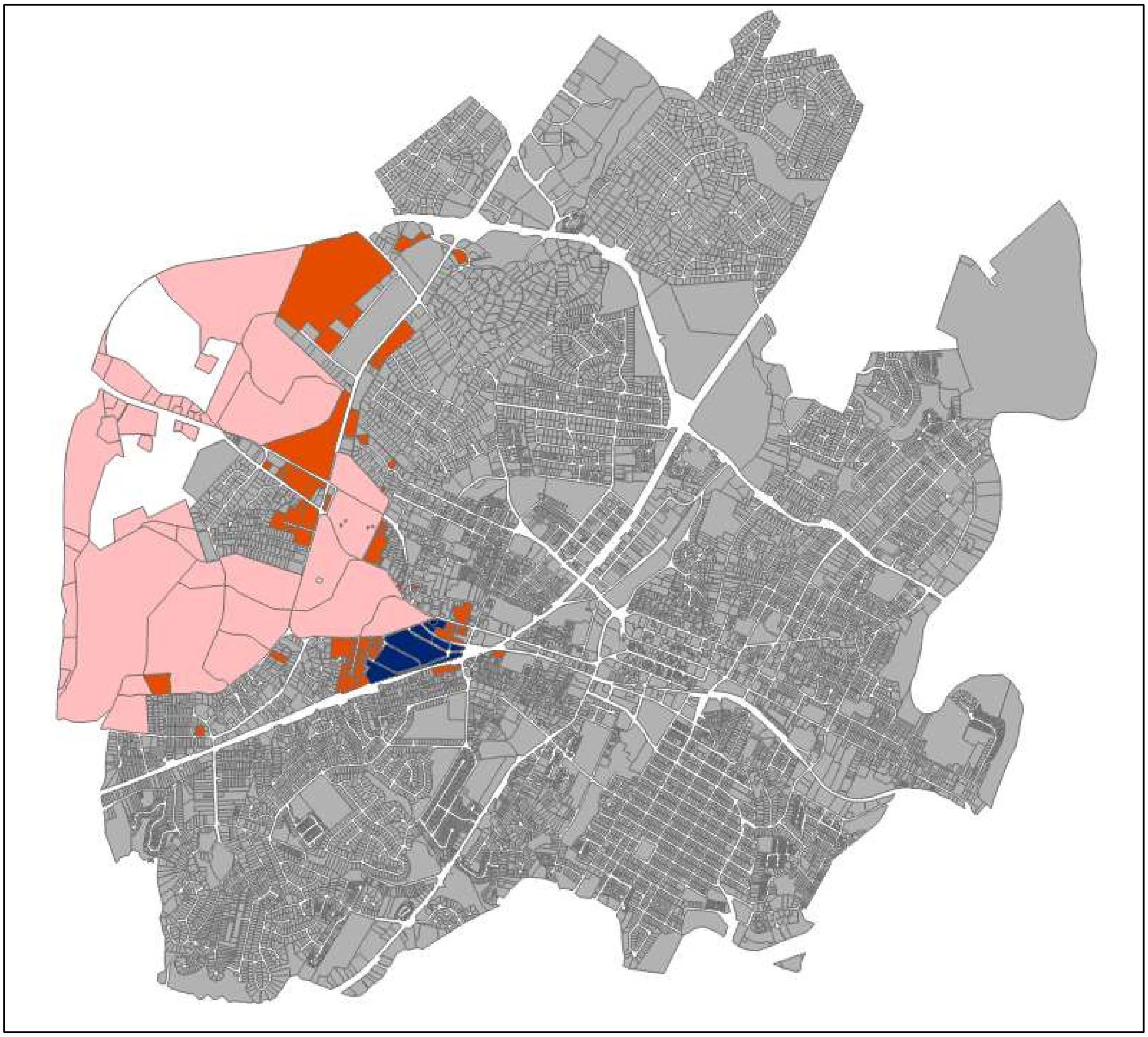


Figure A-4: Locations of City parcels within UVA Grounds (orange) and the Medical Center Core (navy blue). Also shown are Albemarle County parcels within UVA grounds (pink).

Figure A-5: Locations of City parcels within the Medical Center Core (navy blue) and within ½ mile of the Medical Center (teal).

Land Use Partitions. After land use and occupancy classifications were determined, parcels were assigned to land use partitions as shown in Table A-2. Partitions were defined in a priority order (the order is noted in the first column of Table A-2), where parcels assigned to a higher-priority partition were not further considered when defining lower-priority partitions. Figures A-4 and A-5 showed the UVA/Medical Center and Half-Mile Medical Center partitions. Figures A-6 through A-9 show partitions for parks and cemeteries, mixed-use redevelopment areas including neighborhood planning zones and the Half-Mile Medical Center, vacant parcels outside other partitions, and occupied parcels outside other partitions, respectively. Note that for neighborhood planning zones (Figure A-7) and for vacant parcels outside other partitions (Figure A-8), a separate partition is defined for each *ZONE* value.

Pressure Zone Partitions. Parcels were also partitioned by pressure zone using GIS (Figure A-10). First, the centroid of each parcel was determined. Then, these centroids were spatially joined (intersected) with pressure zone polygons in the *Pressure_Zones-2016* layer, associating each centroid with exactly one polygon. Pressure zone designations associated with each centroid were then assigned back to the parcel polygons from which the centroids were derived. Therefore, each parcel was associated with exactly one pressure zone based on the location of its centroid relative to pressure zone boundaries. Note that city parcels almost precisely align with pressure zone boundaries; it is apparent that pressure zones were originally defined using parcel geographic data from the City.

Combined Partitions. In the forecast, land use and pressure zone partitions were used simultaneously, such that each forecast partition corresponded to a specific combination of future land use and pressure zone. While these represent too many combinations to sensibly display on a map, Figure A-11 provides an indication of the associated partition granularity.

Assumed Development Factors for Partitions. Estimates were formed for number of SF and MF dwelling units and NR square feet at maximum buildout density in City partitions assumed to undergo some form of development (Medical Center Half-Mile, Neighborhood Plan, and Other Vacant partitions). Development factors, in terms of future SF units/acre. MF units/acre, and NR sq. ft/acre, were specified for each *ZONE* value. These factors were multiplied by total acreage in each corresponding partition to estimate buildout development. Development factors were derived from zoning and neighborhood plan specifications; current values are shown in Table A-3. These factors can be adjusted as needed within the forecast spreadsheet to create forecast scenarios.

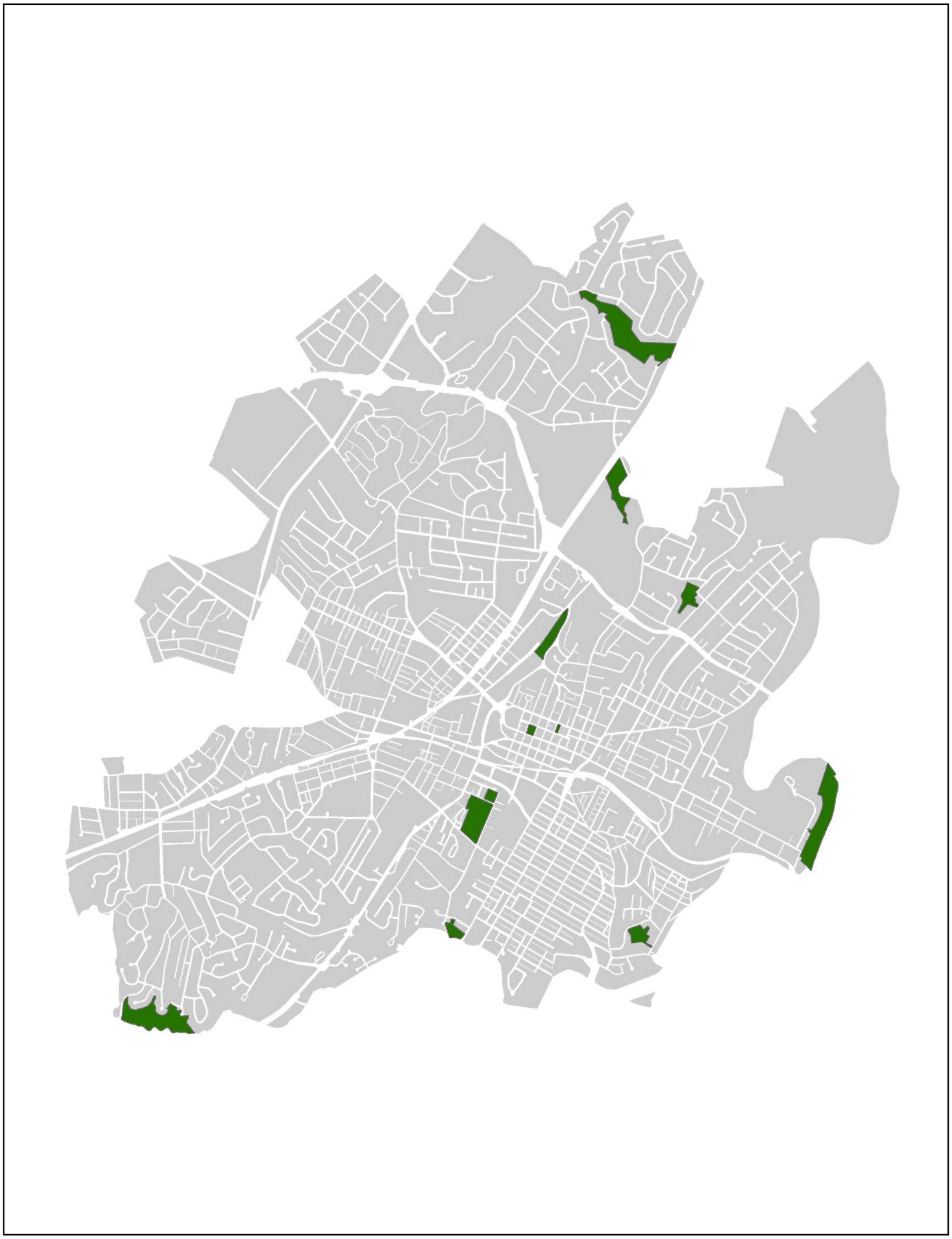


Figure A-6: City Land Use Partitions: Parks and Cemeteries.

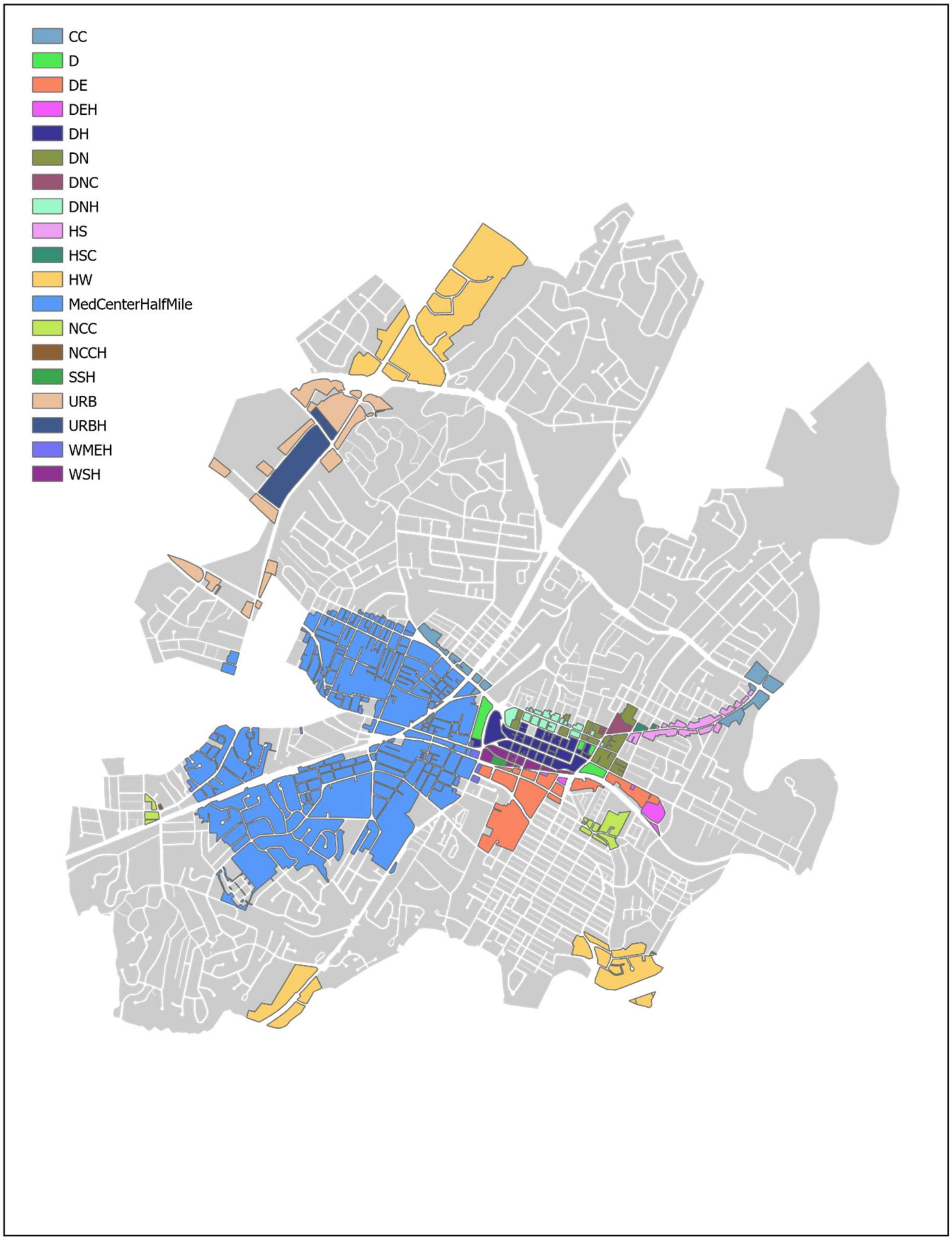


Figure A-7: City Land Use Partitions: Neighborhood Planning Zones and the Medical Center Half-Mile.

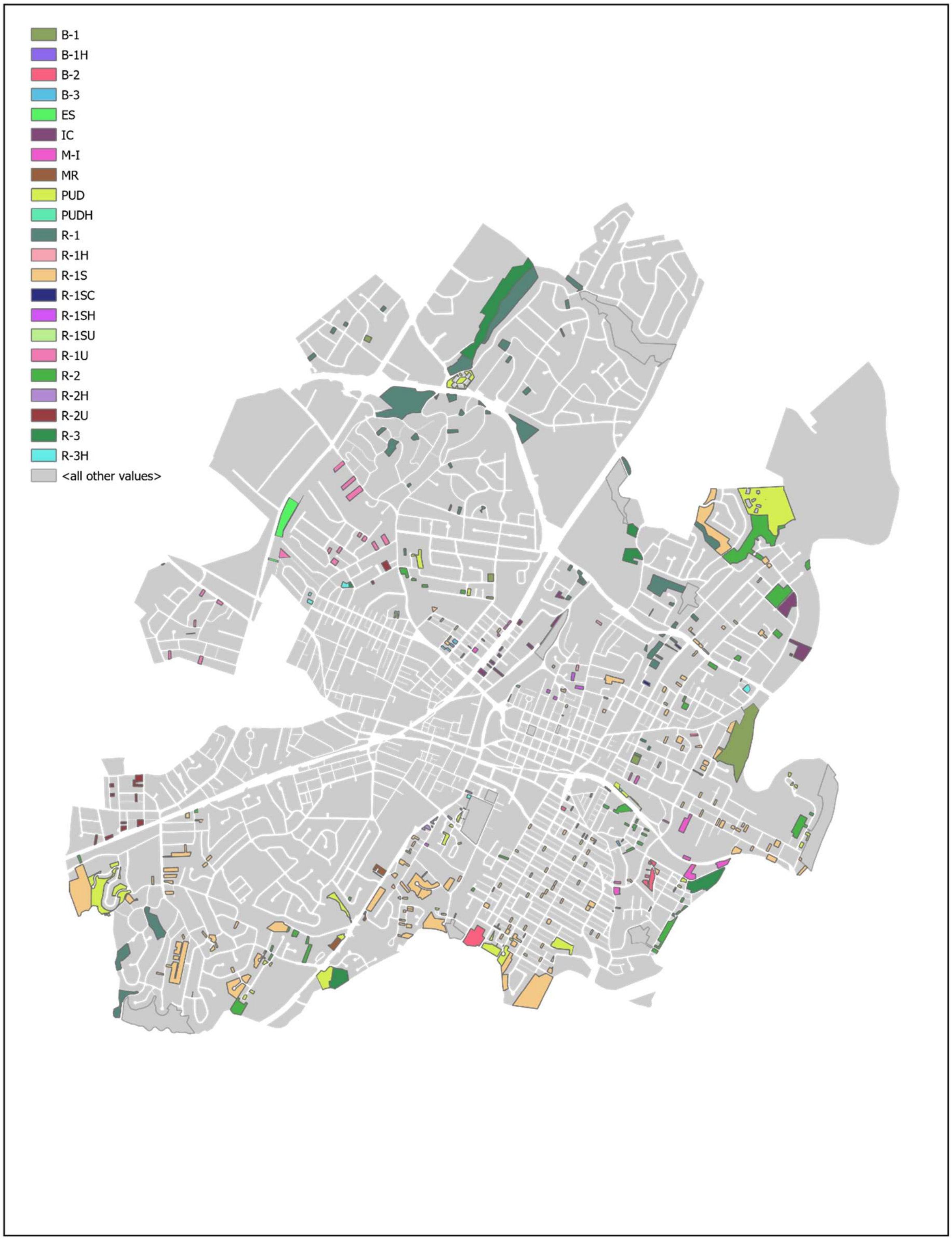


Figure A-8: City Land Use Partitions: Vacant Parcels Outside Earlier Partitions.

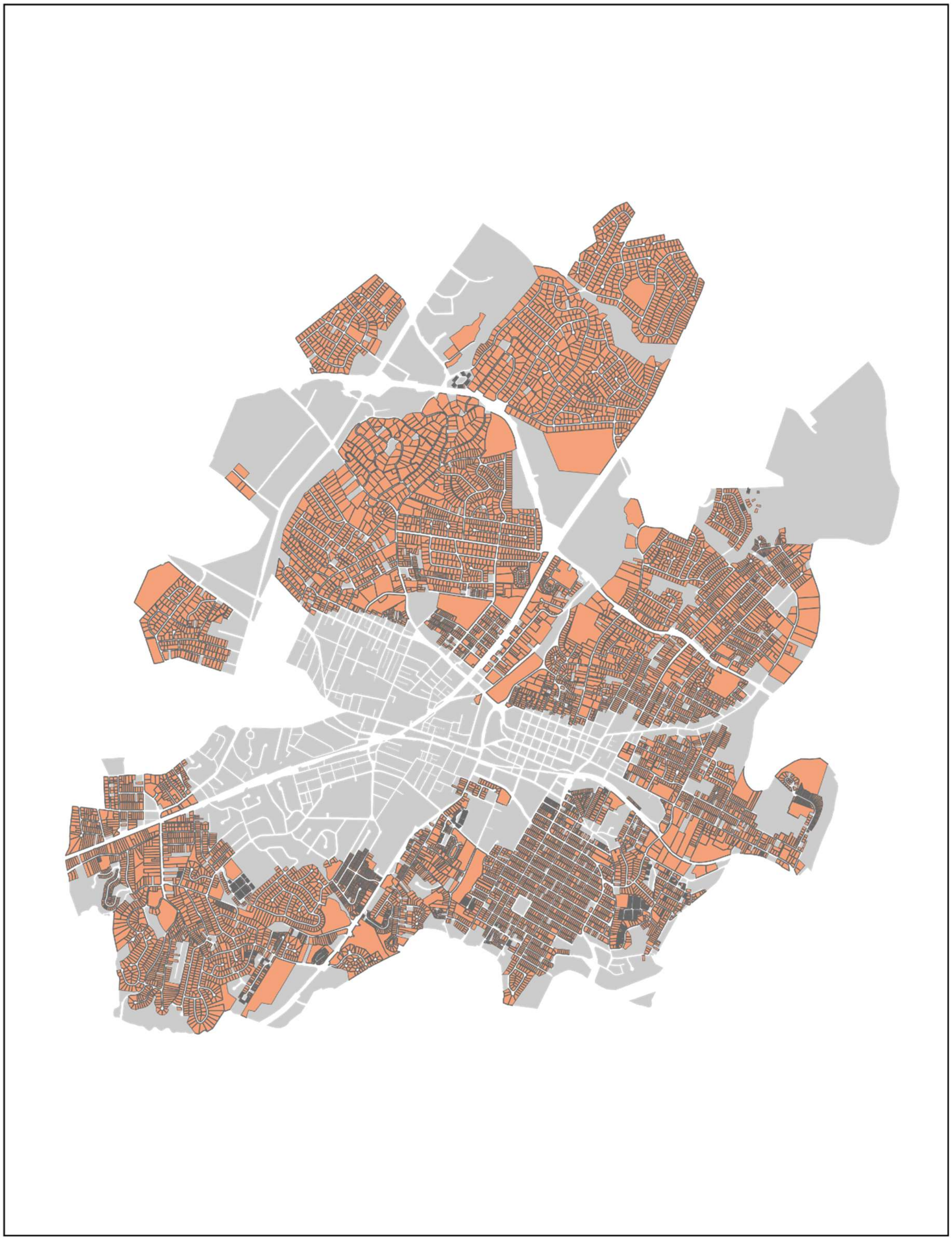


Figure A-9: City Land Use Partitions: Occupied Parcels Outside Earlier Partitions.

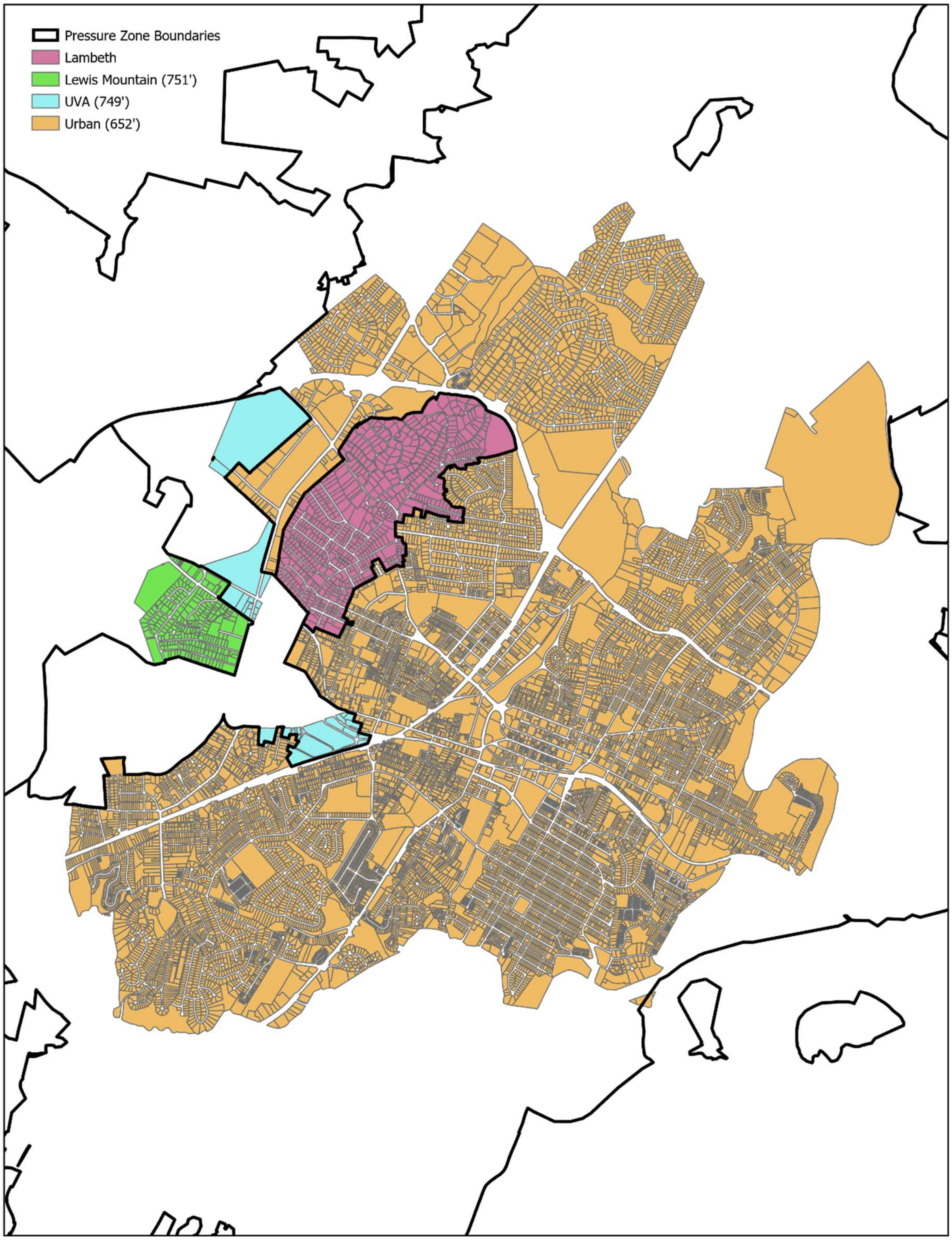


Figure A-10: City Pressure Zone Partitions

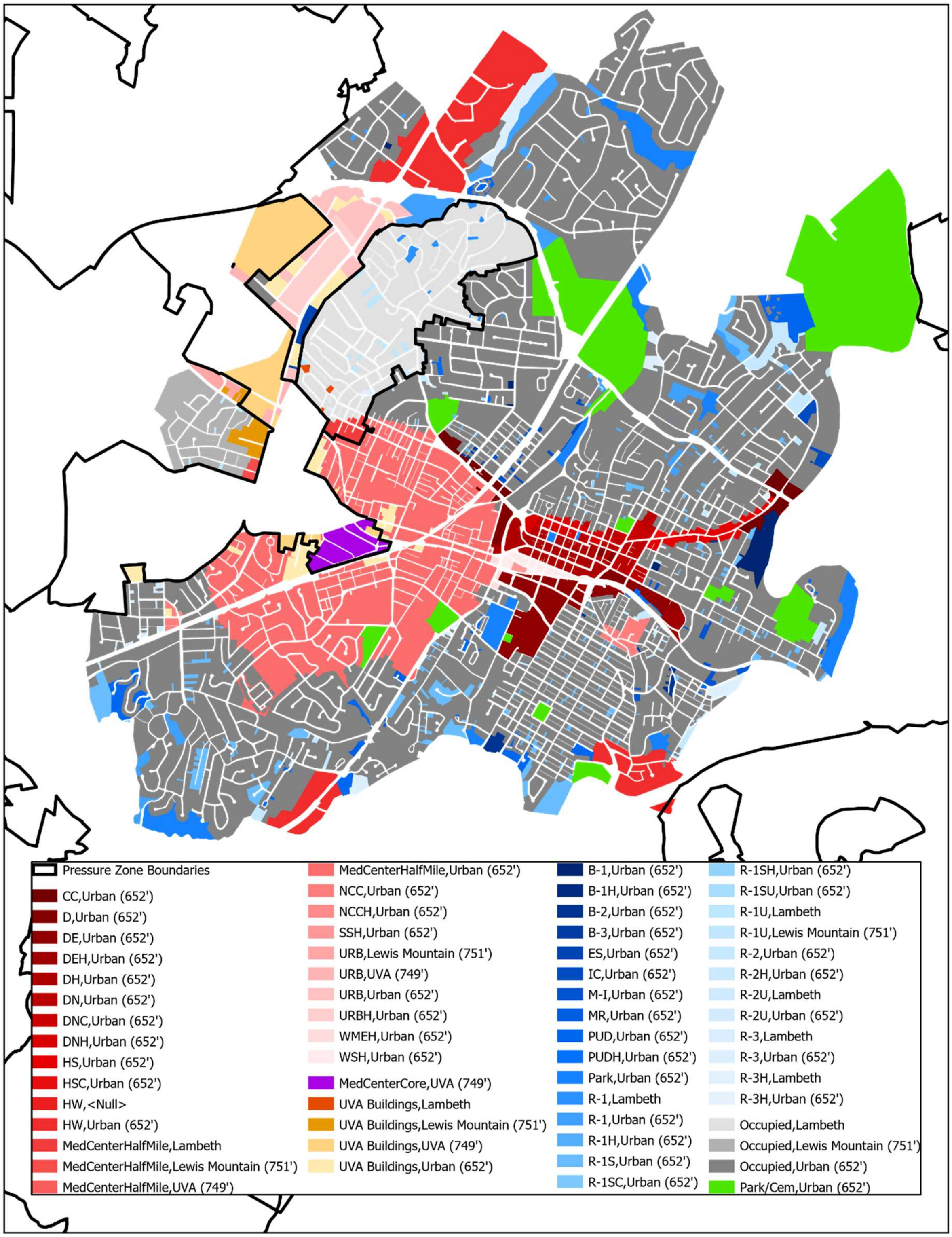


Figure A-11: Complete City Land Use Partition

Table A-3: Assumed Maximum Density Buildout Development Factors for Charlottesville *ZONE* Classifications

ZONE	SF units/acre	MF units/acre	NR ksf/acre[A]
MedCenterHalfMile	-	48	20
CC	-	48	20
CDH	-	48	20
CH	-	48	20
D	-	48	20
DE	-	48	20
DEH	-	48	20
DH	-	48	20
DN	-	48	20
DNC	-	48	20
DNH	-	48	20
HS	-	48	20
HSC	-	48	20
HW	-	48	20
NCC	-	48	20
NCCH	-	48	20
SSH	-	48	20
URB	-	48	20
URBH	-	48	20
WME	-	48	20
WMEH	-	48	20
WMNH	-	48	20
WMSH	-	48	20
WMW	-	48	20
WMWH	-	48	20
WSH	-	48	20

All neighborhood zones listed above, including the MedCenterCore, were assumed to be developed to Mixed-Use characteristics with 48 MF units/acre, 20 NR ksf/acre, and no SF units at buildout conditions.

ZONE	SF units/acre	MF units/acre	NR ksf/acre[A]
B-1[C]	-	-	10.02
B-1C[C]	-	-	10.02
B-1H[C]	-	-	10.02
B-2[C]	-	-	10.02
B-2H[C]	-	-	10.02
B-3[C]	-	-	10.02
B-3H[C]	-	-	10.02
ES[C]	-	-	10.02
IC[C]	-	-	10.89
ICH[C]	-	-	10.89
M-I[C]	-	-	10.89
MR[C]	-	21	-
PUD[D]	3	-	-
PUDH[D]	8	-	-
R-1[B]	3	-	-
R-1H[B]	3	-	-
R-1S[B]	8	-	-
R-1C[B]	8	-	-
R-1SHC[B]	8	-	-
R-1SC[B]	3	-	-
R-1SH[B]	3	-	-
R-1SU[B]	3	-	-
R-1SUH[B]	3	-	-
R-1U[B]	3	-	-
R-1UH[B]	3	-	-
R-2[B]	8	-	-
R-2C[B]	8	-	-
R-2H[B]	8	-	-
R-2U[B]	8	-	-
R-2UH[B]	8	-	-
R-3[C]	-	43	-
R-3H[C]	-	64	-
UMD[C]	-	21	-
UMDH[C]	-	21	-
UHD[C]	-	43	-
UHDH[C]	-	43	-

A – ksf = square footage in thousands
B – assumptions based on existing occupied development in these zones
C – assumptions based on definitions in zoning ordinances
D – assumptions based on existing lower- and higher-density SF development; PUD ordinances require empty space in development

Development Pacing

Having created the partitions described above, the next step was to pace development within each zone to match the City's population forecasts (Section 3.1.1 and 3.5.1). The values shown in Table A-4 describe the assumed progress, at three time horizons within the forecast period, toward the maximum build-out densities (as previously described). They described the percentage increase in development density for the respective zones between the actual development density in 2017 and the maximum build-out density. The assumed progress toward full build-out density was greater for undeveloped areas than for the areas subject to redevelopment because the existing density of undeveloped parcels is so low and it is assumed a higher fraction of the undeveloped zone will be developed in the future. The resulting development levels produced close facsimiles of the forecasted population for Charlottesville at the indicated forcast horizons. Additional population capacity was tied to new housing units and the persons per dwelling factor used for single family and multifamily housing units (2.53 for SFDUs, 2.01 for MFDUs). It is possibly noteworthy that the assumptions in the model lead to 92-94% of residential capacity growth to take place in multifamily dwelling units over the forecast horizon.

Table A-4: Development Pacing for Charlottesville

Zone / Partition	2030	2045	2070
MedCenterHalfMile	5%	10%	22%
D, DE, DEH, DH	5%	12%	22%
Other mixed use zones (left side Table A-3)	3%	6%	14%
Undeveloped/ vacant (Figure A-8)	8%	15%	35%

A.2 County Partitioning

County partitions were defined using similar concepts to the City, with partitions based on a combination of future land use plans, current occupancy, and pressure zone locations. Unlike the city, however, future land use was characterized via multiple different geographic types, including parcels and pressure zones, County master-planned Development Areas, and existing active or planned development projects, i.e. projects currently between start of permitting and end of construction. These different areas were defined with shapes that partially overlapped one another. To prevent area duplication during County partitioning, partitions were defined in order of superseding future land use definitions (Table A-5), and areas in lower-priority partitions that were overlapped by higher-priority partitions were deleted.

County UVA Partition. The highest-priority partition contained those areas of the County occupied by UVA Grounds. These areas were identified from the county parcel layer (pink section of Figure A-4) by visual cross-referencing with online UVA maps. As with the City, these areas were removed from further County forecasting consideration (a forecast of UVA demand was handled separately, see Section 3.3) and deleted from subsequent partitions.

Development Pipeline Partitions. The next-highest-priority partition contained areas currently permitted for specific developments or under construction. The County (ACOCD) provided a layer with polygons corresponding to these developments (*Development_RWSA*: Figure A-12), each tagged with future land use information indicating planned number of SF or MF units and/or NR square footage. These areas are known as the “Development Pipeline”. Each Development Pipeline polygon served as its own partition by assigning it to the pressure zone containing the polygon’s centroid and by specifying future dwelling unit and/or square footage assumptions based on that development’s permit data. There was no overlap of the County UVA Partition on Development Pipeline polygons, requiring no deletions from the latter. Development Pipeline partitions did, however, overlap some subsequent lower-priority partitions, requiring deletions as those partitions were formed. Table B-8 shows total future SF and MF dwelling units and NR square footage for Development Pipeline partitions aggregated to pressure zone.

Extra Pipeline Partitions. In addition to the Development Pipeline, three major planned developments were identified that had specific future SF/MF unit or NR square footage values that superseded county zoning and master planned development, including Sentara Martha Jefferson Hospital, Fontaine Research Park, and UVA Research Park. Each of these developments were used to define an “Extra Pipeline” partition, the third-highest priority type of partition. Polygons for these three developments were inferred from the County parcel layer (ExtraPipelinePoly: Figure A-13). As with the Development Pipeline, each Extra Pipeline polygon served as its own partition by assigning it to the pressure zone containing the polygon’s centroid and by specifying future dwelling unit and/or square footage assumptions based on that development’s permit data. There was no overlap of the County UVA or Development Pipeline partitions on the Extra Pipeline partition, so no deletions were required from the latter. Extra Pipeline Partitions did, however, overlap some subsequent lower-priority partitions, requiring deletions as those partitions were formed. Table A-5 shows total future MF dwelling units and NR square footage for Extra Pipeline partitions aggregated to pressure zone.

Table A-5: Extra Pipeline Partition Details

Project	Pressure Zone	Net Additional NR space or MF DUs		
		2030	2045	2070
Marth Jefferson Hospital Hos	Urban Ring	540 ksf	-	-
Fontaine Research Park	Urban Ring	500 ksf	366 ksf	-
UVA/North Fork Research Park	Piney Mountain	400 ksf 100 MF DUs	1000 ksf 250 MF DUs	2000 ksf 500 MF DUs

Table A-6: Zoning and Occupancy Values Used to Create County Land Use Partitions

<table>
<tr><th>Partition Priority Level</th><th>Partition(s)</th><th>Land use values</th><th>UseCode values</th><th>Sub-partitioning?</th><th>Future demand</th></tr>
<tr><td>1</td><td>County UVA Grounds</td><td>NA</td><td>NA</td><td>Pressure zone only</td><td>Omitted from County Forecast. UVA forecast handled separately.</td></tr>
<tr><td>2</td><td>Development Pipeline</td><td rowspan="2">NA</td><td rowspan="2">NA</td><td rowspan="2">separate partition for each polygon and pressure zone</td><td rowspan="2">Based on planned SF units, MF units, and NR sq ft for each development</td></tr>
<tr><td>3</td><td>Extra Pipeline</td></tr>
<tr><td>4</td><td>Places29</td><td rowspan="4"><u>Land Use column</u>:
'Airport District, Commercial Mixed Use,Community Mixed Use', 'Employment District', 'Employment Mixed Use', 'Greenspace', 'Heavy Industrial', 'Industrial', 'Institutional', 'Light Industrial', 'Neighborhood Density Residential', 'Neighborhood Density Residential Low', 'Neighborhood Mixed Use', 'Office / R & D / Flex / Light Industrial', 'Parks', 'Parks and Green Systems', 'Privately Owned Open Space', 'Public Open Space', 'Regional Mixed Use', 'River Corridor', 'Rural Area', 'Town/Village Center', 'Urban Density Residential', 'Urban Mixed Use', 'Urban Mixed Use (in Centers)', 'Urban Mixed Use (in areas around Centers)'</td><td rowspan="4">NA</td><td rowspan="4">separate partition for each Development Area, Land Use value, and pressure zone</td><td rowspan="4">Change with redevelopment towards characteristics associated with land use values</td></tr>
<tr><td>5</td><td>Pantops</td></tr>
<tr><td>6</td><td>Southern and Western Neighborhoods</td></tr>
<tr><td>7</td><td>Village of Rivanna</td></tr>
<tr><td>8</td><td>Other Areas currently vacant</td><td rowspan="2"><u>Zoning column</u>:
'C1 Commercial', 'Commercial Office', 'Highway Commercial', 'Light Industry', 'Neighborhood Model District', 'Planned Development Industrial Park', 'Planned Development Mixed Commercial', 'Planned Development Shopping Center', 'Planned Residential Development', 'Planned Unit Development', 'R1 Residential', 'R10 Residential', 'R15 Residential', 'R2 Residential', 'R4 Residential', 'R6 Residential', 'Rural Areas', 'Village Residential'</td><td>'Vacant Commercial Land', 'Vacant Residential Land'</td><td>separate partition for each Zoning value and pressure zone</td><td>Change with new development towards residential or nonresidential characteristics specific to each ZONE type.</td></tr>
<tr><td>9</td><td>Other Areas currently occupied</td><td>Any other than those above</td><td>Pressure zone only</td><td>No change from current</td></tr>
</table>

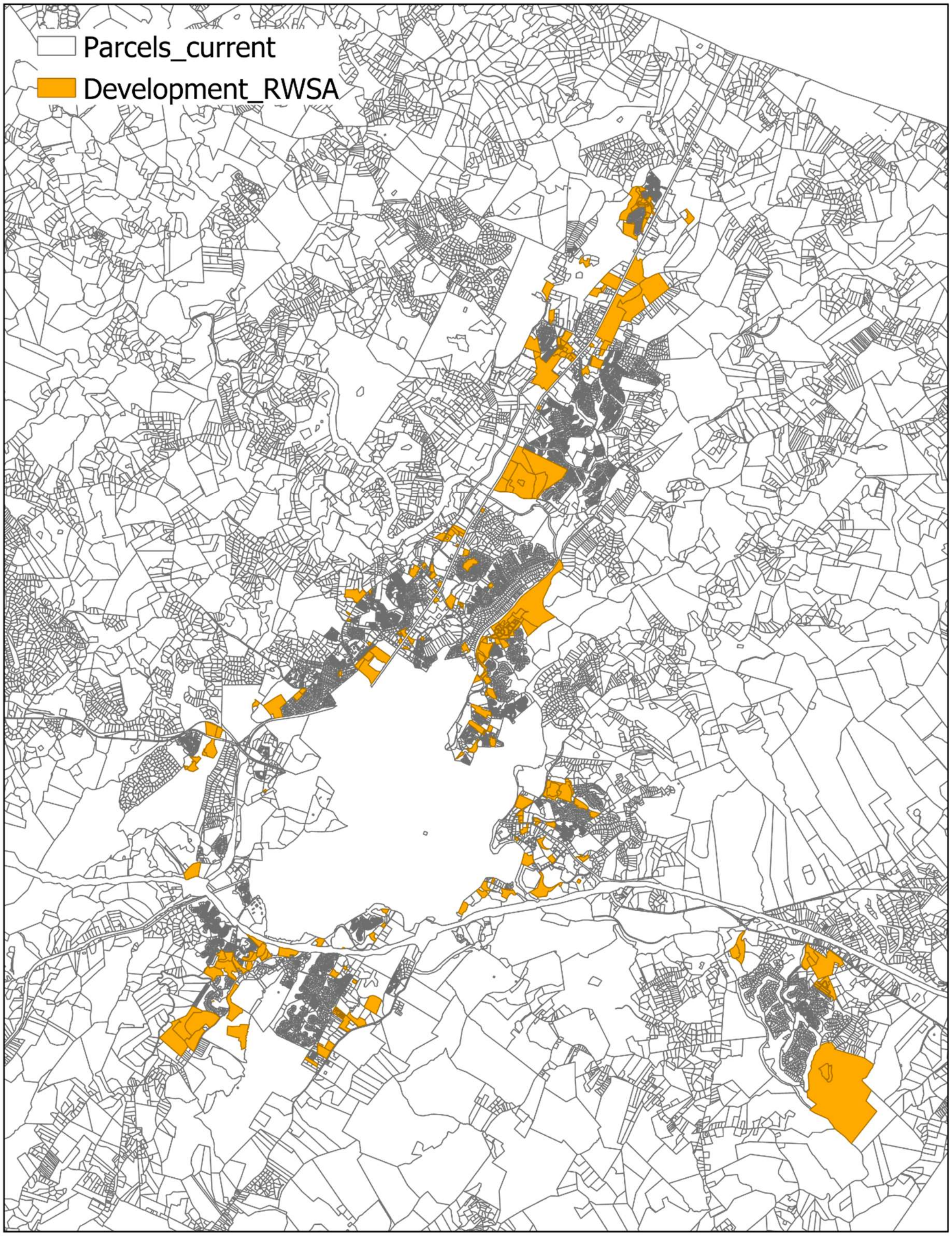


Figure A-12: County Parcel and Development Pipeline Layers.

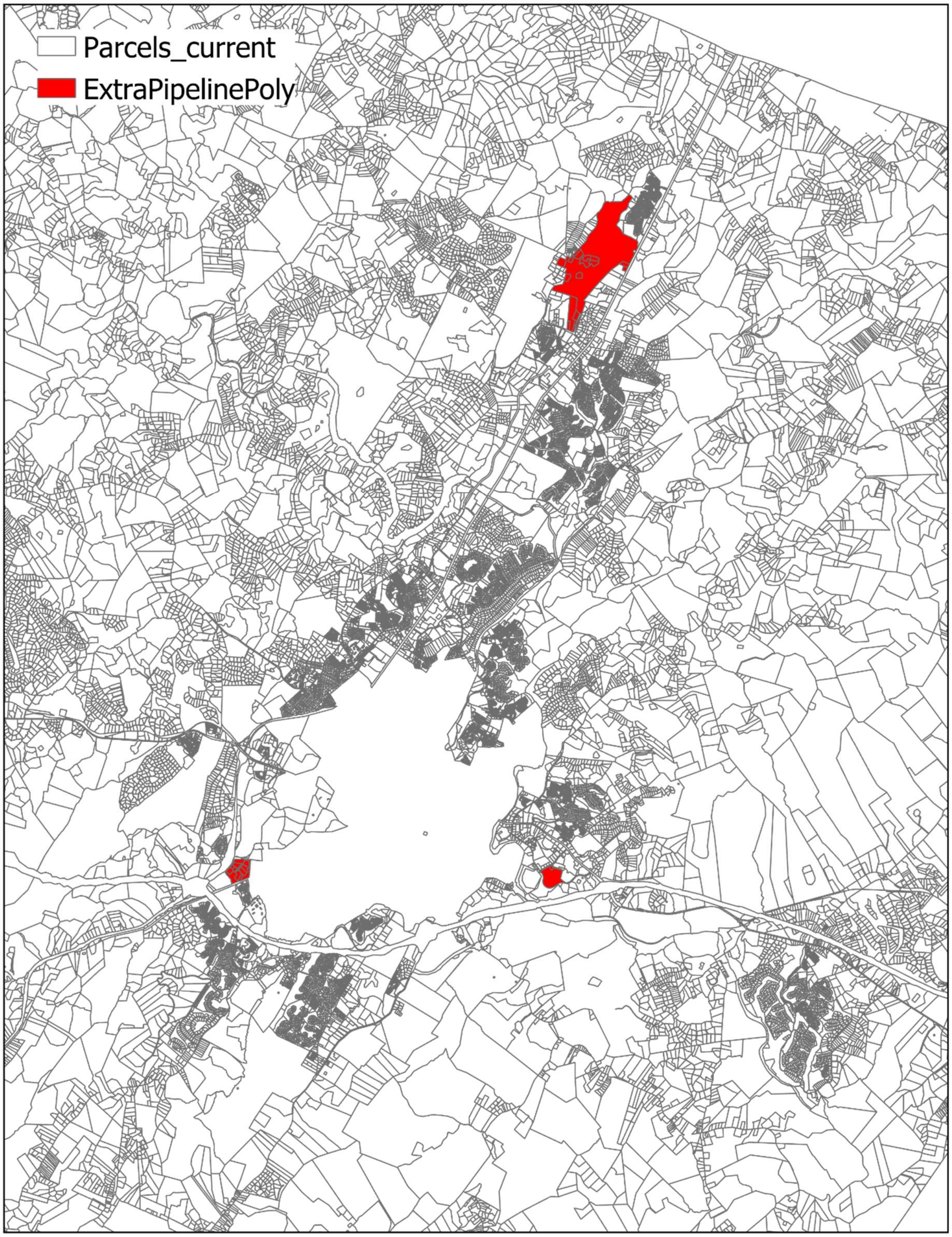


Figure A-13: County Parcel and Extra Pipeline Layers.

County Development Area Partitions. The next four highest-priority partitions were for County Development Areas, including Places29, Pantops, Village of Rivanna, and the Southern and Western Neighborhoods (Figure A-14). The County provided layers containing polygons for these areas, including Places29, Pantops, Village of Rivanna, and the Southern and Western Urban Neighborhoods. Each Development Area layer consisted of multiple polygons, each with a different future land use specification listed in the *Land Use* column of the associated layer's attribute table. Partitioning of Development Areas therefore consisted of

- deleting (trimming) polygons and portions of polygons that were overlapped by County UVA, Development Pipeline, and Extra Pipeline polygons (Figure A-15),
- assigning Development Area polygons to the pressure zones containing their centroids (Figure A-16), and
- defining partitions as groups of trimmed polygons having the same Development Area, Land Use category, and pressure zone (Figure A-17).

Finally, SF, MF, and NR development factors (units/acre and sq. ft/acre) were determined for each *Land Use* category as shown in Tables A-7 through A-10. Development factors were derived from dual assumptions for fraction of total area in each polygon developed for SF, MF, or NR sectoral use multiplied by assumptions for number of SF/MF units and NR square feet per sectoral acre. These values were inferred and estimated from data and descriptions in master plan documents.

Occupied and Vacant County Parcel Partitions. The final set of partitions consisted of occupied and vacant areas inside the County service area but outside higher-priority partitions. These partitions were based on parcel-level county zoning and occupancy data provided in the *Parcels Current* layer, zoning codes contained in the *ZONING* column of that layer's attribute table, and occupancy data contained in the *UseCode* column of *Real_Estate_Residential_Details.csv and Real_Estate_Commercial_Details.csv* files.

- First, the set of parcels contained within the County service area (omitting Crozet and Red Hill) was determined by assigning parcels to the pressure zones containing their centroids and omitting parcels whose centroids were outside any pressure zone. This formed a County parcel/pressure zone layer (*Parcels_current_Intersect_PZ_Clean*, Figure A-18).

- Then, parcels and portions of parcels overlapped by County UVA, Development Pipeline, Extra Pipeline, and Development Area partitions were deleted (trimmed) from the parcel/pressure zone intersect layer (Figure A-19).

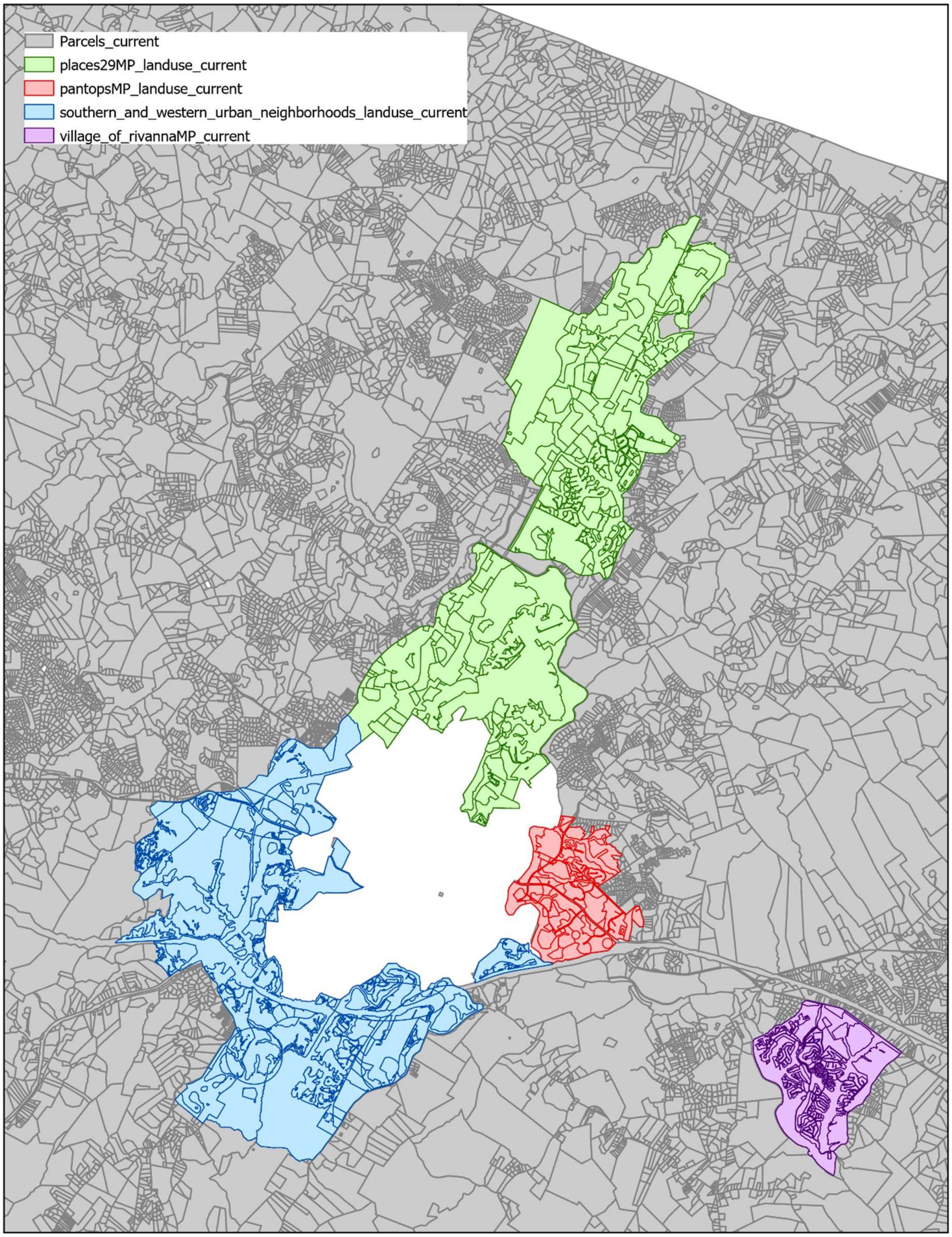


Figure A-14: County Parcel and County Master-Planned Development Area layers.

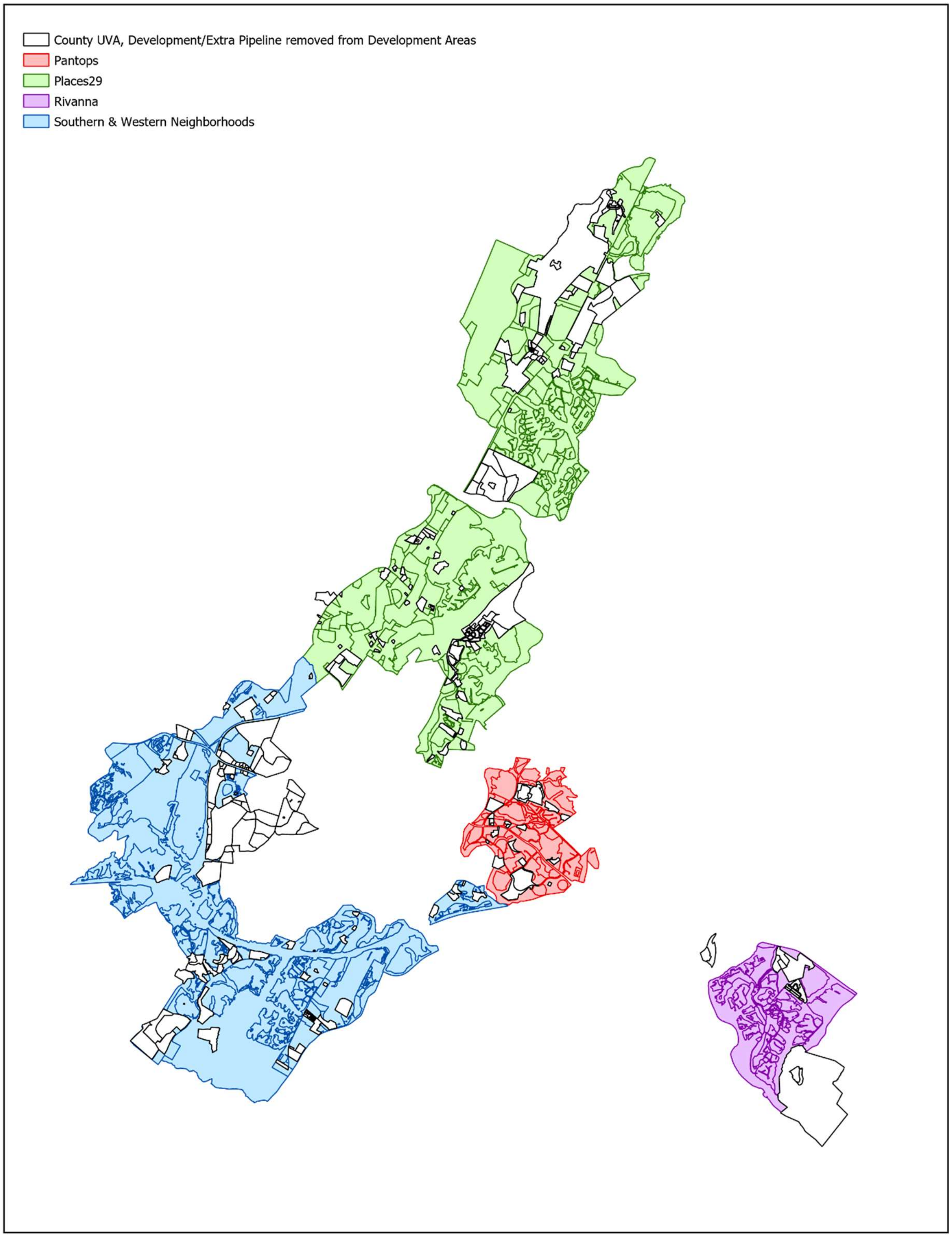


Figure A-15: Deletion of Higher-Priority Partitions from Development Area Polygons.

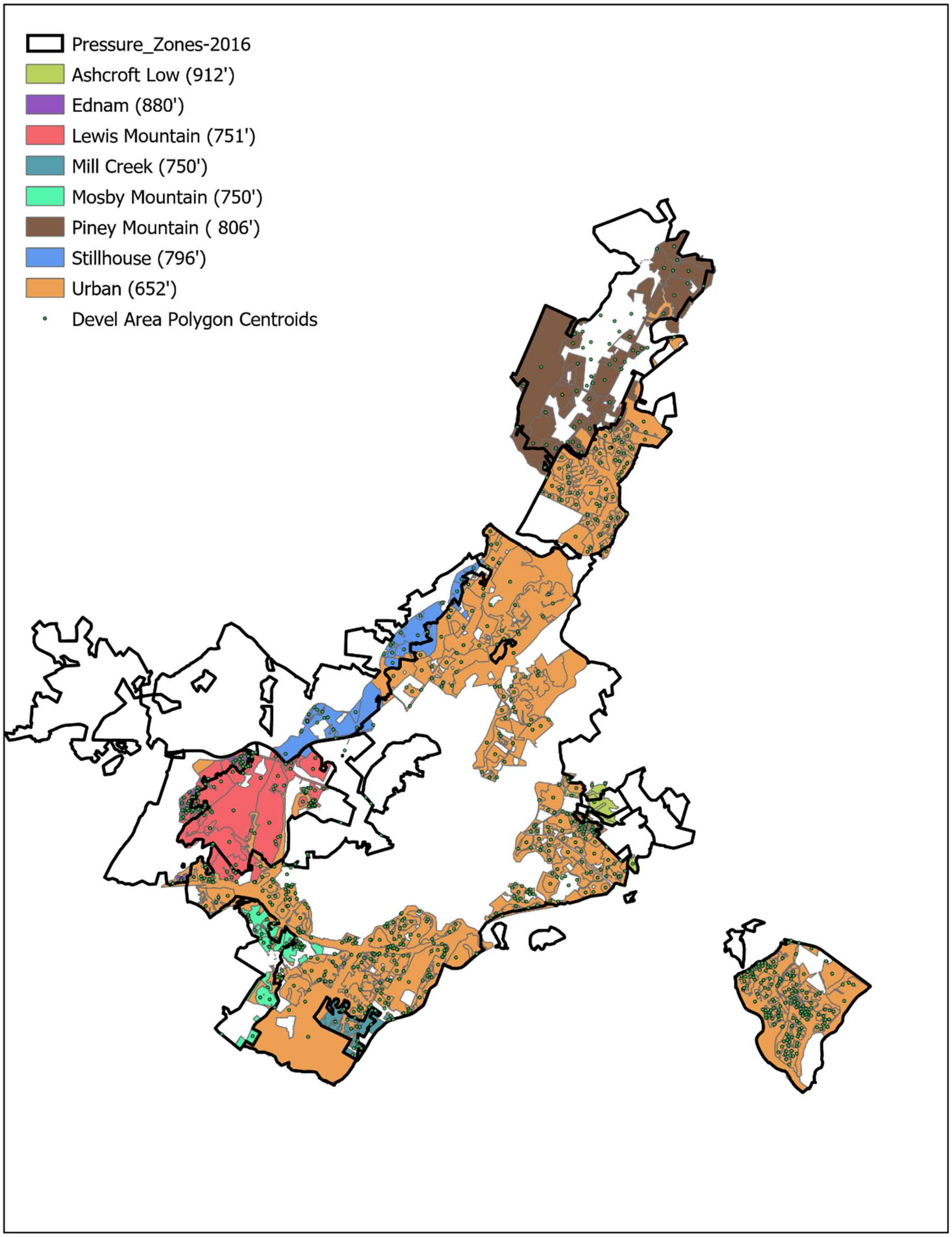


Figure A-16: Assignment of Development Area Polygons to Pressure Zones

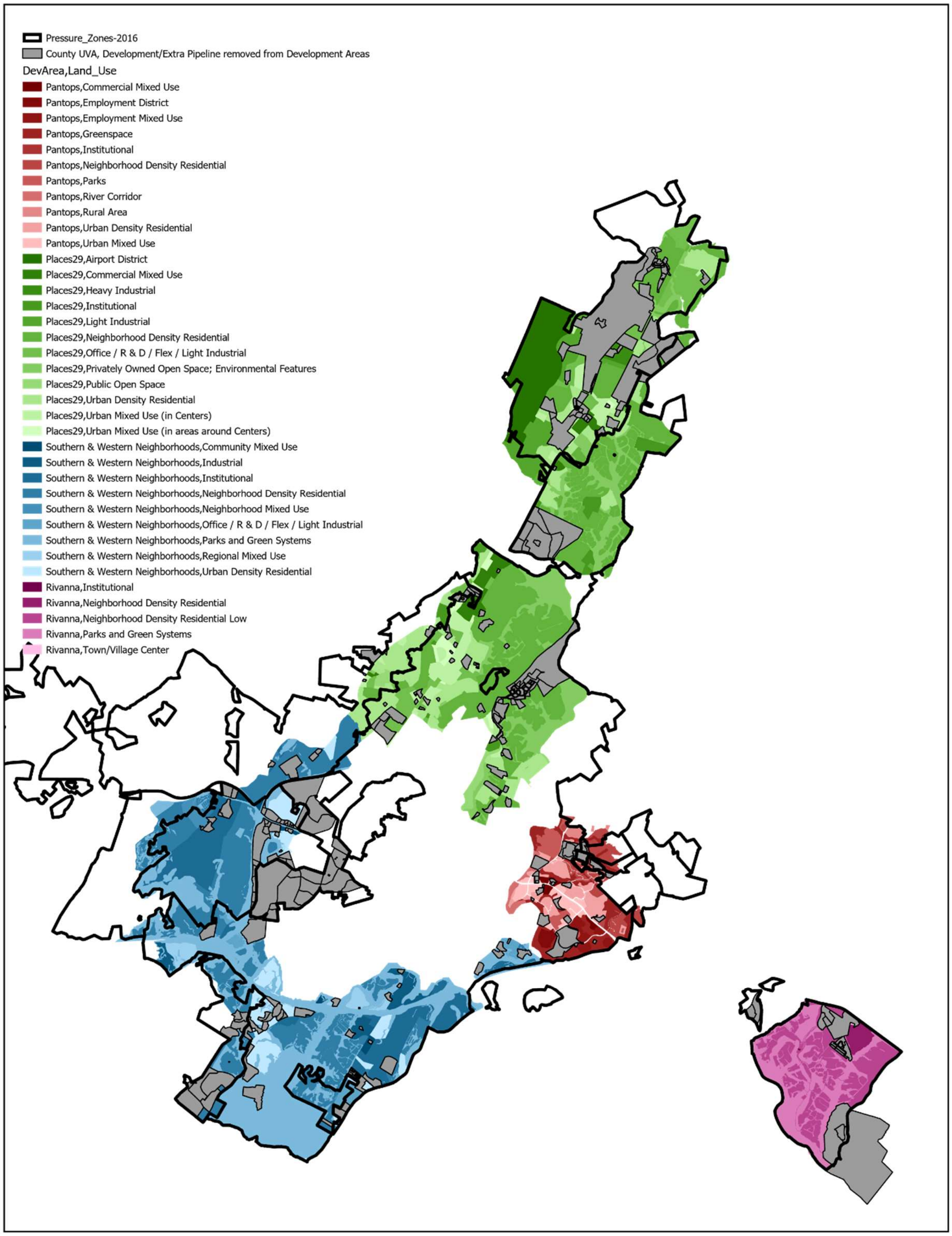


Figure A-17: Development Area Land Use Partitions.

Table A-7: Pantops Land Use Development Factor Assumptions

Land Use	Sector Area Fraction Sector Area/Total Area			Sector Area Development Density Units or ksf/Sector Area			Sector Development Factors Units or ksf/Total Area		
	SF	MF	NR	SF	MF	NR	SF	MF	NR
Commercial Mixed Use	-	0.20	0.60	-	13.00	10.02	-	2.6	6.012
Employment District	-	-	0.80	-	-	10.02	-	-	8.016
Employment Mixed Use	-	0.20	0.60	-	13.00	10.02	-	2.6	6.012
Greenspace	-	-	-	-	-	-	-	-	-
Institutional	-	-	0.60	-	-	10.02	-	-	6.012
Neighborhood Density Residential	0.80	-	-	4.50	-	-	3.6	-	-
Parks	-	-	-	-	-	-	-	-	-
Rural Area	-	-	-	-	-	-	-	-	-
Urban Density Residential	-	0.80	-	-	13.00	-	-	10.4	-
Urban Mixed Use	-	0.35	0.45	-	13.00	10.89	-	4.55	4.9005
River Corridor	-	-	-	-	-	-	-	-	-

Table A-8: Places29 Land Use Development Factor Assumptions

Land Use	Sector Area Fraction Sector Area/Total Area			Sector Area Development Density Units or ksf/Sector Area			Sector Development Factors Units or ksf/Total Area		
	SF	MF	NR	SF	MF	NR	SF	MF	NR
Neighborhood Density Residential	0.80	-	-	4.50	-	-	3.6	-	-
Urban Density Residential	-	0.80	-	-	13.00	-	-	10.4	-
Urban Mixed Use (in Centers)	-	0.35	0.45	-	18.00	10.89	-	6.3	4.9005
Urban Mixed Use (in areas around Centers)	-	0.35	0.45	-	13.00	10.89	-	4.55	4.9005
Institutional	-	-	1.00	-	-	10.02	-	-	10.02
Office / R & D / Flex / Light Industrial	-	-	0.80	-	-	10.02	-	-	8.016
Commercial Mixed Use	-	-	0.80	-	-	10.02	-	-	8.016
Light Industrial	-	-	0.80	-	-	10.89	-	-	8.712
Airport District	-	-	-	-	-	-	-	-	-
Privately Owned Open Space; Environmental Features	-	-	-	-	-	-	-	-	-
Heavy Industrial	-	-	1.00	-	-	10.02	-	-	10.02
Public Open Space	-	-	-	-	-	-	-	-	-

Table A-9: Southern & Western Land Use Development Factor Assumptions

Land Use	Sector Area Fraction Sector Area/Total Area			Sector Area Development Density Units or ksf/Sector Area			Sector Development Factors Units or ksf/Total Area		
	SF	MF	NR	SF	MF	NR	SF	MF	NR
Neighborhood Density Residential	0.80	-	-	4.50	-	-	3.6	-	-
Office / R & D / Flex / Light Industrial	-	-	1.00	-	-	10.02	-	-	10.02
Institutional	-	-	1.00	-	-	10.02	-	-	10.02
Urban Density Residential	-	0.80	-	-	13.00	-	-	10.4	-
Industrial	-	-	1.00	-	-	10.89	-	-	10.89
Parks and Green Systems	-	-	-	-	-	-	-	-	-
Community Mixed Use	-	-	0.80	-	-	10.02	-	-	8.016
Regional Mixed Use	-	-	0.80	-	-	10.02	-	-	8.016
Neighborhood Mixed Use	-	-	0.80	-	-	10.02	-	-	8.016

Table A-10: Village of Rivanna Land Use Development Factor Assumptions

Land Use	Sector Area Fraction Sector Area/Total Area			Sector Area Development Density Units or ksf/Sector Area			Sector Development Factors Units or ksf/Total Area		
	SF	MF	NR	SF	MF	NR	SF	MF	NR
Town/Village Center	300 SF units on one specific Development Area (page 36 of Village of Rivanna Master Plan)								
Neighborhood Density Residential	0.80	-	-	4.50	-	-	3.6	-	-
Institutional	-	-	1.00	-	-	10.02	-	-	10.02
Parks and Green Systems	-	-	-	-	-	-	-	-	-
Neighborhood Density Residential Low	0.80	-	-	2.00	-	-	1.6	-	-

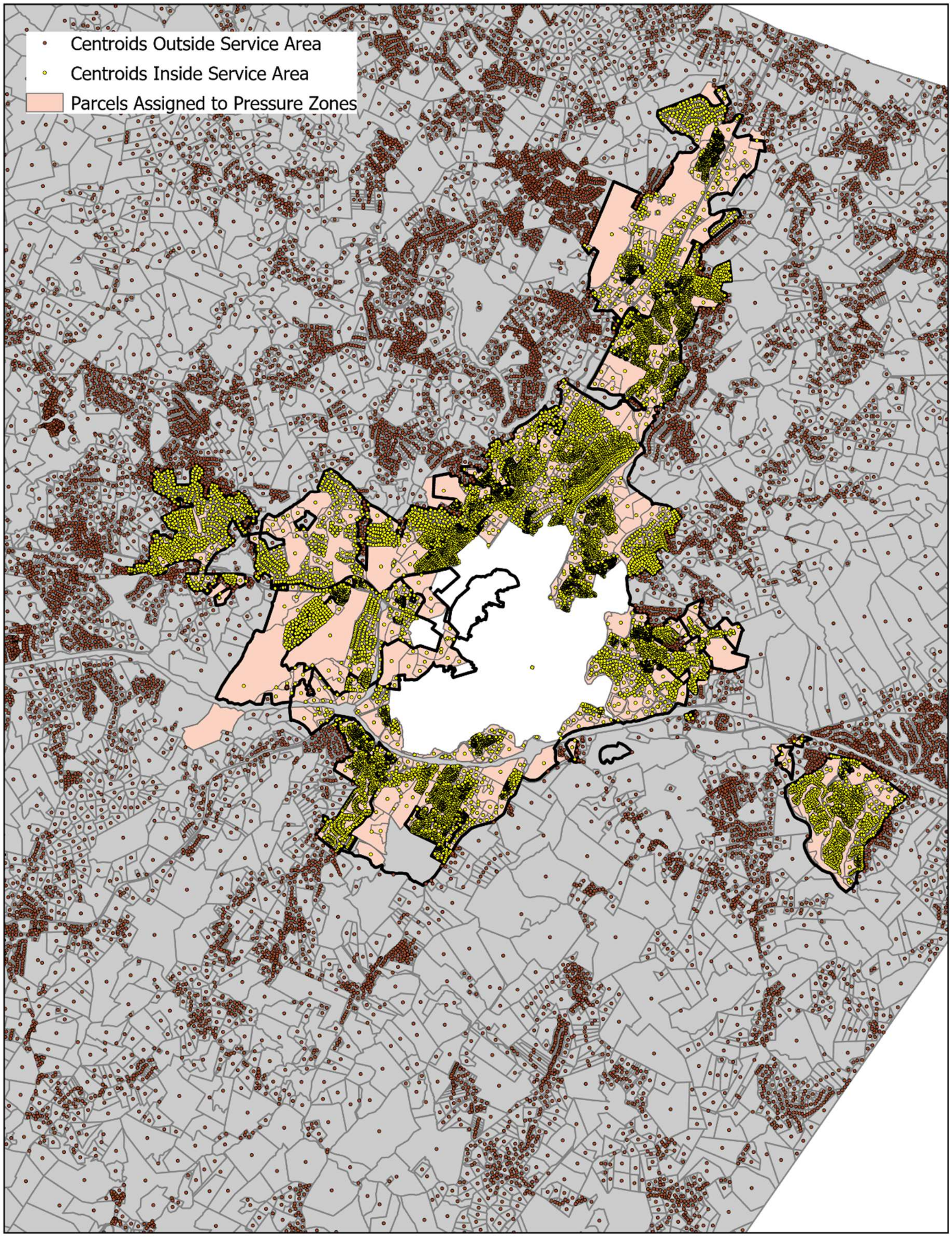


Figure A-18: County Parcels, Parcel Centroids, and Assignment of Parcels to Pressure Zones

Figure A-19: Deletion of Parcel Areas Overlapped by Higher-priority Partitions

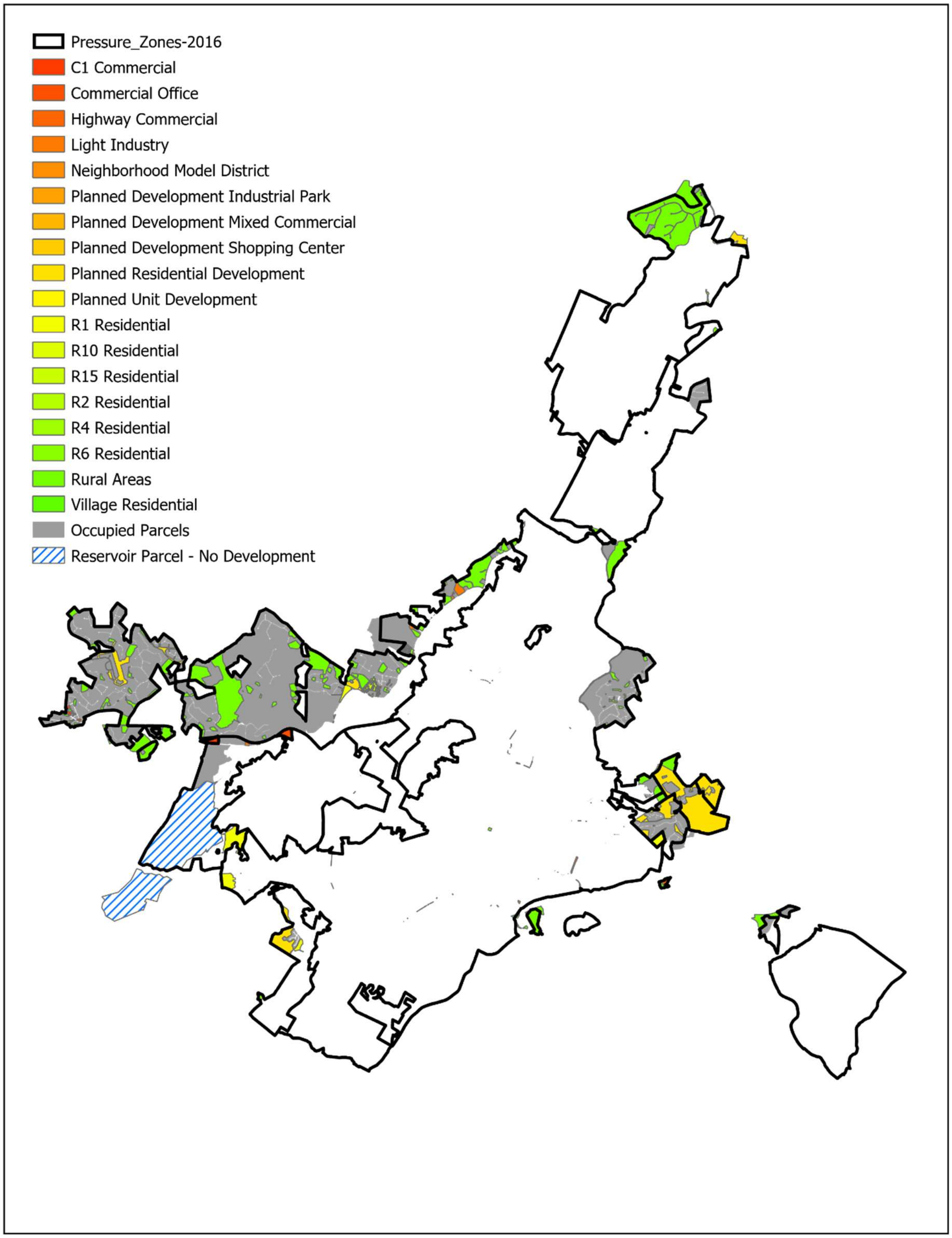


Figure A-20: Occupied and Unoccupied County Parcel Partitions

- Remaining parcels and portions of parcels were then grouped into partitions according to their pressure zone as well as whether they were vacant or occupied. Vacant parcels were those whose *UseCode* values were either 'Vacant Commercial Land' or 'Vacant Residential Land', parcels with other values were considered occupied. Vacant parcels were further partitioned by their *ZONING* values. These occupancy- and zoning-based partitions allowed the forecast to assume that vacant parcels would be developed according to zoning classifications and occupied parcels to not undergo any development (Figure A-20). One large parcel was identified in the extreme southwest of the service area that was considered vacant but that, in actuality, housed a water supply reservoir; this parcel was manually moved to the Occupied partition to prevent assumptions of future development therein.

Finally, SF, MF, and NR development factors (units/acre and sq. ft/acre) were assumed for each *ZONING* value among vacant County parcels (Table A-). These factors were inferred from specifications in zoning ordinance documents where possible.

Table A-11: Vacant County Parcel Development Factor Assumptions

ZONING	SF unit/ac	MF unit/ac	NR ksf/ac
Rural Areas	0.5		
R1 Residential	0.97		
R2 Residential	2		
R10 Residential	10		
R15 Residential		15	
R4 Residential	4		
R6 Residential	6		
Planned Residential Development		35	
Planned Unit Development		35	
C1 Commercial			10.02
Planned Development Industrial Park			10.89
Planned Development Mixed Commercial			10.02
Planned Development Shopping Center			10.02
Commercial Office			10.02
Highway Commercial			10.02
Light Industry			10.89
Neighborhood Model District	4.5		
Village Residential	0.7		

Combined Partitions. As with the City, land use and pressure zone partitions were used simultaneously in forecasting, such that each forecast partition corresponded to a specific combination of future land use and pressure zone. While these represent too many combinations to sensibly display on a map, Figure A-21 provides an indication of the associated partition granularity.

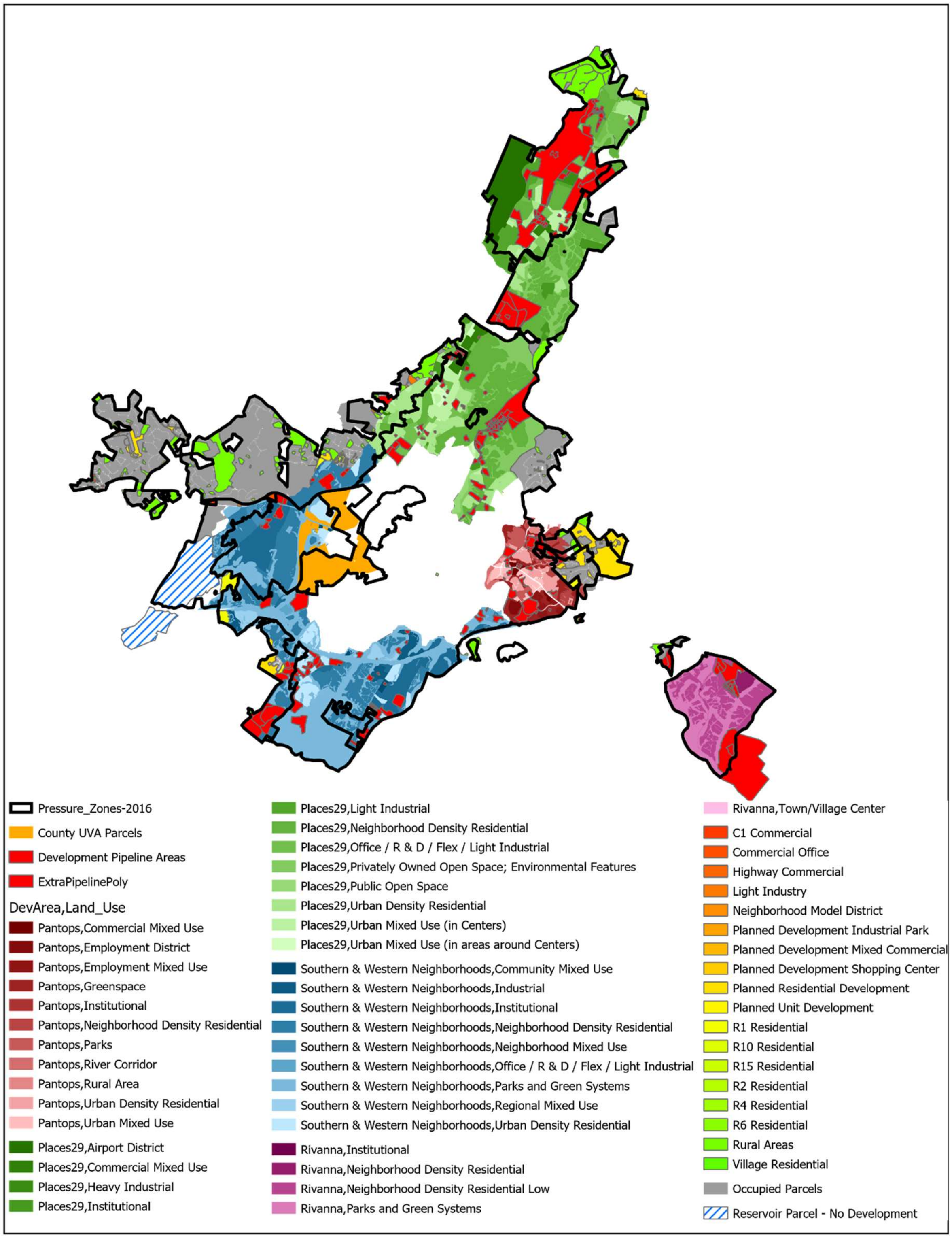


Figure A-21: Complete City Land Use Partition.

A.2.1 County Development Pacing

Having created the partitions as described above, the next step was to develop assumptions regarding the pace of development within them such that in aggregate they match the population forecasts for the County portion of the service area. Those target population values are described in Section 3.2, Table 3-2. The values shown in Table A-12 describe the progress at each time horizon between existing development density as of 2017 and maximum build-out densities (described in Section A.2 above) such that they produce reasonable facsimiles of the forecasted population for the ACSA portion of the service area at those intervals. The Development Pipeline partition was developed to the extent needed to create the number of housing units expected by the ACOCD in a spreadsheet titled “Capacity_Estimate_RWSA_20190118.xlsx”. Additional population capacity was tied to new housing units and the persons per dwelling factor used with single family and multifamily housing units (2.53 for SFDUs, 2.01 for MFDUs).

Table A-12: Development Pacing for ACSA

Partition	2030	2045	2070
Development Pipeline	31%	33%	33%
Places 29	8%	24%	34%
Pantops	8%	24%	34%
S&W Neighborhoods	8%	24%	34%
Village of Rivanna	8%	24%	34%
Vacant/Undeveloped Outside masterplanned areas	8%	24%	34%

Appendix B: Water Intensity Model Details

B.1 Unit Demand Factor Analysis

To complete the buildout demand forecast, it was necessary to estimate future sectoral demand intensities, or single-family demand per dwelling unit, multifamily demand per dwelling unit, and nonresidential demand per square foot. Several published data sources exist that benchmark these values on a national average basis, but when forecasting it is generally best to produce estimates specific to the local service area, thereby accounting for socioeconomic, climatic, and development history and conditions. Individual-meter water use data paired with property appraiser data are often used for these purposes; meters are determined as serving specific SF, MF or NR properties, the number of dwelling units or square feet on each property is determined, and average intensities are determined within each sector as total consumption over a given time period divided by total units or square footage. Usually, a complete matching of all meters to property appraiser data is not available, but a sample of meters associated with property data is sufficient to produce intensity averages.

For RWSA, demand intensities in single-family, multifamily, and nonresidential water use sectors were estimated using City and County meter data for FY 2017, GIS data for meter locations and parcel polygons, and tabular information describing structures on parcels from the City from Charlottesville and the Albemarle County Office of Community Development.

B.1.1 Sectoral Classification of Meters

Both the City and County provided data indicating the type of development (SF, MF, or NR) served by each meter. For the City, use classification for each meter was recorded in a column called *Class* within the historical consumption Excel files. Meters with a *Class* value of ‘R’ and ‘M’ reflected single-family and multifamily use, respectively, while all other codes indicated nonresidential use. Visual comparison of meter locations with aerial and street-view imagery indicated that *Class* values generally aligned with the development characteristics used to define single-family and multi-family in this study. Therefore, *Class* values were used to assign City meters to water use sectors for demand intensity estimations.

For the County, use classification for each meter was indicated in a column called *UserTypeCo* within the GIS attribute table of the County’s meter layer. *UserTypeCo* values contained variants of the text “SF Residential’, ‘MF Residential’, ‘Commercial’, ‘Institutional’, or ‘Industrial’ to indicate types of use. The ACSA generally assigns the ‘SF Residential’ *UserTypeCo* to all dwellings that are individually metered, whether they are detached single-family houses, or multi-unit condominiums or apartments. The ‘MF Residential’ *UserTypeCo* is reserved for master metered apartments and multi-unit housing. Therefore, ‘SF Residential’ accounts were reviewed with aerial and street-view imagery and, if needed, reassigned to the MF designation based on the physical development characteristics[5]. For example, the apartment complex in Figure B-1 consists of multi-unit apartment buildings, the parcel for one of which is

[5] Utilities usually apply sectoral classifications to meters to assign particular rate structures to those meters’ consumption. There may be many reasons behind assignments for individual meters that extend beyond the physical characteristics of the served properties. The adjustments to classifications made here were for purposes of demand forecasting only.

highlighted. However, this parcel and associated buildings are served by meters having *UserTypeCo* 'SF Residential' codes which were initially assumed to indicate single-family residential customers. Once this was discovered, it was determined the accounts across the ACSA system would need further review for consistent classification throughout the study because the code is inconsistent, in these cases, with true nature of the development; a set of multi-unit structures with common areas rather than individual detached houses with separate exterior areas. Because differences in water use behavior between sectors are usually influenced by physical characteristics such as these, it was necessary to classify County meters into water use sectors using a method that represented the physical characteristics of the residential structure. To this end, the following steps were taken:

- Using a GIS spatial join, each meter was identified with whichever parcel contained it or, if it was outside any parcel, whichever parcel was closest (up to a distance of 100 feet).
- Sectoral classification of each meter was then derived from land use data for its associated parcel (in parcel tables obtained from the ACOCD). The column *UseCode* in these tables described the use of each parcel in terms such as 'Apartments', 'Auditorium', 'Bank', 'Service Station', 'Single Family', etc. Each of these terms clearly related to notions of single-family, multifamily, or nonresidential land use (Table B-1), so sectoral assignments based on *UseCode* were used instead of *UserTypeCo* values when estimating sectoral demand intensity.

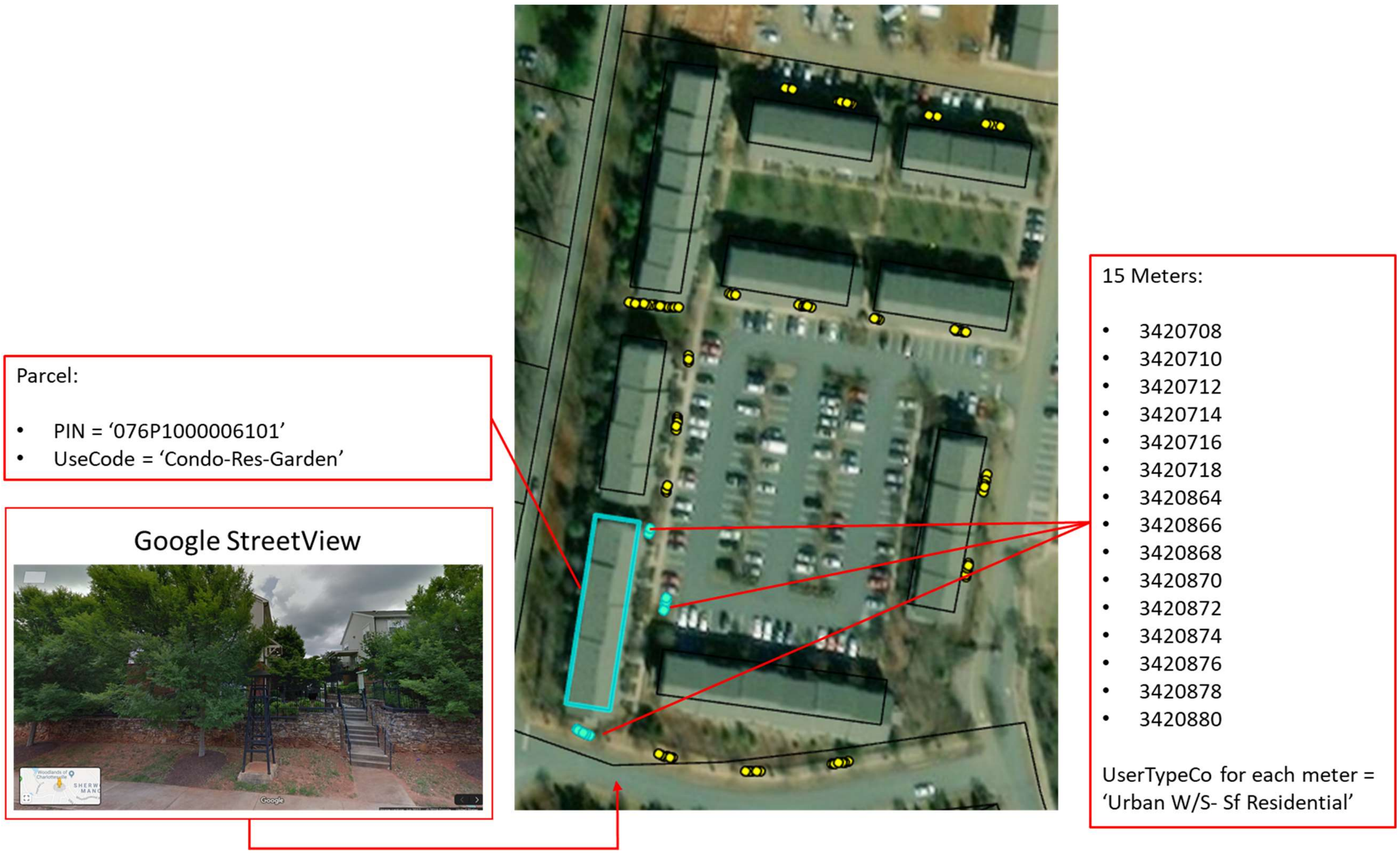


Figure B-1: Example of Different Land Use Classification by ACSA (UserTypeCo for meters) and ACOCD (UseCode for parcels)

Table B-1: Mapping of Parcel Use Codes to Water Use Sectors for County Meters

Single-family (SF): Doublewide, Loft, Mobile Home, Rectory, Single Family, Single Family-Rental, Vacant (R5-R6), Vacant Residential Land	
Multifamily (MF): 3-4 Family, Apartment, Apartments, Apartments (21+Units), Condo-Res-Garden, Condo-Res-TH, Dormitory, Duplex, Fraternity House, Mobile Home Park, Multi Resid Lo Rise Shell, Multi-Family, Multi-Family – Income, Multiple Res - Senior Citizen, Multiple Resid. (Low Rise), Small Apartment	
Nonresidential (NR): All other codes. Examples:	
Administration Bldg	Barber Shop
Armory	Barn
Auditorium	Bed & Breakfast
Auto Dealership Complete	Bowling Alley
Automobile Showroom	Business - Rural
Automotive Center	Cafeteria
Bank	etc.

In the example of Figure B-1, each of the highlighted meters was classified in the multifamily sector due to their proximity to the highlighted parcel.

Single Family Intensity. Following sectoral classification of meters, intensities were estimated for each water use sector using FY 2017 consumption data and estimates of the numbers of dwelling units or square feet in each sector. The single-family sector was most straightforward, as intensity was estimated by assuming each single-family meter served a single dwelling unit.

- City and County consumption records generally consisted of total volume metered over a 30- to 60-day period. For each single-family meter and each reading over July 2016 to June 2017, total gallons consumed and number of days between readings was obtained.
- All single-family consumption volumes thus obtained were summed, producing total gallons consumed through SF meters in FY 2017. Likewise, the numbers of days between readings were summed across all records, producing total meter-consumption-days through SF meters in FY 2017.
- Assuming each meter was associated with one SF unit, average SF demand intensity in gallons per unit per day was determined for FY 2017 by dividing total SF gallons by total SF meter-consumption-days. This estimate was a single average over all readings in FY 2017, reflecting no seasonality due to summer/winter weather or student occupancy.

Average single-family intensity for FY 2017 was estimated to be 109.4 gal/dwelling unit/day.

Table B-2: Estimated FY 2017 Demand Intensities by Sector

Sector	Estimated Intensity
Single-family	109.4 gal/unit/day
Multifamily	79.5 gal/unit/day
Non-Residential	75.0 gal/ksf/day

Nonresidential Intensity. Nonresidential intensities were estimated from total gallons and meter-consumption-days for NR meters over FY 2017, then dividing total gallons divided by total days to produce average gallons per NR meter per day, then dividing that number by the total number of nonresidential building square feet served by those meters.

- Total building square footage on each parcel was provided by both the City and the ACOCD.
- Land use data for County parcels were taken from the same parcel data file and *UseCode* column used to classify County meters. Land use data for City parcels were contained in a similar *UseCode* column in a similar parcel file to that of the County. The City *UseCode* values were used to identify NR parcels in a manner similar to the County parcels.
- Assuming that each NR parcel within the City and County service areas was served by one of the two utilities, total NR square footage was taken as the sum of square footage across City and County parcels contained within the service area (i.e., mapped to some pressure zone). This total square footage was used as the divisor to determine NR intensity in gallons per thousand square feet per day.
- Average nonresidential intensity for FY 2017 was estimated to be 75.0 gal/ksf/day.

Multifamily Intensity. To estimate multifamily intensity, it was necessary to know the number of dwelling units served by each multi-family meter used in the estimate. This requirement generally arises since meters that serve multifamily structures often serve more than one dwelling unit, or even all units, in those structures. Usually, property appraisers can provide information on the number of dwelling units for multifamily parcels; then, through a matching of meters to parcels, consumption per multifamily dwelling unit can be estimated. Unfortunately, neither the City nor the ACOCD had this information generally available for all multifamily parcels. ACOCD, however, was able to provide parcel-level unit information for those multifamily developments constructed after 2000 (including “single-family townhomes”, which were regarded as multifamily structures in this estimate) through Certificate of Occupancy records. Thus, it was possible to identify 3024 dwelling units across 1139 parcels for 36 multifamily properties (Table B-3), and those units were served by a total of 1089 meters matched to their parcels through the sectoral identification process. Even though this represented a subset of newer multifamily dwellings in the County service area only, it was sufficient to produce a reasonable multifamily intensity estimate that could be applied across the region. Average nonresidential intensity for FY 2017 was estimated to be 79.5 gal/ksf/day. Note that this estimate might benefit from greater availability of dwelling unit information, particularly for properties that are older and in denser areas such as the City.

Table B-3: Properties Contained in the Multifamily Intensity Estimation Sample

Development or Location	Type	Number of Meters	Number of Parcels	Number of Dwelling Units
Arden Place	Multifamily	7	7	212
Bailey House Avermore	Multifamily	1	1	92
Carriage Gate	Multifamily	2	2	28
Cavalier Crossing	Multifamily	7	11	132
Commonwealth Senior Living	Multifamily	1	1	86
Eagles Landing Apts	Multifamily	10	18	504
Haven At Stonefield	Multifamily	8	9	276
Jefferson Ridge	Multifamily	5	6	150
Park View at South Pantops	Multifamily	1	1	90
Riverbed Condos Missing 30 Units	Multifamily	2	6	197
Treesdale Park	Multifamily	8	4	88
White Gables Condos Missing 1 Bldg	Multifamily	2	2	20
Woodlands Of Charlottesville	Multifamily	10	10	111
Avinity Loop	Townhome	107	102	102
Belvedere Blvd	Townhome	19	19	19
BlueJay Way	Townhome	37	35	35
Carrington PL	Townhome	9	9	9
Chatham Rdg	Townhome	15	13	13
Elm Tree	Townhome	65	63	63
Glenwood Station	Townhome	29	28	28
Lochlyn Hill Dr	Townhome	5	5	5
Lockwood	Townhome	17	17	17
More Belvedere	Townhome	20	19	19
Pantops Cottage	Townhome	17	17	17
Pebble Beach Ct	Townhome	39	39	39
Rolkin Rd	Townhome	349	343	343
Silk Wood Ct	Townhome	26	25	25
Somer Chase	Townhome	64	64	64
Stonehenge Way	Townhome	14	14	14
Templehof	Townhome	21	22	22
Timberwood	Townhome	72	71	71
TownBrook Crossing	Townhome	18	17	17
Tudor Ct	Townhome	44	44	44
Turnberry	Townhome	32	32	32
Webland	Townhome	6	40	40
	TOTALS	1089	1116	3024

B.2 City and County Buildout Forecasts

Buildout forecasts were developed by multiplying future SF and MF dwelling unit and NR square footage projections for each partition by the demand intensities found in Table B-2.

- **City of Charlottesville.** Tables B-4 through B-6 show total and sectoral current demands and buildout forecasts by land use/pressure zone partition for the City. Table B-7 shows total City demands from these tables summed to pressure zone. Total buildout demand for the City is estimated at 8.01 MGD, while current demand is 3.01 MGD.

- **ACSA.** Tables B-8 through B-15 show total and sectoral current demands and buildout forecasts by land use/pressure zone partition for ACSA. Table B-16 shows total ACSA demands from these tables summed to pressure zone. Total ACSA buildout demand is estimated at 9.82 MGD, while current demand is 4.03 MGD.

The magnitudes of buildout demand in comparison to current demand may seem shocking at first. However, it should be noted that buildout demand assumes that every possible portion of area is developed to full capacity according to development factor assumptions, with multiple caveats:

- No assumption is made of when actual buildout conditions are achieved, *if ever*. Buildout demand merely serves as a maximum limit for future demand and as an endpoint for gradual pacing of actual demand projections over time, an exercise that is described in Appendix A.

- The nature of buildout is subject to planning changes. Actual development intensity in the future may differ from current assumptions of development factors, especially if public support of or opposition to development changes. Also, when expressed in ordinances and master plans, these factors may have been determined based on multiple development goals and criteria, of which future water demand is only one. Development intensity changes directly impact the number of sectoral water users, and thus demand, at buildout.

- Buildout demand as calculated in this work does not include any consideration of increasing water use efficiency in the future. Starting in the early 1980’s, water using appliances (toilets, washing machines, etc.) available in the marketplace have become substantially more efficient as each year has passed. This trend is expected to continue over the long term. As old appliances reach end-of-life and are replaced, the modern replacement appliances will therefore necessarily use less water than their predecessors. Estimation of this effect is beyond the scope of this work but would undoubtedly have an effect of reducing buildout demand.

Table B-4: City of Charlottesville Current Demand and Buildout Forecast: Mixed-Use Redevelopment Areas

ZONE	Pressure Zone	Total	Future Land Use[A]		Sectoral Demands[B]		Total gal/day Demands	
		Acres	MF units	NR ksf	MF gpd	NR gpd	Buildout	Current
CC	Urban (652')	26.6	1277	532	101523	39907	141429	17506
D	Urban (652')	11.5	553	230	43927	17267	61194	9551
DE	Urban (652')	66.8	3208	1337	255071	100264	355335	46051
DEH	Urban (652')	7.7	371	154	29476	11587	41063	18778
DH	Urban (652')	37.3	1788	745	142159	55880	198038	119555
DN	Urban (652')	24.0	1151	480	91518	35974	127492	13117
DNC	Urban (652')	5.2	250	104	19900	7822	27723	5423
DNH	Urban (652')	12.8	615	256	48862	19207	68069	8299
HS	Urban (652')	17.2	825	344	65580	25778	91359	12972
HSC	Urban (652')	1.5	72	30	5752	2261	8013	465
HW	Urban (652')	219.2	10520	4383	836372	328762	1165134	222731
MedCenterHalfMile	Lambeth	10.8	519	216	41277	16225	57503	14068
MedCenterHalfMile	Lewis Mountain (751')	3.8	183	76	14537	5714	20251	365
MedCenterHalfMile	Urban (652')	556.5	26713	11131	2123723	834797	2958520	591087
MedCenterHalfMile	UVA (749')	0.2	9	4	717	282	999	0
NCC	Urban (652')	16.8	808	337	64273	25265	89537	13771
NCCH	Urban (652')	0.3	13	5	1033	406	1439	1539
SSH	Urban (652')	1.6	77	32	6109	2401	8510	2513
URB	Lewis Mountain (751')	8.6	412	172	32778	12884	45662	17108
URB	Urban (652')	57.7	2769	1154	220171	86545	306717	57020
URB	UVA (749')	7.8	374	156	29748	11693	41441	3640
URBH	Urban (652')	39.7	1905	794	151456	59534	210990	36588
WMEH	Urban (652')	2.6	125	52	9910	3895	13805	2699
WSH	Urban (652')	10.2	488	203	38779	15243	54022	19849
						Total (MGD)	**6.13**	**1.23**

A – Acres times development factors in Table A-3.

B – Future land use times demand intensities in Table B-2.

Table B-5: City of Charlottesville Current Demand and Buildout Forecast: Vacant Areas Outside Mixed-Use Redevelopment Areas

ZONE	Pressure Zone	Total Acres	Future Land Use[A]			Sectoral Demands[B]			Total gal/day Demands	
			SF units	MF units	NR ksf	SF gpd	MF gpd	NR gpd	Buildout	Current
B-1	Urban (652')	24.4	0	0	245	0	0	18363	18363	1901
B-1H	Urban (652')	0.0	0	0	0	0	0	17	17	0
B-2	Urban (652')	7.5	0	0	75	0	0	5647	5647	7116
B-3	Urban (652')	1.0	0	0	10	0	0	755	755	803
ES	Urban (652')	6.1	0	0	61	0	0	4607	4607	0
IC	Urban (652')	11.1	0	0	121	0	0	9045	9045	506
M-I	Urban (652')	6.9	0	0	76	0	0	5675	5675	398
MR	Urban (652')	2.7	0	56	0	0	4436	0	4436	295
Park	Urban (652')	120.1	0	0	0	0	0	0	4987	4987
PUD	Urban (652')	58.0	174	0	0	19021	0	0	19021	4557
PUDH	Urban (652')	0.1	1	0	0	123	0	0	123	0
R-1	Lambeth	6.3	19	0	0	2053	0	0	2053	607
R-1	Urban (652')	75.1	225	0	0	24632	0	0	24632	1234
R-1H	Urban (652')	0.4	1	0	0	138	0	0	138	88
R-1S	Urban (652')	103.7	829	0	0	90742	0	0	90742	10183
R-1SC	Urban (652')	0.6	2	0	0	187	0	0	187	0
R-1SH	Urban (652')	1.2	4	0	0	410	0	0	410	287
R-1SU	Urban (652')	0.3	1	0	0	106	0	0	106	131
R-1U	Lambeth	7.4	22	0	0	2439	0	0	2439	1137
R-1U	Lewis Mountain (751')	1.7	5	0	0	565	0	0	565	132
R-2	Urban (652')	41.7	334	0	0	36492	0	0	36492	11926
R-2H	Urban (652')	0.9	8	0	0	823	0	0	823	254
R-2U	Lambeth	0.9	7	0	0	760	0	0	760	0
R-2U	Urban (652')	3.9	31	0	0	3375	0	0	3375	396
R-3	Lambeth	0.3	0	12	0	0	934	0	934	0
R-3	Urban (652')	37.7	0	1622	0	0	128966	0	128966	15038
R-3H	Lambeth	1.0	0	66	0	0	5269	0	5269	107
R-3H	Urban (652')	1.0	0	65	0	0	5134	0	5134	401
								Total (MGD)	**0.37**	**0.06**

A – Acres times development factors in Table A-3.

B – Future land use times demand intensities in Table B-2.

Table B-6: City of Charlottesville Current Demand: Occupied Areas Outside Mixed-Use Redevelopment Areas (Assumed to Not Change in Future)

Pressure Zone	Current Demand, MGD
Lewis Mountain (751')	0.05
Urban (652')	1.48
Lambeth	0.17
Stillhouse (796')	<0.01
UVA (749')	0.02
Total	**1.72**

Table B-7: City of Charlottesville Current Demand and Buildout Forecast by Pressure Zone

Pressure Zone	Total Demand, MGD	
	Current	Buildout
Lewis Mountain (751')	0.06	0.11
Urban (652')	2.74	7.58
Lambeth	0.18	0.23
Stillhouse (796')	<0.01	<0.01
UVA (749')	0.02	0.10
Total	**3.01**	**8.01**

Table B-8: ACSA Current Demand and Buildout Forecast: Development Pipeline

Pressure Zone	Future Land Use[A]			Sectoral Demands[B]			Total gal/day Demands	
	SF units	MF units	NR ksf	SF gpd	MF gpd	NR gpd	Buildout	Current
Urban (652’)	2714	5126	3111	296912	407517	233305	937734	269624
Piney Mountain (806’)	1730	1924	365	189262	152958	27373	369593	77724
Ashcroft Low (912')	180	0	0	19692	0	0	19692	1257
Mosby Mountain (750')	277	0	0	30304	0	0	30304	9103
Lewis Mountain (751')	76	65	16	8314	5168	1163	14645	14952
Stillhouse (796')	67	40	124	7330	3180	9328	19838	3270
Mill Creek (750')	30	0	0	3282	0	0	3282	0
						Total (MGD):	**1.40**	**0.37**

A – Specified in Development Permits. B – Future land use times demand intensities in Table B-2.

Table B-9: ACSA Current Demand and Buildout Forecast: Extra Pipeline

Development Name and Pressure Zone	Future Land Use[A]		Sectoral Demands[B]		Total gal/day Demands	
	MF units	NR ksf	MF gpd	NR gpd	Buildout	Current
Martha Jefferson Hospital: Urban (652’)	0	540	0	48600	0.049	0
Fontaine Research Park: Urban (652’)	0	866	0	64950	0.065	0
UVA Research Park: Piney Mountain (806’)	500	2000	39750	150000	0.190	0

A – Specified in Development Permits. B – Future land use times demand intensities in Table B-2, except for Martha Jefferson Hospital whose demand intensity was assumed to be 90 gal/ksf/day.

Table B-10: ACSA Current Demand and Buildout Forecast: Pantops Development Area

Land Use	Pressure Zone	Total Acres	Future Land Use[A]			Sectoral Demands[B]			Total gal/day Demands	
			SF units	MF units	NR ksf	SF gpd	MF gpd	NR gpd	Buildout	Current
Greenspace	Ashcroft Low (912')	47.9	0	0	0	0	0	0	0	1154
Neighborhood Density Residential	Ashcroft Low (912')	101.7	366	0	0	40065	0	0	40065	26766
Rural Area	Ashcroft Low (912')	2.0	0	0	0	0	0	0	0	0
Commercial Mixed Use	Urban (652')	30.3	0	79	182	0	6266	13670	19936	17970
Employment District	Urban (652')	32.3	0	0	259	0	0	19408	19408	14857
Employment Mixed Use	Urban (652')	66.3	0	172	398	0	13698	29881	43579	22962
Greenspace	Urban (652')	320.5	0	0	0	0	0	0	0	2643
Institutional	Urban (652')	1.2	0	0	7	0	0	532	532	300
Neighborhood Density Residential	Urban (652')	133.9	482	0	0	52747	0	0	52747	19764
Parks	Urban (652')	107.7	0	0	0	0	0	0	27	27
River Corridor	Urban (652')	69.1	0	0	0	0	0	0	0	0
Rural Area	Urban (652')	30.9	0	0	0	0	0	0	0	0
Urban Density Residential	Urban (652')	211.4	0	2199	0	0	174822	0	174822	182387
Urban Mixed Use	Urban (652')	119.6	0	544	586	0	43266	43961	87227	60446
								Total (MGD)	**0.44**	**0.35**

A – Acres times development factors in Table A-7. B – Future land use times demand intensities in Table B-2.

Table B-11: ACSA Current Demand and Buildout Forecast: Village of Rivanna Development Area

Land Use	Pressure Zone	Total Acres	Future Land Use[A]			Sectoral Demands[B]			Total gal/day Demands	
			SF units	MF units	NR ksf	SF gpd	MF gpd	NR gpd	Buildout	Current
Institutional	Urban (652')	0.5	0	0	5	0	0	351	351	662
Neighborhood Density Residential	Urban (652')	70.6	254	0	0	27821	0	0	27821	0
Neighb. Density Residential Low	Urban (652')	680.6	1089	0	0	119133	0	0	119133	126106
Parks and Green Systems	Urban (652')	714.3	0	0	0	0	0	0	13264	13264
Town/Village Center	Urban (652')	1.3	300[C]	0	0	32820	0	0	32820	0
								Total (MGD)	**0.19**	**0.14**

A – Acres times development factors in Table A-10. B – Future land use times demand intensities in Table B-2. C – Units explicitly specified in Master Plan

Table B-12: ACSA Current Demand and Buildout Forecast: Places29 Development Area

Land Use	Pressure Zone	Total Acres	Future Land Use[A]			Sectoral Demands[B]			Total gal/day Demands	
			SF units	MF units	NR ksf	SF gpd	MF gpd	NR gpd	Buildout	Current
Airport District	Piney Mountain (806')	607.9	0	0	0	0	0	0	0	4887
Commercial Mixed Use	Piney Mountain (806')	39.5	0	0	317	0	0	23763	23763	20930
Heavy Industrial	Piney Mountain (806')	40.4	0	0	405	0	0	30353	30353	6475
Institutional	Piney Mountain (806')	<0.1	0	0	0	0	0	1	1	0
Light Industrial	Piney Mountain (806')	309.0	0	0	2692	0	0	201870	201870	18911
Neighborhood Density Residential	Piney Mountain (806')	458.9	1652	0	0	180733	0	0	180733	65214
Office / R & D / Flex / Light Industrial	Piney Mountain (806')	287.8	0	0	2307	0	0	173023	173023	44288
Privately Owned Open Space; Env. Features	Piney Mountain (806')	32.9	0	0	0	0	0	0	1538	1538
Urban Density Residential	Piney Mountain (806')	297.2	0	3090	0	0	245688	0	245688	33482
Urban Mixed Use (in areas around Centers)	Piney Mountain (806')	5.2	0	24	25	0	1882	1912	3794	1538
Urban Mixed Use (in Centers)	Piney Mountain (806')	126.3	0	796	619	0	63261	46423	109684	28098
Commercial Mixed Use	Stillhouse (796')	4.9	0	0	39	0	0	2961	2961	1782
Institutional	Stillhouse (796')	26.6	0	0	266	0	0	19972	19972	5060
Neighborhood Density Residential	Stillhouse (796')	23.9	86	0	0	9397	0	0	9397	7750
Office / R & D / Flex / Light Industrial	Stillhouse (796')	30.3	0	0	243	0	0	18225	18225	4443
Privately Owned Open Space; Env. Features	Stillhouse (796')	2.4	0	0	0	0	0	0	0	0
Public Open Space	Stillhouse (796')	36.2	0	0	0	0	0	0	11321	11321
Urban Density Residential	Stillhouse (796')	250.9	0	2610	0	0	207456	0	207456	226161
Urban Mixed Use (in Centers)	Stillhouse (796')	22.2	0	140	109	0	11132	8169	19301	8419
Commercial Mixed Use	Urban (652')	140.0	0	0	1122	0	0	84158	84158	56242
Institutional	Urban (652')	154.6	0	0	1549	0	0	116203	116203	7486
Neighborhood Density Residential	Urban (652')	2249.1	8097	0	0	885768	0	0	885768	503796
Office / R & D / Flex / Light Industrial	Urban (652')	164.2	0	0	1316	0	0	98706	98706	84895
Privately Owned Open Space; Env. Features	Urban (652')	1049.3	0	0	0	0	0	0	20834	20834
Public Open Space	Urban (652')	64.8	0	0	0	0	0	0	1116	1116
Urban Density Residential	Urban (652')	636.0	0	6614	0	0	525825	0	525825	501589
Urban Mixed Use (in areas around Centers)	Urban (652')	84.8	0	386	416	0	30680	31173	61852	10482
Urban Mixed Use (in Centers)	Urban (652')	231.4	0	1458	1134	0	115875	85032	200908	93528
								Total (MGD)	**3.26**	**1.77**

A – Acres times development factors in Table A-8. B – Future land use times demand intensities in Table B-2.

Table B-13: ACSA Current Demand and Buildout Forecast: Vacant Land outside County Development Areas (Ashcroft High through Piney Mountain Pressure Zones)

ZONING	Pressure Zone	Total Acres	Future Land Use[A]			Sectoral Demands[B]			Total gal/day Demands	
			SF units	MF units	NR ksf	SF gpd	MF gpd	NR gpd	Buildout	Current
Planned Residential Development	Ashcroft High (1341')	7.2	0	253	0	0	20147	0	20147	0
Planned Residential Development	Ashcroft Low (912')	69.9	0	2448	0	0	194583	0	194583	0
R1 Residential	Ashcroft Low (912')	0.3	0	0	0	31	0	0	31	0
Rural Areas	Ashcroft Low (912')	31.7	16	0	0	1732	0	0	1732	0
Planned Residential Development	Ashcroft Middle	350.0	0	12249	0	0	973783	0	973783	0
Rural Areas	Ashcroft Middle	25.9	13	0	0	1415	0	0	1415	0
Highway Commercial	Ednam (880')	1.1	0	0	11	0	0	857	857	0
Light Industry	Ednam (880')	2.7	0	0	29	0	0	2193	2193	61
R1 Residential	Ednam (880')	58.0	56	0	0	6158	0	0	6158	0
Rural Areas	Ednam (880')	1032.0	0[C]	0	0	0	0	0	1843	1843
Commercial Office	Lewis Mountain (751')	0.0	0	0	0	0	0	0	0	0
Highway Commercial	Lewis Mountain (751')	0.0	0	0	0	0	0	0	0	0
R1 Residential	Lewis Mountain (751')	1.9	2	0	0	202	0	0	202	0
R15 Residential	Lewis Mountain (751')	0.0	0	1	0	0	42	0	42	0
Planned Residential Development	Mosby Mountain (750')	70.6	0	2470	0	0	196372	0	196372	0
R1 Residential	Mosby Mountain (750')	8.3	8	0	0	876	0	0	876	0
Rural Areas	Mosby Mountain (750')	4.9	2	0	0	269	0	0	269	0
Light Industry	Piney Mountain (806')	0.4	0	0	4	0	0	299	299	0
Planned Development Ind. Park	Piney Mountain (806')	1.7	0	0	19	0	0	1415	1415	0
Planned Residential Development	Piney Mountain (806')	32.1	0	1124	0	0	89347	0	89347	0
Rural Areas	Piney Mountain (806')	456.1	228	0	0	24948	0	0	24948	15863
								Total (MGD)	**1.51**	**0.02**

A – Acres times development factors in Table A-11. B – Future land use times demand intensities in Table B-2.
C – Partition corresponds to Ragged Mountain Protected Area. Assumed no development.

Table B-14: ACSA Current Demand and Buildout Forecast: Vacant Land outside County Development Areas (Stillhouse and Urban Pressure Zones)

ZONING	Pressure Zone	Total Acres	Future Land Use[A]			Sectoral Demands[B]			Total gal/day Demands	
			SF units	MF units	NR ksf	SF gpd	MF gpd	NR gpd	Buildout	Current
C1 Commercial	Stillhouse (796')	13.4	0	0	134	0	0	10084	10084	0
Commercial Office	Stillhouse (796')	12.9	0	0	129	0	0	9699	9699	0
Light Industry	Stillhouse (796')	18.2	0	0	198	0	0	14851	14851	449
Neighborhood Model District	Stillhouse (796')	1.1	5	0	0	530	0	0	530	0
Planned Residential Development	Stillhouse (796')	89.4	0	3131	0	0	248891	0	248891	0
R1 Residential	Stillhouse (796')	13.1	13	0	0	1395	0	0	1395	0
R10 Residential	Stillhouse (796')	0.0	0	0	0	4	0	0	4	0
R15 Residential	Stillhouse (796')	17.1	0	257	0	0	20409	0	20409	55504
R4 Residential	Stillhouse (796')	0.0	0	0	0	0	0	0	0	0
R6 Residential	Stillhouse (796')	11.3	68	0	0	7396	0	0	7396	4223
Rural Areas	Stillhouse (796')	770.7	385	0	0	42156	0	0	42156	9551
Village Residential	Stillhouse (796')	12.1	8	0	0	926	0	0	926	0
C1 Commercial	Urban (652')	0.0	0	0	0	0	0	23	23	0
Commercial Office	Urban (652')	3.5	0	0	35	0	0	2639	2639	0
Highway Commercial	Urban (652')	4.5	0	0	45	0	0	3403	3403	6038
Light Industry	Urban (652')	0.8	0	0	9	0	0	678	678	0
Neighborhood Model District	Urban (652')	0.0	0	0	0	5	0	0	5	0
Planned Development Mixed Comm.	Urban (652')	1.6	0	0	16	0	0	1221	1221	0
Planned Development Shopping Ctr.	Urban (652')	0.1	0	0	1	0	0	58	58	0
Planned Residential Development	Urban (652')	10.2	0	356	0	0	28323	0	28323	0
Planned Unit Development	Urban (652')	0.2	0	6	0	0	514	0	514	0
R1 Residential	Urban (652')	53.0	51	0	0	5627	0	0	5627	0
R15 Residential	Urban (652')	1.7	0	25	0	0	2010	0	2010	0
R2 Residential	Urban (652')	0.0	0	0	0	3	0	0	3	0
R4 Residential	Urban (652')	9.5	38	0	0	4173	0	0	4173	0
R6 Residential	Urban (652')	1.3	8	0	0	885	0	0	885	0
Rural Areas	Urban (652')	173.1	87	0	0	9469	0	0	9469	1137
								Total (MGD)	**0.42**	**0.08**

A – Acres times development factors in Table A-11. B – Future land use times demand intensities in Table B-2.

Table B-15: ACSA Current Demand: Occupied Areas Outside County Development Areas (Assumed to Not Change in Future)

Pressure Zone	Current Demand, MGD
Ashcroft High (1341')	<0.01
Ashcroft Low (912')	0.02
Ashcroft Middle	<0.01
Ednam (880')	0.01
Lewis Mountain (751')	0.02
Mosby Mountain (750')	0.01
Piney Mountain (806')	<0.01
Stillhouse (796')	0.23
Urban (652')	0.04
Total	**0.32**

Table B-16: ACSA Current Demand and Buildout Forecast by Pressure Zone

Pressure Zone	Total Demand, MGD	
	Current	Buildout
Ashcroft High (1341')	0.00	0.02
Ashcroft Low (912')	0.05	0.27
Ashcroft Middle	0.00	0.98
Ednam (880')	0.04	0.04
Lewis Mountain (751')	0.24	0.75
Mosby Mountain (750')	0.08	0.39
Piney Mountain (806')	0.32	1.65
Stillhouse (796')	0.67	1.04
Urban (652')	2.63	4.69
Total	**4.03**	**9.82**

Appendix C: Annual Weather and Demand Variability Analysis

On time scales as short as a day or as long as a year, weather variations can significantly influence a utility's total demand. Anticipating variability in the demand forecasts due to weather, an analysis was performed to account for the extent of the correlation of weather measures with water demand for this area on an annual basis. An annual basis was chosen since variability at that level would potentially begin to influence the safe yield of RWSA's reservoir system. Fluctuation due to weather, flushing, or fire emergencies at the daily or weekly scale will impact the capacity needs for other types of infrastructure investments such as water treatment and pumping facility size, but it is variability at the annual scale that needs to be accounted for when conducting reservoir yield analyses and determining when it is necessary to bring new reservoir capacity into service.

Weather data (including temperature, precipitation, wind speed, and relative humidity) from 1980 to 2018 was gathered from NOAA's ACIS system including two National Weather Service Cooperative (COOP) stations and the Albemarle airport. Approximately thirty years' worth of data is required to calculate a climate average that is representative of current extremes (IPCC, 2013).

When attempting to use weather variables to explain water demand, it has consistently been found that excluding temperature and precipitation over certain months proved superior to using the entire calendar year of weather data. Specifically, temperature and precipitation data from April to November has had the best fit (highest R^2 value) for previous models. The fact that April through November would prove better matched to water demand appears to be explained by the fact that those months are most likely to include outdoor watering and the greatest building cooling demands in Virginia and North Carolina (where previous models have been developed).

These values were then compared to the mean in units of standard deviation, as depicted for temperature and precipitation in Figure C-1. Using the difference from the mean, rather than directly using the weather measures in the regression model, the model's intercept, in particular, will be meaningful and describe the unit demand in an average weather year.

Figure C-1: April through November Temperature and Precipitation Data

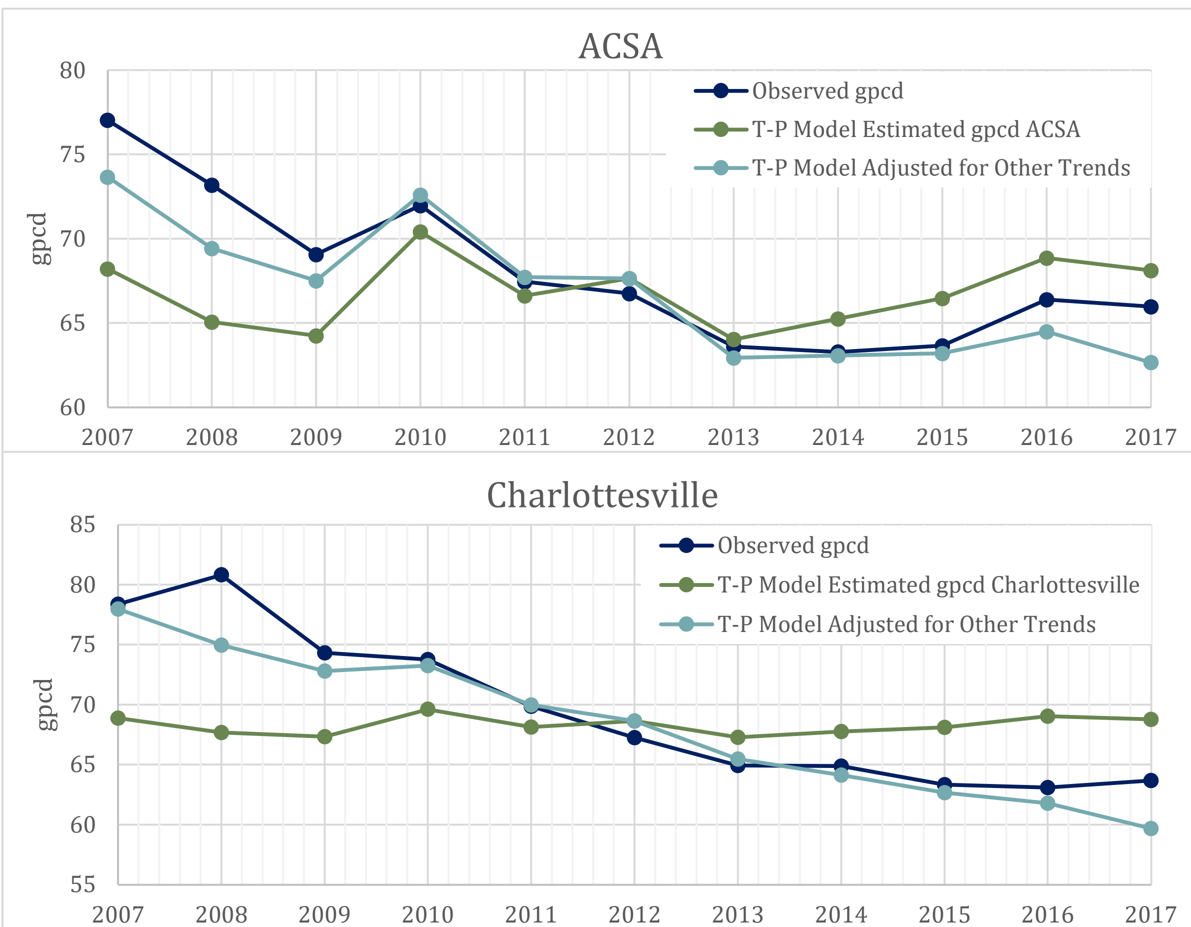
A standard least squares multi-linear regression was performed using temperature and precipitation as the explanatory (independent) variables for aggregate per capita water demand for the City of Charlottesville and ACSA annual per capita demand from 2007 to 2018. Ideally the timeframe chosen to fit the data would not contain major shifts in other variables that influence water use such as the economy, water price, high precipitation events such as from tropical storms or hurricanes, or utility imposed mandatory conservation. For each of the City of Charlottesville and Albemarle County, analyses were performed from 2007, 2008, 2009, and 2010 to 2017 to explore a range of fits with the weather measures. Additionally, the 2010 to 2014 demands for the County were analyzed since this represented a period of constant pricing and 2009 to 2013 for the City of Charlottesville which also represented a period of near constant pricing. The demand in these periods were normalized around their mean value to account for external conservation trends in developing the weather coefficients. In an additional attempt to account for variations outside of weather fluctuations, an average was taken of the five sets of coefficients for each location.

The sets of analyses proved that only temperature and precipitation had consistently reasonable fits with both the City of Charlottesville or ACSA demand data. This was assessed using the adjusted R-squared for each model fit, to account for the number of variables analyzed causing overfitting. The adjusted R^2 for the averaged model is 0.71 for ACSA and 0.82 for the City of Charlottesville. The adjusted R^2 for the UVA model, analyzed using 2010-2018 data, was 0.73. Table C-1 contains the model coefficients and intercepts for each service area. Because the model was set up using variance from the mean, the intercept is meaningful and represents the estimated per capita demand during a year with average weather during the growing season.

Table C-1: Weather Variability Parameters and Climate Normal Unit Demand

Service Area	Temperature Variation (%)	Precipitation Variation (%)	Climate Normal Demand
ACSA	+2.45	-2.17	66.41 gpcd
Charlottesville	+0.83	-0.88	68.14 gpcd
UVA	+3.30	-2.29	87.7 gpd/ksf

Figure C-2: Predicted Unit Demand (gpcd) from Growing Season Temperature and Precipitation



Once the demand response relationships were developed, 5000 trials were generated using Monte Carlo Simulation (MCS) techniques with each trial representing the temperature and precipitation outcome of a single growing season. The Oracle Crystal Ball package was used as the MCS software. The relationship between growing season temperature and precipitation were found to have a weakly-correlated inverse relationship (correlation coefficient = -0.27) based on a statistical fit of the 1980-2018 weather data. The MCS software takes this correlation into account. Table C-2 summarizes the combined influence of temperature and precipitation on water demand by service area. The adjustment to the demand is indicated at each reported percentile, with 'Min' being lowest demand (extreme cool and wet) for the 5000 trials and 'Max' representing the highest demand (extreme heat and dry) observed in the 5000 trials. The modeled demand response to the simulated weather conditions comes from Table C-1.

Table C-2: Modeled Demand Adjustments by Percentile

Percentiles	ACSA Demand Adjustment	Charlottesville Demand Adjustment	UVA Demand Adjustment
Min	-14.04%	-5.06%	-17.68%
1%	-8.50%	-3.15%	-10.41%
5%	-5.85%	-2.16%	-7.26%
10%	-4.45%	-1.64%	-5.35%
25%	-2.43%	-0.88%	-3.00%
50%	-0.23%	-0.07%	-0.30%
75%	1.89%	0.69%	2.30%
90%	3.81%	1.40%	4.69%
95%	4.93%	1.79%	6.15%
99%	7.46%	2.62%	9.50%
Max	13.74%	4.87%	17.58%

References

IPCC, 2013. Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Appendix D: Peak Day Factor Calculation Using System Mass Balance Approach

The Mass Balance Method was developed to provide a second, more in depth, analysis of the peak day demand for the Urban Service Area. The purpose was to filter out peak that might be driven by refilling clearwells at WTPs or other events that might not be truly representative of system demand. This method excludes any in-plant water usage from its peak day calculations. The analysis began by gathering historical pumping and tank level data for the service area and calculating daily system demands in accordance with the system schematic shown in Figure D-1. The system schematic includes pressure zones, tanks, PRVs, treatment plants, and pump stations, which were each used in the analysis. The goal was to provide a second set of statistical results to use in comparison with the peaking factor results determined in the WTP Production Method described in Section 4.

The Mass Balance Method relied heavily on the available historical data for pumping and tank level operations in the Urban Service Area. The Urban Service Area is served by a combination of 13 pump stations and 12 storage tanks. Due to the number of data sources needed to complete this analysis for the Urban System and the inconsistency of recorded data, it was impossible to find any periods when all 25 sources reported reliable values. Figure D-2 shows the available pump station and tank level data provided to Hazen and Sawyer to perform the analysis. The figure shows the fraction of reliable hourly data available in each 24-hr period from July 2010 to December 2018 for each pump station and tank in the system. A full-height purple bar indicates all the data is available from the specified source. A flat line indicates no data and heights in between indicate partial records for the period. The most reliable range of record keeping came over the course of 2017 and 2018, but even then a minimum of 2 of the 25 datasets were incomplete. In the interest of completing the analysis, trends were developed to match historical values and fill in missing data ranges. The trend mimicked historical average monthly data and sloped in the direction of historical values. An example of the trend developed for the Lambeth Pump Station is shown in Figure D-3. Using new input provided by trending data, the years 2013 to 2018 were evaluated for the Mass Balance Method. Figure D-4 illustrates the consistent trend in peaking factors over the past six years. The consistency observed over the time frame may be a result of filling in missing data with average monthly values, thus eliminating the likelihood of peak days in the system. Peaking factors averaged 1.24 throughout the dataset. The maximum and minimum peaking factor was 1.29 in 2016 and 1.17 in 2018, respectively. Figure D-5 illustrates a box and whisker plot of peaking factors for both the WTP Production Method and Mass Balance Method. The Mass Balance method did not accurately represent peaks in the system due to the missing data. Therefore, The WTP Production Method was used to recommend a peaking factor to RWSA and is further addressed in Section 4.

Figure D-1: Mass Balance Method – RWSA System Schematic

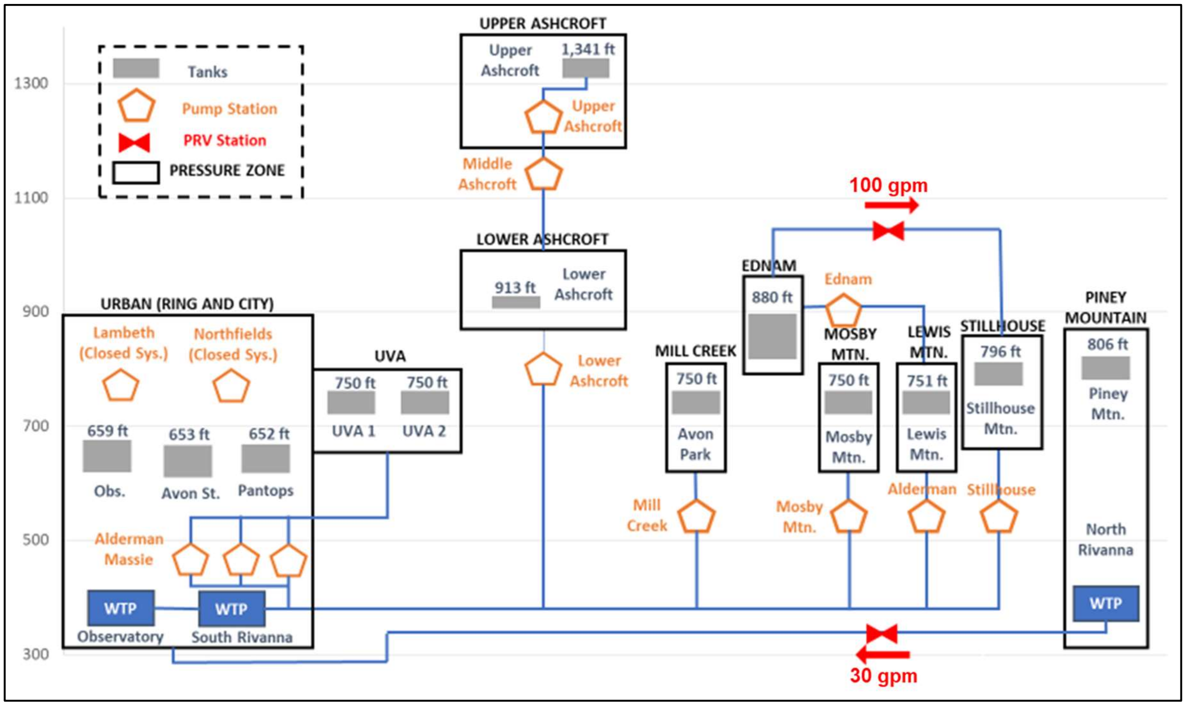


Figure D-2: Mass Balance Method – Hourly Data Availability for Pump Station Flow and Tank Level by Day

Figure D-3: Mass Balance Method – Lambeth PS Example of Trends Developed

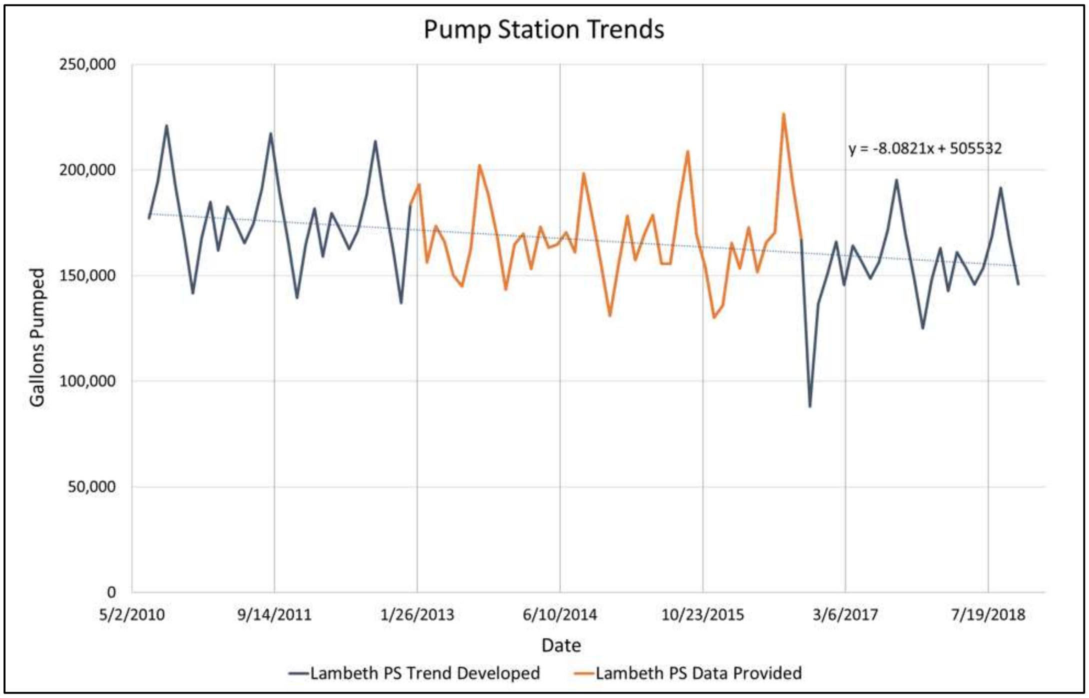


Figure D-4: Mass Balance Method – Historical Maximum Day Peaking Factors

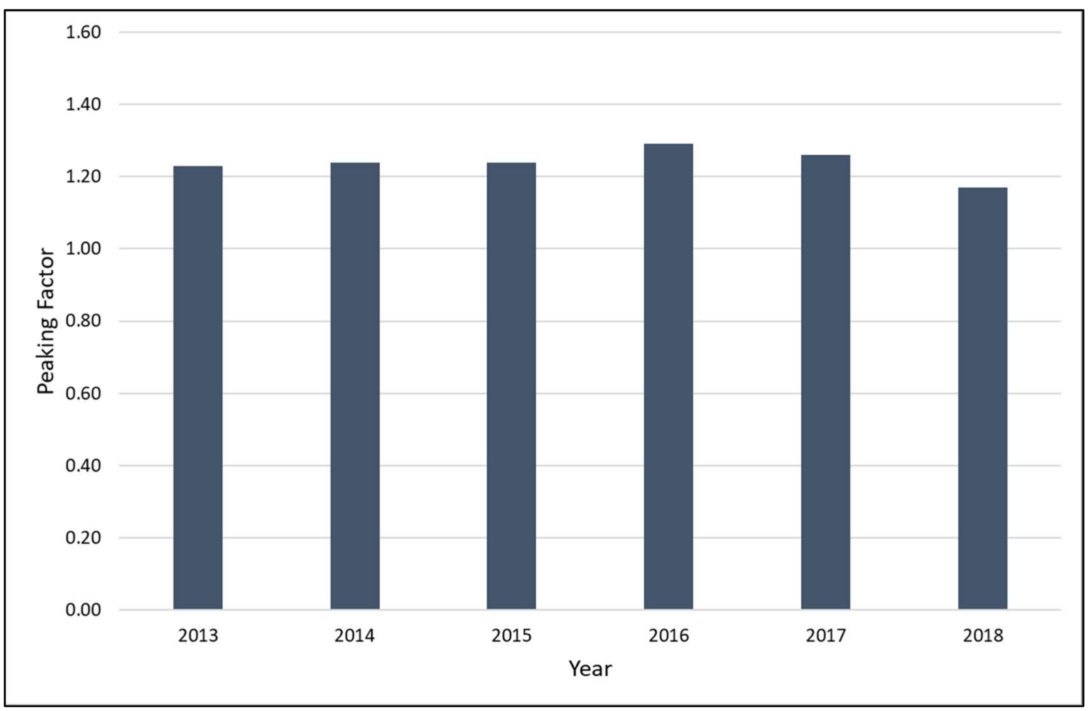
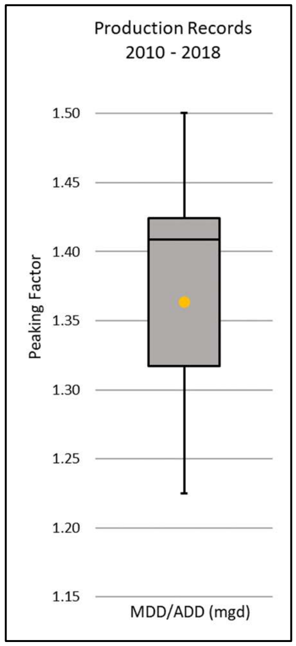
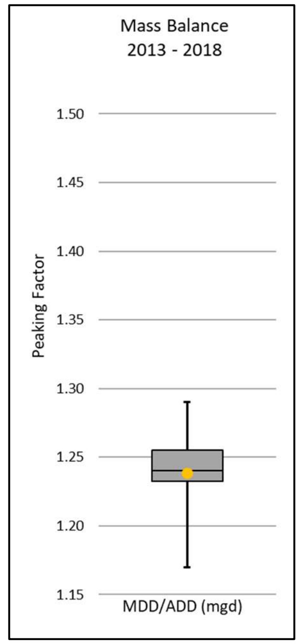


Figure D-5: Peaking Factors – WTP Production Method (left) and Mass Balance Method (right)





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RWSA Safe Yield and Reliability Analysis Update Report

Work Authorization No. 1
Hazen Project No. 31430-000
July 23, 2020

RIVANNA
WATER & SEWER AUTHORITY

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1. Introduction and Purpose

To keep RWSA's comprehensive water supply and infrastructure planning up-to-date, and in accordance with the Ragged Mountain Dam Agreement (RMDA) dated January 1, 2012 (Appendix A), RWSA contracted Hazen and Sawyer (Hazen) to conduct a water demand forecast and safe yield analysis for the Urban Water System. This report addresses the safe yield analysis. The water demand forecast is covered in a separate report by Hazen. [1]

2. Overview

The RMDA states that at least once every ten years after the date of the Agreement, and not later than the year 2020, RWSA shall "update the analysis of safe yield of the Urban Water System following each new bathymetric survey of the South Rivanna Reservoir…using the latest available data on useable storage in the South Rivanna Reservoir, the Ragged Mountain Reservoir, and the Sugar Hollow Reservoir." The method for determining safe yield "shall be as set forth in the regulations of the Virginia Department of Health [VDH]".

Per 12VAC5-590-830 of VDH regulations for surface water sources, the safe yield for a "complex intake", which is applicable to RWSA, is defined as "the minimum withdrawal rate available to withstand the worst drought on record in Virginia since 1930."

Hazen used the RWSA OASIS Hydrologic Model to compute the safe yield for the Urban Water System under a range of infrastructure upgrade and operating scenarios. Developed by HydroLogics (now part of Hazen and Sawyer), the OASIS model has been used extensively by RWSA for analysis on its supply system, including safe yield analysis and drought trigger development[2].

Figure 2-1 shows a schematic of the Urban Water System that depicts the reservoirs, water production facilities, and raw water diversions between the Urban reservoirs.

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[1] RWSA Urban System Water Demand Forecast Report, Hazen and Sawyer, July 14, 2020. Hazen and Sawyer Project No. 31430-000.
[2] Modeling RWSA's Water Supply Operations with OASIS, June 2018, HydroLogics

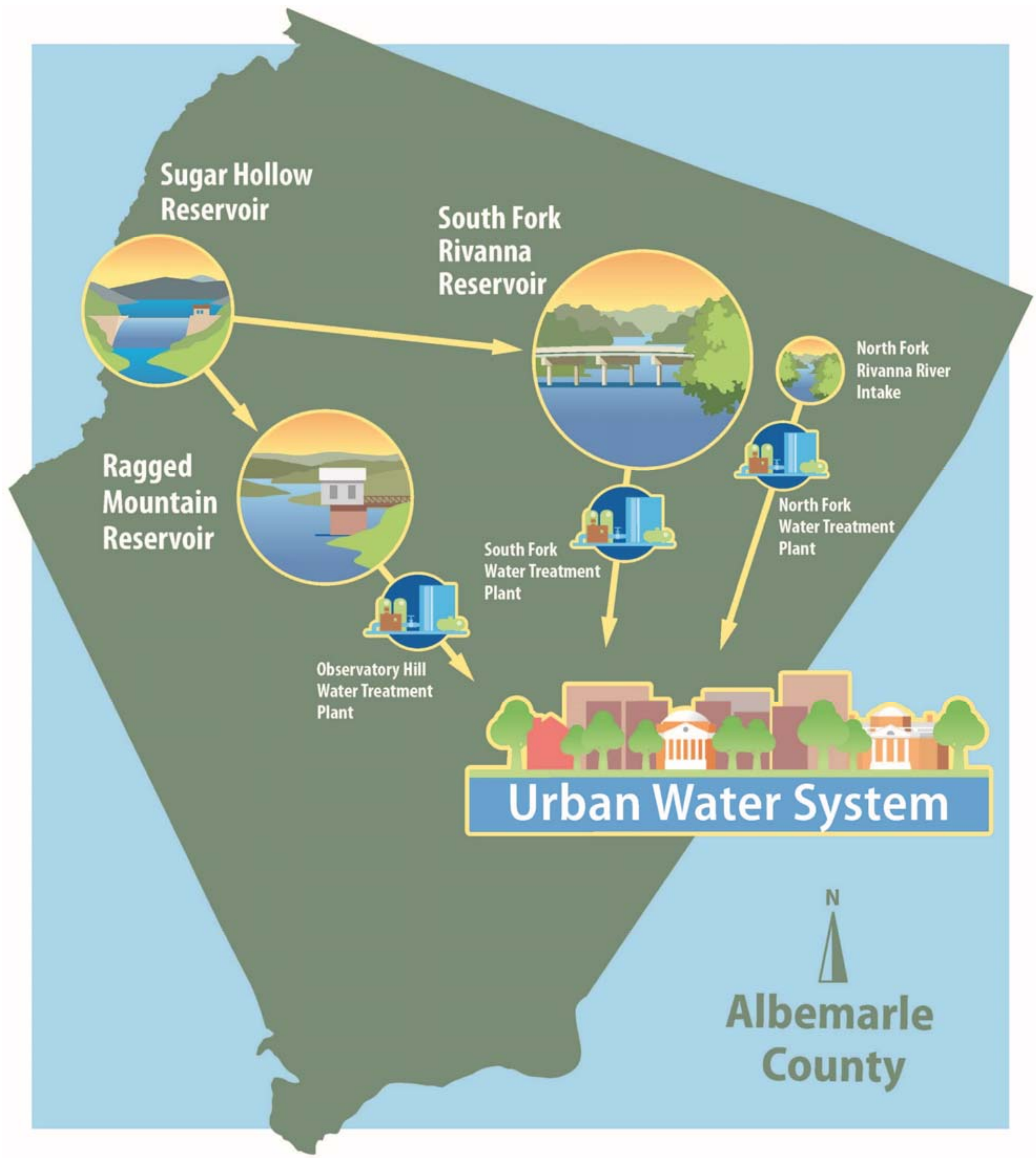

Figure 2-1: RWSA Urban Water System Schematic

The OASIS model is used to simulate the flow of water through the system, with the goal of meeting water supply demands and minimum releases from reservoirs subject to constraints on useable storage and capacities of treatment plants and raw water pipelines.

This report will focus specifically on the safe yield metric. Other measures of reliability – such as the frequency, severity, and duration of drought plan restrictions and drawdown in individual reservoirs – have been explored as part of previous studies and operations exercises.

Hazen evaluated yield under a variety of scenarios related to infrastructure and operations. Yields were categorized as defined below:

1. **"Theoretical" Safe Yield** - This is the best-case scenario in which only the raw water supply sources are limiting. Factors such as treatment capacity and raw water and finished water conveyance capacities are not incorporated into the calculations. This approach is consistent with VDH's definition for safe yield and is typically how RWSA safe yield for the Urban Water System has been presented in the past. This calculation of yield provided the basis for the capacity upgrades following the 2002 drought and the Department of Environmental Quality (DEQ) Virginia Water Protection (VWP) permit for the Urban Water System.

2. **"Operational" Safe Yield** – This calculation factors in the production constraints at the treatment plants which may limit how much of the raw water supply can be used, along with the drought plan triggers which result in cutbacks to demand. Furthermore, it includes the constraints of conveying water between reservoirs and the treatment plants. For example, the operations in the 2020 model scenario reflect that Ragged Mountain Dam water can only be treated at the Observatory water treatment plant (OWTP), and South Rivanna Reservoir water can only be treated at the South Rivanna WTP. Once the future Ragged Mountain to South Rivanna Raw Water Pipeline is installed, water from either reservoir can be treated at either WTP. This will increase redundancy and resiliency as well as operational safe yield. This category of yield provides a more realistic picture of system reliability since it factors in the limitations of what can be withdrawn from the reservoirs for meeting water supply demands.

3. **"DEQ Regulatory" Yield** – Current DEQ staff guidance to municipalities has included consideration for maintaining a system storage reserve in the worst drought (set equal to 60 days of unrestricted demand). While this is not a current regulation, Hazen has proactively evaluated this condition for the RWSA system as the worst-case scenario.

Hazen worked with RWSA staff to develop a comprehensive matrix of yield model runs for a wide variety of structural and operational scenarios over a 50-year planning horizon. These scenarios included infrastructure upgrades (like the South Rivanna to Ragged Mountain pipeline) and operational assumptions (like factoring in demand reductions as a drought develops). These scenarios in turn were organized into timelines to inform the sequencing of capital investments relative to the projected water demands.

3. Reservoir Bathymetry

Bathymetry is defined as the subaqueous survey of lakes and reservoirs to determine the topography of the lake bottom, total volume and the stage-storage curve (which provides incremental volume calculation). Bathymetric studies of the RWSA reservoirs are completed on a periodic basis with the Urban reservoir surveys no more than once every 10 years. Results from the latest updates by Draper Aden Associates are summarized in Table 3-1. Appendix B provides the surveys in graphical form.

Reservoir	Prior Useable Storage (MG) and Year of Survey	Current Useable Storage (MG) and Year of Survey	Changes (MG)
Ragged Mountain	1,513 (2014)	1,441 (2018)	-72
South Rivanna	883 (2009)	885 (2018)	+2
Sugar Hollow	350 (1995)	339 (2015)	-11
Total	**2,746**	**2,600**	

Table 3-1: Urban Reservoir Bathymetry Summary

Safe yield is impacted by South Rivanna Reservoir sedimentation and sedimentation rates. Figure 3-1 shows the impact of sedimentation over time. The usable storage appeared to slightly increase with the last bathymetric survey. It is unknown whether it was due to a storm event, improvements in bathymetric survey techniques, or other factors, but it will continue to be monitored in future surveys. This safe yield work utilized the previous sedimentation rate estimate of 15 MG/year to be conservative.

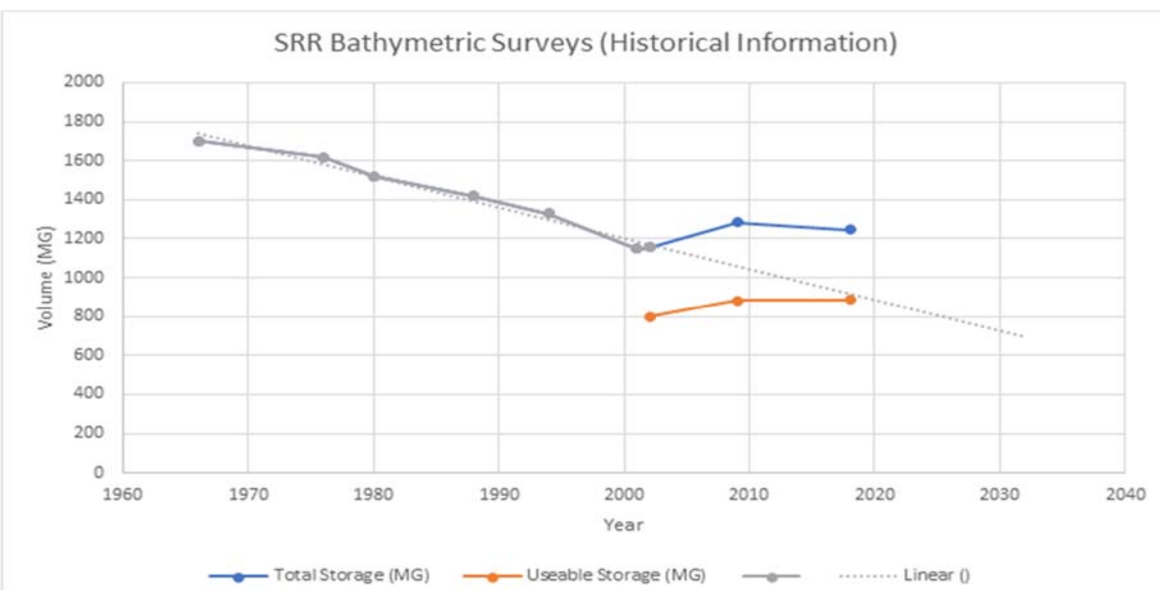

Figure 3-1: Bathymetry for South Rivanna Reservoir

4. Assumptions for Yield Modeling

Key structural improvements considered in the yield analysis included the following:

(1) Upgrades to the OWTP in 2023, which will raise the OWTP capacity to 10 mgd and no longer require a minimum production level (which helps to preserve Ragged Mountain storage)

(2) Addition of the South Rivanna to Ragged Mountain (SR-RM) pipeline, which would accelerate refill of Ragged Mountain, allow water to be pumped in both directions between the South Rivanna Reservoir and Ragged Mountain Reservoir (and both the South Rivanna WTP and OWTP), and increase flow in the Moormans River because the Sugar Hollow to Ragged Mountain pipeline would no longer be used

(3) Raising Ragged Mountain 12 feet to a normal full pool elevation of 683 feet to increase storage capacity (by about 700 MG) and therefore increase yield

The OASIS inflow record starts in the mid-1920s and extends through present, ensuring consideration of the 1930 drought per VDH regulation, as well as the 2001-02 drought. In recent years, HydroLogics staff (now with Hazen and Sawyer) improved the accuracy of the inflows after an extensive verification process using historical operating data and consultation with RWSA staff. Note that model inflows are unregulated, or naturalized -- in which the impacts of historic regulation like reservoir operations on streamflow data are removed-- allowing the user to look at operating the system or meeting demands that may differ from those in the past.

For each OASIS yield run, a set of facilities (infrastructure), demands, and operating rules are simulated over the nearly 100-year unregulated inflow record (as if they were in place for the 100 years), and annual average demand is increased until the simulated system storage (useable storage in Sugar Hollow, South Rivanna, and Ragged Mountain) is fully depleted, or in the case of the DEQ regulatory yield scenario, until the system storage reaches 60 days of supply remaining. The critical drought defining the yield for all scenarios is the 2001-02 drought which produced the lowest inflows on record. This drought lasted approximately 18 months, from the summer of 2001 to the end of 2002. The North Rivanna intake is assumed to withdraw water to help meet system demand (and thus increase yield), with the withdrawal set to a maximum of 2 mgd in the “theoretical” safe yield runs and normal operating limit of 0.5 mgd in the other yield runs. The North Rivanna withdrawal may be limited by available upstream inflow, which does occur in the second year of the 2001-02 drought.

Operating rules include minimum release requirements in accordance with the VWP permit (percent of inflow tied to useable storage, up to a maximum discharge), timing and transfer of water between sources, monthly demand patterns (Appendix C), and in the case of the operational and regulatory yield scenarios, drought plan triggers and associated water use reductions. To take advantage of the useable storage in the reservoirs, Hazen adjusted the operating rules (e.g., shift production from South Rivanna to Observatory WTPs) depending on the assumed storage and production capacities in each of the yield scenarios. Hazen did not adjust the drought plan triggers, which were designed for current conditions but appear to be robust for a wide range of demands. Sedimentation is also factored in for South Rivanna Reservoir, with reductions of 15 MG/year of useable storage. As an example, a simulation of the year 2050 conditions would result in 300 MG less storage in South Rivanna compared to the year 2030 conditions with the consideration of 20 years of sedimentation.

5. Yield Results

1. “Theoretical” Safe Yield

Theoretical safe yield is calculated using the following assumptions. These are consistent with previous calculations of system safe yield.

- No operational constraints for treatment capacity or conveyance at South Rivanna and Ragged Mountain
- No active drought plan
- No monthly demand pattern
- North Rivanna withdrawal up to 2 mgd to help meet system demand

Model run output is shown below in Figure 5-1, with the key variables shown in white (simulated storage, representing the sum of useable storage in Sugar Hollow, South Rivanna, and Ragged Mountain) and red (simulated water supply delivery). Annual average demand that can be met by the system in a repeat of the critical drought (2001-02) without fully depleting storage is 18.6 mgd. This “theoretical” safe yield is based on current (2020) useable system storage summarized in Table 3-1. In future years, safe yield declines due to projected loss in useable storage in South Rivanna associated with sedimentation.

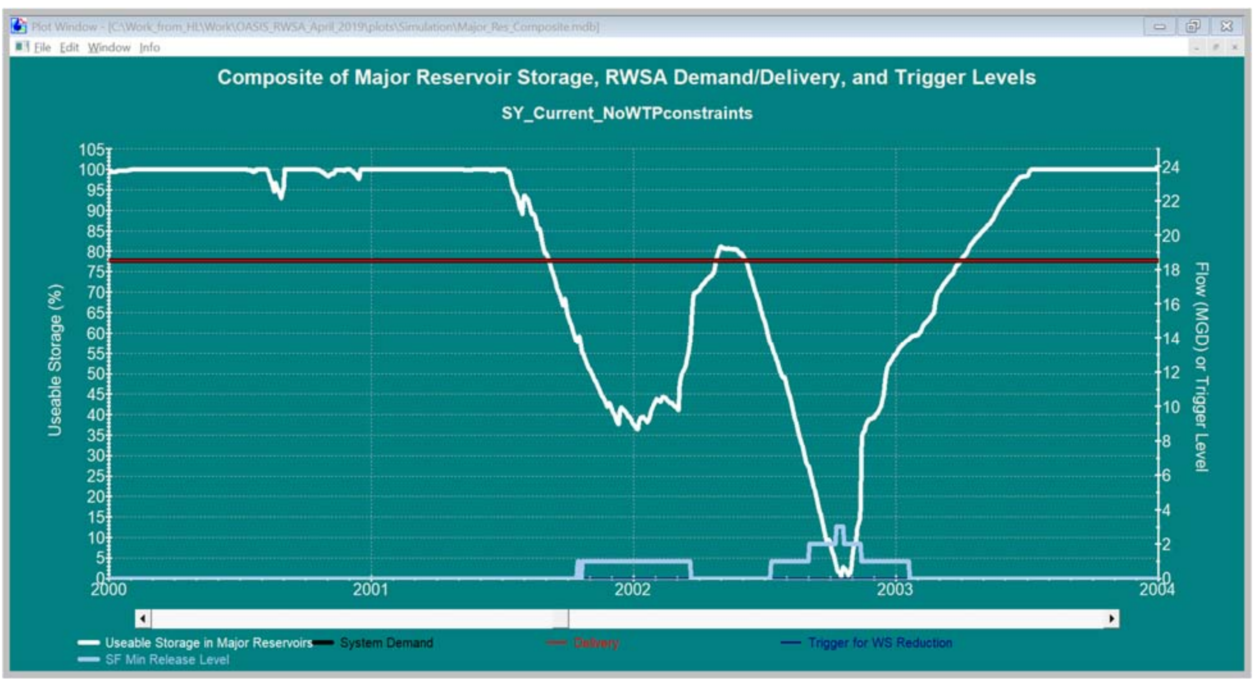

Figure 5-1: Theoretical Safe Yield Determination for Drought of Record (Using 2020 Storage Conditions)

Simulated storage by reservoir for this run is shown in Figure 5-2. In this safe yield run, all storage is exhausted to meet the 18.6 mgd demand. Note that the operating rules are designed to maximize yield. Since South Rivanna Reservoir (labeled South Fork in the plot) with its larger watershed refills quickly, priority is given to meeting water demand from this reservoir first so that raw water is captured for water supply and not spilled unnecessarily downstream. As South Rivanna draws down, water from Ragged Mountain (and supplemented by diversions and releases from Sugar Hollow) will be relied upon to meet relatively more of the demand. No limits on WTP capacity or conveyance exist in the theoretical safe yield run, allowing for flexibility in which supply source to pull from. It should be noted that other considerations, like preferences on minimum reservoir operating levels, are also ignored in order to maximize yield.

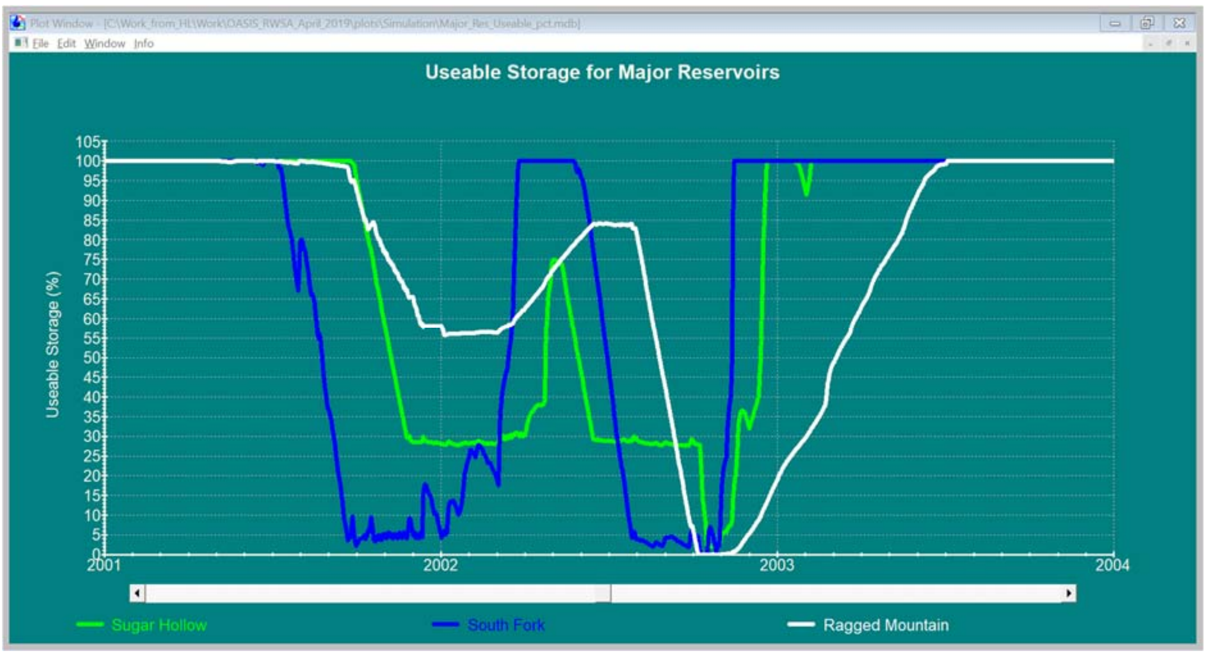

Figure 5-2: Useable Storage by Reservoir from Theoretical Safe Yield Run (Using 2020 Storage Conditions)

2. “Operational” Safe Yield

Operational safe yield is calculated using the following assumptions.

- Limits on WTP capacity at the Observatory
    - 2020: 1 mgd minimum, 4.5 mgd maximum
    - 2023: 0 mgd minimum, 10 mgd maximum
- Limits on WTP capacity at South Rivanna
    - 2020: No minimum, 11 mgd maximum

   - 2023: No minimum, 12 mgd maximum

- Drought plan is active
- Monthly demand pattern (see Appendix C)
- North Rivanna withdrawal up to 0.5 mgd to help meet system demand

When limitations on treatment capacity (both minimum and maximum production) are introduced, thereby limiting flexibility on raw water withdrawals from the reservoirs, the yield is negatively impacted. Under the assumptions described above, the "operational" safe yield in 2020 (where 2020 useable storage is used) is much lower (12.8 mgd) than the theoretical safe yield (18.6 mgd) because of today's WTP constraints. The drawdown plots for 2020 are shown below in Figures 5-3 and 5-4.

Figure 5-3 shows system drawdown in the drought of record. Important differences from the theoretical safe yield run are seen. Focusing on the key variables (storage in white and delivery in red), it can be seen that system storage is not exhausted. In fact, over 20% storage remains. The WTP production constraints in this run require that water be withdrawn at all times from the respective sources (South Rivanna WTP from South Rivanna Reservoir, and OWTP from Ragged Mountain Reservoir). If either supply source has emptied, then the system delivery cannot be met in full, which is required in a safe yield run. It should also be noted that the monthly demand pattern and drought plan are incorporated in this run, meaning that delivery will be reduced by the amount of demand reduction (up to three levels) targeted in the drought plan. The impact of the demand reductions is reflected in the difference between the red (nominal demand) and black (delivery) lines in the plot below.

Figure 5-4 shows simulated drawdown for each of the reservoirs during this drought. Because South Rivanna Reservoir has limited storage capacity, the required production from the WTP causes it to draw down quickly. Once the South Rivanna Reservoir has reached bottom, system demand (after accounting for demand restrictions) can no longer be met, explaining why system storage (in the three Urban reservoirs and shown to be over 20% in the previous figure) is not close to being depleted. Sugar Hollow empties early as water is diverted to Ragged Mountain through the connecting Sugar Hollow pipeline in order to replenish storage in Ragged Mountain. Ragged Mountain is drawing down since OWTP is always operating at minimum capacity or higher when supplementing South Rivanna WTP's capacity.

Note when OWTP capacity in 2023 is increased to 10 mgd, the operational safe yield will increase from 12.8 mgd to 15.1 mgd, mainly because more of the water demand can be met from Ragged Mountain and thus more of the Ragged Mountain storage can be used. System storage is fully depleted under the 2023 condition, so yield is maximized.

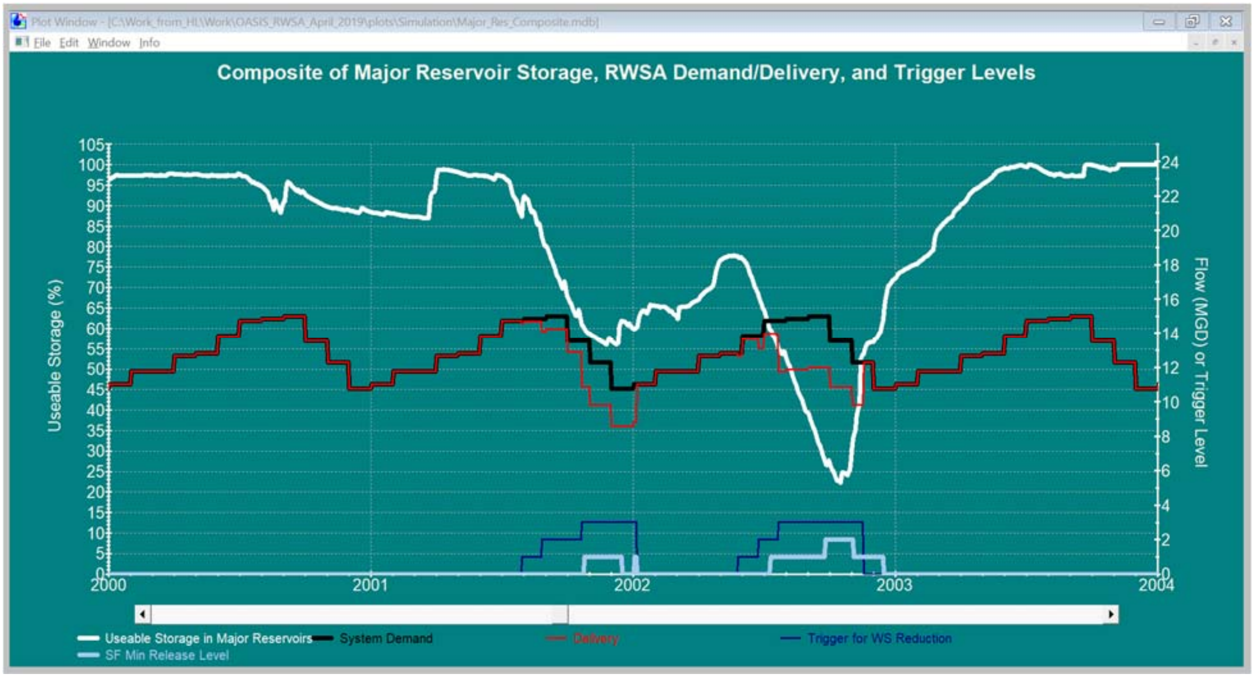

Figure 5-3: Operational Safe Yield Determination for Drought of Record (Using 2020 Storage Conditions)

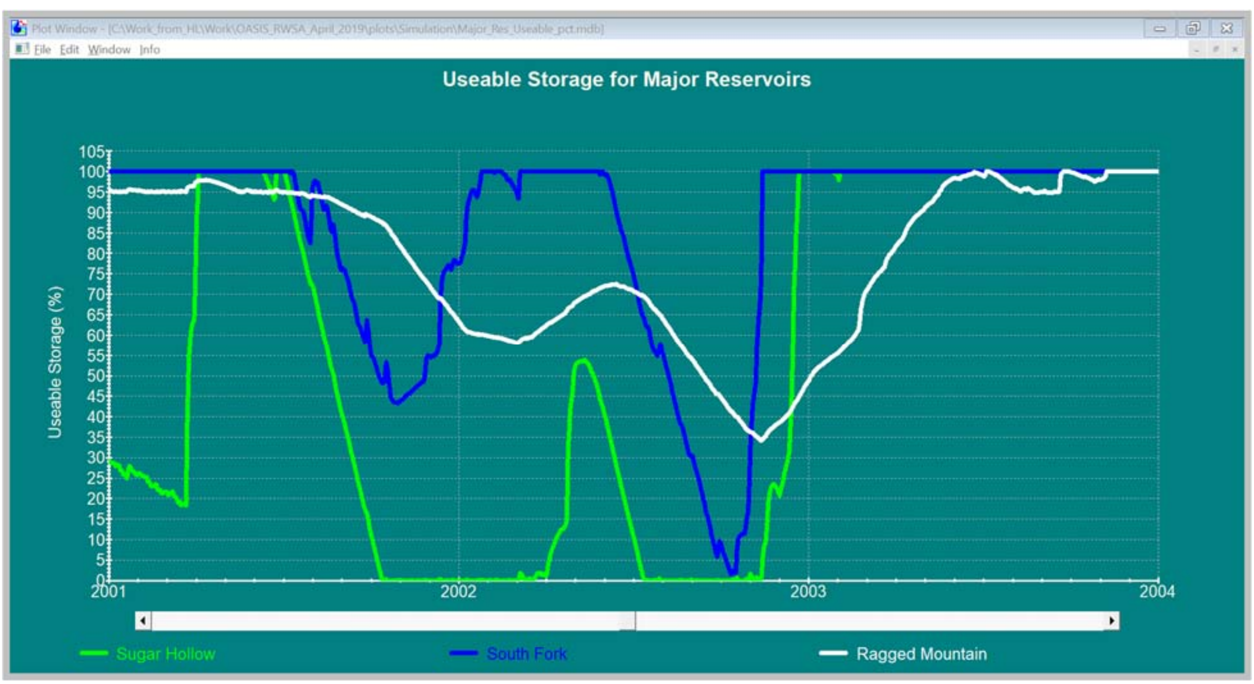

Figure 5-4: Useable Storage by Reservoir from Operational Safe Yield Run (Using 2020 Storage Conditions)

3. "DEQ Regulatory" Safe Yield

DEQ regulatory safe yield uses the same assumptions as the "operational" yield scenario except for one additional limitation: inclusion of a 60-day system storage reserve. This reserve is equivalent to 60-days of demand, and means that when calculating yield, system storage cannot be depleted below this reserve in the worst drought. With this additional limitation, the yield declines further, to 12.0 mgd based on 2020 operational and storage conditions. In the 2020 model run, the true impact of the 60-day reserve is not reflected in the incremental decrease from the operational safe yield. This is because there was 20% useable reservoir capacity remaining in the 2020 operational safe yield run that is being accounted for in the 60-day storage reserve.

For the 2023 condition, the DEQ Regulatory safe yield will be 12.9 mgd, compared to the operational safe yield of 15.1 mgd, which reflects a much higher reduction in safe yield. In the 2023 operational yield run, Ragged Mountain storage can be fully used to support a higher level of demand. In the DEQ regulatory run, it cannot be fully used or else the 60-day system storage reserve would not be met, and so the demand that Ragged Mountain can support is lower.

Figure 5-5 shows system storage not dropping below the yellow line that represents the 60-day system storage reserve. The reserve is equal to 60 days of equivalent system demand, which varies monthly since a monthly pattern is used. The only difference relative to the "operational" safe yield determination is the 60-day reserve. Significant demand reductions would again be necessary to preserve storage. Figure 5-6 shows that to maintain this reserve, not all of the storage in South Fork and Ragged Mountain can be utilized.

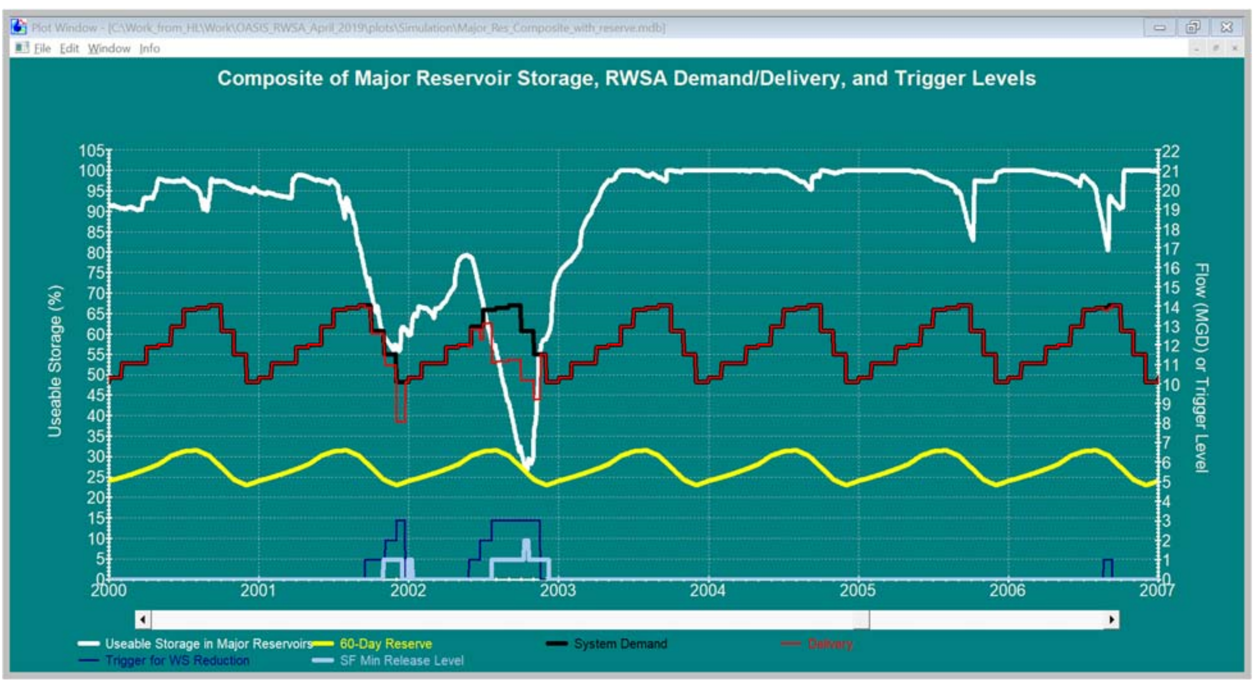

Figure 5-5: DEQ Regulatory Safe Yield Determination for Drought of Record (Using 2020 Storage Conditions)

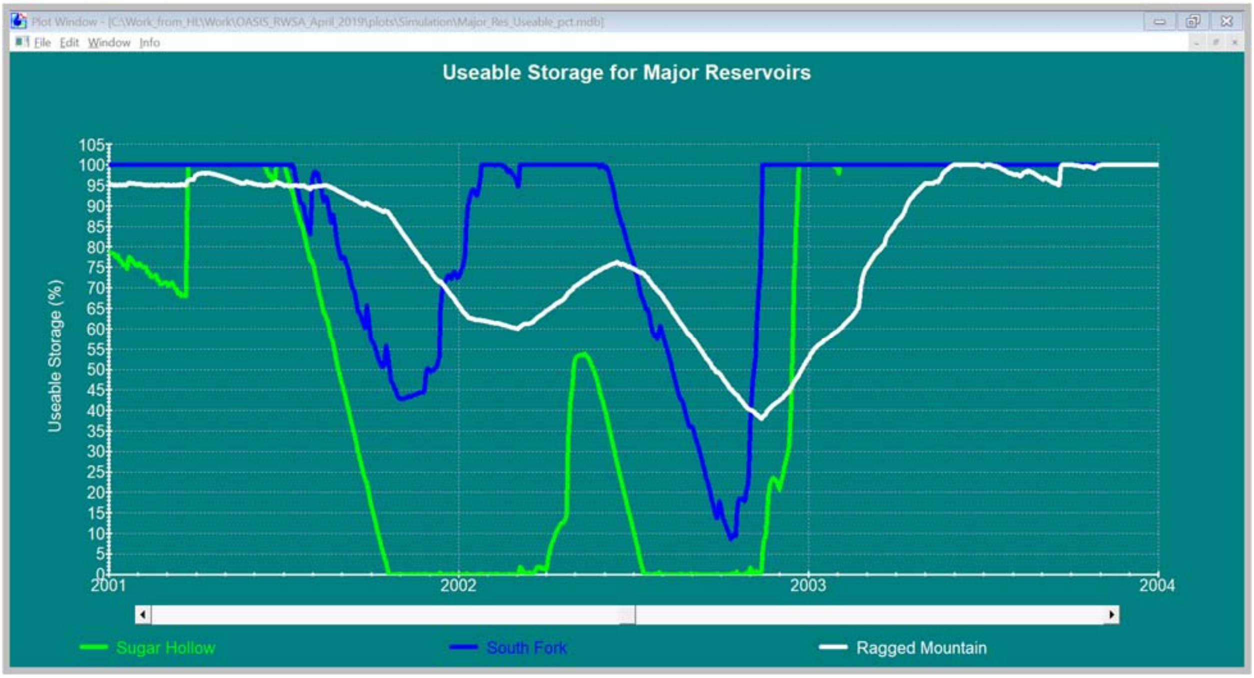

Figure 5-6: Useable Storage by Reservoir from DEQ Regulatory Safe Yield Run (Using 2020 Storage Conditions)

Evaluation of Operational Yield Over the Planning Horizon

Following review of the matrix of yield results, RWSA focused on the operational safe yield scenarios since they were most representative of the actual physical characteristics and limitations within the water supply, conveyance, and treatment system. Use of the traditional "theoretical" safe yield implies that the water in all the reservoirs can be treated as needed at all the water treatment plants, which is not currently possible and provides unattainable results. Planning for the DEQ regulatory safe yield at this time is overly conservative as there is little guidance and no formal regulation in this matter; however, this scenario should continue to be monitored.

RWSA used this evaluation to determine the impact of structural and non-structural constraints, such as pipelines and treatment capacity, and how the Drought Response and Contingency Plan can help preserve supply during drought periods. This provided valuable information as to the timing of improvements and impacts to safe yield.

Figure 5-7 shows the result for operational yield and how the yield will change over time due to loss of useable storage in South Rivanna as a result of sedimentation. As noted, current system operational yield is 12.8 mgd. Capacity upgrades to the OWTP are planned for 2023, explaining the large increase in yield between years 2020 and 2030.

Also plotted in Figure 5-7 are the current water raw water demand projections. In 2060, the demand is projected to reach the operational yield.

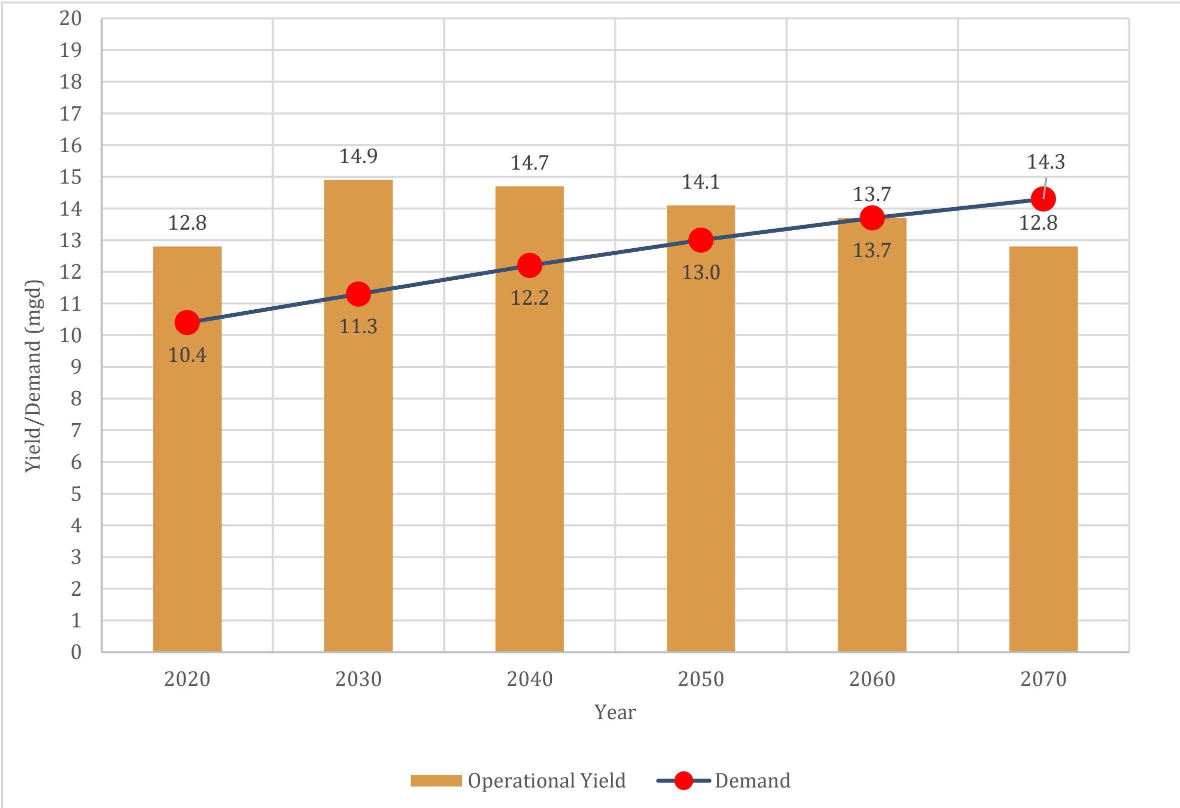

Figure 5-7: Operational Yield Over the Planning Horizon

To provide for adequate yield to meet projected demands over the planning horizon, RWSA evaluated three buildout scenarios that varied by the timing of those actions.

<u>Buildout Scenario A</u>
<u>(Raise Ragged Mountain Pool and Add South Rivanna to Ragged Mountain Pipeline in 2035)</u>

The first scenario involves two buildout actions in 2035 that would be within the term of a renewed VWP permit (2038): raising Ragged Mountain pool by an additional 12 feet and the addition of a pipeline connecting South Fork and Ragged Mountain. As noted, the system is impacted by multi-year droughts like 2001-02, so being able to accelerate Ragged Mountain refill prior to the second year of a drought with surplus South Fork inflows allows storage to be rebalanced and increases yield over the course of the drought. The Ragged Mountain refill operating rule developed in consultation with RWSA staff is 25 mgd from South Fork when South Fork is above 75% full, 10 mgd when it is above 25% full, and no transfer otherwise.

Figure 5-8 shows the water demand and operational safe yield at five-year increments and is reflective of the 2023 expansion to 10 mgd in the Observatory WTP capacity. The increase in yield in 2035 is substantial, increasing from approximately 15 mgd to 21.5 mgd. This increase is the result of extra storage in Ragged Mountain, and the ability to move water between reservoirs (and treatment plants) to take advantage of that extra storage. The reductions in yield beyond 2035 occur because of South Fork sedimentation, but are not necessarily linear, mainly because the drought plan is active in these runs. The drought plan contains three triggers that lead to increasing levels of demand reduction. Triggers may be active more often, or for a longer duration, as system demands increase, helping to preserve storage.

If extended beyond 2070, the demand and yield would not intersect until approximately 2120, thus providing an adequate supply for well beyond the planning horizon.

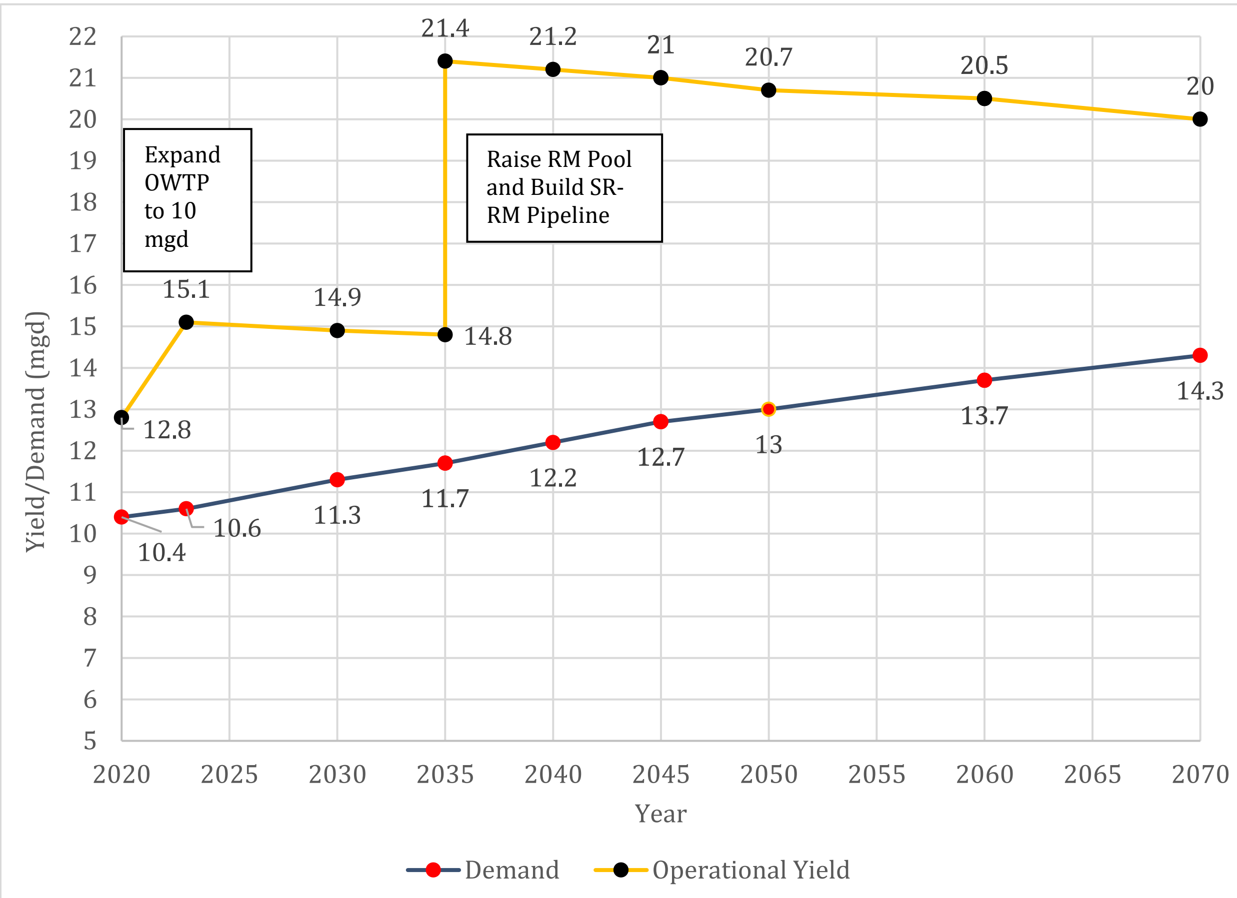

Figure 5-8: Operational Yield with Ragged Mountain Pool Raise and South Rivanna to Ragged Mountain Pipeline in 2035

<u>Buildout Scenario B</u>
<u>(Add South Rivanna to Ragged Mountain Pipeline in 2045 and Raise Ragged Mountain Pool in 2060)</u>

Figure 5-9 shows the yield results associated with buildout scenario B: building the South Rivanna to Ragged Mountain pipeline in 2045 (when water demand is 85% of yield) and raising the Ragged Mountain pool in 2060 (when water demand reaches 85% of yield again). The 85% threshold was selected based on common practice in water supply planning. The increase with the pipeline alone provides approximately 15 years until the 85% threshold is reached. The pipeline alone provides the flexibility in operation of the reservoirs and treatment plants; however, it does not provide the maximum capacity of Ragged Mountain storage. With the pipeline in place, the subsequent raise of the Ragged

Mountain pool results in a large increase in yield as the extra storage in Ragged Mountain can be fully utilized.

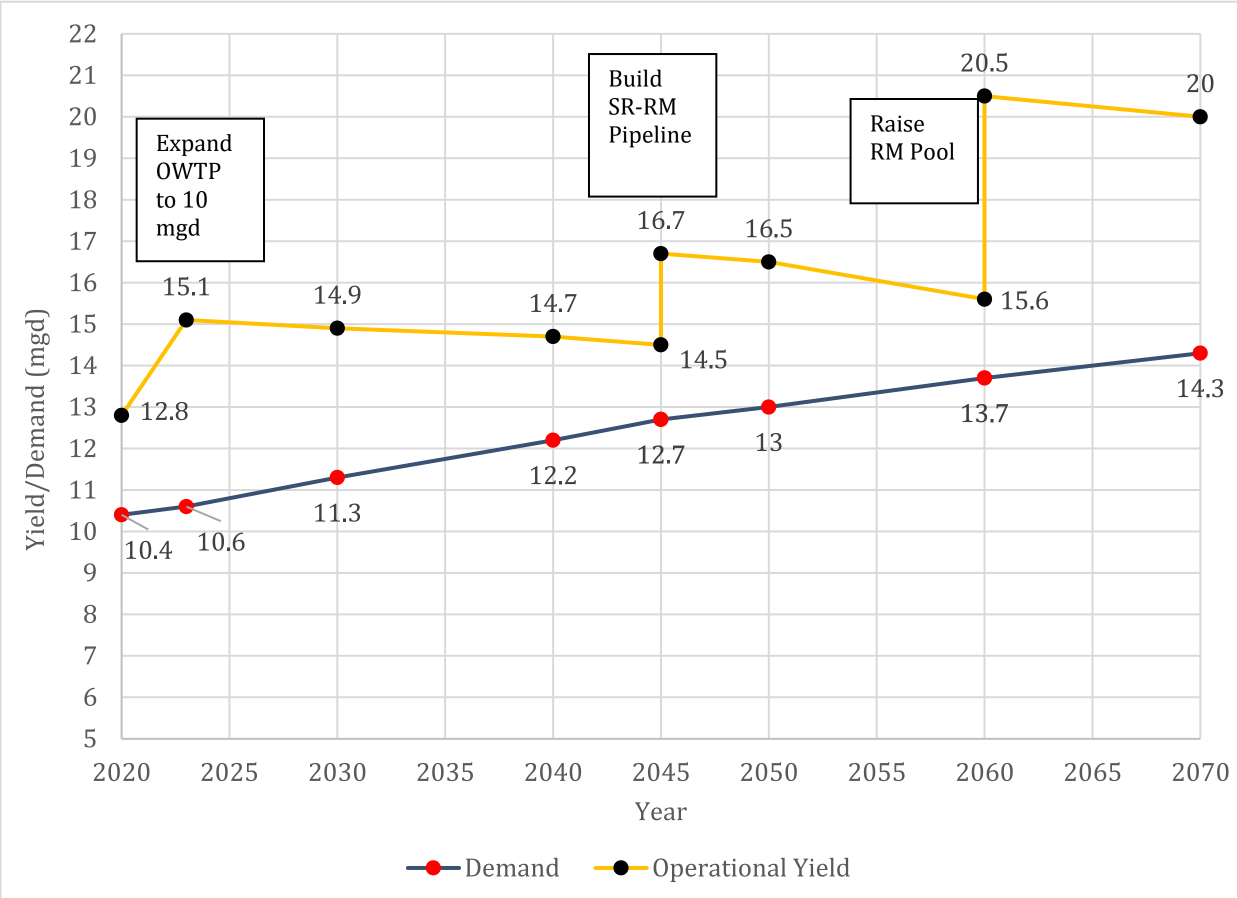

Figure 5-9: Operational Yield with South Rivanna to Ragged Mountain Pipeline in 2045 and Ragged Mountain Pool Raise in 2060

Buildout Scenario C
(Raise Ragged Mountain Pool in 2045 and Add South Rivanna to Ragged Mountain Pipeline in 2050)

The final scenario involves reversing the actions from scenario B and raising the Ragged Mountain pool first (in 2045), then building the pipeline (in 2050), both of which occur when demand reaches 85% of yield. A pool raise alone provides significant additional storage, but as shown in Figure 5-10, a relatively small increase in yield because the operational constraints with no SF-RM pipeline in place still exist which only allow the Ragged Mountain water supply to be treated at OWTP.

The yield increase associated with the pool raise alone (less than 1 mgd) is only realized for approximately 5 years when water demand reaches 85% of the yield again. The full benefit of the extra storage in Ragged Mountain is realized in 2050 when the pipeline is added, increasing yield significantly because water can be utilized flexibly at both South Rivanna and Observatory WTPs.

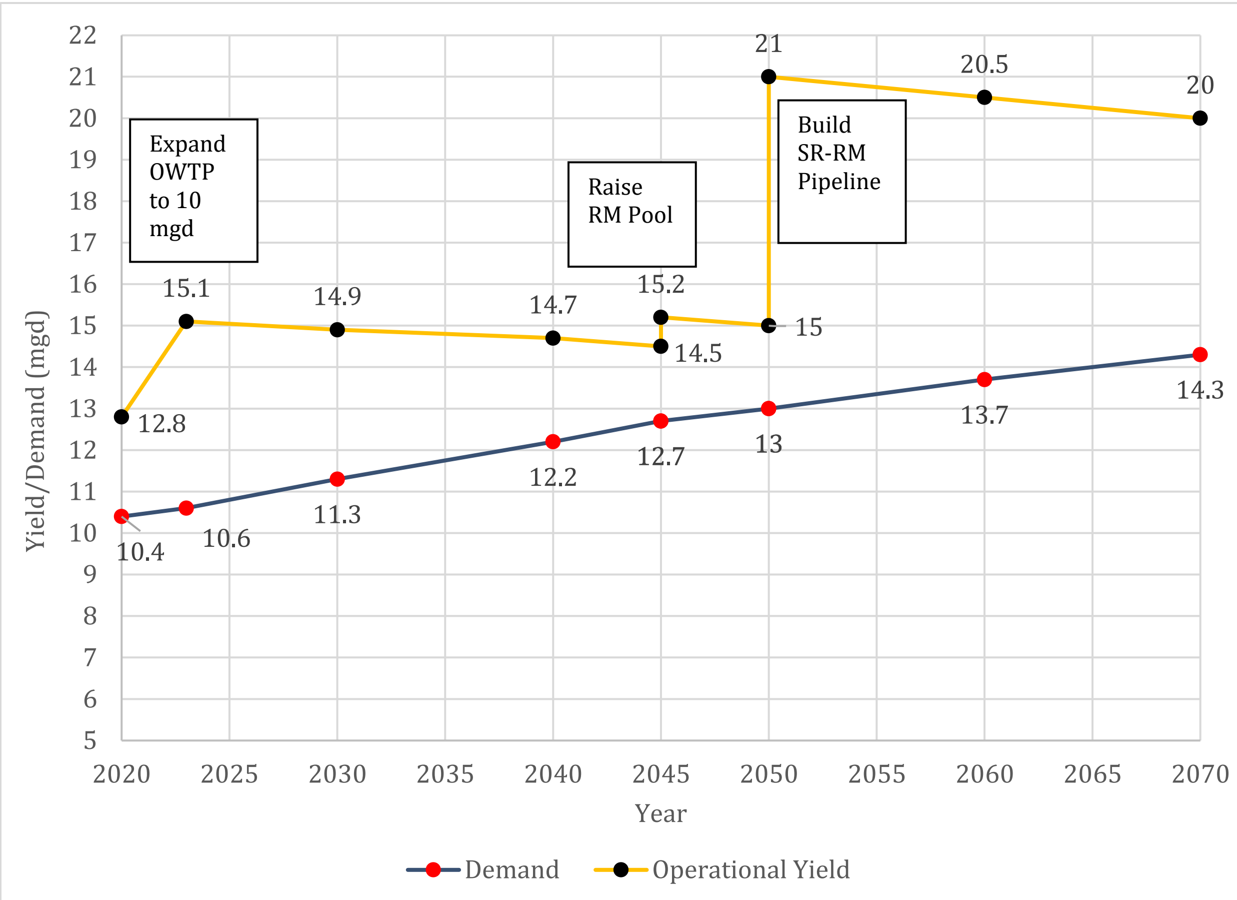

Figure 5-10: Operational Yield with Ragged Mountain Pool Raise in 2045 and South Rivanna to Ragged Mountain Pipeline in 2050

6. Conclusions

RWSA relied on the OASIS model to determine safe yield for a wide range of structural and non-structural constraints, such as pipelines and treatment capacity, and how actions like implementation of the Drought Response and Contingency Plan can help preserve supply during drought periods. This provided valuable information as to the timing of improvements and impacts to safe yield.

Safe yield has traditionally been computed without consideration of operational constraints. “Theoretical” safe yield implies that the water in all the reservoirs can be treated as needed at all the water treatment plants, which is not currently possible and provides unattainable results. RWSA considered two alternative approaches to computing safe yield, “operational” and “DEQ regulatory”, and concluded that “operational” is the most representative of the current physical characteristics and limitations within the water supply, conveyance, and treatment system.

Therefore, the safe yield analysis focused on operational yield and the timing of needed improvements to ensure an adequate water supply over the planning horizon. Three scenarios were considered, in which the improvements associated with the Ragged Mountain pool raise and South Fork to Ragged Mountain pipeline were phased in at various times over the 50-year planning horizon.

Results showed that the benefits on yield with the pool raise are only fully realized with the addition of the South Fork to Ragged Mountain pipeline. The pipeline allows flexibility in the use of the supply sources and the ability to treat that water. Therefore, to maximize supply reliability, not to mention other benefits like supply redundancy and environmental streamflow benefits, executing the improvements at the same time is warranted. RWSA identified joint improvements in the year 2035, meaning these can be completed within the term of the new VWP permits. Whether done jointly or staged, however, the results show that resulting yield will be significant enough to provide adequacy of water supply out to year 2120 based on the projected demand growth and current regulations.

Appendix A: Ragged Mountain Dam Project Agreement

Albemarle County
TMP # 07500-00-00-00100
TMP # 04500-00-00-067A0
TMP # 04500-00-00-069A0

Prepared by:
McGuireWoods LLP

EXEMPTED FROM RECORDATION TAXES UNDER
SECTION 58.1-811.A.3 OF THE
CODE OF VIRGINIA (1950), AS AMENDED

RAGGED MOUNTAIN DAM PROJECT AGREEMENT

This **RAGGED MOUNTAIN DAM PROJECT AGREEMENT** (this "Agreement") made for purposes of identification this 1st day of January, 2012, by and between the **CITY OF CHARLOTTESVILLE, VIRGINIA**, a municipal corporation (the "City"), Grantor for indexing purposes; the **ALBEMARLE COUNTY SERVICE AUTHORITY**, a public body politic and corporate ("ACSA"), Grantor and Grantee for indexing purposes; and the **RIVANNA WATER AND SEWER AUTHORITY**, a public body politic and corporate ("RWSA"), Grantee for indexing purposes.

WITNESSETH:

A. RWSA owns and/or operates facilities for the receipt and treatment of potable water pursuant to the terms of a Four-Party Agreement dated June 12, 1973, among the City, RWSA, ACSA and the Board of Supervisors of Albemarle County (the "Four-Party Agreement") and several supplementary agreements.

B. The facilities operated by RWSA include the Lower and Upper Ragged Mountain Reservoir Dams located on a parcel of land designated as Albemarle County Tax Map 75, Parcel 1, and the South Rivanna Reservoir Dam, located on a parcel of land designated as

Albemarle County Tax Map 45, Parcel 67A, as more particularly described in the Deed referenced in Recital E below.

C. Pursuant to Article IV of the Four-Party Agreement, the City and ACSA have agreed upon a project, not contemplated by their previous agreements, for the construction by RWSA of an earthen dam at the current site of the Ragged Mountain Reservoir to replace the existing dams at the Ragged Mountain Reservoir and increase the pool elevation of the existing Ragged Mountain Reservoir. The new earthen dam will increase the safe yield of the urban water system consisting of all water-related facilities within or serving the City of Charlottesville and the urban growth area of Albemarle County surrounding the City of Charlottesville and includes the areas served by public community water supply from the South Fork Rivanna Water Treatment Plant, the Observatory Water Treatment Plant, and the North Fork Rivanna Water Treatment Plant, as well as all reservoirs, dams, pipelines, pumping stations, storage tanks and other appurtenances connected to water plants and operated by RWSA (the "Urban Water System").

D. ACSA and the City have reached an agreement concerning the sharing of costs for construction of the new earthen dam and related improvements and the amount of compensation for the increased area required to construct the dam and which will be inundated by the reservoir pool supported by the new dam, all as more particularly set forth in the Water Cost Allocation Agreement, dated January 1, 2012 (the "Cost Allocation Agreement").

E. ACSA, the City and RWSA desire to set forth their understandings with respect to the construction of the dam and improvements in phases and the rights of RWSA to build the dam and related improvements upon the land where the existing Ragged Mountain Reservoir is located, which land is owned by the City subject to certain rights conveyed by the City to RWSA pursuant to the Four-Party Agreement as set forth in the Deed and Bill of Sale dated June 13, 1983, recorded in the Clerk's Office of the City of Charlottesville in Deed Book 438 at page 854 and in the Clerk's Office of the County of Albemarle in Deed Book 768 at page 277 (the "Deed").

NOW, THEREFORE, for and in consideration of the premises, the cost allocations and other expense reimbursements set forth in the Cost Allocation Agreement, and other good and valuable consideration, the receipt of all of which is hereby acknowledged, the City, ACSA and RWSA agree as follows:

AGREEMENT

1. Specification of the Project. Pursuant to Article IV of the Four-Party Agreement, ACSA and the City agree to and direct RWSA, and RWSA agrees, to proceed to construct and perform the following (hereinafter referred to as the "Project"):

(a) New earthen dam on the site of and downstream of the existing Lower and Upper Ragged Mountain Dams sufficient to impound and raise the existing maximum normal operating reservoir pool level (641' above mean sea level) an additional forty-two feet (42') (683' above mean sea level) utilizing soil from certain borrow areas on the site to the extent feasible (the "New Ragged Mountain Dam"); provided, however, that until satisfaction of the conditions set forth in Paragraph 3 below, the normal operating reservoir pool level shall be limited to an additional thirty feet (30') (671' above mean sea level) above the existing normal operating reservoir pool level (the "Initial Pool Level"), and only upon satisfaction of such conditions shall the normal operating reservoir pool level be raised an additional twelve feet (12') above the Initial Pool Level (the "Additional Pool Level").

(b) Separate rock-lined spillway for the New Ragged Mountain Dam.

(c) Intake tower for the New Ragged Mountain Dam, with intake gates and a normal spillway at heights necessary to support the Initial Pool Level, constructed in such a manner as to allow the operation of an additional intake gate and spillway to support the Additional Pool Level upon satisfaction of the conditions set forth in Paragraph 3 of this Agreement.

(d) A proposed pipeline, including tunnel, pumping facilities and related infrastructure, connecting the reservoir formed by the New Ragged Mountain Dam (such reservoir, including any expansion as provided in Paragraph 3 of this Agreement, hereinafter referred to as the "Ragged Mountain Reservoir") to the existing South Rivanna Reservoir and connecting to an existing pipeline serving the Observatory Water Treatment Plant (such pipeline, tunnel, pumping facilities and related infrastructure hereinafter referred to as the "SRR-RMR Pipeline").

(e) A floating pedestrian trail bridge and spill boom across the Ragged Mountain Reservoir to be located north of Interstate 64 with truck access to construct and maintain such improvements, including periodic removal of debris from the spill boom (hereinafter referred to as the "Floating Bridge and Spill Boom").

(f) Removal of trees and other vegetation in the areas necessary to construct the improvements described in clauses (a) through (e) above and in the area which will be inundated by the Initial Pool Level and, upon satisfaction of the conditions set forth in Paragraph 3 of this Agreement, in the area which will be inundated by the Additional Pool Level.

(g) Breach of the existing Lower and Upper Ragged Mountain Dams.

(h) Other construction and work necessary or desirable for the purposes set forth in this Agreement to construct and complete the improvements or to satisfy federal, state or local regulations applicable to the activities described in clauses (a) through (g) above, including all mitigation and restoration required by such permits.

The portion of the Project to be constructed on the Ragged Mountain Reservoir site shall be located substantially as shown on the "Land Use Map for the New Ragged Mountain Dam", prepared by Schnabel Engineering dated July 19, 2011, Sheets 1 – 7, a copy of which is attached hereto and recorded herewith, with the exception of the Floating Bridge and Spill Boom, which shall be constructed in coordination with the City's design and development of a trail system within the Ragged Mountain Reservoir site. RWSA shall be responsible for all aspects of the design, right-of-way and easement acquisition, and construction of the Project. RWSA shall require and verify that all individuals and entities under contract with RWSA to perform construction activities pursuant to this Agreement on any property owned by the City of Charlottesville agree to indemnity and hold harmless the City and its officers, officials and employees, and to include the City of Charlottesville as an additional insured on any applicable general liability insurance policies.

2. Confirmation and Grant of Water Rights, Leases, Easements and Rights of Access for the Project. Pursuant to Section 6.1 of the Four Party Agreement RWSA is the sole producer and seller of potable water to the City and ACSA. Further, pursuant to Section 3.2(c) of the Four-Party Agreement and Paragraph V of the Deed, the City leased to RWSA, for so long as the Four-Party Agreement remains in effect, "all water rights in and to....the two Ragged Mountain Reservoirs and the South Rivanna Reservoir, including the rights to maintain and operate all impoundment and pumping facilities, and to withdraw all water that may be available." To the

extent not already provided in the Four-Party Agreement, the City hereby leases to RWSA, for so long as the Four-Party Agreement remains in effect, but not to exceed forty (40) years from the date hereof, all water rights in and to the Ragged Mountain Reservoir, including the rights to maintain and operate all impoundment and pumping facilities, and to withdraw all water that may be available, all as provided in Article V of the Four Party Agreement. The City further grants to RWSA a temporary construction easement and right of access necessary to construct, and install the Project to inundate and support a reservoir pool to the Initial Pool Level and, subject to satisfaction of the conditions set forth in Paragraph 3 of this Agreement, to increase the normal operating reservoir pool to the Additional Pool Level and to construct that portion of the SRR-RMR Pipeline to be constructed on the Ragged Mountain Reservoir site and the South Rivanna Reservoir site.

The City further leases to RWSA, commencing upon the date RWSA begins construction of the SRR-RMR Pipeline and continuing for so long as the Four-Party Agreement remains in effect, but not to exceed a period of forty (40) years from the commencement date, the parcel of land adjacent to the South Rivanna Reservoir consisting of approximately 5.45 acres, more or less, designated in the Albemarle County land records as Tax Map 45, Parcel 69A, and more particularly described in Exhibit A attached hereto and recorded herewith to construct, install, operate, maintain, repair, replace, relocate and extend that portion of the SRR-RMR Pipeline to be located in and adjacent to the South Rivanna Reservoir.

3. Increase to Additional Pool Level. RWSA shall perform bathymetric surveys of the South Rivanna Reservoir and current water demand analyses and water demand projections in accordance with, and at intervals governed by, approved state and federal permits and the Commonwealth of Virginia's Local and Regional Water Supply Planning regulations (9VAC 25-

780), but at least every ten (10) years after the date of this Agreement, with the first such survey to be performed not later than the year 2020. RWSA shall update the analysis of safe yield of the Urban Water System following each new bathymetric survey of the South Rivanna Reservoir performed after the date of this Agreement using the latest available data on useable storage in the South Rivanna Reservoir, the Ragged Mountain Reservoir, and the Sugar Hollow Reservoir. All such bathymetric surveys, water demand projections and safe yield analyses will be performed by an outside consultant selected by RWSA. The method for determining safe yield shall be as set forth in the regulations of the Virginia Department of Health. At any such time that (i) the actual Urban Area water demand (measured as combined flow of treated water entering the Urban Water System from water treatment plants) as an average daily demand over a trailing twelve (12) consecutive month period or (ii) the average daily demand over a period of twelve (12) consecutive months projected out ten (10) years reaches eighty-five percent (85%) or more of the safe yield determined from the most recent safe yield analysis, RWSA, upon the written request of ACSA or the City and without further authorization or approval from the other party, shall modify the intake towers and remove trees and other vegetation necessary to allow the New Ragged Mountain Dam to impound and support a reservoir pool to the Additional Pool Level, and shall raise the reservoir pool to the Additional Pool Level.

4. Permits. The City, as the landowner of record of the parcels referenced in Recital B and Paragraph 2 above hereby authorize RWSA to apply for and secure all permits and approvals necessary for or mandated by the Project and the Project's expansion pursuant to Paragraph 3 of this Agreement.

5. Dredging. Pursuant to Article IV of the Four-Party Agreement, the City and ACSA agree to and direct RWSA, and RWSA agrees, to perform such dredging projects at the

South Rivanna Reservoir as may be specified jointly by the City and ACSA pursuant to the Water Cost Allocation Agreement.

6. Miscellaneous. In the event any one or more of the terms or provisions contained in this Agreement should be held invalid or unenforceable in any respect, the validity and enforceability of the remaining terms and provisions will not in any way be affected or impaired. Any invalid or unenforceable term or provision will be deemed to be void and of no force and effect only to the minimum extent necessary to cause such term or provision to become valid and enforceable, and the balance of this Agreement will be fully enforceable.

IN WITNESS WHEREOF, the duly authorized officers of the City of Charlottesville, Virginia, the Albemarle County Service Authority and the Rivanna Water and Sewer Authority have executed this Agreement as of the date first above written.

[SIGNATURES ON FOLLOWING PAGE]

CITY OF CHARLOTTESVILLE, VIRGINIA

By: Maurice Jones (SEAL)
Maurice Jones, City Manager

APPROVED AS TO FORM:

S. Craig Brown
Craig Brown, City Attorney

COMMONWEALTH OF VIRGINIA
CITY OF CHARLOTTESVILLE, to wit:

The foregoing instrument was acknowledged before me this 24th day of JANUARY, 2012, by Maurice Jones as City Manager of the City of Charlottesville, Virginia.

Mary G. Knowles
Notary Public
Registration No.: 205978

MARY G. KNOWLES
NOTARY PUBLIC
Commonwealth of Virginia
Reg. #205978
My Commission Expires 7/31/14

My Commission Expires: JULY 31, 2014

ALBEMARLE COUNTY SERVICE AUTHORITY

By: Gary B. O'Connell (SEAL)
Gary B. O'Connell, Executive Director

COMMONWEALTH OF VIRGINIA
COUNTY OF ALBEMARLE, to wit:

The foregoing instrument was acknowledged before me this 24TH day of JANUARY, 2012, by Gary B. O'Connell as Executive Director of the Albemarle County Service Authority.

Mary G. Knowles
Notary Public
Registration No.: 205978

My Commission Expires: JULY 31, 2014

MARY G. KNOWLES
NOTARY PUBLIC
Commonwealth of Virginia
Reg. #205978
My Commission Expires 7/31/14

RIVANNA WATER AND SEWER AUTHORITY

By:______________________________(SEAL)
Thomas L. Frederick, Jr., Executive Director

COMMONWEALTH OF VIRGINIA
COUNTY OF ALBEMARLE, to wit:

The foregoing instrument was acknowledged before me this 24TH day of JANUARY, 2013, by Thomas L. Frederick, Jr. as Executive Director of the Rivanna Water and Sewer Authority.

Mary G. Knowles
Notary Public
Registration No.: 205978

MARY G. KNOWLES
NOTARY PUBLIC
Commonwealth of Virginia
Reg. #205978
My Commission Expires 7/31/14

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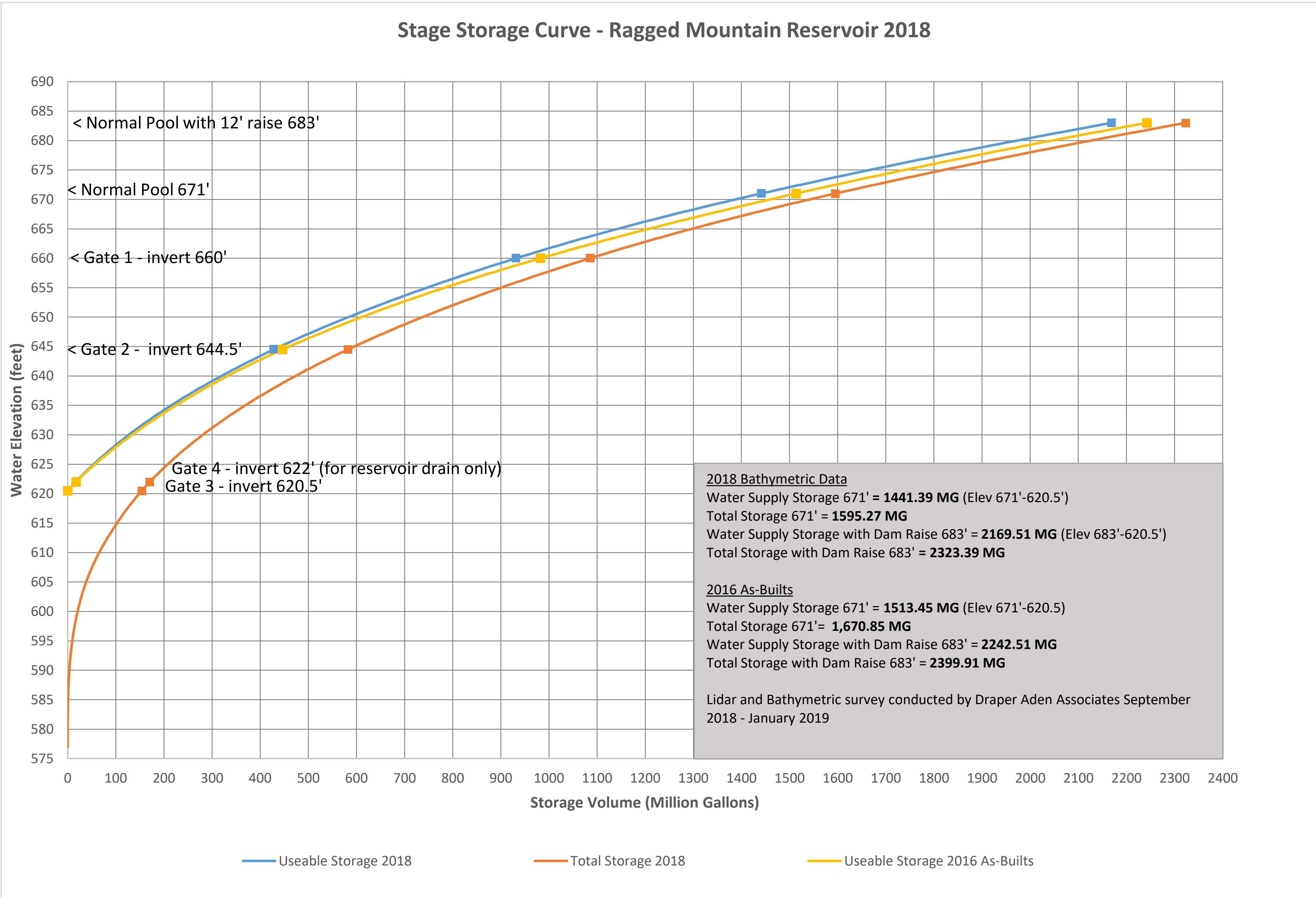
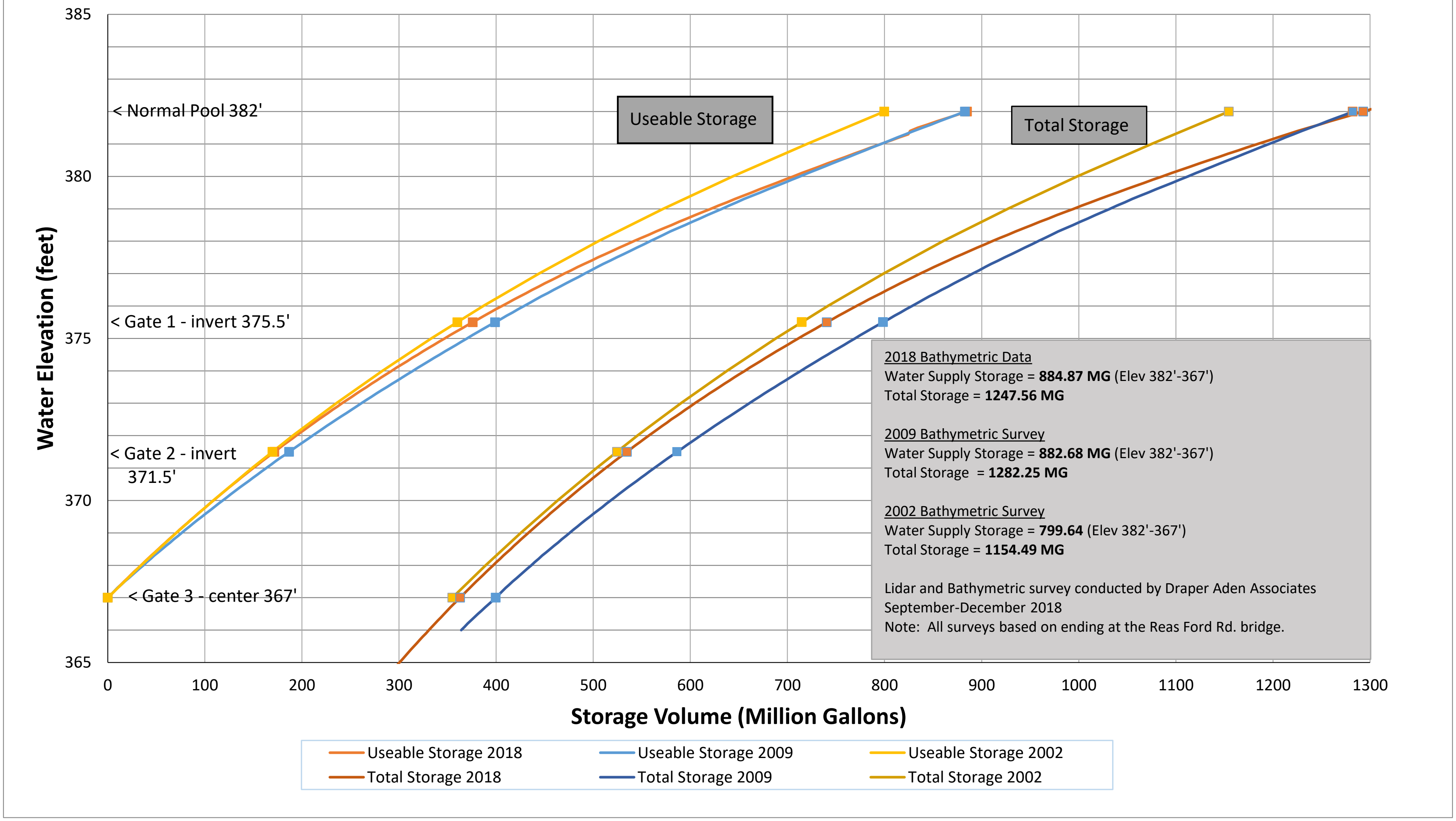
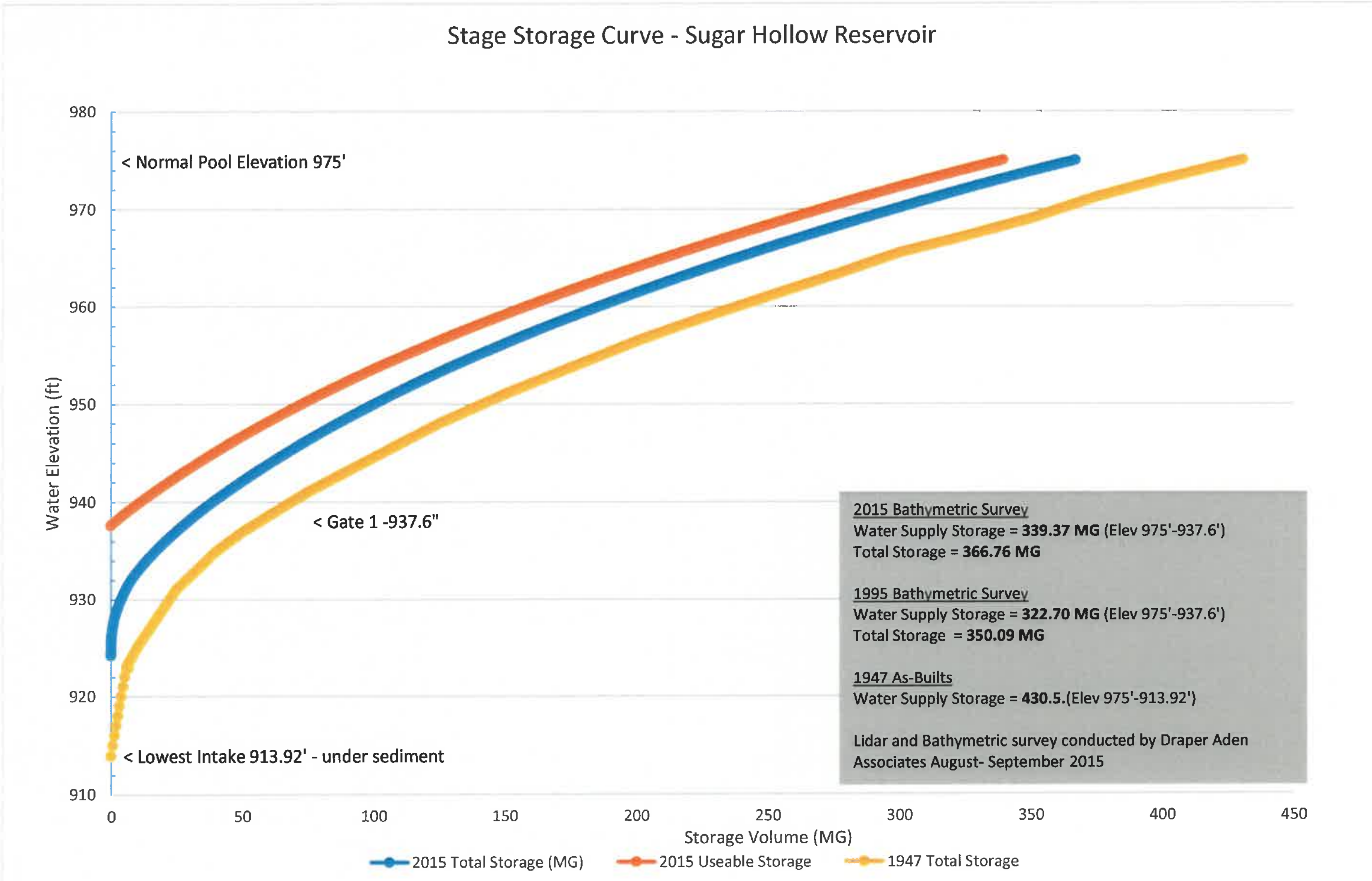
Appendix B: Urban Reservoir Bathymetry


Stage Storage Curve - Ragged Mountain Reservoir 2018
< Normal Pool with 12' raise 683'
< Normal Pool 671'
< Gate 1 - invert 660'
< Gate 2 - invert 644.5'
Gate 4 - invert 622' (for reservoir drain only)
Gate 3 - invert 620.5'
2018 Bathymetric Data
Water Supply Storage 671' = **1441.39 MG** (Elev 671'-620.5')
Total Storage 671' = **1595.27 MG**
Water Supply Storage with Dam Raise 683' = **2169.51 MG** (Elev 683'-620.5')
Total Storage with Dam Raise 683' = **2323.39 MG**
2016 As-Builts
Water Supply Storage 671' = **1513.45 MG** (Elev 671'-620.5)
Total Storage 671'= **1,670.85 MG**
Water Supply Storage with Dam Raise 683' = **2242.51 MG**
Total Storage with Dam Raise 683' = **2399.91 MG**
Lidar and Bathymetric survey conducted by Draper Aden Associates September 2018 - January 2019
Water Elevation (feet)
Storage Volume (Million Gallons)
Useable Storage 2018
Total Storage 2018
Useable Storage 2016 As-Builts

Stage Storage Curve - South Fork Rivanna Reservoir 2018




Stage Storage Curve - Sugar Hollow Reservoir
Water Elevation (ft)
980
970
960
950
940
930
920
910
< Normal Pool Elevation 975'
< Gate 1 -937.6"
< Lowest Intake 913.92' - under sediment
0
50
100
150
200
250
300
350
400
450
Storage Volume (MG)
2015 Total Storage (MG)
2015 Useable Storage
1947 Total Storage
2015 Bathymetric Survey
Water Supply Storage = 339.37 MG (Elev 975'-937.6')
Total Storage = 366.76 MG
1995 Bathymetric Survey
Water Supply Storage = 322.70 MG (Elev 975'-937.6')
Total Storage = 350.09 MG
1947 As-Builts
Water Supply Storage = 430.5.(Elev 975'-913.92')
Lidar and Bathymetric survey conducted by Draper Aden Associates August- September 2015

Appendix C: Monthly Demand Pattern

Month	Fraction of Annual Average
January	0.86
February	0.92
March	0.92
April	0.99
May	1.00
June	1.08
July	1.15
August	1.16
September	1.17
October	1.06
November	0.96
December	0.84

- Used in calculation of operational and DEQ regulatory safe yields. In this case, using July as an example, July demand is 1.15 times the annual average demand. Theoretical safe yield assumes each month's fraction is 1.0, so monthly average demand is the same as the annual average demand.

COMMONWEALTH of VIRGINIA

DEPARTMENT OF ENVIRONMENTAL QUALITY
Street address: 629 East Main Street, Richmond, Virginia 23219
Mailing address: P.O. Box 1105, Richmond, Virginia 23218
TDD (804) 698-4021
www.deq.virginia.gov

Douglas W. Domenech
Secretary of Natural Resources

David K. Paylor
Director

(804) 698-4020
1-800-592-5482

December 28, 2011

Mr. Thomas G. Frederick
Rivanna Water and Sewer Authority
695 Moores Creek Lane
Charlottesville, VA 22902-9016

RE: Final Major Modification No. 1 of VWP Individual Permit No. 06-1574
Ragged Mountain Expansion Project, Albemarle County, Virginia

Dear Mr. Frederick:

Pursuant to the Virginia Water Protection (VWP) Permit Program Regulation 9 VAC 25-210-10 et seq., § 401 of the Clean Water Act Amendments of 1977, and Public Law 95-217, the Department of Environmental Quality (DEQ) has enclosed the final Major Modification No. 1 of the Virginia Water Protection individual permit for the project referenced above.

As provided by Rule 2A:2 of the Supreme Court of Virginia, you have 30 calendar days from the date of service (the date you actually received this decision or the date it was mailed to you, whichever occurred first) within which to appeal this decision by filing a notice of appeal in accordance with the Rules of the Supreme Court of Virginia with the Director, Department of Environmental Quality. In the event that this decision is served on you by mail, three days are added to that period. Refer to Part 2A of the Rules of the Supreme Court of Virginia for additional requirements governing appeals from administrative agencies.

Alternatively, any owner under §§62.1-44.16, 62.1-44.17, and 62.1-44.19 of the State Water Control Law aggrieved by any action the board has taken without a formal hearing, or by inaction of the board, may demand in writing a formal hearing of such owner's grievance, provided a petition requesting such hearing is filed with the board. Said petition must meet the requirements set forth in the board's Procedural Rule Number 1 (9 VAC 25-230-130.B). In cases involving actions of the board, such petition must be filed within 30 calendar days after notice of such action is sent to such owner by certified mail.

Please contact me at brenda.winn@deq.virginia.gov or 804-698-4516 if I can be of further assistance.

Sincerely,

Brenda K. Winn
VWP Water Withdrawal Project Manager

Enclosures: Final Modification Cover Page; Final Modification Part I – Special Conditions and Attachment A; Part II – General Conditions

COMMONWEALTH of VIRGINIA

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1-800-592-5482

VWP Individual Permit Number 06-1574
Effective Date: February 11, 2008
Minor Modification No. 1 Date: March 20, 2009
Major Modification No. 1 Date: December 20, 2011
Expiration Date: February 11, 2023

VIRGINIA WATER PROTECTION PERMIT
MODIFIED PURSUANT TO THE STATE WATER CONTROL LAW
AND SECTION 401 OF THE CLEAN WATER ACT

Based upon an examination of the information submitted by the owner, and in compliance with § 401 of the Clean Water Act as amended (33 USC 1341) and the State Water Control Law and regulations adopted pursuant thereto, the State Water Control Board (board) has determined that there is a reasonable assurance that the activity authorized by this permit, if conducted in accordance with the conditions set forth herein, will protect instream beneficial uses and will not violate applicable water quality standards. The board finds that the effect of the impact, together with other existing or proposed impacts to surface waters, will not cause or contribute to a significant impairment to state waters or fish and wildlife resources.

Permittee: Rivanna Water and Sewer Authority

Address: 695 Moores Creek Lane Charlottesville, VA 22902-9016

Activity Locations: Ragged Mountain Reservoir and South Fork Rivanna River Reservoir in Albemarle County, Virginia and a pipeline between the two reservoirs in Albemarle County and Charlottesville Virginia

Activity Description: The expansion of Ragged Mountain Reservoir for public water supply, including permanent and temporary flooding, excavation, or filling of 13,085 linear feet of stream bed, 2.68 acres of wetlands, and 0.06 of an acre open water; the construction of a pipeline between the two reservoirs; and the construction of intake structures on South Fork Rivanna River Reservoir and Ragged Mountain Reservoir and the withdrawal of water from the two reservoirs.

The permitted activity shall be in accordance with this Permit Cover Page, Part I - Special Conditions and Attachment A, and Part II - General Conditions.

Melanie D. Davenport
Director, Water Division

Dec. 21, 2011
Date

A. *Authorized Activities*

This permit authorizes the following impacts, as described in: the Joint Permit Application and Permit Support Document dated June 30, 2006, received by DEQ on July 5, 2006, and deemed complete by DEQ on May 18, 2007; additional information submitted via correspondence dated 2006 through May 2007; the request for a permit modification dated March 22, 2011, received by DEQ on March 24, 2011; and additional information submitted via correspondence dated July 25 and July 28, 2011.

1. The permanent inundation and fill of 2.63 acres of non-tidal wetlands, including 0.81 acres of palustrine forested wetlands, 0.08 acres of palustrine scrub-shrub wetlands, and 1.73 acres of palustrine emergent wetlands for the construction of reservoir structures and filling of the Ragged Mountain Reservoir to a normal pool elevation of up to 683 feet above mean sea level (msl).

2. The permanent inundation of up to 11,511 linear feet, or approximately 2.2 miles, of stream bed, including unnamed tributaries of Moores Creek, to raise the normal reservoir pool elevation up to 683 feet above mean sea level (msl) and for the installation of culvert extensions and riprap aprons on both sides of Interstate 64.

3. The permanent fill of 881 linear feet (7,048 square feet) of stream bed on an unnamed tributary of Moores Creek with approximately 500 cubic yards of material for the construction of the new Ragged Mountain Reservoir dam.

4. The permanent fill of 0.06 acres of open water in the South Fork Rivanna Reservoir for installation of concrete support piles and piers, raw water intake tower, and raw water pumping station.

5. The permanent excavation below the existing reservoir normal pool elevation to generate fill material to be used in construction of the earthen dam and remove or breach two existing dams (upper and lower) in the Ragged Mountain Reservoir.

6. The temporary excavation of 0.05 acres of emergent wetlands and 693 linear feet of stream bed for the placement of temporary coffer dams and utility trenches for installation of the raw water pipelines, provided all work complies with Special Conditions Part I.C.5, -C.7, -C.8, -C.15, -H.1, and -H.2.

7. The temporary use of mechanical equipment in surface waters when conducted according to the permit Special and General Conditions.

8. The withdrawal of surface water from the South Fork Rivanna River Reservoir, not to exceed a maximum *daily* withdrawal volume of 48.0 million gallons. Authorization of this withdrawal shall also be subject to the conditions in Part I.F below.

9. Surface water impacts resulting from the compensation site creation or restoration activities shall be authorized under this permit, provided that no in-stream work occurs in tributaries within the Buck Mountain Creek compensation site from May 15th through July 31st of any year. The exception for coffer dam installation in Part I.C.8 shall apply. The permittee shall include a detailed summary of the temporary and permanent impacts, including but not limited to the type and amount of impacts, and shall provide proposed compensation for the permanent impacts in the final compensation plan. Any impacts to state waters resulting from the proposed compensation site construction activities shall be compensated for and approved by DEQ prior to construction.

B. *Permit Term*

This permit is valid for 15 years from the date of issuance. If the permittee desires to continue the water withdrawal activities authorized by this permit after it expires, a new application must be submitted to DEQ at least 180 days prior to the expiration of this permit. The application will be evaluated by DEQ based on the regulations and laws in effect at that time.

C. *Conditions Applicable to All Project Construction and Compensatory Mitigation Activities*

1. The activities authorized by this permit shall be executed in such a manner that any impacts to stream beneficial uses are minimized. As defined in § 62.1-10(b) of the Code, "beneficial use" means both instream and offstream uses. Instream beneficial uses include, but are not limited to, the protection of fish and wildlife habitat, maintenance of waste assimilation, recreation, navigation, and cultural and aesthetic values. Offstream beneficial uses include, but are not limited to, domestic (including public water supply), agricultural, electric power generation, commercial, and industrial uses. Public water supply uses for human consumption shall be considered the highest priority.

2. No activity shall substantially disrupt the movement of aquatic life indigenous to the water body, including those species that normally migrate through the area, unless the primary purpose of the activity is to impound water.

3. At crossings of streams, pipes and culverts less than 24 inches in diameter shall be countersunk a minimum of three inches, and pipes and culverts greater than 24 inches in diameter shall be countersunk a minimum of six inches to provide for the re-establishment of a natural stream bottom and to maintain a low flow channel. For multiple-celled culverts, only the bottoms of those cells situated below the limits of

ordinary high water shall be countersunk. To the greatest extent practicable, other cells, pipes, or culverts shall be elevated to provide a natural distribution of flood flows. The requirement to countersink shall not apply to extensions or maintenance of existing culverts that are not countersunk, to floodplain culverts being placed above ordinary high water, to culverts being placed on bedrock, or to culverts required to be placed on slopes 5% or greater.

4. Flows downstream of the project area shall be maintained to protect all beneficial uses as specified in this permit.

5. Excepting the construction of the dam, no activity shall cause more than minimal adverse effect on navigation, and no activity shall block more than half of the width of a stream or water body at any given time.

6. The activity shall not impede the passage of normal or expected high flows, and any associated structure shall withstand expected high flows.

7. Temporary in-stream construction features such as cofferdams shall be made of non-erodible materials.

8. No in-stream work shall occur from May 15th through July 31st of any year on any perennial or intermittent stream being disturbed for installation or relocation of utility lines, including water transport pipelines. This restriction does not apply to utility line crossings installed via directional drilling where the stream bottom is not disturbed. An exception will be made for the *installation* of cofferdams, which may occur during these restricted time periods, provided that all practicable procedures are followed to prevent or reduce the likelihood of events that would cause the coffer dam to lose isolation from free flowing channels. Instream work does not include work that is performed *behind* a cofferdam or in a secured area isolated from a free flowing channel.

   This restriction may be lifted if further mussel surveys performed on perennial or intermittent stream crossings (except those being directionally drilled), or further consultation with the Virginia Department of Game and Inland Fisheries and United States Fish and Wildlife Service, concludes that suitable mussel habitat is not present.

   Once exact pipeline crossings of perennial streams are determined, the permittee shall consult with the Department of Game and Inland Fisheries on the need to perform mussel surveys on perennial tributaries to Ivy Creek. Surveys for freshwater mussels requested by the Department of Game and Inland Fisheries shall be conducted 100 meters upstream through 400 meters downstream of impact areas. Surveys should be performed by a qualified biologist, preferably no more than six months prior to the start of construction. All mussels encountered within the impact area should be relocated upstream into suitable habitat and any listed species should be tagged for future monitoring. Relocation should occur within 30 days of the start of construction to avoid or minimize the chance that mussels will recolonize the work area.

9. Surveys for Indiana bats shall be re-conducted if tree-clearing activities in forested areas do not occur within three years of July 26, 2011. Any surveys conducted as a result of this permit condition shall be performed by a qualified biologist in accordance with standard survey protocols acceptable to the Virginia Department of Game and Inland Fisheries (DGIF) and the United States Fish and Wildlife Service (USFWS). If surveys are necessary, the permittee shall submit a survey plan to DEQ at least 45 days prior to commencing tree-clearing activities, and no tree-clearing activities shall commence until DEQ receives written concurrence from DGIF and USFWS that the activities are not likely to adversely affect this species.

10. All excavation, dredging, or filling in surface waters shall be accomplished in a manner that minimizes bottom disturbance and turbidity. Turbidity levels downstream of any in-stream construction sites shall be minimized to the greatest extent practicable at all times.

11. Erosion and sedimentation controls shall be designed in accordance with the Virginia Erosion and Sediment Control Handbook, Third Edition, 1992, or the most recent version in effect at the time of construction. These controls shall be placed prior to clearing and grading activities and shall be maintained in good working order, to minimize impacts to surface waters. These controls shall remain in place only until clearing and grading activities cease and these areas have been stabilized.

12. All construction, construction access, and demolition activities associated with this project shall be accomplished in a manner that minimizes construction materials or waste materials from entering surface waters. Wet, excess, or waste concrete shall be prohibited from entering surface waters. Measures shall be employed at all times to prevent and contain spills of fuels, lubricants, or other pollutants into surface waters. Any fish kills, or spills of fuels or oils, shall be reported to DEQ immediately upon discovery at (540) 574-7800. If DEQ cannot be reached, the spill shall be reported to the Virginia Department of Emergency Management (DEM) at 1-800-468-8892 or the National Response Center (NRC) at 1-800-424-8802. DEQ shall be notified in writing *within 24 hours or as soon as possible on the next business day* when potential environmentally threatening conditions are encountered which require debris removal or involve potentially toxic substances. Measures to remove the debris or potentially toxic substance, or to change the location of any structure, are prohibited until approved by DEQ, except to the extent that emergency measures are required to protect against imminent threats to public health and safety. In such instances DEQ shall be notified within 24 hours of taking the emergency action. Virginia Water Quality Standards shall not be violated in any surface waters as a result of the project activities.

13. All authorized fill material placed in surface waters shall be clean and free of contaminants in toxic concentrations or amounts in accordance with all applicable laws and regulations.

14. All non-impacted wetlands, streams, open water, and designated upland buffers that are located within fifty feet of any project activities shall be clearly marked or flagged for the life of the construction activity within that area. *The permittee shall notify all contractors and subcontractors that no activities are to occur in these marked areas*.

15. Machinery or heavy equipment used in temporarily impacted wetlands shall be placed on mats or geotextile fabric, or other suitable means shall be implemented, to minimize soil disturbance to the maximum extent practical. Mats, fabrics, or other measures shall be removed as soon as the work is complete in the temporarily impacted wetland.

16. Temporary disturbances to wetlands, stream channels, and/or stream banks during project construction activities shall be avoided and minimized to the maximum extent practicable.

17. All materials (including fill, construction debris, excavated materials, and woody materials) that are temporarily placed in wetlands, in stream channels, or on stream banks shall be placed on mats or geotextile fabric, and shall be immediately stabilized to prevent the materials, or leachate associated with the materials, from entering surface waters. The materials shall be entirely removed within 30 calendar days following completion of that construction activity. After removal, disturbed areas shall be restored to pre-existing conditions (except for mature woody vegetation) in accordance with Part I.H.

18. All required notifications and submittals shall be submitted to the DEQ office stated below, to the attention of the VWP permit manager, unless directed in writing by DEQ subsequent to the issuance of this permit:

    Virginia Dept. of Environmental Quality
    Office of Wetlands and Water Protection
    P. O. Box 1105
    Richmond, Virginia 23218

19. All reports required by this permit and other information requested by DEQ shall be signed by the permittee or a person acting in the permittee’s behalf, with the authority to bind the permittee. A person is a duly authorized representative only if *both* criteria below are met. If a representative authorization is no longer valid because of a change in

responsibility for the overall operation of the facility, a new authorization shall be immediately submitted to DEQ.

a. The authorization is made in writing by the permittee.

b. The authorization specifies either an individual or a position having responsibility for the overall operation of the regulated facility or activity, such as the position of plant manager, superintendent, or position of equivalent responsibility. A duly authorized representative may thus be either a named individual or any individual occupying a named position.

20. All submittals shall contain the following signed certification statement: "I certify under penalty of law that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations."

21. The permittee shall notify the DEQ of any additional impacts to surface waters, including wetlands, and of any change to the type of surface water impacts associated with this project. The permittee shall also notify the DEQ of any substantial or material modifications to the design or configuration of the dam, culverts, in-stream armoring, concrete support piles and piers, intake structure, raw water intake tower, raw water pumping station, existing dam removals, or raw water pipeline installation. Any additional impacts, modifications, or changes affecting surface waters shall be subject to individual permit review and/or modification of this permit. Compensation may be required.

22. The permittee shall provide the public with access to Ragged Mountain Reservoir.

D. *Stream Modifications, Including Intake/Outfall Structures*

1. Any exposed slopes or stream banks shall be stabilized immediately upon completion of work in each impact area. Methods and materials for stabilization shall be in accordance with the Virginia Erosion and Sediment Control Handbook, Third Edition, 1992, or the most recent version in effect at the time of construction.

2. Redistribution of existing stream substrate for erosion control purposes is prohibited, unless otherwise authorized for compensatory mitigation purposes.

3. Material removed from the stream bottom shall not be deposited into surface waters unless otherwise authorized as fill material in this permit.

4. Outlet protection for all outfalls and piped channel sections shall be designed in accordance with Virginia Erosion and Sediment Control Handbook, Third Edition, 1992, or the most recent version in effect at the time of construction. Alternative energy dissipation measures may be installed with prior approval by DEQ.

5. For stream bank protection activities, structures and backfill shall be placed as close to the stream bank as practical, while still avoiding and minimizing impacts to vegetated wetlands to the maximum extent practical. No material shall be placed in excess of the minimum necessary for erosion protection.

6. Asphalt and materials containing asphalt or other toxic substances shall not be used in the construction of submerged sills, breakwaters, dams, or weirs.

7. If stream channelization or relocation is required, all work in surface waters shall be done in the dry, unless authorized by this permit, and all flows shall be diverted around the channelization or relocation area until the new channel is stabilized. The diversion shall be accomplished by leaving a plug at the inlet and outlet ends of the new channel during excavation. Once the new channel has been stabilized, flow shall be routed into the new channel by first removing the downstream plug and then the upstream plug. The new stream channel shall be constructed following the typical sections submitted with the final design plans and should incorporate natural stream channel design principles to the greatest extent practicable. A low flow channel shall be constructed within the channelized or relocated area. The centerline of the channel shall meander, to the extent possible, to mimic natural stream morphology. The rerouted stream flow shall be fully established before construction activities in the old streambed can begin.

E. *Utilities*

1. All utility line work in surface waters shall be performed in a manner that minimizes disturbance in each area. Temporarily disturbed surface waters shall be restored in accordance with the applicable conditions of Part I.H.1 and I.H.2, unless otherwise authorized by this permit.

2. Material resulting from trench excavation may be temporarily sidecast into wetlands not to exceed a total of 90 calendar days, provided the material is not placed in a manner such that it is dispersed by currents or other forces.

3. The trench for a utility line cannot be constructed in a manner that drains wetlands (e.g., backfilling with extensive gravel layers creating a French drain effect).

F. *Water Withdrawal and Instream Flow Conditions*

1. Definitions:

"Natural inflow," when used with respect to South Fork Rivanna Reservoir, is the daily mean discharge rate listed by the United States Geological Survey for the Mechums River near White Hall, Virginia (USGS stream gage 02031000), multiplied by the factor of 2.71 (to compensate for the difference in drainage area), and converted from cubic feet per second to millions of gallons per day by multiplying by a factor of 0.65. Currently, the USGS mean discharge rates are available online at http://waterdata.usgs.gov.

"Natural inflow," when used with respect to Sugar Hollow Reservoir, is the daily mean discharge rate listed by the United States Geological Survey for the Mechums River near White Hall, Virginia (USGS stream gage 02031000), multiplied by the factor of 0.19 (to compensate for the difference in drainage area), and converted from cubic feet per second to millions of gallons per day by multiplying by a factor of 0.65. Currently, the USGS mean discharge rates are available online at http://waterdata.usgs.gov.

"Initial fill," with respect to an Expanded Ragged Mountain Reservoir, refers to the period of time beginning when the facility becomes operational (as defined below), and ending when either (a) the water level at the facility for the first time reaches the normal pool elevation, or (b) a permanent operation and maintenance certificate is issued for the facility by the Virginia Department of Conservation and Recreation, whichever is later.

"Operational," with respect to a new water supply facility, means that it has been completely constructed, can be operated as intended, and is in active service. With respect to an Expanded Ragged Mountain Reservoir, the facility shall be deemed "operational" upon issuance of a temporary operation and maintenance certificate by the Virginia Department of Conservation and Recreation, even though the Reservoir may not fill with water to its full normal pool elevation until some time thereafter.

"Total downstream flow" is the rate at which all water in a stream is moving past a defined point and flowing downstream during a given interval of time. Total downstream flow is expressed in millions of gallons per day and includes, but is not limited to, all water traveling over a dam spillway, water seeping through, around, or under a dam or spillway, water conveyed through a pipeline from a reservoir to the downstream, or water conveyed through a hydroelectric plant from a reservoir to the downstream during the defined interval.

"Urban Water System" is the system of water supply reservoirs, intakes, pipelines, and water treatment facilities that provide potable drinking water to the citizens of the City of Charlottesville and areas of the County of Albemarle surrounding the City as defined by the Board of Supervisors. Water storage for the Urban Water System includes the Sugar Hollow Reservoir, the Ragged Mountain Reservoir, and South Fork Rivanna Reservoir.

"Useable storage" is the volume of water in a reservoir at a particular time that is available for routine withdrawal and use for water supply purposes. It consists of all that volume of water within a reservoir located above the dead storage pool (or sediment pool) up to the water surface elevation. The volume of useable storage at a particular reservoir at a given time depends upon the water surface elevation (which shall be determined by observation), and upon the then-current contour of the reservoir bottom and elevation of the dead storage pool (which shall be determined from the most recent stage-storage curves prepared by the Rivanna Water & Sewer Authority under the seal of a professional engineer on the basis of periodic bathymetric surveys).

"Total useable storage" is the sum of the Useable Storage in each of the storage reservoirs in the Urban Water System at a given time.

2. Where provisions applicable to a fully-Expanded Ragged Mountain Reservoir (Total Useable Storage of 2.189 billion gallons, normal pool elevation of 683 feet) differ from those applicable to an intermediate-Expanded Ragged Mountain Reservoir (Total Useable Storage of 1.549 billion gallons, normal pool elevation of 671 feet), the provisions shown in brackets shall apply to an intermediate-Expanded Ragged Mountain Reservoir.

3. Total downstream flow Provisions before an Expanded Ragged Mountain Reservoir is Operational.

    a. From South Fork Rivanna Reservoir:

        i. When the water level at South Fork Rivanna Reservoir is at or above the spillway elevation of 382 feet, South Fork Rivanna Reservoir will be spilling water on a daily basis and no additional total downstream flow is required.

        ii. When the water level at South Fork Rivanna Reservoir is below the spillway elevation of 382 feet total downstream flow will be at least 8 mgd or natural inflow, whichever is less.

    b. From Sugar Hollow Reservoir:

        i. When the water level at Sugar Hollow Reservoir is at or above the spillway elevation of 975 feet, Sugar Hollow Reservoir will be spilling water on a daily basis and no additional total downstream flow is required.

ii. When the water level at Sugar Hollow Reservoir is below the spillway elevation of 975 feet, total downstream flow past the dam will be at least 0.4 mgd or natural inflow, whichever is less.

c. From Ragged Mountain Reservoir: there are no new requirements.

4. Total downstream flow Provisions After an Expanded Ragged Mountain Reservoir is Operational, But Before the Pipeline from South Fork Rivanna Reservoir to Ragged Mountain Reservoir is Operational.

a. From South Fork Rivanna Reservoir:

i. If total useable storage available to the Urban Water System is equal to or greater than 2.36 billion gallons [1.6 billion gallons], total downstream flow past South Fork Rivanna Reservoir must be at least 70% of the natural inflow or 1.3 mgd, whichever is greater, subject to the following exceptions:

(a) No total downstream flows in excess of 20 mgd shall be required.

(b) If useable storage in South Fork Rivanna Reservoir has been exhausted (e.g., the water level is at or below the lowest operable water supply intake), then total downstream flow past South Fork Rivanna Reservoir shall be whatever volume of water enters that intake unless or until the total downstream flow past South Fork Rivanna Reservoir equals or exceeds 1.3 mgd.

ii. If total useable storage available to the Urban Water System is equal to or greater than 1.36 billion gallons [0.75 billion gallons] but less than 2.36 billion gallons [1.6 billion gallons], total downstream flow past South Fork Rivanna Reservoir must be at least 50% of the natural inflow or 1.3 mgd, whichever is greater, subject to the following exceptions:

(a) No total downstream flows in excess of 20 mgd shall be required.

(b) If useable storage in South Fork Rivanna Reservoir has been exhausted (i.e., the water level is at or below the lowest operable water supply intake), then total downstream flow past South Fork Rivanna Reservoir shall be whatever volume of water enters that intake unless or until the total downstream flow past South Fork Rivanna Reservoir equals or exceeds 1.3 mgd.

iii. If total useable storage available to the Urban Water System is less than 1.36 billion gallons [0.75 billion gallons], total downstream flow past South Fork

Rivanna Reservoir must be at least 30% of the natural inflow or 1.3 mgd, whichever is greater, subject to the following exceptions:

(a) No total downstream flows in excess of 20 mgd shall be required.

(b) If useable storage in South Fork Rivanna Reservoir has been exhausted (i.e., the water level is at or below the lowest operable water supply intake), then total downstream flow past South Fork Rivanna Reservoir shall be whatever volume of water enters that intake unless or until the total downstream flow past South Fork Rivanna Reservoir equals or exceeds 1.3 mgd.

b. From Sugar Hollow Reservoir, when the water level in Sugar Hollow Reservoir is above the lowest operable water intake and an Expanded Ragged Mountain Reservoir has not completed its initial fill.

   i. If the useable storage in Ragged Mountain Reservoir is equal to or greater than 1.53 billion gallons [1.08 billion gallons], total downstream flow past Sugar Hollow Reservoir must be at least 100% of the natural inflow to Sugar Hollow Reservoir; or 10 mgd, whichever is less.

   ii. If the useable storage in Ragged Mountain Reservoir is equal to or greater than 1.1 billion gallons [0.8 billion gallons] but less than 1.53 billion gallons [1.08 billion gallons], total downstream flow past Sugar Hollow Reservoir must be at least 100% of the natural inflow to Sugar Hollow Reservoir; or 2 mgd, whichever is less.

   iii. If the useable storage in Ragged Mountain Reservoir is equal to or greater than 0.66 billion gallons [0.45 billion gallons] but less than 1.1 billion gallons [0.8 billion gallons], total downstream flow past Sugar Hollow Reservoir must be at least 100% of the natural inflow to Sugar Hollow Reservoir; or 1 mgd, whichever is less.

   iv. If the useable storage in Ragged Mountain Reservoir is less than 0.66 billion gallons [0.45 billion gallons], total downstream flow past Sugar Hollow Reservoir must be at least 100% of the natural inflow to Sugar Hollow Reservoir; or 0.4 mgd, whichever is less.

c. From Sugar Hollow Reservoir when the water level in Sugar Hollow Reservoir is above the lowest operable water intake and an Expanded Ragged Mountain Reservoir has completed its initial fill.

   i. If the useable storage in Ragged Mountain Reservoir is equal to or greater than 1.53 billion gallons [1.08 billion gallons], total downstream flow past Sugar

Hollow Reservoir must be at least 100% of the natural inflow to Sugar Hollow Reservoir; or 10 mgd, whichever is less.

ii. If the useable storage in Ragged Mountain Reservoir is less than 1.53 billion gallons [1.08 billion gallons], then total downstream flow must be at least 100% of the natural inflow to Sugar Hollow, or 2 mgd, whichever is less.

iii. When the water level in Sugar Hollow Reservoir is at or below the lowest operable water intake, RWSA must fully open the total downstream flow control device supplied from the lowest operable water intake and leave it in the fully open position until the water level in Sugar Hollow Reservoir is again higher than the lowest water intake.

d. From Ragged Mountain Reservoir: the permittee must provide a total downstream flow past the dam of at least 23,800 gallons per day.

5. Total downstream flow provisions After Both an Expanded Ragged Mountain Reservoir and the Pipeline from South Fork Rivanna Reservoir to Ragged Mountain Reservoir are Operational.

a. From South Fork Rivanna Reservoir:

i. If total useable storage available to the Urban Water System is equal to or greater than 2.36 billion gallons [1.8 billion gallons], total downstream flow past South Fork Rivanna Reservoir must be at least 70% of the natural inflow or 1.3 mgd, whichever is greater, subject to the following exceptions:

(a) No total downstream flows in excess of 20 mgd shall be required.

(b) If useable storage in South Fork Rivanna Reservoir has been exhausted (i.e., the water level is at or below the lowest operable water supply intake), then total downstream flow past South Fork Rivanna Reservoir shall be whatever volume of water enters that intake unless or until the total downstream flow past South Fork Rivanna Reservoir equals or exceeds 1.3 mgd.

ii. If total useable storage available to the Urban Water System is equal to or greater than 1.36 billion gallons [1.0 billion gallons] but less than 2.36 billion gallons [1.8 billion gallons], total downstream flow past South Fork Rivanna Reservoir must be at least 50% of the natural inflow or 1.3 mgd, whichever is greater, subject to the following exceptions:

(a) No total downstream flows in excess of 20 mgd shall be required.

(b) If useable storage in South Fork Rivanna Reservoir has been exhausted (i.e., the water level is at or below the lowest operable water supply intake), then total downstream flow past South Fork Rivanna Reservoir shall be whatever volume of water enters that intake unless or until the total downstream flow past South Fork Rivanna Reservoir equals or exceeds 1.3 mgd.

iii. If total useable storage available to the Urban Water System is less than 1.36 billion gallons [1.0 billion gallons], total downstream flow past South Fork Rivanna Reservoir must be at least 30% of the natural inflow or 1.3 mgd, whichever is greater, subject to the following exceptions:

(a) No total downstream flows in excess of 20 mgd shall be required.

(b) If useable storage in South Fork Rivanna Reservoir has been exhausted (i.e., the water level is at or below the lowest operable water supply intake), then total downstream flow past South Fork Rivanna Reservoir shall be whatever volume of water enters that intake unless or until the total downstream flow past South Fork Rivanna Reservoir equals or exceeds 1.3 mgd.

b. From Sugar Hollow Reservoir:

i. When the water level at Sugar Hollow Reservoir is at or above the spillway elevation of 975 feet, Sugar Hollow Reservoir will be spilling water on a daily basis and no additional total downstream flow is required.

ii. When the water level at Sugar Hollow Reservoir is below the spillway elevation of 975 feet.

(a) If the water level in Sugar Hollow Reservoir is above the lowest operable water intake total downstream flow past Sugar Hollow Reservoir must be at least 90% of the natural inflow to Sugar Hollow Reservoir; or 10 mgd, whichever is less.

(b) If the water level in Sugar Hollow Reservoir is not above the lowest operable water intake, RWSA must fully open the total downstream flow control device supplied from the lowest operable water intake and leave it in the fully open position until the water level in Sugar Hollow Reservoir is again higher than the lowest water intake.

c. From Ragged Mountain Reservoir: the permittee must provide a total downstream flow past the dam of at least 23,800 gallons per day.

6. Monitoring and Reporting of instream flows:

Within eight months of permit issuance, after opportunity for public input, the permittee will provide for DEQ approval, a Flow Measurement Design Plan and Operations Manual. The manual will describe the methods and procedures and any planned improvements for monitoring inflows and releases from Sugar Hollow and South Fork Rivanna River Reservoirs. The manual will describe the procedures that will be made and the frequency and conditions with which they will be made to adjust releases so the total downstream flow requirements of this permit will be met.

The Flow Measurement Design and Operations Plan will determine the suitability of the existing release equipment to meet the special conditions of Section F. In the event that existing release equipment cannot release water so that the total downstream flow past Sugar Hollow or Ragged Mountain Reservoirs is within 10% of the required total downstream flow required by Section F, then the Flow Measurement Design Plan and Operations Manual will include a schedule for the installation of equipment capable of releasing water to satisfy that requirement and a description of the equipment. In no case shall the necessary equipment be installed later than two years after permit issuance. The plan will describe procedures to be used to calibrate and verify releases from the reservoirs and a include schedule for periodic recalibration and verification of the release equipment.

The Flow Measurement Design Plan and Operations Manual will identify the measurements and formulas to calculate natural inflow to Sugar Hollow and South Fork Rivanna reservoirs. The Flow Measurement Design Plan and Operations Manual will specify the frequency of measurements and specify what data will be used and how that data will be compiled to compute natural inflow to the reservoirs. The Flow Measurement Design Plan and Operations Manual will describe the permittee’s records retention policy with regard to data collection and instrument calibration and verification records. The Flow Measurement Design Plan and Operations Manual will describe what contingency procedures, gages and formulas will be used in case the primary gage used to estimate inflow is out of service.

The Flow Measurement Design Plan and Operations Manual will include a schedule for updating useable storage values for each of the three reservoirs through bathymetric studies. The first update will not be required until an expanded Ragged Mountain Reservoir becomes operational.

The Flow Measurement Design Plan and Operations Manual will include the development of a reporting form(s) to be submitted to DEQ annually. The form will be designed to evaluate the permittee’s compliance with the special conditions of Section F. A reporting table designed to check compliance with Special Condition I.F.3 shall be submitted within at least eight months of permit issuance. For each reporting period the table shall record the date, the natural inflow to Sugar Hollow Reservoir and to South Fork Rivanna River Reservoir, whether the reservoirs are at full pond, and the required and actual total downstream flow past Sugar Hollow Reservoir and South Fork Rivanna River Reservoirs.

At least 6 months prior to the date when an expanded Ragged Mountain Reservoir becomes operational, proposed revisions to the Flow Measurement Design Plan and Operations Manual, including a revised Reporting Form shall be submitted to DEQ to comply with Special Condition I.F.4.

At least 6 months prior to the date when both an expanded Ragged Mountain Reservoir and the pipeline from the South Fork Reservoir to the Ragged Mountain Reservoir become operational, proposed revisions to the Flow Measurement Design Plan and Operations Manual, including a revised Reporting Form shall be submitted to DEQ to comply with Special Condition I.F.5.

The required rates of total downstream flow past South Fork Rivanna Reservoir and Sugar Hollow Reservoir shall be determined and the rates of total downstream flow shall be adjusted as necessary twice per week. When the required rate of total downstream flow depends upon the natural inflow to the reservoir, the total downstream flow shall be calculated by determining the average of the natural inflows for the three most recent days for which data are available. No adjustment to the rate of total downstream flow shall be required unless the current calculation of total downstream flow differs from the previously calculated total downstream flow by more than ten percent.

A monitoring report shall be prepared and submitted by January 31st of each year documenting the daily withdrawals, natural inflow, and required and actual total downstream flow in the previous calendar year.

7. Water Conveyance Between facilities:

   a. Except as set forth below, the Rivanna Water & Sewer Authority may convey water between and among its reservoirs and/or water treatment plants at rates up to the capacities of the conveyances involved.

   b. After both an Expanded Ragged Mountain Reservoir and the pipeline from South Fork Rivanna Reservoir to Ragged Mountain Reservoir are Operational.

      i. There shall be no conveyance of water from Sugar Hollow Reservoir to Ragged Mountain Reservoir or Observatory Water Treatment Plant via the existing pipeline.

      ii. There shall be no conveyance of water from South Fork Rivanna Reservoir into

Ragged Mountain Reservoir when the water level at the Expanded Ragged Mountain Reservoir is at or above the spillway elevation.

iii. When the water level at South Fork Rivanna Reservoir is below its spillway elevation and water is released from Sugar Hollow Reservoir to the Moormans River at a rate substantially in excess of the applicable total downstream flow specified herein for the purpose of conveying water into South Fork Rivanna Reservoir for water supply, the Rivanna Water & Sewer Authority will reduce the rate of flow released through the flow control device at Sugar Hollow Reservoir by no more than fifty percent (50 %) per day until the applicable total downstream flow specified herein is achieved.

iv. The maximum withdrawal from South Fork Rivanna Reservoir shall not exceed 48 million gallons per day and the maximum refill of Ragged Mountain Reservoir from South Fork Rivanna Reservoir shall not exceed 25 million gallons per day.

8. Prior to impacting any surface waters as authorized by this permit, the applicant shall submit any existing regional or local water supply conservation plans that apply to the service areas being supplied by the water withdrawn under this permit.

9. The permittee must issue a call for voluntary conservation, prior to reducing flowby to the South Fork Rivanna River to 50% of natural inflow or 1.3 mgd, whichever is greater, under the provisions of Special Conditions I.F.4.a.ii or I.F.5.a.ii; and the retail customers must be practicing mandatory conservation prior to reducing flowby to the South Fork Rivanna River to 30% of natural inflow or 1.3 mgd, whichever is greater, under the provisions of Special Conditions I.F.4.a.iii or I.F.5.a.iii.

10. In the event that the Governor or the Virginia Drought Coordinator declares a drought emergency in the Drought evaluation Region, which includes Albemarle County and the City of Charlottesville, the permittee shall implement the mandatory conservation measures, as detailed in Attachment A of this permit. The permittee shall be responsible for determining when drought emergencies are declared. DEQ may require documentation that mandatory conservation measures were implemented during declared drought emergencies.

11. Water withdrawal monitoring and reporting activities shall comply with this section, with Part I.C, and with Part II. All records and information that result from the monitoring and reporting activities required by this permit, including any records of maintenance activities to the withdrawal system, shall be retained for the life of the permit. This period of retention shall be extended automatically during the course of any unresolved litigation regarding the regulated activity or as requested by the State Water Control Board.

12. *For all permittees whose average daily withdrawal during any single month exceeds 10,000 gallons per day*, the water withdrawals shall be reported to DEQ by January 31st of the next year, as required under State Water Control Board (SWCB) Water Withdrawal Reporting Regulation (9 VAC 25-200 et seq.). The annual monitoring report shall contain the following information: the permittee's name and address, the sources and locations of water withdrawal, the cumulative volume of water withdrawn each month of the calendar year, the maximum day withdrawal and the month in which it occurred, and the method of withdrawal measurement. *For permittees subject to the Virginia Department of Health (VDH) Waterworks Regulations*, the annual reports to DEQ may include, as an alternative, the source and location of water withdrawals, the type of use for the water withdrawn, and reference to the reports filed with VDH that contain the monthly withdrawal data.

G. *Project Construction Monitoring and Submittals for Project Surface Water Impact Sites*

Project Pre-Construction Monitoring and Submittals

1. Final construction plans for the project activities authorized by this permit shall be submitted at least 30 calendar days prior to initiating any land disturbance or construction in permitted impact areas. Construction activities shall not be initiated until DEQ has reviewed and commented on the plans, or until 30 calendar days have passed without DEQ comments being received by the permittee. If DEQ submits comments regarding activities authorized by this permit, construction shall not proceed until comments are resolved to DEQ's satisfaction. Final construction plans shall include, at a minimum but not limited to, the location of all photographic monitoring stations, as described in Part I.G.3 below. Plan revision(s) in permitted areas shall be submitted to DEQ for approval immediately upon determination that a change is necessary. DEQ approval shall be required prior to implementing the revision(s).

2. At least ten calendar days prior to the initiation of any land disturbance or construction activities in permitted areas, the permittee shall submit written notification to DEQ, including a projected schedule for initiating and completing work at each permitted impact area.

3. The permittee shall conduct photographic monitoring of pre-construction conditions in permitted, temporary or permanent impact areas covered by this permit. The photos shall be of sufficient quantity to thoroughly document the environmental conditions at the permitted impact areas prior to disturbance. Photographic monitoring shall be conducted by the following method:

Enumerated photo stations shall be established at each permitted impact area and shall be consistent for the duration of construction activities. Photo stations may be established via water craft or temporary floating structures. Photos will be taken from the same directional orientation during each monitoring event. Each photograph taken shall be labeled with the photo station number, the permitted impact location, the photograph orientation, the date and time of the photograph, the name of the person taking the photograph, and a brief description of the activities being conducted at the time of the photograph. If necessary, this information may be provided on (a) separate sheet(s) of paper attached to the photographs.

Photos shall be submitted with the notification (Part I.G.2) to DEQ that land disturbing or construction activities are planned to begin.

4. Final wetlands and stream compensation plans (final plans) shall be prepared in accordance with the Virginia Water Protection Permit Program Regulation (9 VAC 25-210-10 et. seq.) in effect at the time of plan submittal, and shall be based on the most recent mitigation guidance, if any, posted on DEQ's wetlands web page.

   The final plans shall be approved by DEQ *prior to any construction activity in permitted impact areas*. DEQ shall have 60 calendar days to review and either provide written comments on the final plans or approve the final plans. The final plans as approved by DEQ shall be an enforceable requirement of this permit. Any change to the approved final plans must be submitted to DEQ for approval prior to implementing the change.

   a. The final wetland compensation plan shall include complete information on all components of the conceptual compensatory mitigation plan, as detailed in the Virginia Water Protection Permit Program Regulation (9 VAC 25-210-10 et. seq.) in effect at the time of final plan submittal, including but not limited to, compensation amounts, ratios, wetland types, and locations. In addition, the plan shall include: a summary of the type and acreage of wetland impacts anticipated during the construction of the compensation site and the proposed compensation for these impacts; a site access plan; a monitoring plan, including the proposed success criteria, the monitoring goals, the monitoring schedule, the location of photo stations, monitoring wells, vegetation sampling points, and reference wetlands (if available), and the monitoring provisions contained in this permit; an abatement and control plan for undesirable plant species; an erosion and sedimentation control plan; a construction schedule; and the mechanism for protection in perpetuity of the compensation site(s), including all surface waters and buffer areas within its boundaries.

      The mechanism for protection shall be in place within 180 days of final compensation plan approval. The mechanism for protection shall state that no activity will be performed on the property in any area designated as a compensation area, with the exception of maintenance or corrective action measures authorized by the board. The mechanism of protection applies to ditching, land clearing, or discharge of dredge or fill material, unless these activities are specifically authorized by the board through the issuance of a VWP individual or general permit, or waiver thereof. Such mechanism of protection shall contain the specific phrase "ditching, land clearing, or discharge of dredge or fill material" in the limitations placed on the use of these areas. The mechanism of protection, or an equivalent mechanism for government-owned lands, shall be recorded in the chain of title to the property, and proof of recordation shall be submitted to DEQ within 180 days of final compensation plan approval.

Hydrology analyses should include: For riverine or stream-driven systems, a water budget (for nontidal sites only) based on expected monthly inputs and outputs which will project water level elevations for a typical year, a dry year, and a wet year; For groundwater- and precipitation-driven sites in non-riverine systems, historic groundwater elevation data, if available, or the proposed location of groundwater monitoring wells to collect these data; and For overbank flood-driven systems, gaging station data and a floodplain analysis, including a minimum 10-year continuous simulation which will account for variability in inputs and outputs under varying conditions.

b. The final stream compensation plan shall include complete information on all components of the conceptual compensatory mitigation plan, as detailed in the Virginia Water Protection Permit Program Regulation (9 VAC 25-210-10 et. seq.) in effect at the time of final plan submittal, including but not limited to, compensation amounts, credits and/or credit ratios, condition assessment types, and locations. In addition, the plan shall include: a summary of the type and linear feet of stream bed impacts anticipated during the construction of the compensation site and the proposed compensation for these impacts; a site access plan; an erosion and sedimentation control plan, if appropriate; an abatement and control plan for undesirable plant species; a monitoring plan, including the proposed success criteria, the monitoring goals, the monitoring schedule, and the location of photo stations, vegetation sampling points, survey points, bank pins, scour chains, and reference streams (if available), and the monitoring provisions contained in this permit; a plan view sketch depicting the pattern and all compensation measures being employed; a profile sketch; cross-sectional sketches of the proposed compensation stream; and the mechanism for protection in perpetuity of the compensation site(s), including all surface waters and buffer areas within its boundaries.

The mechanism for protection shall be in place within one year of final compensation plan approval. The mechanism for protection shall state that no activity will be performed on the property in any area designated as a compensation area, with the exception of maintenance or corrective action measures authorized by the board. The mechanism of protection applies to ditching, land clearing, or discharge of dredge or fill material, unless these activities are specifically authorized by the board through the issuance of a VWP individual or general permit, or waiver thereof. Such mechanism of protection shall contain the specific phrase “ditching, land clearing, or discharge of dredge or fill material” in the limitations placed on the use of these areas. The mechanism of protection, or an equivalent mechanism for government-owned lands, shall be recorded in the chain of title to the property, and proof of recordation shall be submitted to DEQ within one year of final compensation plan approval.

c. Any compensation plan proposing the purchase or use of mitigation banking credits shall include: (i) the name of the proposed mitigation bank and the HUC in which it is located; (ii) the number of credits proposed to be purchased or used; and (iii) certification from the bank owner of the availability of credits.

d. Any compensation plan proposing to include contributions to an in-lieu fee fund shall include proof of the willingness of the entity to accept the donation and documentation of how the amount of the contribution was calculated.

Monitoring and Submittals Required During Project Construction

5. Monitoring of water quality parameters shall be conducted as described below during relocation of any flowing stream through a new channel. Corrective measures and additional monitoring may be required if Virginia Water Quality Standards, as detailed in the most recent version of Regulation 9 VAC 25-260-10 et. seq., are not met. The permittee shall report violations of Virginia Water Quality Standards to DEQ within 24 hours of monitoring. All monitoring data shall be submitted to DEQ within seven calendar days of the monitoring event.

    a. One sampling station shall be located upstream of the relocated channel, and one sampling station shall be located immediately downstream of the relocated channel.

    b. At the *upstream* sampling station, temperature, pH, and dissolved oxygen (D.O.) measurements shall be taken immediately *before* opening a new channel, and every 30 minutes thereafter for at least *two* hours.

    c. At the *downstream* sampling station, temperature, pH, and dissolved oxygen (D.O.) measurements shall be taken immediately *after* opening a new channel, and every 30 minutes thereafter until the measurements indicate that the site has stabilized (a minimum of *three* hours).

6. The permittee shall conduct photographic monitoring of sufficient quantity and frequency to thoroughly document all temporary and permanent construction activities in permitted impact areas. Photos shall also document any non-compliant events or problems encountered during the construction activities. For work being conducted in phases, or only in certain areas at the same time, monitoring may begin upon initiating work in those specific permitted impact areas.

   The established, enumerated photo stations in each permitted impact area shall be used for photo monitoring. Photos will be taken from the same directional orientation during each monitoring event. Each photograph taken shall be labeled with the photo station number, the permitted impact location, the photograph orientation, the date and time of the photograph, the name of the person taking the photograph, and a brief description of the activities being conducted at the time of the photograph. If necessary, this information may be provided on (a) separate sheet(s) of paper attached to the photographs.

   Photos shall be submitted as part of the construction monitoring reports detailed in Part I.G.7.

7. Construction monitoring reports shall be submitted to DEQ monthly, due by the 15th of the following month (for example, the report for January is due by February 15th). The reports shall include the following, as applicable:

   a. A written narrative stating whether or not work was performed in each permitted impact area, including installation and maintenance of erosion and sediment controls, during the monitoring period. If work was performed, the narrative shall include a description of the major work items performed, when those items were initiated, when those items are expected to be completed, and any non-compliant events or problems encountered.

   b. A written summary of any corrective actions taken and any subsequent notifications to DEQ regarding non-compliant events or problems encountered during construction activities in permitted impact areas.

   c. A summary of anticipated work to be completed during the next monitoring period in all permitted impact areas.

   d. A labeled site map showing each permitted impact area where work activities occurred during the monitoring period and the photo stations used to document activities.

   e. The photos taken during the monitoring period.

Project Post-Construction Monitoring and Submittals

8. The permittee shall submit written notification within 30 calendar days after the completion of activities in each permitted impact area(s) authorized under this permit. The notification may be included with monthly construction monitoring reports or may be submitted separately. In either case, notification shall include the post-construction photos of disturbances in the particular permitted impact area(s), as described in Part I.G.9.

9. The permittee shall conduct photographic monitoring of sufficient quantity to thoroughly document that all construction activities were completed in permitted impact areas. The established, enumerated photo stations shall be used for photo monitoring. Each photograph taken shall be labeled with the photo station number, the permitted impact location, the photograph orientation, the date and time of the photograph, the name of the person taking the photograph, and the date that activities were completed. If necessary, this information may be provided on (a) separate sheet(s) of paper attached to the photographs.

   For temporary disturbances to surface waters, the permittee shall conduct photographic monitoring immediately after restoration, then once annually in August or September for *two consecutive years*. If restoration is not completed by June 30th of a given year, the monitoring should not begin until August or September of the *following* year in order to allow one growing season to pass. If post-restoration conditions are not equivalent to pre-construction conditions after two years (except for mature woody vegetation), DEQ may require corrective action and continued annual monitoring until the temporary impacts are restored.

   For permanent disturbances, the permittee shall conduct photographic monitoring of all authorized, permanent-impact areas once at the time of completion of construction and stabilization of the area.

   Photos shall be submitted with the post-construction notification detailed in Part I.G.8.

10. Final As-Built plans shall be submitted to DEQ prior to filling the reservoir for all structures completed to that date. These may include, but are not limited to, the dams, access roads, intake structures, water transfer pipelines, pump station, etc. Final As-Built plans for the remaining portions of the project authorized by this permit, such as, but not limited to relocation of utility lines, shall be submitted to DEQ within 90 calendar days after the completion of construction. A licensed land surveyor or a licensed professional engineer shall certify the plans. The plans shall include a narrative comparing the As-

Built plans with the design plans. DEQ shall have 30 calendar days to review the plans and provide comments to the permittee.

H. *Compensatory Mitigation*

1. All temporarily disturbed wetland areas shall be restored to preconstruction conditions within 30 calendar days of completing work in the areas, which shall include re-establishing pre-construction contours, and planting or seeding with appropriate wetland vegetation according to cover type (emergent, scrub/shrub, or forested), except for invasive species identified on DCR's Invasive Alien Plant Species of Virginia list. The permittee shall take all appropriate measures to promote and maintain the revegetation of temporarily disturbed wetlands for a minimum of two years after the area is restored.

2. All temporarily impacted streams and stream banks shall be restored to their original elevations and contours within 30 calendar days following the construction at that stream segment, and the banks shall be seeded or planted with the same vegetative cover type originally present along the banks, including supplemental erosion control grasses if necessary but not including invasive species identified on DCR's Invasive Alien Plant Species of Virginia list. The permittee shall take all appropriate measures to promote and maintain the revegetation of temporarily disturbed streams and stream banks for a minimum of two years after the area is restored.

3. Final compensation for wetland impacts shall be based on the conceptual compensation plans submitted as part of the complete application for this project. The permittee shall provide off-site compensation for 2.61 acres of wetland impacts at the Moores Creek compensation site in Albemarle County, Virginia, as detailed in the final wetland compensation plan approved by DEQ. The compensation site shall be preserved in perpetuity, as described in the final wetlands compensation plan and Part I.G.4.

4. Final compensation for stream impacts shall be based on the conceptual compensation plans submitted as part of the complete application for this project. The permittee shall provide off-site compensation for 13,163 linear feet of stream impacts through a combination of stream restoration, stream riparian buffer restoration and enhancement, and preservation of stream and riparian buffer, a minimum of 100 feet but no more than 300 feet on each bank, at the Buck Mountain Creek compensation site, as detailed in the final stream compensation plan approved by DEQ. Compensation will occur along Buck Mountain Creek and its tributaries. The compensation areas shall be preserved in perpetuity, as described in the final stream compensation plan and Part I.G.4.

5. Compensation for any additional permanent impacts based on the final project and compensation designs will be provided at appropriate ratios, as detailed in the final wetlands and stream compensation plans approved by DEQ.

6. Any change to the compensation options noted in Part I.H.1 through I.H.5 above shall be approved by DEQ prior to initiating any construction activities in surface waters.

I. *Conditions Applicable to Compensatory Mitigation Activities*

1. The permittee is responsible for meeting all of the components of the compensatory mitigation requirements associated with this permit. This responsibility can only be transferred if and when the permit is transferred to another party and then only to the new permit recipient.

2. Compensation site construction shall commence *within 180 calendar days (approximately six months) of beginning project construction activities in* <u>*any*</u> *permitted impact area*. Work in the permitted impact areas shall cease until compensation site construction begins, unless otherwise authorized to continue by DEQ.

3. All vegetation removal for control purposes shall be done by manual means, unless authorized by DEQ in advance. Herbicides or algacides shall not be used in or immediately adjacent to compensation areas without prior authorization by DEQ.

4. Vegetation shall be native species common to the area and shall be suitable for growth in local wetland and/or riparian conditions. Seeds used for compensation site activities shall conform to the Virginia Seed Law (Sections 3.1-262 Code of Virginia) and Virginia Seed Regulations (2 VAC 5-290-10 et. seq.). Planting of woody plants shall occur when vegetation is normally dormant unless otherwise approved in the final compensation plan.

5. Point sources of stormwater runoff shall be prohibited from entering any compensation site prior to treatment by appropriate best management practices (BMPs) that are designed, installed, and maintained as described in the Virginia Erosion and Sediment Control Handbook (Third Edition, 1992, or the most recent version in effect at the time of construction) and the Virginia Stormwater Management Handbook (First Edition, 1999, or the most recent version in effect at the time of construction), or for any compensation site within state forest boundaries, the Forestry Best Management Practices for Water Quality in Virginia Technical Guide (Fourth Edition, July 2002). Appropriate best management practices may include sediment traps, grassed waterways, vegetated filter strips, debris screens, oil and grease separators, and forebays. Installation of alternative practices not described in these references shall be submitted to DEQ for approval prior to beginning construction.

J. *Compensation Site Construction Tasks, Monitoring, and Submittals*

Pre-Construction Tasks, Monitoring, and Submittals for the Compensation Sites

1. At least ten calendar days prior to the initiation of any land disturbance or construction activities at the Moores Creek and Buck Mountain Creek compensation sites (compensation sites), the permittee shall submit written notification to DEQ, including a projected schedule for initiating and completing work at each wetland cell and each stream restoration reach, and the pre-construction photographs described in Part I.J.4.

2. For compensation sites involving land disturbance, a site stabilization plan shall be implemented prior to compensatory mitigation construction activities.

3. All non-impacted wetlands, streams, open water, and designated buffers that are located within the compensation site limits, or that are located within fifty feet of any compensation site construction activities, shall be clearly marked or flagged for the life of the construction activity within that area. *The permittee shall notify all contractors and subcontractors that no activities are to occur in these marked areas*.

4. The permittee shall conduct photographic documentation of pre-construction conditions in each cell of wetlands to be created and in each reach of stream restoration or enhancement at the compensation sites. The photos shall be of sufficient quantity to thoroughly document the environmental conditions prior to disturbance. Photographic documentation shall be conducted by the following method:

   For wetland creation areas and stream restoration areas, enumerated photo stations shall be established in each wetland cell or stream restoration reach of the compensation sites. These locations will be consistent for the duration of compensation site construction activities. Photo stations may be established via water craft or temporary floating structures. Photos will be taken from the same directional orientation during each monitoring event, except for stream restoration reaches, where photographs shall be taken from the center of the stream, facing downstream, so that the entire length of the restoration reach is captured. Each photograph taken shall be labeled with the photo station number, the cell number and wetland type, the stream reach identification number or name, the photograph orientation, the date and time of the photograph, and the name of the person taking the photograph. If necessary, this information may be provided on (a) separate sheet(s) of paper attached to the photographs.

   For preservation areas only, representative photos shall be taken once while marking the non-impact areas noted in Part I.J.3, or once prior to commencing any construction activities at the compensation sites. Each photograph taken shall be labeled with the stream reach identification number or name, the photograph orientation, the date and time of the photograph, and the name of the person taking the photograph. If necessary, this information may be provided on (a) separate sheet(s) of paper attached to the photographs. In lieu of individual photos in large preservation reaches, an aerial photograph shall be submitted provided that the photo contains sufficient detail to identify pre-construction conditions. Each aerial photograph shall be labeled with the stream reach identification numbers or names, the photograph elevation, the date and time of the photograph, and the name of the person or firm taking the photograph.

Photos shall be submitted with the notification (Part I.J.1) to DEQ that land disturbing or construction activities are planned to begin.

Short-Term Monitoring and Submittals during Compensation Site Construction

5. Monitoring of water quality parameters shall be conducted during relocation of any flowing stream through a new channel. Corrective measures and additional monitoring may be required if water quality standards are not met. The permittee shall report violations of water quality standards to DEQ within 24 hours of monitoring. All monitoring data shall be submitted to DEQ within seven calendar days of the monitoring event. The method for monitoring water quality parameters shall be as follows:

   a. One sampling station shall be located upstream of the relocated channel, and one sampling station shall be located immediately downstream of the relocated channel.

   b. At the *upstream* sampling station, temperature, pH, and dissolved oxygen (D.O.) measurements shall be taken immediately *before* opening a new channel, and every 30 minutes thereafter for at least *two* hours.

   c. At the *downstream* sampling station, temperature, pH, and dissolved oxygen (D.O.) measurements shall be taken immediately *after* opening a new channel, and every 30 minutes thereafter until the measurements indicate that the site has stabilized (minimum of *three* hours).

6. The permittee shall conduct photographic monitoring of sufficient quantity and frequency to thoroughly document all construction activities in each wetland cell and stream restoration or enhancement reach at the compensation sites, such as, but not limited to, clearing, grading, installation of water control structures, erosion and sediment control structures, access roads, stream relocations, etc. Photos shall also document any non-compliant events or problems encountered during the construction activities. No photos are necessary in preservation-only areas. For work being conducted in phases, or only in certain areas at the same time, monitoring may begin upon initiating work in those specific areas.

   The established, enumerated photo stations in each wetland cell or stream restoration or enhancement reach shall be used for photo monitoring. Photos will be taken from the same directional orientation during each monitoring event, except for stream restoration reaches, where photographs shall be taken from the center of the stream, facing downstream, so that the entire length of the restoration reach is captured. Each photograph taken shall be labeled with the photo station number, the cell number and wetland type, the stream reach identification number or name, the photograph orientation, the date and time of the photograph, the name of the person taking the photograph, and a brief description of the activities being conducted at the time of the photograph. If necessary, this information may be provided on (a) separate sheet(s) of paper attached to the photographs.

Photos shall be submitted as part of the compensation site construction monitoring reports detailed in Part I.J.7.

7. Compensation site construction monitoring reports shall be submitted to DEQ monthly, due by the 15th of the following month (for example, the report for January is due by February 15th). The reports shall include the following, as applicable:

   a. A written narrative including a description of the major work items performed, when those items were initiated, when those items are expected to be completed, and the details of any non-compliant events or problems that were encountered.

   b. A written summary of any corrective actions taken and any subsequent notifications to DEQ regarding non-compliant events or problems encountered during construction activities.

   c. A summary of anticipated work to be completed during the next monitoring period.

   d. A labeled site map showing where work activities occurred during the monitoring period and the photo stations used to document activities.

   e. The photos taken during the monitoring period.

8. After each cell of the wetland compensation site reaches final grades, but prior to planting the cell, the permittee shall submit a post-grading survey to DEQ. The survey shall be conducted by a licensed land surveyor and certified by a licensed surveyor, licensed professional engineer, or licensed landscape architect. The survey shall document spot elevations (in feet above mean sea level) that are within +/- 0.2 feet (1.2 inches) of the elevations indicated in the site construction grading plan that was approved as part of the final compensation plan. Post-grading elevations for the compensation site shall be sufficient to ensure that wetland hydrology will be achieved on the site to support the goals and objectives of the approved final compensation plan. DEQ shall have 30 calendar days to review the survey and provide comments to the permittee.

Submittals after Compensation Site Construction

9. The permittee shall submit written notification within 30 calendar days after the completion of activities in each wetland cell and each stream restoration or enhancement reach at the compensation sites. The notification may be included with monthly compensation site construction monitoring reports or may be submitted separately. In either case, notification shall include the post-construction photos of the wetland cell or stream reach, using the established, enumerated photo stations.

10. Final As-Built plans of the entire Moores Creek site, and the areas of the Buck Mountain Creek compensation site where stream restoration or enhancement occurred, shall be submitted to DEQ within 90 calendar days of completing construction at each site. A licensed land surveyor or a licensed professional engineer shall certify the plans. The plans shall include a narrative comparing the As-Built plans with the design plans or reference reach information. DEQ shall have 30 calendar days to review the plans and provide comments to the permittee.

Long-Term Monitoring for Success after Compensation Site Construction and in Preservation Areas

11. Success monitoring at all compensation sites shall be conducted in accordance with the current Virginia Water Protection Permit Program Regulation 9 VAC 25-210-10 et. seq. in effect at the time that monitoring begins, with the most recent mitigation guidance found on DEQ's wetlands web page, with the approved final compensatory mitigation plans, and with this permit.

12. Success monitoring at constructed or restored sites shall be conducted on the frequency and duration stipulated in the approved final compensation plans. Success monitoring shall begin at the first full growing season (monitoring year one) following compensation site construction. If construction ends before the beginning of the growing season in a particular year, then *that* year shall be considered as monitoring year one for purposes of success monitoring. If construction ends during or after the growing season in a particular year, the *following* growing season shall be considered as monitoring year one for purposes of success monitoring. The growing season for the area in which the compensation is located is defined by the local U.S.D.A Natural Resources Conservation Service or Soil Conservation Service office.

13. If all success criteria have not been met by November 30th of the last monitoring year specified in the approved final compensation plan, or if visual observations conclude that the site has not met the overall restoration goals, corrective actions shall be implemented in accordance with the DEQ-approved corrective action plan. Annual monitoring shall continue until two sequential, annual reports indicate that all criteria have been

successfully satisfied (e.g., that corrective actions were successful) and the compensation sites have met the overall restoration goals. The permittee shall be solely responsible for ensuring that all necessary corrective actions are implemented so that the compensation sites meet the success criteria, as detailed in the final compensation plans. Should any significant changes to the compensation sites be necessary, the first full growing season after the changes are complete shall become the new monitoring year one. Monitoring shall continue in accordance with the DEQ-approved corrective action plan.

14. Photographic documentation during success monitoring shall be conducted in accordance with the final compensation plans approved by DEQ.

15. Hydrology monitoring at a *nontidal* wetland compensation sites shall be conducted in accordance with the final compensation plans approved by DEQ.

16. Wetland vegetation monitoring shall be conducted in accordance with the final compensation plans approved by DEQ. Undesirable plant species shall be identified and controlled as described in the monitoring and control plan for undesirable plant species, such that they are not dominant species or do not change the desired community structure.

17. Monitoring for the presence of hydric soils or soils under hydric conditions shall be conducted in accordance with the final compensation plans approved by DEQ.

18. Wildlife data collection shall be conducted in accordance with the final compensation plans approved by DEQ.

19. All bank pins and scour chains used to monitor bank and channel stability shall be monitored and measured each monitoring year on the frequency detailed in the DEQ-approved final compensation plans. Maintenance on bank pins and scour chains shall be conducted within 30 days of each inspection.

20. All preserved stream and riparian buffer areas provided as compensation for this project shall be monitored by aerial photography once every five years for the effective term of this permit, beginning upon DEQ's approval of the final stream compensation plan. Aerial photographs shall be of sufficient number to capture all preservation areas and shall be of sufficient scale and elevation to discern changes in vegetation density and coverage in the preservation areas.

Submittals for Success Monitoring at the Compensation Sites

21. Compensation site monitoring reports shall be submitted by December 31st of the years in which a monitoring is required, including the final monitoring year, as identified in the

approved final compensation plans. The reports shall include the following, at a minimum:

a. A general description of the compensation site including a site location map identifying wetland, open water, and stream compensation areas, photo stations, vegetative and soil monitoring stations, monitoring wells (if applicable), wetland zones, survey points, bank pins, and scour chains;

b. Summary of activities completed during the monitoring year;

c. Description of monitoring methods;

d. An analysis of all hydrology information, including monitoring well data, precipitation data, and gauging data from streams, or other open water areas, as detailed in the final compensation plans;

e. Evaluation of hydric soils or soils under hydric conditions;

f. Discussion of the stream geomorphologic parameters measured, including channel dimension, pattern, profile, and materials within defined stream type, as they relate to channel or stream bank stability;

g. An analysis of all vegetative community information, including woody and herbaceous species, both planted and volunteers, set forth in the final compensation plans;

h. Discussion of wildlife or signs of wildlife observed at the compensation sites;

i. Discussion of macroinvertebrate sampling data;

j. Evaluation of instream structures;

k. Discussion of observed success of livestock access limiting measures;

l. Discussion of alterations, maintenance, and/or major storm events resulting in significant change in stream profile or cross section;

m. Comparison of site conditions from the previous monitoring year, or comparison of site conditions to the reference site;

n. A calculation of the acreage of each wetland type based upon that monitoring year's soils, vegetation, and hydrology data, shown on the site location map;

o. Stream restoration reach survey, certified by a licensed land surveyor or a licensed professional engineer, including at a minimum, the stream classification, the required stream cross-sections, a longitudinal profile (including Thalweg, bankfull, and top of bank measurements), a pebble count, all instream structures, and other required information as detailed in the approved final compensation plans;

p. A corrective action plan, if necessary, which includes any proposed actions or maintenance activities, a schedule, and a monitoring plan (e.g., the control of undesirable species, the repair of a damaged water control device, the replacement of damaged, planted vegetation, etc.); and

q. Properly labeled photographs.

22. Within 90 calendar days of the final monitoring event in the final monitoring year, a wetland boundary survey shall be conducted by a licensed land surveyor or a licensed professional engineer, and shall be based upon the results of monitoring data for soils, vegetation, and hydrology. A calculation shall be made of the total acreage of each wetland type. The boundary and acreage per wetland type shall be shown on the most recent version of the compensation site design plan sheet(s). The so-noted compensation design plan sheets shall be submitted to DEQ as part of the final monitoring report or as a separate document.

23. Aerial photographs of preservation areas taken in accordance with Part I.J.20 shall be submitted to DEQ within 30 days of the flight date. Each aerial photograph shall be labeled with the stream reach identification numbers or names, the photograph elevation, the date and time of the photograph, and the name of the person or firm taking the photograph.

Attachment A- Water Conservation

Mandatory Non-essential Water Use Restrictions

The following non-essential water uses will be prohibited during periods of declared drought emergencies. Please note the exceptions that follow each prohibited use. These prohibitions and exceptions will apply to uses from all sources of water and will only be effective when the Governor of Virginia or the Virginia Drought coordinator declares a Drought Emergency. Water use restrictions shall not apply to the agricultural production of food or fiber, the maintenance of livestock including poultry, nor the commercial production of plant materials so long as best management practices are applied to assure the minimum amount of water is utilized.

Unrestricted irrigation of lawns is prohibited.

- Newly sodded and seeded areas may be irrigated to establish cover on bare ground at the minimum rate necessary for no more than a period of 60 days. . Irrigation rates may not exceed one inch of applied water in any 7-day period.
- Gardens, bedding plants, trees, shrubs and other landscape materials may be watered with hand held containers, hand held hoses equipped with an automatic shutoff device, sprinklers or other automated watering devices at the minimum rate necessary but in no case more frequently than twice per week. Irrigation should not occur during the heat of the day.
- All allowed lawn irrigation must be applied in a manner to assure that no runoff, puddling or excessive watering occurs.
- Irrigation systems may be tested after installation, routine maintenance or repair for no more than ten minutes per zone.

Unrestricted irrigation of golf courses is prohibited.

- Tees and greens may be irrigated between the hours of 9:00 p.m. and 10:00 a.m. at the minimum rate necessary.
- Localized dry areas may be irrigated with a hand held container or hand held hose equipped with an automatic shutoff device at the minimum rate necessary.
- Greens may be cooled by syringing or by the application of water with a hand held hose equipped with an automatic shutoff device at the minimum rate necessary.
- Fairways may be irrigated between the hours of 9:00 p.m. and 10:00 a.m. at the minimum rate necessary not to exceed one inch of applied water in any ten-day period.
- Fairways, tees and greens may be irrigated during necessary overseeding or resodding operations in September and October at the minimum rate necessary. Irrigation rates during this restoration period may not exceed one inch of applied water in any seven-day period.
- Newly constructed fairways, tees and greens and areas that are re-established by sprigging or sodding may be irrigated at the minimum rate necessary not to exceed one

inch of applied water in any seven-day period for a total period that does not exceed 60 days.

- Fairways, tees and greens may be irrigated without regard to the restrictions listed above so long as:
    - The only water sources utilized are water features whose primary purpose is stormwater management;
    - Any water features utilized do not impound permanent streams;
    - During declared Drought Emergencies these water features receive no recharge from other water sources such as ground water wells, surface water intakes, or sources of public water supply; and,
    - All irrigation occurs between 9:00 p.m. and 10:00 a.m.
- All allowed golf course irrigation must be applied in a manner to assure that no runoff, puddling or excessive watering occurs.
- Rough areas may not be irrigated.

Unrestricted irrigation of athletic fields is prohibited.

- Athletic fields may be irrigated between the hours of 9:00 p.m. and 10:00 a.m. at a rate not to exceed one inch per application or more than a total of one inch in multiple applications during any ten-day period. All irrigation water must fall on playing surfaces with no outlying areas receiving irrigation water directly from irrigation heads.
- Localized dry areas that show signs of drought stress and wilt (curled leaves, foot-printing, purpling) may be syringed by the application of water for a cumulative time not to exceed fifteen minutes during any twenty four hour period. Syringing may be accomplished with an automated irrigation system or with a hand held hose equipped with an automatic shutoff device at the minimum rate necessary.
- Athletic fields may be irrigated between the hours of 9:00 p.m. and 10:00 a.m. during necessary overseeding, sprigging or resodding operations at the minimum rate necessary for a period that does not exceed 60 days. Irrigation rates during this restoration period may not exceed one inch of applied water in any seven-day period. Syringing is permitted during signs of drought stress and wilt (curled leaves, foot-printing, purpling).
- All allowed athletic field irrigation must be applied in a manner to assure that no runoff, puddling or excessive watering occurs.
- Irrigation is prohibited on athletic fields that are not scheduled for use within the next 120-day period.
- Water may be used for the daily maintenance of pitching mounds, home plate areas and base areas with the use of hand held containers or hand held hoses equipped with an automatic shutoff device at the minimum rate necessary.
- Skinned infield areas may utilize water to control dust and improve playing surface conditions utilizing hand held containers or hand held hoses equipped with an

automatic shutoff device at the minimum rate necessary no earlier than two hours prior to official game time.

Washing paved surfaces such as streets, roads, sidewalks, driveways, garages, parking areas, tennis courts, and patios is prohibited.

- Driveways and roadways may be pre-washed in preparation for recoating and sealing.
- Tennis courts composed of clay or similar materials may be wetted by means of a hand-held hose equipped with an automatic shutoff device at the minimum rate necessary for maintenance. Automatic wetting systems may be used between the hours of 9:00 p.m. and 10:00 a.m. at the minimum rate necessary.
- Public eating and drinking areas may be washed using the minimum amount of water required to assure sanitation and public health.
- Water may be used at the minimum rate necessary to maintain effective dust control during the construction of highways and roads.

Use of water for washing or cleaning of mobile equipment including automobiles, trucks, trailers and boats is prohibited.

- Mobile equipment may be washed using hand held containers or hand held hoses equipped with automatic shutoff devices provided that no mobile equipment is washed more than once per calendar month and the minimum amount of water is utilized.
- Construction, emergency or public transportation vehicles may be washed as necessary to preserve the proper functioning and safe operation of the vehicle.
- Mobile equipment may be washed at car washes that utilize reclaimed water as part of the wash process or reduce water consumption by at least 10% when compared to a similar period when water use restrictions were not in effect.
- Automobile dealers may wash cars that are in inventory no more than once per week utilizing hand held containers and hoses equipped with automatic shutoff devices, automated equipment that utilizes reclaimed water as part of the wash process, or automated equipment where water consumption is reduced by at least 10% when compared to a similar period when water use restrictions were not in effect.
- Automobile rental agencies may wash cars no more than once per week utilizing hand held containers and hoses equipped with automatic shutoff devices, automated equipment that utilizes reclaimed water as part of the wash process, or automated equipment where water consumption is reduced by at least 10% when compared to a similar period when water use restrictions were not in effect.
- Marine engines may be flushed with water for a period that does not exceed 5 minutes after each use.

Use of water for the operation of ornamental fountains, artificial waterfalls, misting machines, and reflecting pools is prohibited.

- Fountains and other means of aeration necessary to support aquatic life are permitted.

Use of water to fill and top off outdoor swimming pools is prohibited.

- Newly built or repaired pools may be filled to protect their structural integrity.
- Outdoor pools operated by commercial ventures, community associations, recreation associations, and similar institutions open to the public may be refilled as long as:
  - Levels are maintained at mid-skimmer depth or lower,
  - Any visible leaks are immediately repaired,
  - Backwashing occurs only when necessary to assure proper filter operation,
  - Deck areas are washed no more than once per calendar month (except where chemical spills or other health hazards occur),
  - All water features (other than slides) that increase losses due to evaporation are eliminated, and
  - Slides are turned off when the pool is not in operation.
- Swimming pools operated by health care facilities used in relation to patient care and rehabilitation may be filled or topped off.
- Indoor pools may be filled or topped off.
- Residential swimming pools may be filled only to protect structural integrity, public welfare, safety and health and may not be filled to allow the continued operation of such pools.

Water may be served in restaurants, clubs, or eating-places only at the request of customers.

Part II – General Conditions

A. Duty to Comply

The permittee shall comply with all conditions of the VWP permit. Nothing in the VWP permit regulations shall be construed to relieve the permittee of the duty to comply with all applicable federal and state statutes, regulations and prohibitions. Any VWP permit violation is a violation of the law, and is grounds for enforcement action, VWP permit termination, revocation, modification, or denial of an application for a VWP permit extension or reissuance.

B. Duty to Cease or Confine Activity

It shall not be a defense for a permittee in an enforcement action that it would have been necessary to halt or reduce the activity for which a VWP permit has been granted in order to maintain compliance with the conditions of the VWP permit.

C. Duty to Mitigate

The permittee shall take all reasonable steps to minimize or prevent any impacts in violation of the permit which may have a reasonable likelihood of adversely affecting human health or the environment.

D. VWP Permit Action

1. A VWP permit may be modified, revoked and reissued, or terminated as set forth in 9 VAC 25-210 et seq.

2. If a permittee files a request for VWP permit modification, revocation, or termination, or files a notification of planned changes, or anticipated noncompliance, the VWP permit terms and conditions shall remain effective until the request is acted upon by the board. This provision shall not be used to extend the expiration date of the effective VWP permit. If the permittee wishes to continue an activity regulated by the VWP permit after the expiration date of the VWP permit, the permittee must apply for and obtain a new VWP permit or comply with the provisions of 9 VAC 25-210-185 (VWP Permit Extension).

3. VWP permits may be modified, revoked and reissued or terminated upon the request of the permittee or other person at the board's discretion, or upon board initiative to reflect the requirements of any changes in the statutes or regulations, or as a result of VWP permit noncompliance as indicated in the Duty to Comply subsection above, or for other reasons listed in 9 VAC 25-210-180 (Rules for Modification, Revocation and Reissuance, and Termination of VWP permits).

E. Inspection and Entry

Upon presentation of credentials, any duly authorized agent of the board may, at reasonable times and under reasonable circumstances:

1. Enter upon any permittee's property, public or private, and have access to, inspect and copy any records that must be kept as part of the VWP permit conditions;

2. Inspect any facilities, operations or practices (including monitoring and control equipment) regulated or required under the VWP permit; and

3. Sample or monitor any substance, parameter or activity for the purpose of ensuring compliance with the conditions of the VWP permit or as otherwise authorized by law.

F. Duty to Provide Information

1. The permittee shall furnish to the board any information which the board may request to determine whether cause exists for modifying, revoking, reissuing or terminating the VWP permit, or to determine compliance with the VWP permit. The permittee shall also furnish to the board, upon request, copies of records required to be kept by the permittee.

2. Plans, specifications, maps, conceptual reports and other relevant information shall be submitted as required by the board prior to commencing construction.

G. Monitoring and Records Requirements

1. Monitoring of parameters, other than pollutants, shall be conducted according to approved analytical methods as specified in the VWP permit. Analysis of pollutants will be conducted according to 40 CFR Part 136 (2000), Guidelines Establishing Test Procedures for the Analysis of Pollutants.

2. Samples and measurements taken for the purpose of monitoring shall be representative of the monitored activity.

3. The permittee shall retain records of all monitoring information, including all calibration and maintenance records and all original strip chart or electronic recordings for continuous monitoring instrumentation, copies of all reports required by the VWP permit, and records of all data used to complete the application for the VWP permit, for a period of at least three years from the date of the expiration of a granted VWP permit. This period may be extended by request of the board at any time.

4. Records of monitoring information shall include:

    a. The date, exact place and time of sampling or measurements;

b. The name of the individuals who performed the sampling or measurements;

c. The date and time the analyses were performed;

d. The name of the individuals who performed the analyses;

e. The analytical techniques or methods supporting the information such as observations, readings, calculations and bench data used;

f. The results of such analyses; and

g. Chain of custody documentation.

H. Transferability

This VWP permit may be transferred to a new permittee only by modification to reflect the transfer, by revoking and reissuing the permit, or by automatic transfer. Automatic transfer to a new permittee shall occur if:

1. The current permittee notifies the board within 30 days of the proposed transfer of the title to the facility or property;

2. The notice to the board includes a written agreement between the existing and proposed permittee containing a specific date of transfer of VWP permit responsibility, coverage and liability to the new permittee, or that the existing permittee will retain such responsibility, coverage, or liability, including liability for compliance with the requirements of any enforcement activities related to the permitted activity; and

3. The board does not within the 30-day time period notify the existing permittee and the new permittee of its intent to modify or revoke and reissue the VWP permit.

I. Property rights

The issuance of this permit does not convey any property rights in either real or personal property, or any exclusive privileges, nor does it authorize injury to private property or any invasion of personal rights or any infringement of federal, state or local law or regulation.

J. Reopener

Each VWP permit shall have a condition allowing the reopening of the VWP permit for the purpose of modifying the conditions of the VWP permit to meet new regulatory standards duly adopted by the board. Cause for reopening VWP permits includes, but is not limited to when the circumstances on which the previous VWP permit was based have materially and substantially changed, or special studies conducted by the board or the permittee show material and substantial change, since the time the VWP permit was issued and thereby constitute cause for VWP permit modification or revocation and reissuance.

K. Compliance with State and Federal Law

Compliance with this VWP permit constitutes compliance with the VWP permit requirements of the State Water Control Law. Nothing in this VWP permit shall be construed to preclude the institution of any legal action under or relieve the permittee from any responsibilities, liabilities, or other penalties established pursuant to any other state law or regulation or under the authority preserved by § 510 of the Clean Water Act.

L. Severability

The provisions of this VWP permit are severable.

M. Permit Modification

A VWP permit may be modified, but not revoked and reissued except when the permittee agrees or requests, when any of the following developments occur:

1. When additions or alterations have been made to the affected facility or activity which require the application of VWP permit conditions that differ from those of the existing VWP permit or are absent from it;

2. When new information becomes available about the operation or activity covered by the VWP permit which was not available at VWP permit issuance and would have justified the application of different VWP permit conditions at the time of VWP permit issuance;

3. When a change is made in the promulgated standards or regulations on which the VWP permit was based;

4. When it becomes necessary to change final dates in schedules due to circumstances over which the permittee has little or no control such as acts of God, materials shortages, etc. However, in no case may a compliance schedule be modified to extend beyond any applicable statutory deadline of the Act;

5. When changes occur which are subject to "reopener clauses" in the VWP permit; or

6. When the board determines that minimum instream flow levels resulting from the permittee's withdrawal of water are detrimental to the instream beneficial use and the withdrawal of water should be subject to further net limitations or when an area is declared a Surface Water Management Area pursuant to §§ 62.1-242 through 62.1-253 of the Code of Virginia, during the term of the VWP permit.

N. Permit Termination

After notice and opportunity for a formal hearing pursuant to Procedural Rule No. 1 (9 VAC 25-230-100) a VWP permit can be terminated for cause. Causes for termination are as follows:

1. Noncompliance by the permittee with any condition of the VWP permit;

2. The permittee's failure in the application or during the VWP permit issuance process to disclose fully all relevant facts or the permittee's misrepresentation of any relevant facts at any time;

3. The permittee's violation of a special or judicial order;

4. A determination by the board that the permitted activity endangers human health or the environment and can be regulated to acceptable levels by VWP permit modification or termination;

5. A change in any condition that requires either a temporary or permanent reduction or elimination of any activity controlled by the VWP permit; and

6. A determination that the permitted activity has ceased and that the compensatory mitigation for unavoidable adverse impacts has been successfully completed.

O. Civil and Criminal Liability

Nothing in this VWP permit shall be construed to relieve the permittee from civil and criminal penalties for noncompliance.

P. Oil and Hazardous Substance Liability

Nothing in this VWP permit shall be construed to preclude the institution of legal action or relieve the permittee from any responsibilities, liabilities, or penalties to which the permittee is or may be subject under § 311 of the Clean Water Act or §§ 62.1-44.34:14 through 62.1-44.34:23 of the State Water Control Law.

Q. Unauthorized Discharge of Pollutants

Except in compliance with this VWP permit, it shall be unlawful for the permittee to:

1. Discharge into state waters sewage, industrial wastes, other wastes, or any noxious or deleterious substances;

2. Excavate in a wetland;

3. Otherwise alter the physical, chemical, or biological properties of state waters and make them detrimental to the public health, to animal or aquatic life, to the uses of such waters for domestic or industrial consumption, for recreation, or for other uses;

4. On or after October 1, 2001 conduct the following activities in a wetland:

    a. New activities to cause draining that significantly alters or degrades existing wetland acreage or functions;

    b. Filling or dumping;

    c. Permanent flooding or impounding;

    d. New activities that cause significant alteration or degradation of existing wetland acreage or functions.

R. Permit Extension

Any permittee with an effective VWP permit for an activity that is expected to continue after the expiration date of the VWP permit, without any change in the activity authorized by the VWP permit, shall submit written notification requesting an extension. The permittee must file the request prior to the expiration date of the VWP permit. Under no circumstances will the extension be granted for more than 15 years beyond the original effective date of the VWP permit. If the request for extension is denied, the VWP permit will still expire on its original date and, therefore, care should be taken to allow for sufficient time for the board to evaluate the extension request and to process a full VWP permit modification, if required.

U.S. Army Corps Of Engineers
Norfolk District

Fort Norfolk, 803 Front Street
Norfolk, Virginia 23510-1096

DEPARTMENT OF THE ARMY PERMIT

Permittee: Thomas L. Frederick, Executive Director, Rivanna Water and Sewer Authority
Permit No.: 06-V1574
Issuing Office: Norfolk District, Corps of Engineers

Note: The term "you" and its derivatives, as used in this permit, means the permittee or any future transferee. The term "this office" refers to the appropriate district or division office of the Corps of Engineers having jurisdiction over the permitted activity or the appropriate official of that office acting under the authority of the commanding officer.

You are authorized to perform work in accordance with the terms and conditions specified below pursuant to:

( ) Section 10 of the Rivers and Harbors Act of 1899 (33 U.S.C. 403).
(**X**) Section 404 of the Clean Water Act (33 U.S.C. 1344).
( ) Section 103 of the Marine Protection, Research and Sanctuaries Act of 1972 (33 U.S.C. 1413).

Project Description: The project involves the expansion of the existing Ragged Mountain Reservoir (RMR). The RMR currently consists of an upper reservoir (constructed in 1880) and a lower reservoir (constructed in 1908). Both dams are deficient by current dam safety standards and must either be repaired or breached. The proposal is to construct a new dam downstream of the lower reservoir that will have a higher crest elevation than the two existing ones. Currently, the upper RMR has a pool elevation of 655 feet, the lower RMR is 641 feet. The new dam will raise the pool elevation to 686 feet. Major components of the RMR expansion are:

1. Replace the existing RMR dams with a new dam at a higher elevation;
2. A nine-mile pipeline connecting RMR with the South Fork Rivanna Reservoir (SFRR);
3. New pump stations at both the RMR and the SFRR. The pump stations and pipeline are capable of transporting water from SFRR to RMR and visa versa;
4. A new pipeline from RMR to the Observatory Water Treatment Plant;
5. A new raw water intake and low lift station at SFRR;
6. A pre-treatment facility at SFRR;
7. Expansion of the water treatment facilities at the SFRR water treatment plant;
8. A release structure to meter flows and release water to the streams.

Project Location: The site is in Albemarle County, Virginia. The two interconnected lakes and associated watershed which comprise the Ragged Mountain Reservoir are located 2 miles southwest of Charlottesville. Elevations range from approximately 600 feet at average water level to more than 1200 feet on Bear Den Mountain, southwest of the upper reservoir.

Project Specific Conditions:

1. Prior to the commencement of any work authorized by this permit, you shall advise the project manager, Michael Schwinn, in writing at: Norfolk District, Corps of Engineers, Regulatory Branch, 803 Front Street, Norfolk, Virginia 23510-1096, of the time the authorized activity will commence and the name and telephone number of all contractors or other persons performing the work. A copy of this permit and drawings must be provided to the contractor and made available to any regulatory representative during an inspection of the project site.
2. The time limit for completing the work authorized ends on **June 3, 2018**. If you find that you need more time to complete the authorized activity, submit your request for a time extension to this office for consideration at least one month before the above date is reached. Should you be unable to complete the authorized activity in the time limit provided, you must submit your request for a time extension to this office for consideration at least one month before the permit expiration date.
3. Enclosed is a "compliance certification" form, which must be signed and returned within 30 days of completion of the project, including any required mitigation. Your signature on this form certifies that you have completed the work in accordance with the permit terms and conditions.
4. A copy of the stream and wetland mitigation plans (see, below) will be submitted to the USFWS for comment; the USFWS has thirty days to comment upon receipt of the mitigation plans.
5. Construction of stream and wetland compensatory mitigation shall be conducted prior to or concurrent with the impacts authorized under this permit.
6. All stipulations in the *Programmatic Agreement Between the Rivanna Water and Sewer Authority, the Virginia Department of Historic Resources and The Norfolk District, Corps of Engineers Concerning the Expansion of Ragged Mountain Reservoir in Albemarle County, Virginia*, shall be carried out in their entirety before any demolition work is done on the dams, Gatekeeper House, or Gate House. No pipeline construction or land-disturbing activities within the pipeline right-of-way, may proceed until Phase I investigations per the stipulations in the programmatic agreement are carried out.

Special Conditions:

Instream Flows

1. Total downstream flow Provisions before the Expanded Ragged Mountain Reservoir is Operational

   a. From South Fork Rivanna Reservoir

i. When the water level at South Fork Rivanna Reservoir is at or above the spillway elevation of 382 feet, South Fork Rivanna Reservoir will be spilling water on a daily basis and no additional total downstream flow is required

ii. When the water level at South Fork Rivanna Reservoir is below the spillway elevation of 382 feet total downstream flow will be at least 8 mgd or natural inflow, whichever is less

b. From Sugar Hollow Reservoir

i. When the water level at Sugar Hollow Reservoir is at or above the spillway elevation of 975 feet, Sugar Hollow Reservoir will be spilling water on a daily basis and no additional total downstream flow is required

ii. When the water level at Sugar Hollow Reservoir is below the spillway elevation of 975 feet, total downstream flow past the dam will be at least 0.4 mgd or natural inflow, whichever is less.

c. From Ragged Mountain Reservoir, there are no new requirements.

2. Total downstream flow Provisions After the Expanded Ragged Mountain Reservoir is Operational, But Before the Pipeline from South Fork Rivanna Reservoir to Ragged Mountain Reservoir is Operational

a. From South Fork Rivanna Reservoir

i. If total useable storage available to the Urban Water System is equal to or greater than 2.36 billion gallons, total downstream flow past South Fork Rivanna Reservoir must be at least 70% of the natural inflow or 1.3 mgd, whichever is greater, subject to the following exceptions

(a) No total downstream flows in excess of 20 mgd shall be required

(b) If useable storage in South Fork Rivanna Reservoir has been exhausted (i.e., the water level is at or below the lowest operable water supply intake), then total downstream flow past South Fork Rivanna Reservoir shall be whatever volume of water enters that intake unless or until the total downstream flow past South Fork Rivanna Reservoir equals or exceeds 1.3 mgd.

ii. If total useable storage available to the Urban Water System is equal to or greater than 1.36 billion gallons but less than 2.36 billion gallons, total downstream flow past South Fork Rivanna Reservoir must be at least 50%

of the natural inflow or 1.3 mgd, whichever is greater, subject to the following exceptions

(a) No total downstream flows in excess of 20 mgd shall be required

(b) If useable storage in South Fork Rivanna Reservoir has been exhausted (i.e., the water level is at or below the lowest operable water supply intake), then total downstream flow past South Fork Rivanna Reservoir shall be whatever volume of water enters that intake unless or until the total downstream flow past South Fork Rivanna Reservoir equals or exceeds 1.3 mgd.

iii. If total useable storage available to the Urban Water System is less than 1.36 billion gallons, total downstream flow past South Fork Rivanna Reservoir must be at least 30% of the natural inflow or 1.3 mgd, whichever is greater, subject to the following exceptions

(a) No total downstream flows in excess of 20 mgd shall be required

(b) If useable storage in South Fork Rivanna Reservoir has been exhausted (i.e., the water level is at or below the lowest operable water supply intake), then total downstream flow past South Fork Rivanna Reservoir shall be whatever volume of water enters that intake unless or until the total downstream flow past South Fork Rivanna Reservoir equals or exceeds 1.3 mgd.

b. From Sugar Hollow Reservoir, when the water level in Sugar Hollow Reservoir is above the lowest operable water intake and the Expanded Ragged Mountain Reservoir has not completed its initial fill:

i. If the useable storage in Ragged Mountain Reservoir is equal to or greater than 1.53 billion gallons, total downstream flow past Sugar Hollow Reservoir must be at least 100% of the natural inflow to Sugar Hollow Reservoir; or 10 mgd, whichever is less

ii. If the useable storage in Ragged Mountain Reservoir is equal to or greater than 1.1 billion gallons but less than 1.53 billion gallons, total downstream flow past Sugar Hollow Reservoir must be at least 100% of the natural inflow to Sugar Hollow Reservoir; or 2 mgd, whichever is less

iii. If the useable storage in Ragged Mountain Reservoir is equal to or greater than 0.66 billion gallons but less than 1.1 billion gallons, total downstream flow past Sugar Hollow Reservoir must be at least 100% of the natural inflow to Sugar Hollow Reservoir; or 1 mgd, whichever is less

iv. If the useable storage in Ragged Mountain Reservoir is less than 0.66

billion gallons, total downstream flow past Sugar Hollow Reservoir must be at least 100% of the natural inflow to Sugar Hollow Reservoir; or 0.4 mgd, whichever is less

a. From Sugar Hollow Reservoir when the water level in Sugar Hollow Reservoir is above the lowest operable water intake and the Expanded Ragged Mountain Reservoir has completed its initial fill

   i. If the useable storage in Ragged Mountain Reservoir is equal to or greater than 1.53 billion gallons, total downstream flow past Sugar Hollow Reservoir must be at least 100% of the natural inflow to Sugar Hollow Reservoir; or 10 mgd, whichever is less.

   ii. If the useable storage in Ragged Mountain Reservoir is less than 1.53 billion gallons, then total downstream flow must be at least 100% of the natural inflow to Sugar Hollow, or 2 mgd, whichever is less.

   iii. When the water level in Sugar Hollow Reservoir is at or below the lowest operable water intake, RWSA must fully open the total downstream flow control device supplied from the lowest operable water intake and leave it in the fully open position until the water level in Sugar Hollow Reservoir is again higher than the lowest water intake

d. From Ragged Mountain Reservoir, RWSA must provide a total downstream flow past the dam of at least 23,800 gpd

3. Total downstream flow provisions After Both the Expanded Ragged Mountain Reservoir and the Pipeline from South Fork Rivanna Reservoir to Ragged Mountain Reservoir are Operational

   a. From South Fork Rivanna Reservoir

      i. If total useable storage available to the Urban Water System is equal to or greater than 2.36 billion gallons. Total downstream flow past South Fork Rivanna Reservoir must be at least 70% of the natural inflow or 1.3 mgd, whichever is greater, subject to the following exceptions

         (a) No total downstream flows in excess of 20 mgd shall be required

         (b) If useable storage in South Fork Rivanna Reservoir has been exhausted (i.e., the water level is at or below the lowest operable water supply intake), then total downstream flow past South Fork Rivanna Reservoir shall be whatever volume of water enters that intake unless or until the total downstream flow past South Fork Rivanna Reservoir equals or exceeds 1.3 mgd.

ii. If total useable storage available to the Urban Water System is equal to or greater than 1.36 billion gallons but less than 2.36 billion gallons, total downstream flow past South Fork Rivanna Reservoir must be at least 50% of the natural inflow or 1.3 mgd, whichever is greater, subject to the following exceptions.

(a). No total downstream flows in excess of 20 mgd shall be required

(b) If useable storage in South Fork Rivanna Reservoir has been exhausted (i.e., the water level is at or below the lowest operable water supply intake), then total downstream flow past South Fork Rivanna Reservoir shall be whatever volume of water enters that intake unless or until the total downstream flow past South Fork Rivanna Reservoir equals or exceeds 1.3 mgd.

iii. If total useable storage available to the Urban Water System is less than 1.36 billion gallons, total downstream flow past South Fork Rivanna Reservoir must be at least 30% of the natural inflow or 1.3 mgd, whichever is greater, subject to the following exceptions

(a). No total downstream flows in excess of 20 mgd shall be required

(b) If useable storage in South Fork Rivanna Reservoir has been exhausted (i.e., the water level is at or below the lowest operable water supply intake), then total downstream flow past South Fork Rivanna Reservoir shall be whatever volume of water enters that intake unless or until the total downstream flow past South Fork Rivanna Reservoir equals or exceeds 1.3 mgd.

b. From Sugar Hollow Reservoir

i. When the water level at Sugar Hollow Reservoir is at or above the spillway elevation of 975 feet, Sugar Hollow Reservoir will be spilling water on a daily basis and no additional total downstream flow is required.

ii. When the water level at Sugar Hollow Reservoir is below the spillway elevation of 975 feet (a). If the water level in Sugar Hollow Reservoir is above the lowest operable water intake total downstream flow past Sugar Hollow Reservoir must be at least 90% of the natural inflow to Sugar Hollow Reservoir; or 10 mgd, whichever is less

(b). If the water level in Sugar Hollow Reservoir is not above the lowest operable water intake, RWSA must fully open the total downstream flow control device supplied from the lowest operable water intake and leave it in the fully open position until the water level in Sugar Hollow Reservoir is again higher than the lowest water intake

c. From Ragged Mountain Reservoir, RWSA must provide a total downstream flow past the dam of at least 23,800 gpd

4. Monitoring and Reporting of instream flows:

Within 8 months of permit issuance, the permittee will provide the Corps a Flow Measurement Design Plan and Operations Manual. The manual will describe the methods and procedures and any planned improvements for monitoring inflows and releases from Sugar Hollow and South Fork Rivanna River Reservoirs. The manual will describe the procedures that will be made and the frequency and conditions with which they will be made to adjust releases so the total downstream flow requirements of this permit will be met.

The Flow Measurement Design and Operations Plan will determine the suitability of the existing release equipment to meet the instream flow requirements of this permit. In the event that existing release equipment cannot release water so that the total downstream flow past Sugar Hollow or Ragged Mountain Reservoirs is within 10% of the required total downstream flow required, then the Flow Measurement Design Plan and Operations Manual will include a schedule for the installation of equipment capable of releasing water to satisfy that requirement and a description of the equipment. In no case shall the necessary equipment be installed later than two years after permit issuance. The plan will describe procedures to be used to calibrate and verify releases from the reservoirs and a include schedule for periodic recalibration and verification of the release equipment.

The Flow Measurement Design Plan and Operations Manual will identify the measurements and formulas to calculate natural inflow to Sugar Hollow and South Fork Rivanna reservoirs. The Flow Measurement Design Plan and Operations Manual will specify the frequency of measurements and specify what data are used and compiled to compute natural inflow to the reservoirs. The Flow Measurement Design Plan and Operations Manual will describe the permittee's records retention policy with regard to data collection and instrument calibration and verification records. The Flow Measurement Design Plan and Operations Manual will describe what contingency procedures, gages and formulas will be used in case the primary gage used to estimate inflow is out of service.

The Flow Measurement Design Plan and Operations Manual will include a schedule for updating useable storage values for each of the three reservoirs through bathymetric studies. The first update will not be required until the expanded Ragged Mountain Reservoir becomes operational.

The Flow Measurement Design Plan and Operations Manual will include the development of a reporting form(s) submitted annually to the Corps. The form will be designed to evaluate the permittee's compliance with the Special Condition 1. A reporting table designed to check compliance with these conditions shall be submitted within at least eight months of permit issuance. For each reporting period the table shall record the date, the natural inflow to Sugar Hollow Reservoir and to South Fork Rivanna River Reservoir, whether the reservoirs are at full pond, and the required and actual total downstream flow past Sugar Hollow Reservoir and South Fork Rivanna River Reservoirs.

At least 6 months prior to the date when the expanded Ragged Mountain Reservoir becomes operational, proposed revisions to the Flow Measurement Design Plan and Operations Manual, including a revised Reporting Form shall be submitted to DEQ to comply with Special Condition 2.

At least 6 months prior to the date when both the expanded Ragged Mountain Reservoir and the pipeline from the South Fork Reservoir to the Ragged Mountain Reservoir become operational, proposed revisions to the Flow Measurement Design Plan and Operations Manual, including a revised Reporting Form shall be submitted to DEQ to comply with Special Condition 3.

The required rates of total downstream flow past South Fork Rivanna Reservoir and Sugar Hollow Reservoir shall be determined and the rates of total downstream flow shall be adjusted as necessary twice per week. When the required rate of total downstream flow depends upon the natural inflow to the reservoir, the total downstream flow shall be calculated by determining the average of the natural inflows for the three most recent days for which data are available. No adjustment to the rate of total downstream flow shall be required unless the current calculation of total downstream flow differs from the previously calculated total downstream flow by more than ten percent.

A monitoring report shall be prepared and submitted by January 31st of each year documenting the daily withdrawals, natural inflow, and required and actual total downstream flow in the previous calendar year.

Stream Mitigation

1. Stream mitigation for 13,163 linear feet of stream impacts shall be based on the Conceptual Stream & Wetland Mitigation Plan – Albemarle County, Virginia, December, 2006 prepared

by Vanasse Hangen Brustlin, Inc. The permittee shall submit a final stream mitigation plan, subject to Corps' approval, detailing a combination of stream restoration, stream riparian buffer restoration and preservation of stream and riparian buffer on the Buck Mountain Creek site.

2. Those sections of Buck Mountain Creek or its tributaries, in which instream work is proposed, shall be surveyed for the James spinymussel before any work is done. A survey plan, approved by the DGIF and USFWS, shall be provided to the Corps and must be conducted by a qualified biologist acceptable to the DGIF and the USWS. This condition may be waived if the permittee provides written concurrence from DGIF and the USFWS that suitable mussel habitat is not present or if construction occurs outside the time-of-year restriction as determined by the DGIF and the USFWS.
3. The mitigation plan shall include the following:
    a. Stream segments and lengths earmarked for stream preservation, riparian buffer enhancement, and Level II enhancements (including types and location of all structures);
    b. Plan view showing riparian buffers and widths;
    c. Planting schedule, including species composition and densities, approved by the Corps;
    d. Noxious weed control plan;
    e. Measures to protect the stream and riparian buffers from livestock grazing, logging, off-road-vehicles, etc.;
    f. Location of any and all access points for livestock crossing, livestock watering, hiking trails or any other similar intrusions;
    g. Measures to preserve the stream mitigation site in perpetuity by deed restriction or some other acceptable real estate instrument. The Corps must give prior approval the real estate instrument used to protect the mitigation site. Use of the attached Restrictive Covenant template will facilitate review and approval. Evidence that the site is legally protected must be submitted to the Corps before any work in jurisdictional waters authorized by this permit can begin;
    h. A ten (10) year monitoring plan that includes:
        i. An annual assessment of overall stream condition based on either the SAAM or SICAM assessment methodology (an abbreviated form, subject to Corps approval, is permissible due to amount of stream mitigation involved);
        ii. Success criteria for the riparian plantings;
        iii. An annual assessment of all instream structures (vanes, root-wads, bank revetments, livestock crossings, livestock watering, etc.) that shall include measured channel cross sections at fixed monuments;
        iv. An annual inspection of any fencing installed to exclude livestock from the stream and riparian areas;
        v. An annual monitoring report shall be submitted no later than October 15 for each year of monitoring.

Wetland Mitigation

1. Wetland mitigation for impacts to 2.61 acres of wetlands shall be based on the Conceptual Stream & Wetland Mitigation Plan – Albemarle County, Virginia, December, 2006 prepared by Vanasse Hangen Brustlin, Inc. The permittee shall submit a final wetland mitigation plan, subject to Corps' approval, detailing approximately 4.0 acres of created wetland in combination with 0.9 acres of preserved wetland adjacent to Moores Creek in the City of Charlottesville, Virginia.
2. The mitigation plan shall contain the information outlined in the NORFOLK DISTRICT CORPS AND VIRGINIA DEPARTMENT OF ENVIRONMENTAL QUALITY RECOMMENDATIONS FOR WETLAND COMPENSATORY MITIGATION, dated July 2004.
3. A boundary survey of the limit of planned wetlands within the wetland mitigation site is required once grading and planting are completed. This survey should be prepared by a licensed surveyor and certified by the licensed surveyor or by a registered professional engineer or licensed landscape architect to conform to the design plans and specifications.
4. An as-built ground survey (or an aerial survey provided by a firm that specializes in aerial surveys and includes documentation of the variation from actual ground conditions such as +/- 0.2 feet) shall be conducted for the entire mitigation site, including invert elevations for all water elevation control structures and spot elevations throughout the site. This survey shall be prepared by a licensed surveyor and certified by the licensed surveyor or by a registered professional engineer and conform to the design plans and specifications. Any changes or deviations in the as-built plans shall be red lined and an explanation provided for the deviation. Surveys and submission of surveys to the Corps shall be done within no more than seven days of grading. The site shall be seeded immediately after completion of grading (i.e. within 7 calendar days) with an approved wetland seed mix to stabilize the site and to minimize invasion of undesirable species.
5. Unless given written approval by the Corps the applicant **shall not plant the compensation site** before it has been demonstrated and accepted by the Corps that the site has free water at or within 12" of the soil surface for a minimum of 12.5% of the region's killing frost-free growing season (as defined in the local soil survey) following grading. The permittee shall install groundwater wells pursuant to a plan accepted by the Corps and submit the hydrological information for that period to the Corps for evaluation. That information shall be keyed to a site plan such that hydrologic conditions across the site can be evaluated and appropriate vegetation can be selected which is compatible with the projected water elevations and duration. In the event that acceptable hydrology is not demonstrated, the Corps may require an monitoring for an additional spring growing season in order to ascertain whether hydrology is sufficient to meet the site's goals.
6. All stormwater inputs to the wetland mitigation site must pass through a continuous separation system or similar device capable of separating and trapping debris, sediment, floatables, neutrally buoyant material and oil and grease before discharging to the wetland. The type of device, including standard details and maintenance schedule shall be submitted as part of the mitigation plan;
7. The wetland mitigation site shall be preserved in perpetuity by deed restriction or some other acceptable real estate instrument. The Corps must give prior approval the real

estate instrument used to protect the mitigation site. Use of the attached Restrictive Covenant template will facilitate review and approval. Evidence that the site is legally protected must be submitted to the Corps before any work in jurisdictional waters authorized by this permit can begin.

8. A ten (10) year monitoring plan that includes:
    a. Wetland boundaries plotted on the site plan based on results of hydrology and vegetation data, and calculation of total wetland acreage based on that boundary;
    b. Photographs showing a view of the wetland area taken from fixed-point stations from a height of approximately five to six feet from each monitoring well. Photos should be taken in each of the four cardinal directions (north, east, south, and west). Permanent markers shall be established to ensure that the same locations on the site are monitored in each monitoring period; fewer photos may be provided if as an alternative, an aerial photo is provided as described in 3. c. below;
    c. One true color or infrared aerial photograph (8" x 10" or larger) depicting the entire site. An aerial photograph should be taken during the growing season and once the site has been graded, planted, and stabilized (preferably in the 3rd or 5th year following final grading);
    d. Hydrologic information, including both raw data and a hydrograph established using these data for the mitigation and reference area(s);
    e. The permittee's plans for well design and installation shall be consistent with current Corps guidance [such as Sprecher 2000 http://www.wes.army.mil/el/wrap/pdf/tnwrap00-2.pdf] and must be accepted by the Corps prior to installation (The number of groundwater wells should be based on the acreage of each type of planned wetland on a given site (palustrine emergent, palustrine forest, etc.). Wells in a given wetland cover type should be placed at roughly the same elevation to provide more detailed data for different wetland types or landscape positions. (This may not be practical in a site with an elevation gradient within one community type) The minimum numbers of monitoring wells, based upon design acreage, are:
        i. <10.0 acres: 1 monitoring well / 1.0 acre (rounded to the next whole acre); every site should have a minimum of 3 monitoring wells;
        ii. 10.0 acres to 20.0 acres: 1 monitoring well / 1.0 acre (rounded to the next whole acre) for the first 10.0 acres, then 1 monitoring well / 2.0 acres for the remaining acreage;
        iii. >20.0 acres: 1 monitoring well / 1.0 acre (rounded to the next whole acre) for the first 10.0 acres, then 1 monitoring well /2.0 acres for the next 10 acres and 1 monitoring well/ 5.0 acres for the remaining acreage.
    f. Installation of a well at or above the planned wetland/upland interface is recommended to facilitate delineation of the actual wetland boundary. This is particularly important in site with little topographic relief or relatively flat topographic gradient. Additional wells may be necessary when the mitigation plan identifies a number of wetland zones or areas with different intended hydrologic regimes. Monitoring wells should be calibrated against test pits. Nested piezometers may be needed if the planned wetland relies upon determination of groundwater movement and/or vertical gradients.

g. The wells will be monitored weekly for ten consecutive weeks beginning at the initiation of the region's growing season (see Condition 5 above for definition of growing season for the region). For sites designed to be seasonally or temporarily saturated, at least one full year of monthly data (taken every two weeks except for the first ten weeks of the growing season) is recommended. Well data should be correlated to precipitation data over the same period. This can help identify and address overly compacted soils, perched water tables, etc.

h. Invert elevations of the wells (bottom of the wells) and surface elevations beside each well are required, particularly for problematic wetland restoration/creation sites. Well locations should be accurately mapped (including survey located or use of GPS).

i. A minimum of 3 plots/acre for herbaceous and woody vegetation sampling should be selected randomly;

   i. Herbaceous or woody plants stem density (stem) counts by species within a 30-foot radius or 20 feet by 20 feet square plot are recommended. Belt transects or other accepted methodologies (such as line intercept methods) may be used in lieu of plots, but should be identified prior to conducting sampling and accepted by the Corps/DEQ. For example, the line intercept method conducted in a wetland planted on 15-foot centers could yield skewed data.

   ii. Herbaceous plants measurements based on percent cover are recommended. As an alternative that may entail fewer sampling points, a species-area curve could be generated from the species list collected from sample plot data. Recommended plot size is 18-inch radius or 40 inches by 40 inches square. Transects or other accepted methodologies (such as line intercept methods) can also be used in lieu of plots.

j. Soil data must be collected for the mitigation and reference area(s) following the third year of monitoring. A comparison of year three soil features with pre and post construction soil features will allow one to determine whether the redoximorphic features are relicts or associated with active processes. This information will be used to determine whether hydric soil conditions are present or whether the soils are becoming progressively "more hydric" with time. At a minimum, within 30 feet of each well site, the soil shall be profiled and classified as hydric or not using both the Corps 1987 Wetland Manual and the NTCHS Field Indicators of Hydric Soils.

k. Identify any invasion by species that may be undesirable at the site such as Phragmites, purple loosestrife, cattails, reed canary grass or fescue. Quantify the extent of invasion of undesirable plants; either by stem counts or percent cover, whichever is appropriate. Specify percent cover of invasive species for each field or cell in the mitigation site.

l. Describe remedial actions conducted since the last monitoring report (modification, relocation of water control structures, control of invasives, grading, soil amendments, deep ripping or chisel plowing of soils, additional planting, etc.);

m. An annual monitoring report shall be submitted no later than October 15 for each year of monitoring.

Pipeline Construction

1. At least ninety (90) days prior to construction, the permittee shall submit to the Corps the selected pipeline alignment and identify all waters and/or wetlands crossings. The permittee shall also include the location of any proposed permanent maintenance roads constructed in wetlands, stream fords, etc.;
2. The method of crossing (open-trench, directional drill, etc) shall be described and standard details of the crossings shall be provided;
3. For pipeline construction in wetlands, the following conditions are required:
    a. In order to avoid impacts to the Indiana bat, no tree-clearing activities in forested wetland areas shall occur between April 1st and September 30th of any year. This restriction may be lifted if the permittee provides written concurrence from the Virginia Department of Game and Inland Fisheries (DGIF) and United States Fish and Wildlife Service (USFWS) that the time-of-year restriction is unnecessary.
    b. Topsoil shall be removed first and stockpiled separately from the subsoil;
    c. Trenching shall occur after the topsoil is removed; subsoil will be handled and stockpiled separately from the topsoil;
    d. If coarse bedding material is used, trench plugs or cutoff walls will be installed to prevent the trench from draining the wetland. The locations and standard details of the trench plugs or cutoff walls shall submitted as part of the overall pipeline plan;
    e. After the pipe is installed the trench will be backfilled with the subsoil leaving the top 6 inches to 12 inches for backfilling with the topsoil;
    f. All excess material will be disposed in an upland area and may not be wasted in the wetland. Any deposition of dredged or excavated materials in upland areas and all earthwork operations shall be carried out in such a manner as to prevent the erosion of these materials and preclude their entry into all waters and wetlands.;
    g. Wetland impacts resulting from any proposed permanent maintenance roads and/or conversion of forested wetlands to shrub/scrub or herbaceous as necessary for pipeline access or maintenance, shall be quantified. The Corps, at its discretion, may require mitigation for such impacts.
4. For pipeline stream crossings that involve open trenching rather than directional bore, the follow conditions are required:
    a. In order to avoid impacts to the Indiana bat, no tree-clearing activities in forested riparian areas shall occur between April 1st and September 30th of any year. This restriction may be lifted if the permittee provides written concurrence from the Virginia Department of Game and Inland Fisheries (DGIF) and United States Fish and Wildlife Service (USFWS) that the time-of-year restriction is unnecessary.
    b. All perennial and intermittent stream crossings shall be surveyed for the James spinymussel before any work is done. A survey plan, approved by the DGIF and USFWS, shall be provided to the Corps and must be conducted by a qualified biologist acceptable to the DGIF and the USWS. This condition may be waived if the permittee provides written concurrence from DGIF and the USFWS that

suitable mussel habitat is not present or if construction occurs outside the time-of-year restriction as determined by the DGIF and the USFWS.

c. Streambanks will be restored and revegetated with woody and herbaceous species within seven (7) days of backfilling the trench;
d. Any deposition of dredged or excavated materials in upland areas and all earthwork operations shall be carried out in such a manner as to prevent the erosion of these materials and preclude their entry into all waters and wetlands;
e. Permanent road crossings must be properly culverted. Culverts less than 24 inches must be countersunk a minimum of 3 inches; greater than 24 inches must be countersunk a minimum of 6 inches;
f. Riparian buffer impacts resulting from any proposed permanent maintenance roads shall be quantified. The Corps, at its discretion, may require mitigation for such impacts.

Historical Properties

1. Expanding the Ragged Mountain Reservoir will have an adverse impacts to properties eligible for listing under the National Historic Preservation Act. These properties are the upper and lower dam, the Gatekeepers House and Gate House.
2. Construction of the pipeline may also affect properties eligible for listing once an exact alignment is known. Therefore, after the specific pipeline alignment is selected, the permittee shall complete the Phase I survey necessary to identify archaeological historic properties within the alignment of the water pipeline.
3. All stipulations in the *Programmatic Agreement Between the Rivanna Water and Sewer Authority, The Virginia Department Historic Resources and the Norfolk District, Corps of Engineers Concerning the Expansion of Ragged Mountain Reservoir in Albemarle County, Virginia* shall be adhered to as a condition of this permit. No demolition work on the dams, Gatekeeper House, Gate House; no pipeline construction or land-disturbing activities within the pipeline right-of-way, may proceed until all stipulations of the programmatic agreement are carried out.

General Conditions:

1. No discharge of dredged or fill material may consist of unsuitable material (e.g.: trash, debris, car bodies, asphalt etc.) and material discharged must be free from toxic pollutants in toxic amounts (see Section 307 of the Clean Water Act).

2. Any temporary fills must be removed in their entirety and the affected areas returned to their preexisting elevation.

3. Appropriate erosion and siltation controls must be used and maintained in effective operating condition during construction, and all exposed soil and other fills, as well as any work below the ordinary high water mark, must be permanently stabilized at the earliest practicable date.

4. The construction or work authorized by this permit will be conducted in a manner so as to minimize any degradation of water quality and/or damage to aquatic life. Also, you will

employ measures to prevent or control spills of fuels or lubricants from entering the waterway.

5. Any heavy equipment working in wetlands must be placed on mats or other measures must be taken to minimize soil disturbance.

6. Failure to comply with the terms and conditions of this permit can result in enforcement actions against the permittee and/or contractor.

7. In granting an authorization pursuant to this permit, the Norfolk District has relied on the information and data provided by the permittee. If, subsequent to notification by the Corps that a project qualifies for this permit, such information and data prove to be materially false or materially incomplete, the authorization may be suspended or revoked, in whole or in part, and/or the Government may institute appropriate legal proceedings.

8. All dredging and/or filling will be done so as to minimize disturbance of the bottom or turbidity increases in the water that tend to degrade water quality and damage aquatic life.

9. Your use of the permitted activity must not interfere with the public's right to reasonable navigation on all navigable waters of the United States.

10. You must maintain the activity authorized by this permit in good condition and in conformance with the terms and conditions of this permit. You are not relieved of this requirement if you abandon the permitted activity, although you may make a good faith transfer to a third party in compliance with General Conditions 3 below. Should you wish to cease to maintain the authorized activity or should you desire to abandon it without a good faith transfer, you must obtain a modification of this permit from this office, which may require restoration of the area.
11. If you discover any previously unknown historic or archaeological remains while accomplishing the activity authorized by this permit, you must immediately notify this office of what you have found. We will initiate the Federal and state coordination required to determine if the remains warrant a recovery effort or if the site is eligible for listing in the National Register of Historic Places.
12. If you sell the property associated with this permit, you must obtain the signature of the new owner in the space provided and forward a copy of the permit to this office to validate the transfer of this authorization.
13. If a conditioned water quality certification has been issued for your project, you must comply with the conditions specified in the certification as special conditions to this permit.
14. You must allow representatives from this office to inspect the authorized activity at any time deemed necessary to ensure that it is being or has been accomplished in accordance with the terms and conditions of your permit.

Further Information:

1. <u>Limits of this authorization</u>:

a. This permit does not obviate the need to obtain other Federal, state or local authorizations required by law.
b. This permit does not grant any property rights or exclusive privileges.
c. This permit does not authorize any injury to the property or rights of others.
d. This permit does not authorize interference with any existing or proposed Federal projects.

2. Limits of Federal Liability: In issuing this permit, the Federal Government does not assume any liability for the following:
   a. Damages to the permitted project or uses thereof as a result of other permitted or unpermitted activities or from natural causes.
   b. Damages to the permitted project or uses thereof as a result of current or future activities undertaken by or on behalf of the United States in the public interest.
   c. Damages to persons, property, or to other permitted or unpermitted activities or structures caused by the activity authorized by this permit.
   d. Design or construction deficiencies associated with the permitted work.
   e. Damage claims associated with any future modification, suspension, or revocation of this permit.

3. Reliance on Applicant's Data. The determination of this office that issuance of this permit is not contrary to the public interest was made in reliance on the information you provided.

4. Reevaluation of Permit Decision. This office may reevaluate its decision on this permit at any time the circumstances warrant. Circumstances that could require a reevaluation include, but are not limited to, the following:
   a. You fail to comply with the terms and conditions of this permit.
   b. The information provided by you in support of your permit application proves to have been false, incomplete, or inaccurate (See 3 above).
   c. Significant new information surfaces which this office did not consider in reaching the original public interest decision.

   Such a reevaluation may result in a determination that it is appropriate to use the suspension, modification, and revocation procedures contained in 33 CFR 325.7 or enforcement procedures such as those contained in 33 CFR 326.4 and 326.5. The referenced enforcement procedures provide for the issuance of an administrative order requiring you to comply with the terms and conditions of your permit and for the initiation of legal action where appropriate. You will be required to pay for any corrective measures ordered by this office, and if you fail to comply with such directive, this office may in certain situations (such as those specified in 33 CFR 209.170) accomplish the corrective measures by contract or otherwise and bill you for the cost.

5. Extensions. Project specific condition 2 establishes a time limit for the completion of the activity authorized by this permit. Unless there are circumstances requiring either a prompt completion of the authorized activity or a reevaluation of the public interest decision, the Corps will normally give favorable consideration to a request for an extension of this time limit.

Your signature below, as a permittee, indicates that you accept and agree to comply with the terms and conditions of this permit.

(Permittee)

6/3/08

(Date)

This permit becomes effective when the Federal official, designated to act for the Secretary of the Army, has signed below.

Michael A. Schwinn
Chief, Western Virginia
Regulatory Section

6/3/08

(Date)

When the structures or work authorized by this permit are still in existence at the time the property is transferred, the terms and conditions of this permit will continue to be binding on the new owner(s) of the property. To validate the transfer of this permit and the associated liabilities associated with compliance with its terms and conditions, have the transferee sign and date below.

(Transferee)

(Date)

Attachment F – Property Owner List (JPA Section 1)

Property Owner's Name	Mailing Address (if applicable)	City	State	ZIP Code
CITY OF CHARLOTTESVILLE	P O BOX 911	CHARLOTTESVILLE	VA,	22902
HOLIDAY TRAILS INC	400 HOLIDAY TRAILS LANE	CHARLOTTESVILLE	VA,	22903
CITY OF CHARLOTTESVILLE	PO BOX 911	CHARLOTTESVILLE	VA,	22902
CITY OF CHARLOTTESVILLE	605 E MAIN STREET	CHARLOTTESVILLE	VA,	22902
MAKIELSKI, STANISLAW J & VALERIE JEAN CONNER FAMILY TRUST	534 OAKLAND AVE	TALLAHASSEE	FL,	32301
CITY OF CHARLOTTESVILLE	PO BOX 911	CHARLOTTESVILLE	VA,	22902
CITY OF CHARLOTTESVILLE	PO BOX 911	CHARLOTTESVILLE	VA,	22902
CITY OF CHARLOTTESVILLE	PO BOX 911	CHARLOTTESVILLE	VA,	22902
HURTT, WILLIAM JACOB JR AND HURRT SACRE, REBECCA	4913 RICHMOND ROAD	KESWICK	VA,	22947
HURTT, WILLIAM JACOB JR AND HURRT SACRE, REBECCA	4913 RICHMOND ROAD	KESWICK	VA,	22947
SHRUM, RICHARD L OR SUSAN S	1214 RESERVOIR RD	CHARLOTTESVILLE	VA,	22903
HARRIS, JASON GREGG & TERESSA LYNN HARRIS	16360 COPPER STILL TERRACE	MOSELEY	VA,	23120
UNIVERSITY OF VIRGINIA FOUNDATION	P O BOX 400218	CHARLOTTESVILLE	VA,	22904-4218
DINH, TON	1201 HARRIS ST	CHARLOTTESVILLE	VA,	22903
UNIVERSITY OF VIRGINIA FOUNDATION	PO BOX 400218	CHARLOTTESVILLE	VA,	22904
FARMINGTON COUNTRY CLUB	1625 COUNTRY CLUB CIRCLE	CHARLOTTESVILLE	VA,	22901
JOHNSON, CECIL H	1150 RESERVOIR RD	CHARLOTTESVILLE	VA,	22903
UNIVERSITY OF VIRGINIA FOUNDATION	PO BOX 400218	CHARLOTTESVILLE	VA,	22904
REGENTS SCHOOL OF CHARLOTTESVILLE INC	200 BOB FINLEY WAY	CHARLOTTESVILLE	VA,	22903
UNIVERSITY OF VIRGINIA FOUNDATION	PO BOX 400218	CHARLOTTESVILLE	VA,	22904
UNIVERSITY OF VIRGINIA FOUNDATION	P O BOX 400218	CHARLOTTESVILLE	VA,	22904-4218
WHITTEN, WILLIAM OR OLIVIA B	580 RIO ROAD	CHARLOTTESVILLE	VA,	22901

RECTORS & VISITORS OF THE UVA C/O O MANAGEMENT	575 ALDERMAN ROAD	CHARLOTTESVILLE	VA,	22901
BURTON, WALTER H & CORINNE	1853 WOODBURN ROAD	CHARLOTTESVILLE	VA,	22901
STEWART, NEIL M	58 CANTERBURY ROAD	CHARLOTTESVILLE	VA,	2.29E+08
DALLAS, DAVID L JR OR SUSAN W	56 CANTERBURY ROAD	CHARLOTTESVILLE	VA,	22903
VERKERKE, J HOULT & ANN THERESE VERKERKE	54 CANTERBURY RD	CHARLOTTESVILLE	VA,	22903
KIMBLE, LANITA M	1857 WOODBURN ROAD	CHARLOTTESVILLE	VA,	22901
CHANTHAMIXAY, VADSANA; BOBBY CHANTHAMIXAY & KINGSTON CHANTHAMIXAY	731 SEATON AVENUE UNIT 412	ALEXANDRIA	VA,	22305
WHALEY, ROBERT O JR OR SUSAN M SEIDLER	52 CANTERBURY ROAD	CHARLOTTESVILLE	VA,	22903
FREY, MATTHEW J OR MARIAN J	50 CANTERBURY RD	CHARLOTTESVILLE	VA,	22903
YEMEN, TERRANCE A OR GERALDINE M	48 CANTERBURY ROAD	CHARLOTTESVILLE	VA,	22903
FREY, DAVID OR CYNTHIA ANN	46 CANTERBURY RD	CHARLOTTESVILLE	VA,	22903
DENNIS PATRICK DORAN, JENNIFER O DORAN & FLORENCE D DORAN	44 CANTERBURY ROAD	CHARLOTTESVILLE	VA,	22903
TUCKER, HERBERT F OR ANN E	42 CANTERBURY ROAD	CHARLOTTESVILLE	VA,	22903-4702
LANKENAU, HARRY R OR SUSAN C	38 CANTERBURY RD	CHARLOTTESVILLE	VA,	22903
UNIVERSITY OF VIRGINIA FOUNDATION	P O BOX 400218	CHARLOTTESVILLE	VA,	22904
MARRI, MOHAN R OR RAMALAKSHMI MARRI	36 CANTERBURY RD	CHARLOTTESVILLE	VA,	22903
ROGERS, EDWIN O OR ASHLEY T	34 CANTERBURY RD	CHARLOTTESVILLE	VA,	22903
GROVES, DUSTIN & AISLINN GROVES	32 CANTERBURY ROAD	CHARLOTTESVILLE	VA,	22903
HALING, JOEL A OR PATRICIA M	30 CANTERBURY RD	CHARLOTTESVILLE	VA,	22903
CROSBY, ALEXANDER	28 CANTERBURY RD	CHARLOTTESVILLE	VA,	22903-4702
UNIVERSITY OF VIRGINIA FOUNDATION	P O BOX 400218	CHARLOTTESVILLE	VA,	22904-4218

COMMONWEALTH OF VIRGINIA DEPARTMENT	P O BOX 3758	CHARLOTTESVILLE	VA,	22901
OAK GREEN LLC	795 OLD GARTH RD	CHARLOTTESVILLE	VA,	22901
FONTAINE LAND TRUST; WILLIAM W STEV	P O BOX 8147	CHARLOTTESVILLE	VA,	22903
BARBOUR, CHARLES L & PENSACOLA C	1875 WOODBURN ROAD	CHARLOTTESVILLE	VA,	22901
PATTERSON, GRAHAM B JR	1475 SHANGRI-LA DR	LEWISVILLE	NC,	27023
338 RIO LAND TRUST	C/O GEORGE HARRISON GILLIAM, TRUSTEE PO BOX 6156	CHARLOTTESVILLE	VA,	22901
VELIKY COMMERCIAL PROPERTIES LLC	201 15TH STREET NW STE 1A	CHARLOTTESVILLE	VA,	22903
WOOD, WRILEY C A & LEONORA D	14 CANTERBURY RD	CHARLOTTESVILLE	VA,	22903
WOOD, A DEL GRECO OR ELIZABETH A B	12 CANTERBURY RD	CHARLOTTESVILLE	VA,	22903
ROSSER ASSOCIATES	2421 IVY ROAD SUTIE 300	CHARLOTTESVILLE	VA,	22903
MATTHEWS, STEPHEN E; ELIZABETH FEIL MATTHEWS & PHYLISS P FEIL	10 CANTERBURY RD	CHARLOTTESVILLE	VA,	22903
GUNTER, PAULA CHRISTINE	8 CANTERBURY RD	CHARLOTTESVILLE	VA,	22903
DAHL, THOMAS P OR KIRSTIN F	8 TRACE CIRCLE	STAUNTON	VA,	24401
GARDNER, LAURENCE H II TRUST ETAL & MARILYN G GARDNER TRUST ETAL	4 CANTERBURY RD	CHARLOTTESVILLE	VA,	22903
1CANTERBURY LLC	33 CANTERBURY RD	CHARLOTTESVILLE	VA,	22903
JPA TOWER INVESTORS LLC	PO BOX 5509	CHARLOTTESVILLE	VA,	22905
RECTORS & VISITORS OF THE UNIVERSIT	575 ALDERMAN ROAD	CHARLOTTESVILLE	VA,	22901
SCHLEIFER, BARRY F OR ELISE K	104 CAVALIER DR	CHARLOTTESVILLE	VA,	22901
MEDICAL FACILITIES OF AMERICA LXXVI (76) LIMITED PARTNERSHIP	2917 PENN FOREST BLVD STE 300	ROANOKE	VA,	24018
MIDYETTE, BUXTON SAUNDERS & SHIRLEY KOONTZ MIDYETTE	102 CAVALIER DR	CHARLOTTESVILLE	VA,	22901
THE RECTOR AND VISITORS OF THE UNIVERSITY OF VIRGINIA	PO BOX 400884	CHARLOTTESVILLE	VA,	22904-4884
OAKLEIGH ALBEMARLE LLC	690 BERKMAR CIR	CHARLOTTESVILLE	VA,	22901

GWATHMEY JR, FRANK W GWATHMEY, KELLY GRAHAM	101 CAVALIER DR	CHARLOTTESVILLE	VA,	22901
CAMILLE DERKSEN-GAMBLE DAVID GRAFFAGNINI	100 TALLY HO DRIVE	CHARLOTTESVILLE	VA,	22901
HUBBARD, GAIL E	401 COLTHURST DRIVE	CHARLOTTESVILLE	VA,	22901
HAUGHEY, THOMAS M & PAULA DALY TRS. REVOCABLE TRUST	201 COLTHURST DRIVE	CHARLOTTESVILLE	VA,	22901
ALSHAIKHLI, AMMAR	425 RIO ROAD WEST	CHARLOTTESVILLE	VA,	22901
HAUGHEY, THOMAS M & PAULA DALY TRS REVOCABLE TRUST	201 COLTHURST DRIVE	CHARLOTTESVILLE	VA,	22901
ROSE, TIM R OR MARGARET W	126 FALCON DRIVE	CHARLOTTESVILLE	VA,	22901
HAUGHEY, THOMAS M & PAULA DALY TRS. REVOCABLE TRUST	201 COLTHURST DRIVE	CHARLOTTESVILLE	VA,	22901
ROSE, TIM R OR MARGARET W	126 FALCON DRIVE	CHARLOTTESVILLE	VA,	22901
UNIVERSITY OF VIRGINIA FOUNDATION	PO BOX 400218	CHARLOTTESVILLE	VA,	22904-4218
YANG, YANG & LIN YANG	1854 WOODBURN RD	CHARLOTTESVILLE	VA,	22901
RENNICK, GEORGE R OR SHIRLEY M	400 COLTHURST DR	CHARLOTTESVILLE	VA,	22901
DEDINCA, HAMDI & SHEFKIE DEDINCA	1882 WOODBURN ROAD	CHARLOTTESVILLE	VA,	22901
DAWA, NORBU & DOLMA CHOZIN	1868 WOODBURN STREET	CHARLOTTESVILLE	VA,	22901
TOWER LAND TRUST; WILLIAM K KING TR	P O BOX 5548	CHARLOTTESVILLE	VA,	22905
DEDINCA, HAMDI & SHEFKIE DEDINCA	1894 WOODBURN RD	CHARLOTTESVILLE	VA,	22901
GILLIES, GEORGE T OR MELANIE B	202 COLTHURST DRIVE	CHARLOTTESVILLE	VA,	22901
NORTH EIGHT LLC	7325 CARTER RD	SCHUYLER	VA,	22969
RECTORS & VISITORS OF THE UVA C/O O MANAGEMENT	575 ALDERMAN ROAD	CHARLOTTESVILLE	VA,	22901
RECTORS & VISITORS OF THE UVA C/O O MANAGEMENT	575 ALDERMAN ROAD	CHARLOTTESVILLE	VA,	22901
THE RECTOR & VISITORS OF THE UNIVERSITY OF VIRGINIA C/O OFFICE OF SPACE & RE MGMT	P O BOX 400726	CHARLOTTESVILLE	VA,	2.29E+08
VALENTE, ARTHUR & ALYSON VALENTE	620 WOODBROOK DR STE 6	CHARLOTTESVILLE	VA,	22901

BRIDGENET LLC	P O BOX 526	CHARLOTTESVILLE	VA,	22902
RMC7, LLC	5195 MAGNOLIA RDG RD	CHARLOTTESVILLE	VA,	22901
THE RECTOR & VISITORS OF THE UNIVERSITY OF VIRGINIA C/O OFFICE OF SPACE & RE MGMT	P O BOX 400726	CHARLOTTESVILLE	VA,	2.29E+08
GUERLAIN, STEPHANIE A E HASCHART, ROBERT J	2901 BARRACKS RD	CHARLOTTESVILLE	VA,	22901
KALERGIS, DAVID G; MARY M KALERGIS; HUGH CAMP KALERGIS & JOHANNA LIBERTY KALERGIS	220 MONTVUE DR	CHARLOTTESVILLE	VA,	22901
GUERLAIN, STEPHANIE A E & ROBERT J HASCHART	2901 BARRACKS RD	CHARLOTTESVILLE	VA,	22901
SLUTZKY, DAVID OR MELISSA	1705 LAMBS RD	CHARLOTTESVILLE	VA,	22901
JACKSON, FRENCH T & ESTELIA BARNES	1801 LAMBS ROAD	CHARLOTTESVILLE	VA,	22901-8974
RMC7, LLC	5195 MAGNOLIA RDG RD	CHARLOTTESVILLE	VA,	22901
THOMPSON, NEIL D THOMPSON, KELLIE P	1981 LAMBS RD	CHARLOTTESVILLE	VA,	22901
PERKINS, MARY KIMBERLY	1995 LAMBS ROAD	CHARLOTTESVILLE	VA,	22901
PERKINS, MARY KIMBERLY	1995 LAMBS ROAD	CHARLOTTESVILLE	VA,	22901
LOAVES & FISHES FOOD PANTRY INC	PO BOX 8001	CHARLOTTESVILLE	VA,	22906
BRIMACOMBE, JOHN MARK & JANEEN MICHELE BRIMACOMBE	3114 BARRACKS ROAD	CHARLOTTESVILLE	VA,	22901
HUANG, JINGFEI	P O BOX 8045	CHARLOTTESVILLE	VA,	22906
HOUSTON, STUART E & DONNA M HOUSTON	PO BOX 53	IVY	VA,	22945
CONNECT CHURCH C/O TERRY LEHMANN, ET ALS, TRUSTEES	2080 LAMBS RD	CHARLOTTESVILLE	VA,	22901
SMITH, ROBERT H OR JUDITH S J	P O BOX 5344	CHARLOTTESVILLE	VA,	22905-5344
PATEL LIVING TRUST	3250 BARRACKS ROAD	CHARLOTTESVILLE	VA,	22901
LY, HA TO OR YU HUA CHANG LY	76 COLTHURST DR	CHARLOTTESVILLE	VA,	22901
BABA VENTURES INC	2808 HYDRAULIC RD	CHARLOTTESVILLE	VA,	22901

ST DAVID'S ANGLICAN CHURCH; WILLIAM LEE ANDERSON, GRANT HOWLETT, ETAL TRS	P O BOX 5342	CHARLOTTESVILLE	VA,	22905
COUNTY OF ALBEMARLE	401 MCINTIRE ROAD	CHARLOTTESVILLE	VA,	22902
HAUGHEY THOMAS M & PAULA DALY TRS. REVOCABLE TRUST	201 COLTHURST DRIVE	CHARLOTTESVILLE	VA,	22901
ROSLYN FARM OF ALBEMARLE COUNTY LLC	80 ROSLYN FOREST LANE	CHARLOTTESVILLE	VA,	22901
INSCOE, BOBBY L OR DOLLY L	100 COLTHURST DRIVE	CHARLOTTESVILLE	VA,	22901-2039
BOLLER, STEPHEN L OR DIANE F	200 COLTHURST DRIVE	CHARLOTTESVILLE	VA,	22901
MILLER, JANE OR DEBORAH A TYSON	204 COLTHURST DRIVE	CHARLOTTESVILLE	VA,	22901
ESPINOSA, WILLIAM H	208 COLTHURST DR	CHARLOTTESVILLE	VA,	22901
CHURCH OF JESUS CHRIST OF LATTER-DAY STS C/O LDS CHURCH TAX DIVISION	50 E NORTH TEMPLE ST	SALT LAKE CITY	UT,	84150-3620
NAYLOR, LEMUEL R & BEULAH	2948 HYDRAULIC ROAD	CHARLOTTESVILLE	VA,	22901
DRILLERS SERVICE INCORPORATED	P O DRAWER 1407	HICKORY	NC,	28603
ALBEMARLE BAPTIST CHURCH; JAMES A WINKEY, JAMES B NELSON & JAMES E WILDER TRS	P O BOX 7057	CHARLOTTESVILLE	VA,	22906
MESA ASSOCIATES	3025-A MCNAUGHTON DRIVE	COLUMBIA	SC,	29223
CVDL INC	P O BOX 5807	CHARLOTTESVILLE	VA,	22905
UNION RIDGE CHURCH CEMETERY C/O GWEN MAGRUDER	2636 HYDRAULIC ROAD	CHARLOTTESVILLE	VA,	22901
J F BELL FUNERAL HOME INC	108 6TH ST N W	CHARLOTTESVILLE	VA,	22903
GARDENCOURT PROPERTY OWNERS ASSOCIA	P O BOX 6716	CHARLOTTESVILLE	VA	
PLANNED PARENTHOOD SOUTH ATLANTIC	100 SOUTH BOYLAN AVE	RALEIGH	NC,	27603
VAN DER LINDE HOMES INC	2820 HYDRAULIC ROAD SUITE #1	CHARLOTTESVILLE	VA,	22902
CLMB LLC	259 HYDRAULIC ROAD STE 203	CHARLOTTESVILLE	VA,	22901
UNION RIDGE CHURCH C/O GWEN MAGRUDER	2636 HYDRAULIC ROAD	CHARLOTTESVILLE	VA,	22901

HARRINGTON, AMANDA LEIGH	25 ROSLYN HEIGHTS ROAD	CHARLOTTESVILLE	VA,	22901
FARABAUGH, MICHAEL ANTHONY LIVING TRUST; MICHAEL ANTHONY FARABAUGH TRUSTEE	24 ROSLYN HEIGHTS RD	CHARLOTTESVILLE	VA,	22901-8120
UNITY OF CHARLOTTESVILLE	2825 HYDRAULIC CIR	CHARLOTTESVILLE	VA,	22901
CAMPOS, JULIO CESAR & MIRNA ADRIANA PENA VARGAS	2030 LAMBS ROAD	CHARLOTTESVILLE	VA,	22901
TWO LITTLE LADIES LLC	2813 HYDRAULIC ROAD	CHARLOTTESVILLE	VA,	22901
HYDRAULIC ROAD LLC	P O BOX 7765	CHARLOTTESVILLE	VA,	22906
370 RIO LLC	370 RIO ROAD WEST	CHARLOTTESVILLE	VA,	22901
VIRGINIA TELEPHONE & TELEGRAPH OF VA	W 3RD STREET	FARMVILLE	VA,	23901
VIRGINIA TELEPHONE & TELEGRAPH CO	W 3RD STREET	FARMVILLE	VA,	23901
BICKEL, MARY C	440 RIO RD W	CHARLOTTESVILLE	VA,	22901
GAONA, JOSE & ELPIDIA GAONA	442 RIO RD WEST	CHARLOTTESVILLE	VA,	22901
TOWNWOOD MOBILE HOME PARK	P O BOX 5306	CHARLOTTESVILLE	VA,	22905
RAHIM, ABDUL W; HABIB RAHIM & SHAID RAHIM	1433 MAYMONT CT	CHARLOTTESVILLE	VA,	22902
HOWELL, GWEN H & J WENDALL HOWELL	470 W RIO RD	CHARLOTTESVILLE	VA,	22901
HOWELL, J WENDELL OR BILLIE JEAN	445 W RIO RD	CHARLOTTESVILLE	VA,	22901
CHARLOTTESVILLE RIO ROAD APARTMENTS LLC	110 DRAPER RD NW SUITE B	BLACKSBURG	VA,	24060
HOWELL, GWENDOLYN H & JUDY D	470 WEST RIO ROAD	CHARLOTTESVILLE	VA,	22901
CHARLOTTESVILLE RIO ROAD APARTMENTS LLC	110 DRAPER RD NW SUITE B	BLACKSBURG	VA,	24060
MOBILE PARKS OF CHARLOTTESVILLE INC C/O WENDELL WOOD	410 EDNAM DR	CHARLOTTESVILLE	VA,	22903
TOWNWOOD PROPERTY OWNERS ASSOCIATIO	1675 COOL SPRING RD	CHARLOTTESVILLE	VA,	22901
CHARLOTTESVILLE RIO ROAD APARTMENTS LLC	110 DRAPER RD NW SUITE B	BLACKSBURG	VA,	24060

GARDENCOURT PROPERTY OWNERS ASSOCIA	P.O. BOX 6249	CHARLOTTESVILLE,	VA	
MOBILE PARKS OF CHARLOTTESVILLE INC C/O WENDELL WOOD	410 EDNAM DRIVE	CHARLOTTESVILLE	VA,	22903
COMMONWEALTH OF VIRGINIA	1601 ORANGE ROAD	CULPEPER	VA,	22701-3819
EJM GARDEN LLC	2538 SCOTTSVILLE RD	CHARLOTTESVILLE	VA,	22902
GARDENCOURT PROPERTY OWNERS ASSOCIA	P O BOX 6716	CHARLOTTESVILLE,	VA	
YOUNG, ALAN	108 YOGAVILLE WAY	BUCKINGHAM	VA,	23921
BOUCHARD, CAROLINE QUINN	853 MOULTRIE STREET	SAN FRANCISCO	CA,	94110
BRASS RAIL LLC	413 ALTAMONT ST	CHARLOTTESVILLE	VA,	22902
BIRNAM WOOD HOMEOWNERS ASSOCIATION INC C/O CHADWICK WASHINGTON	P O BOX 5306	CHARLOTTESVILLE	VA,	22905
EJM GARDEN LLC	P O BOX 5548	CHARLOTTESVILLE	VA,	22906
FOUR SEASONS PATIO HOUSE ASSOCIATIO	P O BOX 6569	CHARLOTTESVILLE	VA,	22901
COMMONWEALTH OF VIRGINIA C/O VDOT RIGHT OF WAY DIVISION	1601 ORANGE ROAD	CULPEPER	VA,	22701-3819
WOODBURN LAND TRUST; M CLIFTON MCCL	P O BOX 5548	CHARLOTTESVILLE	VA,	22905
RIO WEST LIMITED PARTNERSHIP	307 W RIO ROAD	CHARLOTTESVILLE	VA,	22901
CARRIKER, BRUCE W & KIMBERLY T CARRIKER REVOCABLE TRUST	C/O BRUCE & KIMBERLY CARRIKER, TRUSTEES 590 TANAGER WOODS CT	EARLYSVILLE	VA,	22936
UNIVERSITY MONTESSORI SCHOOL INC	1034 RESERVOIR ROAD	CHARLOTTESVILLE	VA,	22903
UNIVERSITY OF VIRGINIA FOUNDATION	P O BOX 400218	CHARLOTTESVILLE	VA,	22904
UNIVERSITY OF VIRGINIA FOUNDATION	P O BOX 400218	CHARLOTTESVILLE	VA,	22904
COMMONWEALTH OF VIRGINIA, DEPARTMENT OF FORESTRY	900 NATURAL RESOURCES DR	CHARLOTTESVILLE	VA,	22903
RECTORS AND VISITORS OF THE UNIVERSITY OF VIRGINIA	PO BOX 400884	CHARLOTTESVILLE	VA,	22904-4884
TRINITY PRESBYTERIAN CHURCH	PO BOX 5102	CHARLOTTESVILLE	VA,	22905

COUNTY SCHOOL BOARD OF ALBEMARLE	401 MCINTIRE ROAD	CHARLOTTESVILLE	VA,	22901
WOODBURN COURT LLC	PO BOX 5306	CHARLOTTESVILLE	VA,	22905
CRYSTAL R HOBBS	2021 WOODBURN RD	CHARLOTTESVILLE	VA,	22901-8108
ALBEMARLE SOCIETY FOR THE PREVENTION OF CRUELTY TO ANIMALS INC	P O BOX 7047	CHARLOTTESVILLE	VA,	22906
ALBEMARLE SOCIETY FOR THE PREVENTION OF CRUELTY TO ANIMALS INC	PO BOX 7047	CHARLOTTESVILLE	VA,	22906
VALENTE, ARTHUR M & ALYSON C VALENTE	620 WOODBROOK DR SUITE 6	CHARLOTTESVILLE	VA,	22901
ALBEMARLE SOCIETY FOR THE PREVENTION OF CRUELTY TO ANIMALS INC	PO BOX 7047	CHARLOTTESVILLE	VA,	22906
ESTES, PHILLIP MANSFIELD & DORIS WILLIAMS ESTES	2110 WOODBURN RD	CHARLOTTESVILLE	VA,	22901
BRANDT, JOHN E B INDIVIDUALLY & AS	1636 MULBERRY AVENUE	CHARLOTTESVILLE	VA,	22901
ALBEMARLE SOCIETY FOR THE PREVENTION OF CRUELTY TO ANIMALS INC	PO BOX 7047	CHARLOTTESVILLE	VA,	22906
WEBER, LEWIS A LIVING TRUST	2186 WOODBURN RD	CHARLOTTESVILLE	VA,	22901
BERKMAR DEVELOPMENT LLC	2496 OLD IVY RD	CHARLOTTESVILLE	VA,	22903
JOHNSTON, JACOBA KAY	1108 FOREST HILLS AVE	CHARLOTTESVILLE	VA,	22903
BERKMAR DEVELOPMENT LLC	2496 OLD IVY RD	CHARLOTTESVILLE	VA,	22903
WEBER, LEWIS A LIVING TRUST	2186 WOODBURN RD	CHARLOTTESVILLE	VA,	22901
WEBER, LEWIS A LIVING TRUST	2186 WOODBURN RD	CHARLOTTESVILLE	VA,	22901
WEBER, LEWIS A LIVING TRUST	2186 WOODBURN RD	CHARLOTTESVILLE	VA,	22901
THIRD MESA LLC	P O BOX 6551	CHARLOTTESVILLE	VA,	22906
THIRD MESA LLC	P O BOX 6551	CHARLOTTESVILLE	VA,	22906
RIDGEWOOD MOTEL & MANOR LP	2883 SEMINOLE TRAIL	CHARLOTTESVILLE	VA,	22911
HINES, ZELDA MAE OR WILLE LEE HINES	2204 WOODBURN ROAD	CHARLOTTESVILLE	VA,	22901

WOOD, HUNTER W REVOCABLE TRUST C/O HUNTER W WOOD, TRUSTEE	PO BOX 5548	CHARLOTTESVILLE	VA,	22905
VICTORIAN PROPERTIES LLC	610 W RIO ROAD	CHARLOTTESVILLE	VA,	22901
COUNTY OF ALBEMARLE	401 MCINTIRE ROAD	CHARLOTTESVILLE	VA,	22902
WOOD, HUNTER W REVOCABLE TRUST C/O HUNTER W WOOD, TRUSTEE	PO BOX 5548	CHARLOTTESVILLE	VA,	22905
GIBSON, PATRICIA PRICE	1210 INGLECRESS DR	CHARLOTTESVILLE	VA,	22901
COMMONWEALTH OF VIRGINIA VDOT RIGHT OF WAY SECTION	1601 ORANGE ROAD	CULPEPER	VA,	22701-3819
COMMONWEALTH OF VIRGINIA VDOT RIGHT OF WAY SECTION	1601 ORANGE ROAD	CULPEPER	VA,	22701-3819
RIVER HEIGHTS ASSOCIATES LIMITED	P O BOX 5548	CHARLOTTESVILLE	VA,	22905

Modeling RWSA's Water Supply Operations with OASIS

Addendum to the
User Manual for OASIS with OCL™

June 2018

Prepared for

RIVANNA
WATER & SEWER AUTHORITY

by

HYDROLOGICS
Advancing the management of water resources

Contents

Section 1. Introduction

This report describes how OASIS is used to model the raw water supply operations of the Rivanna Water and Sewer Authority (RWSA) in Charlottesville, Virginia and the surrounding area. This report is not intended to replace the User Manual for OASIS, which is available from the Help menu of the model. Rather, it is intended to document the data used in this application as well as the current operations of the system. Information about the OASIS modeling platform is included only to the extent necessary to provide context for the application-specific data.

The model can be used in two modes: (1) a simulation mode to evaluate system performance for a given set of demands, operating policies, and facilities over the daily historic inflow record; and (2) a position analysis mode for real-time management, particularly for drought trigger assessment. In the latter mode, the model uses multiple ensemble inflow forecasts to provide a probabilistic assessment of conditions up to one year in the future. Both modes use a default "basecase" scenario meant to represent current conditions.

The model uses a "finalized" inflow data set that extends from October 1, 1925 through September 30, 2017. This data set was developed using an approach that relies on USGS gages within the Rivanna River basin and gages from nearby basins, described in Appendix C of this document.

To account for how wet or dry the basin is when running real-time forecasts, which is needed to produce more accurate reservoir storage forecasts, the user must update inflows through the present day. "Provisional" inflows are generated through the model interface, based on both provisional gage data along with operational data provided by RWSA. The remainder of this document summarizes the components of the model and the major operations in the basins. Appendix A lists the run code used in the basecase simulation run (run name "Basecase") that is based on today's facilities, operations, and demands. Appendix B contains the static input data for the basecase run. Appendix C contains detailed information on the development of inflows for the model. Appendices D-E contain supplemental information on inflow development and verification, as well as model and operating rules development that was previously presented to RWSA staff in PowerPoint files.

Section 2. Model Components

2.1 Schematic

The model uses a map-based schematic that includes nodes for reservoirs, raw water withdrawals (water treatment facilities), finished water demands, and pumping stations, and arcs that convey water between nodes. The model schematic is shown on the following page and is sized to show the full system. To make the schematic more legible, the user can adjust the schematic size from the model's graphical user interface (GUI). The schematic and associated physical data were developed with input from RWSA staff. The model has 32 nodes and 40 connecting arcs. There are 7 reservoir nodes (three of which are not used in system operations), 2 demand nodes, and other miscellaneous nodes to account for minimum flow requirements, gage locations, and interconnections.

The user can click on any node or arc on the schematic to access specific information like reservoir elevation-storage-area data or minimum streamflow requirements. These data are also contained in tables contained on other tabs of the model.

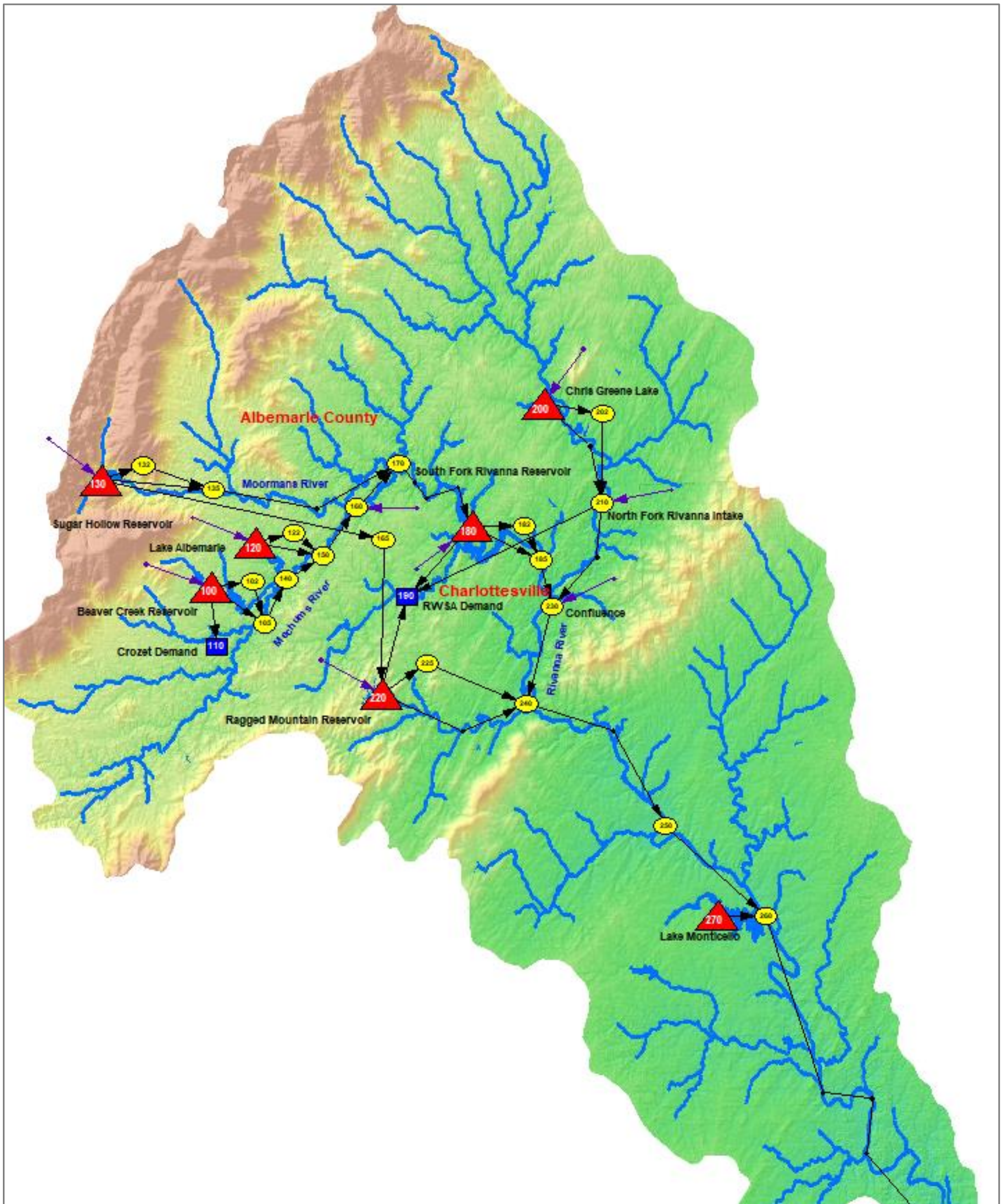


Figure 1. Schematic of RWSA's Water Supply System in OASIS

2.2 Model Input

Input data for the model is stored in three forms: static and pattern data, timeseries data, and user-defined data using Operations Control Language (OCL). The timeseries data are stored outside the model run. The other data are embedded in the run and copy over automatically when creating a new run.

Static and pattern data are contained in the GUI and represent data that do not change during the model simulation. These include physical data like reservoir elevation-storage-area relationships and repeating data that occur every year in the simulation (like monthly demand patterns or seasonal minimum release patterns). Timeseries data change with each day in the simulation record and typically consist of inflows and reservoir net evaporation. OCL allows the user to define more elaborate operating rules than are permitted from the GUI. The OCL code for the basecase simulation can be found in Appendix A. The code and accompanying comments provide a detailed description on how the system is being modeled.

Static and Pattern Data

Tables containing the model's static and pattern data can be found in Appendix B. Reservoir information includes elevation-storage-area relationships, minimum and maximum allowable storage, and any rule curves and drought curves which dictate the preferred operating elevation throughout the year or the timing of drought response. Basic details on major system reservoirs (those that constitute the Urban system) are shown in Table 1 below. All details on major and minor system reservoirs and lakes are contained in Appendix B.

Table 1. RWSA Major Reservoirs

	Sugar Hollow	South Fork	Ragged Mt.
Effective Watershed Area (mi^2) (Total minus full pool surface area)	**17.4**	**258.5**	**1.7**
Full Pool Elevation (ft)	**975**	**382**	**671**
Full Pool Storage (MG)	**375**	**1282**	**1671**
Dead Storage Elevation (ft)	**938**	**367**	**621**
Dead Storage (MG)	**36**	**400**	**157**
Useable Storage (MG / %)	**339 / 90%**	**882 / 69%**	**1514 / 91%**

To offer flexibility in setting the minimum flows and reservoir releases, the model defines them in OCL, in some cases referencing pattern and lookup tables found in the GUI.

Nodes associated with treatment plant production and finished water demands use an annual average demand subject to a monthly pattern.

Water treatment plant and transmission constraints are defined by maximum capacities on arcs. Targets for the desired conveyance of water between points in the distribution system are defined in OCL.

Timeseries Data

The timeseries data are stored in a basedata timeseries file (***basedata.dss***), which contains all the inflow and net evaporation (evaporation less precipitation) data. Development of timeseries data is described in detail in Appendix C.

Inflows in the model represent incremental unregulated runoff to the point specified. For reservoirs, the surface area of the reservoir is subtracted from the drainage area as measured at the dam.

Net evaporation in the model is computed as evaporation minus precipitation, in inches. In the model, net evaporation is multiplied by the surface are of the reservoirs (as computed by the elevation-storage-area tables) and subtracted from storage for each model simulation time step.

Provisional inflow updates for real-time forecasting can be done directly from the interface by selecting the Update Record tab, by following these steps:

1. First the user presses the Download Data Button to download USGS gage data and NWS precipitation station data.

2. Once the data has downloaded, the user needs to check for any blanks or erroneous values. These will be highlighted by colored cells in the table. Note that until the USGS finalizes flows at the end of the water year (September 30); the flows used in the provisional updates could be subject to change and should periodically be reviewed.

3. Next, the user closes the model and opens the ***update_record.mdb*** file in the *Basedata* directory and pastes the required operating records from RWSA's SCADA system (as formatted in a spreadsheet supplied to RWSA staff) into the *Hydrologic Update Data* tab within the database.

4. Finally, the user opens the model interface and press the "Update Record" button under the *Update Record* tab to run the automated routine that computes local inflows and net evaporation and appends them to the basedata file.

Further detail on the calculation of provisional inflows, including the USGS gages used and the data required from RWSA operations, can also be found in Appendix C.

Operating Rules

The water allocation priorities are set by the user in the GUI by applying weights to nodes and arcs, and by specifying operations in OCL. The specific weights used in the model for the basecase scenario can be found in the code in Appendix A and in tables in Appendix B. The most common operating rules are for storing water in reservoirs versus releasing the water to meet local water supply demands or minimum releases, and these are reflected by the weighting scheme. Simply stated, if a minimum flow in a river is more important than meeting the demand, a higher weight on the minimum flow means water supply deliveries will be scaled back as needed during drought to meet the minimum flow. The minimum flows used in the basecase scenario are shown below and reflect the protocols in RWSA's Virginia Water Protection Permit from DEQ.

Table 2. RWSA Reservoirs Minimum Release Requirements

Reservoir	Required Minimum Release
Sugar Hollow (SH)	< 1080 MG useable Ragged Mountain (RM)storage, release 100% of the natural inflow (3-day avg.) or 2 mgd, whichever is less. Otherwise, release 100% of the natural inflow or 10 mgd, whichever is less.
South Fork (SF)	< 750 MG useable (SH + SF + RM), release 30% of natural inflow (3-day avg.) < 1600 MG useable (SH + SF + RM), release 50% of natural inflow Otherwise, release 70% of the inflow or 1.3 mgd, whichever is more. At a minimum, always release 1.3 mgd (unless SF is empty); at a maximum, release 20 mgd (unless spilling).
Ragged Mountain	0.03 mgd

OCL allows the user to model more complex operating rules, such as tying demand reductions to drought triggers or river flows that are common in drought management. Table 3 details the triggers and actions for RWSA; the drought plan uses forecast based triggers, which take the form of activating when there is an ***X%*** chance of reaching ***Y%*** system storage in ***Z weeks***, as determined by running the model in Position Analysis (forecast) mode (see Section 2.3).

Table 3. RWSA Drought Triggers and Associated Actions

Drought Stage	Trigger	Drought Stage Action
Stage 1	20% chance of reaching 80% total system storage In 12 weeks	1% demand reduction
Stage 2	10% chance of reaching 70% total system storage In 10 weeks	5% demand reduction
Stage 3	5% chance of reaching 60% total system storage In 8 weeks	15% demand reduction

For the RWSA system, the decision on which reservoirs to withdraw water from or transfer water to/from are determined by a set of operating rules dependent on the time of year and on reservoir levels. See the stylized flowchart in Figure 2 for descriptions of these rules, which are also defined in OCL. All the OCL files are accessible from the model interface. The OCL code for the basecase scenario, including comments which describe each block of code, are found in Appendix A.

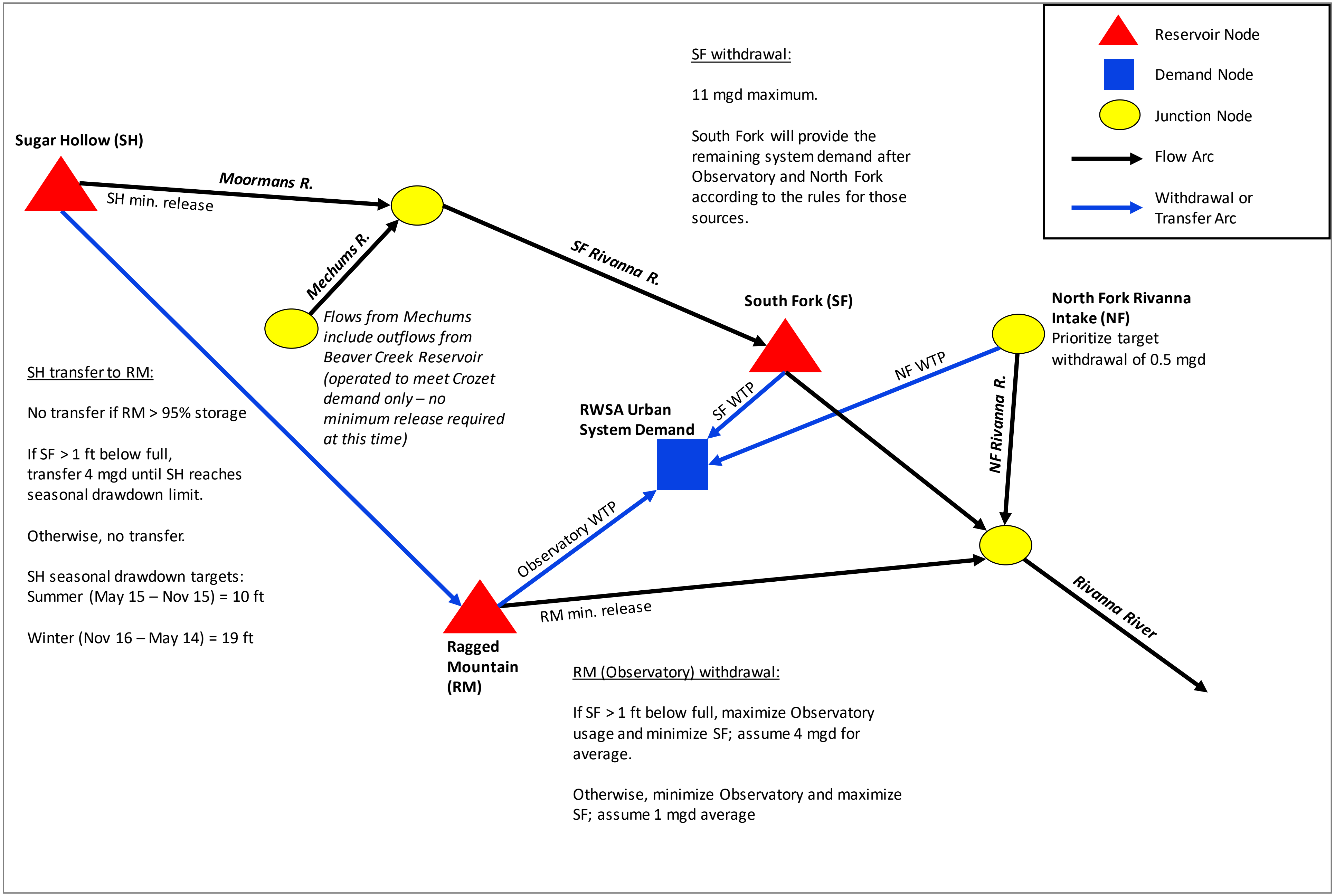


Figure 2. Flowchart of RWSA Urban System Operations

2.3 Run Configurations

The model can be used in two modes: (1) a simulation mode to evaluate system performance for a given set of demands, operating policies, and facilities over the historic inflow record; and (2) a position analysis mode for real-time management, using ensemble streamflow forecasts. General information on creating, modifying, and executing runs is provided in the User Manual for OASIS, which is available from the Help menu of the model.

Simulation

In simulation mode, the model uses the operating policies described in the previous pages and in Appendix A to evaluate the system reliability at current demand levels. Users can easily analyze the sensitivity of the system to increased demands by changing the annual average demand value assigned to the RWSA Demand node (number 190). Further analysis of alternative operating rules and minimum release protocols is also possible by utilizing the parameters set in the model GUI and in the OCL. The model can also be used to compute the system safe yield (SY) by incrementally increasing system demands until system storage reaches a minimum threshold (often zero).

Position Analysis

In position analysis mode, the user can select from Conditional or Non-Conditional Forecasts on the Setup tab. By executing a run, the model will by default produce a forecast (typically of river flows or reservoir elevations) for up to the next 365 days, although if desired, this forecast horizon can be stretched to two years since the system experiences multi-year droughts. A forecast can be made on any date in the historic inflow record or no more than one day after the end of the inflow record. Typically, it will be used starting the day after the last update of the inflow and net evaporation record. For example, if these records end September 30, 2017, the user can run a forecast for October 1, 2017. If a month has passed, and the user wants to run a forecast for November 1, 2017, the user would update the inflows and net evaporation for October using the Update Record tab and then start the position analysis run on November 1. For a reservoir, or locations affected by the operation of a reservoir upstream, the forecast is dependent on the starting elevation of the reservoir. On the Setup tab, the user simply inputs the starting elevation (or storage), the starting date of the forecast run, and clicks Run.

2.4 Model Output

The model allows the user to customize output files (tables or plots) and save them for routine use. Alternatively, the user can click on any node or arc on the schematic or go to the Setup tab and select Quick View to access and save tabular or plotted output. Detail on creating and modifying output tables and plots is found in Chapter 6 of the OASIS User Manual. Several pre-formatted tables and plots specific to performance measures of interest of interest for RWSA have been provided with the model application. Tabular output data can be exported to Excel or other programs for further analysis and graphical display if desired. The balance sheet, also described in the OASIS User Manual (Chapter 5), can also serve as a useful tool for tracking water through the system.

Current System Reliability

The following plots characterize the reliability of RWSA's system under current demand levels (10 mgd annual average), showing simulated storage in the Urban system for the period of hydrologic record and individual reservoir storage during the most severe drought on record (2001 – 2002).

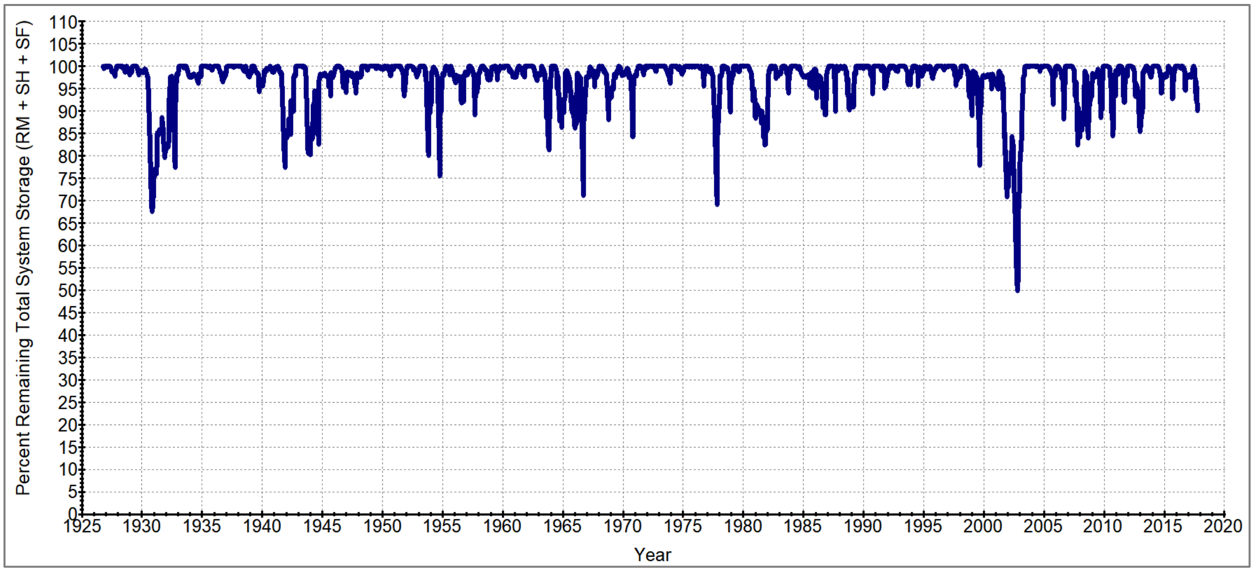


Figure 3. RWSA System Storage, Basecase Simulation, 1925 – 2017

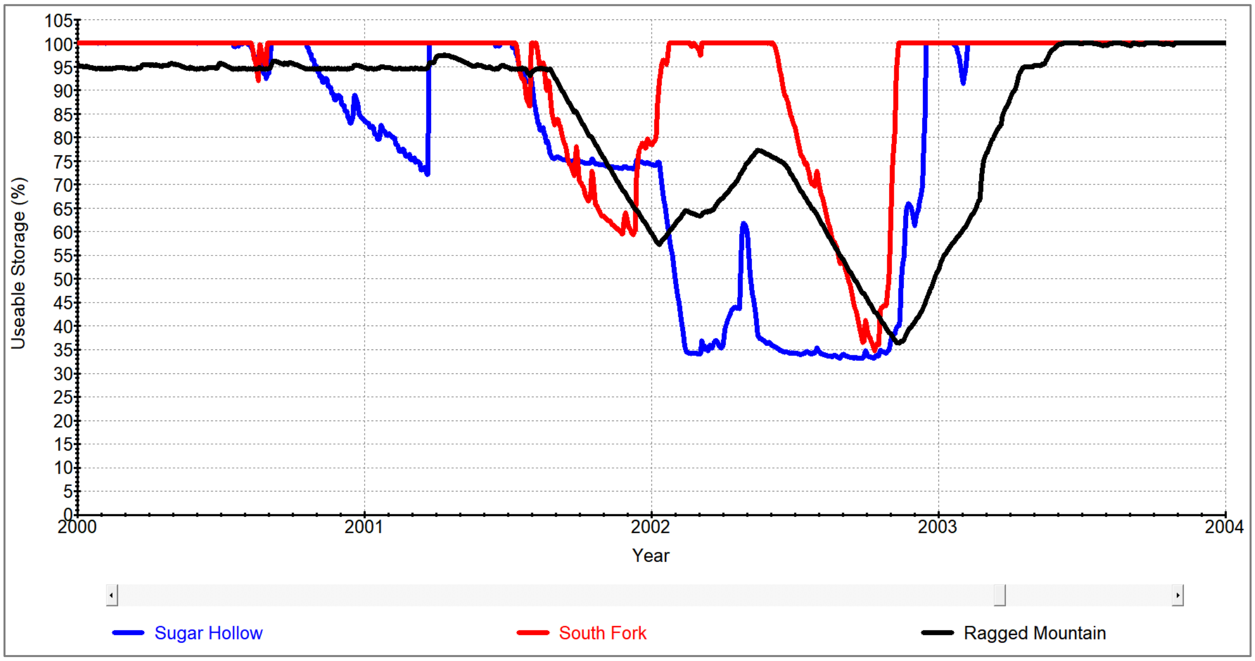


Figure 4. RWSA Major Reservoir Storage, Basecase Simulation, 2001 – 2002 Drought

Table 4 summarizes other reliability metrics under current conditions based on a 90+ year inflow record. Note that South Fork emergency pumps would be required periodically in order to access storage below about 65% of its useable supply. Additional information about system reliability is provided in Appendix E in the PowerPoint presentation.

Table 4. System Reliability Metrics

Useable Storage Reserve in Critical Drought (% and in terms of days of supply remaining)	Stage 1 Trigger Activation (# of years)	Stage 2 Trigger Activation (# of years)	Stage 3 Trigger Activation (# of years)	Reductions to South Fork Minimum Releases (# of years)	Activation of South Fork Emergency Pumps (# of years)
38% and 105 days	8	5	1	1	10

Appendix A. OCL Files in RWSA OASIS Basecase Scenario

Contents

Main.ocl

```
/*  MAIN.OCL
   Sets location for input files and calls other OCL files   */

:Include: OCL\constants.ocl
:Include: ocl\Forecast-Trigger_Parms.ocl
:Include: ocl\Forecast_Horizon_Days.ocl

:Static: statdata.mdb
:Time:   [HomeDir]\basedata\basedata.dss

:if: {[UseForecast]=1}
   :if: {[ForecastData]=cond}
      :Time:   [HomeDir]\basedata\forecasts_cond.dss
   :else:
      :Time:   [HomeDir]\basedata\forecasts_non_cond.dss
   :endif:
:endif:

:Include: ocl\udef_list.ocl


:Commands:

    :Include: ocl\set_inflows.ocl
      :Include: ocl\operating_rules.ocl
      :Include: ocl\user_def_ops.ocl

    Solve :  { priority : 1 }



:End:
```

Udef_list.ocl

```
/* User-defined variables */

:UDEF:

// Negative inflow filter

:For: { [nd] = {100, 120, 130, 160, 180, 200, 210, 220, 230} }

Udef : _TempInf[nd]
Udef : _InfDeficit[nd]

:Next:

// Storage Variables

Udef :  _Usable_SFRR_Stor
Udef :  _Usable_RM_Stor
Udef :  _Usable_SH_Stor

Udef :  _Usable_system_Stor
Udef :  _Usable_system_Stor_Vol


Udef :  _Avail_SFRR_Stor
Udef :  _Avail_RaggedMt_Stor
Udef :  _Avail_SugHollow_Stor
Udef :  _Avail_BCreek_Stor
Udef :  _Avail_LakeAlb_Stor
Udef :  _Avail_CGreene_Stor

// Variables used for setting min releases

Udef  :  _Trigger_Flow_Red_Level  init {0}

Udef :  _Spill_CGreene
Udef :  _Avail_NFRivanna_Flow

Udef :  _NFRiv_Flow
Udef :  _Avg_NFRiv_Flow

Udef :  _NatInf_SFRR

Udef :  _Max_Stor_RaggedMt
Udef :  _BC_Release_Loss


Udef :   _SH_rel_limit
Udef :   _SF_rel_limit

Udef :  _3_Day_Avg_SF_NatInflow
Udef :  _3_Day_Avg_SH_NatInflow
```

```
udef  :  _minrelease_SH
udef  :   _counter_SHtrigger  init {0}


Udef :  _minrelease_SF


Udef :  _Proj_SF_Spill


// Variables for Drought Plan

Udef : _Trigger_1_On       init{0}
Udef : _Trigger_2_On       init{0}
Udef : _Trigger_3_On       init{0}

Udef :  _Trig_Level

Udef : _Consvn_1_Demand
Udef : _Consvn_1_Demand_NF

Udef : _Consvn_2_Demand
Udef : _Consvn_2_Demand_NF

Udef : _Consvn_3_Demand
Udef : _Consvn_3_Demand_NF

Udef : _Proj_1_Demand
Udef : _Proj_2_Demand
Udef : _Proj_3_Demand

Udef : _Proj_Demand_Refill

Udef : _Proj_1_Evap
Udef : _Proj_2_Evap
Udef : _Proj_3_Evap


Udef : _Proj_Evap_Refill

Udef : _Proj_1_MinFlow
Udef : _Proj_2_MinFlow
Udef : _Proj_3_MinFlow

Udef : _Proj_MinFlow_Refill

Udef : _Proj_1_Inflow
Udef : _Proj_2_Inflow
Udef : _Proj_3_Inflow


Udef : _Proj_1_Storage
Udef : _Proj_2_Storage
```

```
Udef : _Proj_3_Storage

Udef : _Proj_Storage_Refill

Udef : _Stage_1_Counter    init{0}
Udef : _Stage_2_Counter    init{0}
Udef : _Stage_3_Counter    init{0}


Udef : _Ph1_event_counter  init{0}
Udef : _Ph2_event_counter  init{0}
Udef : _Ph3_event_counter  init{0}
```

Set_Inflows.ocl

```
/* This file sets inflows to each point in the model,
filtering for negatives (which may occur in the provisional record) */


:For: { [nd] = {100, 120, 130, 160, 180, 200, 210, 220, 230} }

Set : _TempInf[nd]    { Value : timesers([nd]/inflow) }
Set : inflow[nd]      { Value : max{0, _TempInf[nd]- _InfDeficit[nd](-1) } }
Set : _InfDeficit[nd]{ Value : max{0, _InfDeficit[nd](-1) - _TempInf[nd]} }

:Next:
```

Operating_Rules.ocl

```
/*  Operating_Rules.OCL  */


// Note here on out, we're using lower_rule instead of dead_Stor and
upper_rule instead of max_stor to depict the usable storage.
// Reservoir zones have been adjusted accordingly in the Reservoir node table
in the GUI.
// For Beaver Creek, the lower rule represents depth down to the sediment
storage.  Before, it included a reserve for making releases from BC to the
// RWSA system during extreme drought.  That is no longer assumed to occur.

Set : _Avail_SFRR_Stor        { value : Storage180 / upper_rule180 }
Set : _Avail_RaggedMt_Stor    { value : Storage220 / upper_rule220 }
Set : _Avail_SugHollow_Stor   { value : Storage130 / upper_rule130 }
Set : _Avail_BCreek_Stor      { value : Storage100 / upper_rule100 }
Set : _Avail_LakeAlb_Stor     { value : Storage120 / upper_rule120 }
Set : _Avail_CGreene_Stor     { value : Storage200 / upper_rule200 }


Set :  _Usable_SFRR_Stor    {  value :  (Storage180 - lower_rule180) /
(upper_rule180 - lower_rule180)  }
Set :  _Usable_RM_Stor      {  value :  (Storage220 - lower_rule220) /
(upper_rule220 - lower_rule220)  }
Set :  _Usable_SH_Stor      {  value :  (Storage130 - lower_rule130) /
(upper_rule130 - lower_rule130)  }


Set :  _Usable_System_Stor_Vol       {  value  :  storage130 + storage180 +
storage220 - lower_rule130 - lower_rule180 - lower_rule220 }
Set :  _Usable_System_Stor           {  value  :  _Usable_System_Stor_Vol / (
upper_rule130 + upper_rule180 + upper_rule220 - lower_rule130 - lower_rule180
- lower_rule220 ) }

// Assume 0 minimum release for Beaver Creek.  Only being modeled to meet
Crozet demand.  Currently a study is being undertaken to finalize operations
and intake design.
Set : min_flow100.105 { value : 0 }

Set : max_flow100.105 { value : min_flow100.105 }

// The following code limits the withdrawal from the NF Rivanna intake to 0.5
mgd to reflect max demand that can be met in that part of the system due to
hydraulic constraints there and at the pump station.

Set MinWD_NFIntake :  min_flow210.190   {   value   :  0.5 }
Set MaxWD_NFIntake :  max_flow210.190   {   Value   :  0.5 }


/*  The following determines the amount of flow available today for
withdrawal from the NF
Rivanna.  If the available flow was set equal to flow210.230, that would give
us yesterday's flow,
```

```
which is not what we want.  */

Set :  _Spill_CGreene       {  value :  max {0, storage200 + inflow200 -
evap200 - max_stor200 } }
Set :  _Avail_NFRivanna_Flow {  value :  min { _Spill_CGreene + inflow210,
max_flow210.190 } }


/*  Establish the 3-day average natural inflow to Sugar Hollow based on the
last 3 days */
Set :  _3_Day_Avg_SH_NatInflow    { value  :  ( inflow130 + inflow130(-1) +
inflow130(-2) ) /  3  }



/*  This sets the minimum release from Sugar Hollow */

Set  :  _MinRelease_SH

{ condition  :  weekday{year, month, day} <= 1  or weekday{year, month, day}
= 4

    {  Condition :   default
       Value     :   1.0 * _3_Day_Avg_SH_NatInflow

    }

   condition  :  default
   value      :  _MinRelease_SH(-1)

}


Set  :  min_flow130.135
{     condition  :  storage130 + inflow130 - evap130 - upper_rule130 > 0
      value      :  0

      condition  :  default
      value      :  _minrelease_SH
}

// Post RM expansion to the intermediate raise level, post-RM fill
requirements.
Set :  max_flow130.135
{
      condition  :  (storage220 - lower_rule220) < 1080
      value      :  min { min_flow130.135, 2 }

      condition  :  default
      value      :  min { min_flow130.135, 10 }
}


/*  Set SH-RM transfer  */
```

```
Set MinTransfer_SH :  min_flow130.165
// Add in a seasonal component to SH-RM transfers
// First for the winter/spring (11/16 - 5/14), use 19 ft drawdown for Sugar
Hollow as the lower limit.
// Also add in qualifier that SF > 1 ft below spillway in order to keep
transferring from SH to RM.
// Change amount transferred to 4 MGD.
// These came from drought exercise and reflect RWSA preferences.
{     Condition : julian < 136 or julian > 320
      {     Condition : _Avail_RaggedMt_Stor * 100 < 95  and (elevation130 >=
stor_to_elev{ 130, upper_rule130 } - 19) and (elevation180 >= stor_to_elev{
180, upper_rule180 } - 1)
                  Value : 4.0

            Condition : default
            Value     : 0
      }

      // In the summer/fall (5/15 - 11/15), use 10 ft drawdown as the lower
limit
      Condition : default
      {     Condition : _Avail_RaggedMt_Stor * 100 < 95  and (elevation130 >=
stor_to_elev{ 130, upper_rule130 } - 10) and (elevation180 >= stor_to_elev{
180, upper_rule180 } - 1)
                  Value : 4.0

            Condition : default
            Value     : 0
      }
}

// Max sure the transfer never exceeds the prescribed amount
Set MaxTransfer_SH :  max_flow130.165 { Value : min_flow130.165 }


/*  The maximum treatment capacity at South Fork is 11 mgd */
Set MaxTrmtCapSF :  max_flow180.190  {   value :       11.0  }

/*  When SFRR is >1 ft below spillway, minimize Observatory with intermittent
production schedule averaging 1 MGD.
    When below 1 ft below spillway, maximize Observatory at 4 mgd  */

Set MaxWD_RaggedMt :  max_flow220.190
{   Condition : elevation180 >= stor_to_elev{ 180, upper_rule180 } - 1
    Value     :  max {1.0, demand190 - 0.4 - 11}

      Condition : default
    Value     : max {4.0, demand190 - 0.4 - 11}
}


// Min release from RM (equiv to seepage)
Constraint RM_Seepage : {  dflow220.225 = 0.0238 }
```

```
/*  The following code limits the withdrawal from Lake Albemarle  */

Set MaxWD_LakeAlbemarle :  max_flow120.150  { value : 0 }



Set :  _Trigger_Flow_Red_Level

{  condition  :  weekday{year, month, day} <= 1  or weekday{year, month, day}
= 4

      {   condition   :  (storage180 - lower_rule180) <= 0 /* and
                         inflow180 + inflow100 + inflow120 + inflow130 +
inflow160 < convert_units {2.0, cfs, MG}                         */
          value       :  3

          condition   :  _Usable_System_Stor_Vol  < 750
          value       :  2

          condition   :  _Usable_System_Stor_Vol  < 1600
          value       :  1

          condition   :  default
          value       :  0
      }

   condition  :  default
   value      :  _Trigger_Flow_Red_Level(-1)
}


/*  Establish the 3-day average natural inflow to South Fork based on the
last 3 days */
Set :  _3_Day_Avg_SF_NatInflow
{    condition  :  abs_period < 3
     value      :  convert_units {2, cfs, MG}

     condition  :  default
     value  :      ( (inflow180 + inflow100 + inflow120 + inflow130 +
inflow160) + (inflow180(-1) + inflow100(-1) + inflow120(-1) + inflow130(-1) +
inflow160(-1) )
                   +  (inflow180(-2) + inflow100(-2) + inflow120(-2) +
inflow130(-2) + inflow160(-2) ) )/  3
}


Set MinReleaseSFRR :  min_flow180.185
{    condition  :   weekday{year, month, day} <= 1 or weekday{year, month,
day} = 4
```

```
    {   //  When SF is empty, intent is to release no more than the natural
inflow or regulated inflow, whichever is less, even if it less than 1.3 mgd
or 2 cfs.
        //  However, do not release more than 2 cfs since we'd be releasing
100% of the inflow, when in fact during this period probably the release
would be only
        //  30% of the inflow.
        condition  :    _Trigger_Flow_Red_Level = 3
        value      :    max { min {convert_units {2, cfs, MG}, inflow180 +
inflow100 + inflow120 + inflow130 + inflow160 , flow170.180 + inflow180 -
evap180}, 0 }

        condition  :    _Trigger_Flow_Red_Level = 2
        value      :    max {  convert_units {2, cfs, MG}, 0.30 *
_3_Day_Avg_SF_NatInflow }

        condition  :    _Trigger_Flow_Red_Level = 1
        value      :    max {  convert_units {2, cfs, MG}, 0.50 *
_3_Day_Avg_SF_NatInflow }

        Condition  :   default
        Value      :   max {  convert_units {2, cfs, MG}, 0.70 *
_3_Day_Avg_SF_NatInflow  }
    }

   condition  :  default
   value      :  min_flow180.185(-1)

}

Set MaxReleaseSFRR :  max_flow180.185  {  value :  min { min_flow180.185, 20
} }  /* max required min release of 20 mgd */
```

User_Def_Ops.ocl

```
/*  File is user_def_ops.ocl */

/*  This section computes the projected demand, min flow, and net evap for
each of the three forecast horizons.  The forecast horizon # is the forecast
used to help establish when level # (same number) restrictions are imposed.
*/

/*  The triggers are invoked based on combined total storage in SF, SH, and
RM. Chris Greene is not used to meet NF demand.  Instead, this demand must
rely on natural inflow.  */

/*  For the projections of storage, use only those variables which affect
combined storage in the three reservoirs.  This would consist of minimum
release from SF, not SH, since water released from SH is stored in SF and
thus is not lost from the system; demand that is met from this combined
storage (so North Fork demand would be excluded since it is met from the NF
intake); evaporation for the three reservoirs plus reservoirs upstream; and
inflows for all inflow locations upstream and including the reservoirs */

/*  The ranking of the inflow is based on the supernode, which is the
combined inflow from all inflow locations.
      The projections of inflow below use only the portion of the system that
affects combined storage from the three reservoirs, so technically the
ranking could be different if we limited the supernode to just these
locations.  [It is not likely since the inflow points are within close
proximity to one another, so watershed differences should be small]. The
forecast program will be set up eventually to better define which nodes are
used to establish the supernode.  There is no ranking for evap */



/*  If forecasts are used, set the switch here */
:if: {[UseForecast]=1}

    /* First Trigger Horizon */

Set : _Proj_1_Demand
{   Condition : weekday{year, month, day} <= 1
    Value     : accumulate { demand190, 0, +[Forecast_1_Horizon_Days] }

    Condition : default
    Value     : _Proj_1_Demand(-1)
}


Set : _Proj_1_MinFlow  /*  Min flow from South Fork using 20 mgd or 70% of
the natural inflow, whichever is less. */
{
    Condition : weekday{year, month, day} <= 1
    Value     : min { accumulate { 20 , 0, +[Forecast_1_Horizon_Days] },
                        7 * (timesers(100/[ForcCode_1]) +
timesers(120/[ForcCode_1]) + timesers(130/[ForcCode_1]) +
```

```
                               timesers(160/[ForcCode_1]) +
timesers(180/[ForcCode_1]) ) * 0.7 }

    Condition : default
    Value     : _Proj_1_MinFlow(-1)
}


/* Since timestep is daily and forecasts in dss file are weekly, the forecast
must be multiplied by 7 */

Set : _Proj_1_Evap
{  value :  convert_units { stor_to_area { 100, storage100 } * 7 *
timesers(100/Evap_[ForcCode_1]) / 12 + stor_to_area { 120, storage120 } * 7 *
timesers(120/Evap_[ForcCode_1]) / 12 +
                                          stor_to_area { 130, storage130 } *
7 * timesers(130/Evap_[ForcCode_1]) / 12 + stor_to_area { 180, storage180 } *
7 * timesers(180/Evap_[ForcCode_1]) / 12 +
                                          stor_to_area { 220, storage220 } *
7 * timesers(220/Evap_[ForcCode_1]) / 12, af, mg }
}

Set :  _Proj_1_Inflow
{  value :  7 * (timesers(100/[ForcCode_1]) +   timesers(120/[ForcCode_1]) +
timesers(130/[ForcCode_1]) +
                timesers(160/[ForcCode_1]) + timesers(180/[ForcCode_1]) +
timesers(220/[ForcCode_1]) )
}


    /* Second Trigger Horizon */

Set : _Proj_2_Demand
{
    Condition : weekday{year, month, day} <= 1
    Value     : accumulate { demand190, 0, +[Forecast_2_Horizon_Days] }
                * ( 1 -  [Dem_1_Red_Factor] / 100 )


    Condition : default
    Value     : _Proj_2_Demand(-1)
}


Set : _Proj_2_MinFlow
{
    Condition : weekday{year, month, day} <= 1
    Value     :  min { accumulate { 20 , 0, +[Forecast_2_Horizon_Days] },
                       7 * (timesers(100/[ForcCode_2]) +
timesers(120/[ForcCode_2]) + timesers(130/[ForcCode_2]) +
                                timesers(160/[ForcCode_2]) +
timesers(180/[ForcCode_2]) ) * 0.7 }
```

```
    Condition : default
    Value     : _Proj_2_MinFlow(-1)
}

Set : _Proj_2_Evap
{  value :  convert_units { stor_to_area { 100, storage100 } * 7 *
timesers(100/Evap_[ForcCode_2]) / 12 + stor_to_area { 120, storage120 } * 7 *
timesers(120/Evap_[ForcCode_2]) / 12 +
                                          stor_to_area { 130, storage130 } *
7 * timesers(130/Evap_[ForcCode_2]) / 12 + stor_to_area { 180, storage180 } *
7 * timesers(180/Evap_[ForcCode_2]) / 12 +
                                          stor_to_area { 220, storage220 } *
7 * timesers(220/Evap_[ForcCode_2]) / 12, af, mg }
}

Set :  _Proj_2_Inflow
{  value :  7 * (timesers(100/[ForcCode_2]) +   timesers(120/[ForcCode_2]) +
timesers(130/[ForcCode_2]) +
                timesers(160/[ForcCode_2]) + timesers(180/[ForcCode_2]) +
timesers(220/[ForcCode_2]) )
}


    /* Third Trigger Horizon */

Set : _Proj_3_Demand
{
    Condition : weekday{year, month, day} <= 1
    Value     : accumulate { demand190, 0, +[Forecast_3_Horizon_Days] }
                * ( 1 - ([Dem_1_Red_Factor] + [Dem_2_Red_Factor])/ 100 )


    Condition : default
    Value     : _Proj_3_Demand(-1)
}


Set : _Proj_3_MinFlow
{
    Condition : weekday{year, month, day} <= 1
    Value     : min { accumulate { 20 , 0, +[Forecast_3_Horizon_Days] },
                         7 * (timesers(100/[ForcCode_3]) +
timesers(120/[ForcCode_3]) + timesers(130/[ForcCode_3]) +
                                timesers(160/[ForcCode_3]) +
timesers(180/[ForcCode_3]) ) * 0.7 }

    Condition : default
    Value     : _Proj_3_MinFlow(-1)
}
```

```
Set : _Proj_3_Evap
{  value :  convert_units { stor_to_area { 100, storage100 } * 7 *
timesers(100/Evap_[ForcCode_3]) / 12 + stor_to_area { 120, storage120 } * 7 *
timesers(120/Evap_[ForcCode_3]) / 12 +
                                          stor_to_area { 130, storage130 } *
7 * timesers(130/Evap_[ForcCode_3]) / 12 + stor_to_area { 180, storage180 } *
7 * timesers(180/Evap_[ForcCode_3]) / 12 +
                                          stor_to_area { 220, storage220 } *
7 * timesers(220/Evap_[ForcCode_3]) / 12, af, mg }
}

Set :  _Proj_3_Inflow
{  value :  7 * (timesers(100/[ForcCode_3]) +   timesers(120/[ForcCode_3]) +
timesers(130/[ForcCode_3]) +
                timesers(160/[ForcCode_3]) + timesers(180/[ForcCode_3]) +
timesers(220/[ForcCode_3]) )
}


/*  This part is for the refill.  Lift each set of restrictions if there is a
95% chance of refilling to 95% full over the typical forecast horizon used
for the trigger development.  The 95% is based on using 5th percentile
inflows and net evap, so it is not strictly 95% chance of reaching the
storage threshold since this would be influenced by the actual min release.
This uses the [ForcCode_3] forecast horizon and risk factor which is 8 weeks
and 5% .     */


Set : _Proj_Demand_Refill
{
    Condition : weekday{year, month, day} <= 1
    Value     : accumulate { demand190, 0, +[Forecast_3_Horizon_Days] }
                * ( 1 - ([Dem_1_Red_Factor] + [Dem_2_Red_Factor] +
[Dem_3_Red_Factor] ) / 100 )


    Condition : default
    Value     : _Proj_Demand_Refill(-1)
}


Set : _Proj_MinFlow_Refill
{
    Condition : weekday{year, month, day} <= 1
    Value     : min { accumulate { 20 , 0, +[Forecast_3_Horizon_Days] },
                         7 * (timesers(100/[ForcCode_3]) +
timesers(120/[ForcCode_3]) + timesers(130/[ForcCode_3]) +
                                timesers(160/[ForcCode_3]) +
timesers(180/[ForcCode_3]) ) * 0.7 }

    Condition : default
    Value     : _Proj_MinFlow_Refill(-1)
}
```

```
Set : _Proj_Evap_Refill
{  value :  convert_units { stor_to_area { 100, storage100 } * 7 *
timesers(100/Evap_[ForcCode_3]) / 12 + stor_to_area { 120, storage120 } * 7 *
timesers(120/Evap_[ForcCode_3]) / 12 +
                                         stor_to_area { 130, storage130 } *
7 * timesers(130/Evap_[ForcCode_3]) / 12 + stor_to_area { 180, storage180 } *
7 * timesers(180/Evap_[ForcCode_3]) / 12 +
                                         stor_to_area { 220, storage220 } *
7 * timesers(220/Evap_[ForcCode_3]) / 12, af, mg }
}


/*  This section computes the projected storage using the current storage and
projected inflow, demand, minimum flow, and evaporation for each of the three
forecast horizons.   */

Set : _Proj_1_Storage
{   Condition : weekday{year, month, day} <= 1
    Value     : min{ storage130 +storage180 + storage220 + _Proj_1_Inflow -
_Proj_1_Demand - _Proj_1_Evap - _Proj_1_MinFlow,
                     upper_rule130 + upper_rule180 + upper_rule220}

    Condition : default
    Value     : _Proj_1_Storage(-1)
}

Set : _Proj_2_Storage
{   Condition : weekday{year, month, day} <= 1
    Value     : min{ storage130 +storage180 + storage220 + _Proj_2_Inflow -
_Proj_2_Demand - _Proj_2_Evap - _Proj_2_MinFlow,
                     upper_rule130 + upper_rule180 + upper_rule220}

    Condition : default
    Value     : _Proj_2_Storage(-1)
}


Set : _Proj_3_Storage
{   Condition : weekday{year, month, day} <= 1
    Value     : min{ storage130 +storage180 + storage220 +  _Proj_3_Inflow -
_Proj_3_Demand - _Proj_3_Evap - _Proj_3_MinFlow,
                     upper_rule130 + upper_rule180 + upper_rule220}

    Condition : default
    Value     : _Proj_3_Storage(-1)
}

/*  To repeat, refill projection uses inflow associated with trigger 3
criteria for risk factor and forecast horizon.  */

Set : _Proj_Storage_Refill
{   Condition : weekday{year, month, day} <= 1
    Value     : min{ storage130 + storage180 + storage220 + _Proj_3_Inflow -
_Proj_Demand_Refill - _Proj_Evap_Refill - _Proj_MinFlow_Refill,
```

```
                      upper_rule130 + upper_rule180 + upper_rule220}

    Condition : default
    Value     : _Proj_Storage_Refill(-1)
}


/*  This section evaluates whether any of the three triggers were on during
the last time step.  If so, it checks to see whether the reservoir has re-
filled to the release storage threshold, or if the projection of reaching
that threshold is met, in which case the triggers are released.  If the
trigger was not on in the last timestep, it compares the projected storage
(on the first day of each week) with the threshold to determine whether it
should be turned on. 28 days must elapse before moving to the next phase of
restrictions */


Set : _Trigger_3_On
{
    Condition : _Trigger_3_On(-1) = 1
    {
        Condition :  _Proj_Storage_Refill >= [Release_Storage] *
(upper_rule130 + upper_rule180 + upper_rule220) or
                    storage130 + storage180 + storage220 >= [Release_Storage]
* (upper_rule130 + upper_rule180 + upper_rule220)
          Value     : 0

        Condition : default
        Value     : _Trigger_3_On(-1)
    }

    Condition : _Stage_2_Counter(-1) >= 28
    {
        Condition : weekday{year, month, day} <= 1
        {
            Condition : _Proj_3_Storage <= [Trigger_3_Storage] *
(upper_rule130 + upper_rule180 + upper_rule220)
            Value     : 1
        }

        Condition : default
        Value     : _Trigger_3_On(-1)
    }

    Condition : default
    Value     : _Trigger_3_On(-1)
}

Set : _Trigger_2_On
{
    Condition : _Trigger_2_On(-1) = 1
    {
        Condition :  _Proj_Storage_Refill >= [Release_Storage] *
(upper_rule130 + upper_rule180 + upper_rule220) or
```

```
                   storage130 + storage180 + storage220 >= [Release_Storage]
* (upper_rule130 + upper_rule180 + upper_rule220)
            Value      : 0

        Condition : default
        Value     : _Trigger_2_On(-1)
    }

    Condition : _Stage_1_Counter(-1) >= 28
    {
        Condition : weekday{year, month, day} <= 1
        {
            Condition : _Proj_2_Storage <= [Trigger_2_Storage] *
(upper_rule130 + upper_rule180 + upper_rule220)
            Value      : 1
        }

            Condition : default
        Value      : _Trigger_2_On(-1)
    }

      Condition : default
    Value      : _Trigger_2_On(-1)
}


Set : _Trigger_1_On
{
    Condition : _Trigger_1_On(-1) = 1
    {
        Condition :  _Proj_Storage_Refill >= [Release_Storage] *
(upper_rule130 + upper_rule180 + upper_rule220) or
                   storage130 + storage180 + storage220 >= [Release_Storage]
* (upper_rule130 + upper_rule180 + upper_rule220)
          Value      : 0

        Condition : default
        Value      : _Trigger_1_On(-1)
    }

    Condition : weekday{year, month, day} <= 1
    {
        // No trigger activation unless total storage < 90%
            Condition : _Proj_1_Storage <= [Trigger_1_Storage] *
(upper_rule130 + upper_rule180 + upper_rule220) and
                             storage130 + storage180 + storage220 < 0.9 *
(upper_rule130 + upper_rule180 + upper_rule220)
          Value      : 1
    }

    Condition : default
    Value      : _Trigger_1_On(-1)
}
```

```
/*  If NOT using forecasts, the trigger is activated or de-activated when the
storage level hits the trigger level */
:else:

Set : _Trigger_3_On
{
    Condition : _Trigger_3_On(-1) = 1
    {
        Condition : storage130 + storage180 + storage220 >= [Release_Storage]
* (upper_rule130 + upper_rule180 + upper_rule220)
        Value     : 0

        Condition : default
        Value     : _Trigger_3_On(-1)
    }

    Condition : _Stage_2_Counter(-1) >= 28
    {
        Condition : weekday{year, month, day} <= 1
        {
            Condition : storage130 + storage180 + storage220 <=
[Trigger_3_Storage] * (upper_rule130 + upper_rule180 + upper_rule220)
            Value     : 1
        }
        Condition : default
        Value     : _Trigger_3_On(-1)
    }
    Condition : default
    Value     : _Trigger_3_On(-1)
}

Set : _Trigger_2_On
{
    Condition : _Trigger_2_On(-1) = 1
    {
        Condition : storage130 + storage180 + storage220 >= [Release_Storage]
* (upper_rule130 + upper_rule180 + upper_rule220)
        Value     : 0

        Condition : default
        Value     : _Trigger_2_On(-1)
    }

    Condition : _Stage_1_Counter(-1) >= 28
    {
        Condition : weekday{year, month, day} <= 1
        {
            Condition : storage130 + storage180 + storage220 <=
[Trigger_2_Storage] * (upper_rule130 + upper_rule180 + upper_rule220)
            Value     : 1
        }
        Condition : default
        Value     : _Trigger_2_On(-1)
    }
```

```
    Condition : default
    Value     : _Trigger_2_On(-1)
}


Set : _Trigger_1_On
{
    Condition : _Trigger_1_On(-1) = 1
    {
        Condition : storage130 + storage180 + storage220 >= [Release_Storage]
* (upper_rule130 + upper_rule180 + upper_rule220)
        Value     : 0

        Condition : default
        Value     : _Trigger_1_On(-1)
    }

    Condition : weekday{year, month, day} <= 1
    {
        Condition : storage130 + storage180 + storage220  <=
[Trigger_1_Storage] * (upper_rule130 + upper_rule180 + upper_rule220)
            Value     : 1
    }

    Condition : default
    Value     : _Trigger_1_On(-1)
}


:endif:



Set :  _Trig_Level
    {  condition   :  _Trigger_3_On  = 1
       value       :  3

       condition   :  _Trigger_2_On = 1
       value       :  2

       condition   :  _Trigger_1_On  = 1
       value       :  1

       condition   :  default
       value       :  0
    }
```

```
/*  This section sets/resets the counters used to maintain the proper spacing
    of conservation stages.  */

Set : _Stage_1_Counter
{
    Condition : _Stage_1_Counter(-1) != 0
    {
        Condition : _Trigger_1_On = 0

        Value     : 0


        Condition : default
        Value     : _Stage_1_Counter(-1) + 1
    }

    Condition : _Trigger_1_On = 1
    Value     : 1

    Condition : default
    Value     : 0
}


Set : _Stage_2_Counter
{
    Condition : _Stage_2_Counter(-1) != 0
    {
        Condition : _Trigger_2_On = 0

        Value     : 0
    }

    Condition : _Trigger_2_On = 1
    Value     : _Stage_2_Counter(-1) + 1

    Condition : default
    Value     : _Stage_2_Counter(-1)
}

Set : _Stage_3_Counter
{
    Condition : _Stage_3_Counter(-1) != 0
    {
        Condition : _Trigger_3_On = 0

        Value     : 0
    }

    Condition : _Trigger_3_On = 1
    Value     : _Stage_3_Counter(-1) + 1
```

```
    Condition : default
    Value     : _Stage_3_Counter(-1)
}


/*  This section determines the demand depending upon which level of
conservation
    is in place. */

Set : _Consvn_1_Demand
{
    Condition : _Trigger_1_On = 1
    Value     : Demand190 * ( 1 - ( [Dem_1_Red_Factor] ) / 100 )

    Condition : default
    Value     : Demand190
}

Set : _Consvn_2_Demand
{
    Condition : _Trigger_2_On = 1
    Value     : Demand190 * ( 1 - ( [Dem_1_Red_Factor] + [Dem_2_Red_Factor] )
/ 100 )

    Condition : default
    Value     : Demand190
}

Set : _Consvn_3_Demand
{
    Condition : _Trigger_3_On = 1
    Value     : Demand190 * ( 1 - ( [Dem_1_Red_Factor] + [Dem_2_Red_Factor] +
[Dem_3_Red_Factor] ) / 100 )

    Condition : default
    Value     : Demand190
}



/*  Make sure the delivery never exceeds the reduced demand during a
conservation stage */

Constraint   Demand_Limit_Consvn_1 :
            {   Condition   :  _Trigger_1_On = 1
                Expression :  dflow210.190 + dflow180.190 + dflow220.190 <=
_Consvn_1_Demand }


Constraint   Demand_Limit_Consvn_2 :
            {   Condition   :  _Trigger_2_On = 1
                Expression :  dflow210.190 + dflow180.190 + dflow220.190 <=
_Consvn_2_Demand }
```

```
Constraint   Demand_Limit_Consvn_3 :
            {   Condition  :  _Trigger_3_On = 1
                Expression :  dflow210.190 + dflow180.190 + dflow220.190 <=
_Consvn_3_Demand }



/*  Count all trigger events lasting at least 10 days */

Set : _Ph1_event_counter
{   Condition : _Stage_1_Counter = 10 and _Stage_1_Counter(-1) = 9
    Value     : _Ph1_event_counter(-1) + 1

    Condition : default
    Value      : _Ph1_event_counter(-1)
}

Set : _Ph2_event_counter
{   Condition : _Stage_2_Counter = 10  and _Stage_2_Counter(-1) = 9
    Value     : _Ph2_event_counter(-1) + 1

    Condition : default
    Value      : _Ph2_event_counter(-1)
}

Set : _Ph3_event_counter
{   Condition : _Stage_3_Counter = 10 and _Stage_3_Counter(-1) = 9
    Value     : _Ph3_event_counter(-1) + 1

    Condition : default
    Value      : _Ph3_event_counter(-1)
}
```

Appendix B. Static Data Tables in the RWSA OASIS Basecase Scenario

Contents

Monthly Demand Patterns

Name	Ann. Avg. (mgd)	Month	Day	Month Fraction		Name	Ann. Avg. (mgd)	Month	Day	Month Fraction
Crozet	0.5	1	1	0.932		RWSA	10.0	1	1	0.920
Crozet	0.5	1	31	0.932		RWSA	10.0	1	31	0.920
Crozet	0.5	2	1	0.948		RWSA	10.0	2	1	0.960
Crozet	0.5	2	29	0.948		RWSA	10.0	2	29	0.960
Crozet	0.5	3	1	0.951		RWSA	10.0	3	1	0.950
Crozet	0.5	3	31	0.951		RWSA	10.0	3	31	0.950
Crozet	0.5	4	1	0.965		RWSA	10.0	4	1	1.000
Crozet	0.5	4	30	0.965		RWSA	10.0	4	30	1.000
Crozet	0.5	5	1	1.038		RWSA	10.0	5	1	0.990
Crozet	0.5	5	31	1.038		RWSA	10.0	5	31	0.990
Crozet	0.5	6	1	1.044		RWSA	10.0	6	1	1.040
Crozet	0.5	6	30	1.044		RWSA	10.0	6	30	1.040
Crozet	0.5	7	1	1.061		RWSA	10.0	7	1	1.080
Crozet	0.5	7	31	1.061		RWSA	10.0	7	31	1.080
Crozet	0.5	8	1	1.068		RWSA	10.0	8	1	1.100
Crozet	0.5	8	31	1.068		RWSA	10.0	8	31	1.100
Crozet	0.5	9	1	1.103		RWSA	10.0	9	1	1.130
Crozet	0.5	9	30	1.103		RWSA	10.0	9	30	1.130
Crozet	0.5	10	1	1.011		RWSA	10.0	10	1	1.000
Crozet	0.5	10	31	1.011		RWSA	10.0	10	31	1.000
Crozet	0.5	11	1	0.970		RWSA	10.0	11	1	0.940
Crozet	0.5	11	30	0.970		RWSA	10.0	11	30	0.940
Crozet	0.5	12	1	0.907		RWSA	10.0	12	1	0.890
Crozet	0.5	12	31	0.907		RWSA	10.0	12	31	0.890

Reservoir Storage-Area-Elevation Tables

Name	Node Number	Elevation (ft)	Storage (MG)	Area (acres)
Crozet	100	498.7	0	0
Crozet	100	515.4	68.3	29.31
Crozet	100	518.7	105.5	40.3
Crozet	100	523.7	183.8	56.3
Crozet	100	528.7	289	71.9
Crozet	100	533.7	416.5	84.9
Crozet	100	536	482.6	91.6
Crozet	100	537	513	95.2
Crozet	100	538	544.7	99
Crozet	100	538.7	567.6	102.4
Crozet	100	539	577.8	105.2
Crozet	100	539.3	588.1	106.9
Crozet	100	539.5	595.1	107.9
Crozet	100	540	613	110.9
Crozet	100	540.5	631.2	113.5
Crozet	100	541	649.9	115.8
Crozet	100	542	688.4	120.2
Crozet	100	543	728.3	124.5
Crozet	100	545	812	132.5
Crozet	100	552.1	1154.9	165.2
Crozet	100	556.7	1419.7	188.5
Crozet	100	559.4	1592	203.3
Crozet	100	568.8	2306.6	264.9
Albemarle	120	472	0	0
Albemarle	120	473	0	0.1
Albemarle	120	475	0.3	1
Albemarle	120	477	2.9	7.6
Albemarle	120	479	8.5	9.8
Albemarle	120	481	15.6	12.3
Albemarle	120	483	24.8	15.4
Albemarle	120	485	35	17.4
Albemarle	120	487	47.2	19.3
Albemarle	120	489	60.6	21.5

Name	Node Number	Elevation (ft)	Storage (MG)	Area (acres)
Albemarle	120	491	75	24.1
Albemarle	120	493	92	27.5
Albemarle	120	495	111	31
Albemarle	120	497	133	37
Albemarle	120	500	180.5	60.7
Albemarle	120	501	200	63.8
Albemarle	120	503	244	70.1
Albemarle	120	505	292	76.4
Albemarle	120	507	334	82.6
Albemarle	120	520	777.4	123.4
Sugar Hollow	130	923	8.61	0.00029844
Sugar Hollow	130	924	8.62	0.03755739
Sugar Hollow	130	925	8.66	0.2672406
Sugar Hollow	130	926	8.81	0.7637741
Sugar Hollow	130	927	9.19	1.65994
Sugar Hollow	130	928	9.92	2.888499
Sugar Hollow	130	929	11.02	3.929982
Sugar Hollow	130	930	12.44	4.925758
Sugar Hollow	130	931	14.17	5.877525
Sugar Hollow	130	932	16.29	7.506221
Sugar Hollow	130	933	18.99	9.164555
Sugar Hollow	130	934	22.13	10.32876
Sugar Hollow	130	935	25.6	11.24431
Sugar Hollow	130	936	29.37	12.19298
Sugar Hollow	130	937	33.43	13.0812
Sugar Hollow	130	938	37.76	13.90257
Sugar Hollow	130	939	42.37	14.81736
Sugar Hollow	130	940	47.29	15.78767
Sugar Hollow	130	941	52.49	16.64043
Sugar Hollow	130	942	57.93	17.25776
Sugar Hollow	130	943	63.55	17.82835
Sugar Hollow	130	944	69.36	18.39741
Sugar Hollow	130	945	75.34	18.9601
Sugar Hollow	130	946	81.51	19.69876
Sugar Hollow	130	947	87.95	20.45915
Sugar Hollow	130	948	94.59	21.093

Name	Node Number	Elevation (ft)	Storage (MG)	Area (acres)
Sugar Hollow	130	949	101.47	21.88925
Sugar Hollow	130	950	108.57	22.56516
Sugar Hollow	130	951	115.91	23.44603
Sugar Hollow	130	952	123.56	24.32465
Sugar Hollow	130	953	131.44	25.01809
Sugar Hollow	130	954	139.56	25.86909
Sugar Hollow	130	955	147.98	26.81625
Sugar Hollow	130	956	156.65	27.51563
Sugar Hollow	130	957	165.57	28.3537
Sugar Hollow	130	958	174.77	29.31897
Sugar Hollow	130	959	184.25	30.0582
Sugar Hollow	130	960	193.98	30.94158
Sugar Hollow	130	961	203.99	31.76036
Sugar Hollow	130	962	214.24	32.5348
Sugar Hollow	130	963	224.75	33.36075
Sugar Hollow	130	964	235.53	34.22286
Sugar Hollow	130	965	246.6	35.1937
Sugar Hollow	130	966	257.96	36.02831
Sugar Hollow	130	967	269.59	36.87659
Sugar Hollow	130	968	281.52	37.95264
Sugar Hollow	130	969	293.8	38.91067
Sugar Hollow	130	970	306.35	39.73096
Sugar Hollow	130	971	319.2	40.80685
Sugar Hollow	130	972	332.44	42.1861
Sugar Hollow	130	973	346.17	43.76761
Sugar Hollow	130	974	360.44	45.51431
Sugar Hollow	130	975	375.37	47.02331
South Fork	180	366	364.03	100.6632
South Fork	180	367	399.566	107.0167
South Fork	180	368	436.108	113.3756
South Fork	180	369	475.71	120.1713
South Fork	180	370	517.967	127.3239
South Fork	180	371	562.891	134.2856
South Fork	180	372	610.485	141.3078
South Fork	180	373	660.834	148.3185
South Fork	180	374	713.833	155.1556

Name	Node Number	Elevation (ft)	Storage (MG)	Area (acres)
South Fork	180	375	769.548	162.4283
South Fork	180	376	828.279	171.2965
South Fork	180	377	890.807	182.3732
South Fork	180	378	958.204	196.2969
South Fork	180	379	1032.08	216.3148
South Fork	180	380	1112.49	228.9297
South Fork	180	381	1195.94	232.4544
South Fork	180	382	1282.25	233.4394
South Fork	180	383	1369.36	233.817
South Fork	180	384	1456.93	233.817
South Fork	180	385	1544.05	233.817
South Fork	180	386	1631.16	233.817
South Fork	180	387	1718.28	233.817
South Fork	180	388	1805.4	233.817
South Fork	180	389	1892.51	233.817
South Fork	180	390	1979.63	233.817
South Fork	180	391	2066.75	233.817
South Fork	180	392	2153.86	233.817
South Fork	180	393	2240.98	233.817
South Fork	180	394	2328.1	233.817
South Fork	180	395	2415.22	233.817
South Fork	180	396	2502.33	233.817
South Fork	180	397	2589.45	233.817
South Fork	180	398	2676.57	233.817
South Fork	180	399	2763.68	233.817
South Fork	180	400	2850.8	233.817
Ragged Mountain	220	580	0	0
Ragged Mountain	220	590	3.2	2.8
Ragged Mountain	220	600	21.5	8.9
Ragged Mountain	220	610	67.2	19.9
Ragged Mountain	220	620	151.9	33.5
Ragged Mountain	220	622	174.72	35.44
Ragged Mountain	220	623	187.45	37.25
Ragged Mountain	220	624	200.18	39.06
Ragged Mountain	220	625	214.26	41.14
Ragged Mountain	220	626	228.34	43.22

Name	Node Number	Elevation (ft)	Storage (MG)	Area (acres)
Ragged Mountain	220	627	243.52	44.905
Ragged Mountain	220	628	258.7	46.59
Ragged Mountain	220	629	274.99	48.29
Ragged Mountain	220	630	291.28	49.99
Ragged Mountain	220	631	308.63	51.62
Ragged Mountain	220	632	325.98	53.25
Ragged Mountain	220	633	344.4	54.25
Ragged Mountain	220	634	362.82	55.25
Ragged Mountain	220	635	382.51	58.485
Ragged Mountain	220	636	402.2	60.44
Ragged Mountain	220	637	423.225	62.475
Ragged Mountain	220	638	444.25	64.51
Ragged Mountain	220	639	466.79	66.85
Ragged Mountain	220	640	489.33	69.19
Ragged Mountain	220	641	513.26	74.48
Ragged Mountain	220	642	538.1	77.32
Ragged Mountain	220	643	563.82	79.83
Ragged Mountain	220	644	590.33	82.29
Ragged Mountain	220	645	617.69	84.99
Ragged Mountain	220	646	645.94	87.72
Ragged Mountain	220	647	675.08	90.44
Ragged Mountain	220	648	705.1	93.15
Ragged Mountain	220	649	728.2	95.86
Ragged Mountain	220	650	767.79	98.57
Ragged Mountain	220	651	800.49	101.42
Ragged Mountain	220	652	834.12	104.28
Ragged Mountain	220	653	868.72	107.34
Ragged Mountain	220	654	904.33	110.43
Ragged Mountain	220	655	940.96	113.61
Ragged Mountain	220	656	978.63	116.79
Ragged Mountain	220	657	1017.33	119.99
Ragged Mountain	220	658	1057.08	123.18
Ragged Mountain	220	659	1097.88	126.42
Ragged Mountain	220	660	1139.74	129.67
Ragged Mountain	220	661	1182.64	132.85
Ragged Mountain	220	662	1226.57	136.01

Name	Node Number	Elevation (ft)	Storage (MG)	Area (acres)
Ragged Mountain	220	663	1271.57	139.34
Ragged Mountain	220	664	1317.66	142.69
Ragged Mountain	220	665	1364.84	146.08
Ragged Mountain	220	666	1413.13	149.47
Ragged Mountain	220	667	1462.52	152.83
Ragged Mountain	220	668	1513	156.18
Ragged Mountain	220	669	1564.56	159.44
Ragged Mountain	220	670	1617.17	162.69
Ragged Mountain	220	671	1670.85	165.96
Ragged Mountain	220	672	1725.6	169.22
Ragged Mountain	220	673	1781.41	172.55
Ragged Mountain	220	674	1838.32	175.88
Ragged Mountain	220	675	1896.33	179.31
Ragged Mountain	220	676	1955.46	182.76
Ragged Mountain	220	677	2015.7	186.13
Ragged Mountain	220	678	2077.03	189.48
Ragged Mountain	220	679	2139.45	192.78
Ragged Mountain	220	680	2202.93	196.08
Ragged Mountain	220	681	2267.5	199.41
Ragged Mountain	220	682	2333.16	202.74
Ragged Mountain	220	683	2399.91	206.1
Ragged Mountain	220	684	2467.75	209.46
Ragged Mountain	220	685	2536.72	212.98
Ragged Mountain	220	686	2606.84	216.52
Ragged Mountain	220	687	2678.14	220.2
Ragged Mountain	220	688	2750.64	223.9
Ragged Mountain	220	689	2824.34	227.55
Ragged Mountain	220	690	2899.24	231.2
Ragged Mountain	220	691	2975.35	235.02
Ragged Mountain	220	692	3052.71	238.85
Ragged Mountain	220	693	3131.34	242.78
Ragged Mountain	220	694	3211.25	246.73
Ragged Mountain	220	695	3292.42	250.52
Ragged Mountain	220	696	3374.82	254.29

Reservoir Rule Curves

Name	Node Number	Month	Day	Upper Rule (MG)	Lower Rule (MG)
Crozet	100	1	1	567.60	68.30
Crozet	100	12	31	567.60	68.30
Albemarle	120	1	1	133.00	33.30
Albemarle	120	12	31	133.00	33.30
Sugar Hollow	130	1	1	375.37	36.00
Sugar Hollow	130	12	31	375.37	36.00
South Fork	180	1	1	1282.00	400.00
South Fork	180	12	31	1282.00	400.00
Chris Greene	200	1	1	334.00	272.50
Chris Greene	200	12	31	334.00	272.50
Ragged Mountain	220	1	1	1671.00	157.00
Ragged Mountain	220	12	31	1671.00	157.00

Model Weighting – Demands, Reservoirs, and Arcs

Demands

Name	Node Number	Weight
Crozet	110	45000
RWSA	190	1500

Reservoirs

Name	Node Number	A-Zone Weight (Dead Stor)	B-Zone Weight (Below Lower Rule)	C-Zone Weight (Useable Stor)	D-Zone Weight (Flood Stor)
Beaver Creek	100	50000	40000	50	-200
Albemarle	120	40000	40000	40000	-200
Sugar Hollow	130	40000	50	50	-200
South Fork	180	7000	50	50	-200
Chris Greene	200	40000	40000	40000	-200
Ragged Mountain	220	40000	50	50	-200

Arc Weights – Minimum Releases, WTP targets, Transfers

Name	Arc Number	Weight
SH Min. Rel.	130.135	500
SH-RM Transfer	130.165	10
SF Min. Rel	180.185	1000
CG Release	200.210	100
NF WTP	210.190	120
RM WTP	220.190	75

Constants Table

Constant_Name	Constant_Value	Constant_Description
Release_Storage	0.95	End restrictions at 95% storage

Appendix C. Finalized Inflow Data Development for the RWSA OASIS Model

Contents

Section 1. Introduction

This report provides a detailed account of the inflow development for the Rivanna Water and Sewer Authority (RWSA) OASIS model. The finalized inflow record runs from October 1925 to September 2017[1]. This period is designed to capture as many drought events as possible, including the extreme droughts of the 1930s, 1960s, and the early 2000s. There are 10 streamflow gages in the basin that are used in this project as well as 18 reference gages outside of the basin. These are listed in Table 1. These gages have at least 10 years of daily data with which to make valid statistical comparisons with other gages. Most of the gages have incomplete records, meaning they do not span the full period from 1925 to 2017. Some of the gages were used just to provide more data for *Fillin* (see below) when computing statistics. All gages selected for use have either a *fair*, *good*, or *excellent* rating from the USGS, meaning the error in reported flow is estimated to be 5 to 15%.

The inflow dataset is based on unregulated gage flows. Gages only show the actual flow in the stream; they have no information about what the flow would have been without human intervention. “Regulations”, often referred to as “impairments”, are modifications of the natural flows due to change in reservoir storage (including evaporation and precipitation on the reservoir surface), consumptive withdrawals of water, wastewater returns, and diversions coming into the basin. If water is withdrawn above a gage and returned to the river below the gage, the regulation is the entire withdrawal. For this document, the word “impairment” is generally avoided since it has specific use by Virginia DEQ related to water quality.

Note that the accuracy of these inflows (both final and provisional) were tested using the OASIS model. The results of these verifications were presented in the file ***RWSA_Model_Update_Review_2-23-18 rev_2-26-18.pptx***.

The next section describes the process used to compute daily flows and gains. Because of the noise in the data, it is important to look at the data at each step to find unrealistic values. These are noted later.

[1] As described in Section 6, a provisional record extends beyond this date, but this does not account for all of the actual regulation. Future updates will require complete regulation data for the inflow dataset to be considered finalized.

Table 1. List of Gages

Gage Number	Name	DA (sq. mi.)	Remarks
02031000	Mechums River Near White Hall, VA	95.3	
02032250	Moormans River Near Free Union, VA	77	Regulated by SF Rivanna reservoir
02032515	SF Rivanna River Near Charlottesville, VA	259	Regulated by SF Rivanna reservoir
02032640	NF Rivanna River Near Earlysville, VA	108	
02032680	NF Rivanna River Near Proffit, VA	174	
02034000	Rivanna River At Palmyra, VA	663	Some diurnal fluctuation at times mostly at low and medium flow caused by SF Rivanna River Reservoir, diversions and discharge upstream at Charlottesville.
02033500	Rivanna Riv bl Moors Cr nr Charlottesville, VA	503	Scale up this record to Palmyra D.A. and combine with that record
02031500	NF Moormans River near White Hall, VA	11.2	
02032500	SF Rivanna River Near Earlysville, VA	215	Regulated by Sugar Hollow, Beaver Creek, and Lake Albemarle
02032400	Buck Mountain Creek near Free Union, VA	34.5	
01626000	South River Near Waynesboro, VA	127	Diversion from Coles Run Reservoir u/s, capacity 80 MG., by Augusta County Service Authority. There is discharge from a WWTP upstream from station, originating from well fields. Slightly regulated by flood-detention reservoirs.
01626500	South River At Waynesboro, VA	133	
01662500	Rush River At Washington, VA	14.6	
01662800	Battle Run Near Laurel Mills, VA	25.8	At times, unknown amount of diversion for irrigation upstream from gage.
01665500	Rapidan River Near Ruckersville, VA	115	Diversion 0.4 mi upstream from station since 1973.
01666500	Robinson River Near Locust Dale, VA	179	
01671500	Bunch Creek Near Boswells Tavern, VA	4.34	
02024915	Pedlar River At Forest Road Near Buena Vista, VA	27.1	
02027000	Tye River Near Lovingston, VA	93	
02027500	Piney River At Piney River, VA	47.7	Periodic dewatering of upstream quarries adds small amount of inflow at times.
02028500	Rockfish River Near Greenfield, VA	94.8	
02030000	Hardware River Bl Briery Run Nr Scottsville, VA	116	
02034500	Willis River At Lakeside Village, VA	262	
02036500	Fine Creek At Fine Creek Mills, VA	22.4	
01627500	South River at Harriston, VA	212	Discharges from industrial and municipal wastewater treatment plants upstream from station, originating from well fields.
02030500	Slate River near Arvonia, VA	226	
01625000	Middle River near Grottoes, VA	373	Discharges of ~6.0 ft^3/s from WWTP's upstream (mostly diverted from another basin for industrial and municipal supply). Small diurnal fluctuation at low flow caused by mills and irrigation.
02022500	Kerrs Creek near Lexington, VA	35.1	

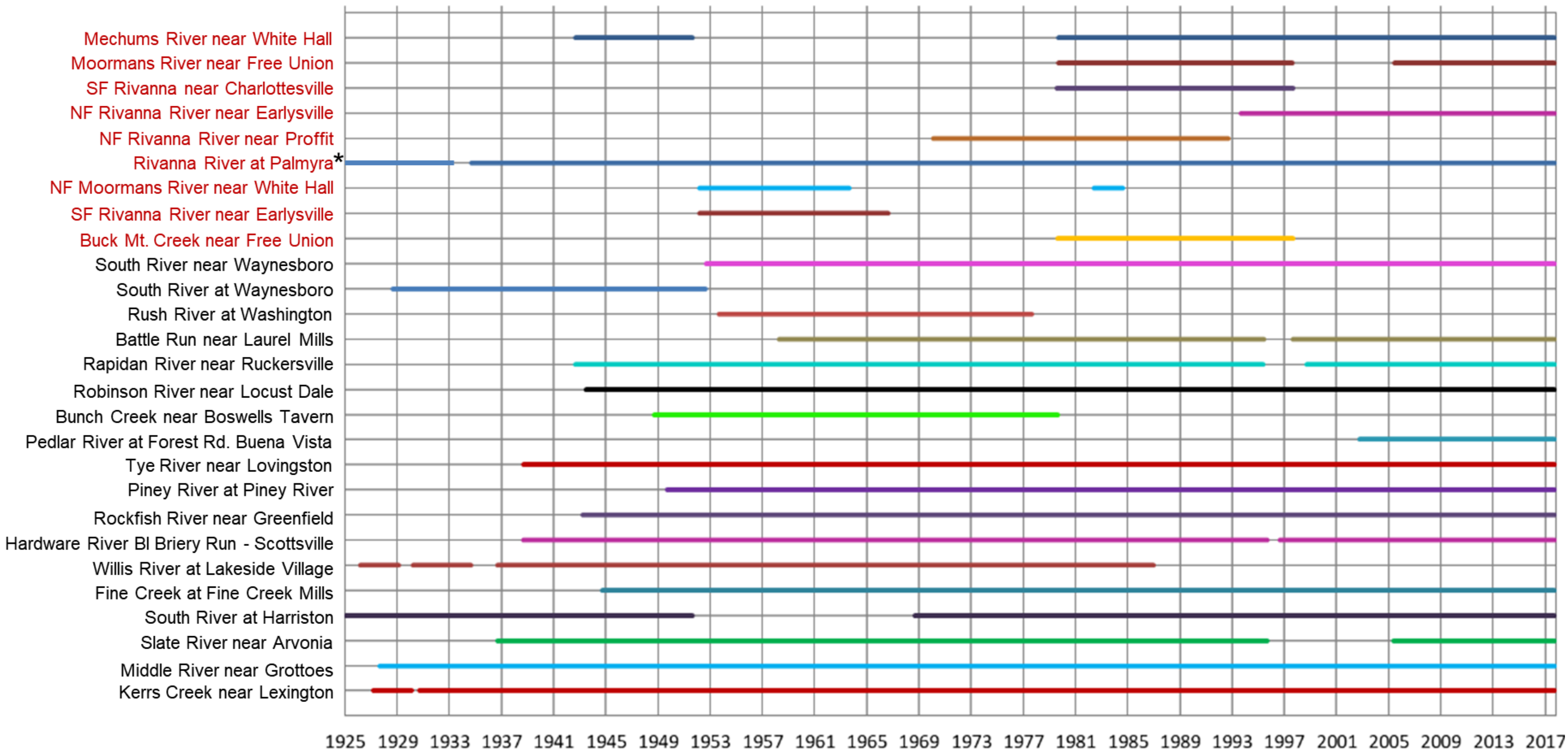


Figure 1. Timeline of Gage Data

Gages in red are within the Rivanna River basin
** Prior to 1934 use the Rivanna bl Moores Cr gage scaled up to Palmyra gage drainage area*

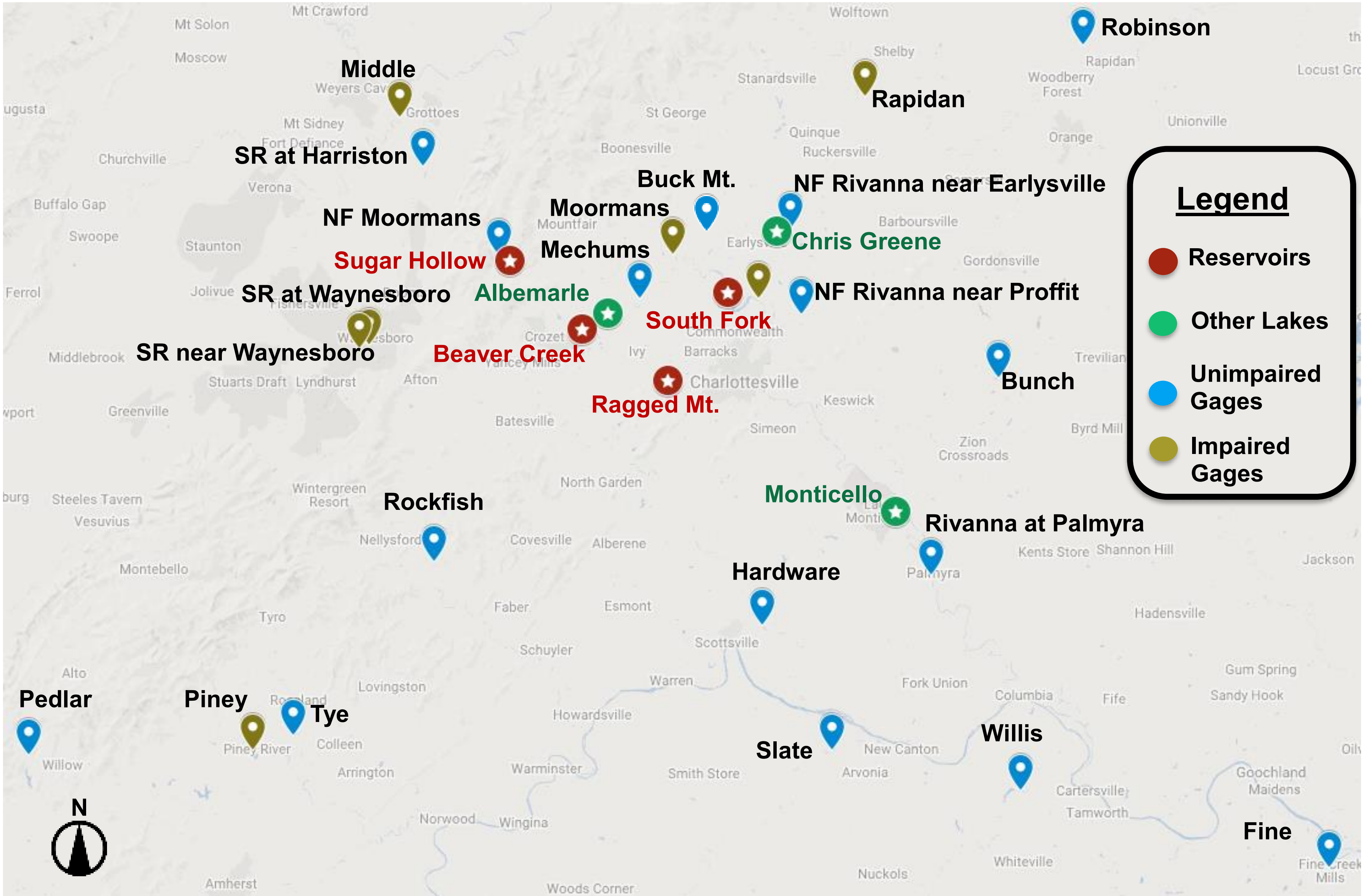


Figure 2. Map of Gages and Reservoirs

Section 2. Data and General Procedure

The first step in building the inflow record is to compute the unregulated gage flows. These computations are contained in the spreadsheet in the ***inflow_unregulation.xls*** in the 'Inflows' directory. The unregulated gage data is summarized in the ***unregulated_summary.xls*** file. Regulations in the basin accumulate as each downstream gage is included. The regulation is calculated as follows:

Unregulated gage flow = gage flow + upstream water withdrawal– wastewater return - upstream diversion into the basin + upstream change in reservoir storage + upstream evaporation on the reservoir surface - upstream precipitation on the reservoir surface.

The timeline of regulation data is shown in Figure 2.

Daily regulation data from 2008 to 2017 were provided by RWSA. Monthly reservoir contents and withdrawals for 2001-2002 were also provided by RWSA so that the major regulations during the extreme drought could be captured. Data beyond this period were not readily available.

Daily precipitation data for the reservoirs was provided by RWSA from 2008 to 2017. Prior to 2008, the following CO-OP stations were used to develop the precipitation record back to 1925: Charlottesville Albemarle Airport, Charlottesville 2W, Crozet 2N, and Charlottesville 1W.

Evaporation data are based on monthly values from a lake surface evaporation study by USGS in Durham, NC[2], resulting in monthly pattern of evaporation on each reservoir surface, which is then disaggregated to each day using the monthly average. Most evaporation data are collected in pans and then adjusted for the humidity at the lake surface. The USGS data are collected directly from the lake surface, improving the overall accuracy. For each reservoir, HydroLogics calculated a daily timeseries of net evaporation (or the difference between evaporation and precipitation) for the hydrologic record. These data are contained in spreadsheets in the "Evap-Precip" folder. These data are used to (1) estimate the historic change in reservoir storage due to net evaporation and (2) estimate net evaporation on the reservoir surface during OASIS model simulations.

[2] Turner, J.F., "Evaporation Study in a Humid Region, Lake Michie North Carolina,", USGS Pub. No. 272-G, 1966.

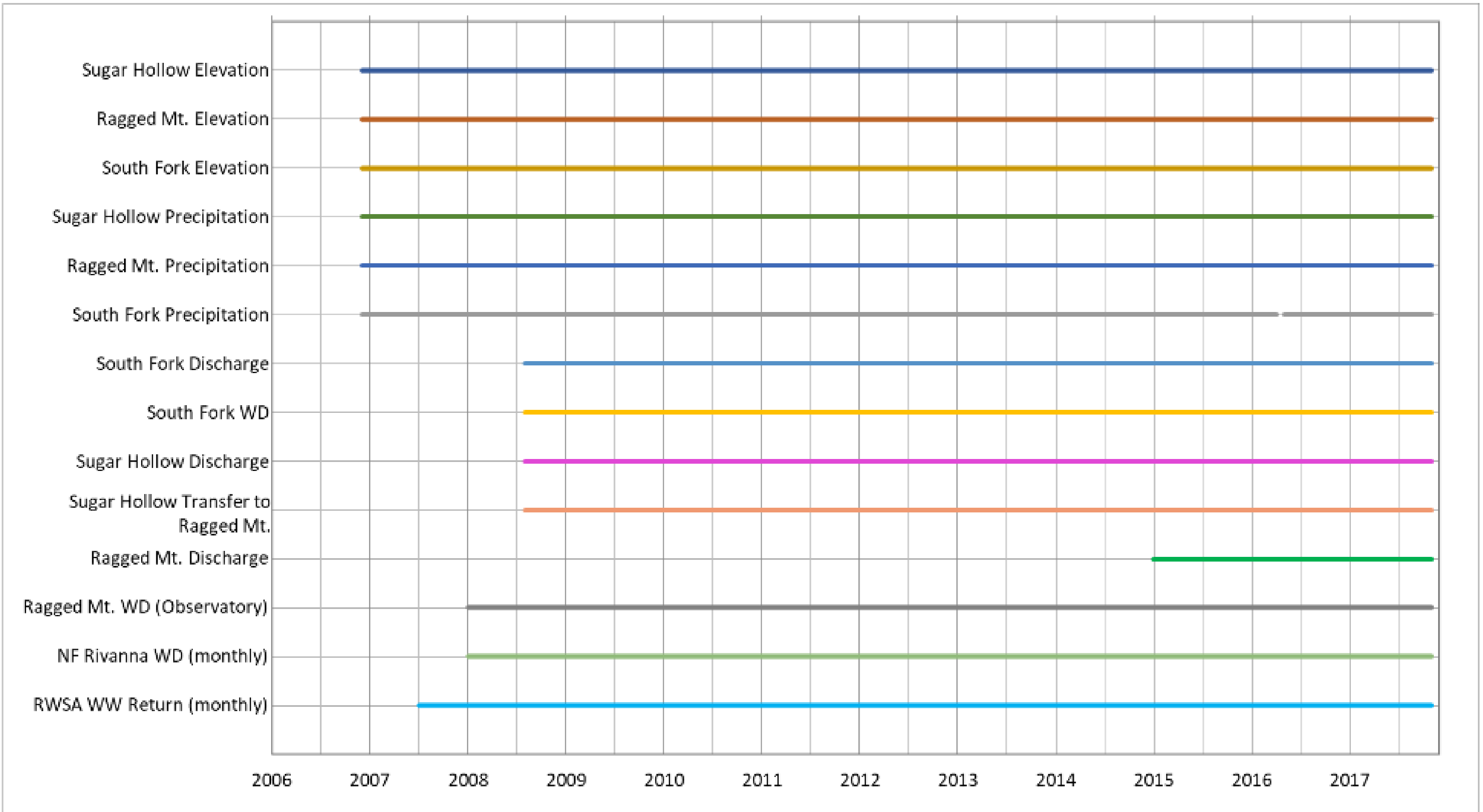


Figure 2. Timeline of Regulation Data

- *Discharges do not include spill*
- *Historic withdrawal and reservoir elevation data available from 2001-2002.*
- *Daily Ragged Mt. WD and discharge data only available for 2015-17. For verification, assume the minimum release requirement made prior to this.*

The second step in the inflow development process is to fill in the missing flows for each gage with missing records. This requires assembling a monthly record of unregulated flows based on the daily unregulated data computed above. These flows are fed into a program named *Fillin* (developed by William Alley and Alan Burns of the USGS[3]). We will refer to these as "extended" flows. This is done monthly because *Fillin* only works with monthly data. The gages being extended that will be used in the remainder of this document are as follows:

- Mechums River Near White Hall,
- Moormans River Near Free Union,
- North Fork (NF) Rivanna River Near Earlysville and Proffit (both NF gages combined into one record)
- Rivanna River at Palmyra and below Moors Creek near Charlottesville (both main stem Rivanna gages combined into one record),
- Buck Mountain Creek near Free Union.

Fillin uses a regression equation – monthly or annual, depending on the correlations – to extend the dependent gage using a reference independent gage:

*Extended flow = dependent gage mean + correl * (sum_y_sq / sum_x_sq)*
** (dependent gage flow – independent gage mean)*

where correl is the correlation coefficient between dependent & independent variable,
sum_x_sq and sum_y_sq are the sum of the independent and dependent flows squared.
Note that this equation is applied to log-transformed flows.

The correlations for the gages used in this model were presented in the file ***RWSA_Model_Update_Review_2-23-18 rev_2-26-18.pptx***. The actual reference gages used for each month to extend each gage are found in the file ***summary.dat*** in the *Fillin* directory.

Next, the gain at Palmyra is computed from the extended flows that will be used to compute the inflow at the main stem Rivanna below the RWSA system. All other local inflows to the model nodes are detailed Section 3. The Palmyra gain =

Palmyra extended flow – Moormans flow – Mechums flow – Buck Mt. flow – NF Rivanna flow

[3] "Mixed-Station Extension of Monthly Streamflow Records," *Journal of Hydraulic Engineering*, ASCE, Vol. 109, No. 10, October 1983.

Note that this gain is corrected for any negatives, detailed in section 4.

The next step is to disaggregate the monthly flows and gains into daily values. This is done using flows for a daily, unregulated gage that is local or has similar drainage area (call it a "reference gage") along with our monthly flows. We multiply the monthly value by the ratio of that day's flow to that month's flow at the reference gage. The disaggregation formula is:

daily ratio = daily reference value / monthly reference value
*daily computed value = monthly computed value * daily ratio*

This process is handled in the *Disaggregation* tab of the ***RWSA_Inflow_Calcs_Mar2018.xlsx*** spreadsheet.

The reference gages used for disaggregation are as follows:

- 1925 – 1943 : South R. at Harriston
- 1943 – 2017 : Rockfish R. nr Greenfield

It is important to note that we are not trying to replicate history in computing the OASIS inflows; rather, we are trying to build daily flows whose variation is *representative* of history while preserving monthly unregulated gaged flows as "ground truth".

The last step in the process is to compute the OASIS nodal inflows based on the flows computed above. This step is described in detail in Section 3.

Section 3. Computing Inflows at OASIS Nodes from the Flows and Gains

This section describes the computation of inflows at OASIS nodes from flows and gains at gages described above. The drainage area adjustments rely on the drainage areas of the inflow locations in Table 3 below as well as the drainage areas of the gages themselves. The total drainage areas at reservoir or lake locations are net of any surface area at full pond since net evaporation is computed separately during model simulations.

Node 100 (Beaver Ck Reservoir)	Mechums flow * (9.4 / 95.3) * cfsm adj. factor[4]
Node 120 (Lake Albermarle)	Mechums flow * (3.54 / 95.3)
Node 130 (Sugar Hollow Reservoir)	Moormans flow * (17.43 / 77)
Node 160 (Mechums gage)	Mechums flow – inflow100 – inflow 120
Node180 (SF Rivanna Reservoir)	(Moormans flow + Buck Mt flow + Mechums flow) * (258.53 – 17.43 – 95.3) / (77 + 34 + 95.4)
Node200 (Chris Green Lake)	NF Rivanna flow * (5.67 / 115)
Node210 (NF Rivanna Intake)	NF Rivanna flow – inflow200
Node220 (Ragged Mt. Reservoir)	Mechums flow * (1.7 / 95.3)
Node230 (Rivanna confluence)	(Palmyra gain – inflow180) * (71.47) / (663 – 115 – 95.3 – 34 – 77)

[4] Beaver Ck Reservoir inflow development is detailed in the report "Crozet Water Supply Modeling,", March 2018

Table 3. List of Drainage Areas (in square miles)

Description	Total Drainage Area	Incremental Drainage Area
Sugar Hollow	17.43	n/a
Beaver Creek	9.39	n/a
Lake Albemarle	3.54	n/a
Mechums Gage	95.3	82.37
South Fork	258.53	145.8
Chris Greene	5.67	n/a
NF Intake	115	109.33
Ragged Mt.	1.7	n/a
Confluence	445	71.47

Section 4. Error Checking and Inflow Filtering

As noted in Section 1, because of the noisy data, error checking is necessary. These are some of the errors that can occur:

- Negative unregulated gage flow. These are physically impossible and should be corrected on at least a monthly basis. They may occur due to errors in the monthly regulations.

- Negative gains. These are sometimes legitimate. However, there are times when a high runoff event hits a gage at the very end of the month, while not arriving at the gage downstream until the beginning of the next month. This can cause a highly negative gain in the first month and a highly positive gain the next month. These should be corrected.

- There are pathological cases where the scaling can cause one gage to have a large positive flow, while the adjacent gage has a large negative flow. This can occur when the two extended values are similar in magnitude but opposite in sign. These should be adjusted.

Negative inflow adjustments. Monthly flows and gains were adjusted in the *file* ***Unregulated_Summary.xlsx*** before being put into the ***fillin_input.dss*** file that is read into the *Fillin* program. Next, once extended flows are pasted from the ***extended_flows.dss*** file into the *Filled in Flow* tab of the file ***RWSA_Inflow_Calcs_Mar2018.xlsx***, negative gains for Palmyra are corrected.

Second, to prevent model infeasibility from potentially large negative provisional inflows, we added code in the OASIS model operations control language (OCL) to filter remaining daily negative inflows. The negative inflow is “stored” until there is a sufficiently positive inflow to release the accumulated negative flows, thereby preserving mass over a multi-day period. Since the negative inflows are generally very small and infrequent, the filtering has negligible impact on being able to match the monthly unregulated gage flow.

Section 5. Extending the Record Beyond September 2017

As mentioned earlier, the finalized inflow record ends on September 30, 2017. This section describes how to finalize updates to the record when new records (including regulations) become available. This is not to be confused with *provisional* updates used to facilitate real-time forecasting, which are done directly from the model interface using the Update Record tab.

Let us assume that we are adding data from October 1, 2017 to September 30, 2018 (the end of the water year for which data will be finalized). Note that we are only adding to the record. We are not changing any of the values prior to September 2017

1. Assemble the new gage records in Table 1 and place in the files ***Charlottesville_Gages_March2018.xlsx.***

2. Compute the regulation at each gage and add them to the gage flows. This has been done in the unregulation spreadsheet described earlier (called ***inflow_unregulation.xlsx)***. Next put the daily unregulated flows into the spreadsheet ***unregulated_summary.xlsx*** to compute the monthly unregulated flows using a spreadsheet pivot table. Check these flows for any negatives and correct as needed.

3. Append the new unregulated flows to the ***fillin_input.dss*** file (monthly averages). Modify the file ***fillin.cf*** to make the end year 2018. Save that file and run the ***fillin.exe*** file.

4. Paste the values for the following flows from ***extended_flows.dss*** into the *Filled in Flows* tab of the file ***RWSA_Inflow_Calcs_Mar2018.xlsx***, and save that file under a new name:

    - Moorm flow
    - BuckM flow
    - Mechu flow
    - NFRiv flow
    - Palm flow

5. Correct any negatives in the computed Palmyra gain in the same tab.

6. Append the South River at Harriston and Rockfish River monthly and daily flows in the *Disaggregation* tab in the same file.

7. The final inflows for the model will automatically be updated in the tab *Final Inflows* in the same file. Append the new inflows from this tab to the ***basedata.dss*** file in the Basedata folder for the model.

8. The basedata file will now contain this finalized data starting on October 1, 2017 and will be used for all future runs. Be sure to remove any provisional data from the file ***update_record.mdb*** in the Basedata folder covering the same time period as it would overwrite the finalized inflows if executed.

Section 6. Provisional Inflows

In order to update model inflows in real-time so that (conditional) forecasts can be generated, a provisional inflow update methodology has also been embedded in the OASIS model. To update the inflows, the model user inputs the daily data below for the time period being updated into the "Inflow Update" tab in the GUI (or for easier transfer of data from Excel, the data can be directly pasted into the file ***update_record.mdb*** found in the Basedata directory).

- Drawdown for Sugar Hollow, Beaver Ck, SF Rivanna, and Ragged Mt reservoirs
- Withdrawals for SF, NF, Observatory, and Crozet
- Transfer from SH to Ragged Mtn.
- WW discharge to Moore's Creek
- Precipitation from the Charlottesville 2W CO-OP station
- The following USGS gage flows:

02032250	Moormans River Near Free Union, VA
02031000	Mechums River Near White Hall, VA
02032640	NF Rivanna River Near Earlysville, VA
02034000	Rivanna River At Palmyra, VA

Once the data have been entered and QA/QC done, the user presses the Update Record button on the same tab. A module then computes all of the required inflows for the model and appends them to the basedata. Note that any data in the Update Record tab will overwrite any data in the basedata.dss file for overlapping dates.

The methodology used for computing the provisional inflows is largely the same as that in the finalized methodology detailed previously, except for a couple of key differences:

- The SF Rivanna Reservoir inflow does not contain the filled-in Buck Mountain gage flow, so the local inflow to the reservoir is now just the Mechums and Moormans gages scaled by drainage area.
  - The calculation for the local inflow to the OASIS node is as follows, since the OASIS model includes inflows for Sugar Hollow and Mechums:
    *(Unregulated Mechums + Moormans gages) * (258.53 – 95.3 – 17.43) / (95.3 + 77)*

  - To compute the total natural inflow to SF Rivanna Reservoir (for purposes of minimum release calculation), the following equation would be used:
    *(Unregulated Mechums + Moormans gages) * 258.53 / (95.3 + 77) = (Unregulated Mechums + Moorman gages) * 1.50*

- Unregulated gages are being computed daily instead of monthly. As mentioned previously, inflow filtering is being done in the model run, so any errors causing negative flows resulting from the daily unregulation are automatically adjusted.

Section 7. Inflow Verification Supplemental Presentation

RWSA OASIS Model Update Review

February 23, 2018

revised February 26, 2018

Advancing the Management of Water Resources

Casey Caldwell

Steve Nebiker

Hannah Billian

HYDROLOGICS

www.hydrologics.net

Scope of Work

- Operations Exercise
- Inflow Development
- Operating Rule Refinement
- Training
- DEQ Support

Inflow Development Approach

- Unimpair streamflow data when impairment data are available
  - Challenge is obtaining impairment data
  - Unimpaired gage flow = gage flow + (upstream) water withdrawal – WW discharge + reservoir transfers + change in reservoir storage + lake net evaporation

- Fill in (on a monthly basis) missing gage records using most highly correlated gages
  - Note: Most highly correlated gages may be ones with impairments. These impairments may be minimal relative to the monthly time step and to the overall streamflow.
  - Impairments may be offsetting. For example, reduction in storage at Sugar Hollow may be offset by increases in storage at Ragged Mt. and South Fork, so net impairment at downstream gage like Palmyra may be small. Also, water withdrawal and wastewater discharge from urban system are not significantly different relative to streamflow at gages downstream like Palymra. When these may not be true – namely storage changes in an extreme drought– we have estimated the impairment from select periods like 2001-02 and unimpaired the gage flows.
  - If annual correlation is stronger than monthly correlation, the former will be used for that month.

- Filter out negative flows in gains (typically caused by errors in impairments or time of travel issues)

- Scale flows to preserve volume at most downstream gage

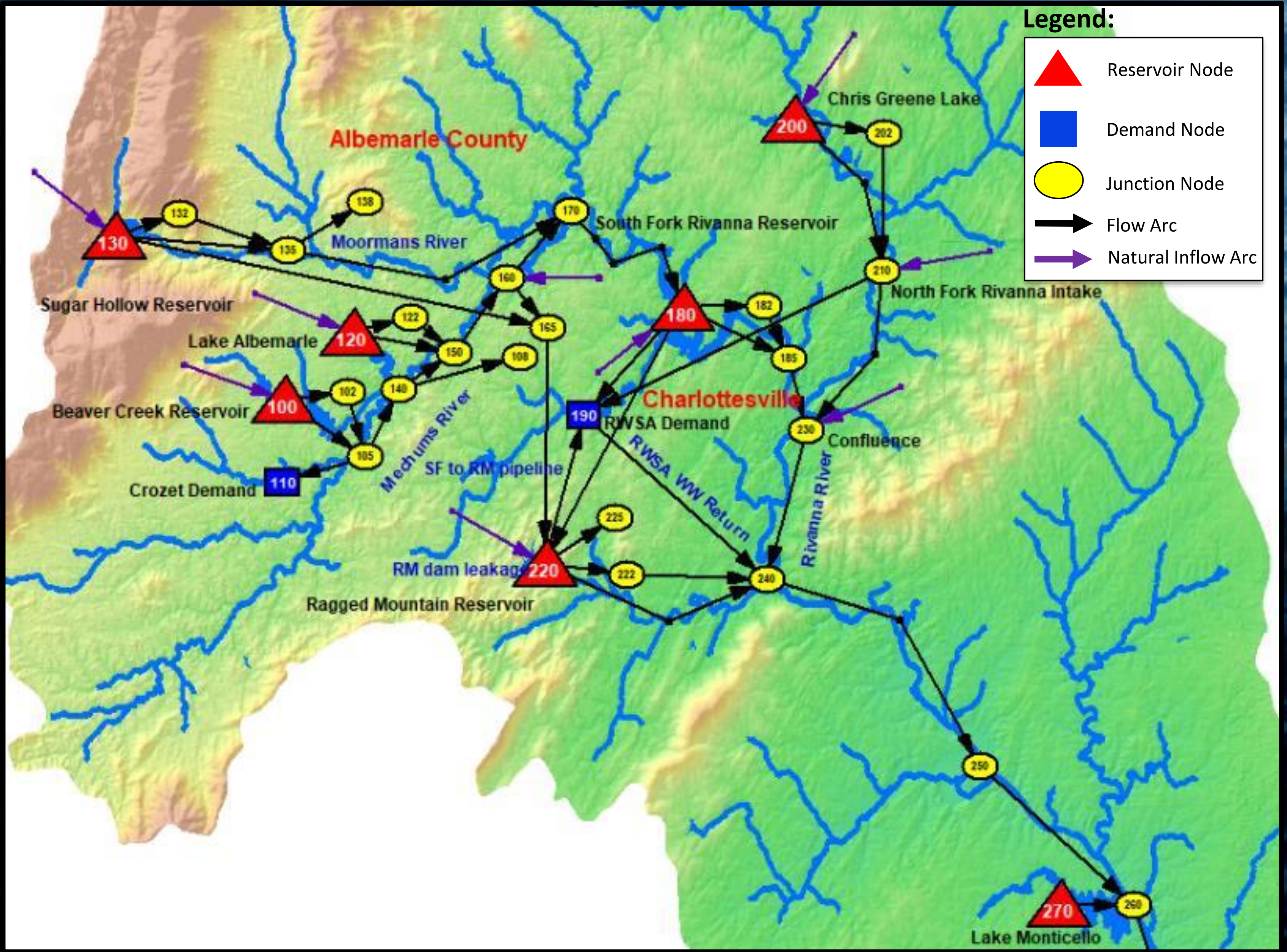
- Disaggregate monthly flows to daily

Goal: Developing daily inflow record where daily variation is *representative* of history while preserving monthly unimpaired gaged flows as “ground truth”

Inflow Development Approach (cont'd.)

- Conduct verifications to assess and improve inflow accuracy
- Develop long-term inflow record to include the 1930s drought (per DEQ safe yield regulation)
  - This constitutes the "comprehensive" approach wherein impairments are included when available historically and statistical approaches are used to fill-in missing gages
  - Script files will provide user with a quick means to update this dataset every five years or so when impairment data are compiled
- Develop "provisional" approach to enable real-time updates to inflows
  - Needed to generate reservoir storage forecasts
  - Simplifies number of needed impairments
    - Similar to approach taken by RWSA wherein South Fork and Sugar Hollow inflow are based on a drainage area adjustment of the Mechums gage.

Model Schematic

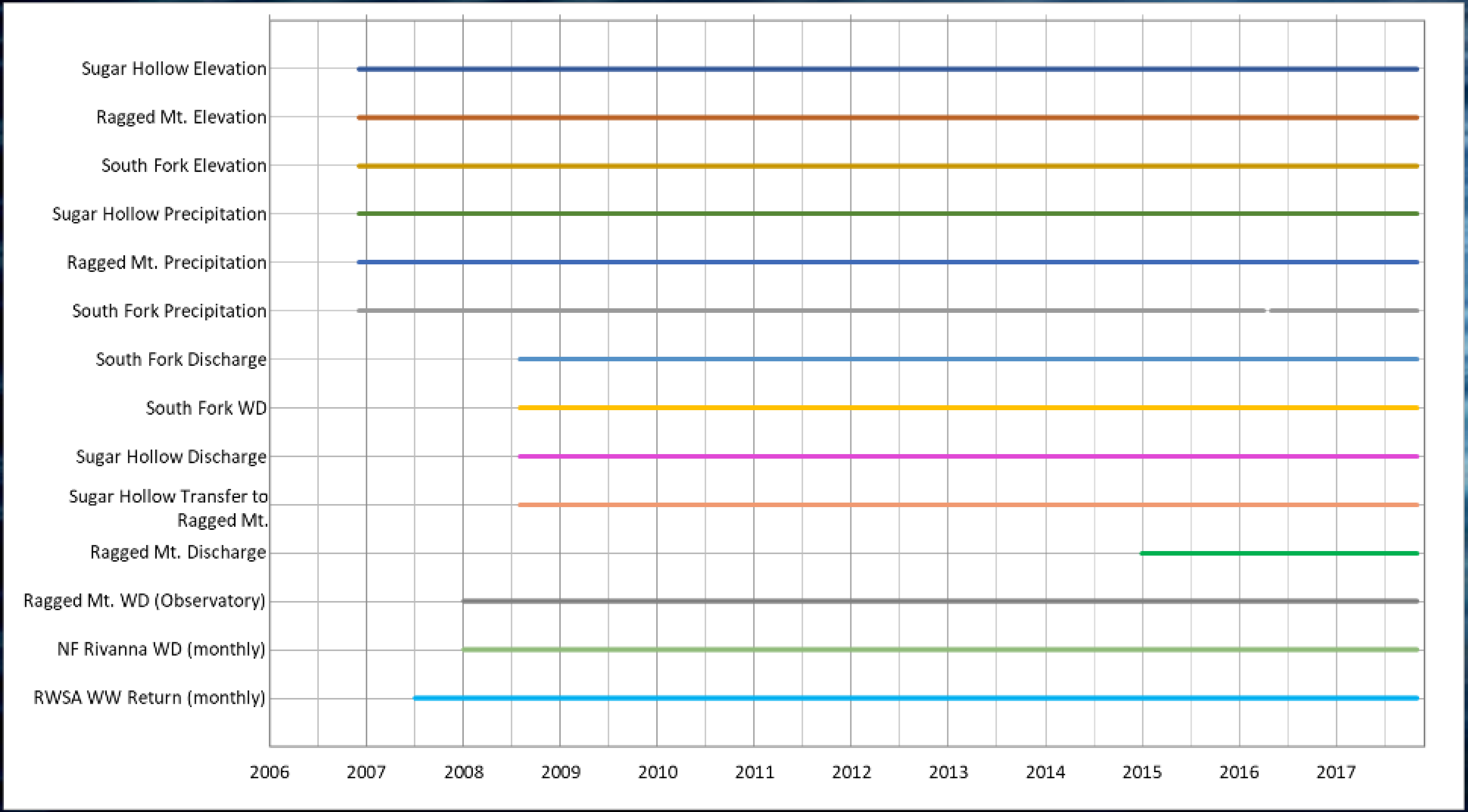


HYDROLOGICS

Impairment Data

- Reservoir elevation (storage), net evaporation, downstream releases through outlet works (not including spillway flow), and transfers
- WTP water (raw) production and wastewater discharges
- Focus on urban reservoirs (Sugar Hollow, Ragged Mt., and South Fork)

Impairment Data Timeline



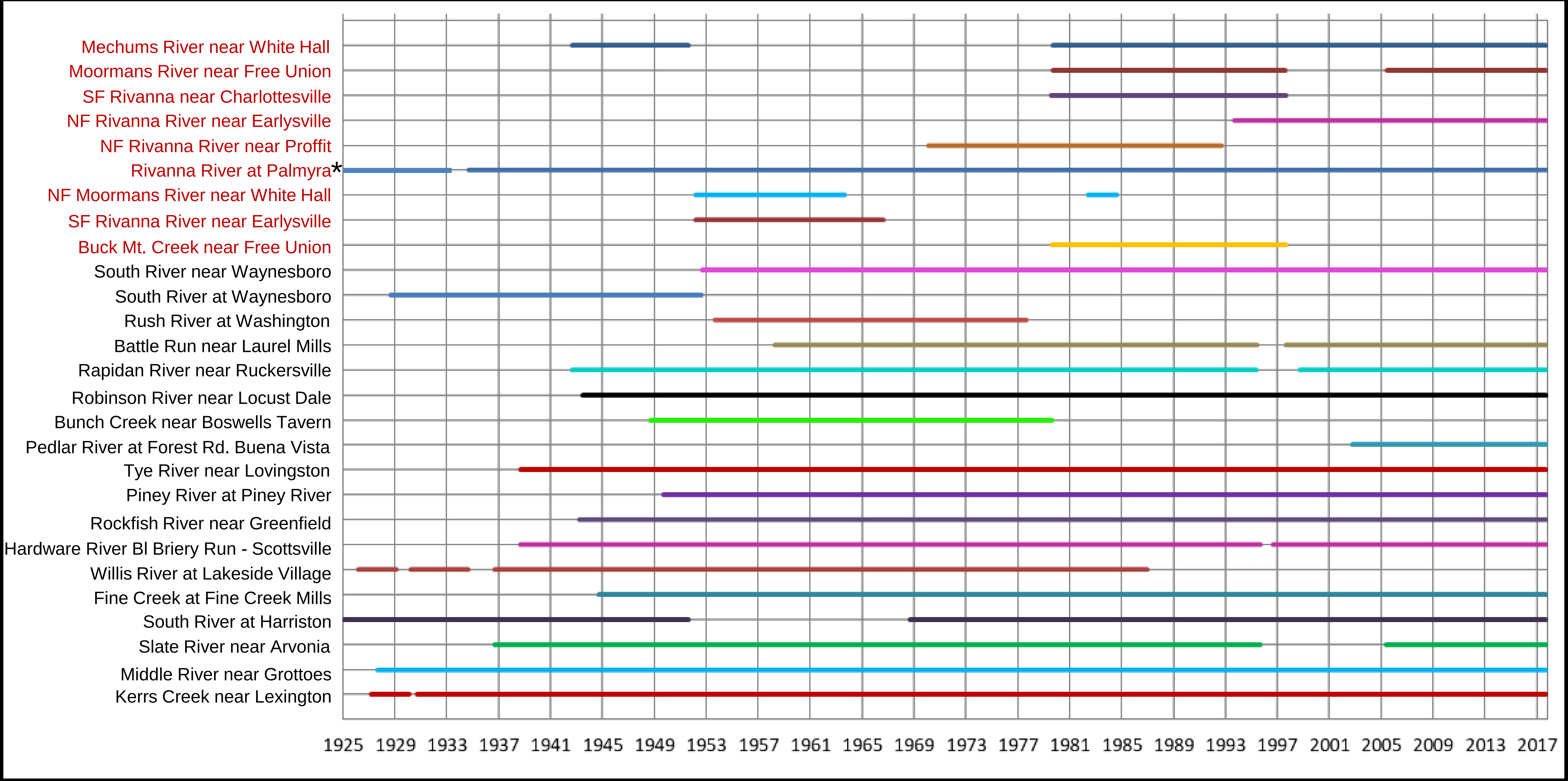
- Discharges do not include spill
- Historic withdrawal and reservoir elevation data available from 2001-2002.
- Daily Ragged Mt. production and discharge data only available for two years (2015-16). For verification, assume minimum release requirement prior to this.

Available Gages

Gage Number	Name	DA (sq. mi.)	Remarks
02031000	Mechums River Near White Hall, VA	95.3	
02032250	Moormans River Near Free Union, VA	77	Regulated by SF Rivanna reservoir
02032515	SF Rivanna River Near Charlottesville, VA	259	Regulated by SF Rivanna reservoir
02032640	NF Rivanna River Near Earlysville, VA	108	
02032680	NF Rivanna River Near Proffit, VA	174	
02034000	Rivanna River At Palmyra, VA	663	Some diurnal fluctuation at times mostly at low and medium flow caused by South Fork Rivanna River Reservoir, diversions and discharge upstream at Charlottesville.
02033500	Rivanna Riv bl Moors Cr nr Charlottesville, VA	503	Scale up this record to Palmyra D.A. and combine with that record
02031500	NF Moormans River near White Hall, VA	11.2	
02032500	SF Rivanna River Near Earlysville, VA	215	Regulated by Sugar Hollow, Beaver Creek, and Lake Albemarle
02032400	Buck Mountain Creek near Free Union, VA	34.5	
01626000	South River Near Waynesboro, VA	127	Diversion from Coles Run Reservoir u/s, capacity 80 MG., by Augusta County Service Authority. There is discharge from a WWTP upstream from station, originating from well fields. Slightly regulated by flood-detention reservoirs.
01626500	South River At Waynesboro, VA	133	
01662500	Rush River At Washington, VA	14.6	
01662800	Battle Run Near Laurel Mills, VA	25.8	At times, unknown amount of diversion for irrigation upstream from gage.
01665500	Rapidan River Near Ruckersville, VA	115	Diversion 0.4 mi upstream from station since 1973.
01666500	Robinson River Near Locust Dale, VA	179	
01671500	Bunch Creek Near Boswells Tavern, VA	4.34	
02024915	Pedlar River At Forest Road Near Buena Vista, VA	27.1	
02027000	Tye River Near Lovingston, VA	93	
02027500	Piney River At Piney River, VA	47.7	Periodic dewatering of upstream quarries adds small amount of inflow at times.
02028500	Rockfish River Near Greenfield, VA	94.8	
02030000	Hardware River Bl Briery Run Nr Scottsville, VA	116	
02034500	Willis River At Lakeside Village, VA	262	
02036500	Fine Creek At Fine Creek Mills, VA	22.4	
01627500	South River at Harriston, VA	212	Discharges from industrial and municipal wastewater treatment plants upstream from station, originating from well fields.
02030500	Slate River near Arvonia, VA	226	
01625000	Middle River near Grottoes, VA	373	Discharges of ~6.0 ft^3/s from WWTP's upstream (mostly diverted from another basin for industrial and municipal supply). Small diurnal fluctuation at low flow caused by mills and irrigation.
02022500	Kerrs Creek near Lexington, VA	35.1	

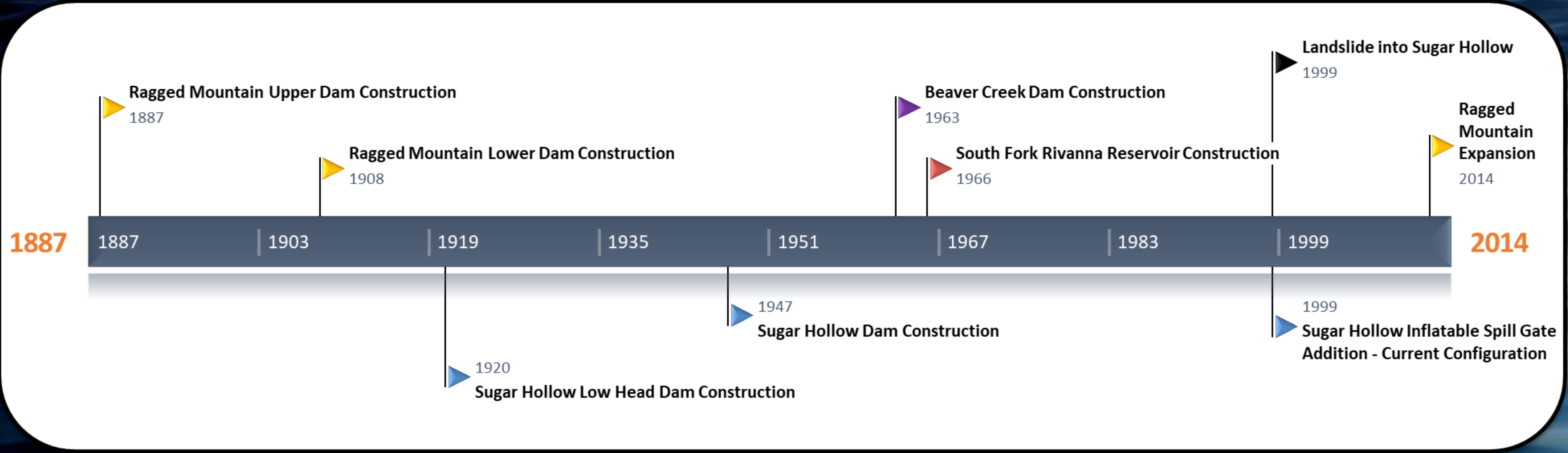
-Gages in red are those in basin, although they may no longer be active
-Only using gages with records ≥ 10 years

Gage Timeline



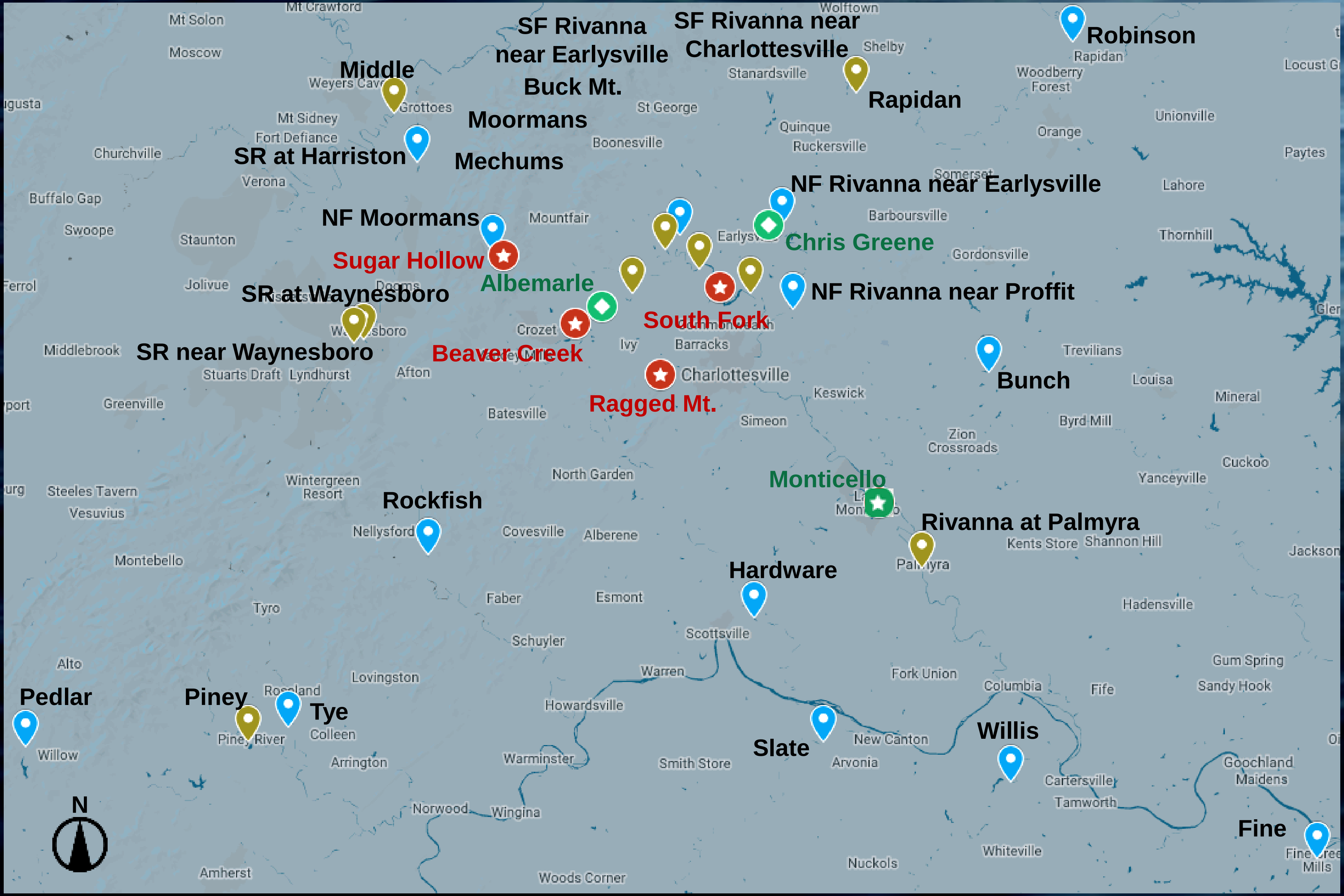
* Prior to 1934 use the Rivanna bl Moores Cr gage scaled up to Palmyra drainage area

Reservoir Timeline



HYDROLOGICS

All Gages

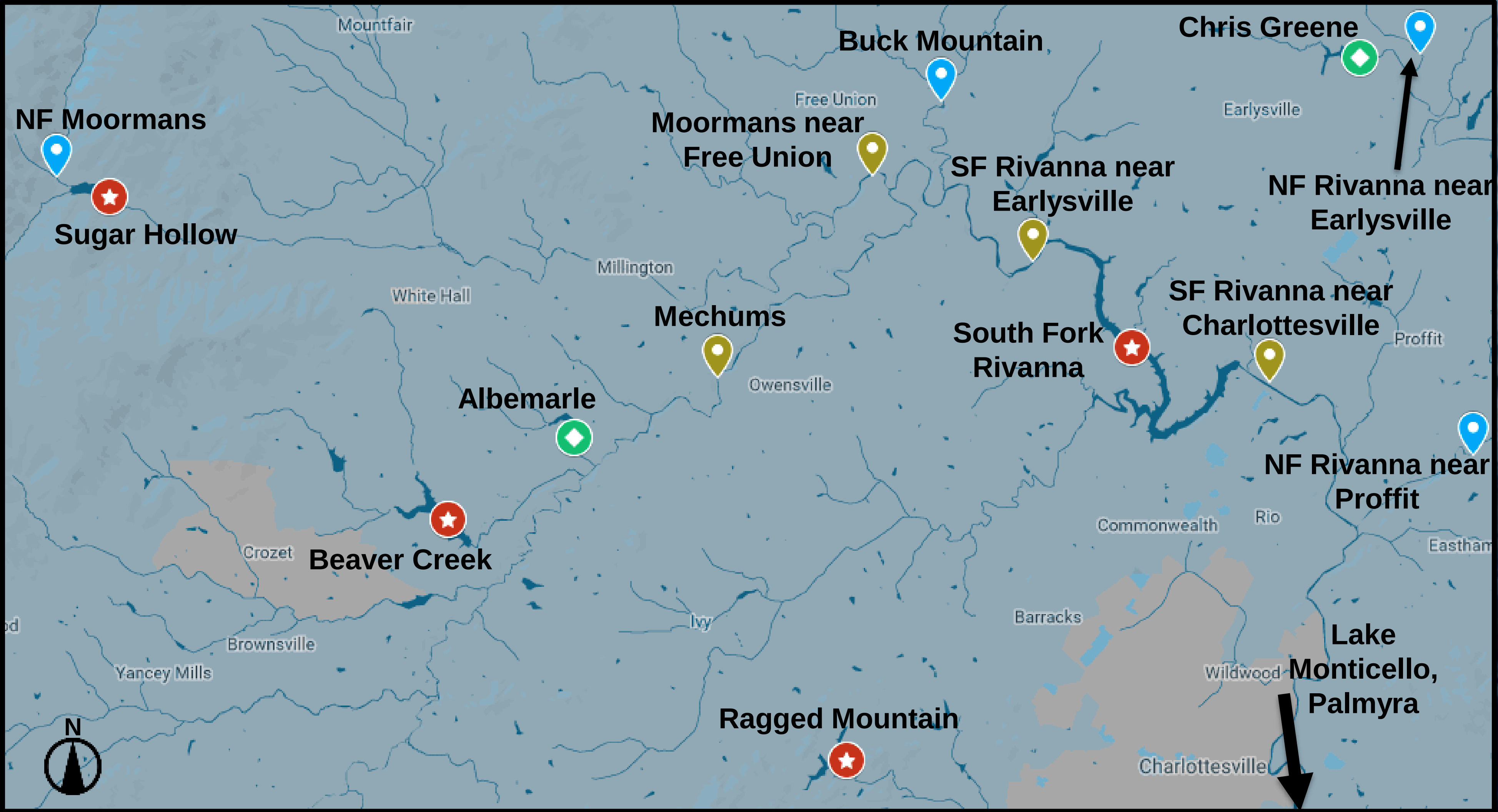


Legend

- Reservoirs
- Other Lakes
- Unimpaired Gages
- Impaired Gages

HYDROLOGICS

Basin Gages



Mountfair
Buck Mountain
Chris Greene
Free Union
Earlysville
NF Moormans
Moormans near
Free Union
SF Rivanna near
Earlysville
NF Rivanna near
Earlysville
Sugar Hollow
Millington
White Hall
SF Rivanna near
Charlottesville
Mechums
South Fork
Rivanna
Proffit
Owensville
Albemarle
NF Rivanna near
Proffit
Rio
Commonwealth
Crozet
Beaver Creek
Eastham
Barracks
Ivy
Brownsville
Lake
Monticello,
Palmyra
Yancey Mills
Wildwood
Ragged Mountain
N
Charlottesville

Legend
Reservoirs
Other Lakes
Unimpaired
Gages
Impaired Gages

Drainage Areas

	Sugar Hollow	South Fork	Ragged Mt.	Beaver Creek	Lake Albemarle	Chris Greene
Total Watershed Area (mi^2)	17.51	259.1	1.81	9.55	3.60	5.75
Surface Area of Full Pool (mi^2)	0.08	0.57	0.11	0.16	0.06	0.08
Effective Watershed Area (mi^2)	17.43	258.53	1.70	9.39	3.54	5.67

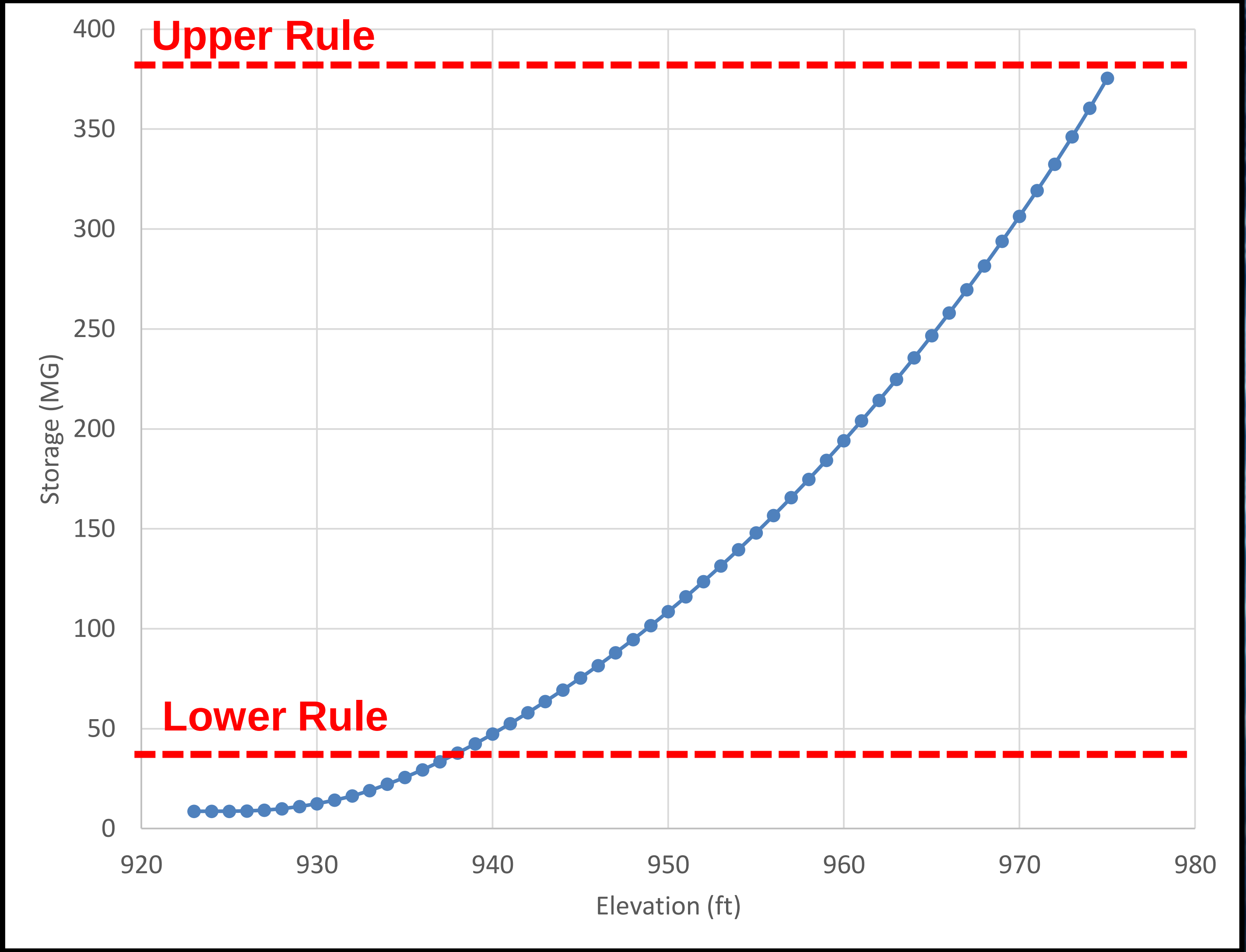
From Gannett Fleming safe yield reports

Bathymetry

- Use to convert elevation to storage and area
- No spill rating curves used (except for Beaver Creek and South Fork)
  - Not flood control reservoirs
  - South Fork storage estimated between 383 ft and 400 ft.
- Stage-Storage data source for Urban Reservoirs:
  - “Yearly Report 12-2017 revised 12 22 2017.xlsx”
- Reservoir area data sources:
  - “StageStorageTable_HDR_2009Survey(2002_Limits)_formated_SOUTH FORK SAE.xlsx”
  - “SH Reservoir_Volumes_Final_Corrected - 05-06-16.xlsx”
  - “FINAL NRMD - Revised Storage Table - 10-13-16.pdf”

Sugar Hollow Reservoir

- **Upper Rule (Max Storage):** 375 MG (975 ft.)
- **Lower Rule (Dead Storage):** 36 MG (938 ft.)
- **Useable Storage:** 339 MG (90%)
- **Drainage Area (at dam):** 17.51 sq. miles

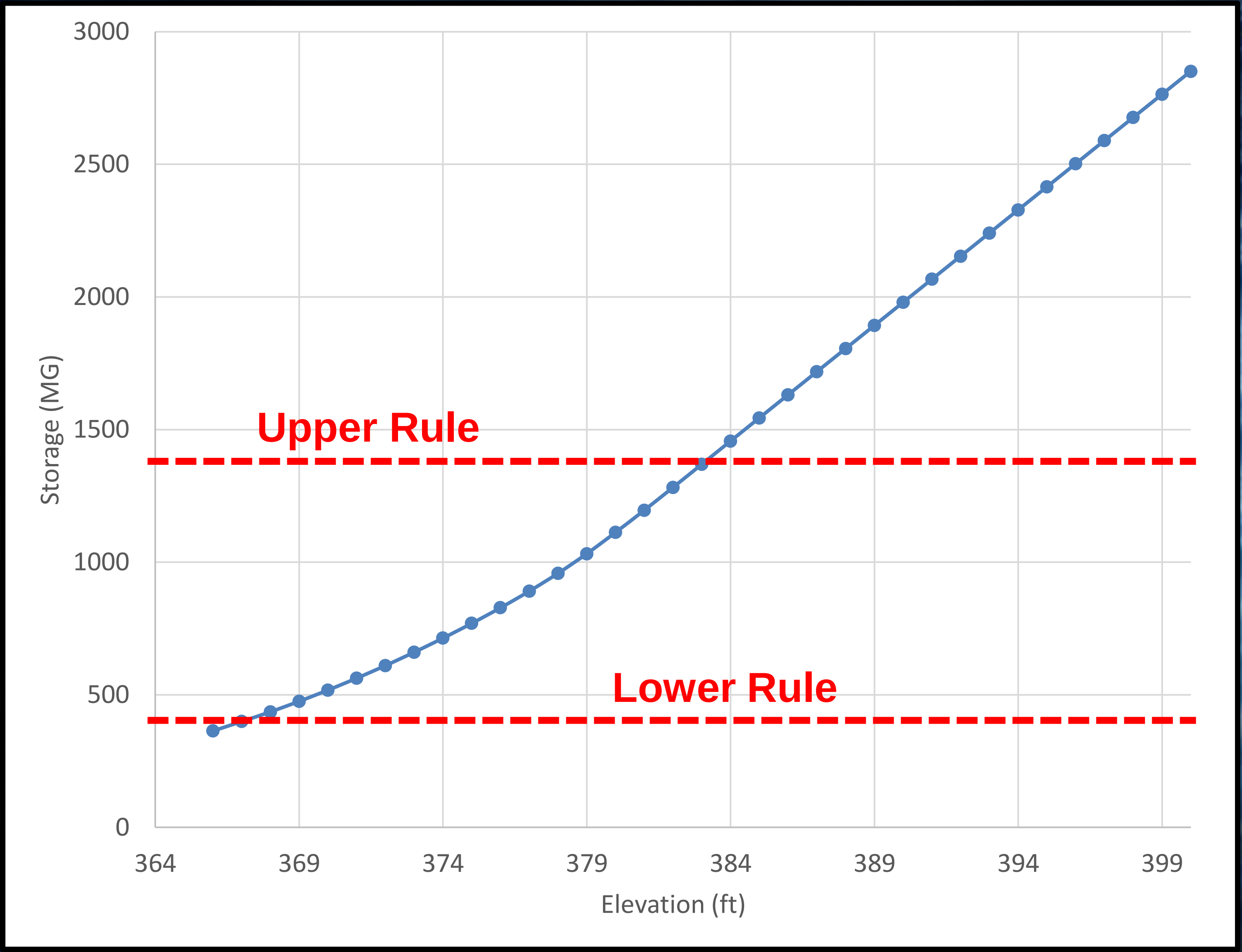


- Data based on 2015 bathymetry.
- SAE table limited to 975 feet.

HYDROLOGICS

South Fork Rivanna Reservoir

- **Upper Rule (Max Storage):** 1282 MG (382 ft.)
- **Lower Rule (Dead Storage):** 400 MG (367 ft.)
- **Useable Storage:** 882 MG (69%)
- **Drainage Area at Dam:** 259.10 sq. miles

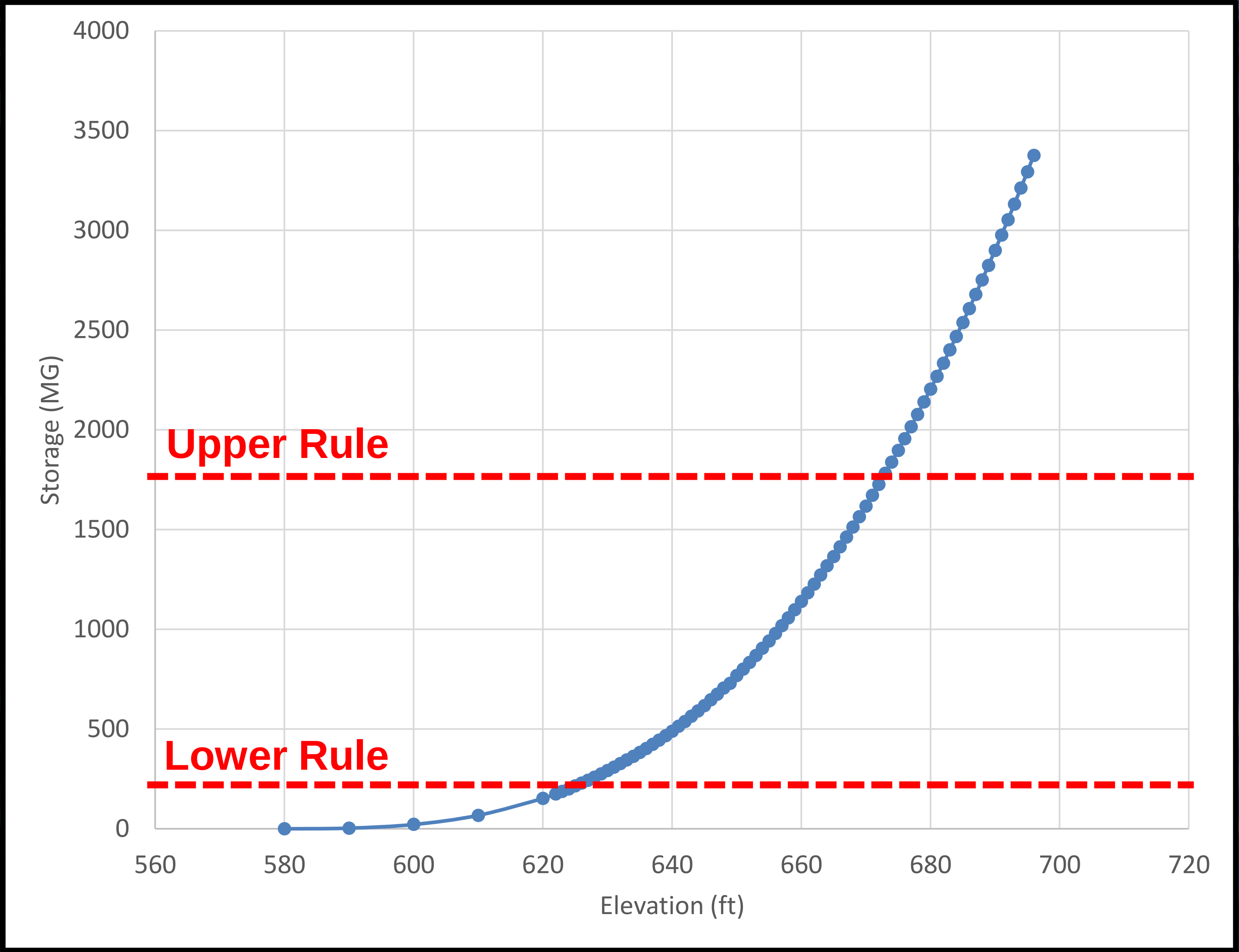


- Data based on 2009 bathymetry.
- SAE table from HDR limited to 383 feet. Storage extrapolated above 383 feet based on the change in storage from 382-383 feet.

HYDROLOGICS

Ragged Mountain Reservoir

- **Upper Rule (Max Storage):** 1671 MG (671 ft.)*
- **Lower Rule (Dead Storage):** 157 MG (621 ft.)
- **Useable Storage:** 1513 MG (91%)
- **Drainage Area at Dam:** 1.81 sq. miles



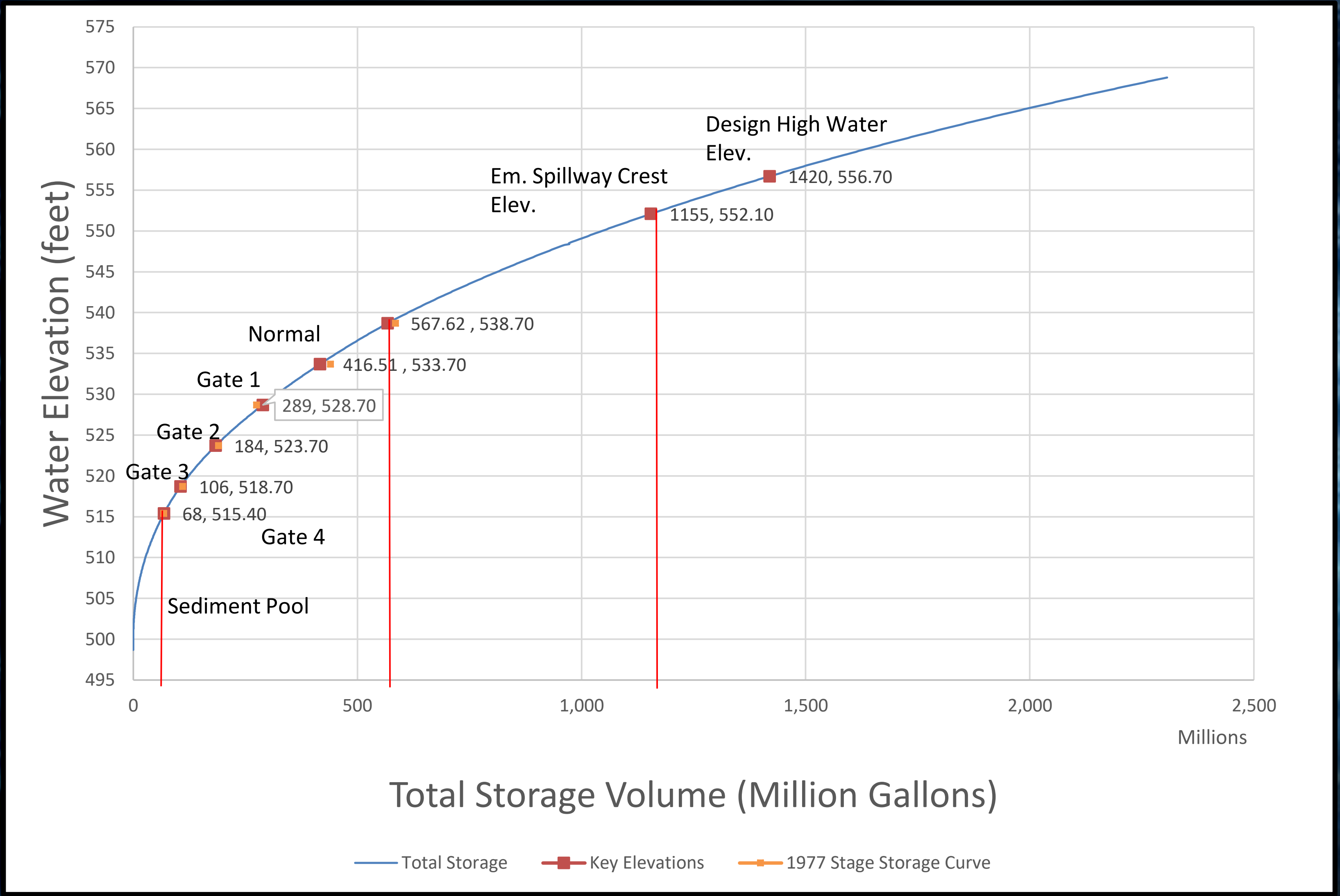
- Data based on 2016 bathymetry.
- *At intermediate fill; at full-build-out, will increase to 683 feet.

HYDROLOGICS

Beaver Creek Reservoir

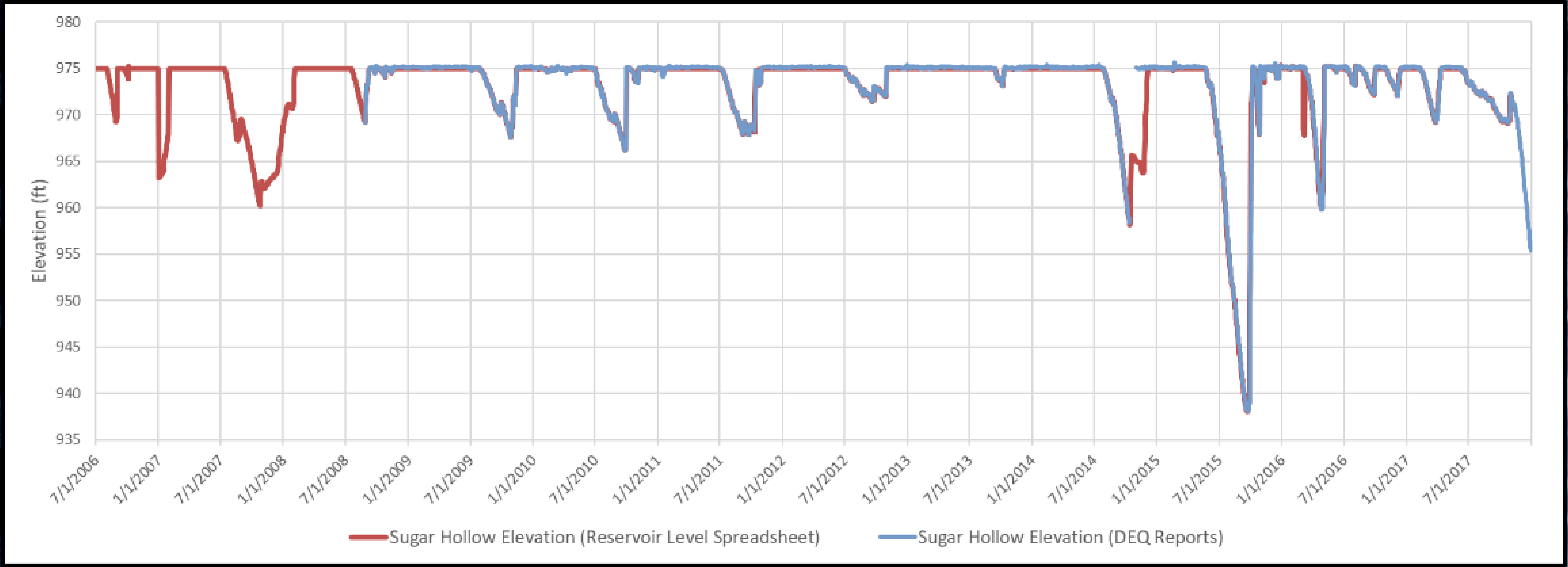
- **Upper Rule (Max Storage):** 568 MG (539 ft.)
- **Lower Rule (Dead Storage):** 68 MG (515 ft.)
- **Useable Storage:** 500 MG (88%)
- **Drainage Area:** 9.39 sq. miles

Data Source:
"BCR SAE 2017-08-01.xlsx"



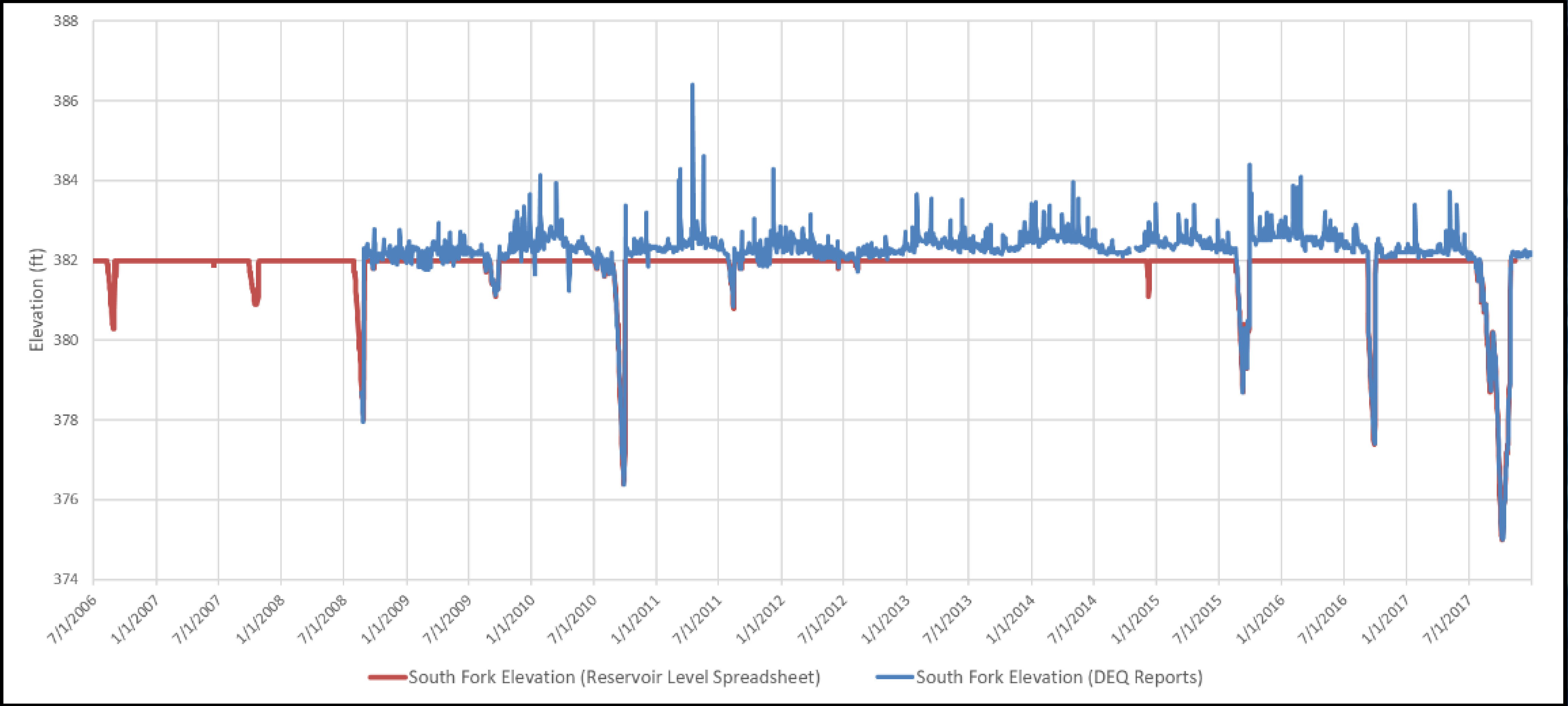
HYDROLOGICS

Sugar Hollow Reservoir



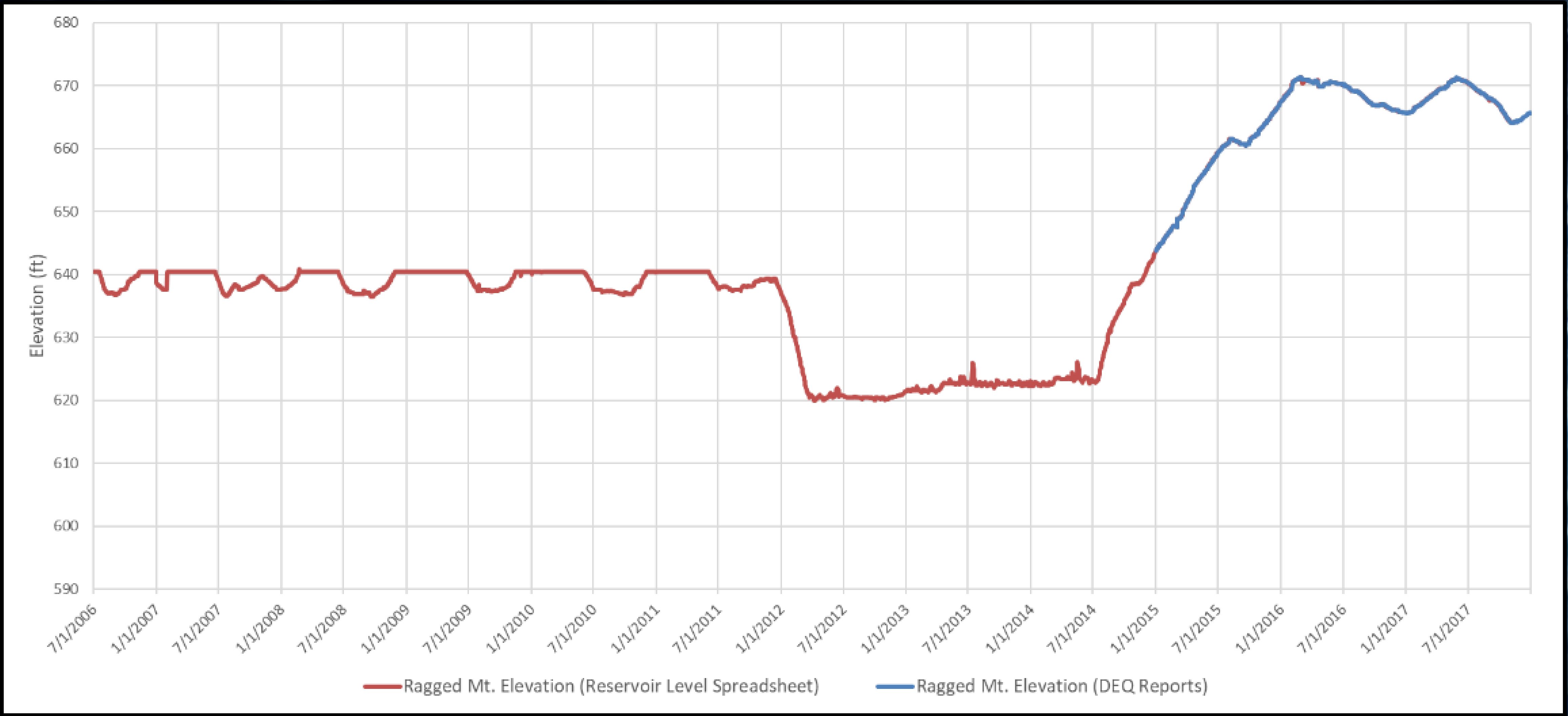
- Primary source of reservoir elevation data used by HydroLogics are the “yearly report to DEQ” spreadsheets”.
- Missing periods filled in with “Reservoir Level Spreadsheet” data from files titled “RESERVOIR LEVEL yyyy.xlsx”
- Datasets may show different values!

South Fork Rivanna Reservoir



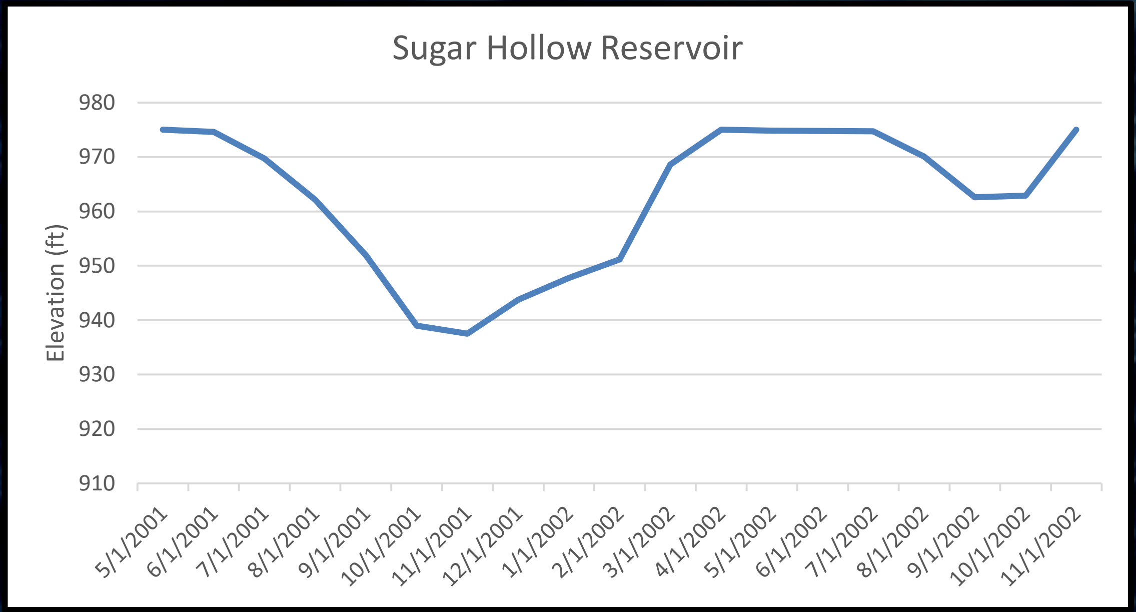
HYDROLOGICS

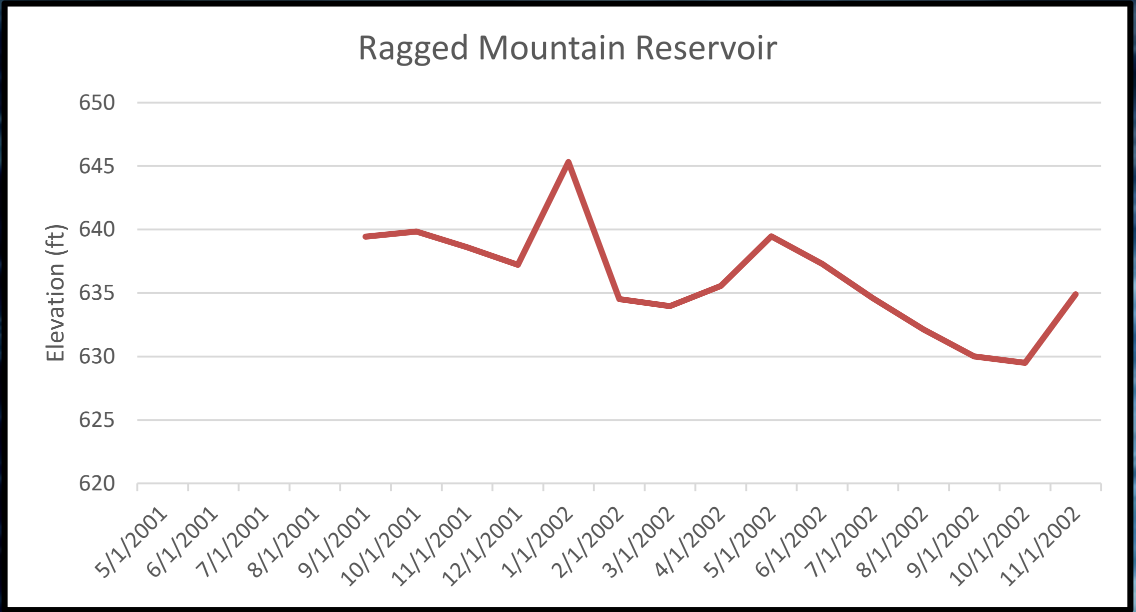
Ragged Mountain Reservoir

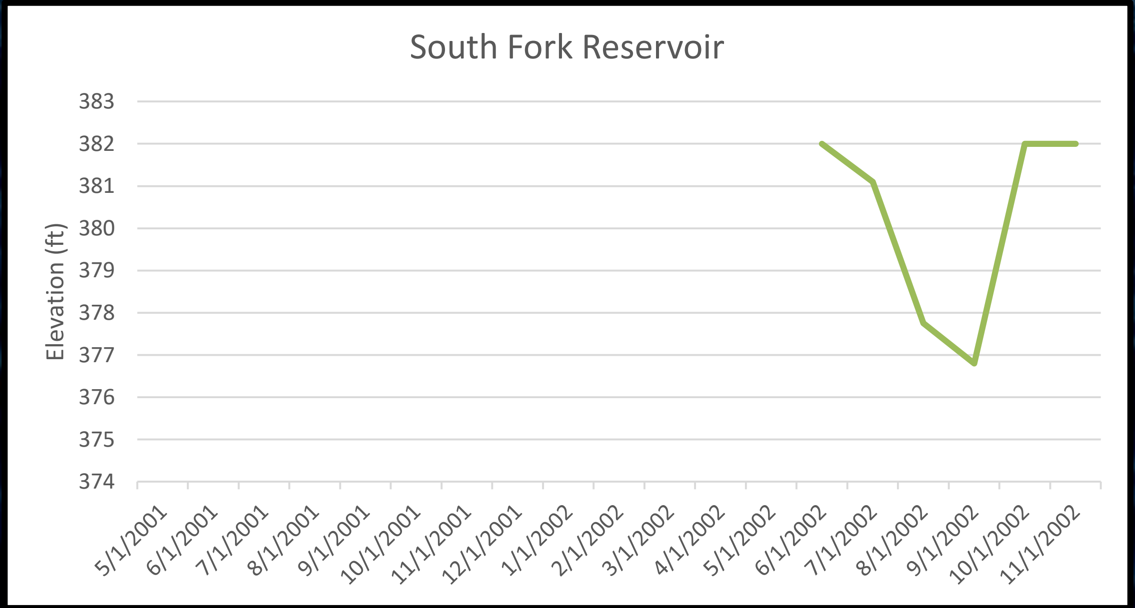


HYDROLOGICS

2001-2002 Reservoir Elevations (Monthly)

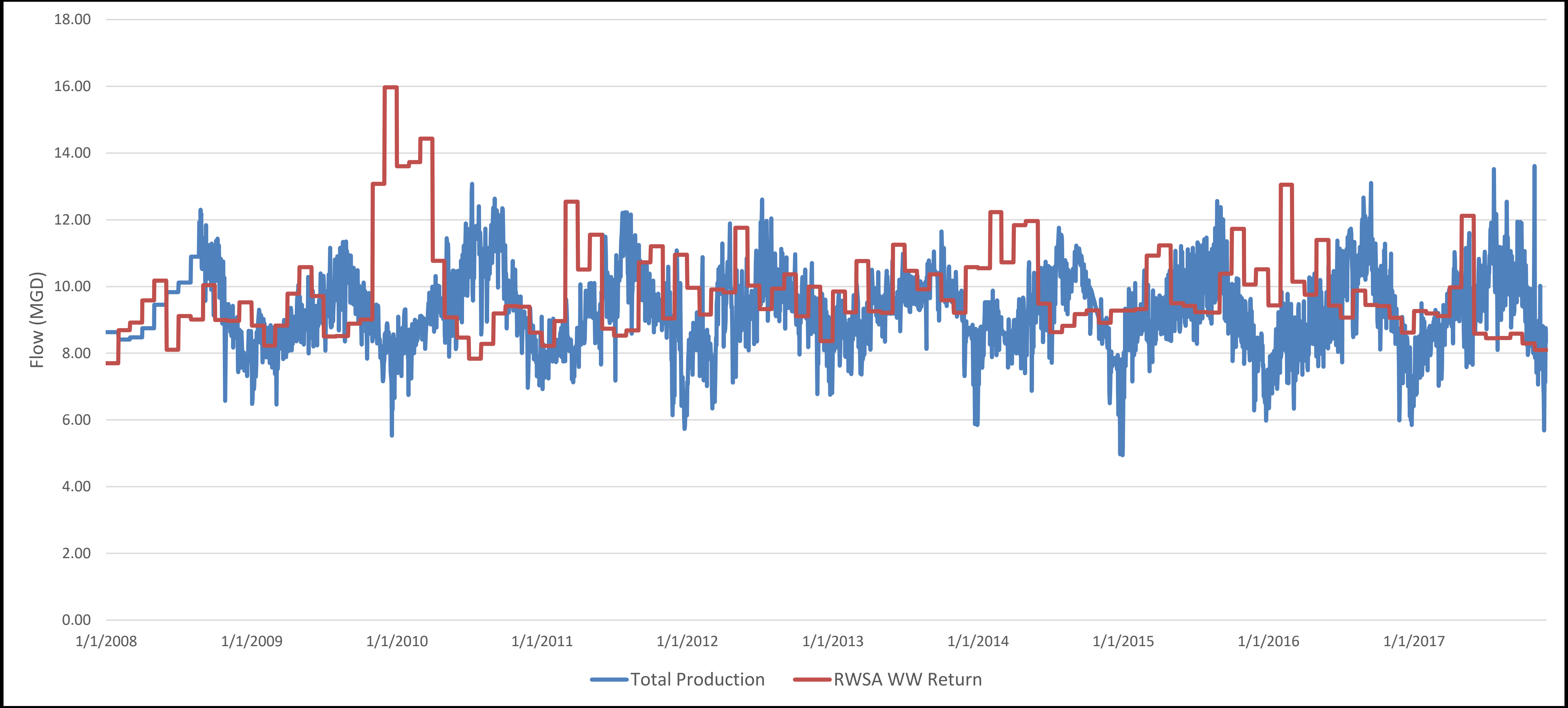






HYDROLOGICS

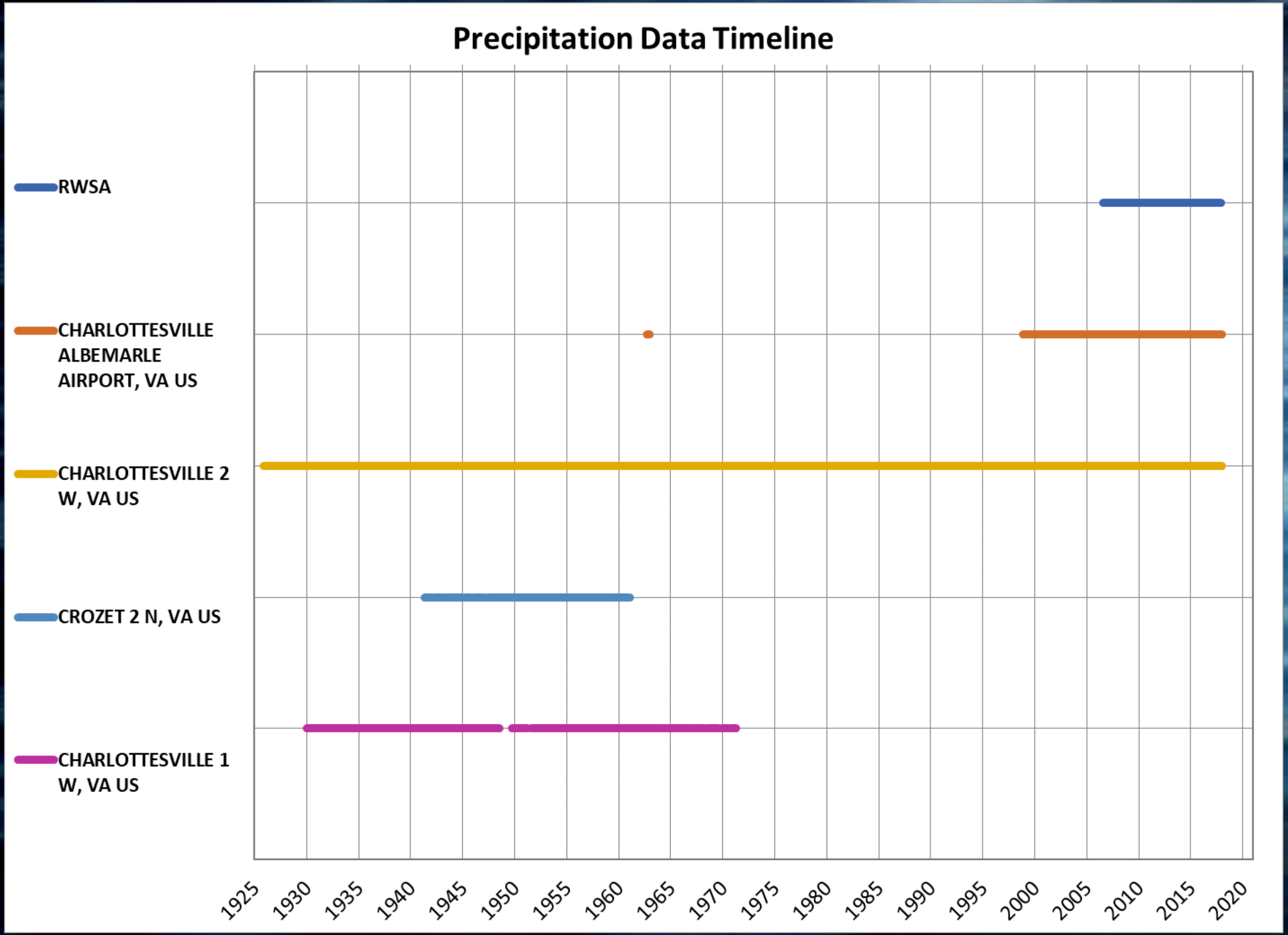
Total Production vs. WW Returns



HYDROLOGICS

Precipitation

- Used reservoir precipitation provided by RWSA when available.
- Filled in missing periods with data recorded by NOAA stations by proximity to reservoir.



HYDROLOGICS

Evaporation

Evap in/mo		Gannett Fleming
	Lake Michie (Durham, NC)	Currently Used in Model for RWSA
Jan	1.55	1.05
Feb	1.68	1.5
Mar	2.17	1.75
Apr	3.00	3.05
May	4.34	3.4
Jun	4.20	4.5
Jul	4.65	5.3
Aug	4.34	4.9
Sep	4.20	4
Oct	3.41	2.75
Nov	2.40	2
Dec	1.86	1.2

Gannett Fleming evaporation data source:
Meyer, A. F. 1942. Evaporation from Lakes and Reservoirs. Minnesota Resources Commission, St. Paul, MN. June 1942.

Lake Michie data source: https://pubs.usgs.gov/pp/0272g/report.pdf

HYDROLOGICS

Current Model Inflows

- Inflows developed by Gannett Fleming for its original safe yield modeling in early 2000s.
- Existing USGS gage flows were adjusted based on contributing drainage area and missing periods were filled in using a <u>single</u> regression equation based on period-of-record overlap.
- No monthly regressions used to capture seasonal variation.
- No verification was conducted.

Gages Used by Gannett Fleming

- Sugar Hollow
  - North Fork Moormans River near White Hall gage.
  - Missing periods were filled in with the Rockfish River near Greenfield gage.

- South Fork Rivanna
  - Used SF Rivanna near Earlysville, Moormans River near Free Union, Mechums River, and Buck Mountain Creek gages.
    - Some gages used have upstream impairments.
  - Missing periods were filled in with NF Rivanna near Proffit, Rivanna River near Charlottesville and at Palmyra, and the Slate River near Arvonia gages.

- Ragged Mountain
  - Drainage area adjustment of Sugar Hollow Reservoir inflows.

- Mechums River Pumping Station
  - Used Mechums and SF Rivanna near Earlysville.
  - Missing periods were filled in with Rivanna River near Charlottesville and at Palmyra and NF Rivanna near Proffit gages.

- Beaver Creek and Lake Albemarle
  - Drainage area adjustment of Mechums River Pumping Station inflow.

- Chris Greene
  - Drainage area adjustment of North Fork Rivanna Intake (used NF Rivanna near Earlysville and Proffit gages).

HYDROLOGICS

Sample of Gannett Fleming Methodology

- Sugar Hollow and Ragged Mt.
  - Compute monthly cfs/mi² using Rockfish River near Greenfield (94.6 mi²).
  - Transform by multiplying above to the power of 1.53 and then multiplying by 0.71.
  - Multiply by the daily variation at the Palymra gage to get daily cfsm to each reservoir, then multiply by drainage area to get daily inflow.
  - Gannett Fleming did not use Moormans River near Free Union gage when available since it is impaired.
    - The gage was reactivated around completion of their safe yield analysis, so it can be used if Sugar Hollow impairment data are available.

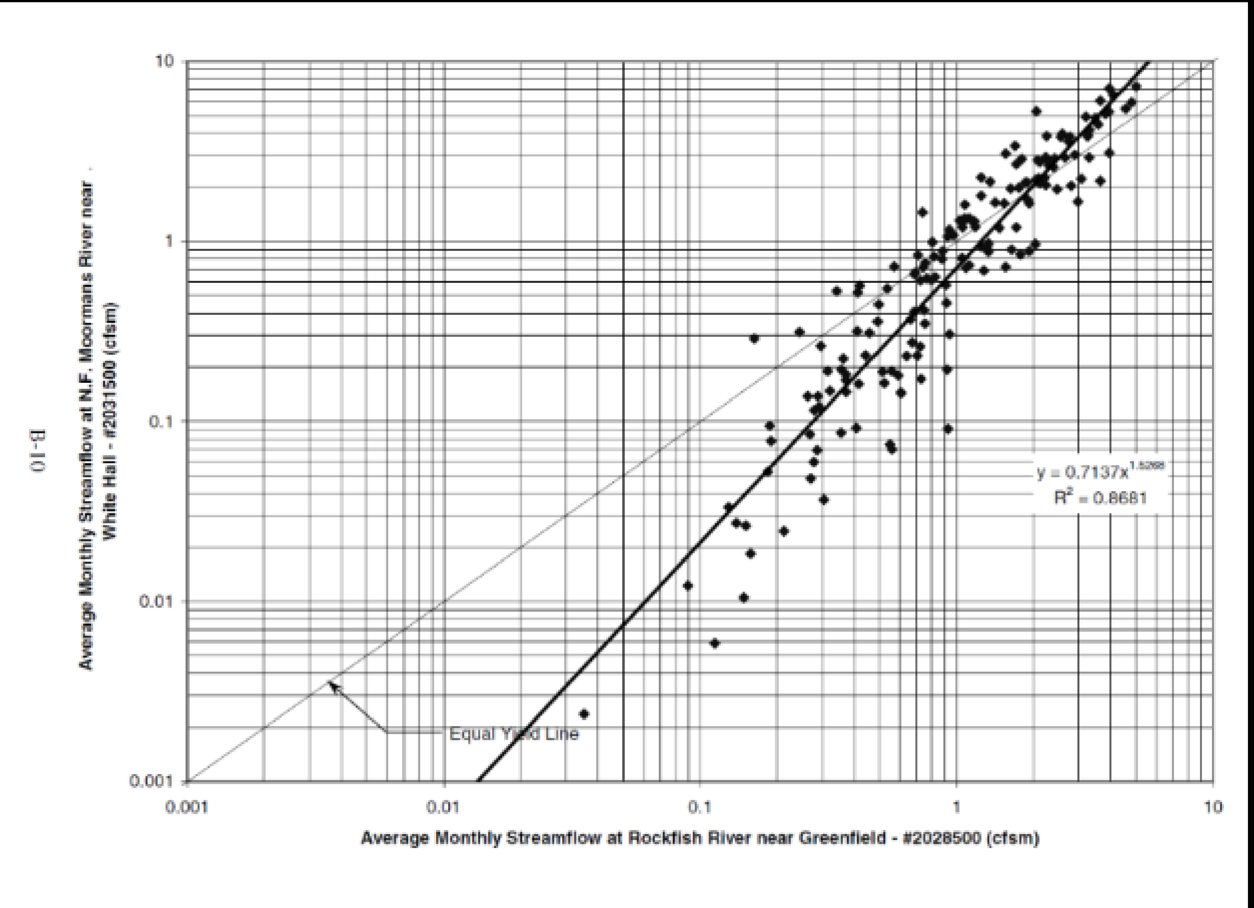


Figure B.10. Scatter Graph of Concurrent Monthly Average Flows

Inflow Verification Methodology

- 2008-2016
  - Force model to match historic releases & withdrawals from South Fork and Sugar Hollow reservoirs.
  - For South Fork, match Mechums gage flows to isolate inflow errors to gains between there, Sugar Hollow, and South Fork.
  - This run will help identify errors in the inflows to South Fork and Sugar Hollow.
  - No error assumed to be in the elevation or discharge or production data, which may not be reasonable.
    - South Fork mud gates known to leak water that is not accounted for in the discharge data

Inflow Verification Datasets

(1) Gannett Fleming (using its methodology)

(2) RWSA (to determine minimum releases since tied to "natural" inflows)

- Sugar Hollow: 0.19 * Mechums gage
- South Fork: 2.71 * Mechums gage
- Note: Mechums will be less flashy and have more baseflow than gages in steeper terrains, so it will have relatively more unit runoff during dry periods and less runoff during wet periods. A fixed adjustment will not capture this dynamic

Inflow Verification Datasets (continued)

(3) HydroLogics Methodology

Sugar Hollow:

- Unimpaired Moormans at Free Union gage (when data is available 2008-present)
  - Since spill is not measured with Sugar Hollow discharge data, need to rely on downstream gage at Free Union
  - This will also be the provisional inflow approach
- When Moormans unimpaired flows not available prior to 2008, test using NF Moormans gage or Moormans at Free Union, filled in for period of record using monthly & annual regressions with other gages
  - If they produce similar results prefer to use Free Union, due to concerns about changes in topography in North Fork Moormans watershed in the 1999 landslide

South Fork Rivanna:

- Use Moormans at Free Union unimpaired gain plus Buck Mountain flow, scaled up to the dam; fill in using monthly & annual regressions when gages not available
- For provisional inflows, can't back-calculate since spill is not measured, so scale up the unimpaired Moormans gage by drainage area = Moormans x 1.89

Ragged Mountain:

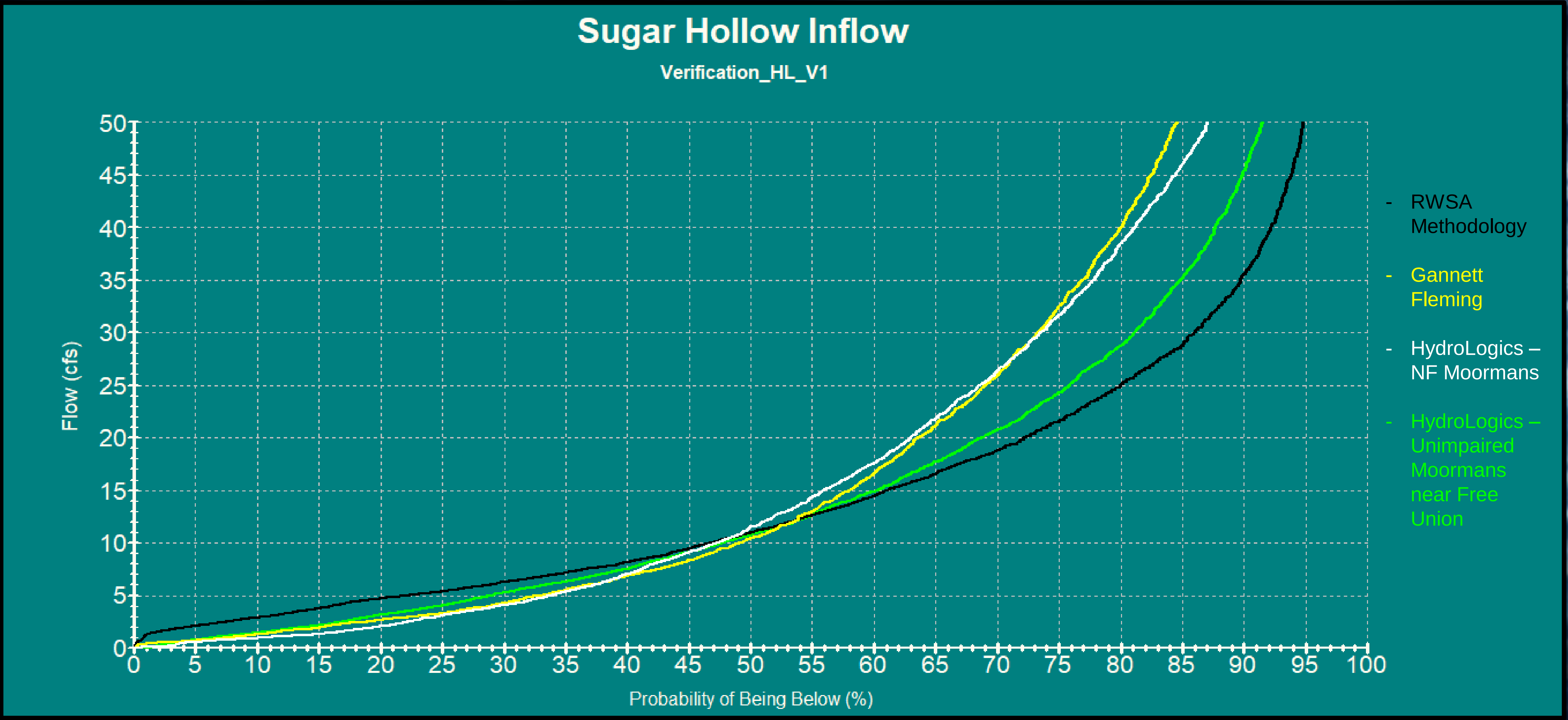
- Test drainage area adjustment of various inflow reference sites: Sugar Hollow, South Fork, Mechums, and North Fork

North Fork Intake:

- Use the two North Fork gages (Earlysville & Proffit), scaled to the intake site, and filled in for missing periods using monthly & annual regressions with other gages

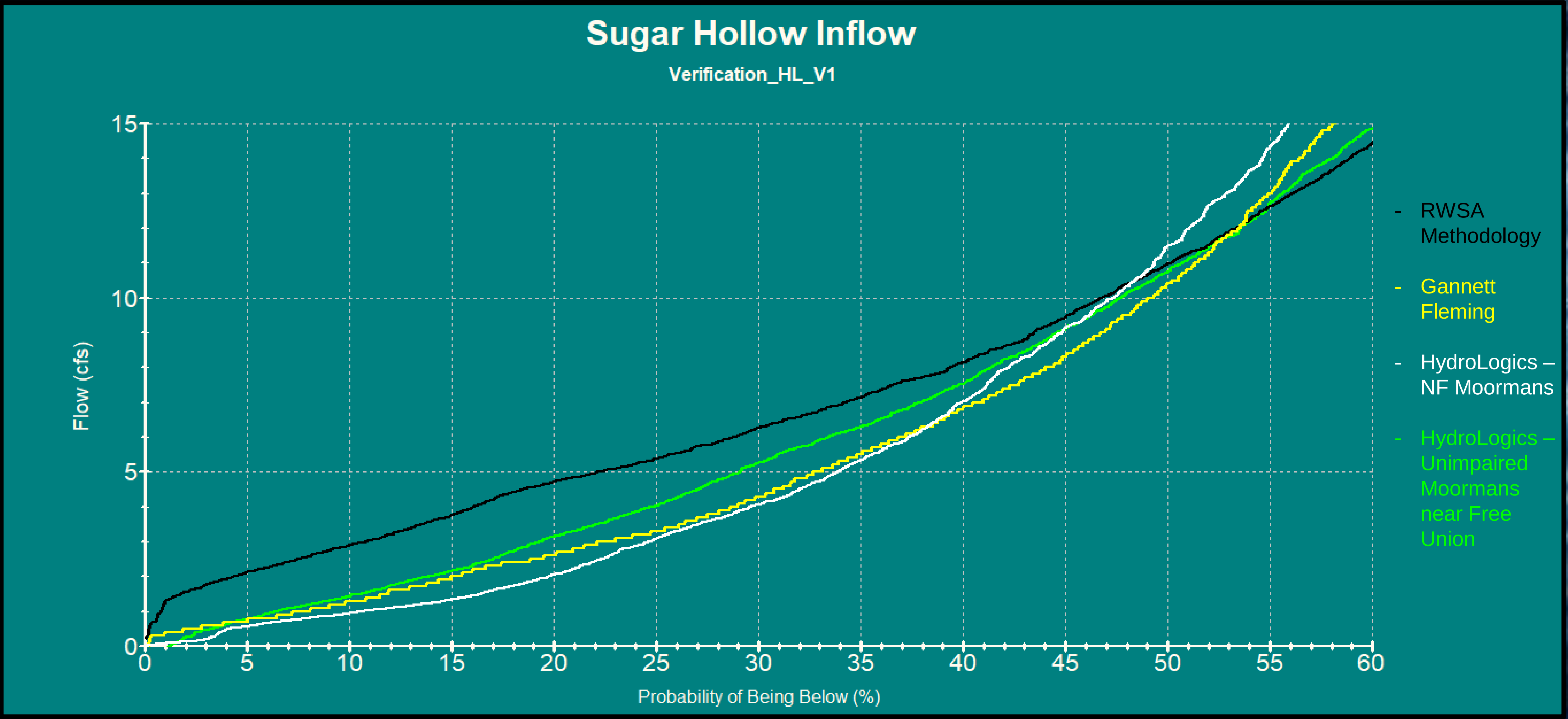
HYDROLOGICS

Sugar Hollow Inflows – 8/22/2008 – 09/30/2017

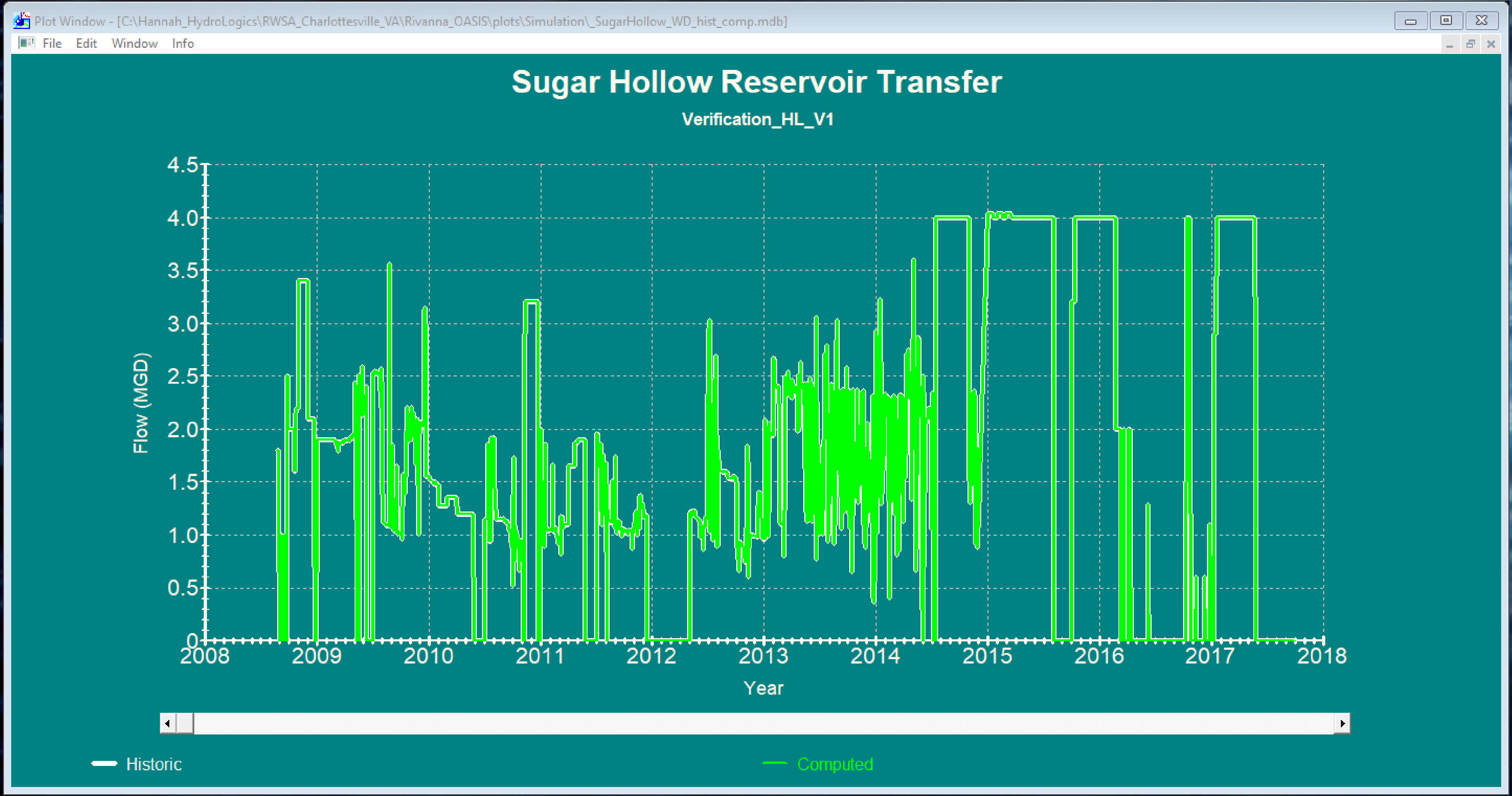


HYDROLOGICS

Sugar Hollow Inflows – 8/22/2008 – 09/30/2017

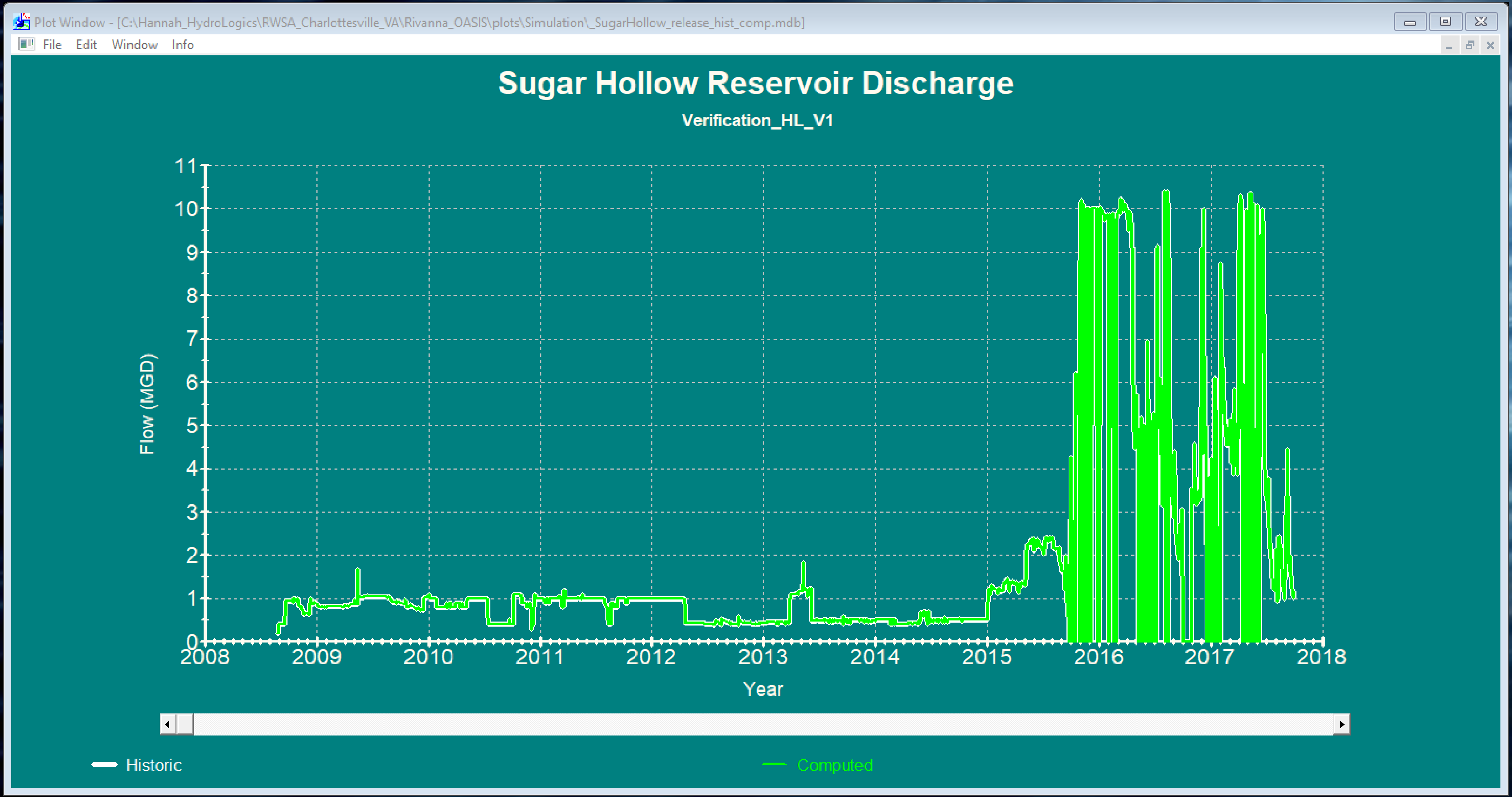


Sugar Hollow

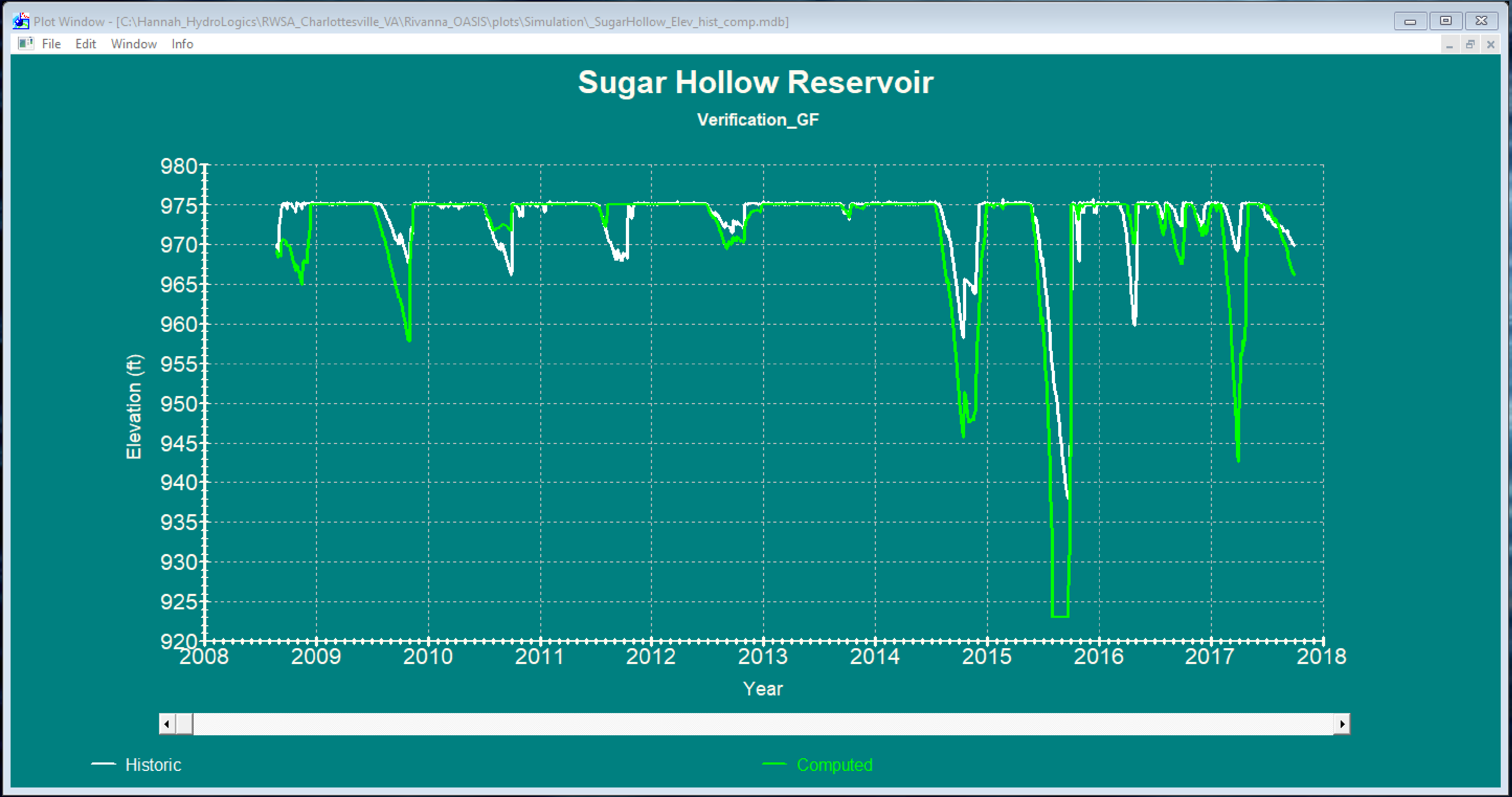


HYDROLOGICS

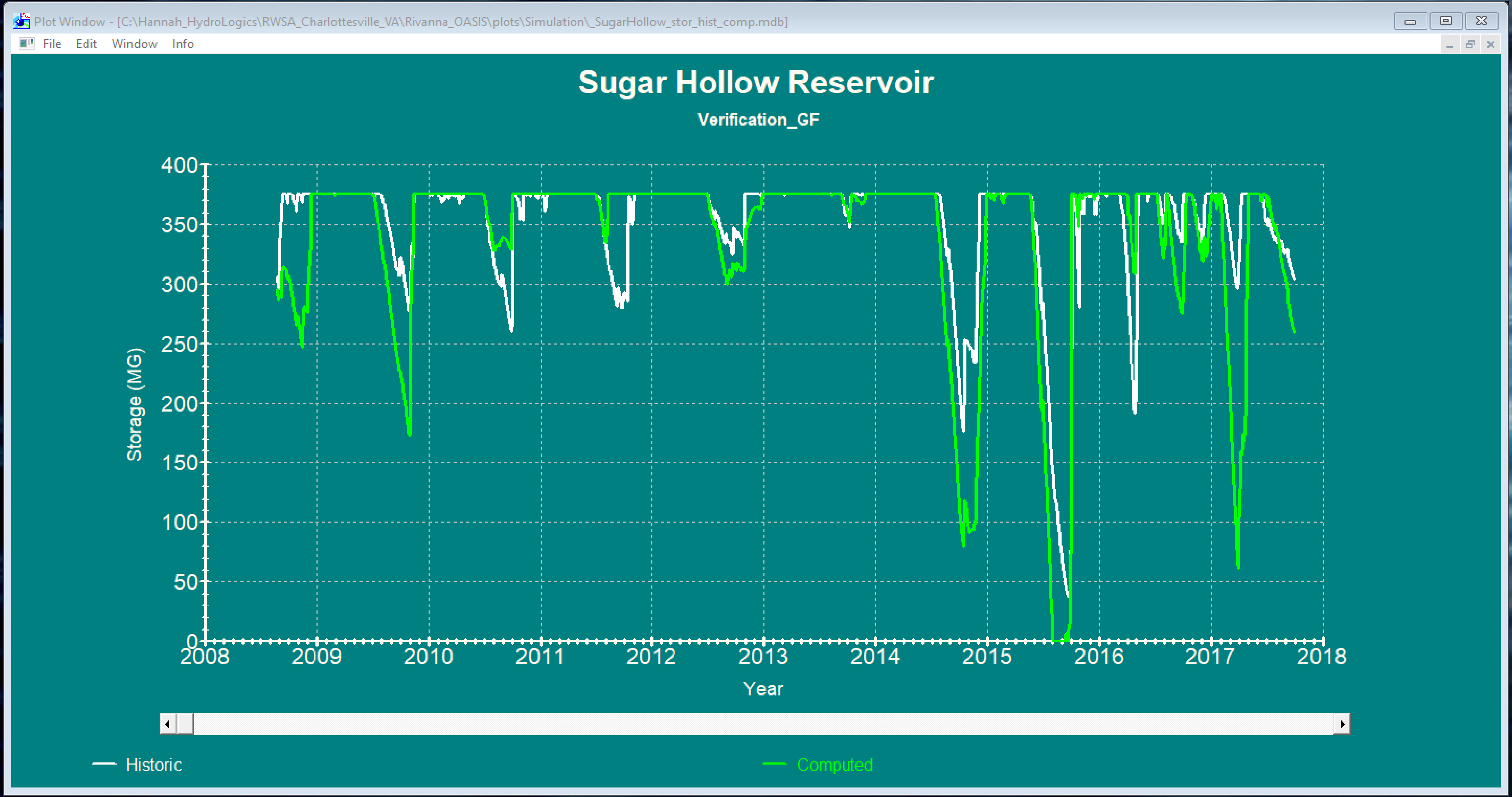
Sugar Hollow



Verification Using Gannett Fleming Inflows

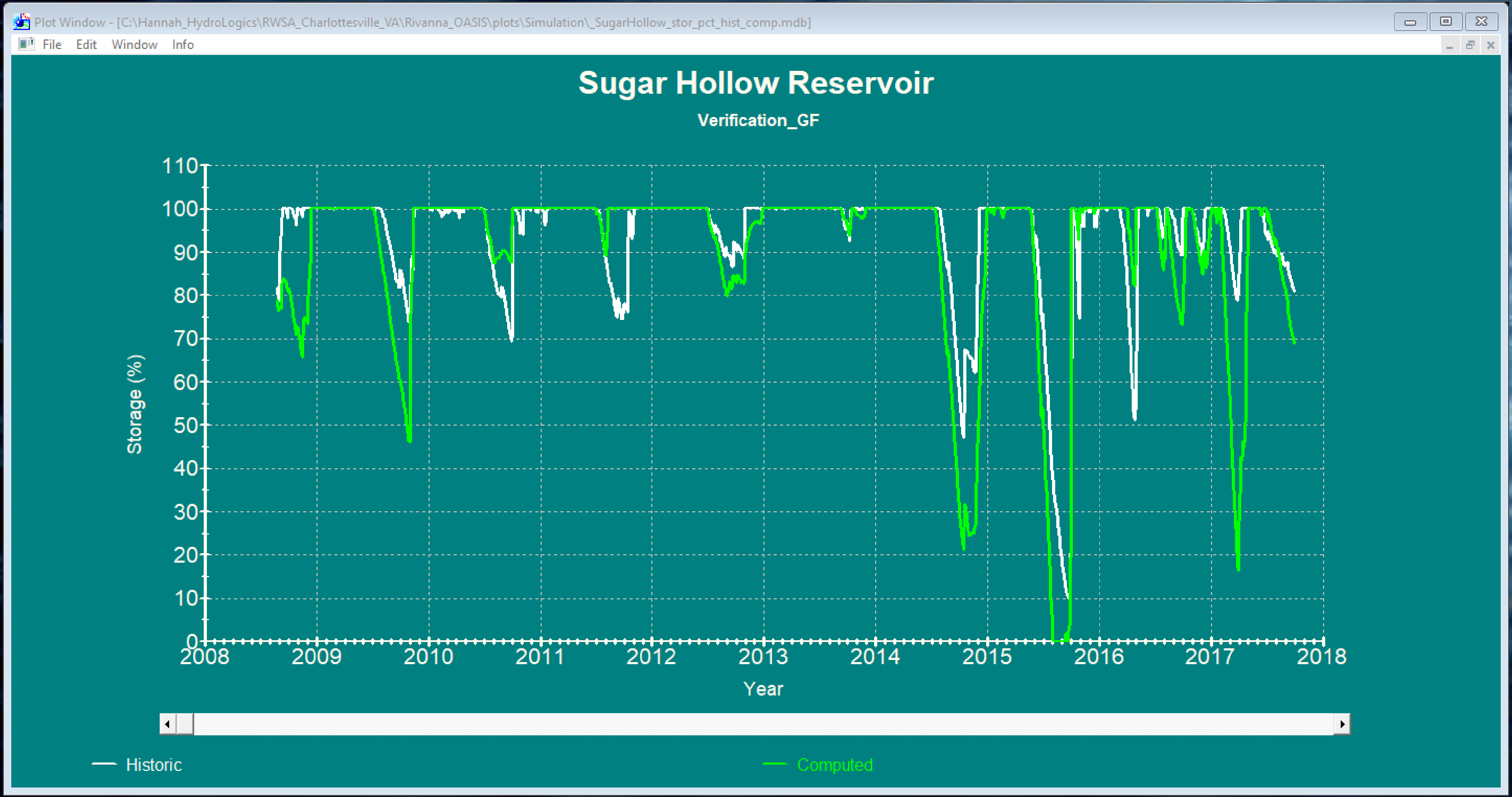


Using Gannett Fleming Inflows

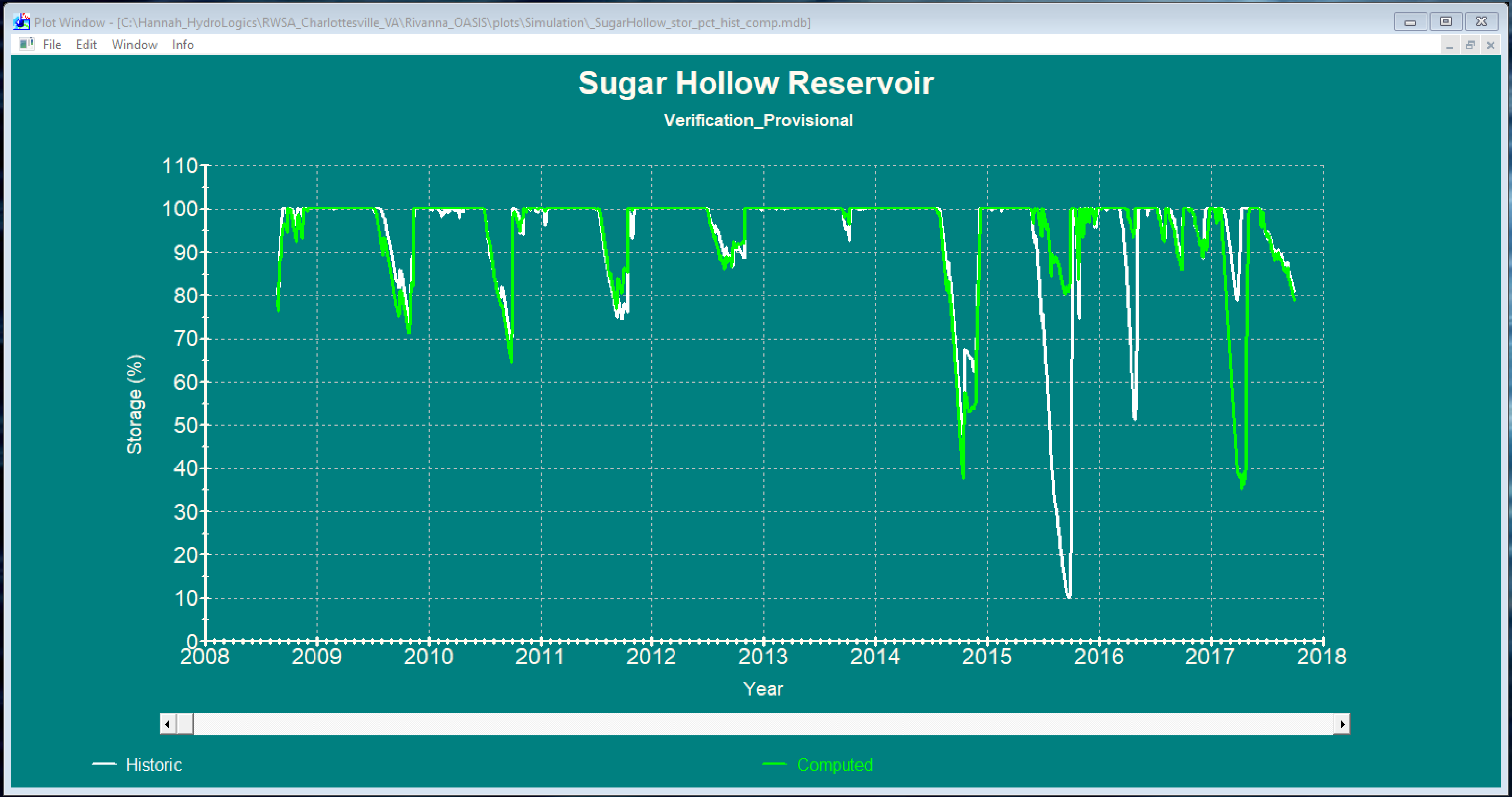


HYDROLOGICS

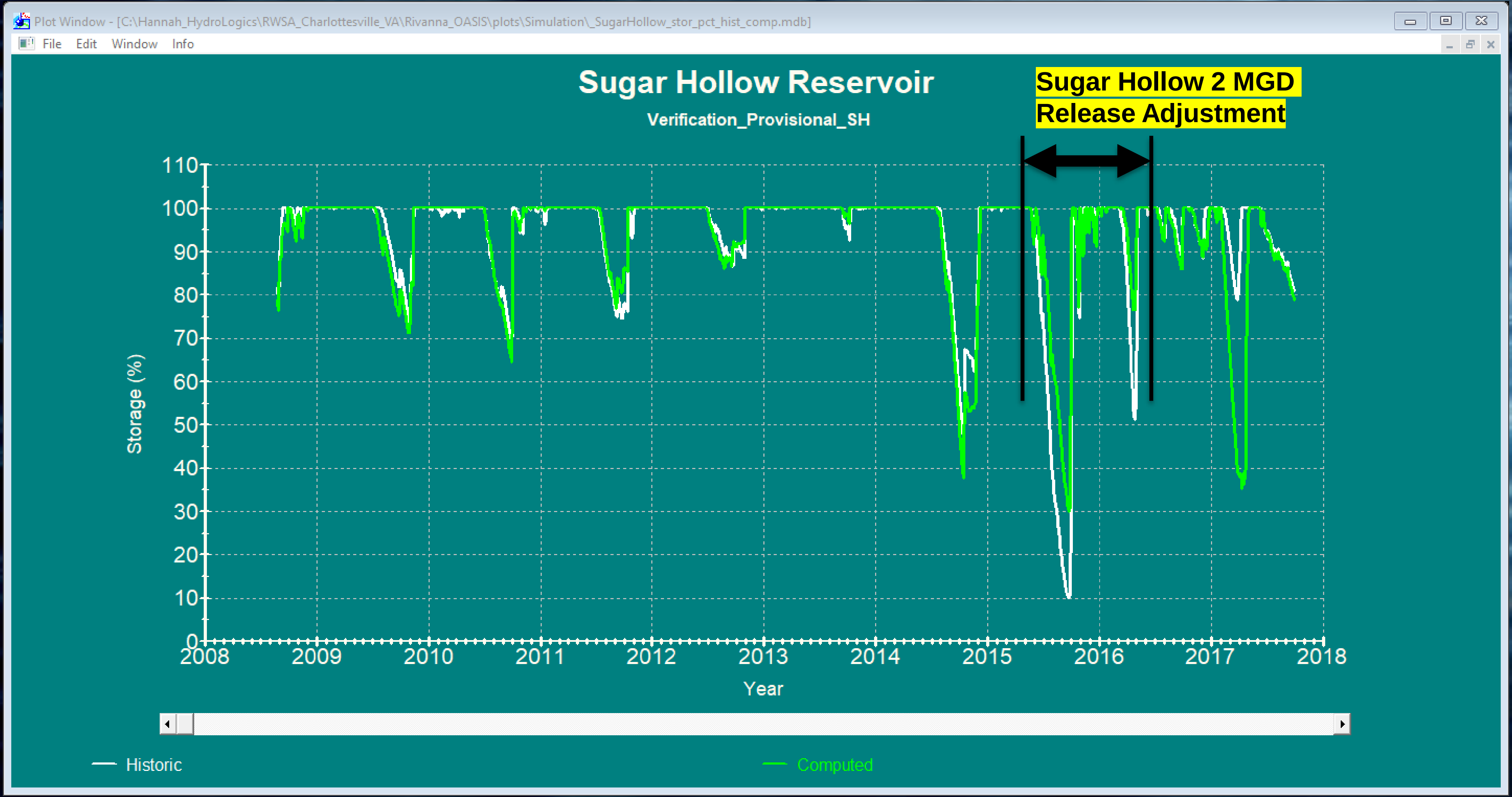
Using Gannett Fleming Inflows



HydroLogics Inflows – Moormans gage UIF, scaled

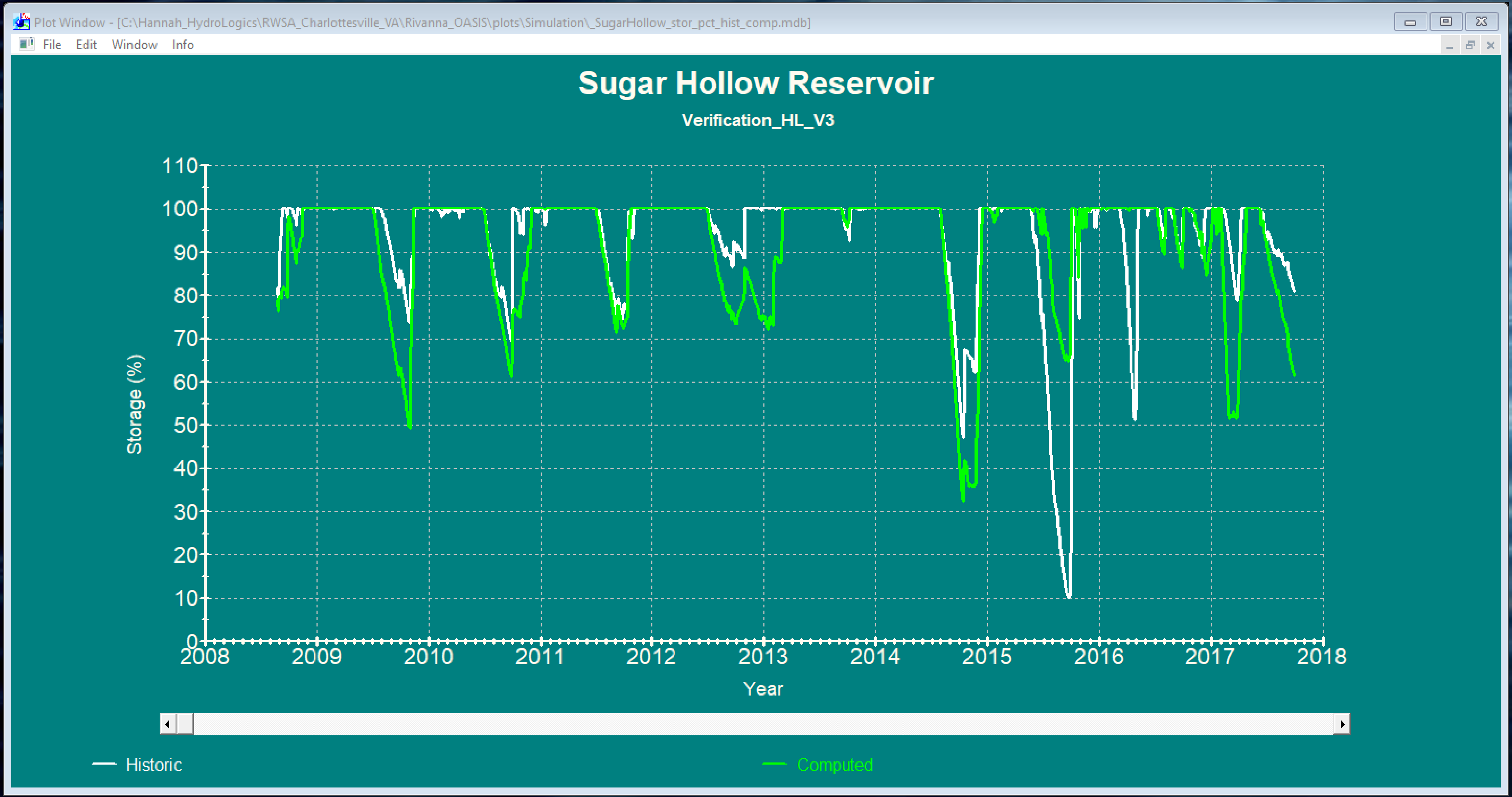


HydroLogics Inflows – Moormans gage UIF, scaled



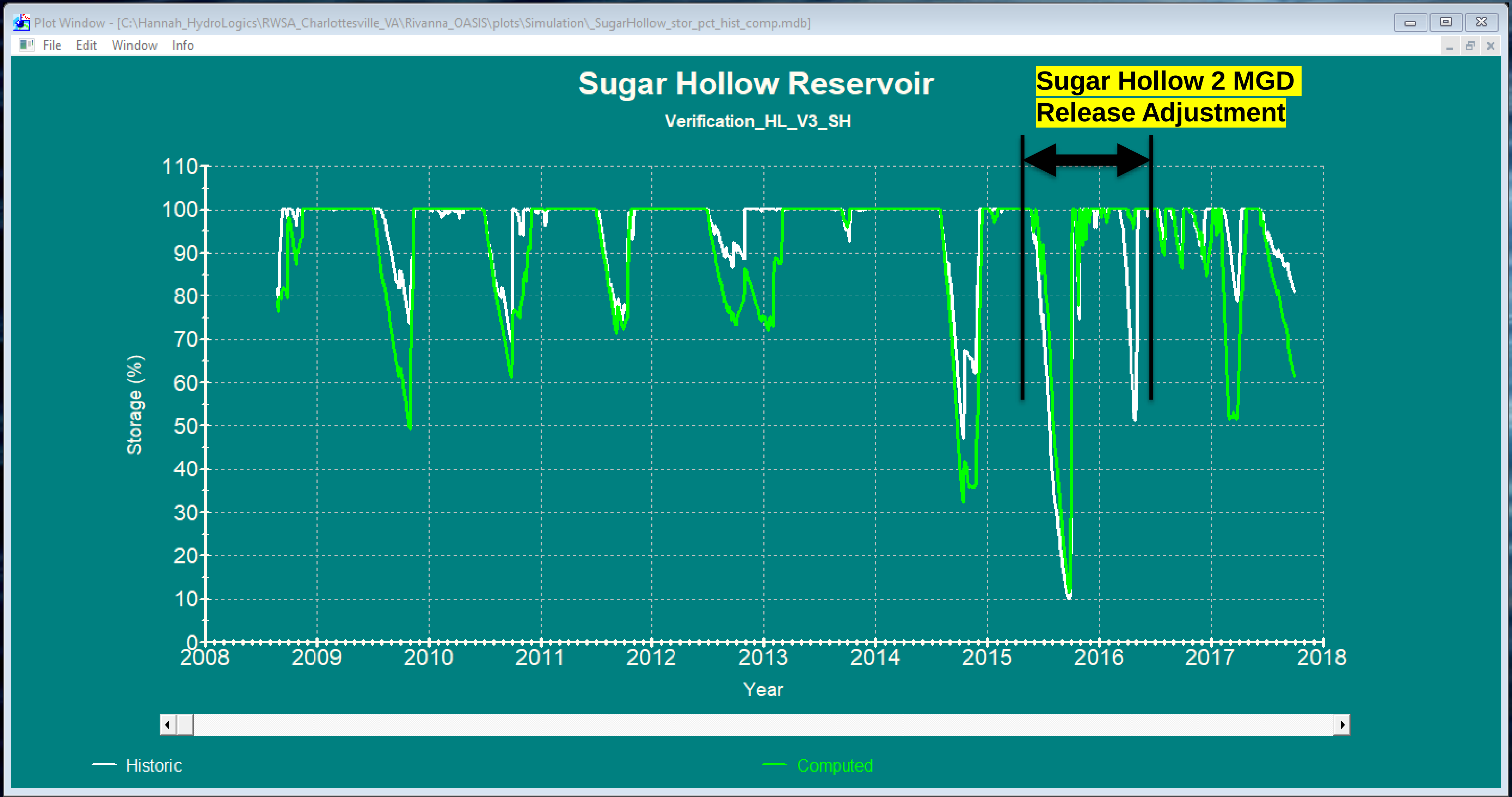
Note: Adjustment is done since study by RWSA concluded that 2015-2016 releases may have been underestimated by ~1.5 -3.5 mgd

HydroLogics Inflows – Filled-in NF Moormans gage, scaled to dam



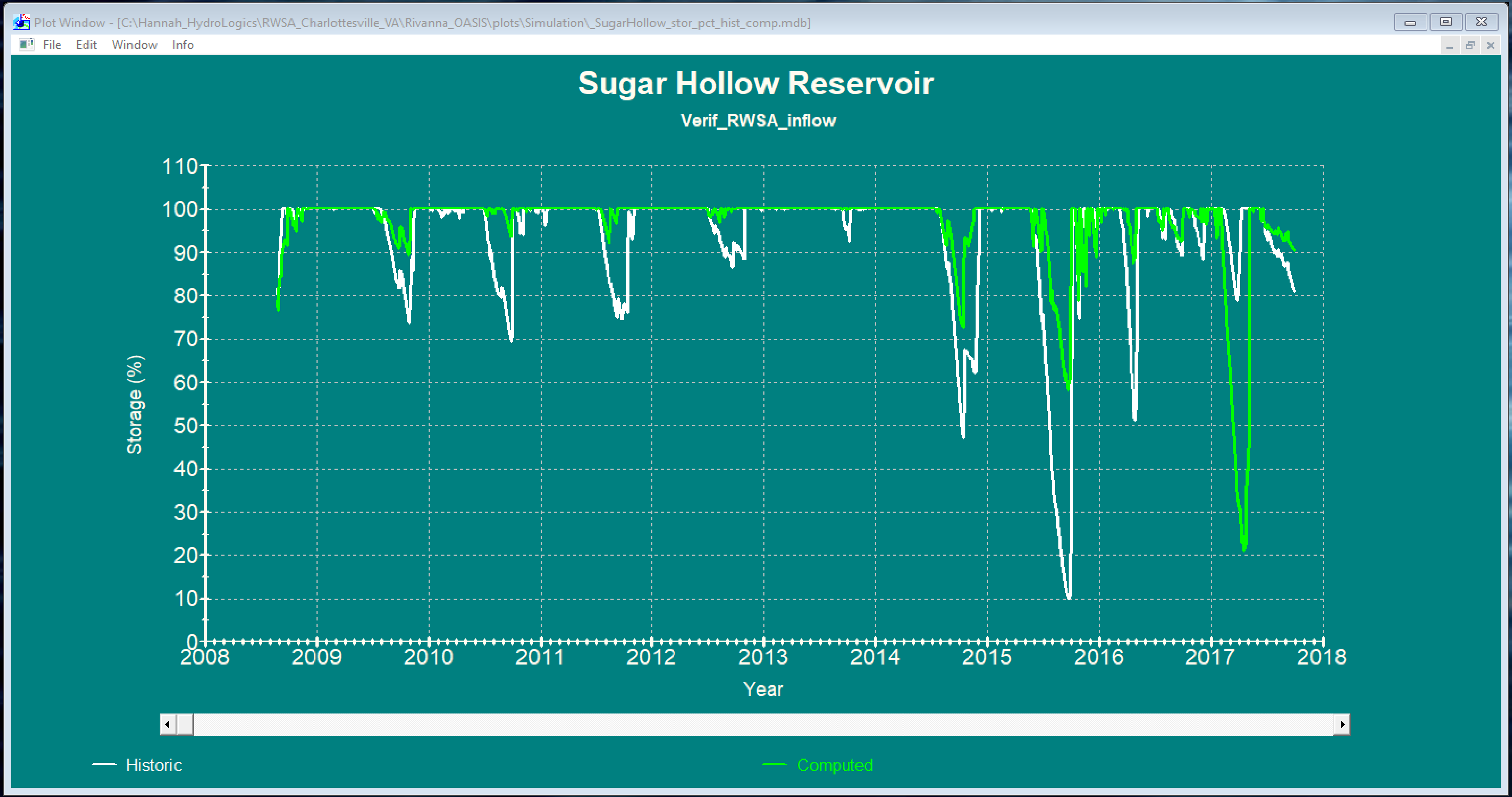
Note: Cannot test filled in Moormans Free Union for verification since the gage is in service for this period; see period of record results for comparison to NF Moormans filled in

HydroLogics Inflows – Filled-in NF Moormans gage, scaled to dam



Note: Adjustment is done since study by RWSA concluded that 2015-2016 releases may have been underestimated by ~1.5 -3.5 mgd

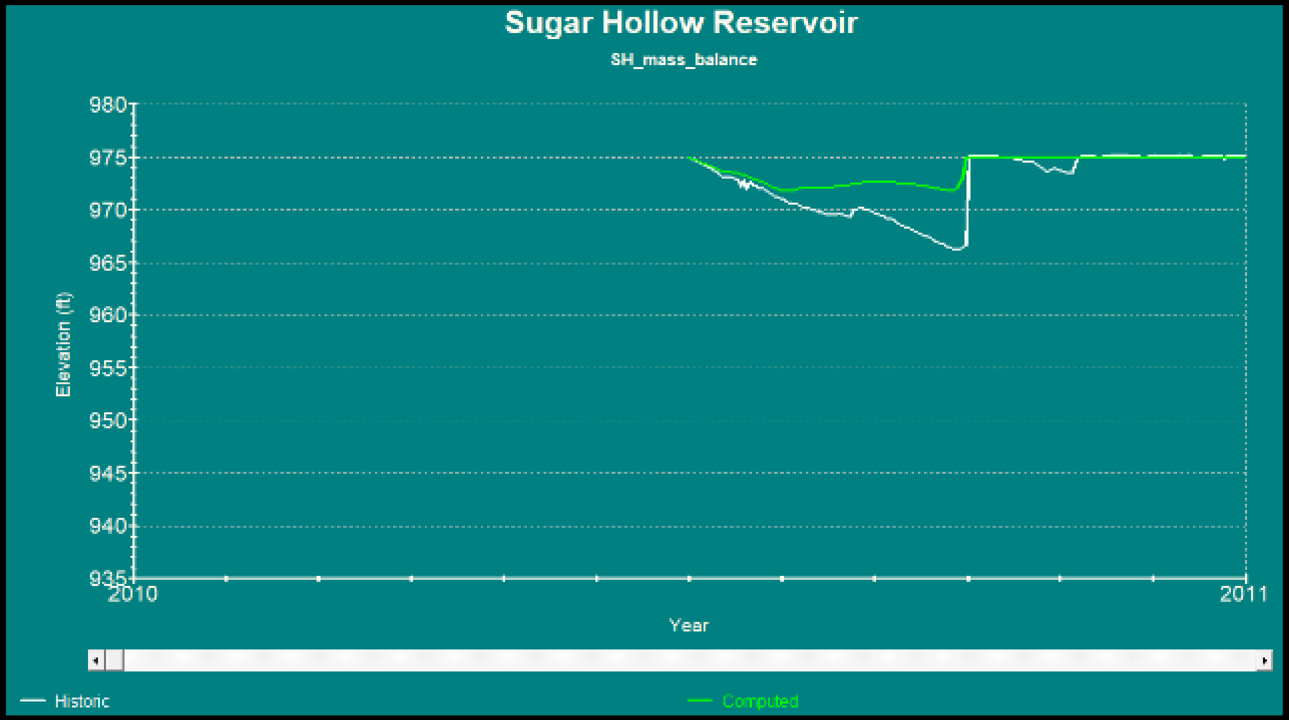
Using RWSA (Mechums Adjusted) Inflows



HYDROLOGICS

Mass Balance Using Gannett Fleming Inflows

- Error is computed storage change – historic change in storage over the drawdown period.
- On average an additional 0.8 MGD is going into reservoir.



Sugar Hollow Reservoir

July 1 to Sept 27, 2010

All units in MG

	Computed	Historic
Release	43	43
Transfer to Ragged Mt.	105	105
Inflow	113	??
Net evap	8	??
Storage Change	43	115
Starting elevation (feet)	975	975
Ending elevation (feet)	972	966.2
Elevation change (feet)	3	8.8

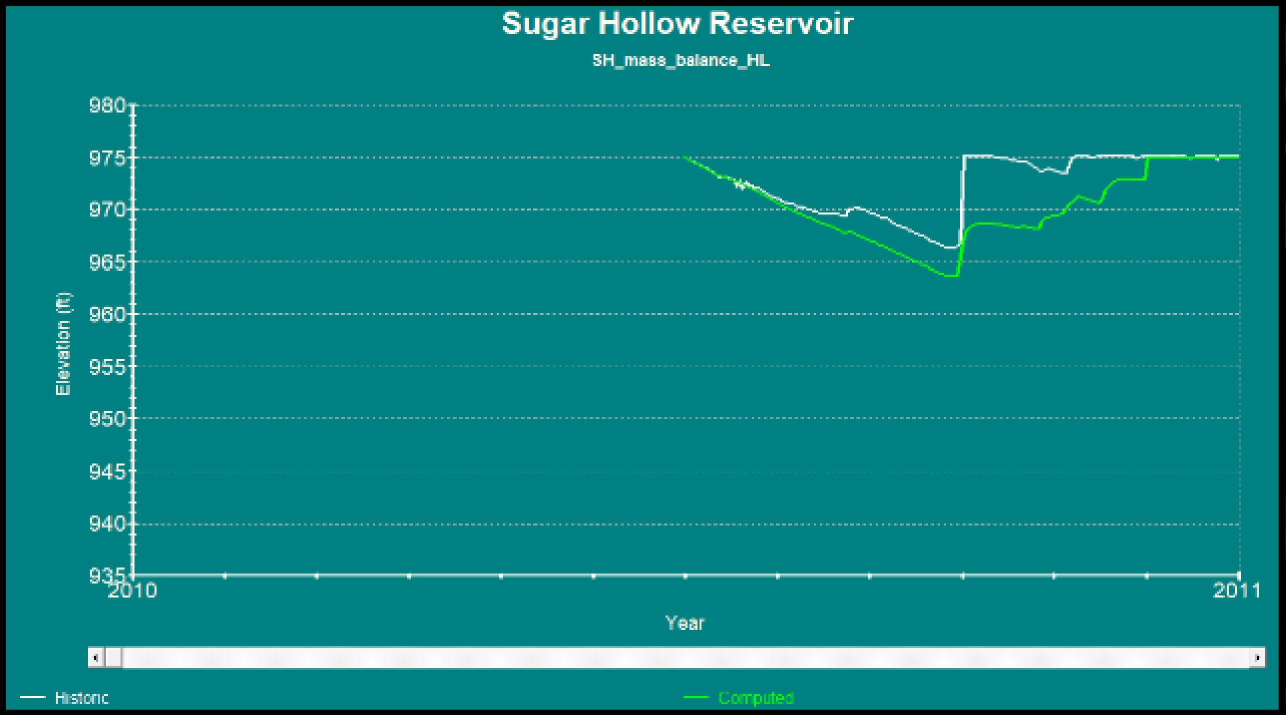
Error = 43 - 115, or -72 MG over the course of 3 months, or 88 days

or -0.8 mgd

Average production	1.2	mgd
Average release	0.5	mgd
Average outflow	1.7	mgd
Average inflow	1.3	mgd

Mass Balance Using HydroLogics Inflows – Filled in NF Gage

- Error is computed storage change – historic change in storage over the drawdown period.
- On average 0.3 MGD less is going into reservoir.



Sugar Hollow Reservoir

July 1 to Sept 27, 2010

All units in MG

	Computed	Historic
Release	43	43
Transfer to Ragged Mt.	105	105
Inflow	13	??
Net evap	5	??
Storage Change	140	115
Starting elevation (feet)	975	975
Ending elevation (feet)	963.7	966.2
Elevation change (feet)	11.3	8.8

Error = 140 - 115, or 25 MG over the course of 3 months, or 88 days

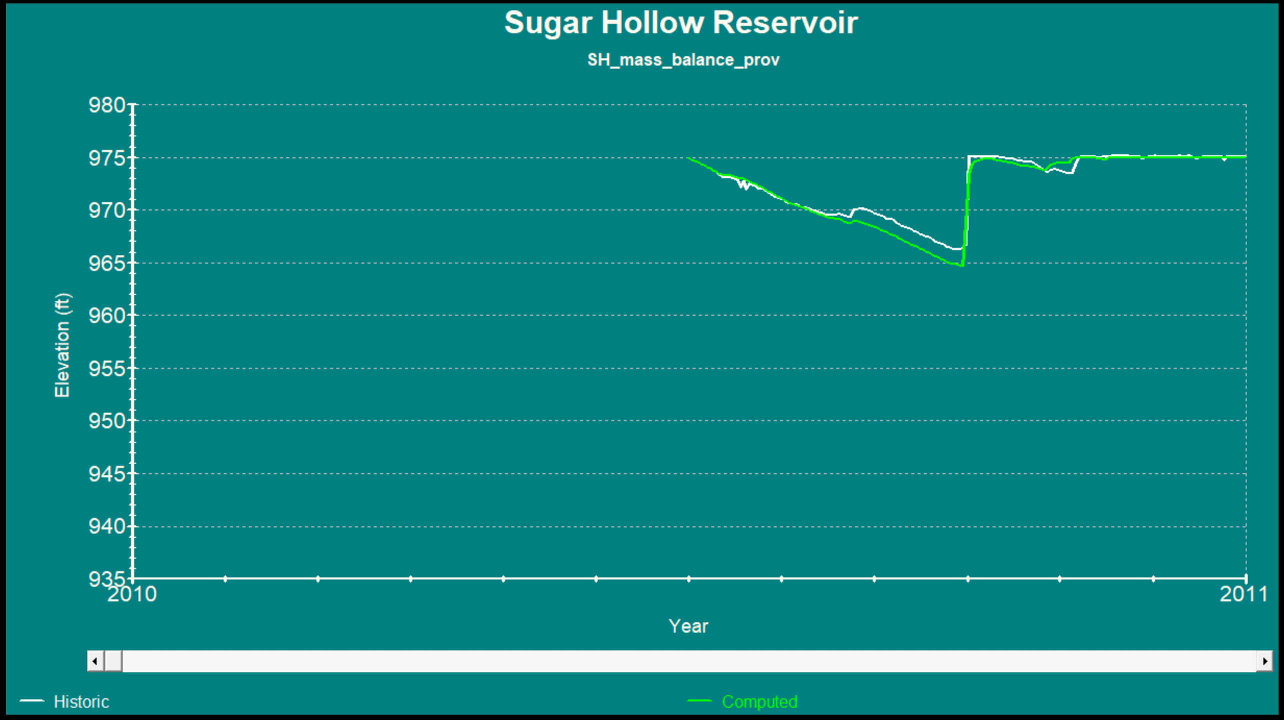
or 0.3 mgd

Average production	1.2	mgd
Average release	0.5	mgd
Average outflow	1.7	mgd
Average inflow	0.1	mgd

HYDROLOGICS

Mass Balance Using HydroLogics Inflows – Unimp. Moormans Gage

- Error is computed storage change – historic change in storage over the drawdown period.
- On average 0.1 MGD less is going into reservoir.



Sugar Hollow Reservoir

July 1 to Sept 27, 2010

All units in MG

	Computed	Historic
Release	43	43
Transfer to Ragged Mt.	105	105
Inflow	25	??
Net evap	5	??
Storage Change	128	115
Starting elevation (feet)	975	975
Ending elevation (feet)	964.9	966.2
Elevation change (feet)	10.1	8.8

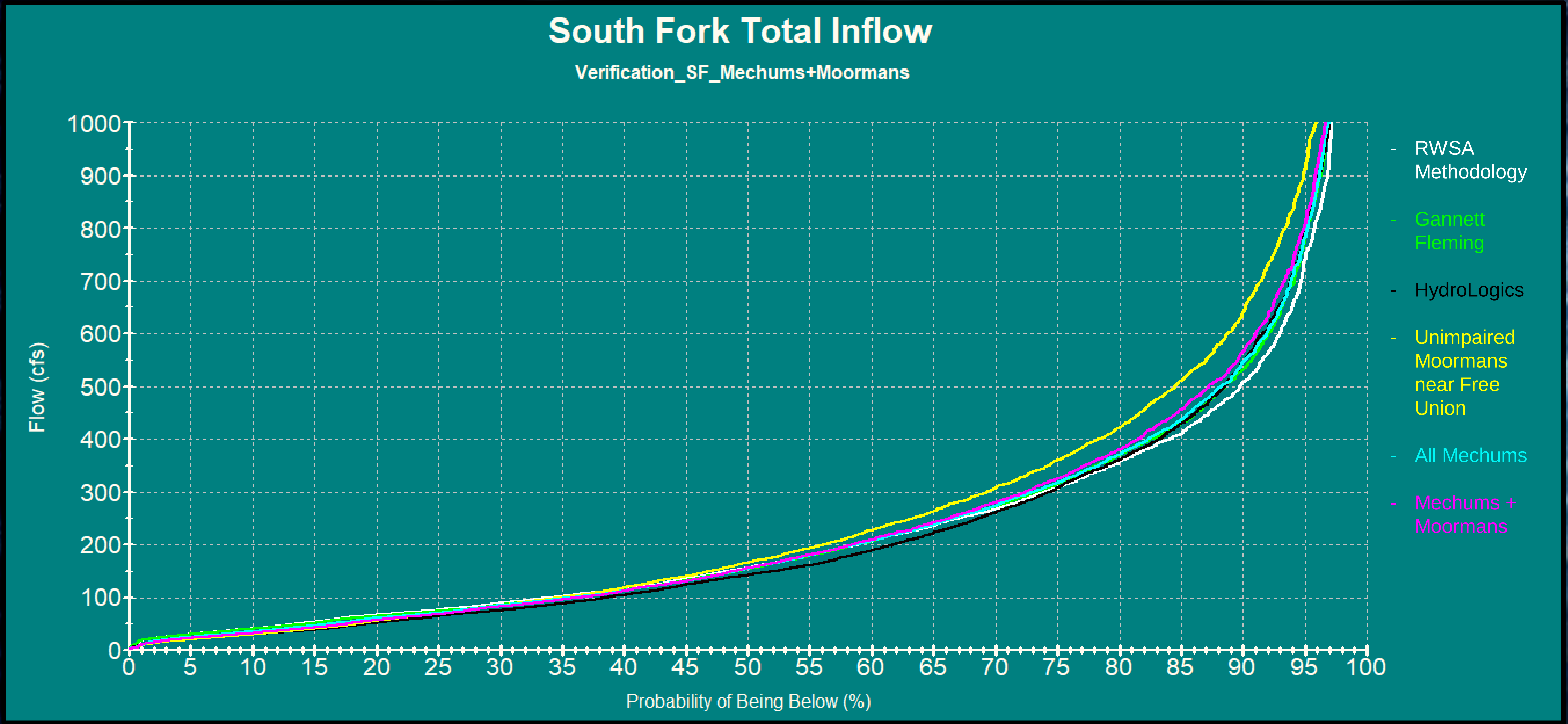
Error = 128 - 115, or 13 MG over the course of 3 months, or 88 days

or 0.1 mgd

Average production	1.2	mgd
Average release	0.5	mgd
Average outflow	1.7	mgd
Average inflow	0.3	mgd

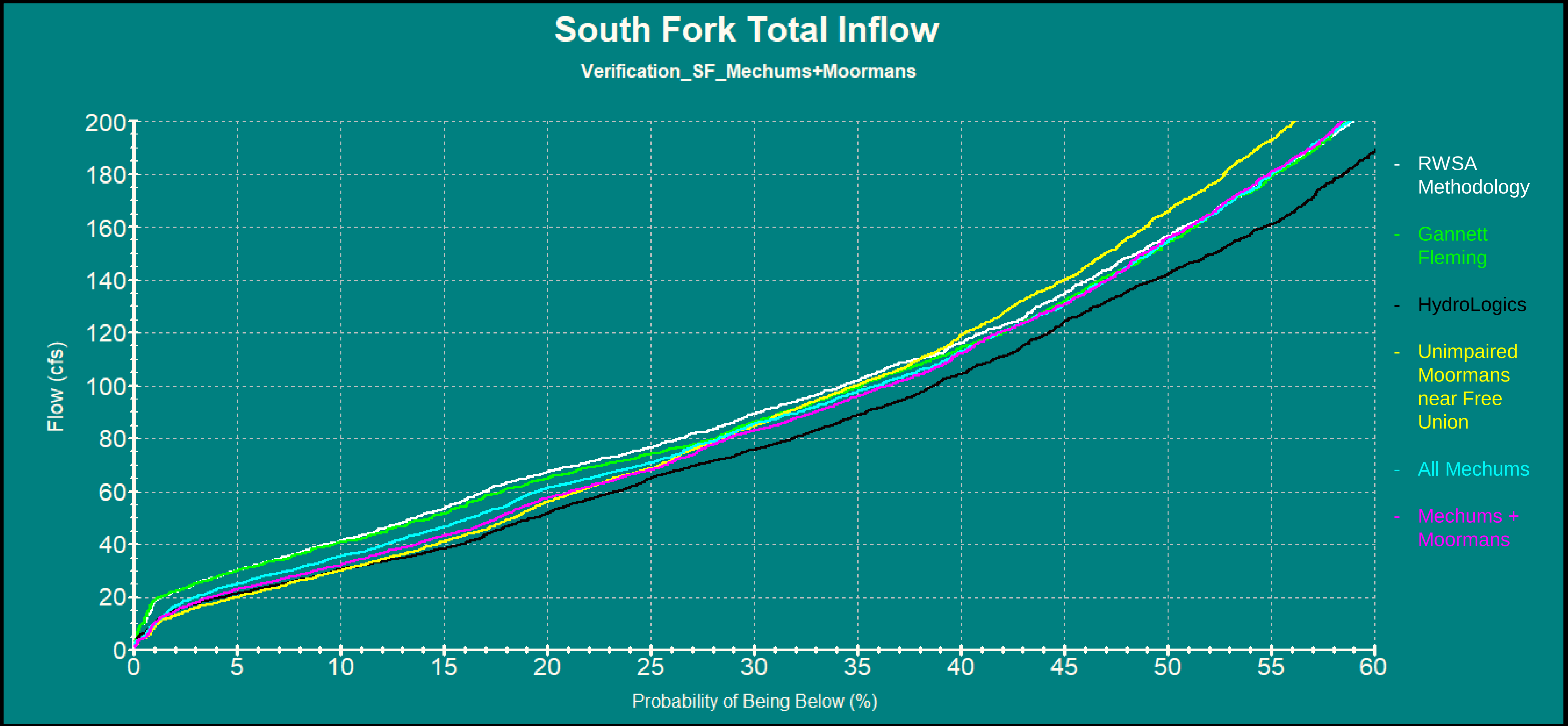
HYDROLOGICS

South Fork Inflows – 8/22/2008 – 09/30/2017

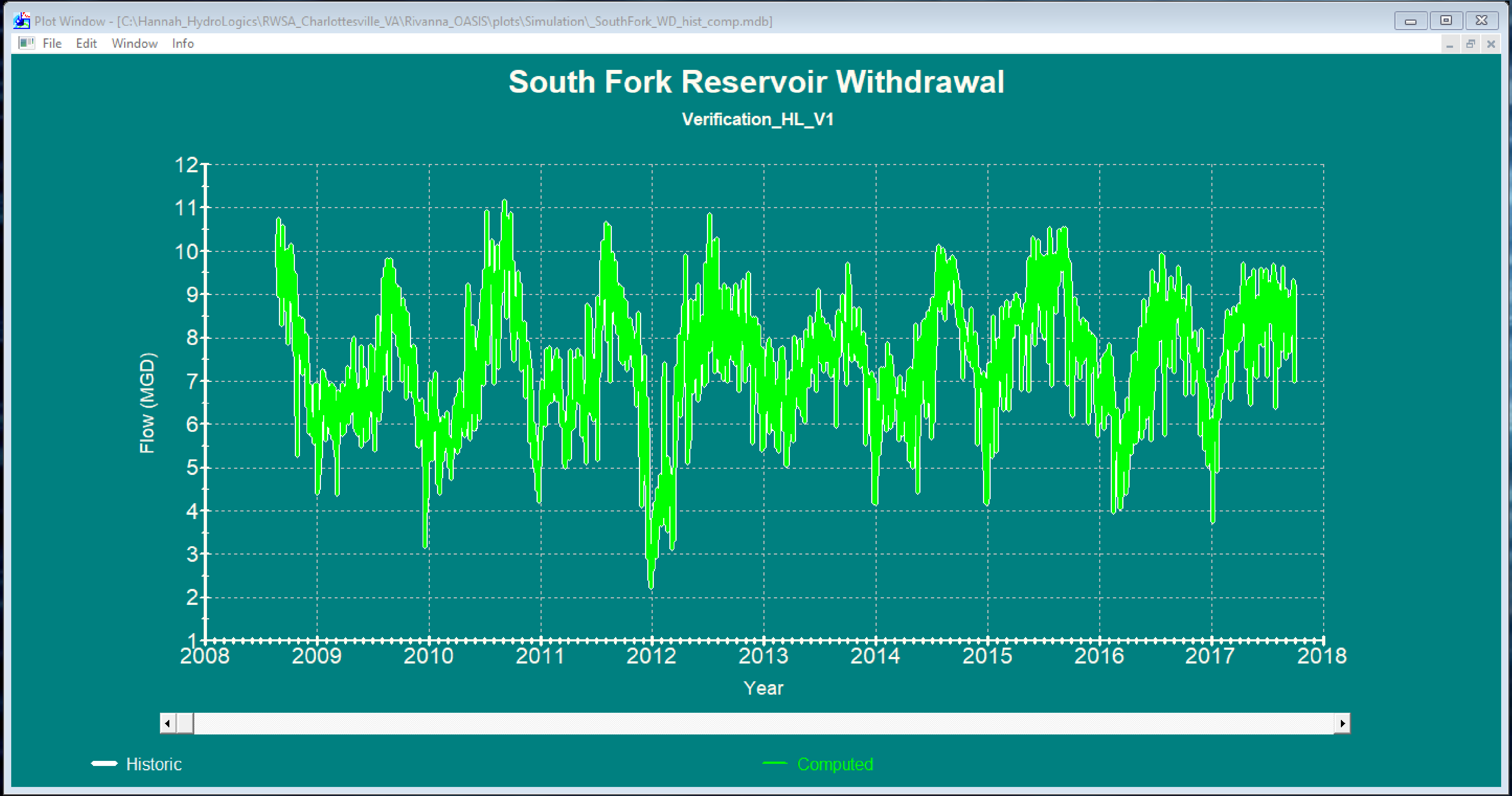


HYDROLOGICS

South Fork Inflows – 8/22/2008 – 09/30/2017

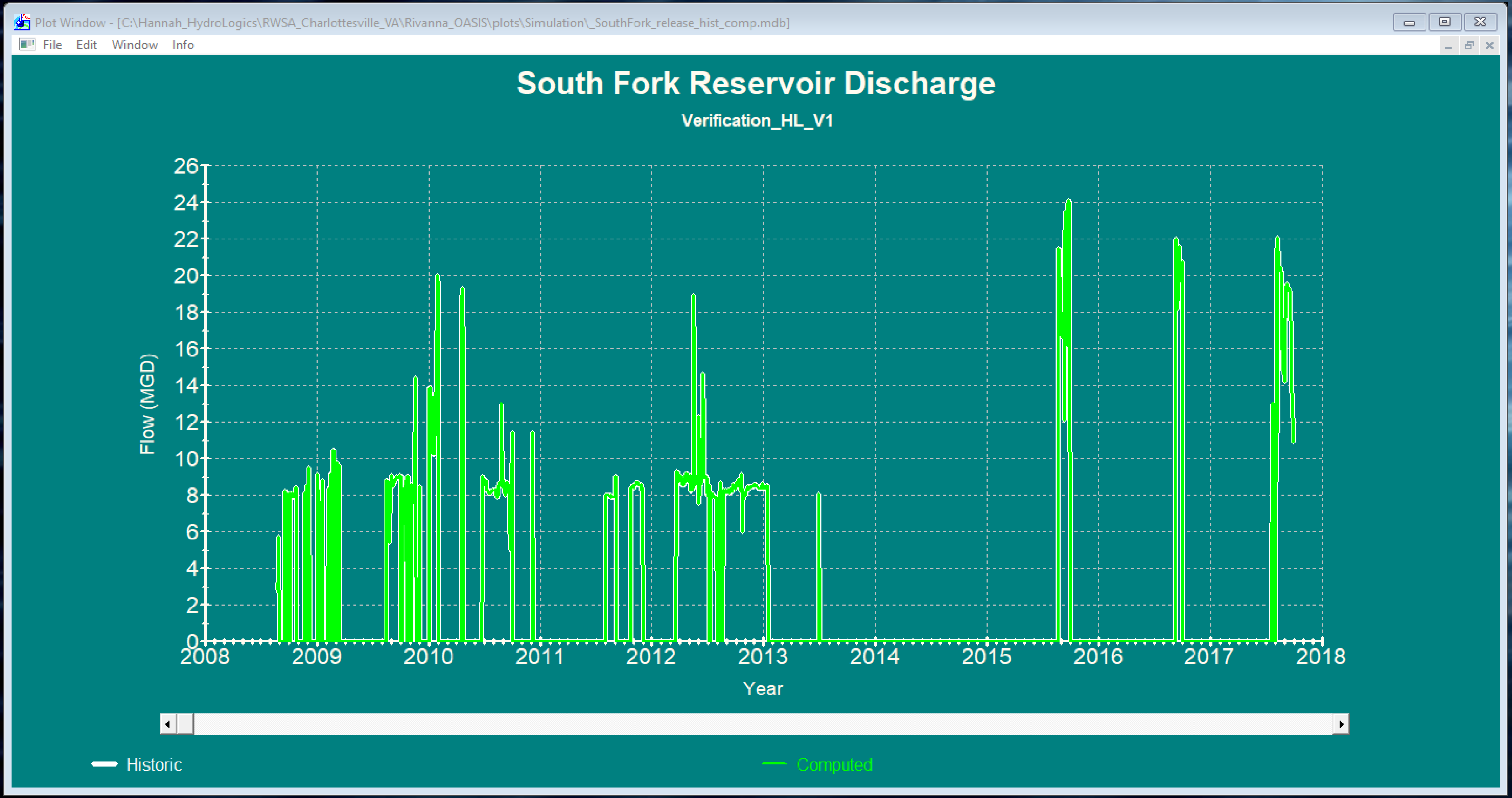


South Fork



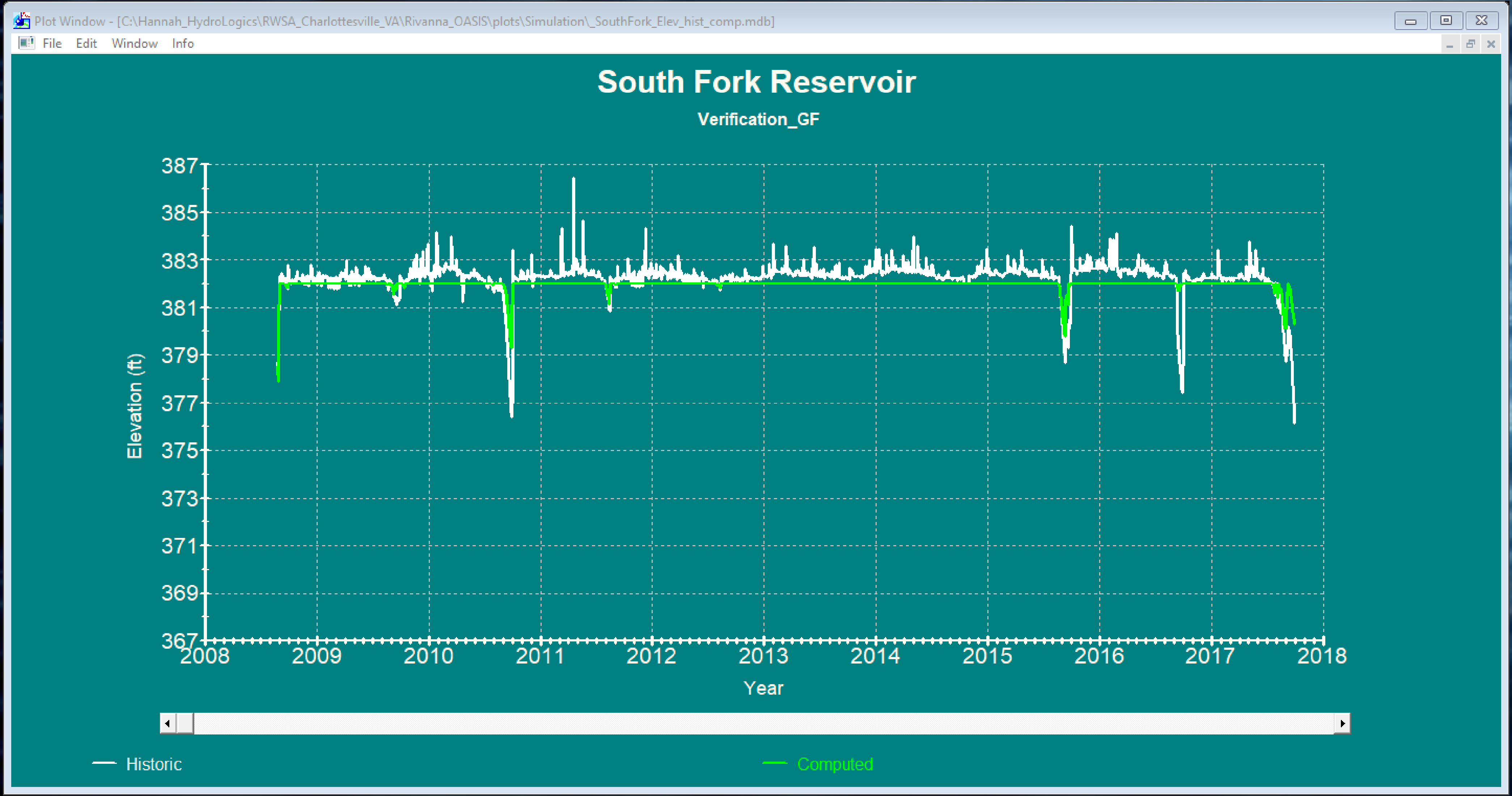
HYDROLOGICS

South Fork

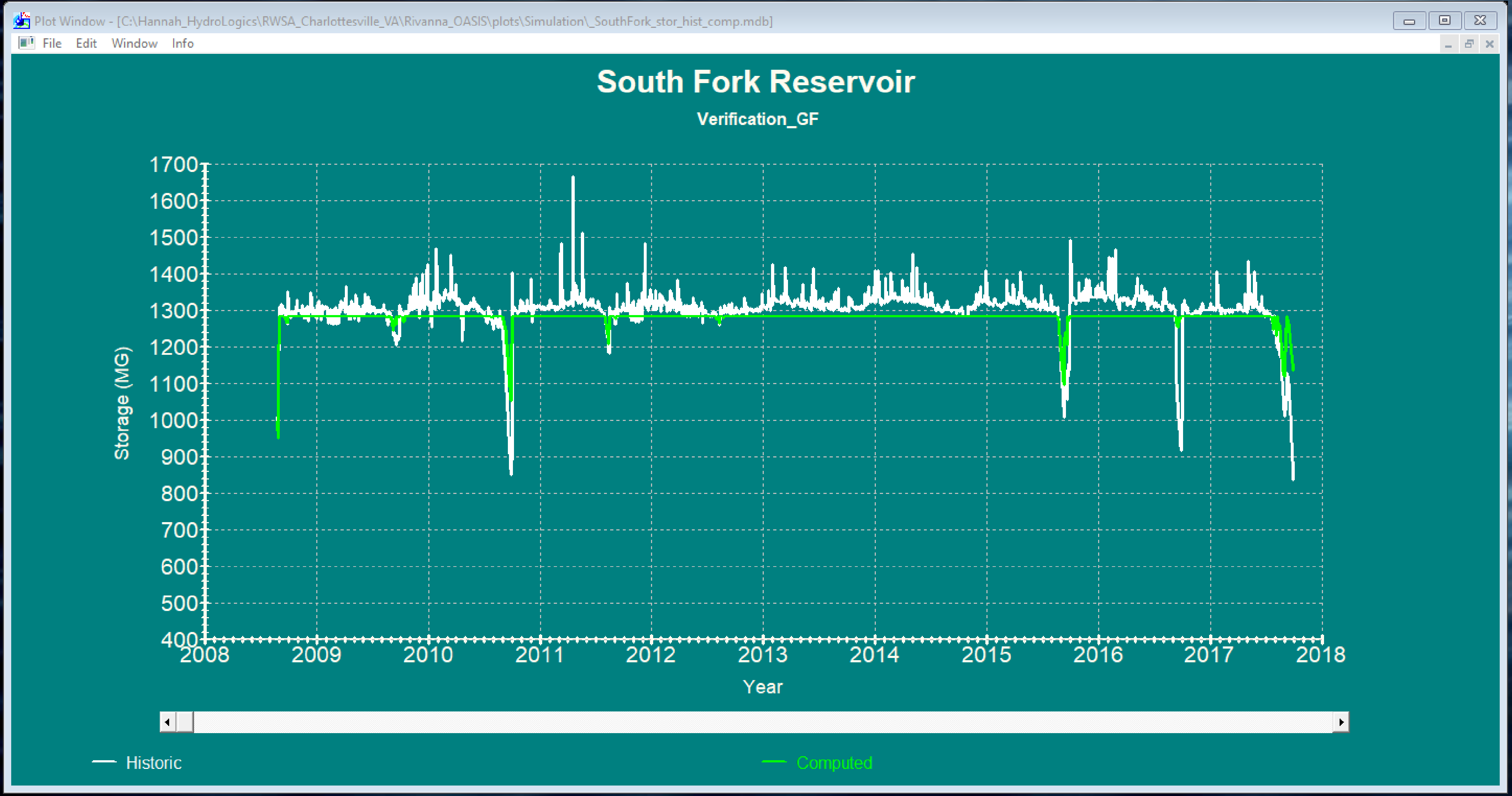


HYDROLOGICS

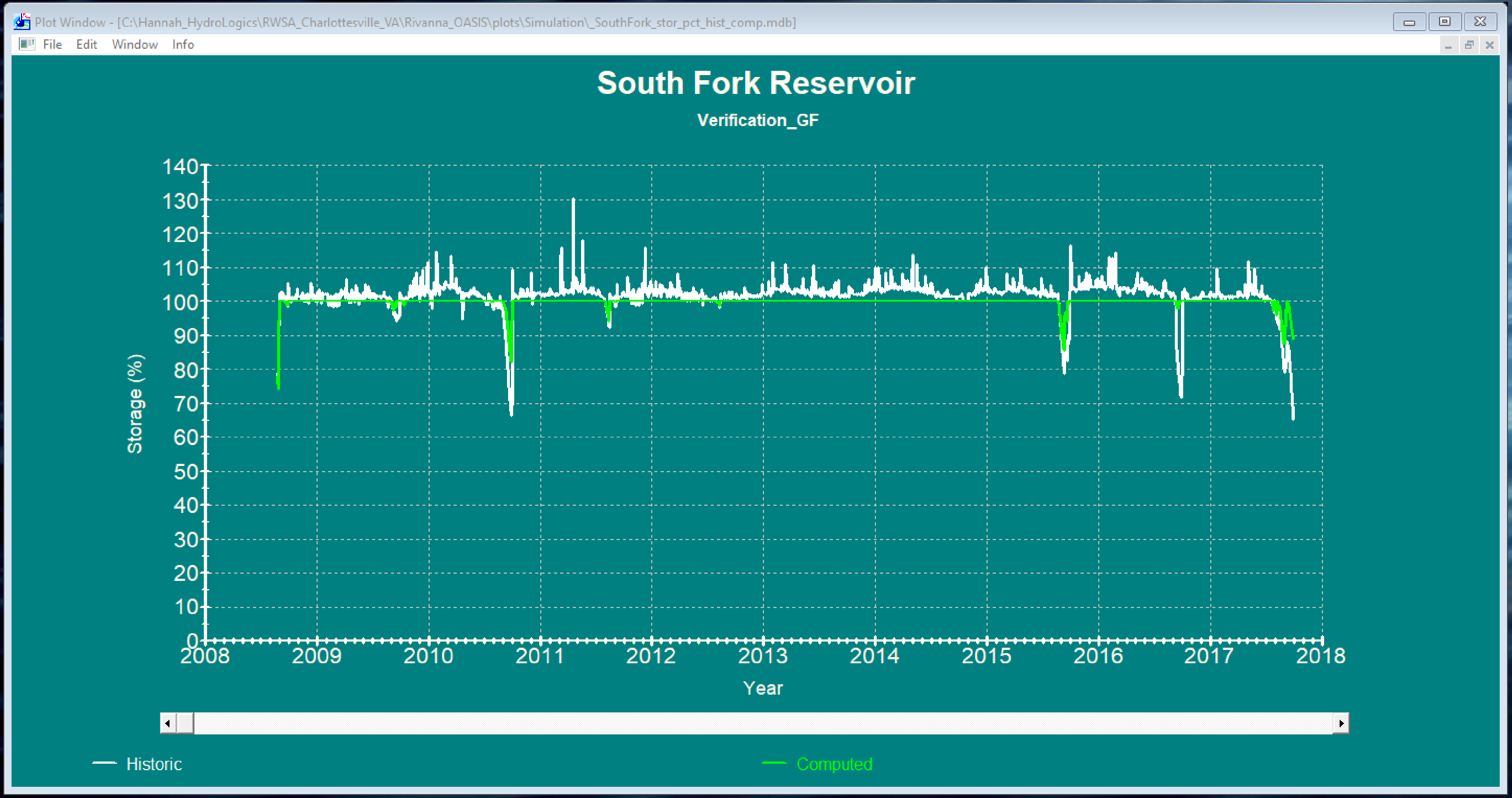
Verification Using Gannett Fleming Inflows



Using Gannett Fleming Inflows

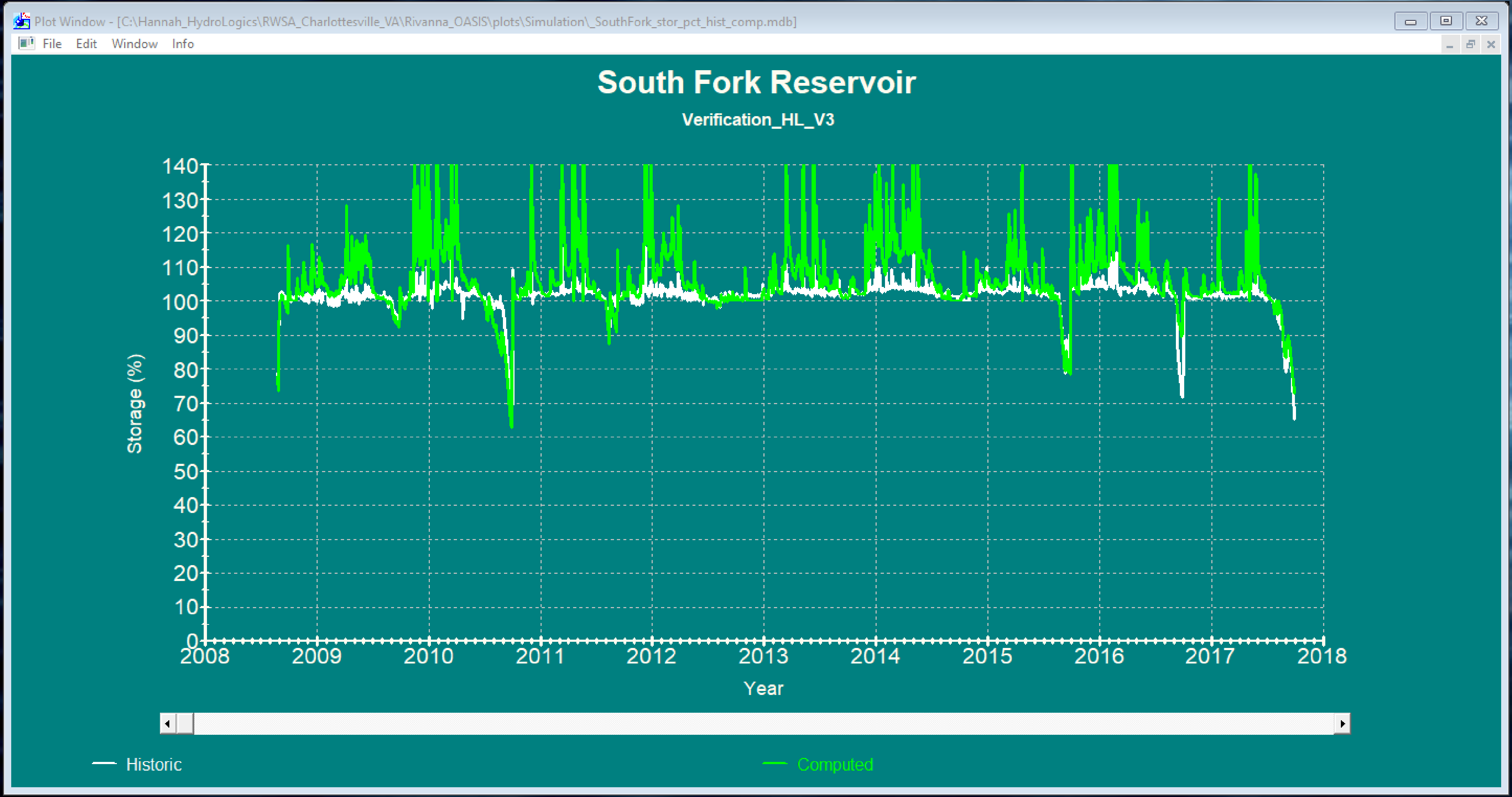


Using Gannett Fleming Inflows



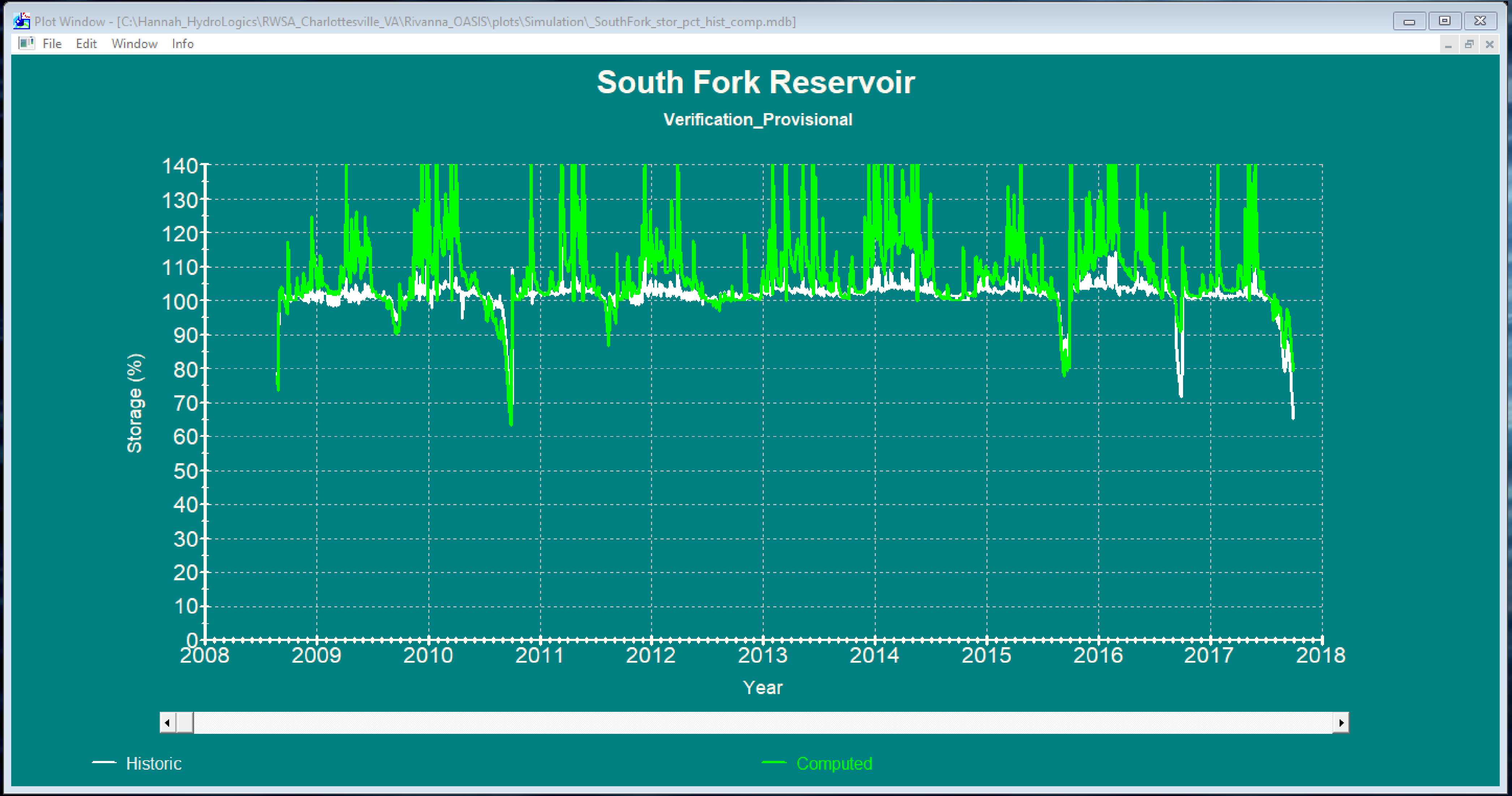
HYDROLOGICS

HydroLogics Inflows - Moormans & Buck Mt. gages, scaled to dam



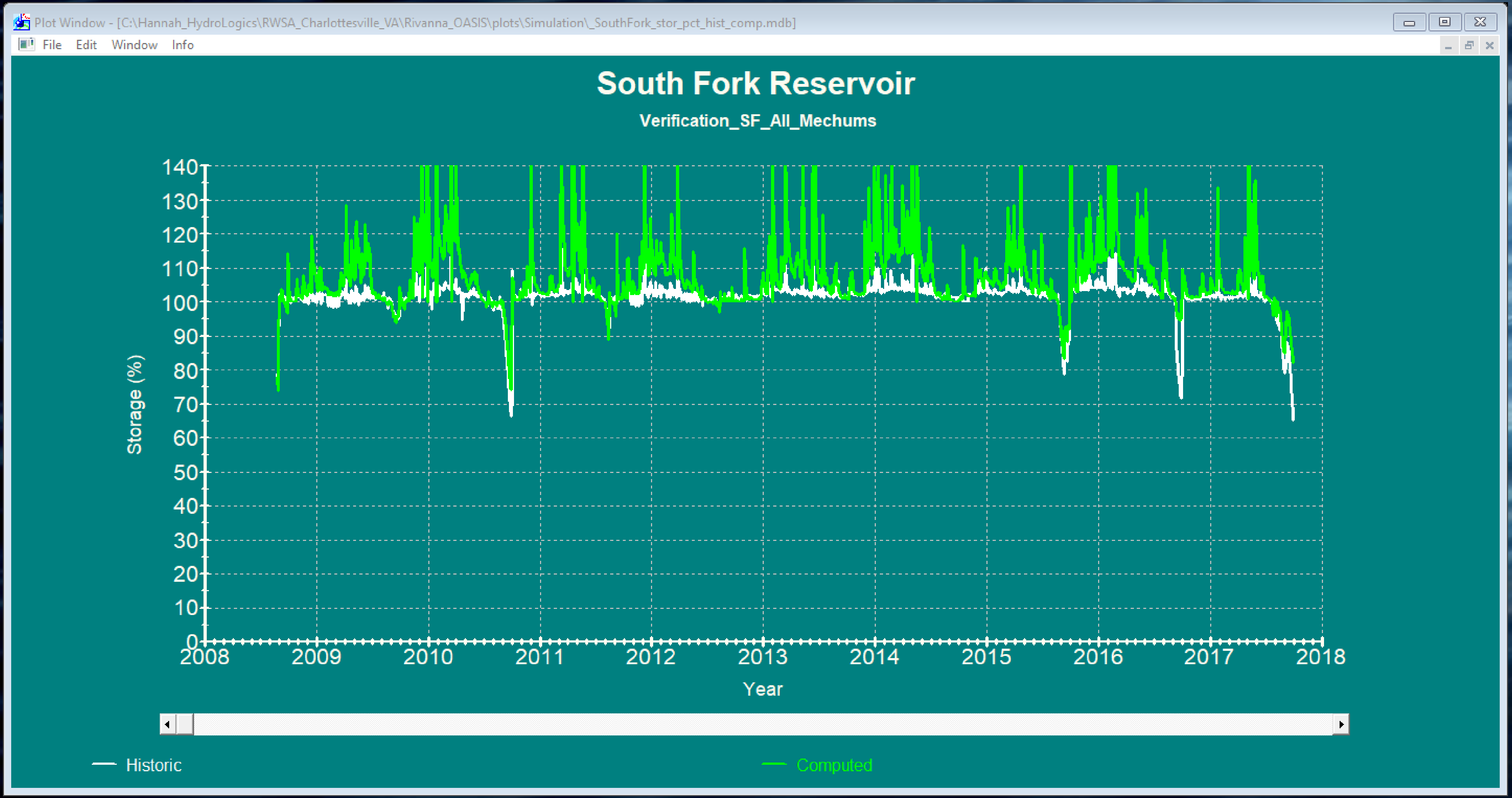
Note: Mechums gage still used for inflow to that point in the model

HydroLogics Provisional Inflows - Moormans gage UIF, scaled for gain from Moormans & Mechums down to South Fork



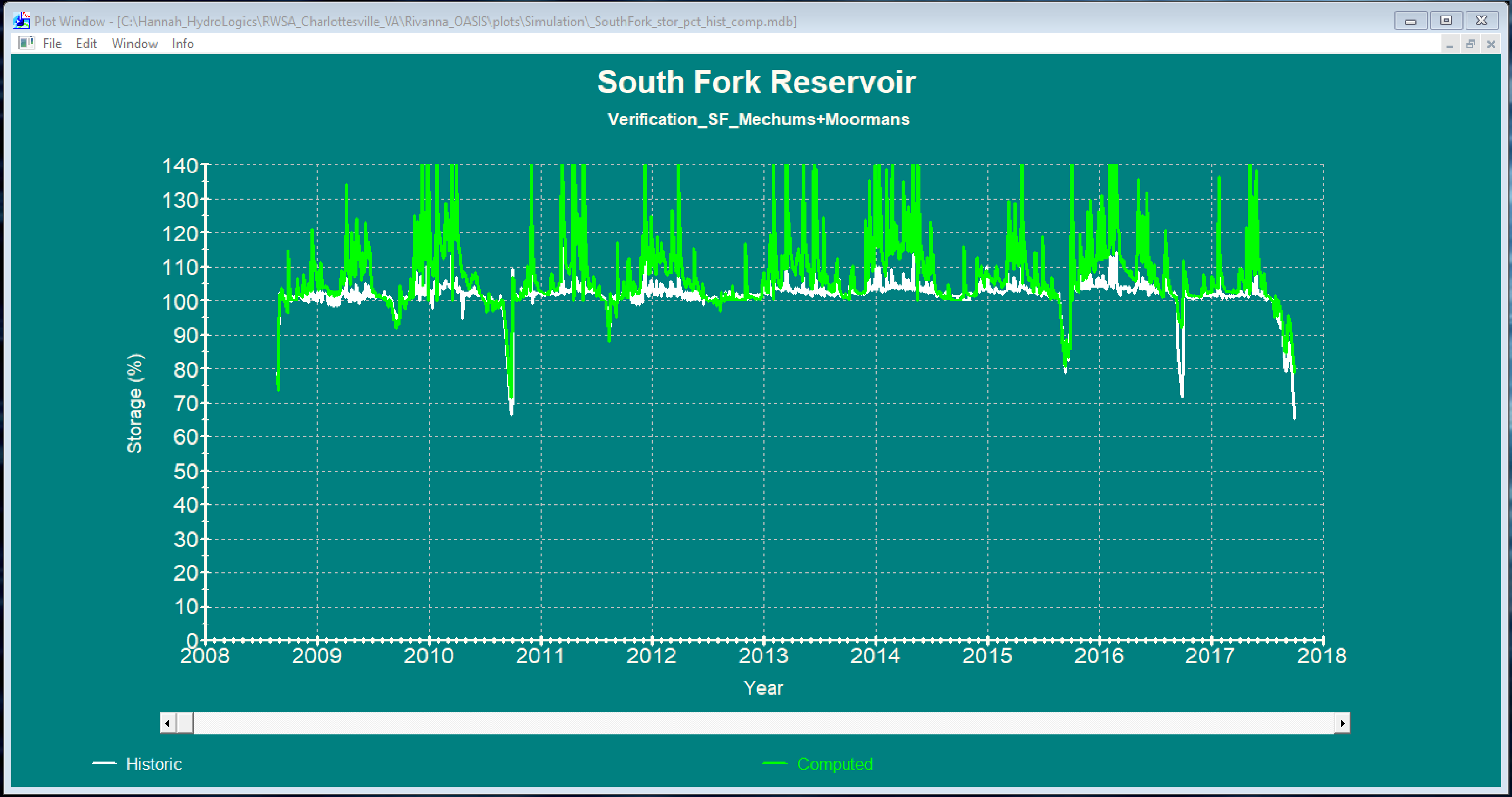
Note: Mechums gage still use for inflow to that point in the model

Provisional Test: Using "All Mechums" scaled for gain from Moormans & Mechums down to South Fork



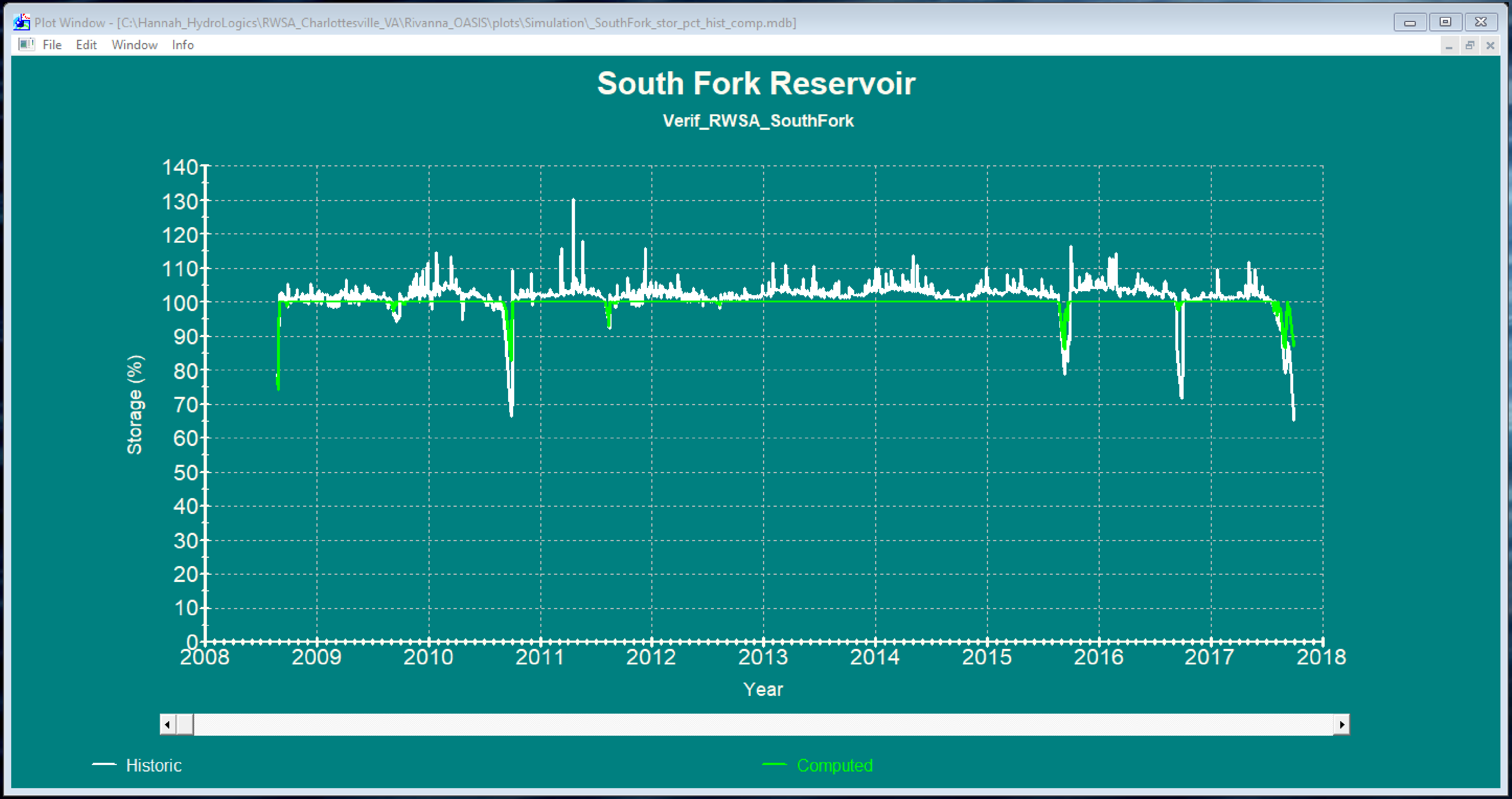
Note: Moormans gage still used for inflow to that point in the model

Provisional Test: Using "Mechums + Moormans" Inflows scaled for gain from Moormans & Mechums down to South Fork



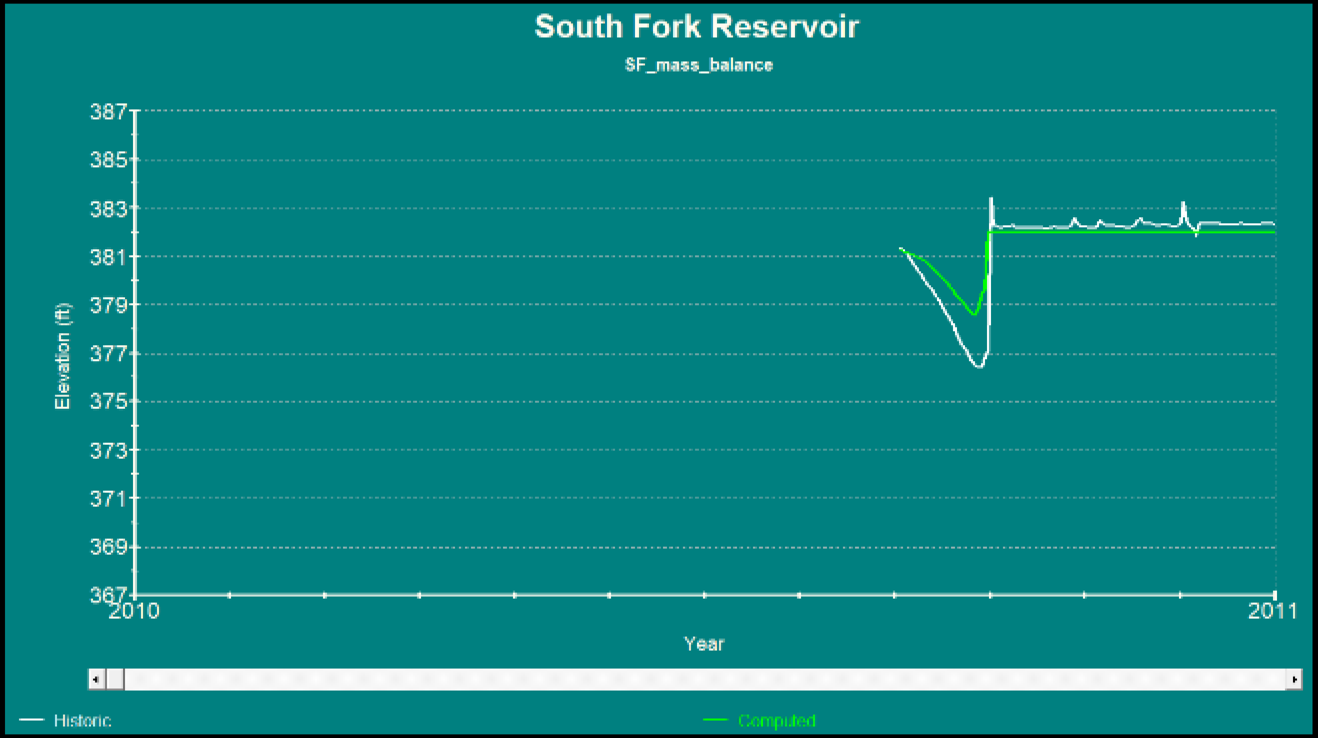
HYDROLOGICS

Using RWSA Current Method: Mechums Adjusted Gage for entire inflow to South Fork



Mass Balance Using Gannett Fleming Inflows

- Error is computed storage change – historic change in storage over the drawdown period.
- On average an additional 6.0 MGD is going into reservoir.



South Fork Rivanna Reservoir

Sept 2 to Sept 26, 2010

All units in MG

	Computed	Historic
Release	196	196
RWSA Delivery	253	253
Upstream Inflow	102	??
Nat Inflow	143	??
Net evap	18	??
Storage Change	222	367
Starting elevation (feet)	381.3	381.3
Ending elevation (feet)	378.6	376.5
Elevation change (feet)	2.7	4.8

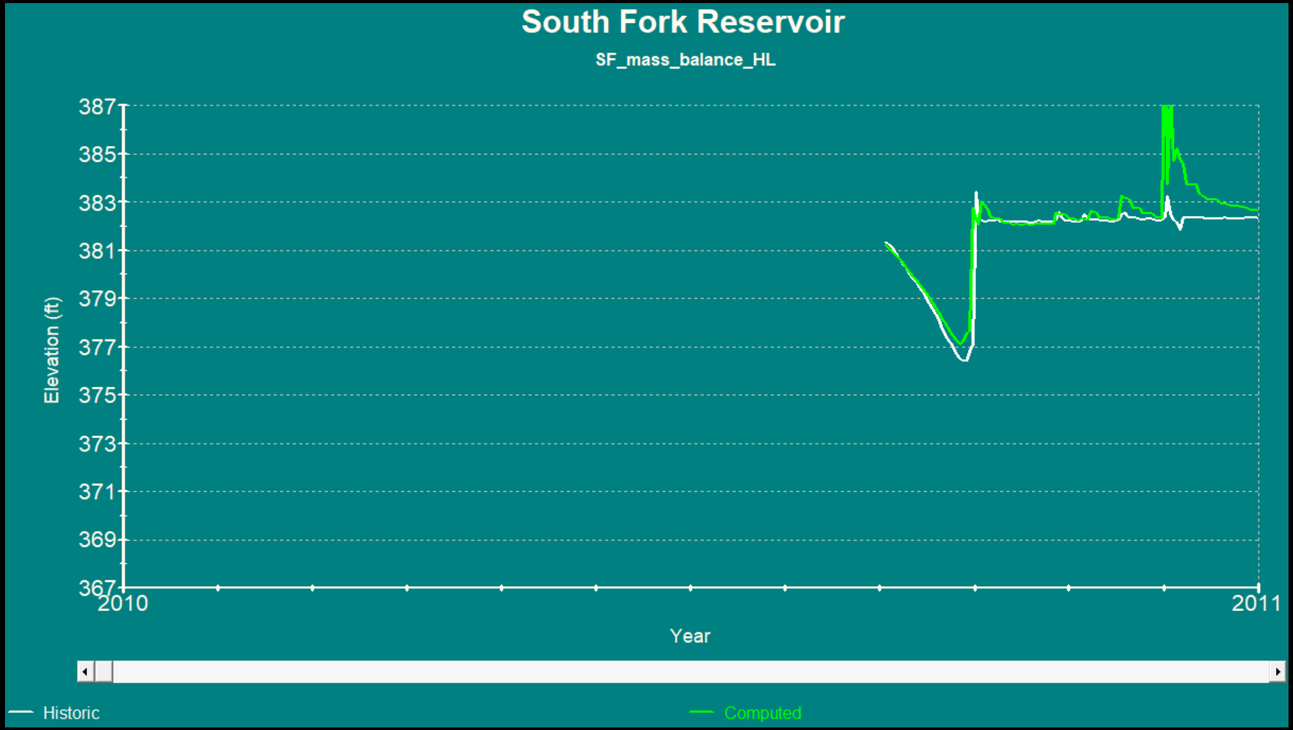
Error = 222 - 367 or -145 MG over the course of 24 days

or -6.0 mgd

Average production	10.5	mgd
Average release	8.2	mgd
Average outflow	18.7	mgd
Average inflow	10.2	mgd

Mass Balance Using HydroLogics Inflows

- Error is computed storage change – historic change in storage over the drawdown period.
- On average an additional 1.7 MGD is going into reservoir.



South Fork Rivanna Reservoir

Sept 2 to Sept 26, 2010

All units in MG

	Computed	Historic
Release	196	196
RWSA Delivery	253	253
Upstream Inflow	98	??
Nat Inflow	43	??
Net evap	18	??
Storage Change	326	367
Starting elevation (feet)	381.3	381.3
Ending elevation (feet)	377.1	376.5
Elevation change (feet)	4.2	4.8

Error = 326 - 367, or -41 MG over the course of 24 days

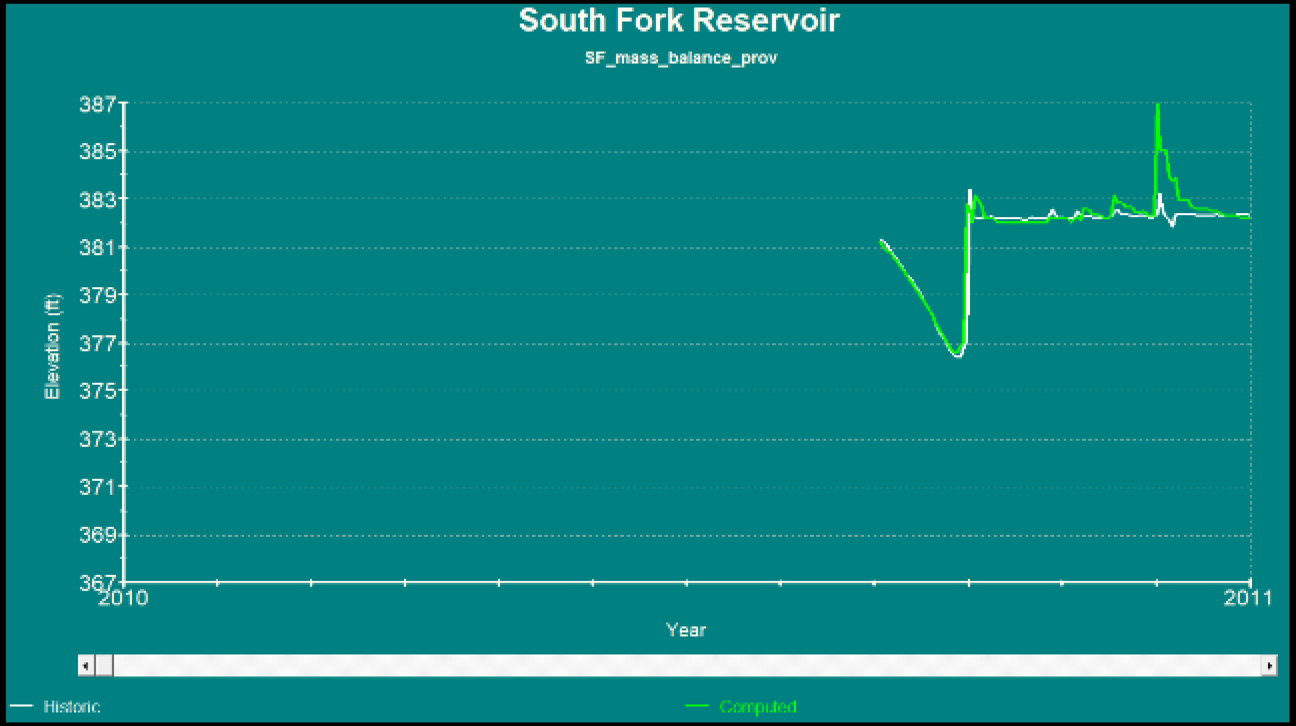
or -1.7 mgd

Average production	10.5	mgd
Average release	8.2	mgd
Average outflow	18.7	mgd
Average inflow	5.9	mgd

HYDROLOGICS

Mass Balance Using HydroLogics Provisional Inflows

- Error is computed storage change – historic change in storage over the drawdown period.
- On average an additional 1.7 MGD is going into reservoir.



South Fork Rivanna Reservoir

Sept 2 to Sept 26, 2010

All units in MG

	Computed	Historic
Release	196	196
RWSA Delivery	253	253
Upstream Inflow	98	??
Nat Inflow	12	??
Net evap	17	??
Storage Change	356	367
Starting elevation (feet)	381.3	381.3
Ending elevation (feet)	376.6	376.5
Elevation change (feet)	4.7	4.8

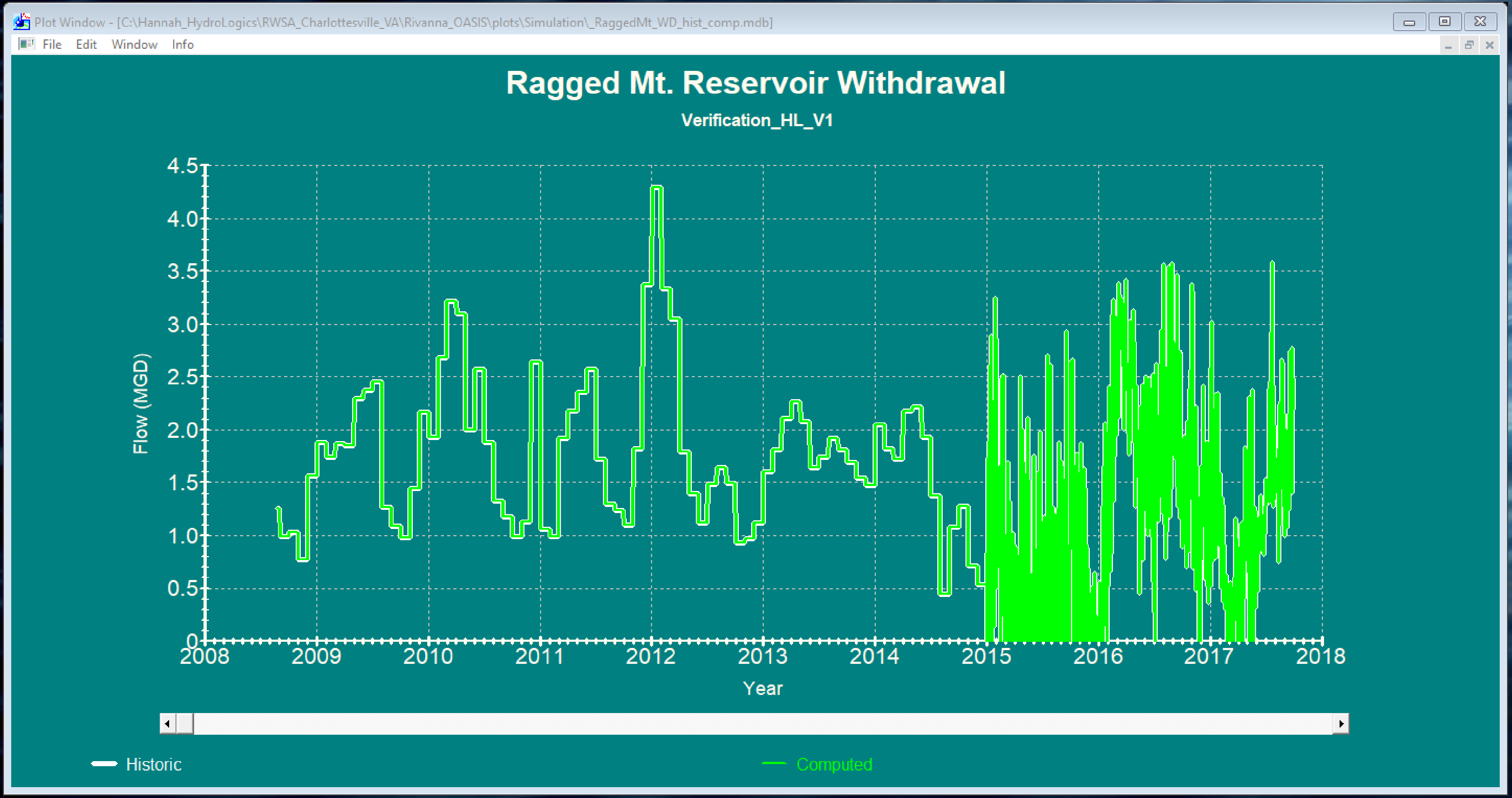
Error = 356 - 367, or -1 MG over the course of 24 days

or -0.04 mgd

Average production	10.5 mgd
Average release	8.2 mgd
Average outflow	18.7 mgd
Average inflow	4.6 mgd

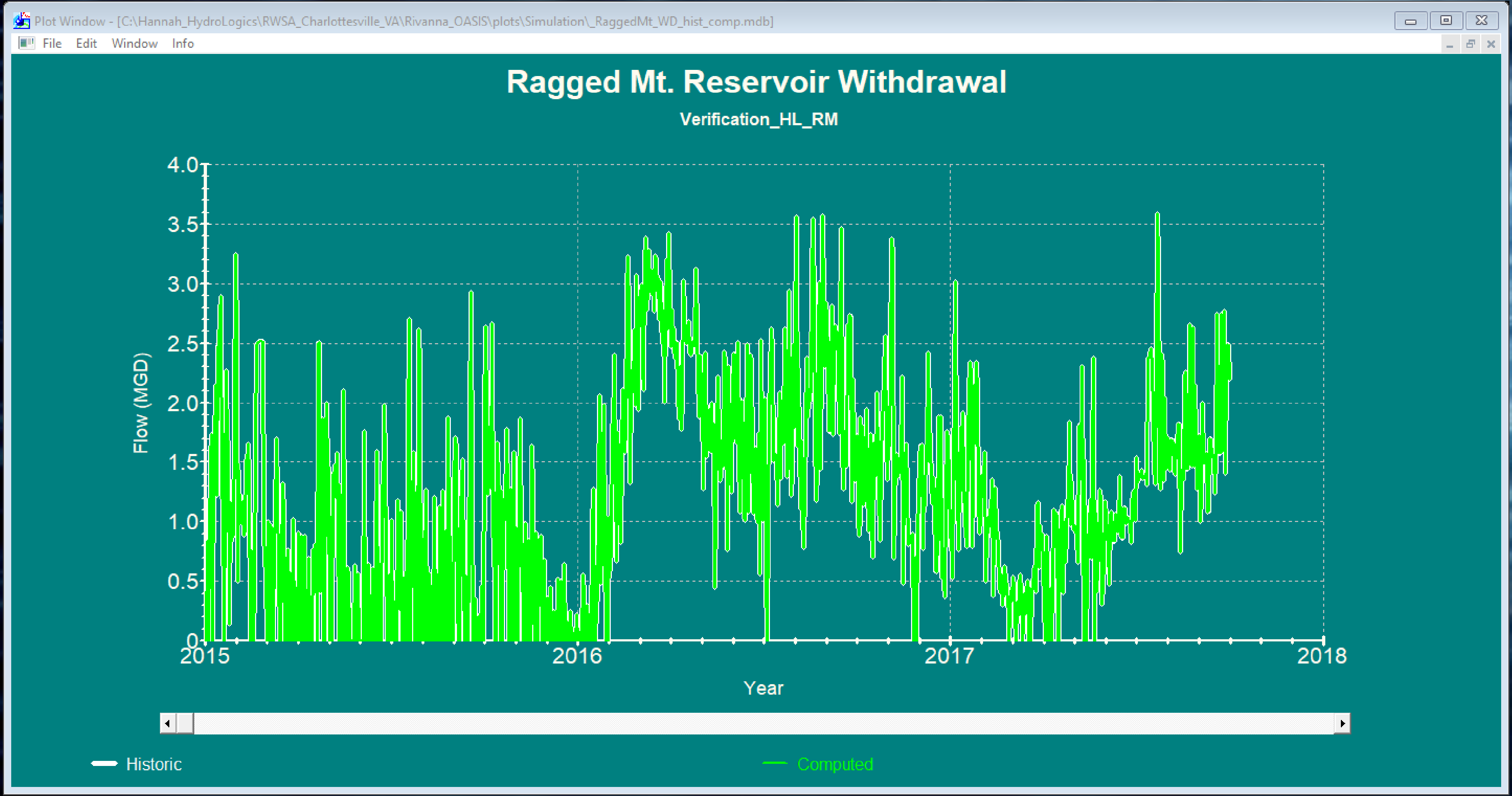
HYDROLOGICS

Ragged Mountain

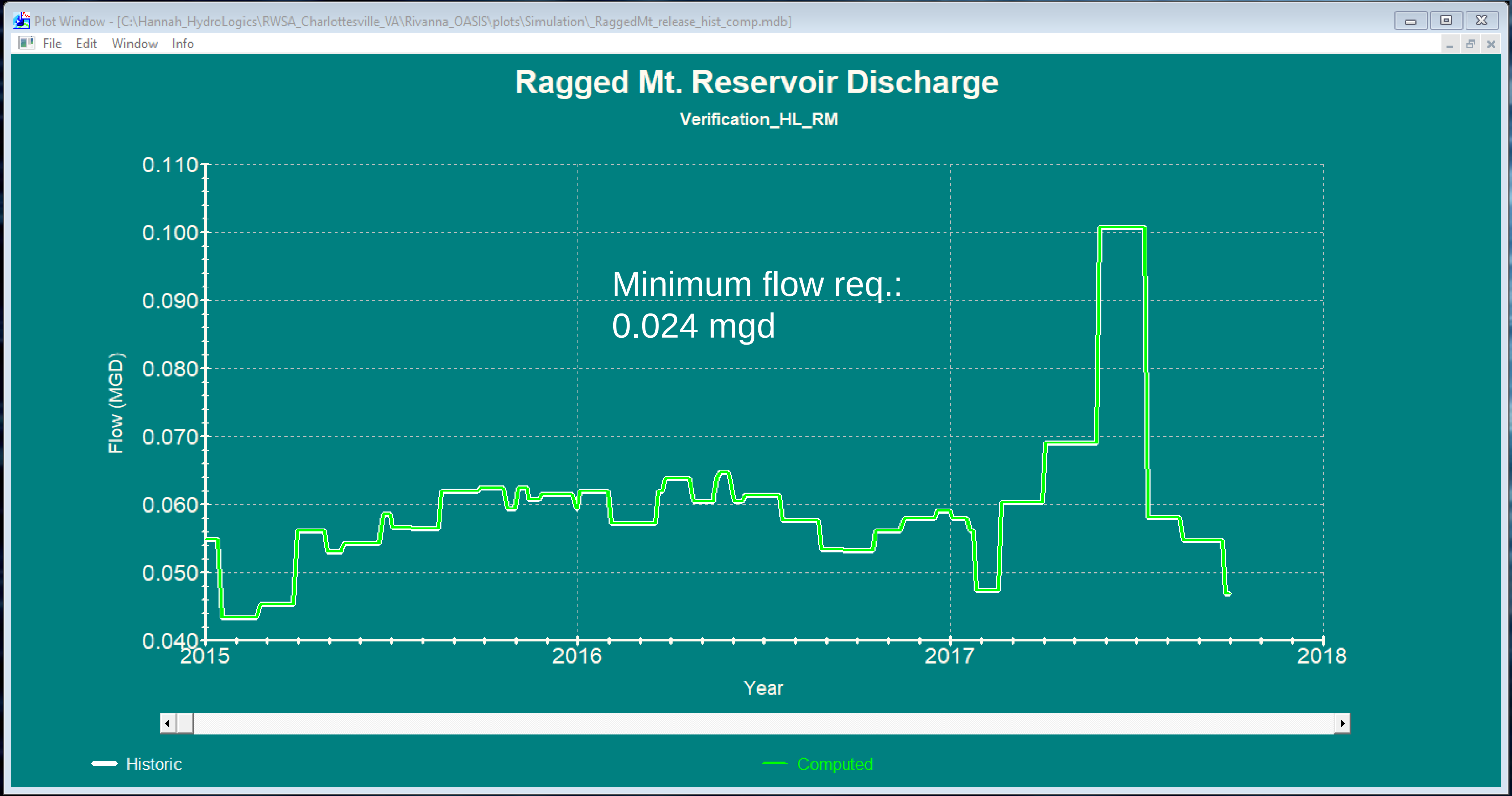


HYDROLOGICS

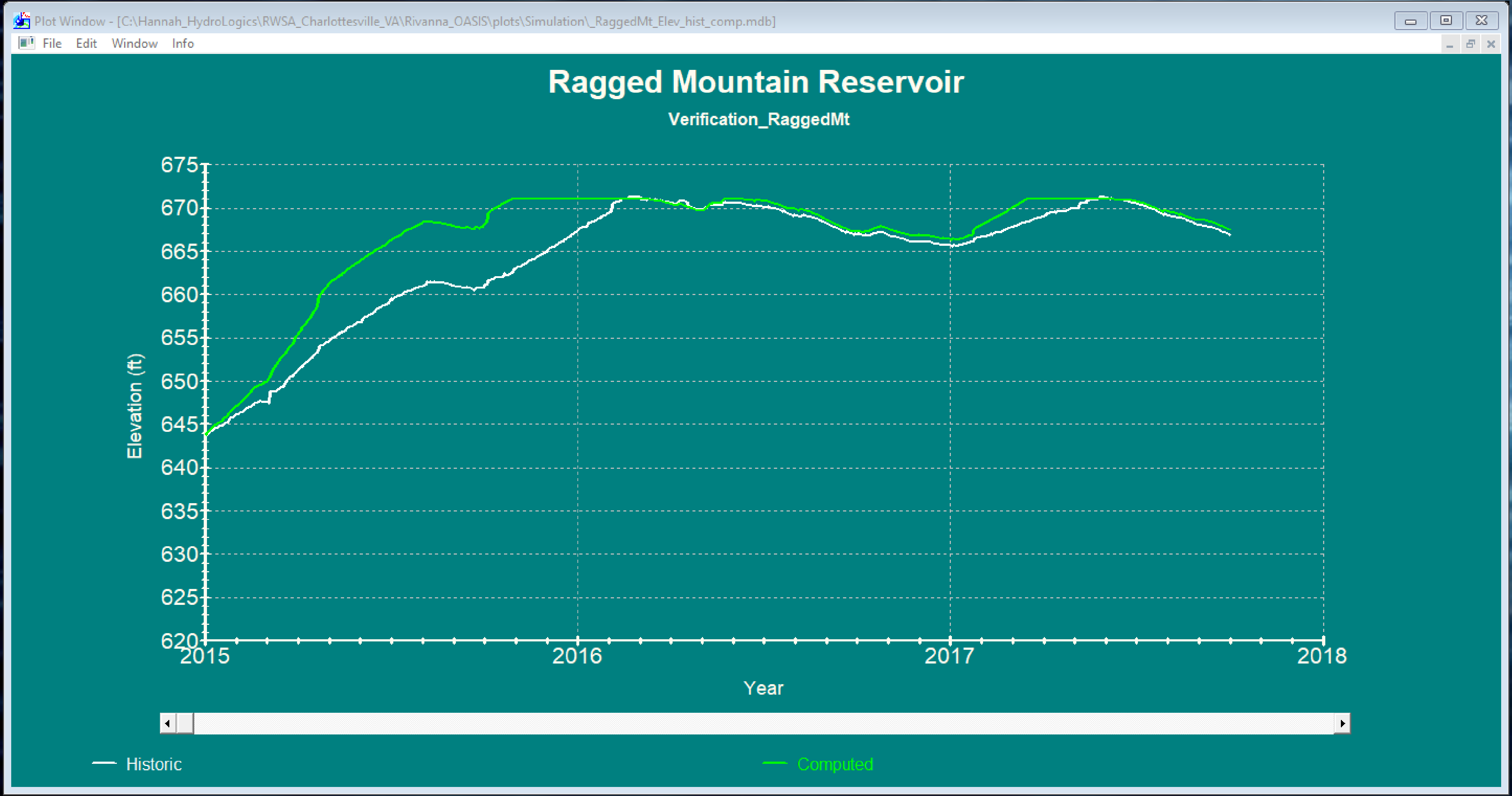
Ragged Mountain – Post-Fill Period



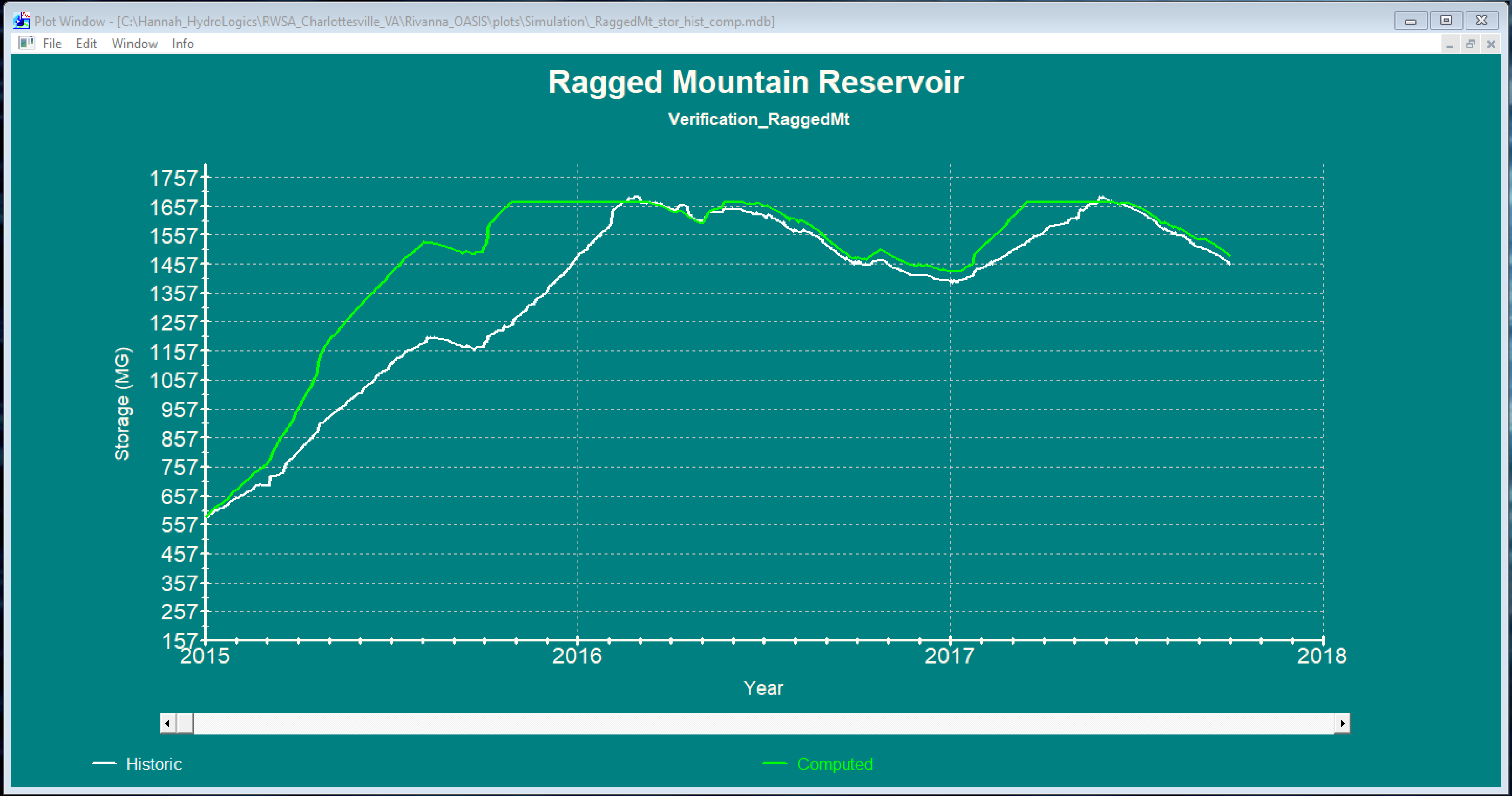
Ragged Mountain – Post-fill Period



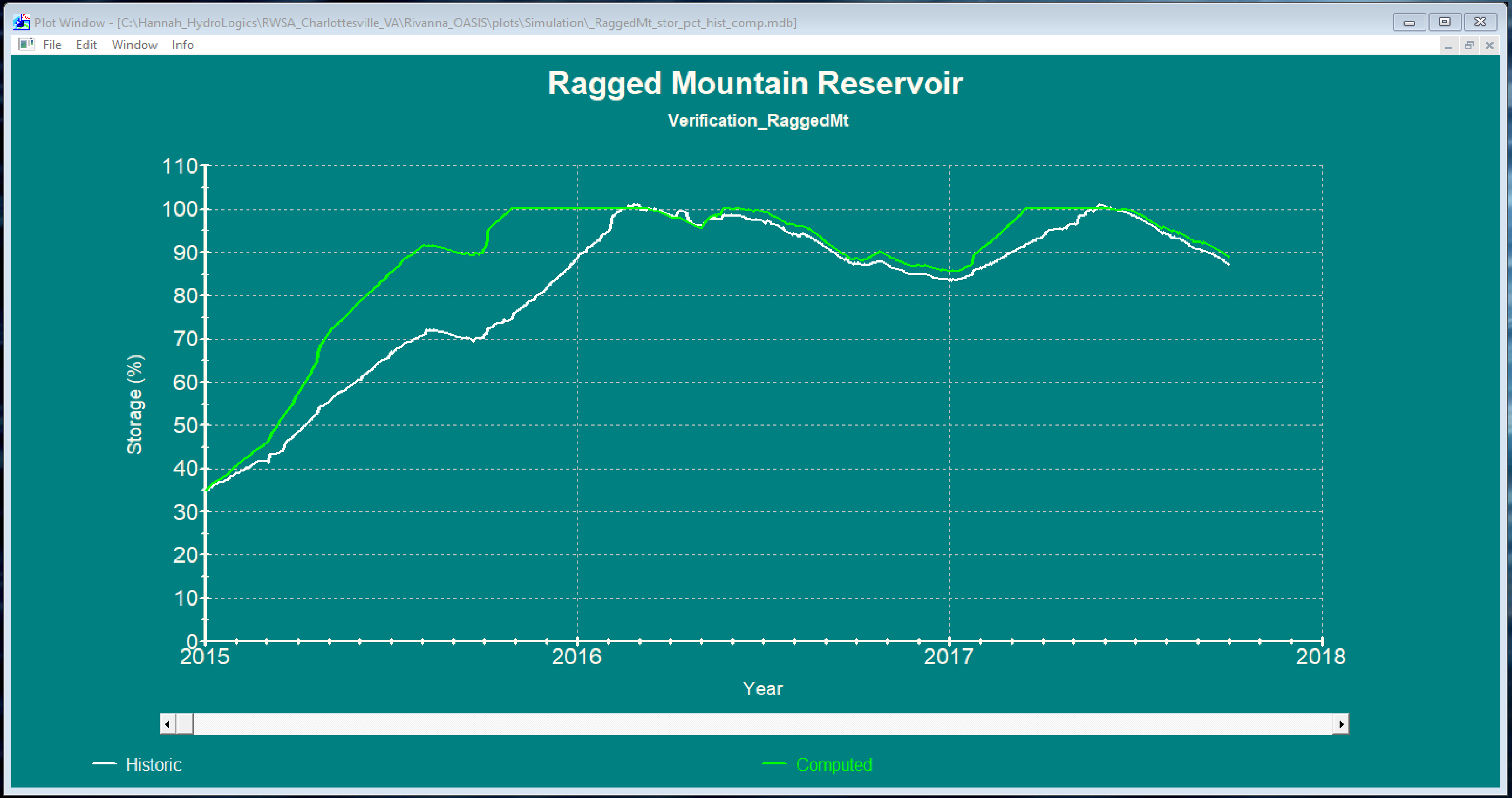
Using Gannett Fleming Inflows



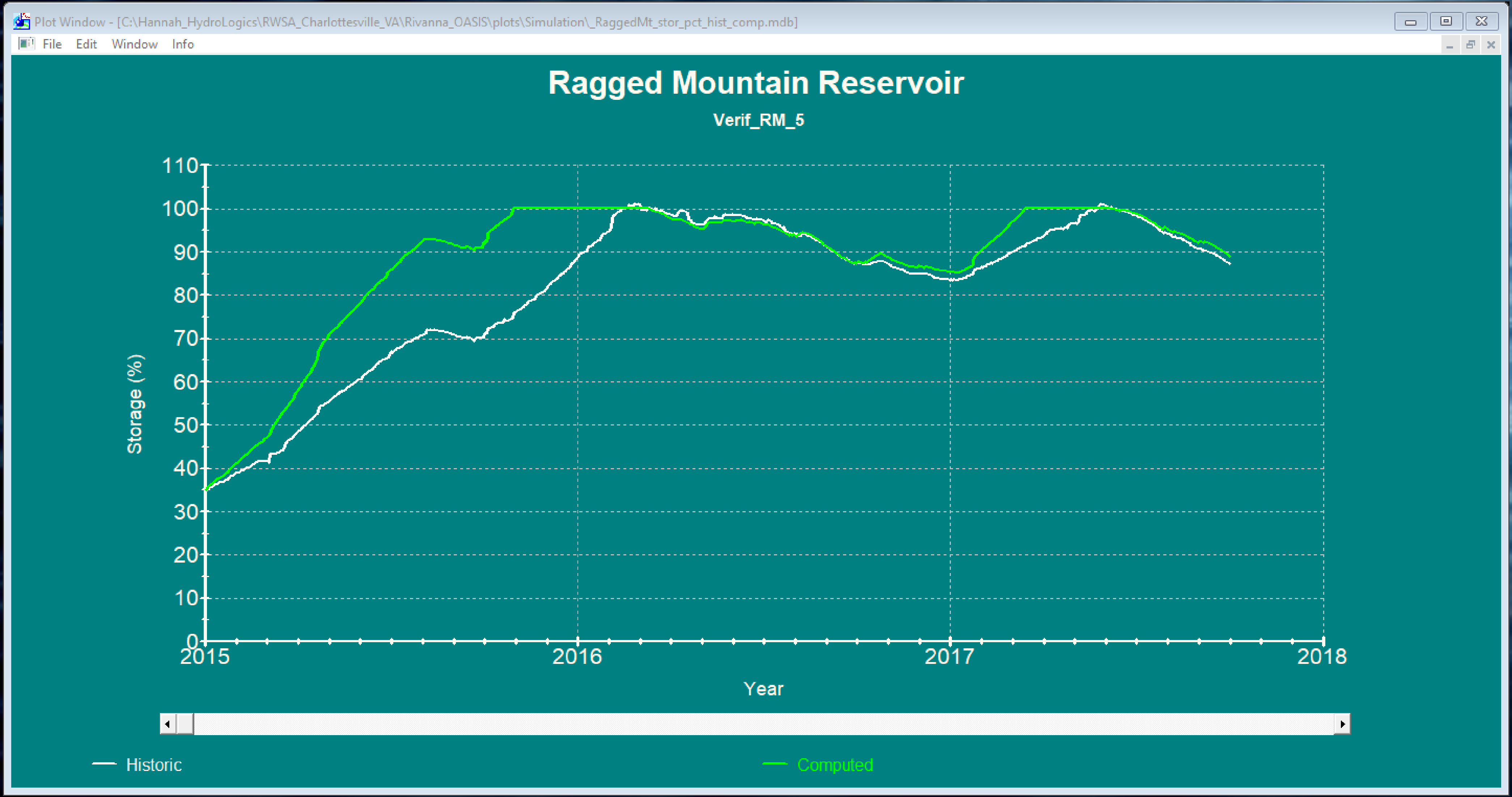
Using Gannett Fleming Inflows



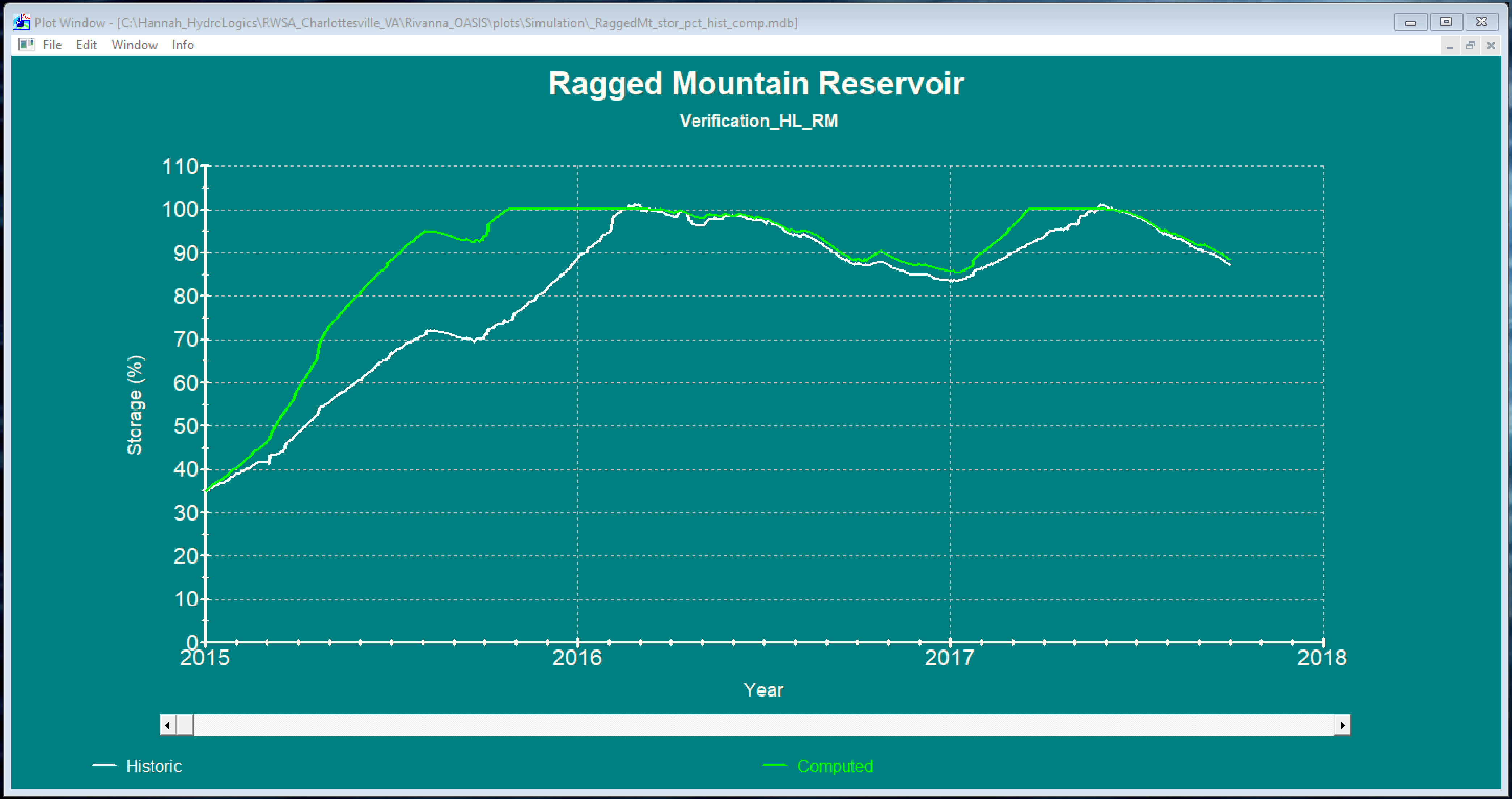
Using Gannett Fleming Inflows



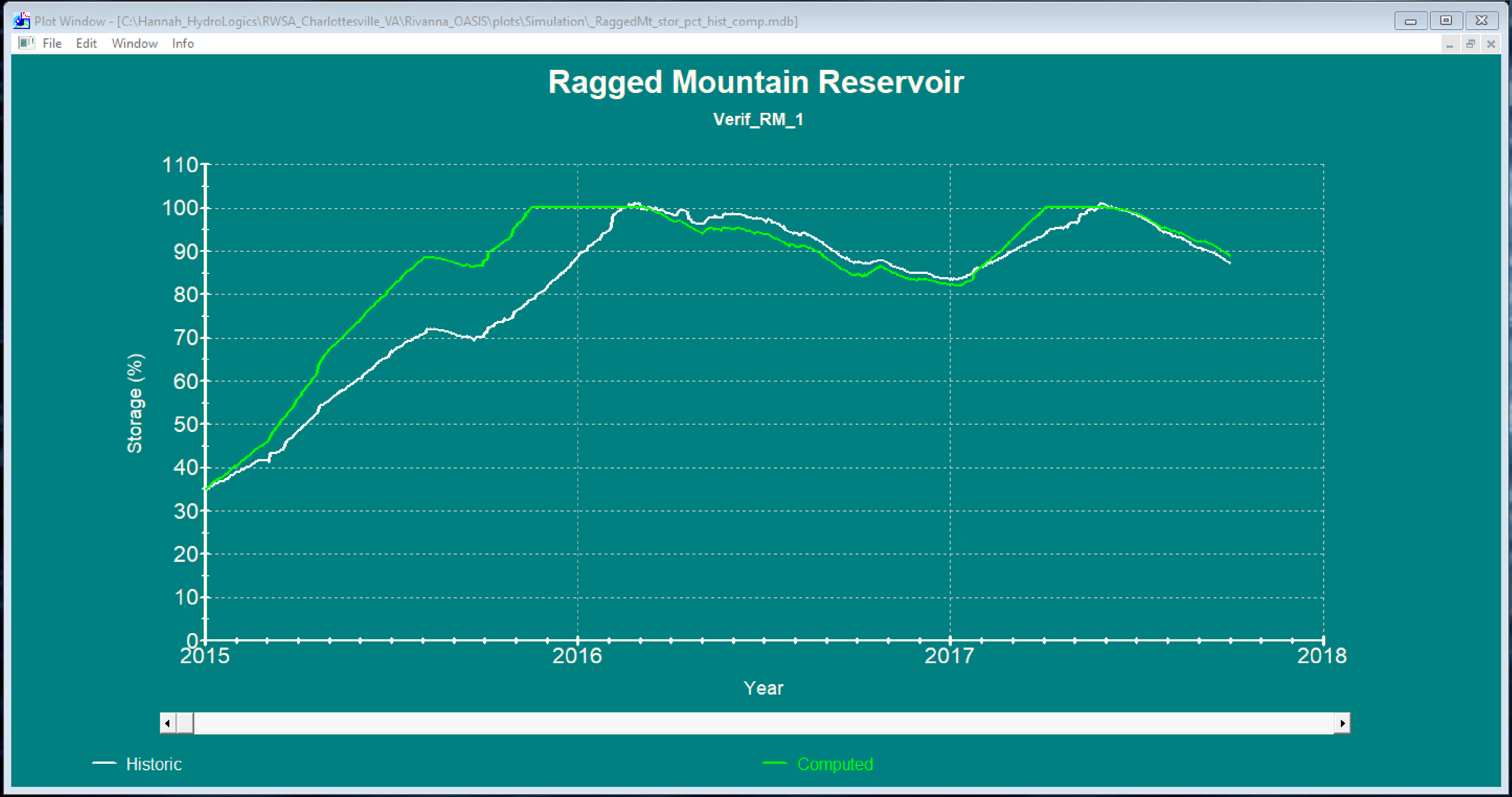
HydroLogics Inflows – DA adjustment of Moormans UIF



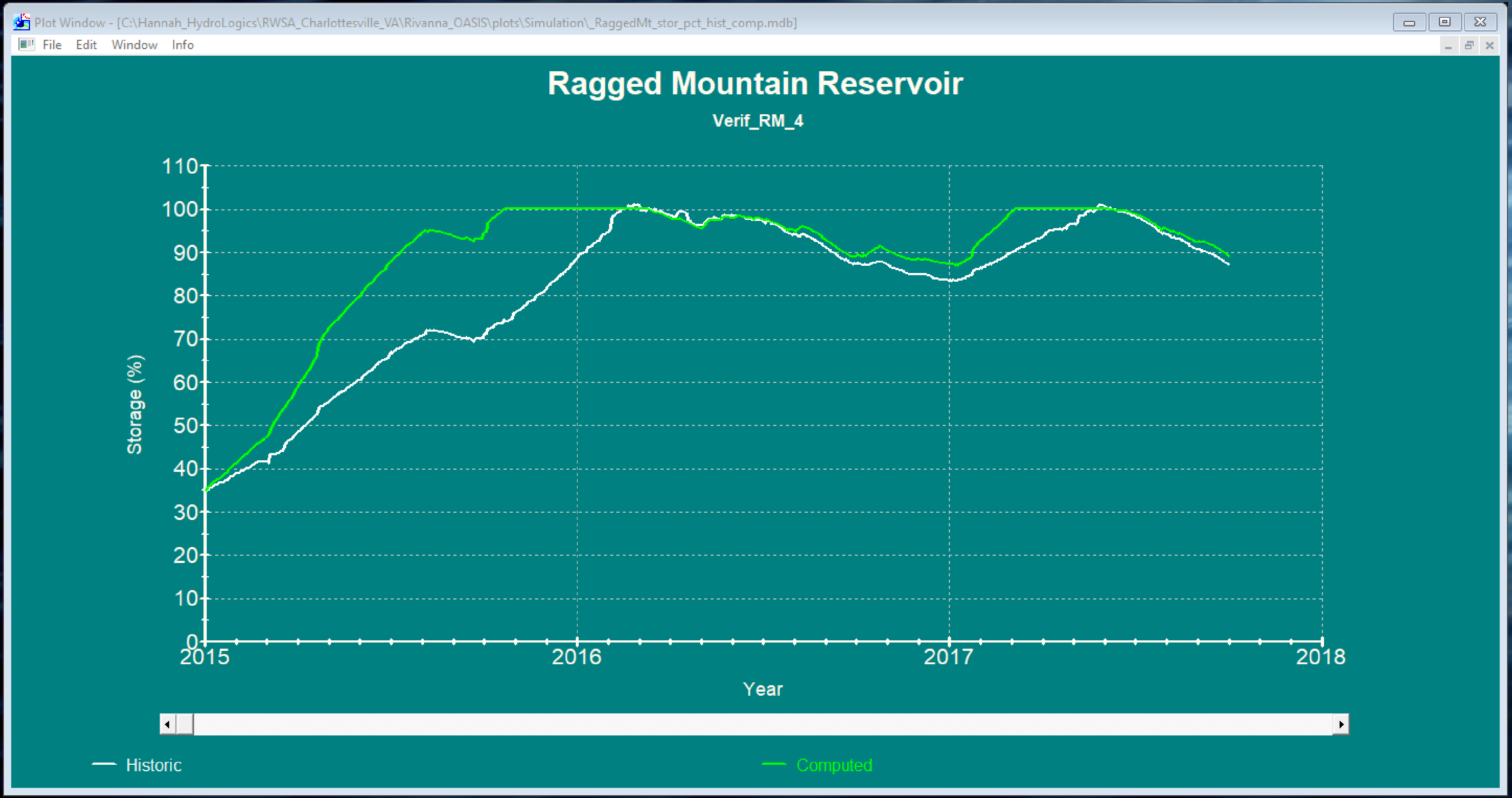
HydroLogics Inflows – DA Adjust of NF Moor filled in gage



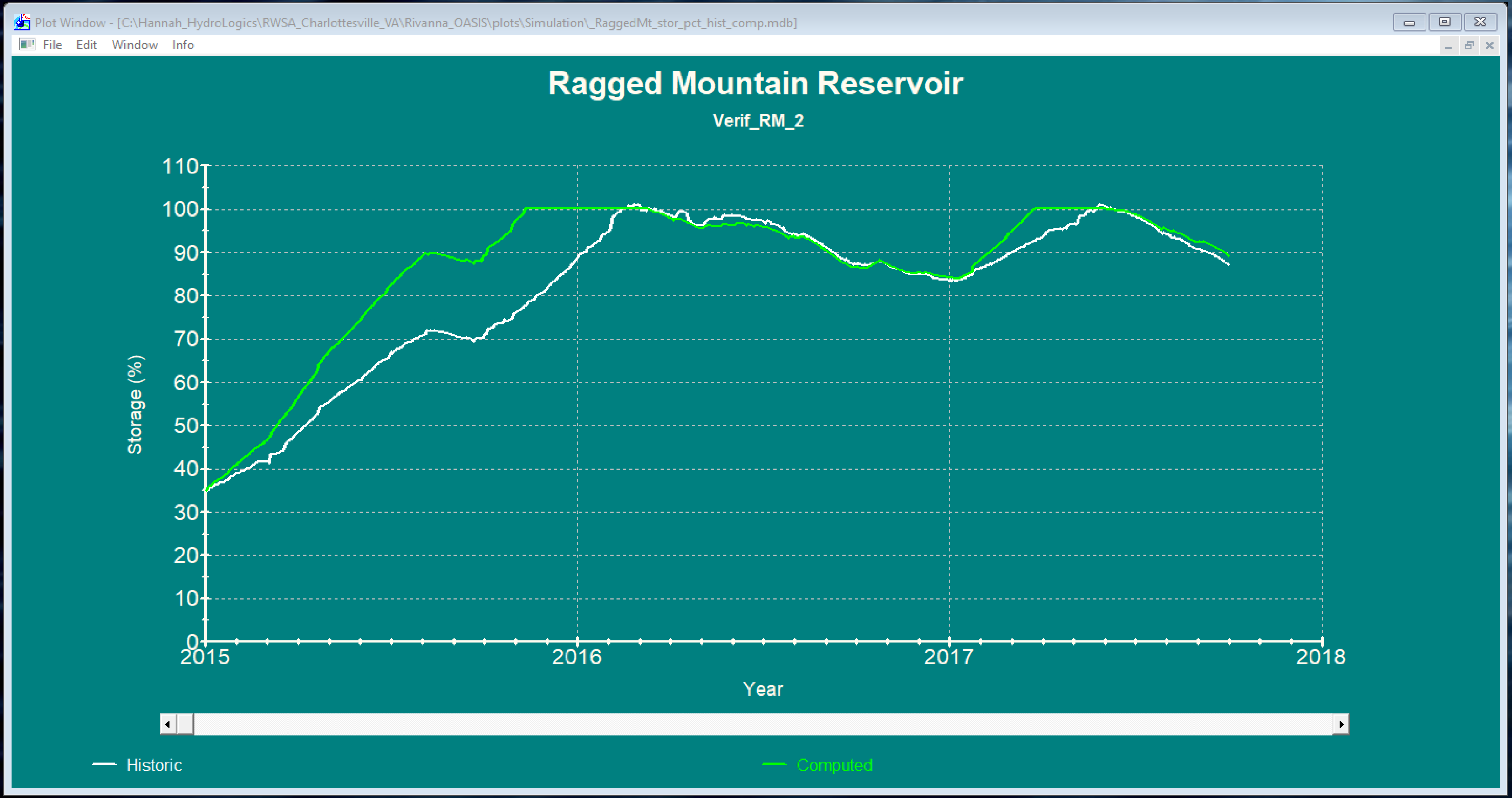
HydroLogics Inflows – DA adjustment of SF inflow



HydroLogics Inflows – DA adjustment of prov. SF inflow

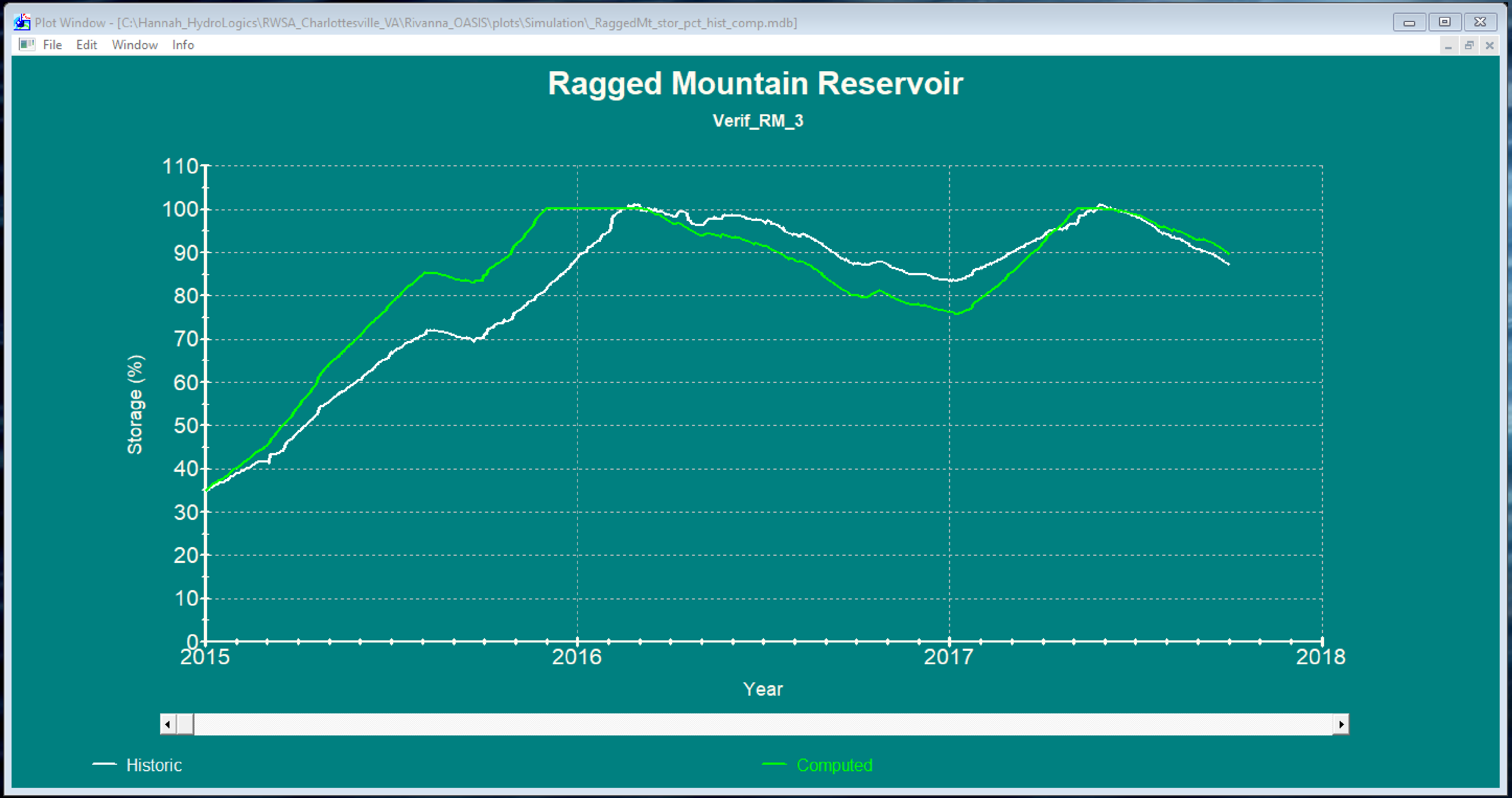


HydroLogics Inflows – DA adjustment of Mechums gage UIF



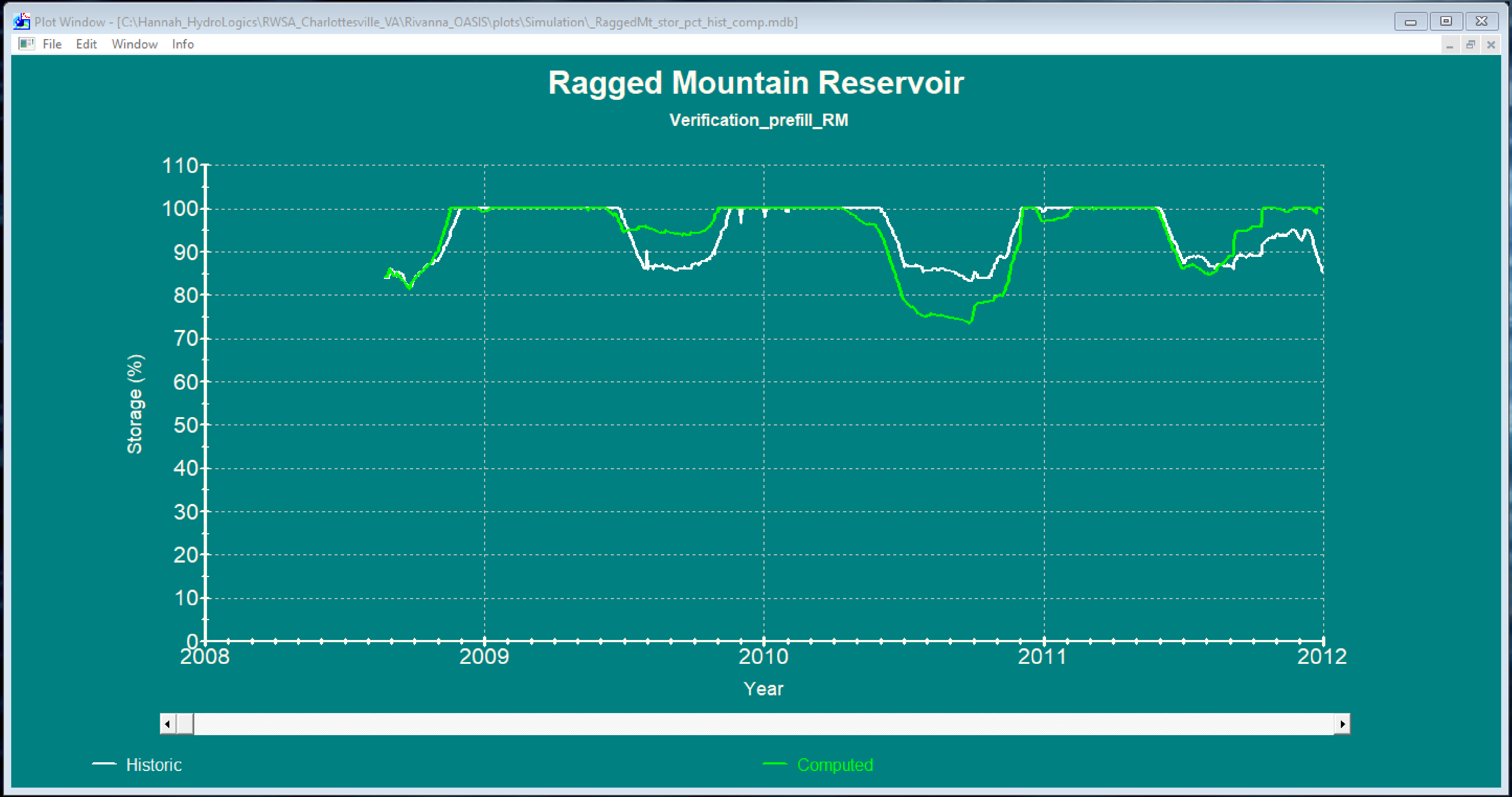
HYDROLOGICS

HydroLogics Inflows – DA adjustment of NF Rivanna Inflow

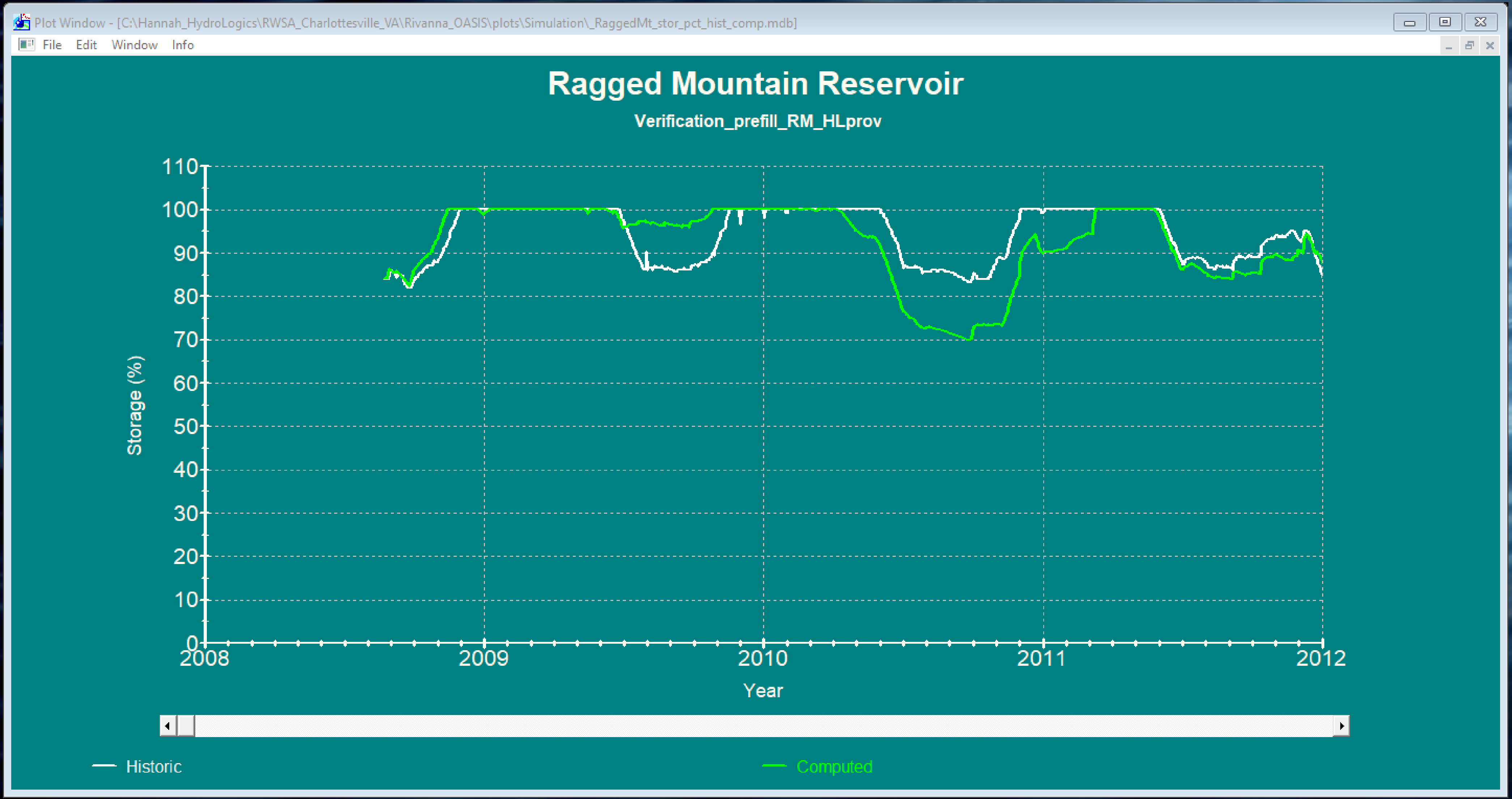


Ragged Mountain – Pre-Fill

Using Gannett Fleming Inflows

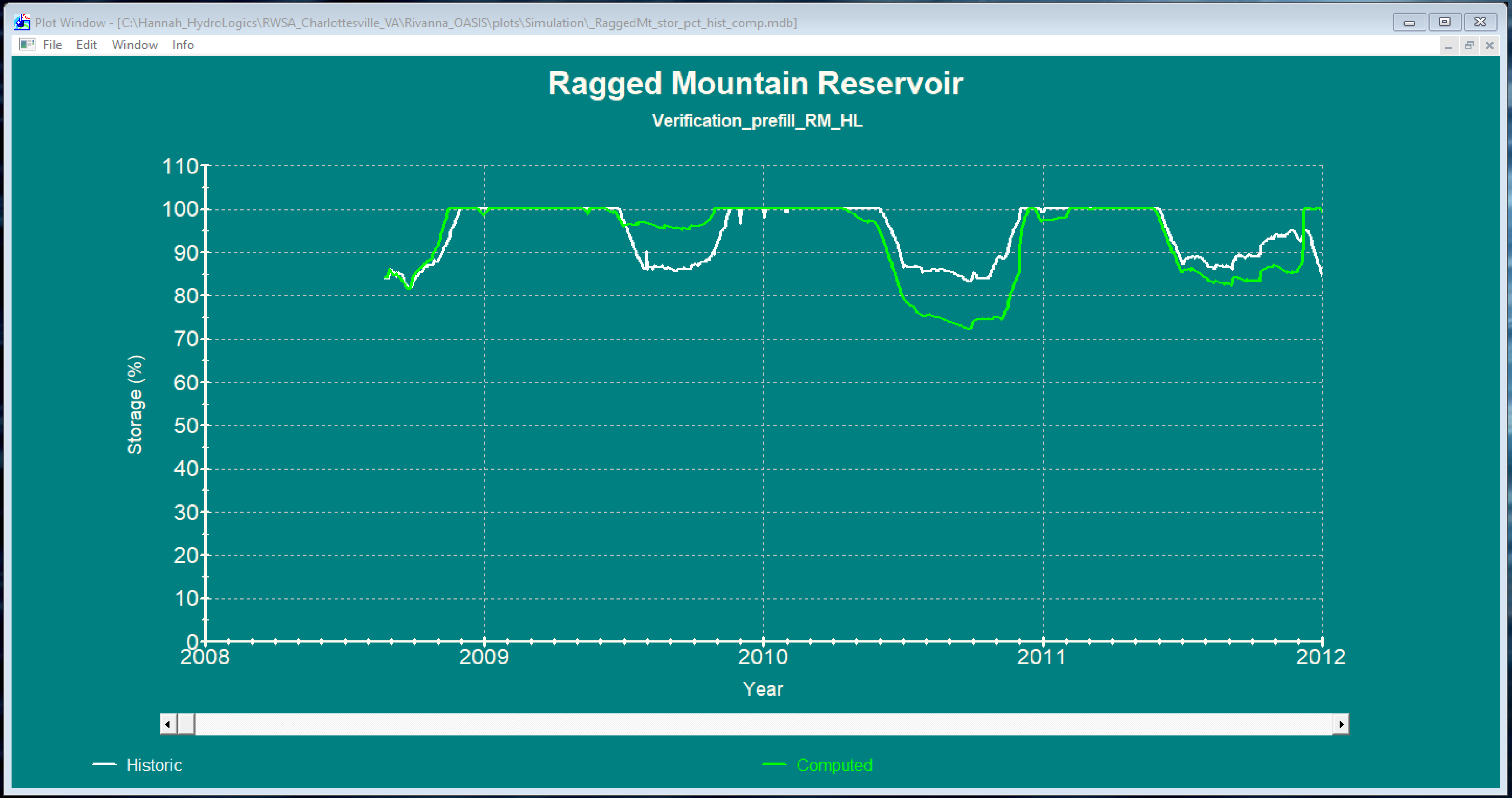


HydroLogics Inflows – DA adjustment of Moormans UIF

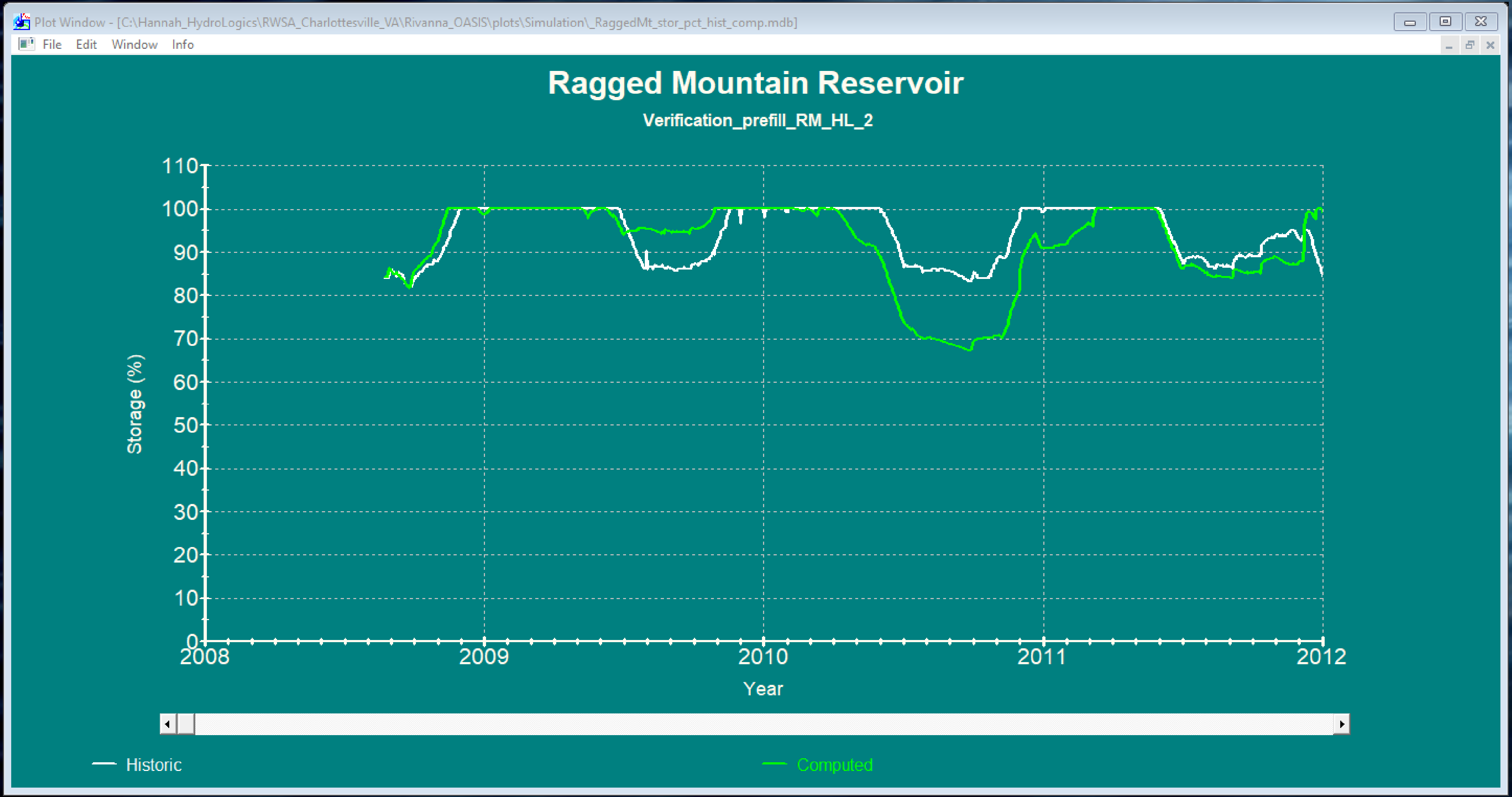


HYDROLOGICS

HydroLogics Inflows – DA Adjust of NF Moor filled in gage

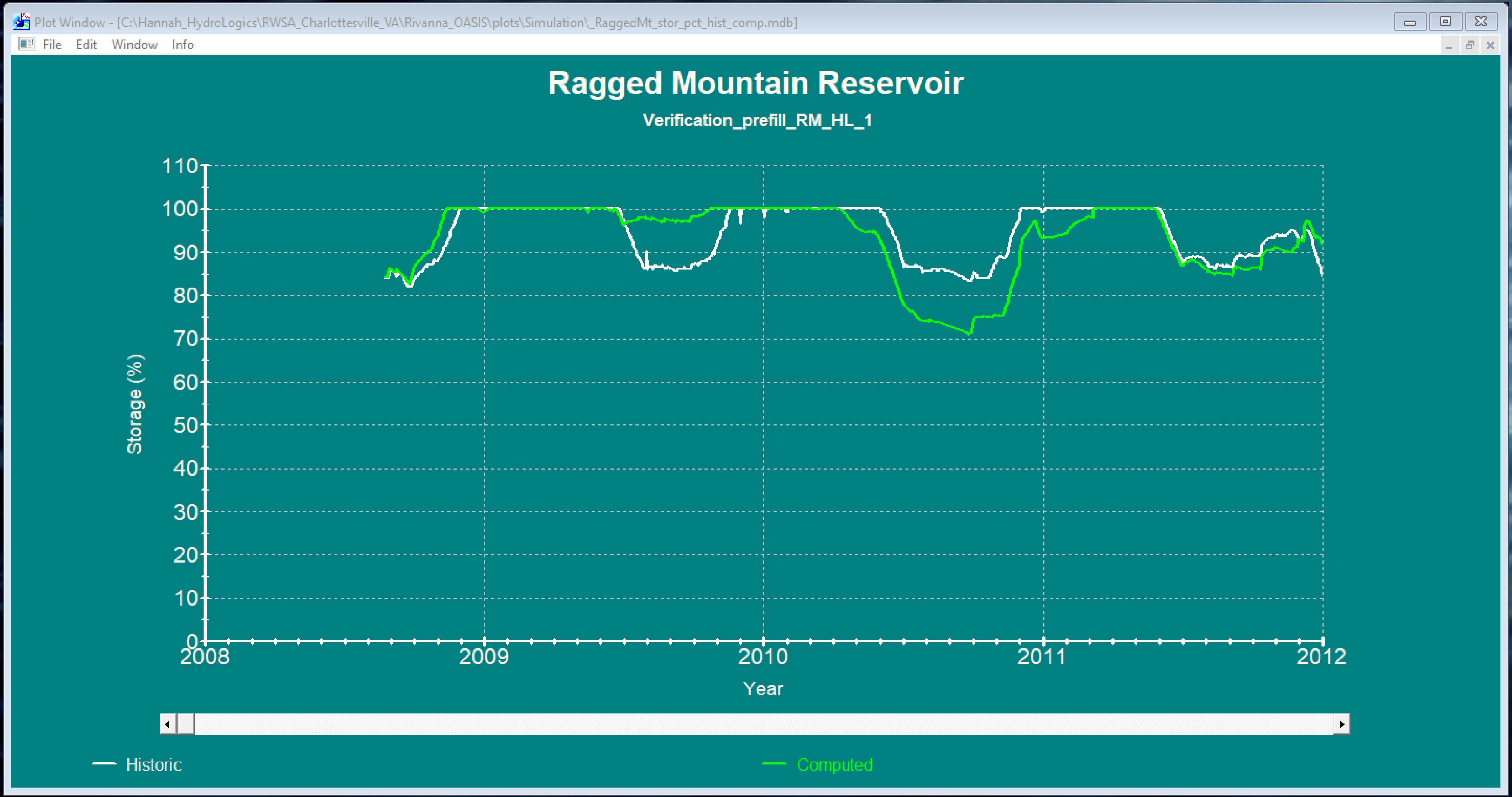


HydroLogics Inflows – DA adjustment of SF inflow



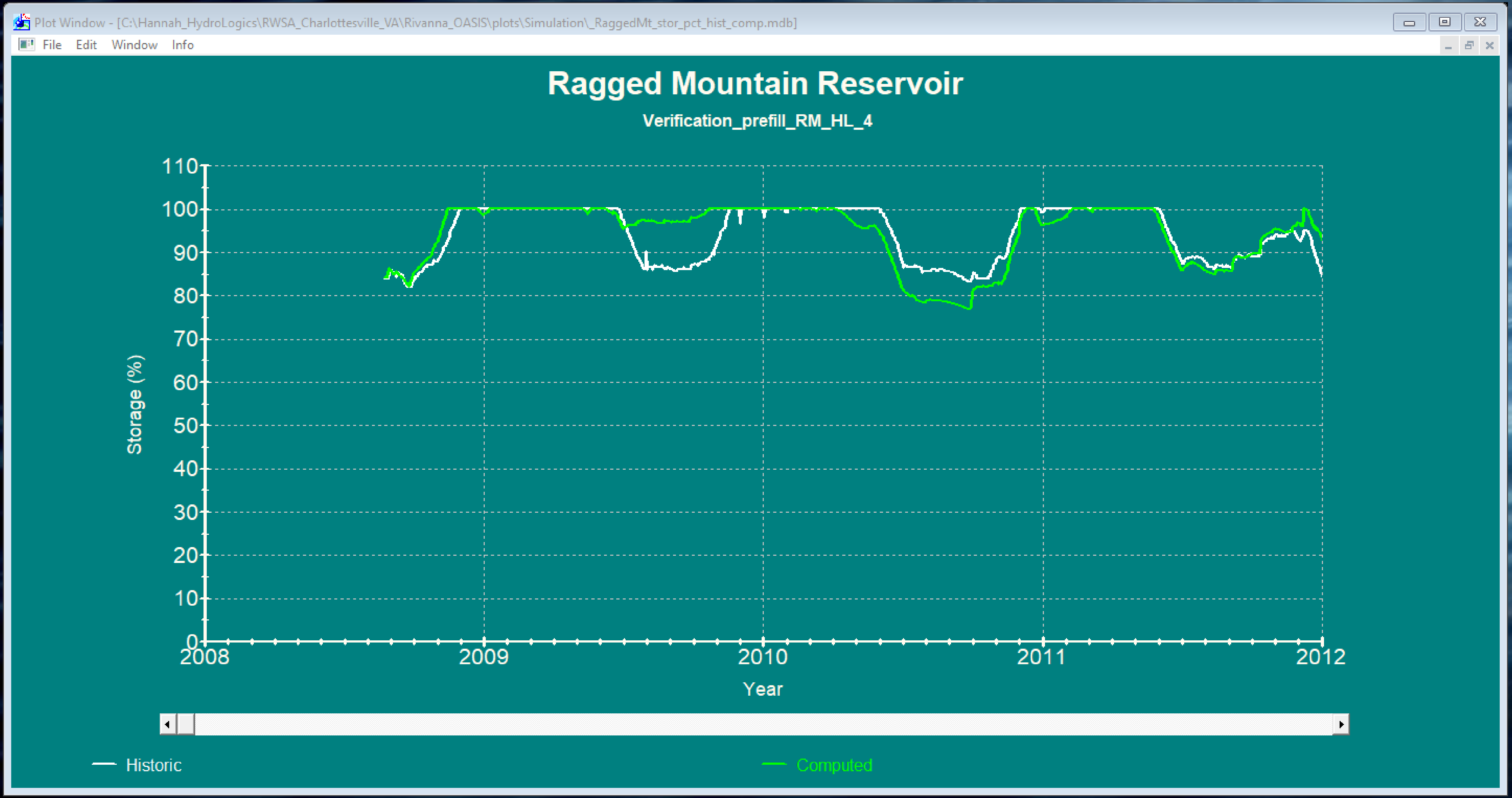
HYDROLOGICS

HydroLogics Inflows – DA adjustment of prov. SF inflow



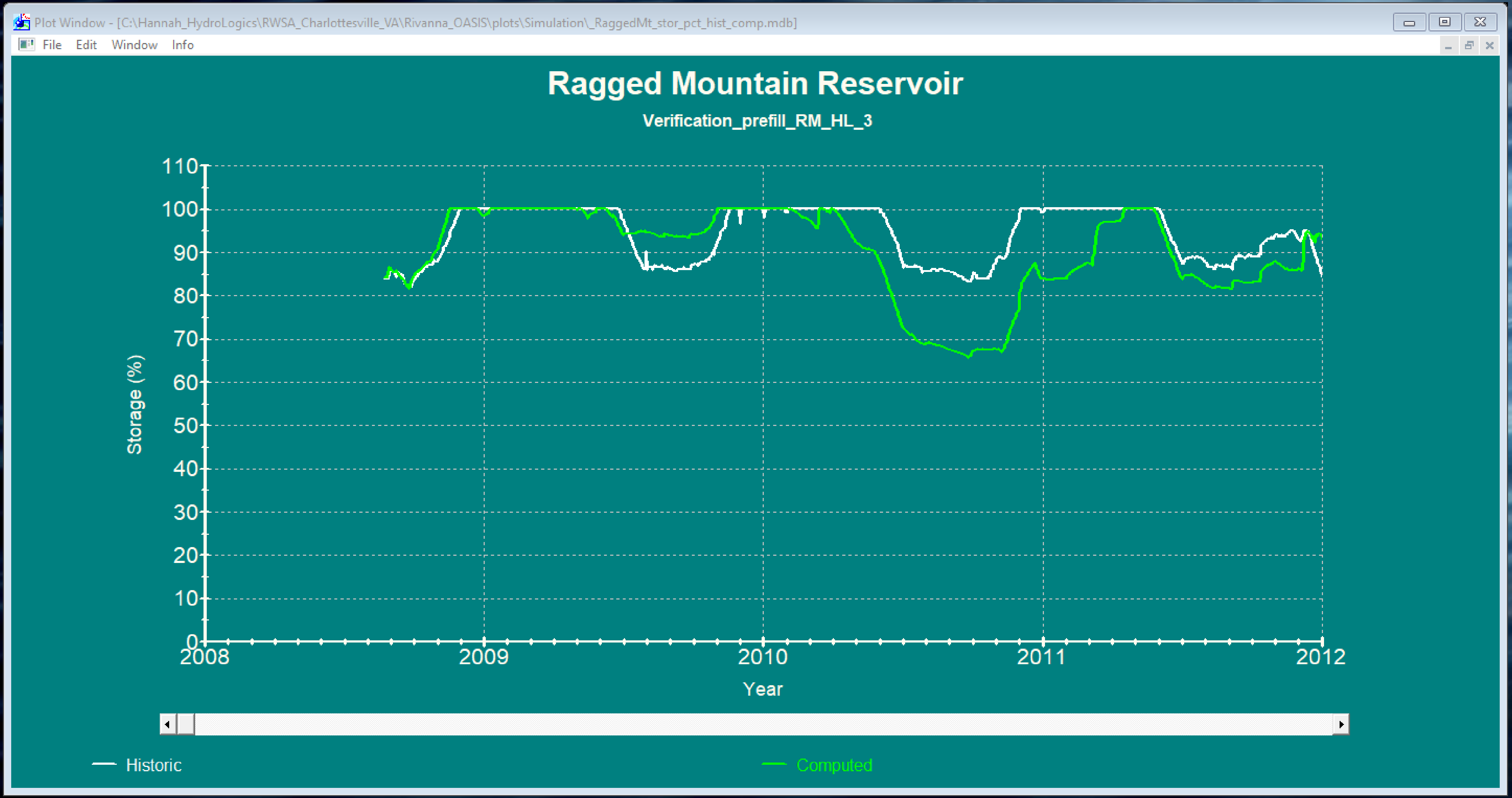
HYDROLOGICS

HydroLogics Inflows – DA adjustment of Mechums gage UIF



HYDROLOGICS

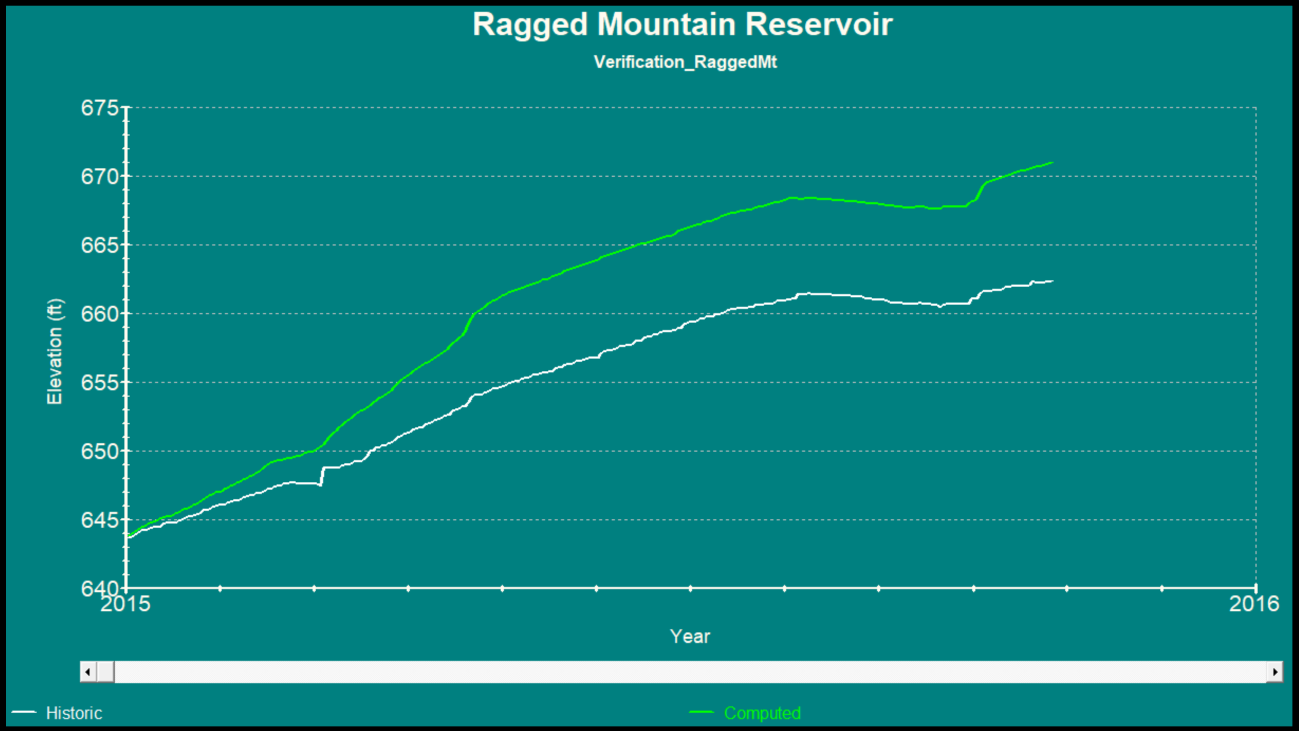
HydroLogics Inflows – DA adjustment of NF Rivanna Inflow



HYDROLOGICS

Ragged Mountain Reservoir

- Error is computed storage change – historic change in storage.
- On average an additional 1.42 MGD is going into reservoir.



Ragged Mountain Reservoir

Jan 1 to Oct 26, 2015

All units in MG

	Computed	Historic
Release	23	23
RWSA Delivery	231	231
Transfer from Sugar Hollow	949	949
Nat Inflow	405	??
Net evap	12	??
Storage Change	1088	663
Starting elevation (feet)	643.9	643.9
Ending elevation (feet)	671	662.4
Elevation change (feet)	27.1	18.5

Error = 1088 - 663, or 424 MG over the course of 9 months, or 298 days

or 1.42 mgd

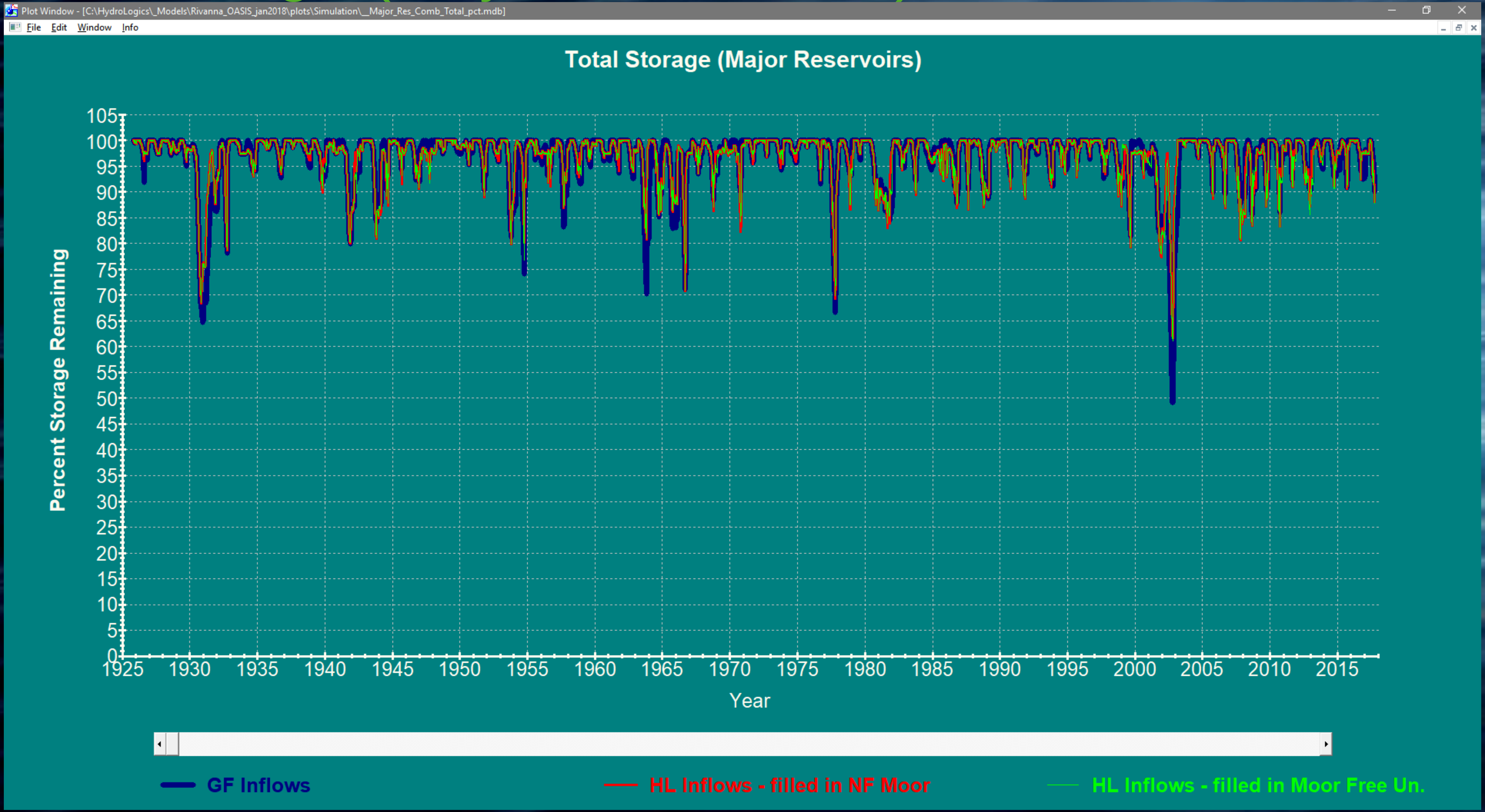
Average production	0.8	mgd
Average release	0.1	mgd
Average outflow	0.9	mgd
Average inflow	4.5	mgd

Period of Record Results

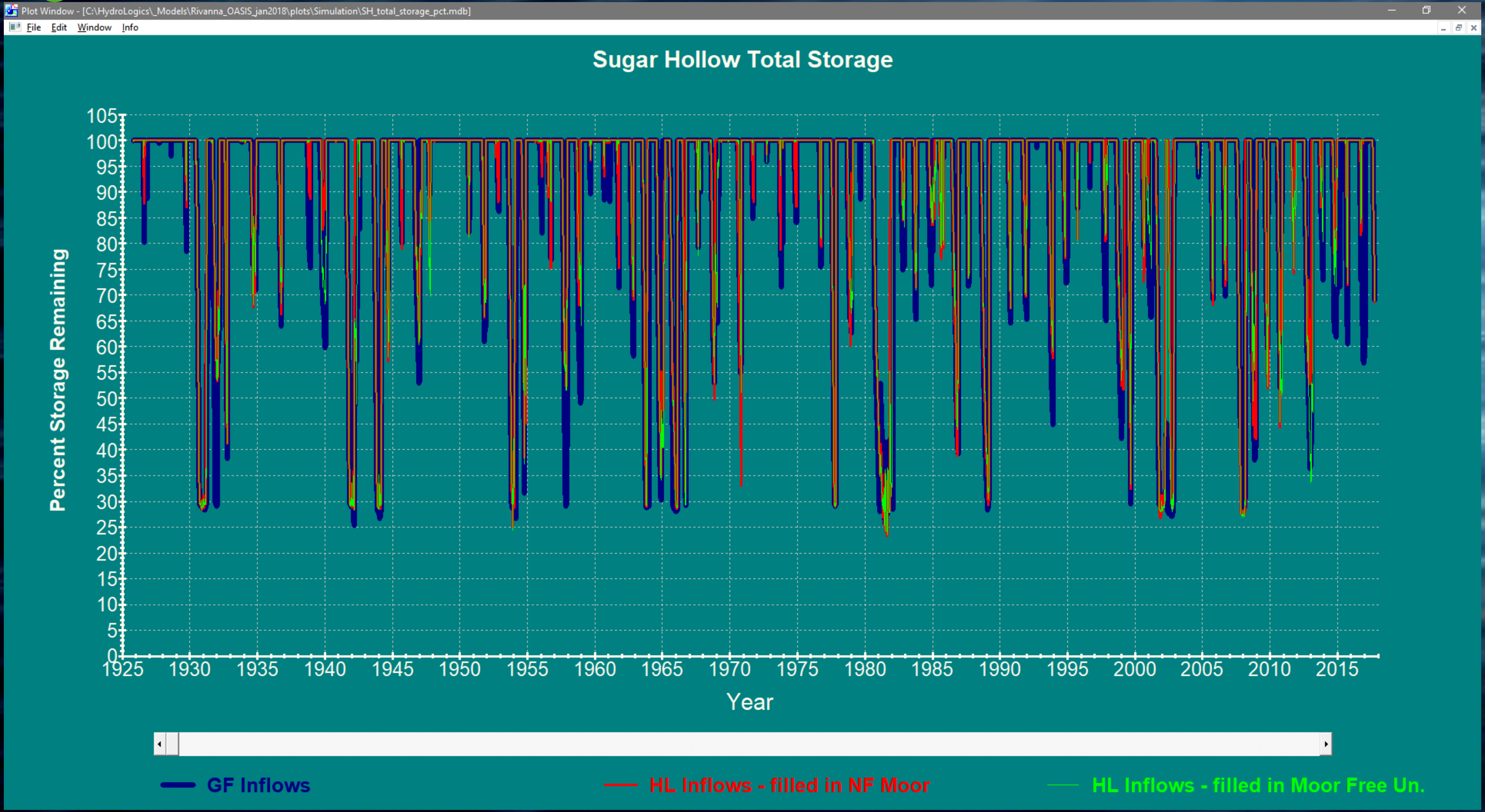
- For Sugar Hollow, show two options for HydroLogics inflows:
  1) Filled in NF Moormans gage
  2) Filled in Moormans Free Union gage

- Since the 1999 landslide altered the topography of the North Fork Moormans watershed and there are concerns that the historic gage flow may not accurately represent current runoff characteristics, would prefer to use the Free Union gage if results are similar

Total Storage (Major Reservoirs)

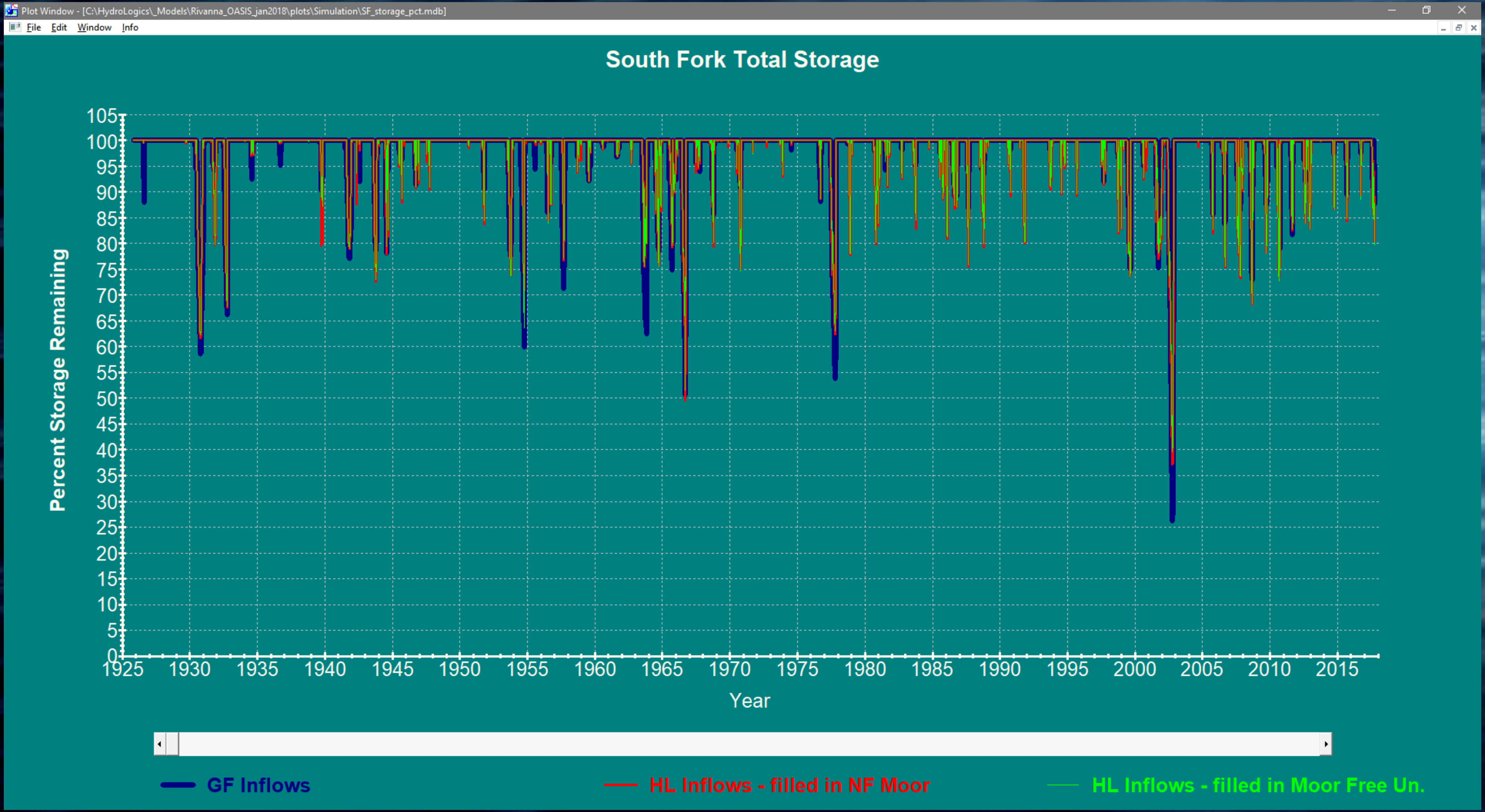


Sugar Hollow

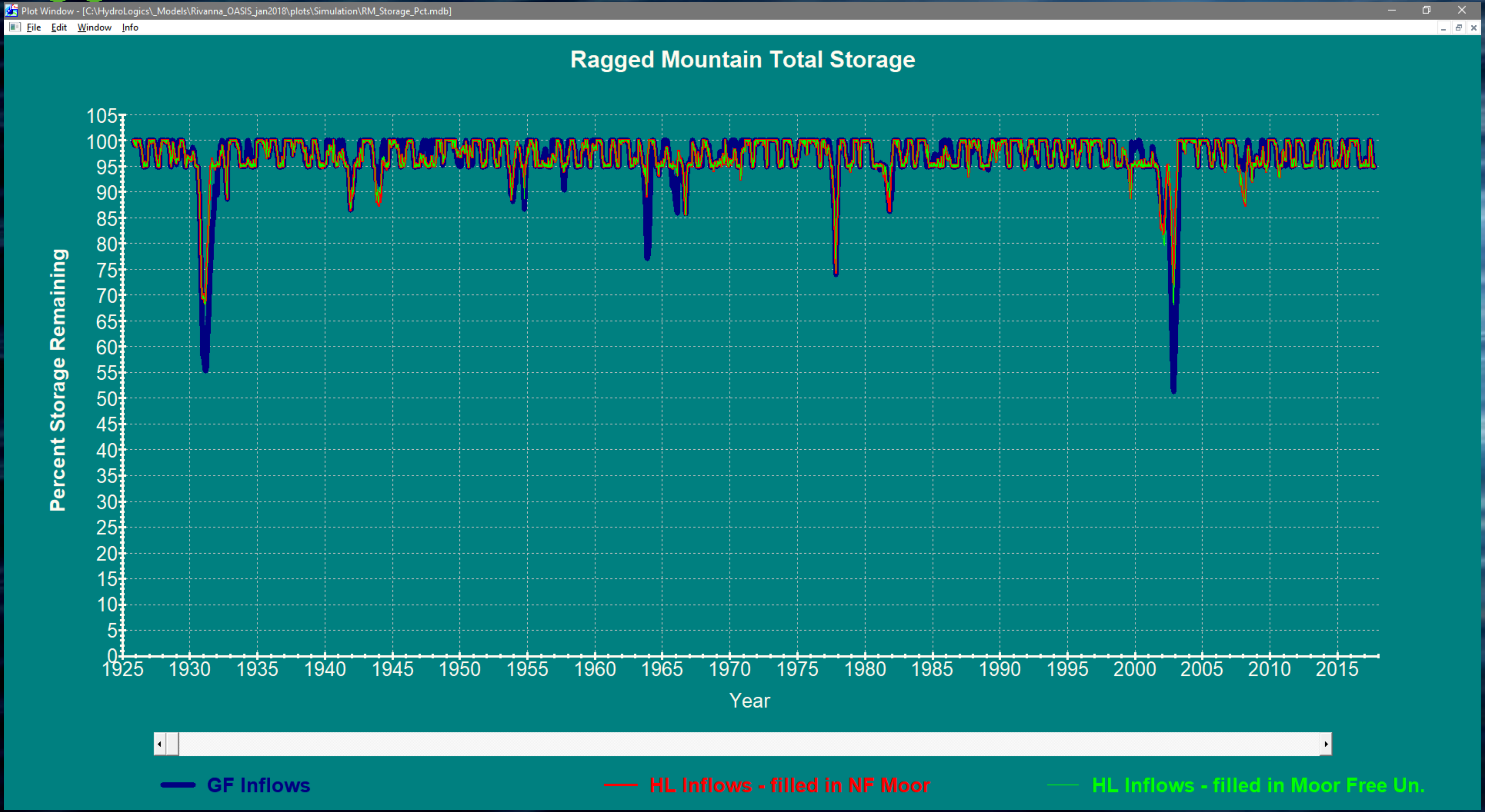


HYDROLOGICS

South Fork

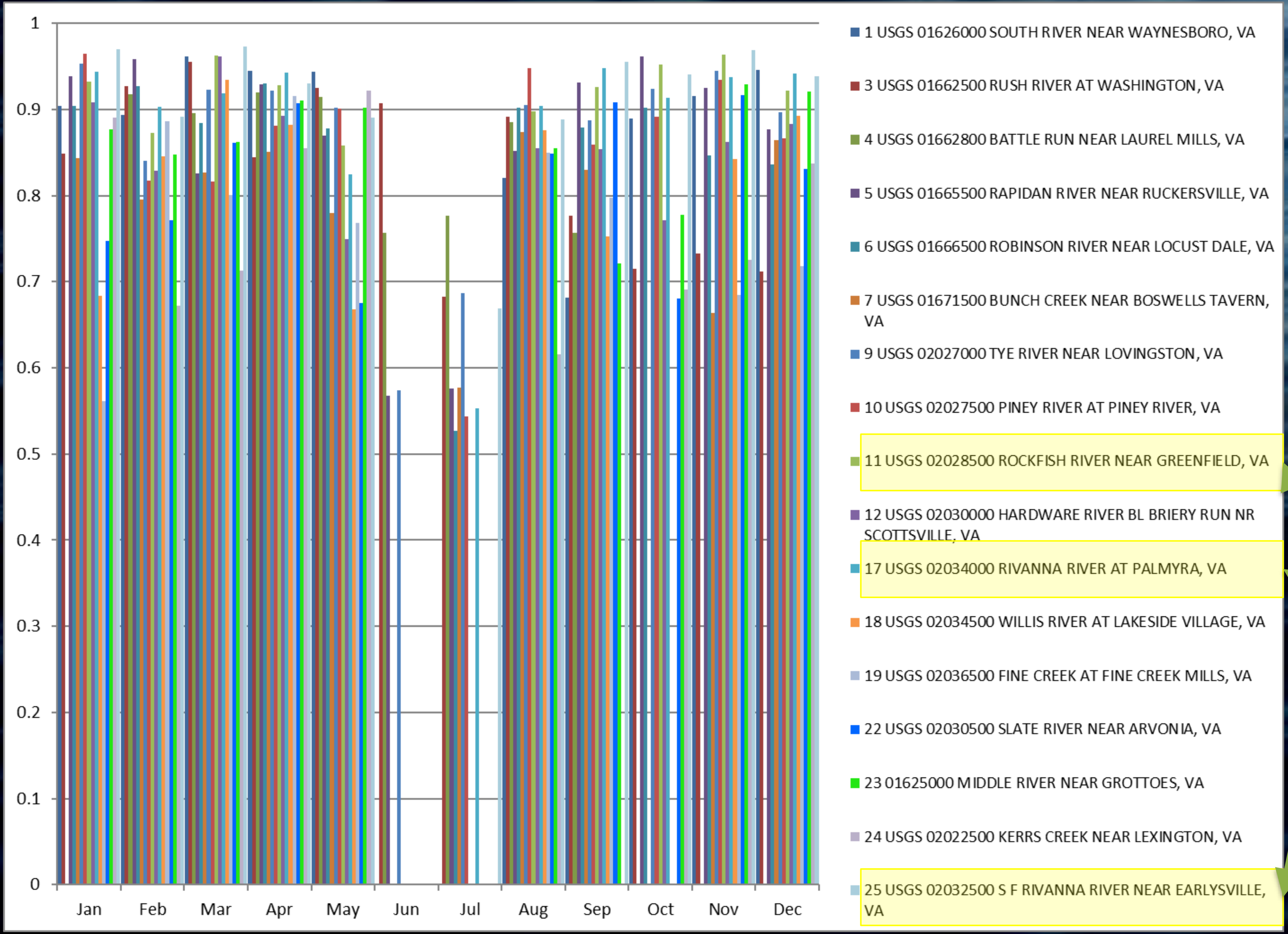

Plot Window - [C:\HydroLogics_Models\Rivanna_OASIS_jan2018\plots\Simulation\SF_storage_pct.mdb]
File Edit Window Info
South Fork Total Storage
Percent Storage Remaining
105
100
95
90
85
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
1925 1930 1935 1940 1945 1950 1955 1960 1965 1970 1975 1980 1985 1990 1995 2000 2005 2010 2015
Year
GF Inflows
HL Inflows - filled in NF Moor
HL Inflows - filled in Moor Free Un.

Ragged Mountain



Correlations for Gage Extension

North Fork Moormans River Monthly Correlations



Strongest Monthly Gage Correlations

Note: gages unimpaired first if impairment data are needed (e.g., Palmyra)

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North Fork Moormans River Annual Correlations

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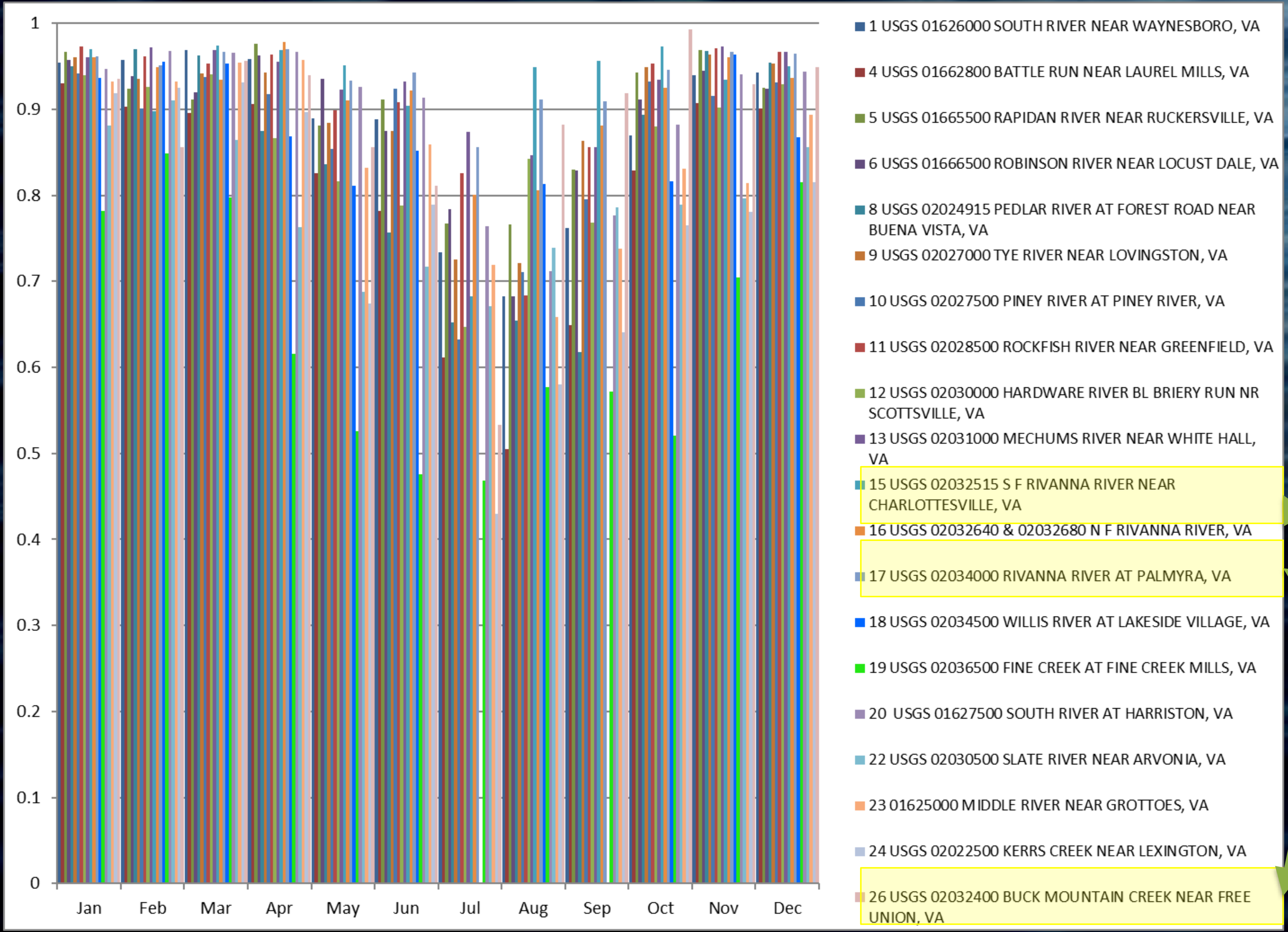
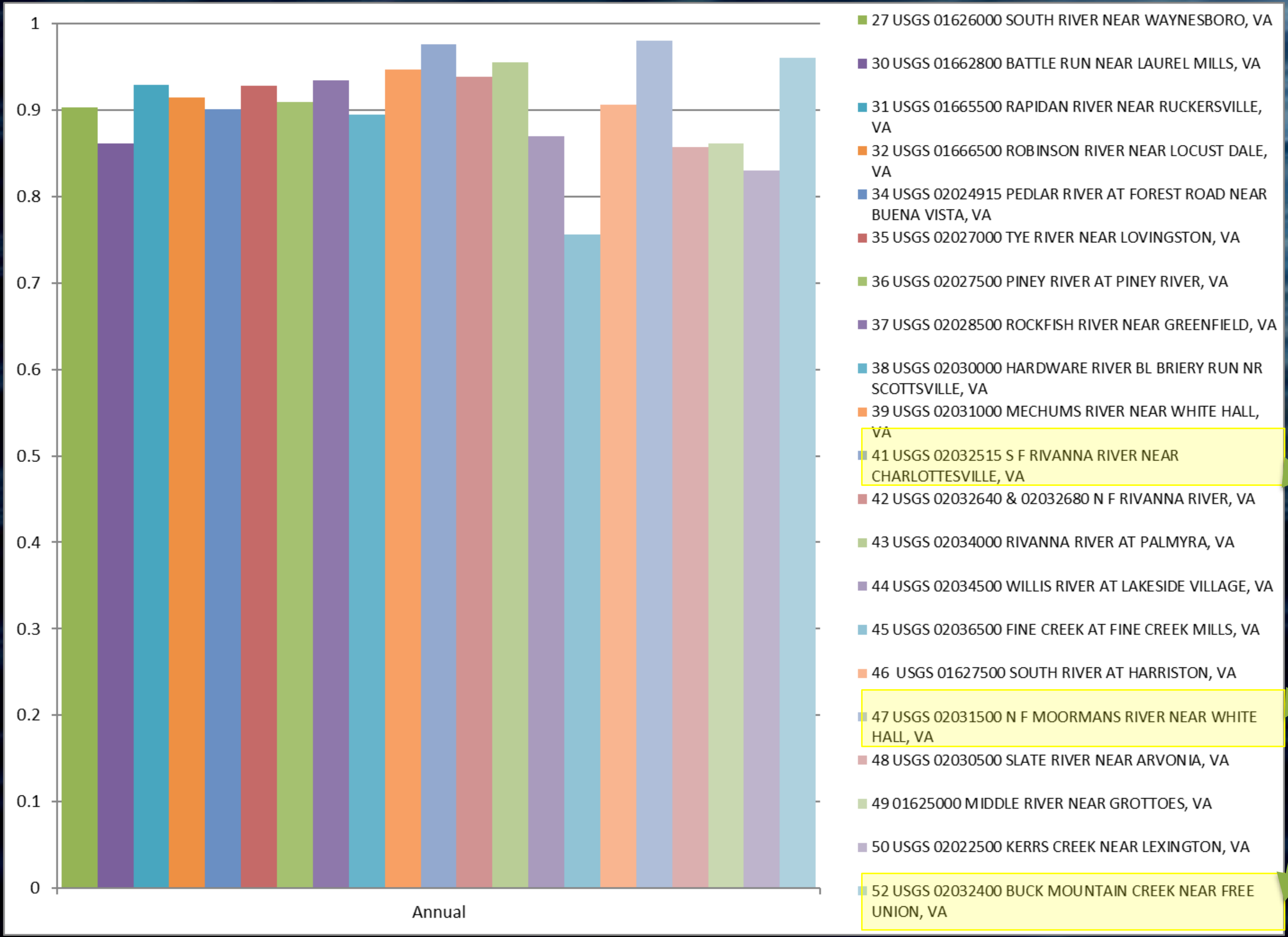
Moormans near Free Union Monthly Correlations



Strongest Monthly Gage Correlations

Moormans near Free Union Annual Correlations



Strongest Annual Gage Correlations

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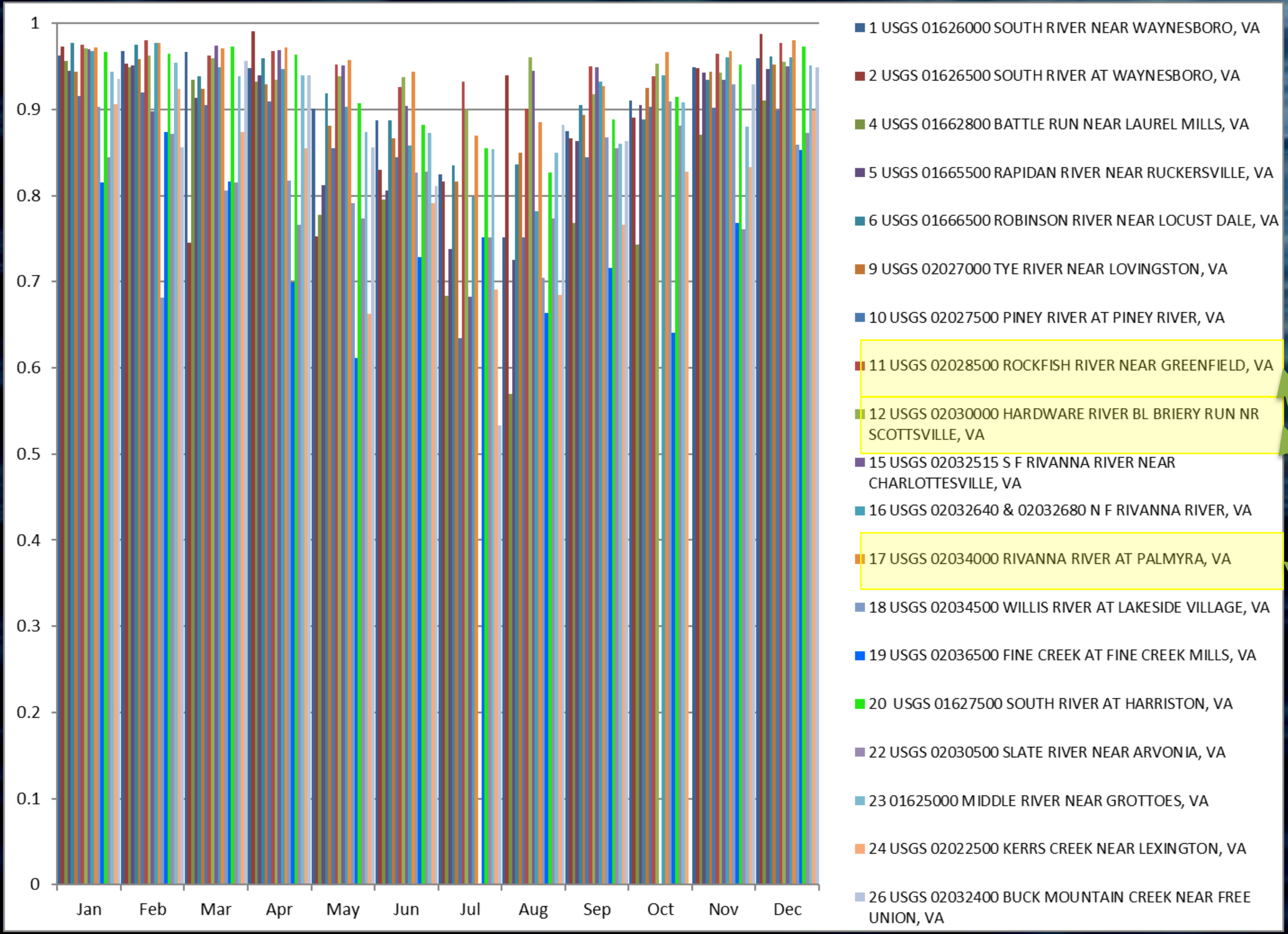
Mechums Monthly Correlations



Strongest Monthly Gage Correlations

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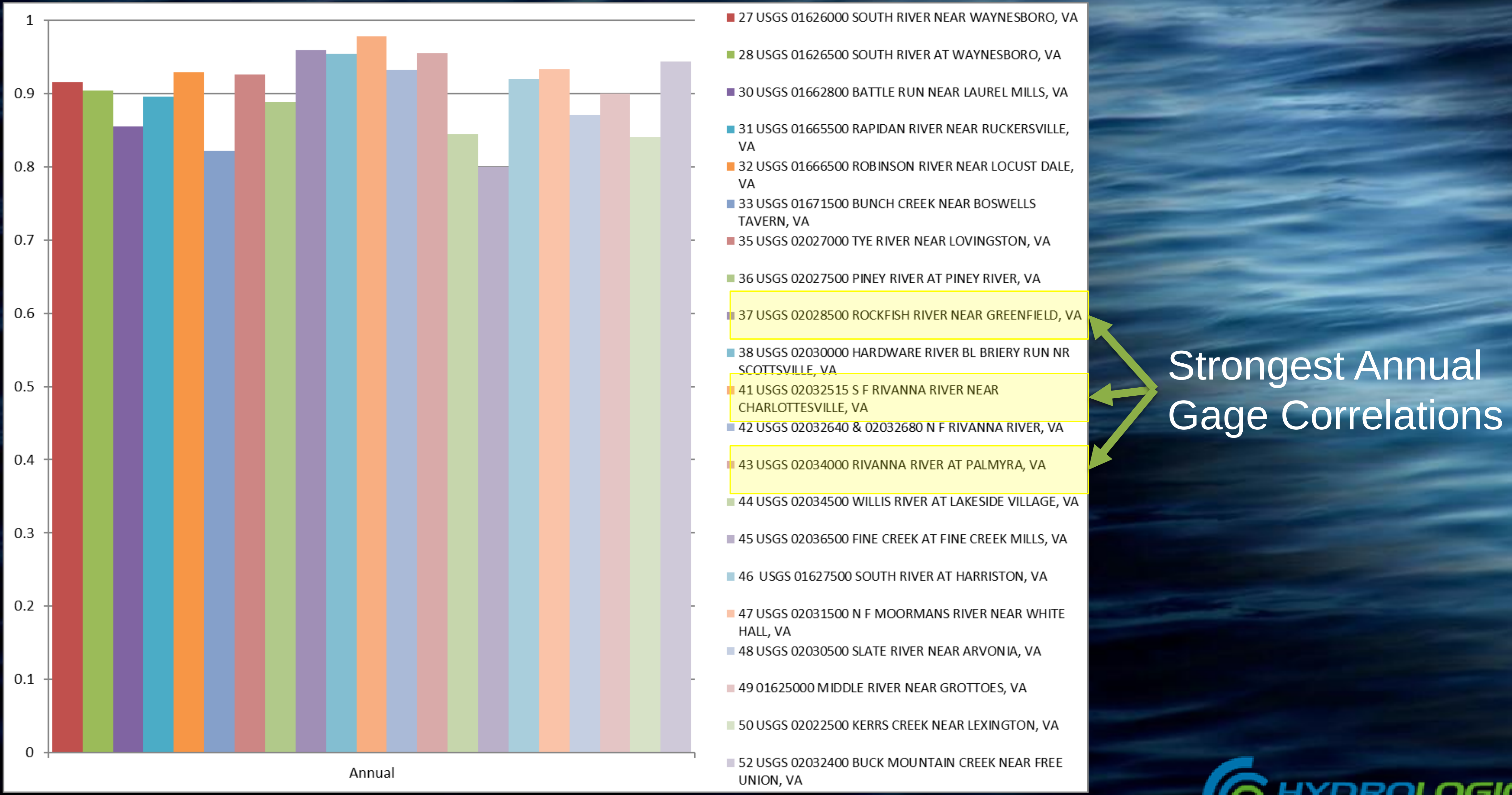
Mechums Annual Correlations



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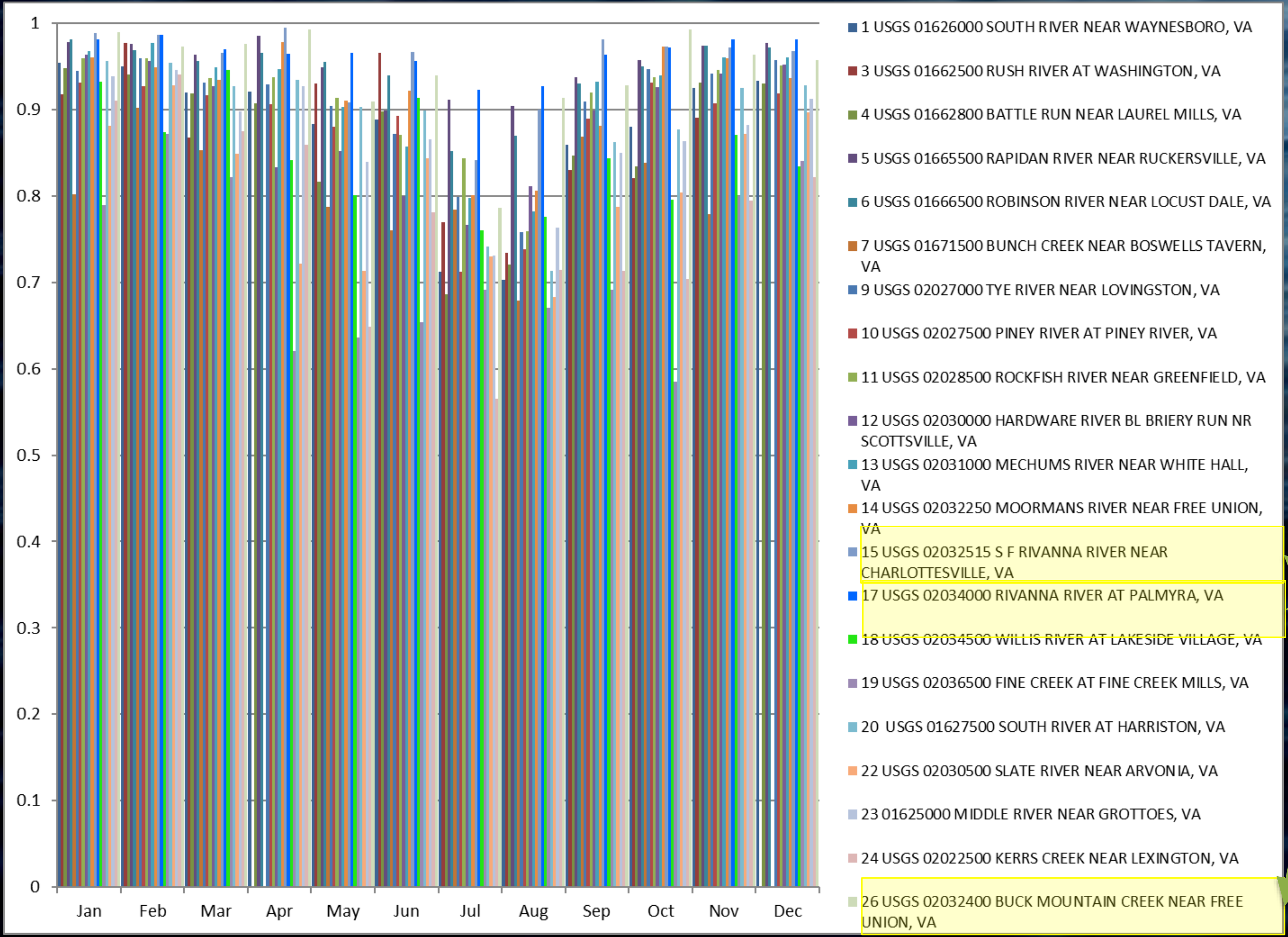
NF Rivanna Monthly Correlations



Strongest Monthly Gage Correlations

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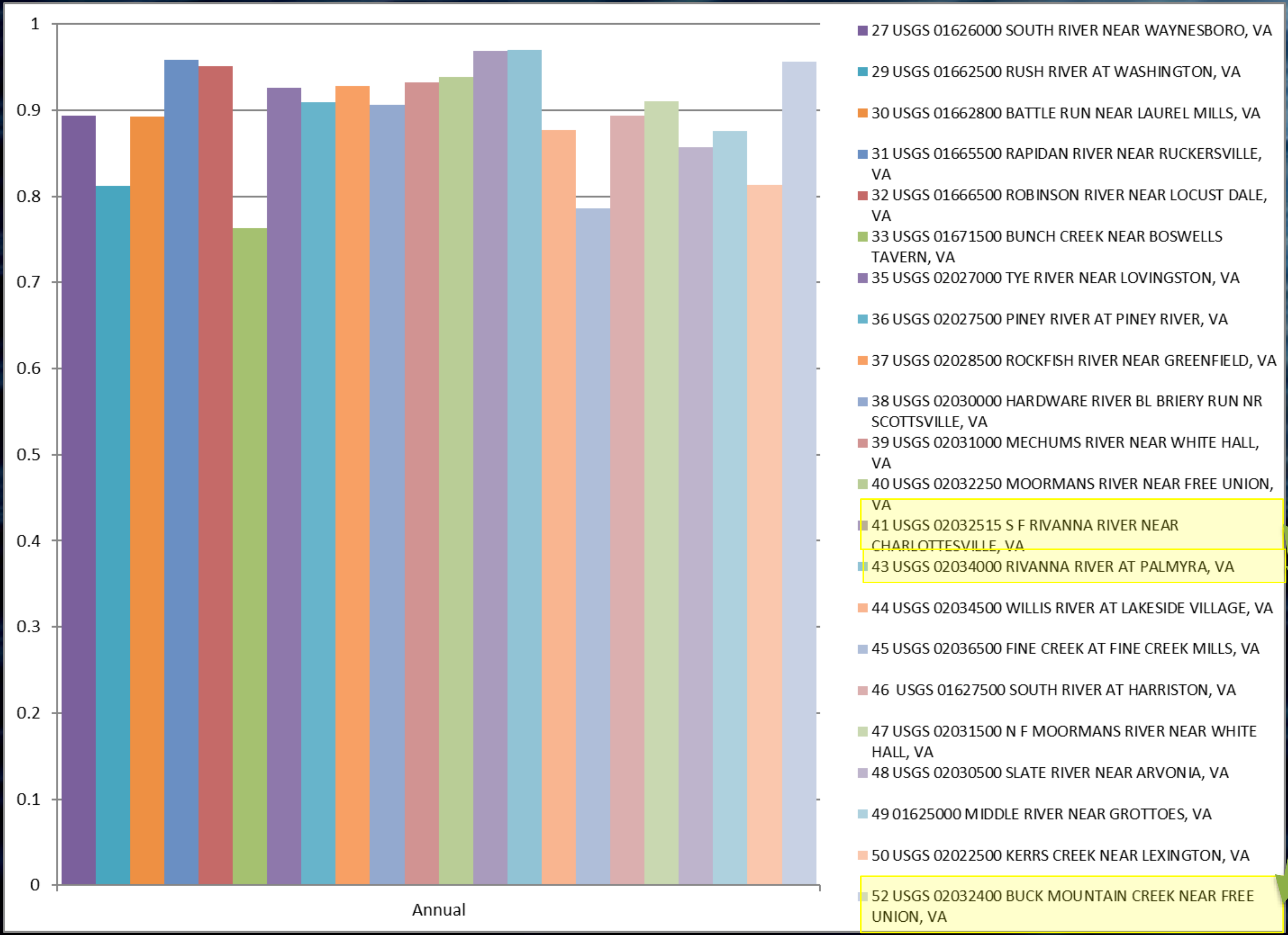
NF Rivanna Annual Correlations



Strongest Annual Gage Correlations

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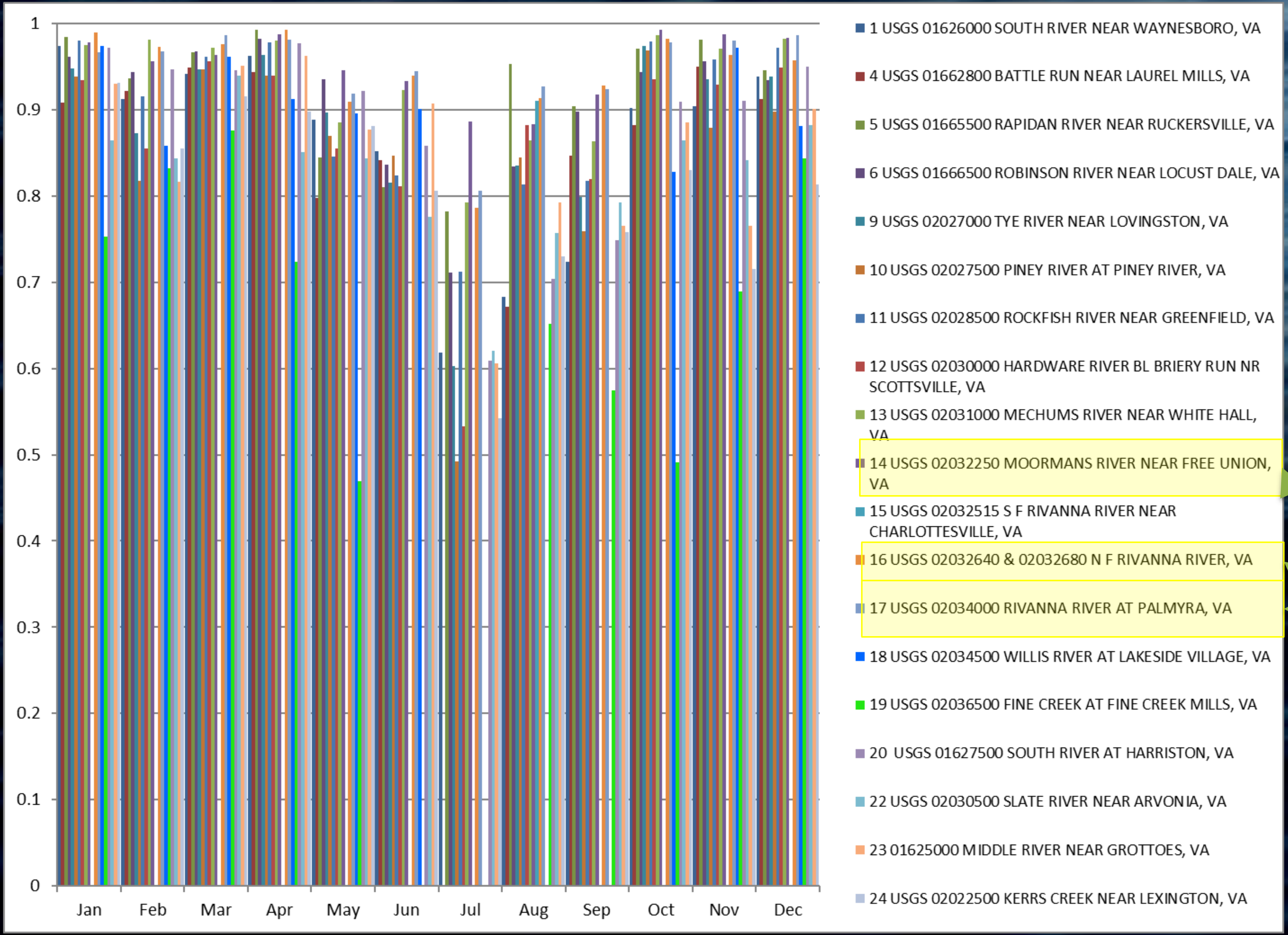
Buck Mountain Monthly Correlations



Strongest Monthly Gage Correlations

Buck Mountain Annual Correlations

Strongest Annual Gage Correlations

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Next Steps

- Finalize comprehensive inflows & documentation

- Finalize provisional inflows and technique for updating inflows for RWSA staff and OASIS model forecasts
  - An inflow update tab will be provided in the OASIS model that automates the calculations

Likely provisional recommendations:

- Sugar Hollow: unimpaired Moormans gage, scaled back to dam (x 0.226)
- South Fork: unimpaired Moormans + Mechums gages, scaled up to SF inflow
  - If computing ***total*** inflow to SF, factor is x 1.50
  - If computing ***local*** inflow to SF, factor is x 0.85, since the model has inflows at SH and Mechums gage
- Ragged Mountain: Mechums gage, scaled to dam (x 0.018)

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Appendix D. PowerPoint Presentation: Inflow Verification and Development

RWSA OASIS Model Update Review

May 16, 2018

Steven Nebiker

Casey Caldwell

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Scope of Work

- Operations Exercise
- Inflow Development
- Operating Rule Refinement
- Training
- DEQ Support

Motivation for Upgrades

- 2017 experience indicated need for more refined and coordinated operations
- Revisit inflows given their importance to system reliability and determination of minimum releases
- Understand system dynamics under today’s operating conditions
- Evaluate potential changes to the operating rules, including drought plan and permit conditions for minimum releases

HydroLogics – Modeling Chronology

- Early (2004): Emulation
  - Gannett Fleming inflows (for period of record starting in 1925)
  - Gannett Fleming operating rules
  - Used to confirm safe yield through buildout
- Midway (2007 – 2014): Alternatives Development
  - Gannett Fleming inflows
  - Gannett Fleming operating rules and RWSA constraints
  - Used to develop drought triggers and minimum release rules
    - Minimum releases included a percent of inflow, with inflow based on Gannett Fleming methodology
    - Rules tested over the historic inflow record starting in 1925
  - Implementation of rules, including estimate of inflow on which SH and SF releases were calculated, not done by HydroLogics
- Late (2017/18): Operational Refinement
  - HydroLogics inflows
  - HydroLogics operating rules and RWSA constraints and preferences

Operational Refinement (2017/18)

- Evaluation of inflow datasets
  - Gannett Fleming – used for safe yield planning, based on annual regressions and drainage area adjustment of gages in (regulated) and out (unregulated) of basin
  - RWSA Permit – used for minimum release calculations at SH and SF, based on drainage-area adjustment of (regulated) Mechums gage.
    - Would not have been used to determine system reliability, including safe yield, since Mechums gage did not exist for entire period of record. In other words, system inflows would have used the Gannett Fleming dataset. A percent of those inflows would be released at SH and SF. The question that may not have been answered at the time is : does the RWSA Permit approach for estimating minimum releases produce any significant differences?
  - HydroLogics – used for planning and operations (proposed to replace permit-calculated inflows), based on monthly regressions and drainage-area adjustment of gages in (unregulated) and out (unregulated), with more heavy reliance on gages in the basin
- Ideally, all inflows should be unregulated so that we can remove impacts of historic operation and look at operating system differently than in the past
  - However, availability of operations data can be limiting

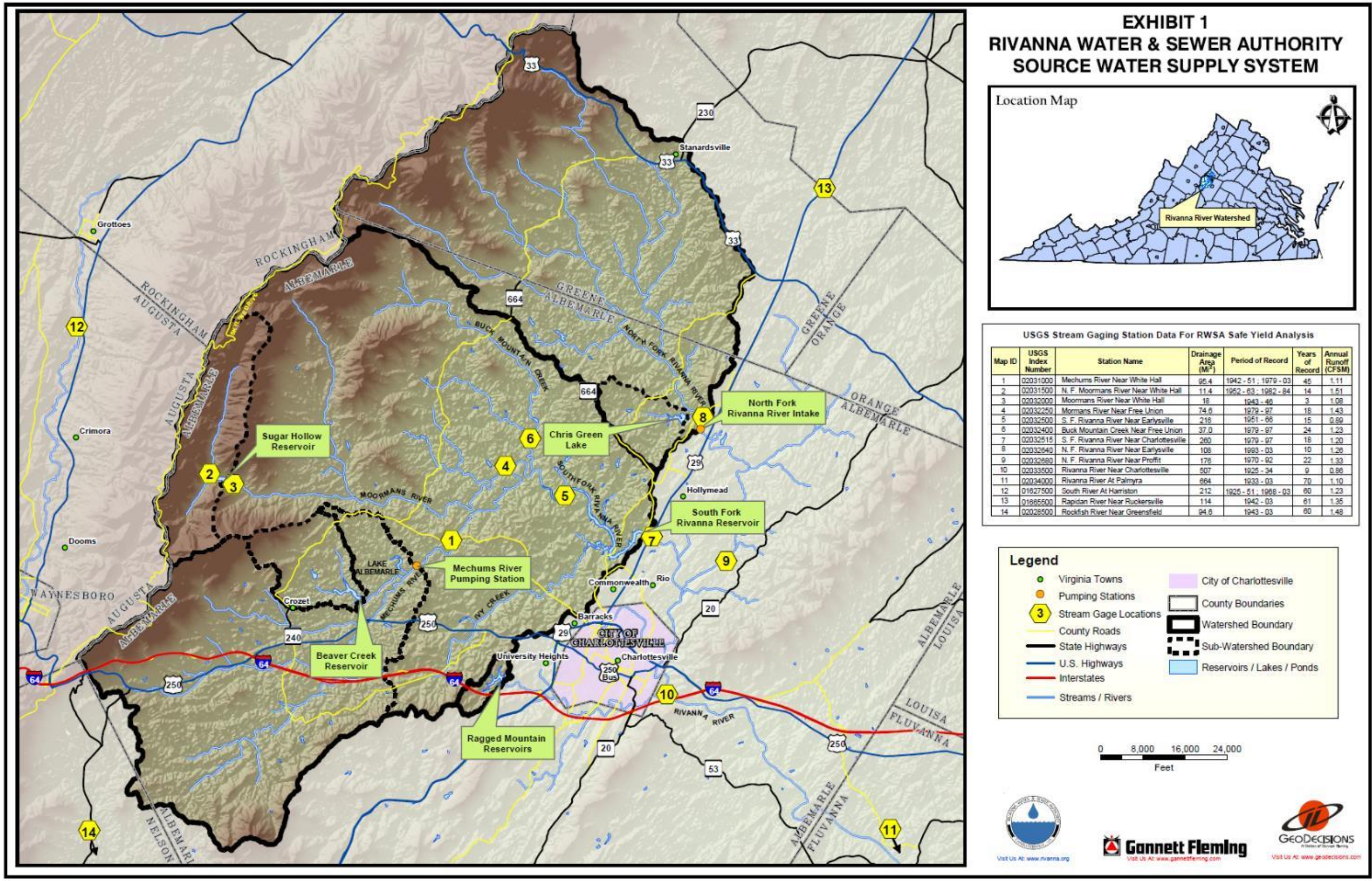
Minimum Releases

- Error in inflow estimation for SF greater than SH since releases from SF are lost from the sytem, whereas releases from SH can be recaptured at SF.

Operational Refinement (2017/18)

- Use most accurate inflow dataset to develop basecase scenario representing current conditions
- Evaluated through inflow verification using historical data
  - 2008 to present available on a daily basis
  - HydroLogics has also revisited 2001-02 given its importance in determining safe yield
- Reliability metrics like safe yield and drought plan activation will change due to many factors, including
  - New inflows
  - New operational assumptions (including WTP constraints, preferred minimum lake levels) based on feedback from staff, including drought exercise

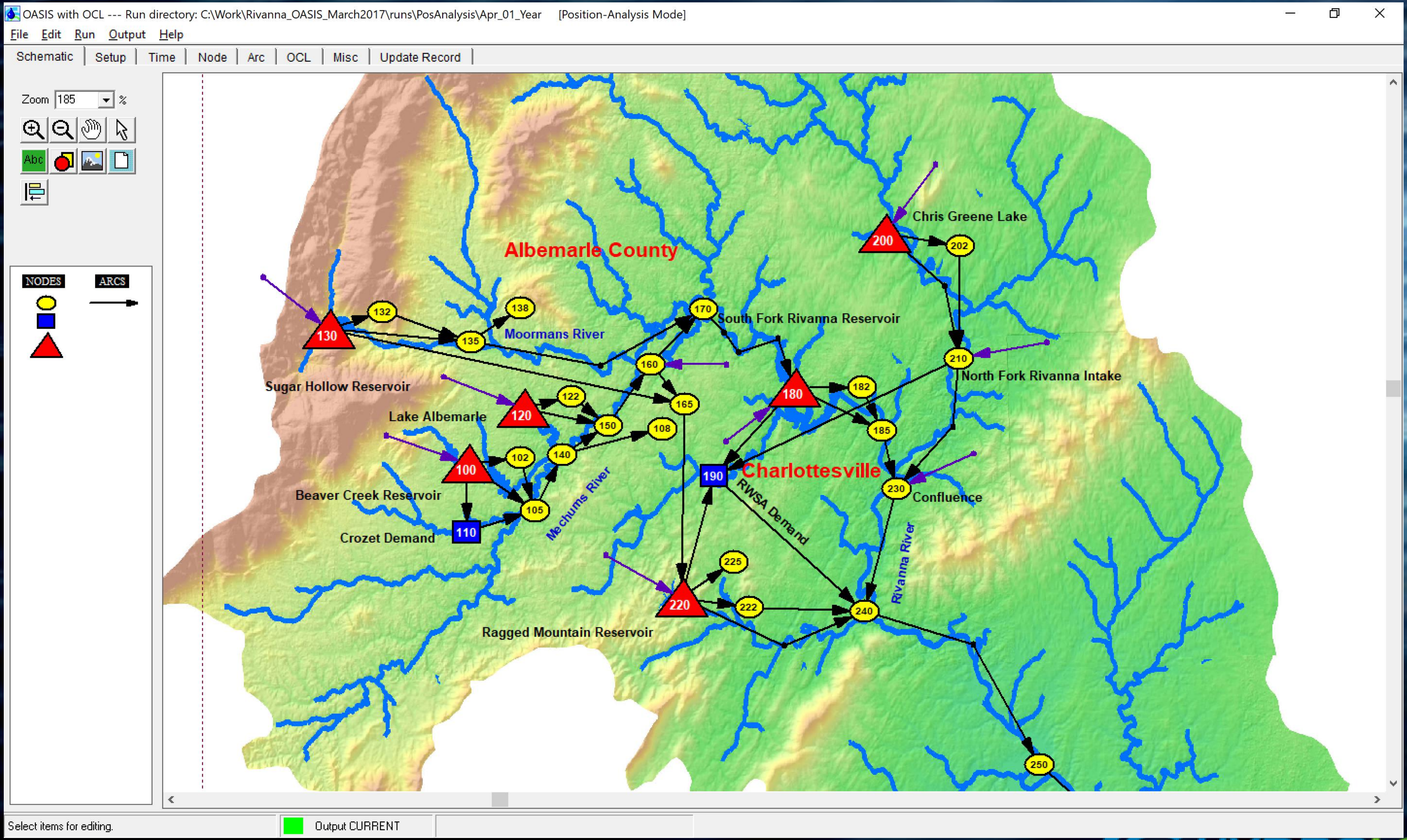
Gannett Fleming Inflows (documented in its Safe Yield Report)



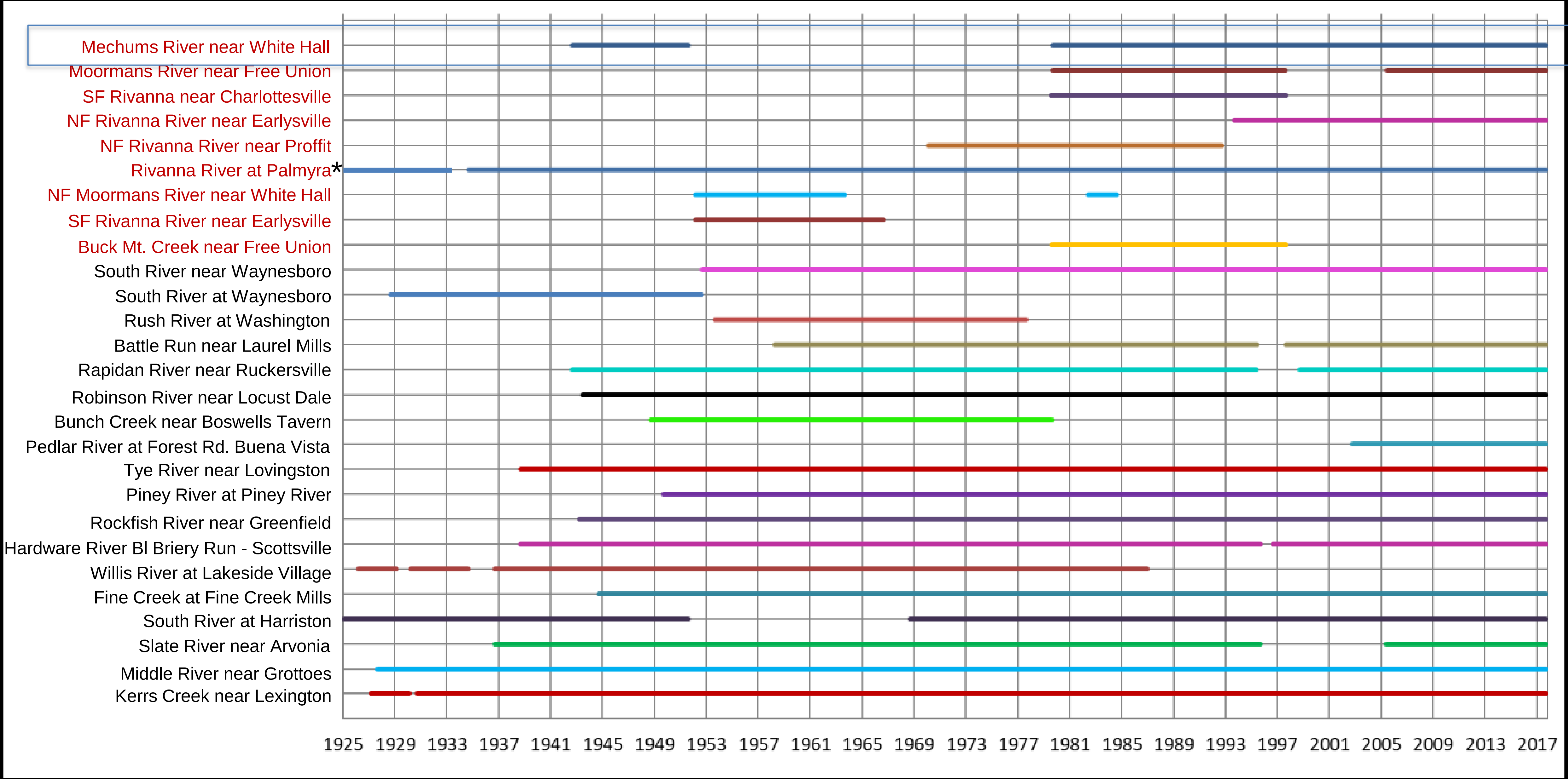
USGS Stream Gaging Station Data For RWSA Safe Yield Analysis

Map ID	USGS Index Number	Station Name	Drainage Area (Mi^2)	Period of Record	Years of Record	Annual Runoff (CFSM)
1	02031000	Mechums River Near White Hall	95.4	1942 - 51 ; 1979 - 03	45	1.11
2	02031500	N. F. Moormans River Near White Hall	11.4	1952 - 63 ; 1982 - 84	14	1.51
3	02032000	Moormans River Near White Hall	18	1943 - 46	3	1.08
4	02032250	Mormans River Near Free Union	74.6	1979 - 97	18	1.43
5	02032500	S. F. Rivanna River Near Earlysville	216	1951 - 66	15	0.89
6	02032400	Buck Mountain Creek Near Free Union	37.0	1979 - 97	24	1.23
7	02032515	S. F. Rivanna River Near Charlottesville	260	1979 - 97	18	1.20
8	02032640	N. F. Rivanna River Near Earlysville	106	1993 - 03	10	1.26
9	02032680	N. F. Rivanna River Near Proffit	176	1970 - 92	22	1.33
10	02033500	Rivanna River Near Charlottesville	507	1925 - 34	9	0.86
11	02034000	Rivanna River At Palmyra	664	1933 - 03	70	1.10
12	01627500	South River At Harriston	212	1925 - 51 ; 1968 - 03	60	1.23
13	01665500	Rapidan River Near Ruckersville	114	1942 - 03	61	1.35
14	02028500	Rockfish River Near Greensfield	94.6	1943 - 03	60	1.48

HydroLogics Inflow Locations (consistent with Gannett Fleming modeling)



Gage Timeline



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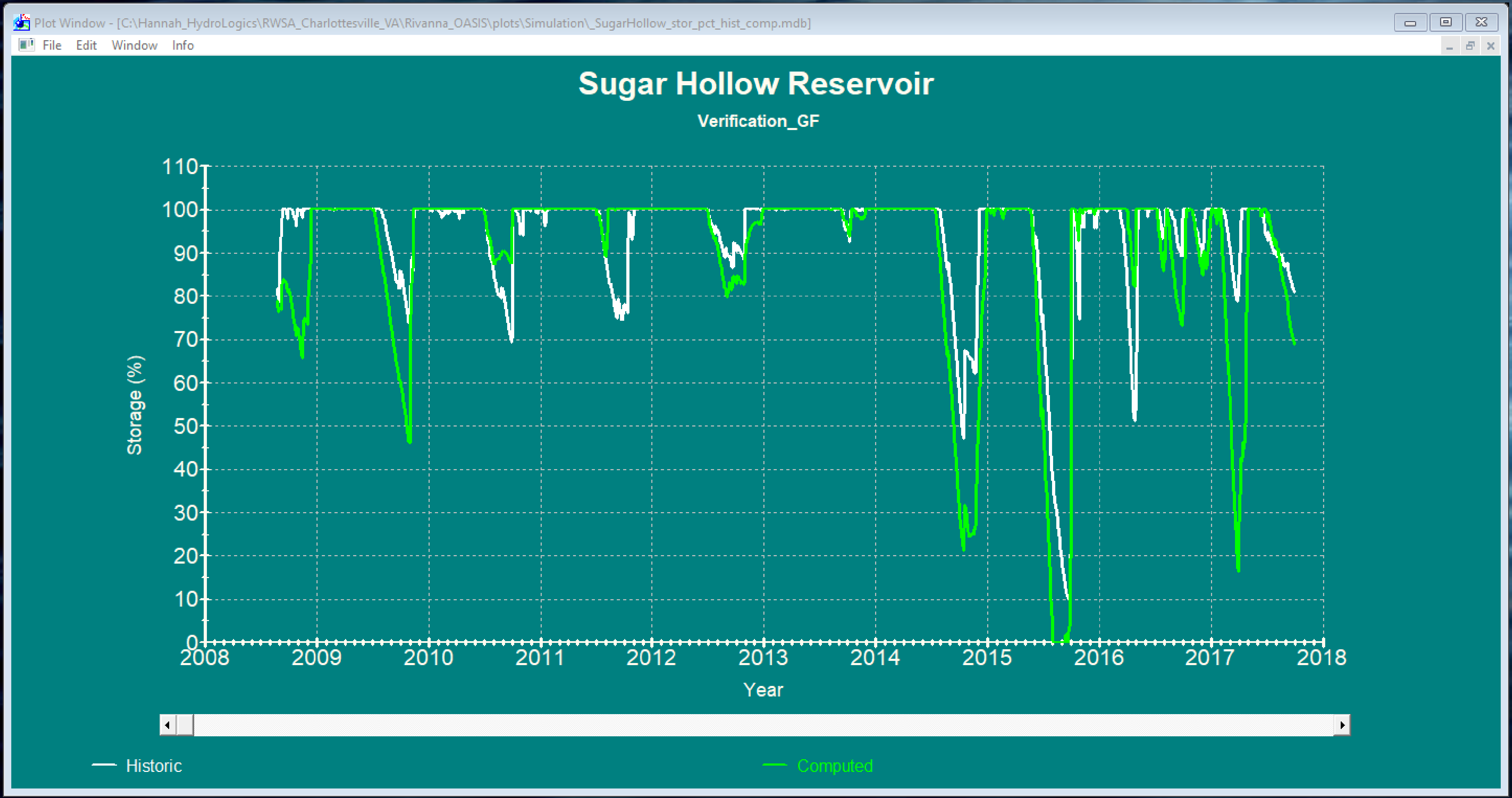
Inflow Verification

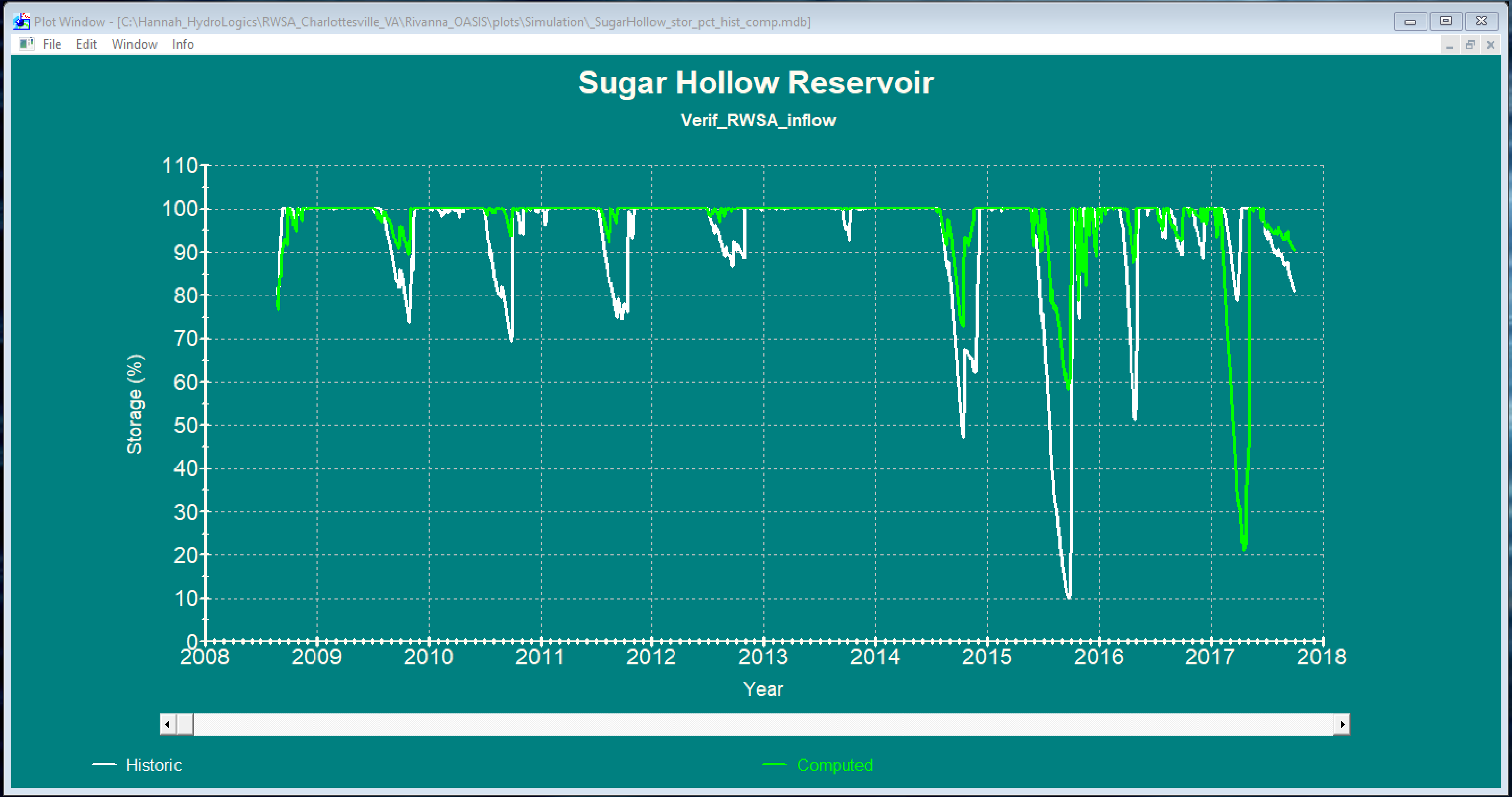
- Presented in detail in inflow development phase
- To recap, verification involved matching reported WTP production, transfers, and reservoir releases
- Inflow accuracy determined by comparing computed and historic elevations
  - Timeseries and probability distributions of inflows are not sufficient!
- To verify, test three inflow datasets
  - Gannett Fleming
  - "RWSA Permit", which is used to calculate the minimum releases (% of inflow)
  - HydroLogics
- In this case, focus on SH and SF for the verification since those are the two locations where "RWSA Permit" inflows are calculated
  - Gannett Fleming: SH inflows based largely on Rockfish River using annual regression. SF inflows based mostly on Mechums (regulated) gage.
  - RWSA Permit: based on Mechums (regulated) gage
  - HydroLogics: SH inflows based largely on Moormans River. SF inflows based mostly on Mechums and Moormans Rivers. Unregulated and filled-in as needed, using monthly regressions.

Sugar Hollow

Inflows Using Gannett Fleming Approach



Inflows Using RWSA Permit Approach (Mechums Gage * 0.19)



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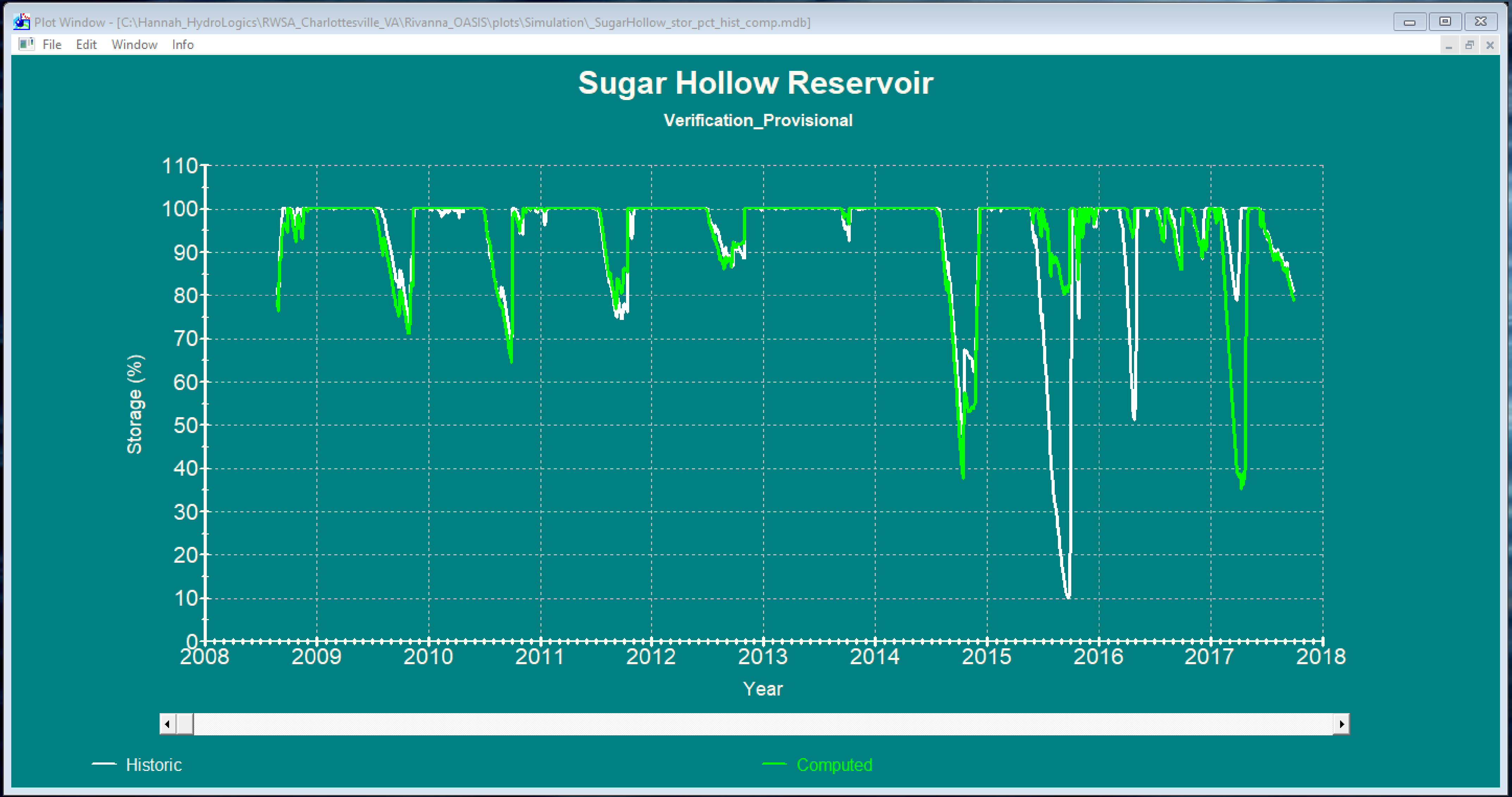
Inflows Using HydroLogics Approach



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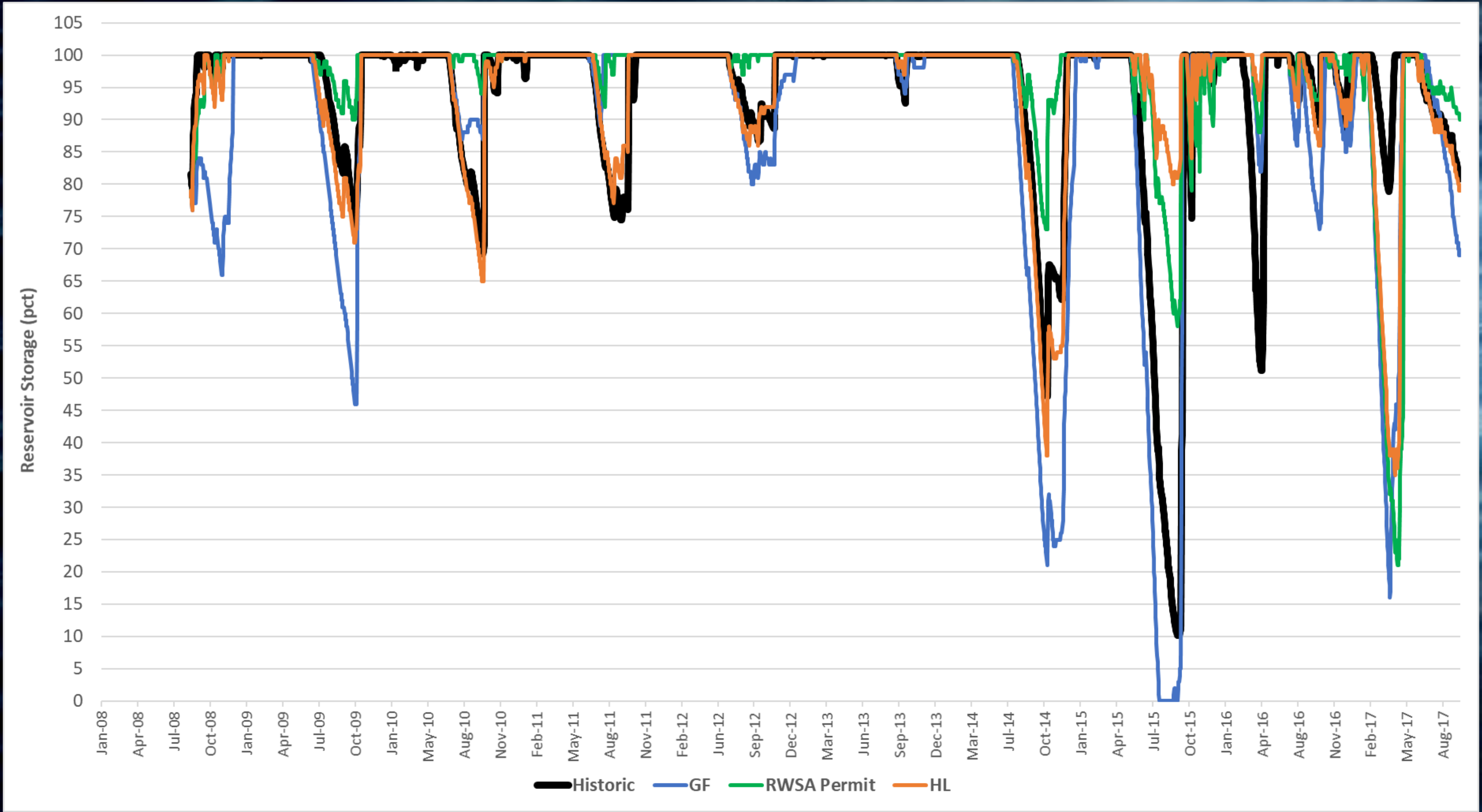
2008-2017 Sugar Hollow Storage Verification



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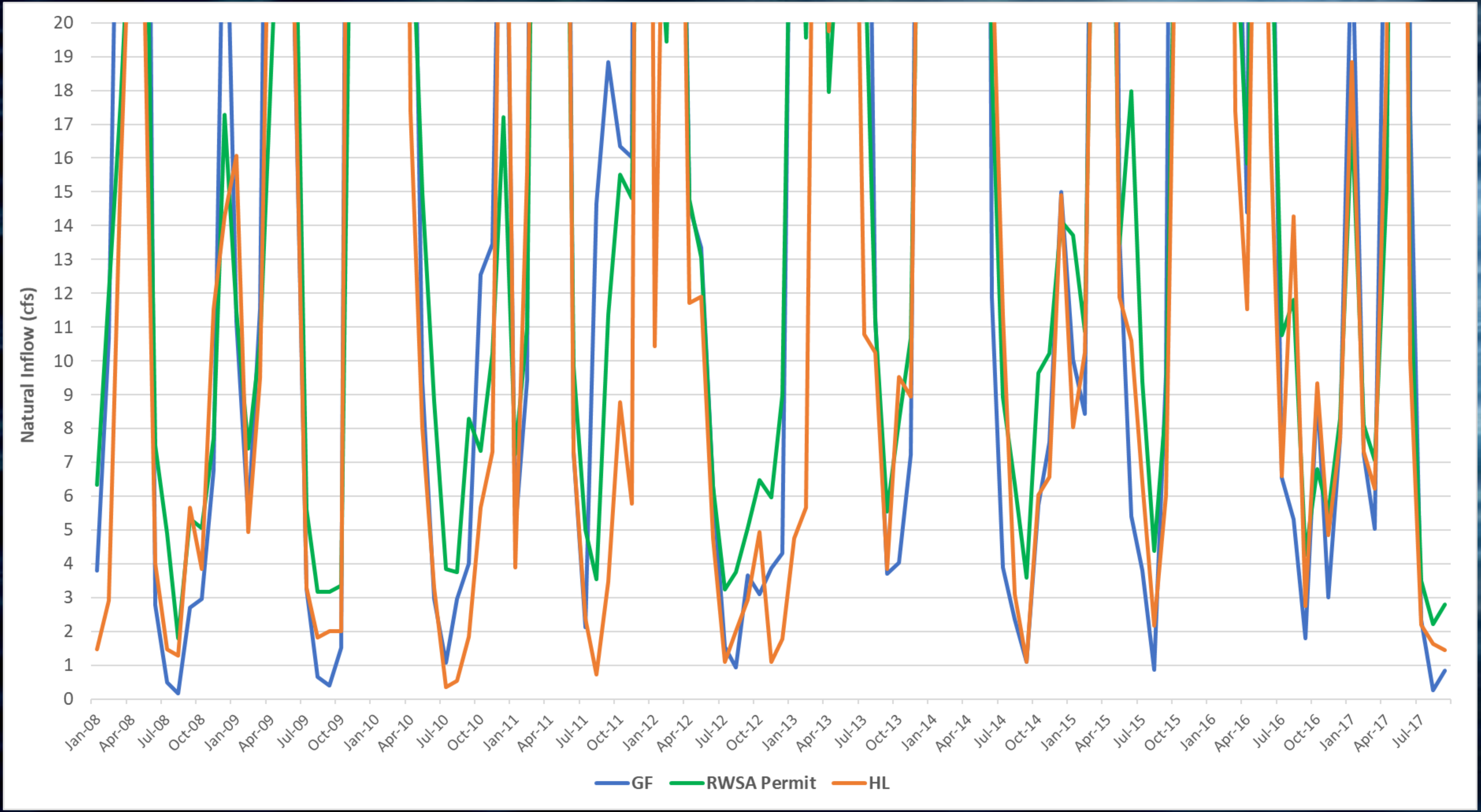
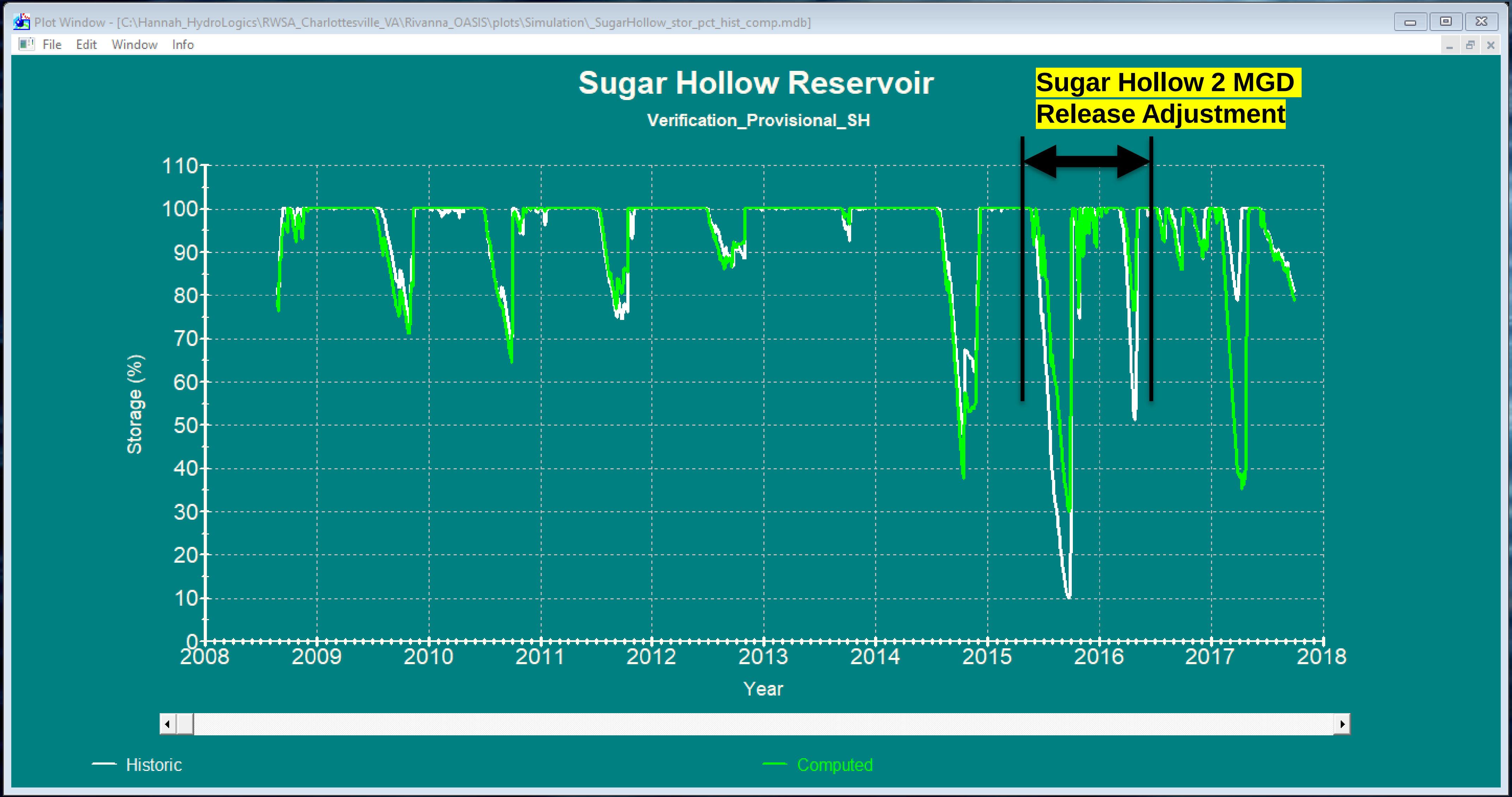
2008-2017 Sugar Hollow Inflows



Sugar Hollow Inflows – 8/22/2008 – 09/30/2017

Sugar Hollow Inflows – 8/22/2008 – 09/30/2017

Further Improvement to Verification Made Through Adjustment to Operating Data -- Using HydroLogics Inflows as the Example



Note: Adjustment is done since study by RWSA concluded that 2015-2016 releases may have been underestimated by ~1.5 -3.5 mgd

South Fork

Inflows Using Gannett Fleming Approach

Note: Ignores surcharge, or storage above full pond, since focus is on drawdown periods.

Inflows Using RWSA Permit Approach (Mechums Gage x 2.7)

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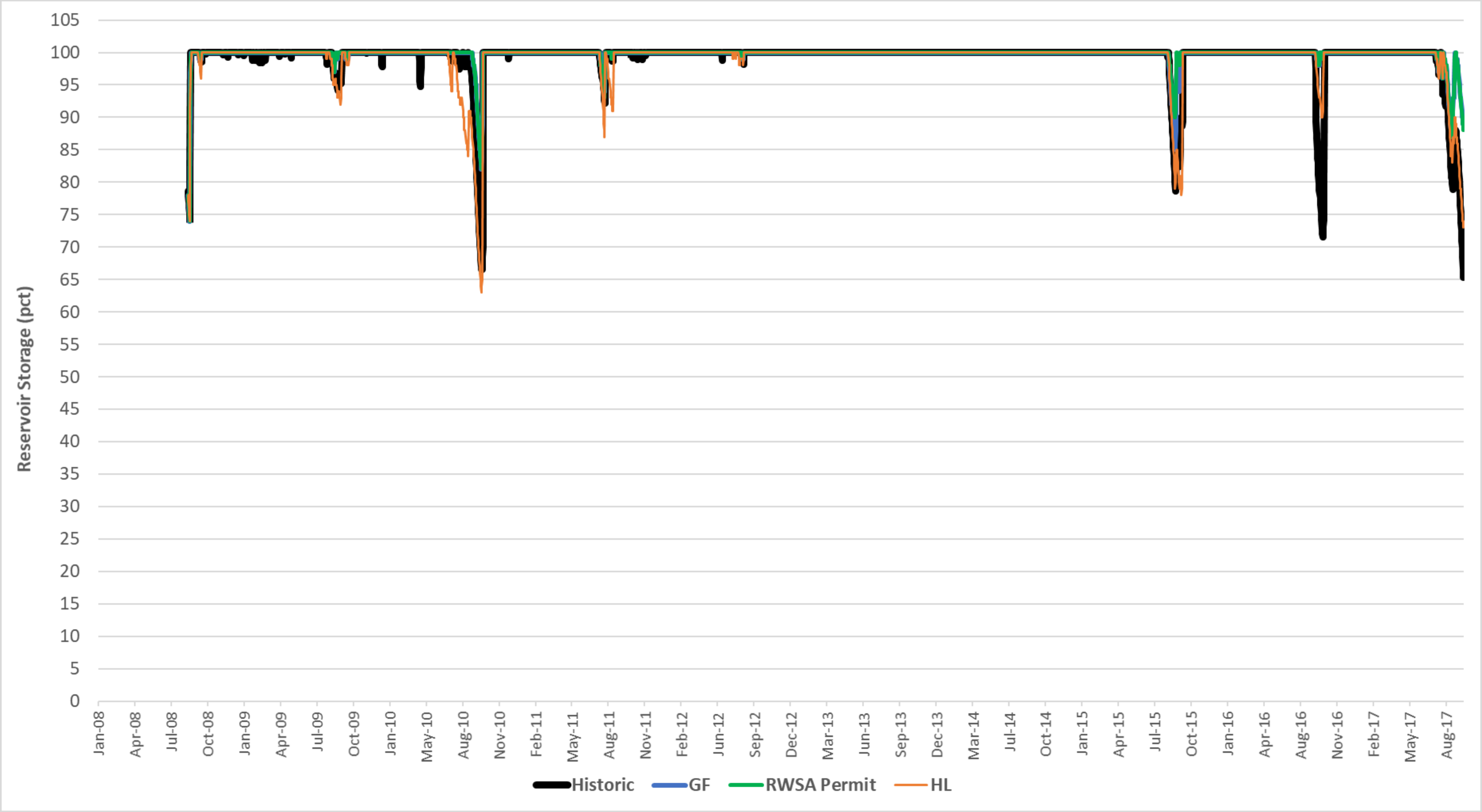
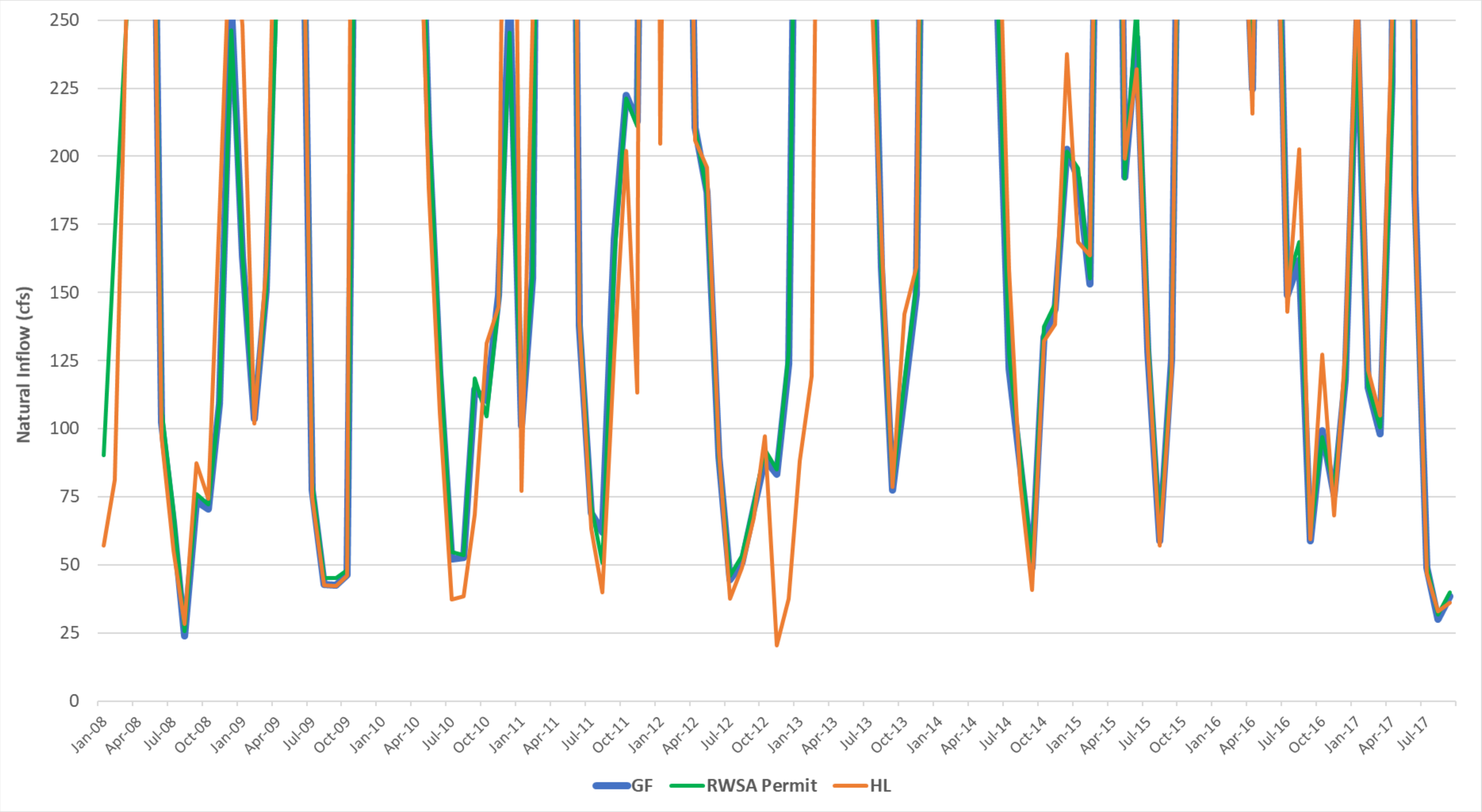
Inflows Using HydroLogics Approach

In 2016 and 2017, mudgates were open, so an additional 1-2 mgd were not accounted for

2008-2017 South Fork Storage Verification



2008-2017 South Fork Inflows (Monthly Avg.)



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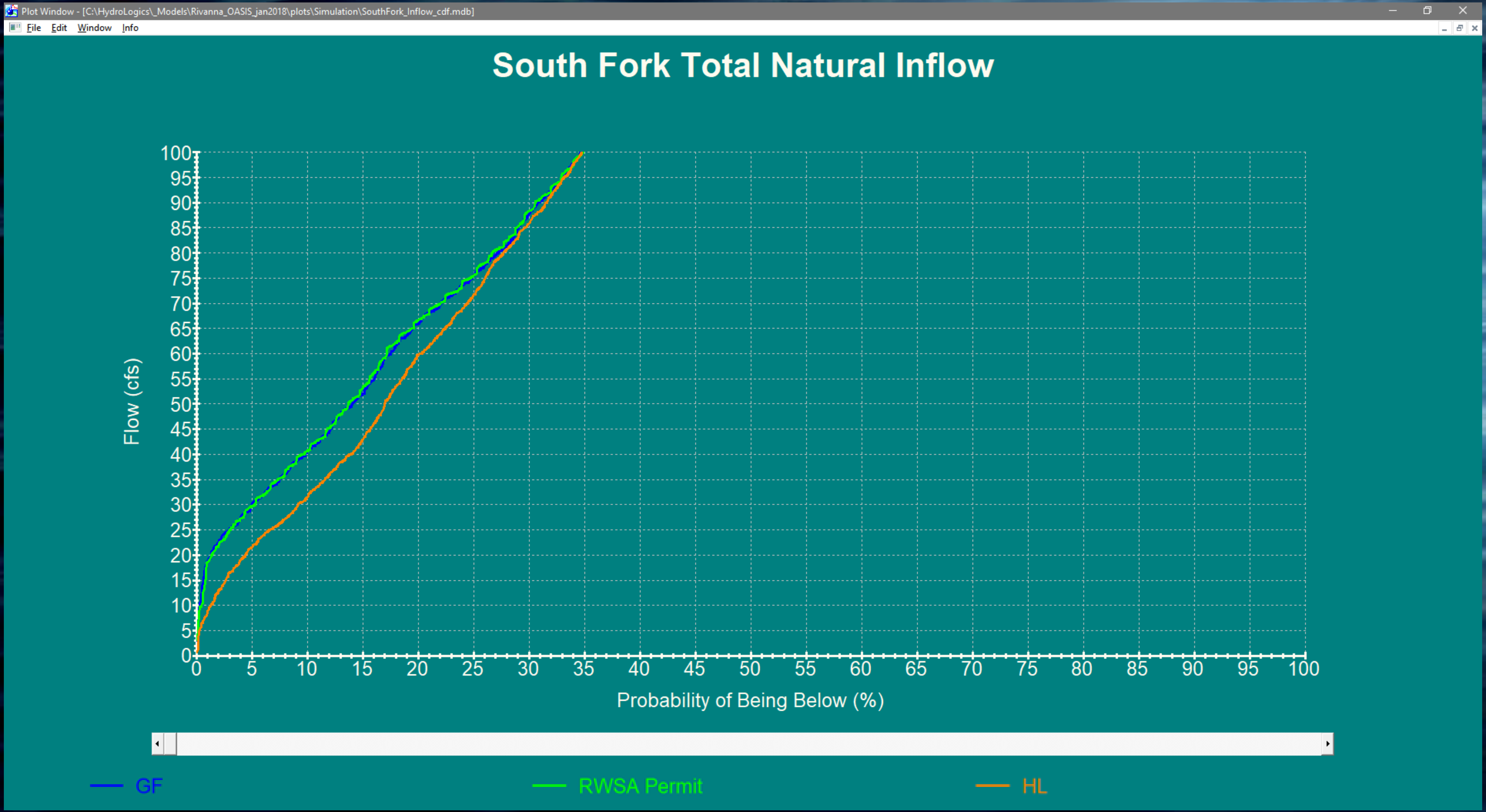
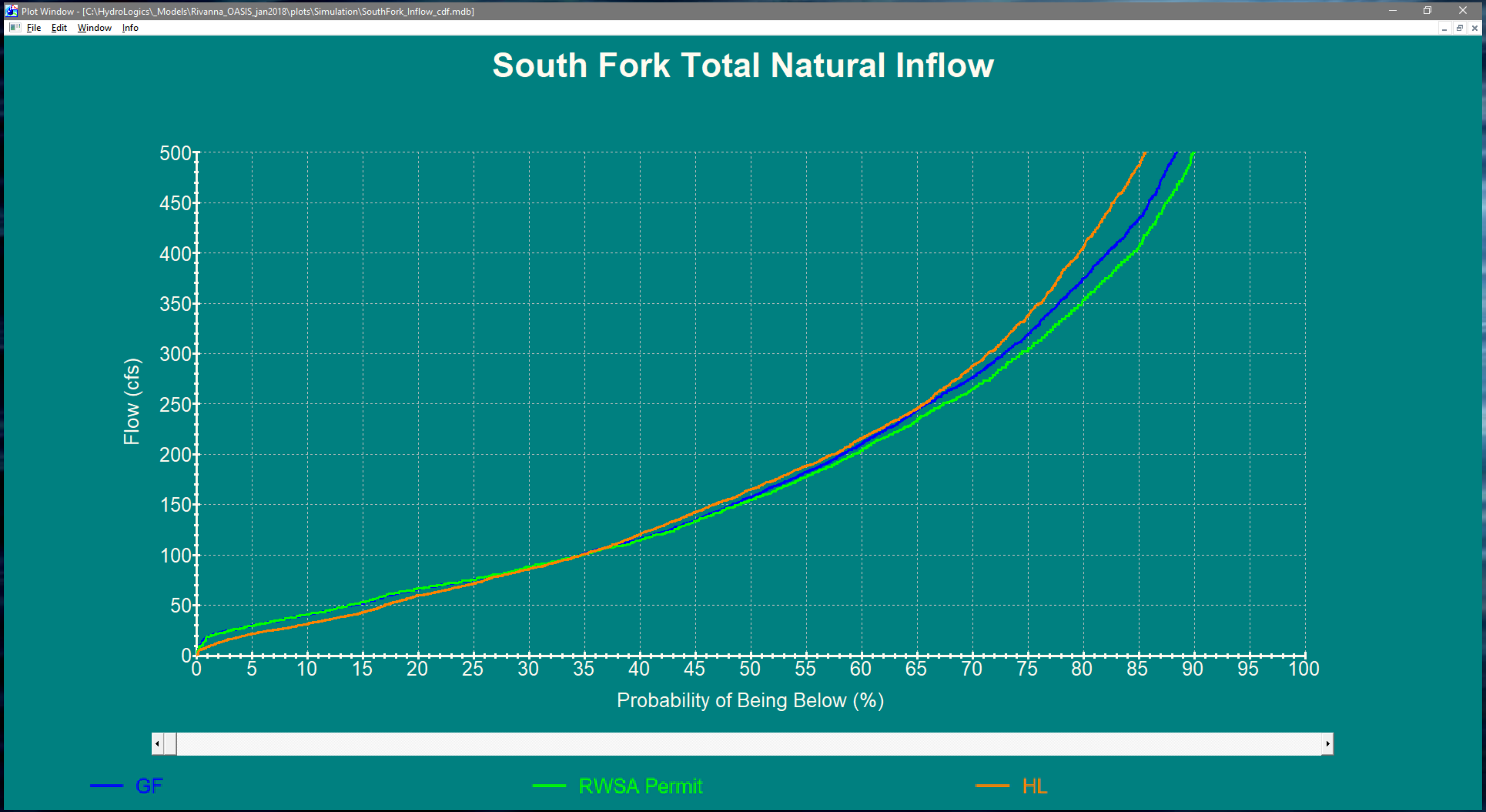
South Fork Inflows – 8/22/2008 – 09/30/2017



HYDROLOGICS

South Fork Inflows – 8/22/2008 – 09/30/2017



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2001-02

- Generally determines safe yield of system (based on period-of-record inflow datasets for Gannett Fleming and HydroLogics that includes the drought of 1930)

2001-02 Inflows (Total Natural Inflow)

	Sugar Hollow (cfs)			South Fork (cfs)		
	GF	RWSA Permit	HL	GF	RWSA Permit	HL
Jul-01	1.4	3.5	1.8	48	50	44
Aug-01	0.4	1.7	2.1	23	24	31
Sep-01	0.1	1.6	1.0	21	23	21
Oct-01	0.1	2.0	0.9	26	28	23
Nov-01	0.1	2.5	0.8	33	36	28
Dec-01	1.2	3.3	1.8	45	47	39
Jan-02	1.4	3.1	1.7	42	44	61
Feb-02	1.3	2.8	2.2	38	40	48
Mar-02	6.6	6.6	6.9	94	94	109
Apr-02	8.4	7.8	17	112	111	181
May-02	3.3	4.6	6.1	65	66	85
Jun-02	0.1	1.1	1.3	15	16	20
Jul-02	0.0	0.4	0.9	4.9	5.4	9.4
Aug-02	0.0	0.1	0.3	0.7	0.8	3.3
Sep-02	0.0	0.1	0.4	0.9	0.9	4.5
Oct-02	1.5	1.9	1.8	26	27	30
Nov-02	20	13	10	194	187	205

GF and RWSA Permit for South Fork based primarily on the Mechums gage, and differ only by the difference in Sugar Hollow. GF for Sugar Hollow uses Rockfish Creek, RWSA Permit uses Mechums. HydroLogics uses primarily Moormans River, Free Union (filled-in) for Sugar Hollow. We base South Fork on Mechums (unregulated) + filled-in Free Union and Buck Mt..

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Mechums Gage Regulation 2001-2002

	Storage Change + Net Evap (cfs)	Withdrawal (cfs)	Total U/S Regulation (cfs)	Gage Flow (cfs)	Unregulated Gage Flow (cfs)
Jul-01	-1.5	0.7	-0.7	18.5	17.8
Aug-01	-0.9	0.6	-0.3	8.8	8.6
Sep-01	-1.3	0.6	-0.7	8.4	7.6
Oct-01	-0.9	0.7	-0.3	10.5	10.2
Nov-01	-2.4	0.5	-1.9	13.1	11.2
Dec-01	-2.1	0.5	-1.6	17.2	15.6
Jan-02	-0.9	0.5	-0.4	16.1	15.8
Feb-02	0.6	0.5	1.1	14.7	15.8
Mar-02	2.1	0.5	2.5	34.6	37.1
Apr-02	1.8	0.5	2.3	40.8	43.1
May-02	1.8	0.5	2.3	24.3	26.7
Jun-02	-0.4	0.7	0.3	6.0	6.2
Jul-02	-0.8	0.7	-0.1	2.0	1.9
Aug-02	-0.6	0.7	0.0	0.3	0.3
Sep-02	-0.2	0.5	0.3	0.3	0.7
Oct-02	0.8	0.4	1.2	9.8	11.0
Nov-02	5.9	0.4	6.4	69.1	75.4

Gannet Fleming Report – South Fork Inflow

reservoir. For the period from 1942 to 1951 and from 1997 to 2003, the streamflows recorded at Mechums River near While Hall were the primary source of flow data. These flows were transposed by making a linear adjustment based on contributing drainage area to obtain the river flows into the reservoir for their period of record.

Review of the daily streamflow records published by the USGS at Mechums River near White Hall (Gage #2031000) indicates that the instantaneous low flow at this gage for the period of record occurred during the 2002 drought event. During the periods of August 23-28 and September 3-26, 2002, no flow was recorded at this gage. According to Mr. Gene Powell, the Senior Environmental Engineer with the Virginia Department of Environmental Quality who is responsible for this gaging station, these flow records are accurate and have been verified. Mr. Powell confirmed that there was a 22-day period in September 2002 of essentially no flow at this gage. He noted that the riverbed had standing water but that no moving water was observed. Mr. Powell also made a site visit to Moormans River where he noted that the riverbed appeared to be dry. He also visited Ivy Creek and observed a trickle of flow. No observations were made of Buck Mountain Creek.

According to the USGS published streamflow data, the lowest flow on record for Buck Mountain Creek was 0.23 MGD which occurred on August 21, 1987. On this same date the flow at the Mechums River Gage and the Moormans River Gage were 7.1 MGD and 0.49 MGD, respectively. It therefore appears to be a reasonable assumption that whenever there was no flow in the Mechums River, there was probably no flow in the other tributaries that flow into the South Fork Rivanna River.

- For 2001-02, GF did not use a regression – **just drainage area adjustment of Mechums gage for entire SF local inflow**

2001-2002 Verification

- We only have daily SF and RM production and spot measurements for reservoir elevations

- Assume old minimum release protocols were in place in 2001
  - 0.4 mgd from SH above 80%
  - 8 mgd or the natural inflow, whichever is less, from SF
    - So when flows get very low, releasing 100% of the inflow

- Cut off SH & SF releases in June 2002 based on estimate of actual operations from RWSA staff

- Assumptions for SH to RM transfer, based on known drawdown
  - 4 mgd from SH->RM for 2001 drawdown,
  - Cut off SH transfer when SH refilling in winter 2001/2002
  - 2 mgd for 2002 (since SH did not draw down as would have expected in 2002)

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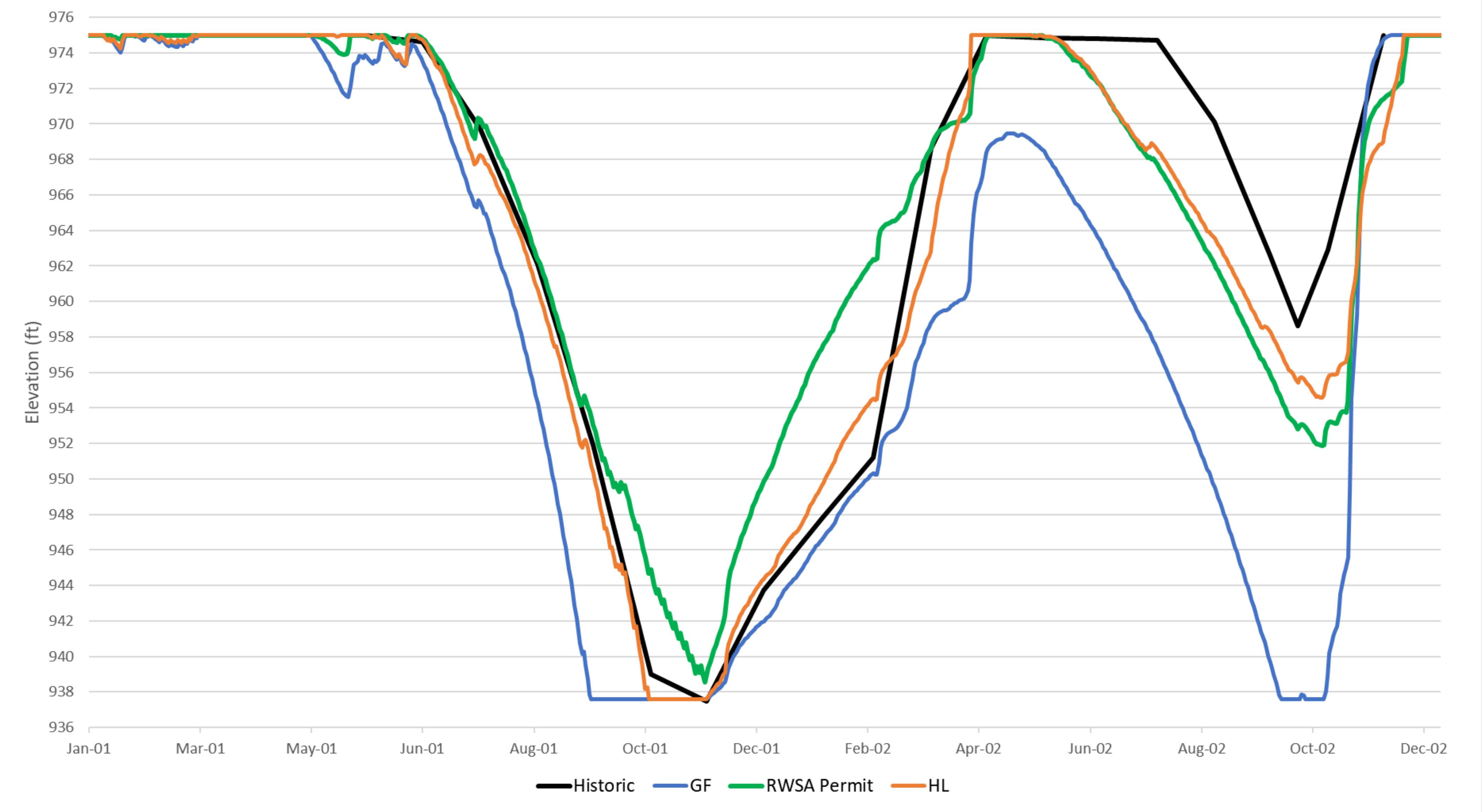
Sugar Hollow Verification



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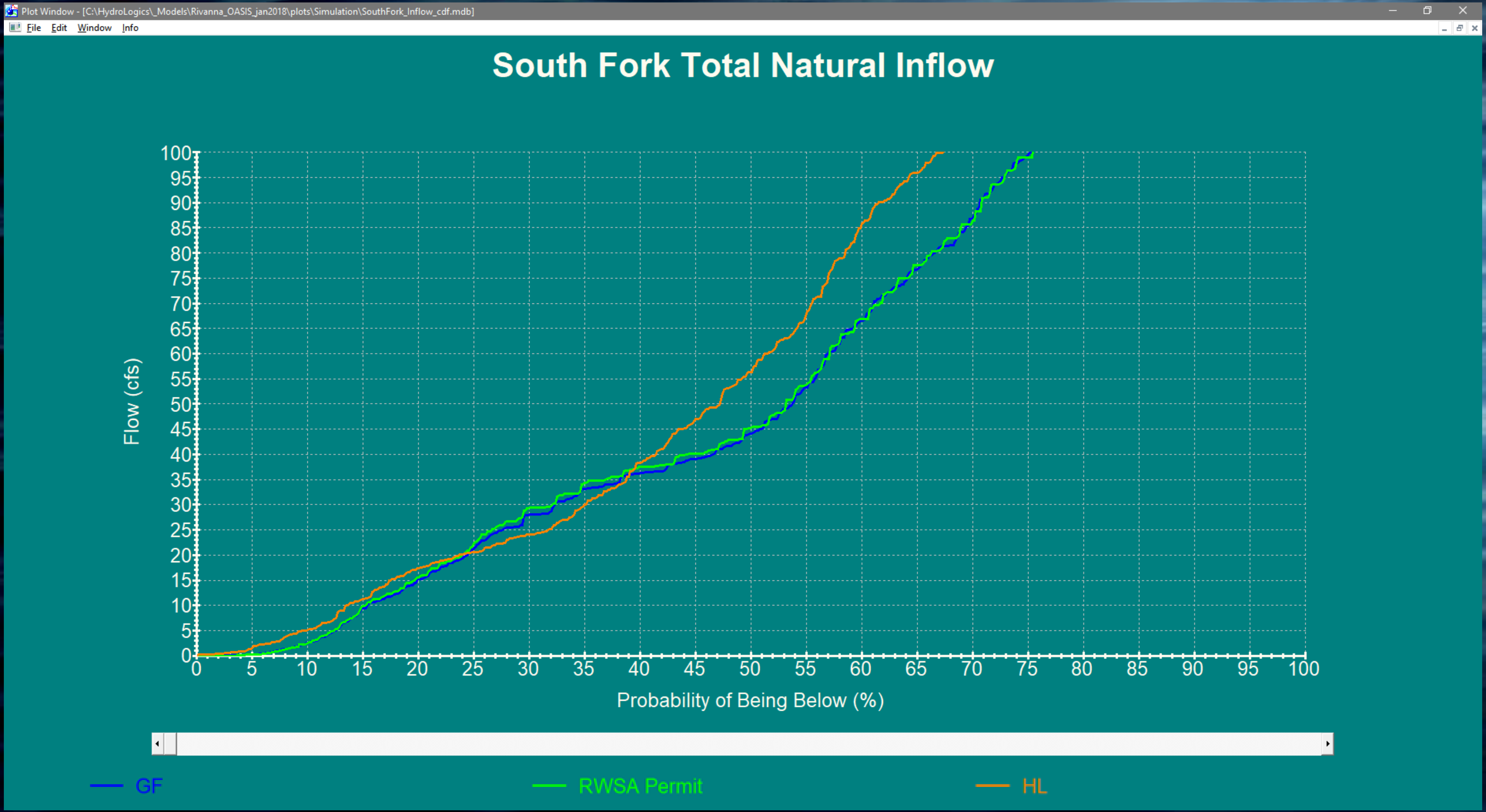
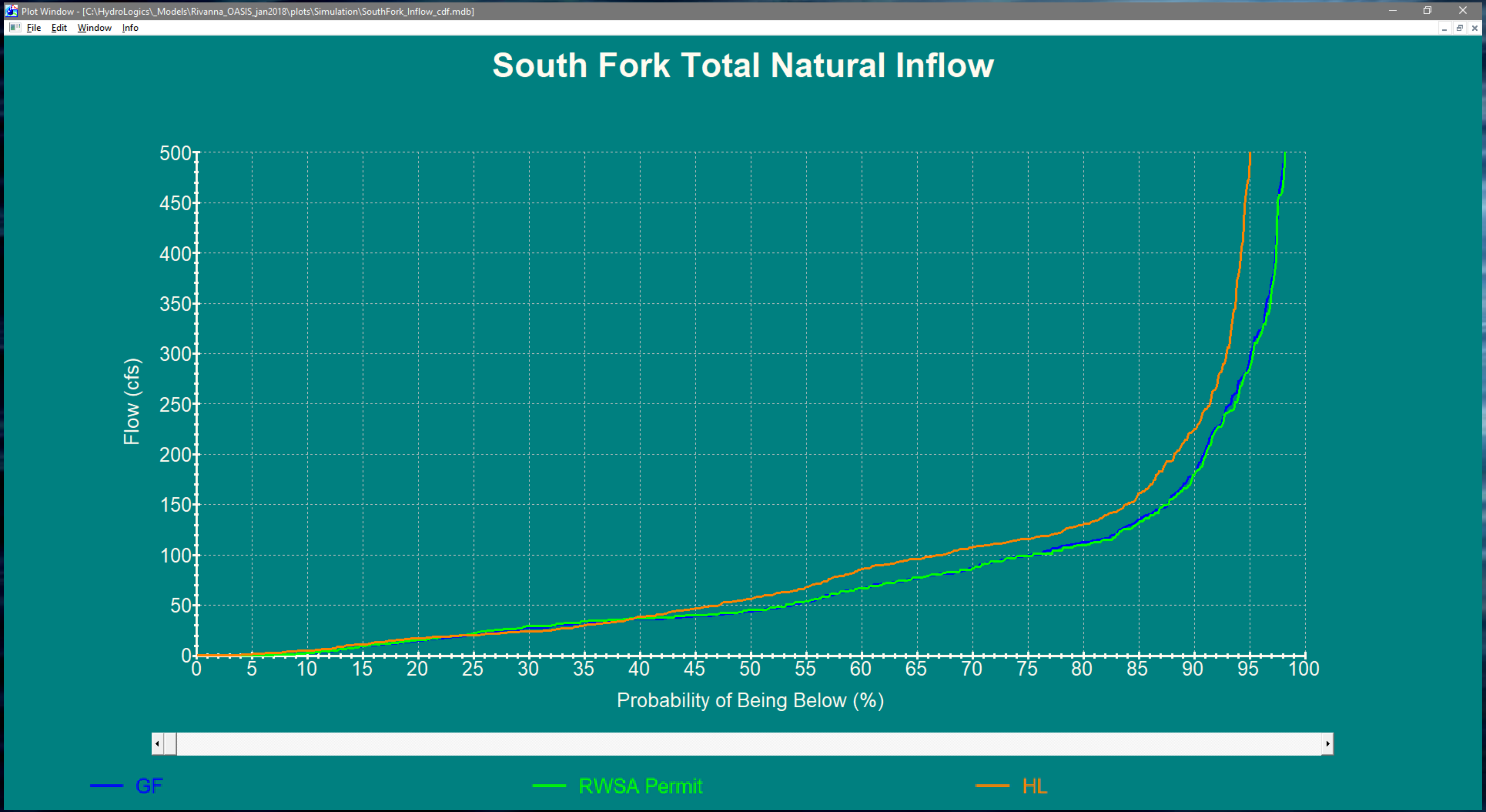
07/2001 – 10/2002 Sugar Hollow Inflows

South Fork Verification

07/2001 – 10/2002 South Fork Inflows



07/2001 – 10/2002 South Fork Inflows



Conclusions

- Impact of inflow methodology varies based on the drought
- HydroLogics inflows more accurate based on better fit with historical operations data
- Permit should be updated to reflect HydroLogics methodology for estimating inflows to SH and SF

Impacts of New Inflow Methodology

- Show probability distributions for the period of record between Gannett Fleming and HydroLogics
- Show impact on system storage

Sugar Hollow Inflows 1925 – 2017

Sugar Hollow Inflows 1925 – 2017

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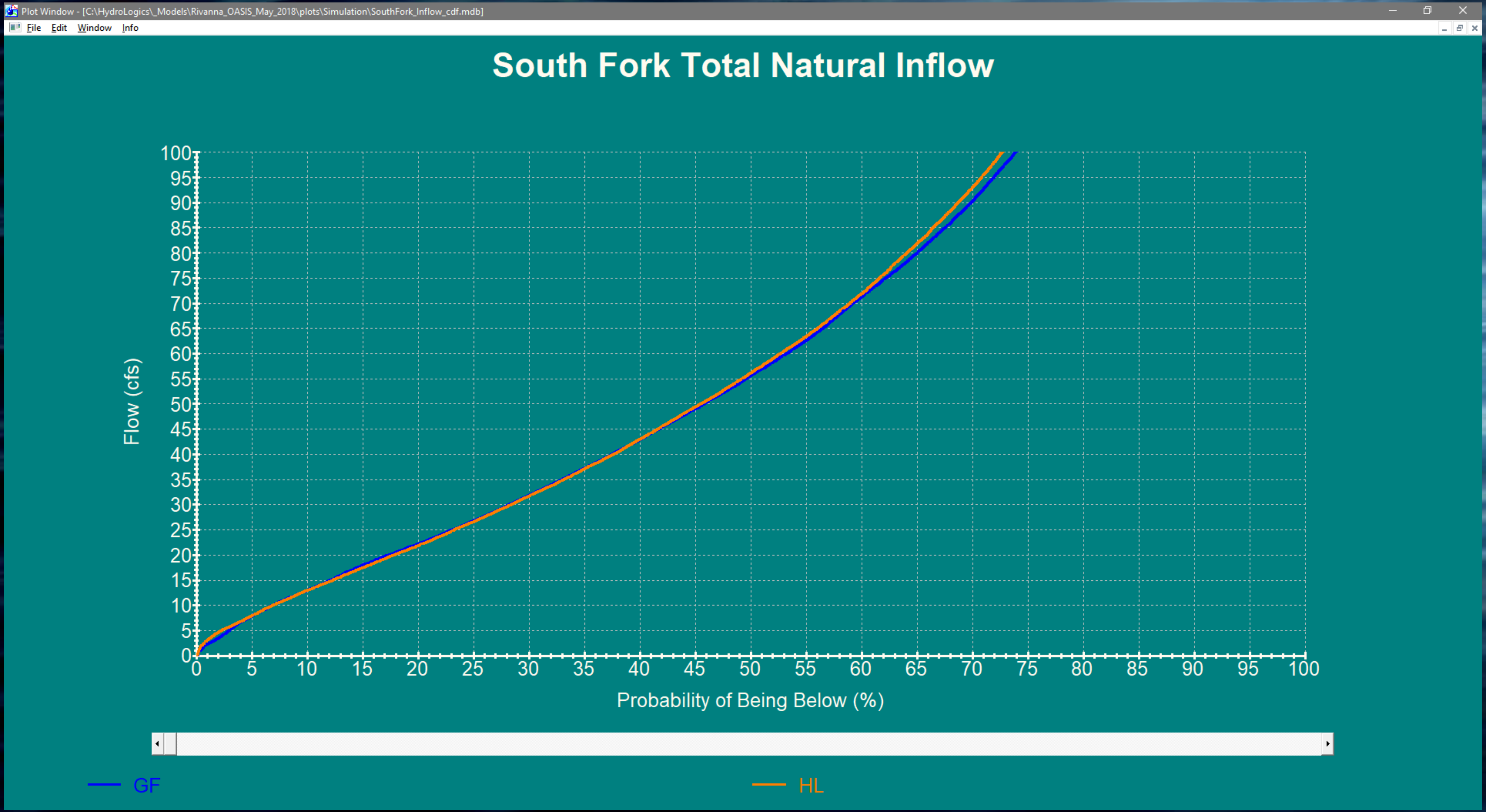
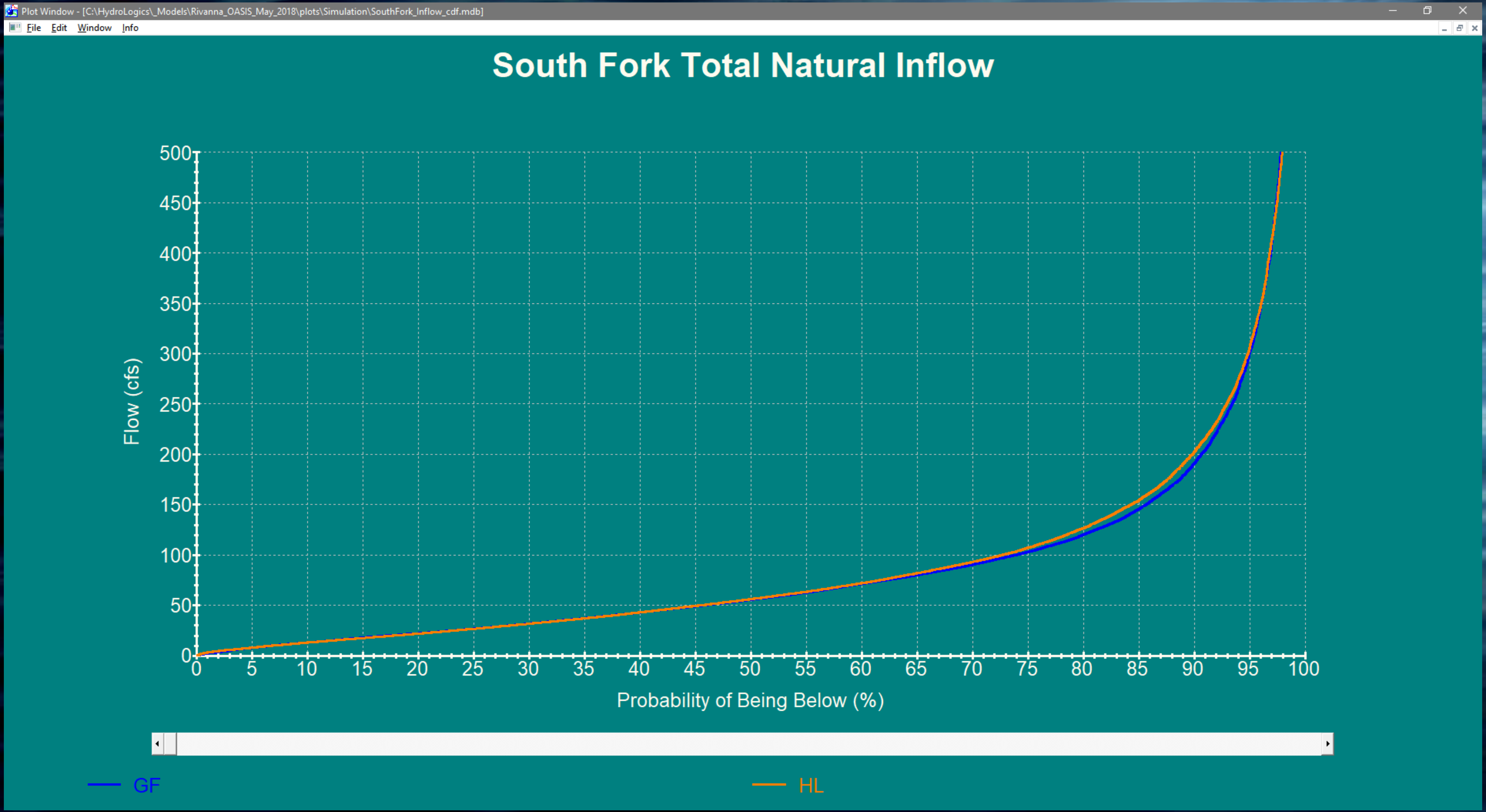
South Fork Inflows 1925 – 2017



South Fork Inflows 1925 – 2017



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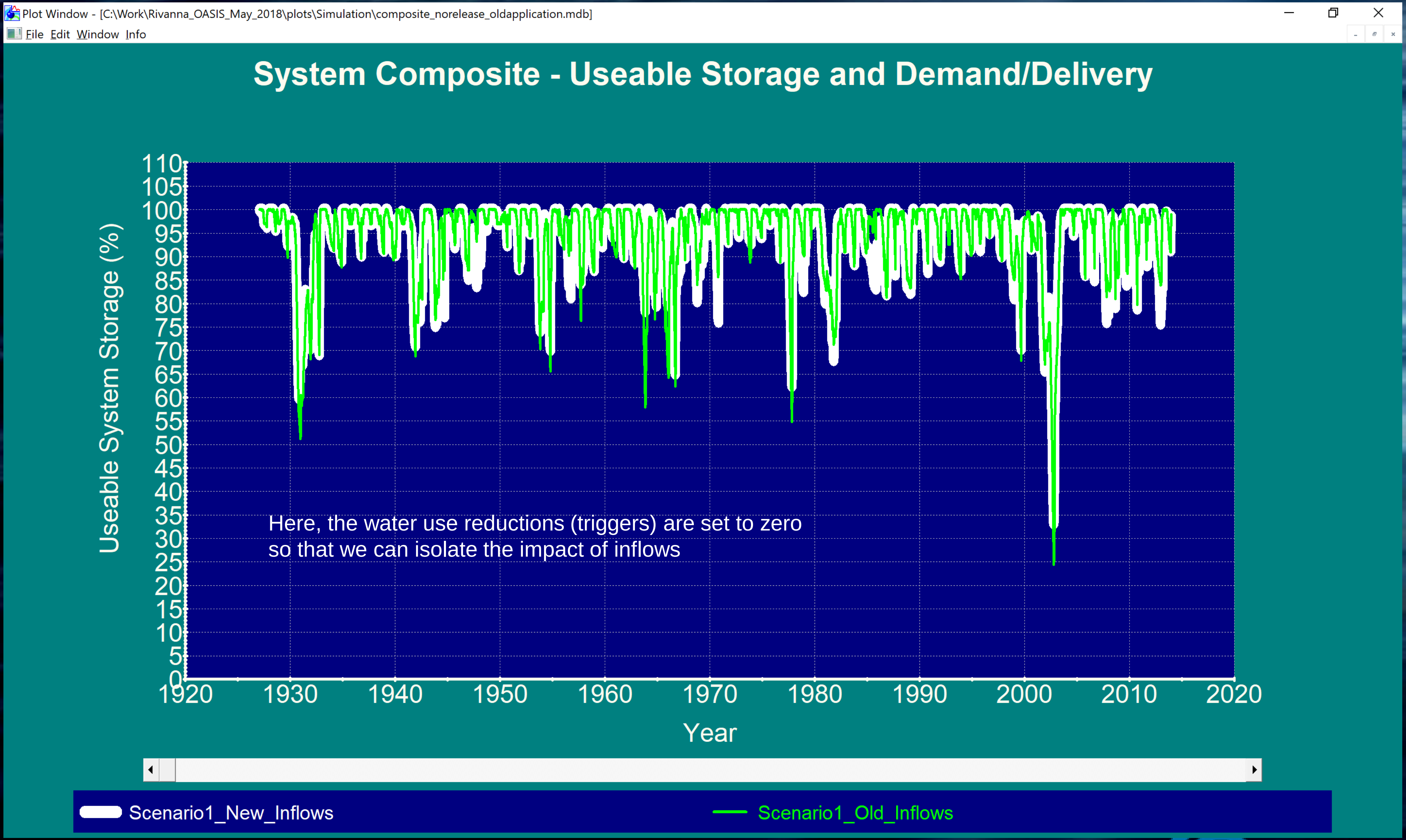
“Scenario 1” – Used Earlier in 2018 to Show Current Conditions



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Appendix E. PowerPoint Presentation: Model Development and Reliability Assessment

RWSA OASIS
Model Update Review
- Operational Assessment

May 16, 2018

Steven Nebiker
Casey Caldwell

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Operations

- Focus on current conditions and develop operating rules around them
  - Safe yield requires evaluation of future conditions (like WTP production constraints), so beyond scope
- Coordinate with DEQ on updated operations, including minimum release calculations
- Train RWSA staff on model use for setting minimum releases and running reservoir storage forecasts

Operations Assessment

- Minimum storage and drought trigger activation dependent on many key assumptions like:
  - Inflows
  - WTP production at all three WTPs, including min. and max., and whether NF is interconnected to help meet main system demand that exceeds NF portion of that demand
  - Transfer policy between SH and RM (both amount and when to start and stop)
  - Trigger criteria (probability, storage level, and forecast horizon)

2017 Analysis

- What caused the disconnect between modeled and actual?

	in MG					
	mass balance from Aug 4 to Oct 6 over drawdown period					
	number of days		64			
	change in useable storage		**495.2**			
	drawdown		6.8	feet		
3	calculated min release	total	932.8		**70% of inflow throughout**	
	actual min release	total	1062.3			
	overrelease		**129.5**		**so 13% higher release than required**	
	Water supply withdrawal		559.0			
	net evap based on OASIS simulation		20.0			
	TOTAL ESTIMATED OUTFLOW		1491.8			
SF inflow for permit	mechums gage x 2.71 (permit calculation)		1515.0			
	"req" release = 70% of inflow, or 20 mgd max		928.0		close to "calculated" above	
HL estimate of SF inflow	mechums + moormans, unimp., x 1.5		1351			
	overestimated inflow		164.0		**so about 10% lower**	
	"req" release = 70% of inflow, or 20 mgd max		845.0			
	overestimated release due to errors in inflow		**83.0**		so about 10% lower	
	estimated leakage through mud gates at 3 mgd		192		so about 20% of the required flow of 933 MG	
	mechums provisional, gage		559.0		diff	
	mechums final, gage		527.0		32.0	**so 5% lower with final readings**
	TOTAL ESTIMATED INFLOW		1515.0			
	CHANGE IN STORAGE		-23.2			
	ADD OVERRELEASE to update change in storage		106.3			
	add overestimate of inflow to update change in storage		189.3			
	add estimated leakage through mud gates to update change in storag		**381.3**			
	add overestimated mechums gage flow to change in storage		413.3			
	add net evap to get total additional change in storage		**433.3**			
	compare to the actual of 495 MG; difference is due to errrors in inflows, outflows... but we are close					
	RWSA releases 3-day moving avg inflow, so varies each day. Don't fix for three days?					
	however, using 0.65 as mgd conversion, not 0.646, so overestimating a bit, plus mgd calculation is rounded, leading to consistent overrelease during drawdown					

HYDROLOGICS

Provisional Inflow Methodology

Section 6. Provisional Inflows

In order to update model inflows in real-time so that (conditional) forecasts can be generated, a provisional inflow update methodology has also been embedded in the OASIS model. To update the inflows, the model user inputs the daily data below for the time period being updated into the “Inflow Update” tab in the GUI (or for easier transfer of data from Excel, the data can be directly pasted into the file ***update_record.mdb*** found in the Basedata directory).

- Drawdown for Sugar Hollow, Beaver Ck, SF Rivanna, and Ragged Mt reservoirs
- Withdrawals for SF, NF, Observatory, and Crozet
- Transfer from SH to Ragged Mtn.
- WW discharge to Moore’s Creek
- Precipitation from the Charlottesville 2W CO-OP station
- The following USGS gage flows:

02032250	Moormans River Near Free Union, VA
02031000	Mechums River Near White Hall, VA
02032640	NF Rivanna River Near Earlysville, VA
02034000	Rivanna River At Palmyra, VA

Once the data have been entered and QA/QC done, the user presses the Update Record button on the same tab. A module then computes all of the required inflows for the model and appends them to the basedata. Note that any data in the Update Record tab will overwrite any data in the basedata.dss file for overlapping dates.

The methodology used for computing the provisional inflows is largely the same as that in the finalized methodology detailed previously, except for a couple of key differences:

- The SF Rivanna Reservoir inflow does not contain the filled-in Buck Mountain gage flow, so the local inflow to the reservoir is now just the Mechums and Moormans gages scaled by drainage area.
    - The calculation for the local inflow to the OASIS node is as follows, since the OASIS model includes inflows for Sugar Hollow and Mechums:
      *(Unimpaired Mechums + Moormans gages) * (258.53 – 95.3 – 17.43) / (95.3 + 77)*
    - To compute the total natural inflow to SF Rivanna Reservoir (for purposes of minimum release calculation), the following equation would be used:
      *(Unimpaired Mechums + Moormans gages) * 258.53 / (95.3 + 77) = (Unimpaired Mechums + Moorman gages) * 1.50*

HYDROLOGICS

Provisional Inflow Methodology

- Sugar Hollow: unregulated Moormans gage, scaled back to dam (x 0.226)
- South Fork: unregulated Moormans + Mechums gages, scaled up to SF inflow
  - If computing ***total*** inflow to SF, factor is x 1.50
  - If computing ***local*** inflow to SF, factor is x 0.85, since the model has inflows at SH and Mechums gage
- Ragged Mountain: unregulated Mechums gage, scaled to dam (x 0.018)'
- Beaver Creek: unregulated Mechums gage, scaled to dam and adjusted by seasonal flow-percentile adjustment factor

- Gage records are automatically downloaded from OASIS interface
- Data used to unregulate gages (reservoir storage, withdrawals, transfers) and precip. data is pasted in from RWSA operations spreadsheets
- Inflows to model are then updated from OASIS interface
- Alternatively a spreadsheet could be developed to easily compute inflows for minimum release calculations

HYDROLOGICS

OASIS with OCL --- Run directory: C:\HydroLogics_Models\Rivanna_OASIS_May_2018\runs\PosAnalysis\Fcast_20180501 [Position-Analysis Mode]

File Edit Run Output Help

Schematic | Setup | Time | Node | Arc | OCL | Misc | Update Record

Download Options

Update Data

Download Data

Update Record

Hydrologic Update

Month	Day	Year	Ragged Mt Storage MG	Crozet WD MGD	SF Rivanna WD MGD	RWSA WW Return MGD	Ragged Mt Transfer MGD	North Rivanna WD MGD	Beaver Creek Precip IN	Sugar Hollow Precip IN	SF Rivanna Precip IN	Ragged Mt WD MGD	Ragged Mt Precip IN	Mechums Gage Cfs	Moormans Free Union Gage Cfs	No
3	5	2018	1492.3	0.54	6.507	7.37	4	0.18	0	0	0	0.757	0	38.2	39.8	
3	6	2018	1492.3	0.54	6.121	7.37	2	0.18	0.02	0.02	0.02	0.642	0.02	39.1	39.3	
3	7	2018	1492.3	0.54	7.004	7.37	0	0.18	0	0	0	0.583	0	40.9	42.4	
3	8	2018	1492.3	0.54	6.853	7.37	2	0.18	0	0	0	0	0	38.1	39.5	
3	9	2018	1492.3	0.54	6.512	7.37	3	0.18	0	0	0	0.496	0	36.5	35.5	
3	10	2018	1492.3	0.54	6.18	7.37	4	0.18	0	0	0	0	0	34.9	29	
3	11	2018	1497.37	0.54	6.414	7.37	4	0.18	0	0	0	0.765	0	35.3	28	
3	12	2018	1497.37	0.54	6.985	7.37	4	0.18	0.07	0.07	0.07	0.664	0.07	36.4	27.6	
3	13	2018	1502.45	0.54	6.426	7.37	4	0.18	0	0	0	0.921	0	39.2	28.8	
3	14	2018	1502.45	0.54	6	7.37	4	0.18	0	0	0	1.427	0	35.6	26.1	
3	15	2018	1507.52	0.54	7.021	7.37	4	0.18	0	0	0	0.507	0	33.8	27.7	
3	16	2018	1507.52	0.54	7.496	7.37	4	0.18	0	0	0	0.937	0	32.8	25.1	
3	17	2018	1507.52	0.54	6.83	7.37	4	0.18	0.03	0.03	0.03	0.599	0.03	32.5	24.6	
3	18	2018	1512.6	0.54	6.385	7.37	4	0.18	0	0	0	0.945	0	33.4	24.8	
3	19	2018	1512.6	0.54	7.079	7.37	4	0.18	0	0	0	0.0954	0	32.3	24	
3	20	2018	1512.6	0.54	6.488	7.37	4	0.18	0.77	0.77	0.77	0.954	0.77	59.1	41.6	
3	21	2018	1517.73	0.54	7.075	7.37	4	0.18	0.7	0.7	0.7	0	0.7	81.2	55.8	
3	22	2018	1527.99	0.54	7.333	7.37	4	0.18	0	0	0	0.493	0	74.5	53.6	
3	23	2018	1527.99	0.54	6.901	7.37	4	0.18	0	0	0	1.013	0	87	74.1	
3	24	2018	1533.12	0.54	6.97	7.37	4	0.18	0	0	0	0.371	0	75.1	71.1	
3	25	2018	1533.12	0.54	7.11	7.37	4	0.18	0	0	0	0.279	0	68.2	73	
3	26	2018	1533.12	0.54	7.459	7.37	4	0.18	0	0	0	0.774	0	60.7	66.1	
3	27	2018	1538.25	0.54	6.954	7.37	4	0.18	0.18	0.18	0.18	1.205	0.18	62.1	66.7	
3	28	2018	1538.25	0.54	7.34	7.37	4	0.18	0.01	0.01	0.01	0.995	0.01	66.4	71.2	
3	29	2018	1543.43	0.54	8.215	7.37	4	0.18	0	0	0	0.852	0	61.9	74.3	
3	30	2018	1548.61	0.54	7.575	7.37	4	0.18	0	0	0	1.33	0	58.2	72.6	
3	31	2018	1548.61	0.54	7.521	7.37	4	0.18	0	0	0	0.288	0	52.2	66.2	
4	1	2018	1548.61	0.54	7.835	7.37	4	0.18	0	0	0	0.528	0	49.6	59	
4	2	2018	1548.61	0.54	6.972	7.37	4	0.18	0.06	0.06	0.06	0.445	0.06	51.1	61.1	
4	3	2018	1553.8	0.54	7.765	7.37	4	0.18	0	0	0	0.523	0	50.4	58.8	
4	4	2018	1558.98	0.54	7.503	7.37	4	0.18	0	0	0	0	0	50	52.8	
4	5	2018	1558.98	0.54	7.948	7.37	4	0.18	0	0	0	1.166	0	43.3	44.6	
4	6	2018	1558.98	0.54	6.487	7.37	4	0.18	0	0	0	0.854	0	41.7	42.8	
4	7	2018	1558.98	0.54	7.545	7.37	4	0.18	0.06	0.06	0.06	0.585	0.06	44.1	39.7	
4	8	2018	1564.16	0.54	7.491	7.37	4	0.18	0	0	0	0.527	0	41.5	39.4	
4	9	2018	1564.16	0.54	7.372	7.37	4	0.18	0.01	0.01	0.01	0.833	0.01	39.5	35.7	
4	10	2018	1569.4	0.54	6.78	7.37	4	0.18	0	0	0	1.575	0	39.7	34.4	
4	11	2018	1569.4	0.54	7.62	7.37	4	0.18	0	0	0	0.751	0	37.9	30.6	
4	12	2018	1569.4	0.54	7.98	7.37	4	0.18	0	0	0	0.63	0	37.3	30.8	
4	13	2018	1574.63	0.54	8.464	7.37	4	0.18	0	0	0	0.965	0	35.8	28.1	
4	14	2018	1574.63	0.54	7.503	7.37	4	0.18	0	0	0	0.971	0	34.7	29.3	
4	15	2018	1574.63	0.54	8.199	7.37	4	0.18	1.49	1.49	1.49	0.967	1.49	44.2	29.2	
4	16	2018	1579.87	0.54	8.19	7.37	4	0.18	0.51	0.51	0.51	0	0.51	930	754	
4	17	2018	1590.34	0.54	7.722	7.37	4	0.18	0	0	0	0.778	0	321	412	
4	18	2018	1595.63	0.54	7.351	7.37	4	0.18	0	0	0	1.268	0	215	256	
4	19	2018	1595.63	0.54	7.021	7.37	4	0.18	0.02	0.02	0.02	1	0.02	171	188	
4	20	2018	1595.63	0.54	8.561	7.37	4	0.18	0	0	0	0.778	0	135	137	
4	21	2018	1595.63	0.54	6.866	7.37	4	0.18	0	0	0	0.756	0	129	111	
4	22	2018	1595.63	0.54	6.518	7.37	4	0.18	0	0	0	1.198	0	123	93.3	
4	23	2018	1595.63	0.54	7.213	7.37	4	0.18	0	0	0	1.456	0	100	81.3	
4	24	2018	1600.92	0.54	8.039	7.37	4	0.18	1.04	1.04	1.04	0.542	1.04	159	141	
4	25	2018	1611.49	0.54	7.049	7.37	4	0.18	0.07	0.07	0.07	0.891	0.07	473	517	
4	26	2018	1616.78	0.54	7.98	7.37	4	0.18	0.01	0.01	0.01	0.583	0.01	254	348	
4	27	2018	1616.78	0.54	8.681	7.37	4	0.18	0.52	0.52	0.52	0.25	0.52	250	306	
4	28	2018	1622.12	0.54	8.003	7.37	4	0.18	0	0	0	0.005	0	197	245	
4	29	2018	1627.46	0.54	8.599	7.37	4	0.18	0	0	0	0.699	0	158	194	
4	30	2018	1627.46	0.54	7.559	7.37	4	0.18	0	0	0	0.633	0	136	162	

Output CURRENT

Reservoir Summary

	Current Model				Gannet Fleming Report			
Reservoir	**Upper Rule (MG)**	**Lower Rule (MG)**	**Useable Storage (MG / %)**		**Upper Rule (MG)**	**Lower Rule (MG)**	**Useable Storage (MG / %)**	
SH	375	36	339	90%	360	36	324	90%
SF*	1282	400	882	69%	1155	355	800	69%
RM	1671	157	1514	91%	1671	157	1514	91%
BC**	568	68	500	88%	587	66	521	89%
Alb	133	33	100	75%	133	33	100	75%
CG	334	273	61	18%	334	273	61	18%
Major Res	**3328**	**593**	2735	82%	**3186**	**548**	2638	83%
Minor Res	**1035**	**374**	661	64%	**1054**	**372**	682	65%

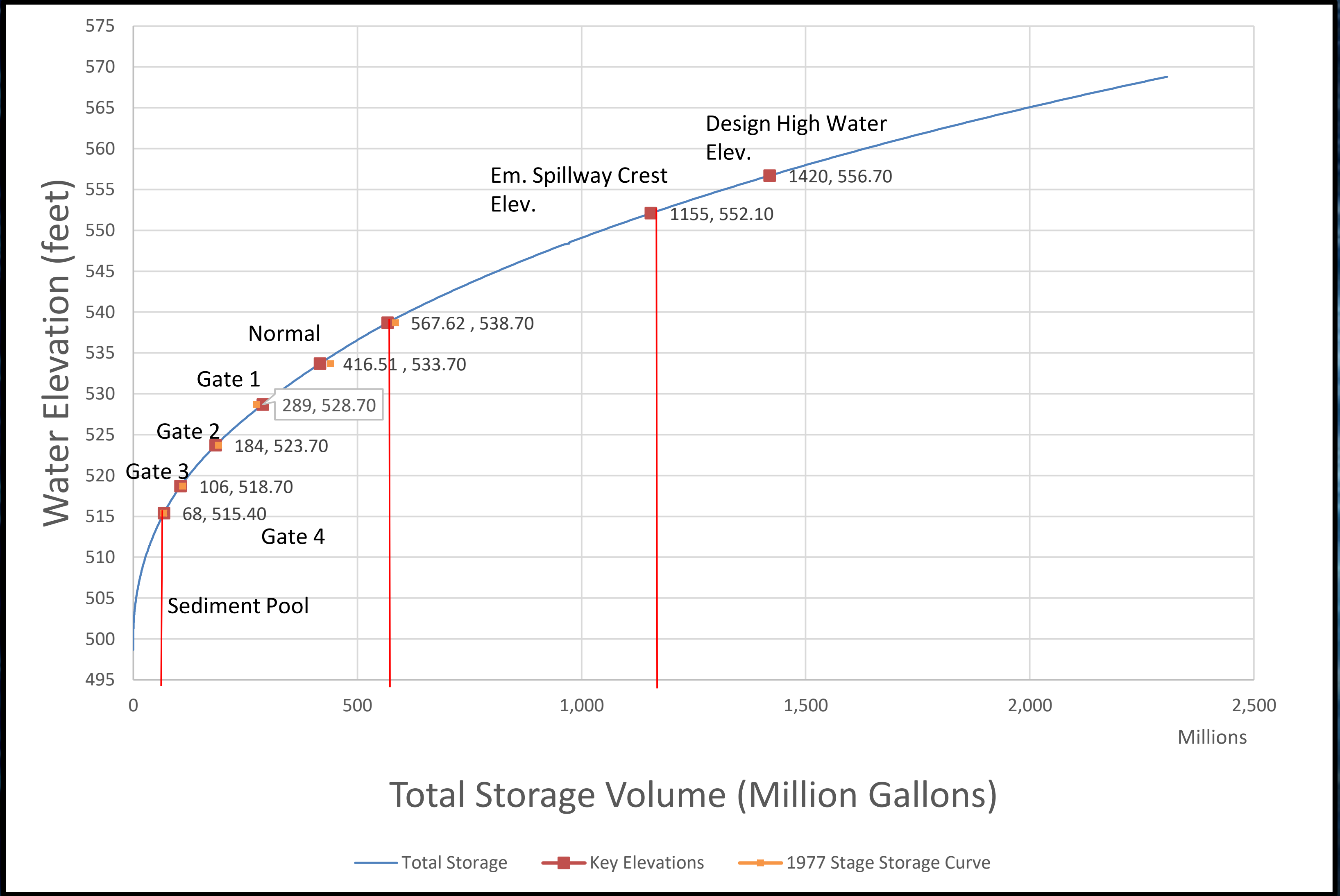
* SF lower rule is lowest intake elevation; emergency are needed to access this storage; lowest storage that does not require emergency pumps = 563 MG (371 ft)
** Beaver Creek upper rule is the bottom of the spillway; spillway operations above that level were modeled in the recent Crozet study.

HYDROLOGICS

HYDROLOGICS

Beaver Creek Reservoir

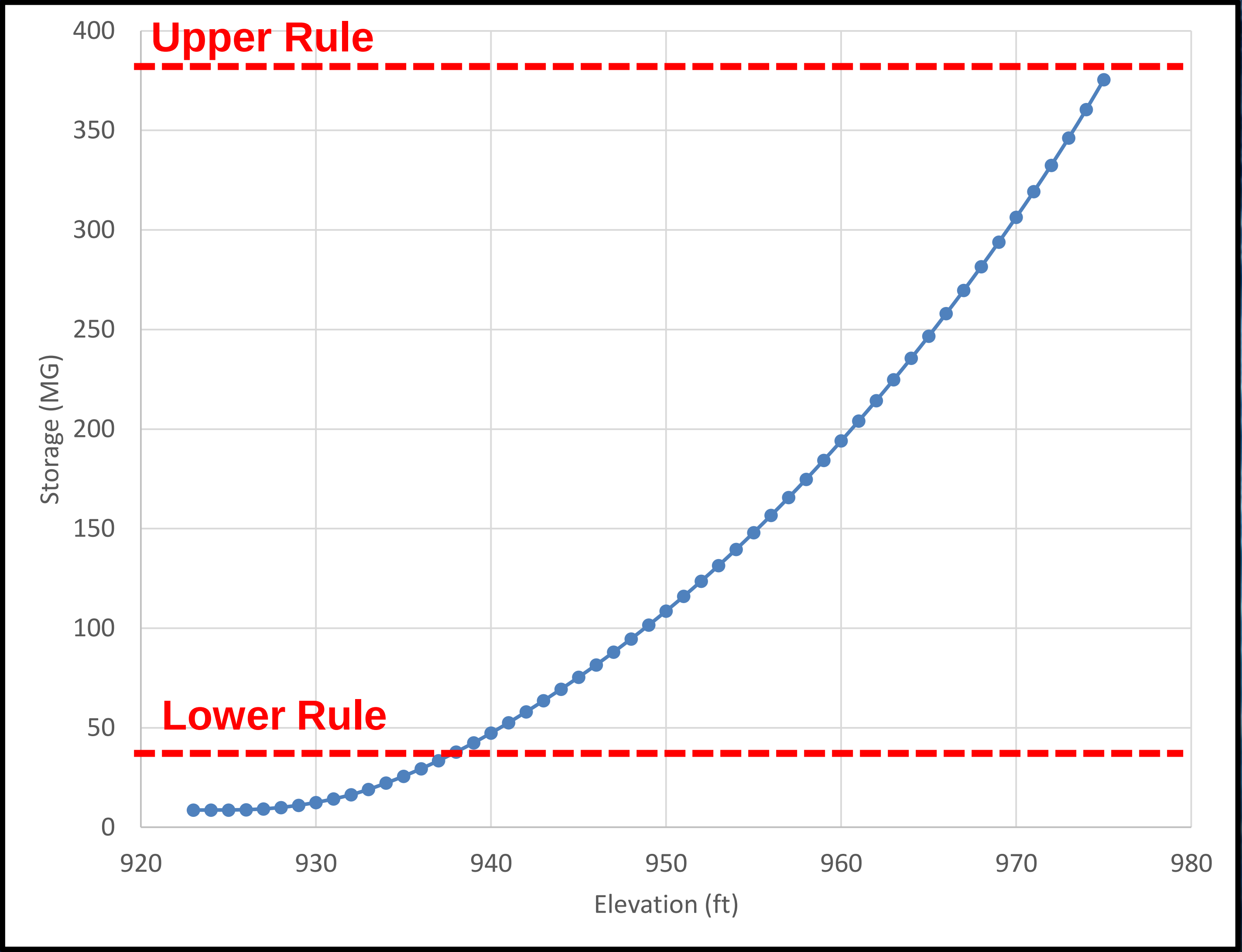
- **Upper Rule (Max Storage):** 568 MG (539 ft.)
- **Lower Rule (Dead Storage):** 68 MG (515 ft.)
- **Useable Storage:** 500 MG (88%)
- **Drainage Area At Dam:** 9.55 sq. miles



Data Source:
"BCR SAE 2017-08-01.xlsx"

Sugar Hollow Reservoir

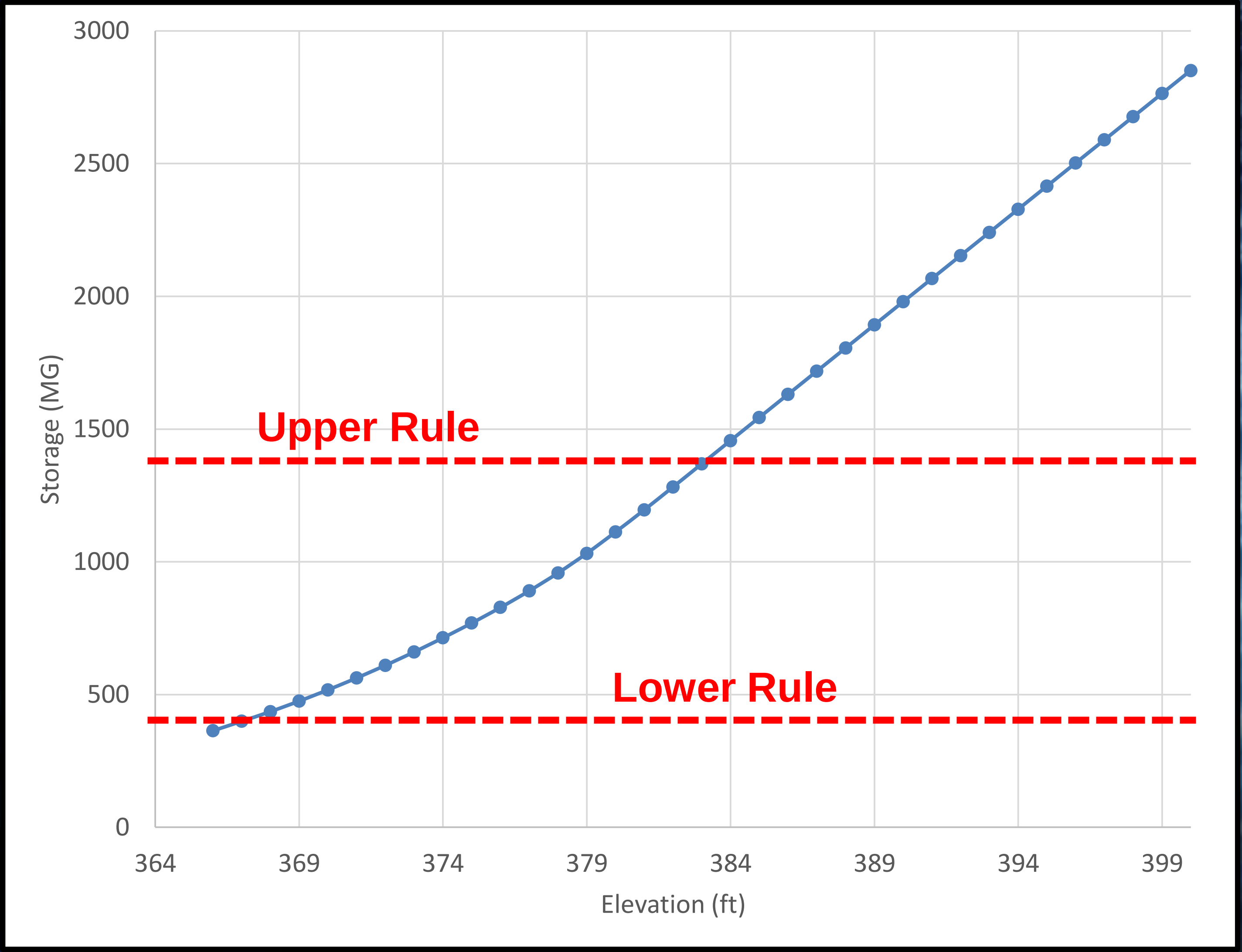
- **Upper Rule (Max Storage):** 375 MG (975 ft.)
- **Lower Rule (Dead Storage):** 36 MG (938 ft.)
- **Useable Storage:** 339 MG (90%)
- **Drainage Area at Dam:** 17.51 sq. miles



- Data based on 2015 bathymetry.
- SAE table limited to 975 feet.

South Fork Rivanna Reservoir

- **Upper Rule (Max Storage):** 1282 MG (382 ft.)
- **Lower Rule (Dead Storage):** 400 MG (367 ft.)
- **Useable Storage:** 882 MG (69%)
- **Drainage Area at Dam:** 259.10 sq. miles

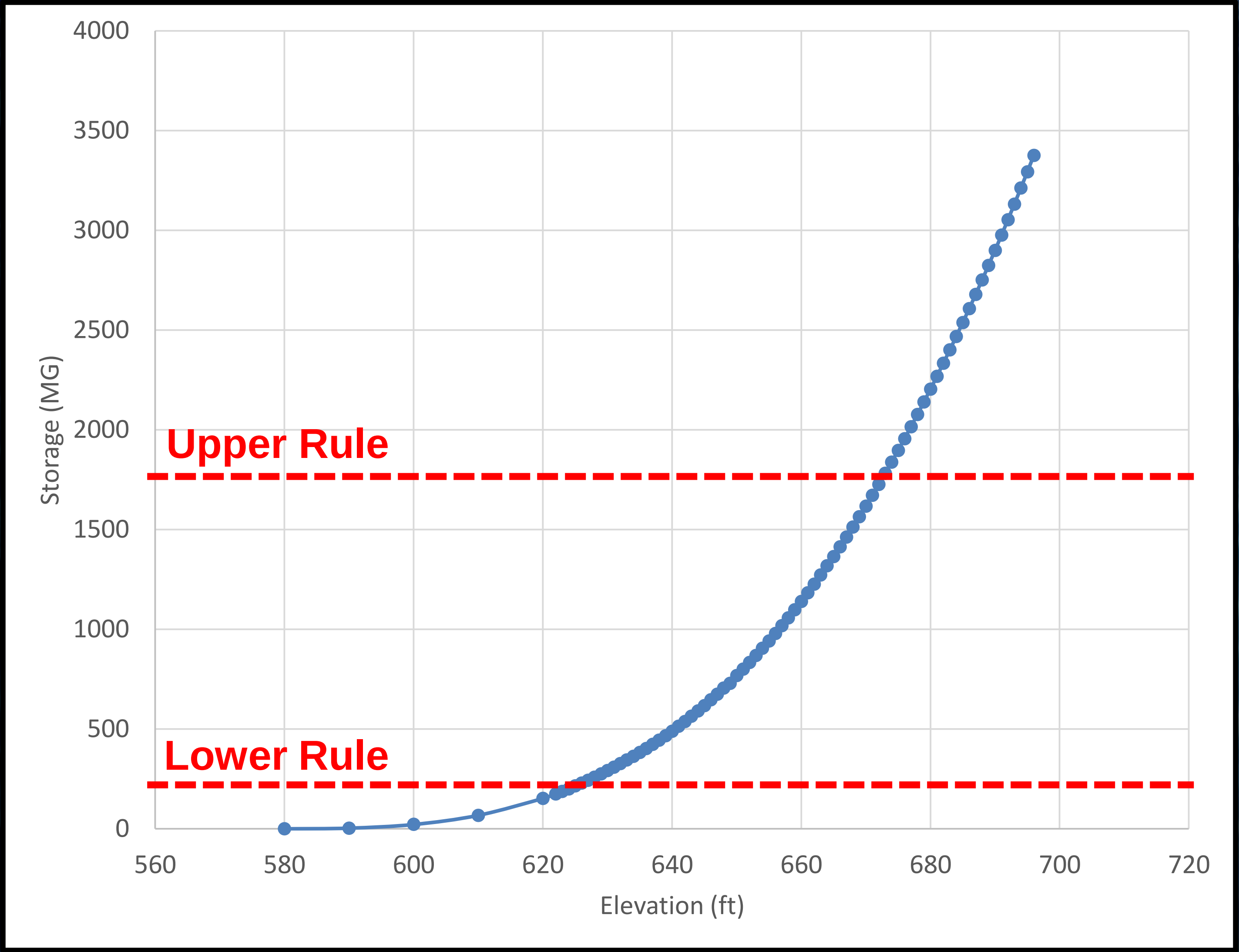


- Data based on 2009 bathymetry.
- SAE table from HDR limited to 383 feet. Storage extrapolated above 383 feet based on the change in storage from 382-383 feet.

HYDROLOGICS

Ragged Mountain Reservoir

- **Upper Rule (Max Storage):** 1671 MG (671 ft.)*
- **Lower Rule (Dead Storage):** 157 MG (621 ft.)
- **Useable Storage:** 1514 MG (91%)
- **Drainage Area at Dam:** 1.81 sq. miles



- Data based on 2016 bathymetry.
- *At intermediate fill; at full-build-out, will increase to 683 feet.

HYDROLOGICS

Bathymetry (from Safe Yield Summary)

n:\community water supply\safe yield\safe yield summary 7-28-2016.docx

2016

- RM (2014 O&M) 620.3'-671' = 1,543.62 MG
  (Pre-Construction Permit 1,549 MG)
- RM (Future Expansion 2014 O&M) 620.3'-683'= 2,459.70 -178.49MG = 2,281.21 MG
  (Pre-Construction Permit 2,189 MG)
- SF (2010 Bathy) 367'-382' = 882 MG
- SH (2015 Bathy) 922.8'-975' = 339.4 MG

Virginia State Water Control Board – Definition of Safe Yield

References:

1. Gannett Fleming, *RWSA Safe Yield Study*, January 2004
2. Gannett Fleming, *RWSA Safe Yield Study Supplement 1*, July 2004
3. Hydrologics, RWSA Safe Yield Assessment Letter, December 2014
4. Hydrologics, RWSA Safe Yield Assessment email, August 2016
5. Hydrologics, RWSA Safe Yield Assessment email, August 2, 2016
6. Hydrologics, RWSA Safe Yield Assessment email, October 2014
7. VHB, Permit Support Document, 2006

Drainage Areas

- Used in permit estimate of inflow to reservoirs.
- Drainage areas net of surface area

- Inflows
  - – Gaged, in and out of basin, drainage-area adjusted

	UNREGULATED INFLOWS USED IN MODEL CALCULATIONS (BASED ON GANNETT FLEMING)										
		node 120	node 100	node 160	node 130	node 180	node 220	node 200	node 210		(OASIS NODE NUMBERS)
	Drainage	Albemarle	BC	Mechums	SH	SF Rivanna	RM	cgreene	NF rivanna		
	Area (mi2)	**3.54**	**9.39**	**78.25**	**17.43**	**149.62**	**1.7**	**5.67**	**109.25**		
			Total at Mechums node			Total at SF node					
	total			91.18		258.23					
GAGES	Mechums at White Hall			95.4		**Ratio of drainage areas for SH and SF**					
						SH	**0.18**	**(compared to 0.19 used by RWSA in its inflow adjustment)**			
						SF	**2.70**	**(same as used by RWSA)**			

Current vs. Projected Conditions

- System expansion (RM, WTPs, + SF-RM pipeline) based on the following key assumptions by Gannett Fleming in early 2000s
  - Demand increasing from approximately 12.5 mgd to 18.7 mgd in 2055
    - System expansion based around providing safe yield = 18.7 mgd
  - Useable storage in SF dropping from 800 MG to 200 MG by 2055
- Where are we today?
  - SF useable storage = 880 MG
  - Annual average demand = 10 mgd

"Triggers" vs. Operating Rules

- Triggers are filed with the state through the Drought Response Plan and VWP permit
  - Water supply cutbacks shown in the Drought Response Plan *"Final DROUGHT RESPONSE AND CONTINGENCY PLAN 2015 for Board.pdf" accessible from the RWSA website (/community-water-supply-plan/*
  - Minimum release rules shown in the VWP permit ("Final DEQ VWP Major Mod Permit 12-28-11.pdf")
- Operating rules are generally not filed with the state
  - Examples: when to increase WTP production; when to transfer from SH to RM

“Water supply” triggers

- Trigger 1 (watch, 0% demand reduction but use 1% for model to easily demonstrate its activation)
  - 20% chance of dropping below 80% (total storage) in 12 weeks. Drought plan uses 75% useable storage.
- Trigger 2 (warning, with total of 5% demand reduction)
  - 10% chance of dropping below 70% storage in 10 weeks. Drought plan uses 60% useable storage. [Actually this would be 65% based on current bathymetry that is used in the model].
- Trigger 3 (emergency, with total of 20% demand reduction)
  - 5% chance of dropping below 60% storage in 8 weeks. Drought plan uses 50% useable storage.

- DEQ added to permit requirement (“special conditions”) that these triggers may be overridden by “minimum release” triggers, DEQ and Drought Monitor, or even the Governor

9. The permittee must issue a call for voluntary conservation, prior to reducing flowby to the South Fork Rivanna River to 50% of natural inflow or 1.3 mgd, whichever is greater, under the provisions of Special Conditions I.F.4.a.ii or I.F.5.a.ii; and the retail customers must be practicing mandatory conservation prior to reducing flowby to the South Fork Rivanna River to 30% of natural inflow or 1.3 mgd, whichever is greater, under the provisions of Special Conditions I.F.4.a.iii or I.F.5.a.iii.

10. In the event that the Governor or the Virginia Drought Coordinator declares a drought emergency in the Drought evaluation Region, which includes Albemarle County and the City of Charlottesville, the permittee shall implement the mandatory conservation measures, as detailed in Attachment A of this permit. The permittee shall be responsible for determining when drought emergencies are declared. DEQ may require documentation that mandatory conservation measures were implemented during declared drought emergencies.

“Water supply” triggers

- Refill triggers (as opposed to the prior drawdown triggers) not specified. Only general guidance is listed in the drought plan (see below)

> Drought stages may be discontinued or reduced in severity after the water supply has sufficiently recovered such that water use restrictions are no longer necessary. It is recommended that drought declarations remain in force until recovery of useable storage is such that modeled water conditions result in a probability of recurrence less than the modeled hydrologic conditions defined for entering each stage in Section 4 of this Plan.

Drought Plan and Updates

- Use of useable vs. total storage for triggers
- Indicates use of Chris Greene in extreme droughts like 2002, as well as Beaver Creek
- Mentions operating rules that favor WQ under normal operating conditions
- Mentions bed loss of 10% in Mechums when releases from Beaver Creek to augment RWSA supply during drought (although those releases will no longer be applicable)

Sugar Hollow Reservoir is located on the Moormans River and drains an area 17.5 square miles in size. As is the case with South Fork dam, regulatory release requirements at Sugar Hollow dam also vary based on total system storage (incorrect), and natural inflow to the reservoir. Releases range from 100% of natural inflow or 10 mgd, whichever is less, when Ragged Mountain useable storage is equal to or greater than 1.08 billion gallons, to 100% of natural inflow, or 2 mgd, whichever is less, when Ragged Mountain useable storage is less than 1.08 billion gallons.

Current Drought Plan

Formal public declaration of a change in drought stage for this Plan will be guided by the following:

- Determination by the Commonwealth of Virginia's Drought Monitoring Task Force that a Watch, Warning, or Emergency condition exists for the Middle James region of Virginia. This is the region that includes Albemarle County and the City of Charlottesville in the Commonwealth's drought management plan.

- A drought emergency declaration by the Governor of Virginia or the Virginia Drought Coordinator affecting the region of the Commonwealth which includes Albemarle County and the City of Charlottesville.

- Review of data maintained by the National Oceanic and Atmospheric Administration (NOAA), the National Weather Service (NWS), and the Virginia State Climatology Office.

- Modeled hydrologic conditions (using OASIS®) predict a probability of a shortage of local water supply as follows:

  Drought Watch Stage: 20% or greater probability that total useable reservoir storage will be less than 75% within 12 weeks. 75% total useable reservoir storage is equivalent to 78% of total reservoir storage.

  Drought Warning Stage: 10% or greater probability that total useable reservoir storage will be less than 60% of full within 10 weeks. 60% total useable reservoir storage is equivalent to 74% of total reservoir storage.

  Drought Emergency Stage: 5% or greater probability that total useable reservoir water storage will be less than 50% of full within 8 weeks. 50% total useable reservoir storage is equivalent to 70% of total reservoir storage.

- Review of streamflow data monitored by the U. S. Geological Survey for the Mechums River gage and the North Fork Rivanna gage.

- Water supply storage stages can also be declared due to unusual events that threaten the available supply of water, such as acute contamination of the water in a reservoir, loss due to a failure causing significant loss of stored water from a dam, or related types of circumstances.

C. *RWSA Water Supply System Operating Procedures*

Operating procedures for the RWSA Urban Service Area are in place to most efficiently utilize the existing raw water resources. Under normal operating conditions, the system is operated to maximize the quality of the water produced at each water treatment plant and to efficiently transport water to the water distribution systems of the Albemarle County Service Authority and the City of Charlottesville.

As drought conditions begin, total system storage decreases. The Sugar Hollow Reservoir will normally stop spilling, followed by the South Fork Rivanna Reservoir. As these conditions occur, RWSA will maximize production at the South Fork Rivanna Water Treatment Plant over the Observatory Water Treatment Plant, while maintaining operating pressures at all delivery points to the City of Charlottesville that do not exceed the reasonable operating limits of the City's system. As a drought becomes more persistent, production at the South Fork Water Treatment Plant will continue to be emphasized, and the drawdown of the Sugar Hollow Reservoir will take priority over the Ragged Mountain Reservoir since the larger watershed area upstream of Sugar Hollow will permit the water supply to recover more quickly when rainfall does occur. Storage in the Ragged Mountain Reservoir will be held as long as possible, except to the extent that the Ragged Mountain Reservoir will be drawn down enough to prevent transfers from Sugar Hollow to cause spillage from the dam.

Further optimization of the Water Supply System Operating Procedures would be possible if the North Rivanna and South Rivanna distribution systems were interconnected and a new pump station were built.and if the South Fork and Observatory water distribution systems were further reinforced by the completion of a transmission main between Pantops and Avon Street (referred to as the "Southern Loop"). The Route 29 Pump Station Site Acquisition is in the currently proposed RWSA Capital Improvement Program for 2015-2019 A location is established for emergency transfer of water between the Norht Rivanna and South Rivanna systems using portable equipment that will help provide needed service during a drought event.

Supplemental stream flows to the South Fork Rivanna Reservoir will be instituted during drought conditions as defined under Section 3 of this Plan.

3. Emergency Water Sources

A. Beaver Creek Reservoir

LOGICS

Demands

- New monthly demand pattern for urban system? Old shown below
- Do drought plan reductions need to be revisited given success of long-term conservation?
- Do drought plan reductions need to be seasonal rather than uniform across the year?
- Maintain 28-day waiting period between drought phases?
- Waiting period on lifting phases?

Demand Pattern at Node 190, 'RWSA Demand'

Month	Day	Demand
1	1	0.920
1	31	0.920
2	1	0.960
2	29	0.960
3	1	0.950
3	31	0.950
4	1	1.000
4	30	1.000
5	1	0.990
5	31	0.990
6	1	1.040
6	30	1.040
7	1	1.080
7	31	1.080
8	1	1.100
8	31	1.100
9	1	1.130
9	30	1.130
10	1	1.000
10	31	1.000
11	1	0.940
11	30	0.940
12	1	0.890
12	31	0.890

mgd Units

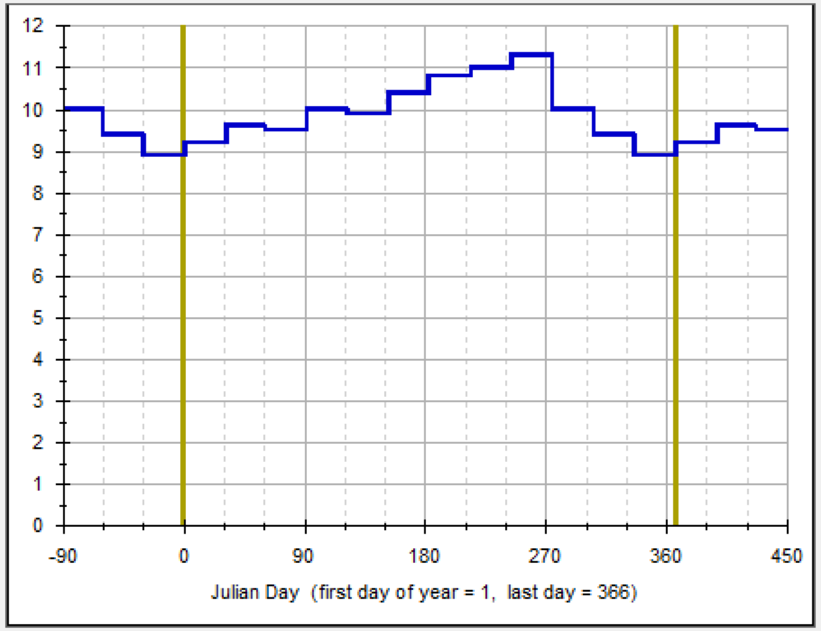
10 Multiplication Factor

Change Node

Import Data

OK

Cancel



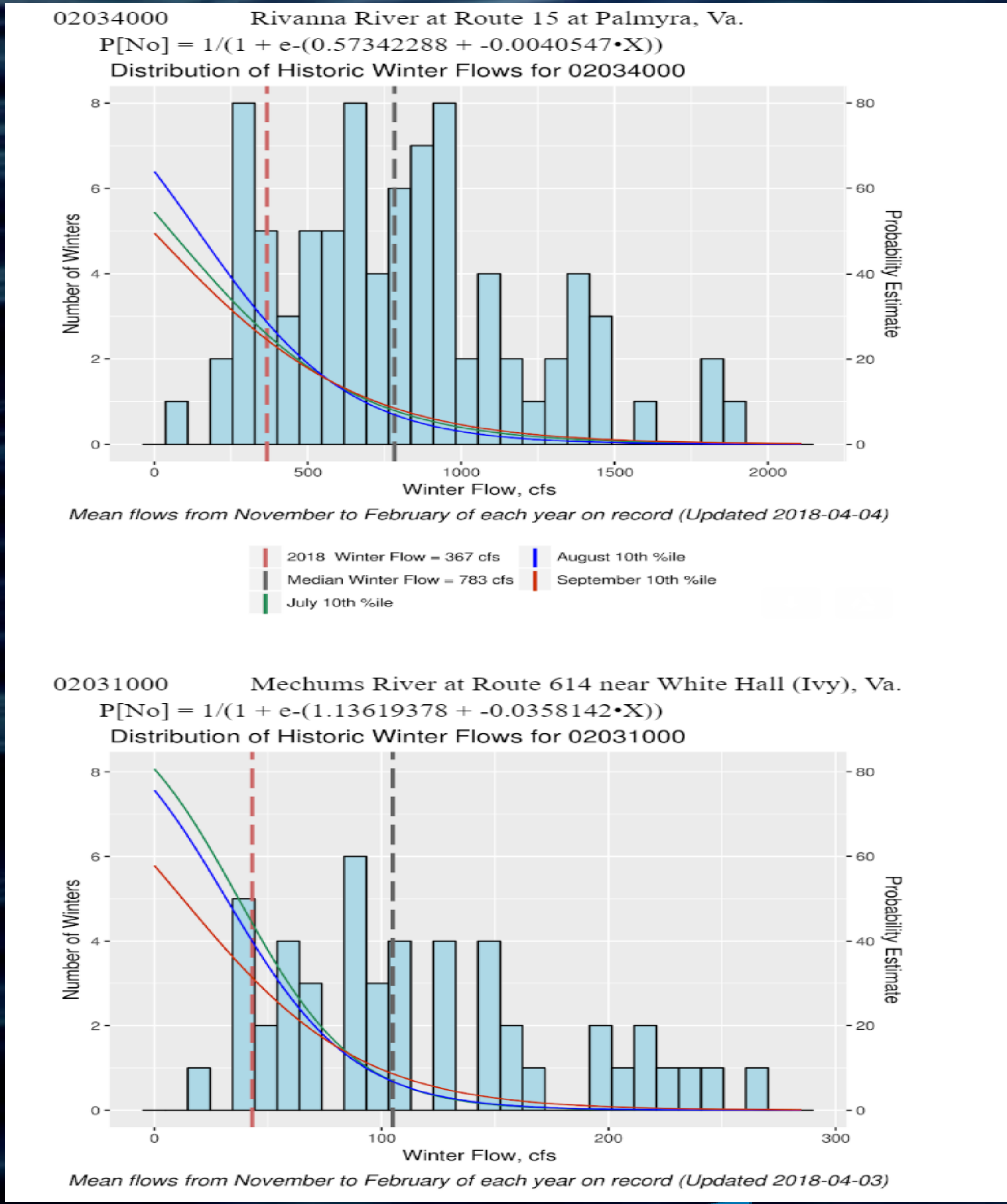
HYDROLOGICS

"Minimum Release" Triggers

- Tied to useable storage in RM for setting SH release and useable storage in RM/SH/SF for setting SF release
- For simplicity, should consider tying to drought triggers so demand and minimum release reductions occur at the same time
  - Have not looked at impact of doing this, but it will help to conserve storage
- DEQ may now prefer to implement a drought outlook-based approach using seasonal regressions

HYDROLOGICS

DEQ Alternative



Permit Releases

Minimum Release Determination

Scenario	SH	SF
Before expansion of RM	0.4 mgd or natural inflow, whichever is less	8 mgd or natural inflow, whichever is less
After expansion of RM, filled to intermediate level of 671 feet, with no pipeline for SF-RM	< 1080 MG useable (RM), release 100% of the natural inflow or 2 mgd, whichever is less Otherwise, release 100% of the natural inflow or 10 mgd, whichever is less Natural inflow to SH = Mechums gage * 0.19 (drainage-area adjustment, all in mgd)	< 750 MG useable (RM + SF + SH), release 30% of natural inflow < 1600 MG useable (RM + SF + SH), release 50% of natural inflow Otherwise, release 70% of the infow or 1.3 mgd, whichever is more At a minimum, release 1.3 mgd (unless SF is empty); at a maximum, release 20 mgd (unless spilling) Natural inflow to SF = Mechums gage * 2.71 (drainage-area adjustment, all in mgd)

Details provided in the permit:
Final DEQ VWP Major Mod Permit 12-28-11.pdf

From the permit, RM volumes:
671 feet = 1549 MG useable storage
683 feet = 2189 MG useable storage

SF-RM pipeline only considered if RM were filled to final level of 683 feet
SH transfers to RM would be discontinued once SF-RM pipeline were built

Min release requirements associated with fill to 683 feet shown below:

Scenario	SH	SF
After expansion of RM, filled to full level of 683 feet, with no pipeline for SF-RM	< 1530 MG useable (RM), release 100% of the natural inflow or 2 mgd, whichever is less Otherwise, release 100% of the natural inflow or 10 mgd, whichever is less Natural inflow to SH = Mechums gage * 0.19 (drainage-area adjustment, all in mgd)	< 1360 MG useable (RM + SF + SH), release 30% of natural inflow < 2360 MG useable (RM + SF + SH), release 50% of natural inflow Otherwise, release 70% of the infow or 1.3 mgd, whichever is more At a minimum, release 1.3 mgd (unless SF is empty); at a maximum, release 20 mgd (unless spilling) Natural inflow to SF = Mechums gage * 2.71 (drainage-area adjustment, all in mgd)
After expansion of RM, filled to intermediate level of 671 feet, with pipeline for SF-RM	Release 90% of the inflow Natural inflow to SH = Mechums gage * 0.19 (drainage-area adjustment, all in mgd)	< 1000 MG useable (RM + SF + SH), release 30% of natural inflow < 1800 MG useable (RM + SF + SH), release 50% of natural inflow Otherwise, release 70% of the infow or 1.3 mgd, whichever is more At a minimum, release 1.3 mgd (unless SF is empty); at a maximum, release 20 mgd (unless spilling) Natural inflow to SF = Mechums gage * 2.71 (drainage-area adjustment, all in mgd)
After expansion of RM, filled to full level of 683 feet, with pipeline for SF-RM	Release 90% of the inflow Natural inflow to SH = Mechums gage * 0.19 (drainage-area adjustment, all in mgd)	< 1360 MG useable (RM + SF + SH), release 30% of natural inflow < 2360 MG useable (RM + SF + SH), release 50% of natural inflow Otherwise, release 70% of the infow or 1.3 mgd, whichever is more At a minimum, release 1.3 mgd (unless SF is empty); at a maximum, release 20 mgd (unless spilling) Natural inflow to SF = Mechums gage * 2.71 (drainage-area adjustment, all in mgd)

Minimum Releases

- No safety factor is needed since flow requirement is totalized
- RWSA currently adjusts each day, although that is not required by permit

> The required rates of total downstream flow past South Fork Rivanna Reservoir and Sugar Hollow Reservoir shall be determined and the rates of total downstream flow shall be adjusted as necessary twice per week. When the required rate of total downstream flow depends upon the natural inflow to the reservoir, the total downstream flow shall be calculated by determining the average of the natural inflows for the three most recent days for which data are available. No adjustment to the rate of total downstream flow shall be required unless the current calculation of total downstream flow differs from the previously calculated total downstream flow by more than ten percent.

- Ramping (above minimum release) is mentioned in permit

> iii. When the water level at South Fork Rivanna Reservoir is below its spillway elevation and water is released from Sugar Hollow Reservoir to the Moormans River at a rate substantially in excess of the applicable total downstream flow specified herein for the purpose of conveying water into South Fork Rivanna Reservoir for water supply, the Rivanna Water & Sewer Authority will reduce the rate of flow released through the flow control device at Sugar Hollow Reservoir by no more than fifty percent (50 %) per day until the applicable total downstream flow specified herein is achieved.

HYDROLOGICS

Current System Operations (Basecase)

Operations for Current System (Basecase)

19 feet at SH actually equal to 36% useable, 42% total (not 30%!)

SF equal to 91% useable, 94% total

10 feet at SH actually equal to 63% useable, 66% total (not 60%)

Also add in provision that transfer from SH to RM only occurs when RM < 95% (total)

After our discussions last week and meeting on Friday, a summary of our updated strategy follows:

From about Nov 15 – May 15:

- When SFRR is overflowing:
  - Fill RMR by (1) transferring from SHR. Stop transfer when SHR level reaches <u>19 feet</u> below top of dam = 30% storage, and (2) minimizing use of OWTF (intermittent production schedule averaging 1 MGD), while maximizing SRWTP production.
- When SFRR is NOT overflowing (about 1.0' below top of dam):
  - Fill SFRR by (1) terminating transfer from SHR, (2) maximizing use of OWTF (4 – 5 mgd) while minimizing SRWTP production, and (3) assessing and correcting any issue with gates or meter.

From about May 15 – Nov 15:

- When SFRR is overflowing:
  - Fill RMR by (1) transferring from SHR. Stop transfer when SHR level reaches <u>10 feet</u> below top of dam = 60% storage, and (2) minimizing use of OWTF (intermittent production schedule averaging 1 MGD), while maximizing SRWTP production.
- When SFRR is NOT overflowing (about 1.0' below top of dam): SAME as other season
  - Fill SFRR by (1) terminating transfer from SHR, (2) maximizing use of OWTF (4 – 5 mgd) while minimizing SRWTP production, and (3) assessing and correcting any issue with gates or meter.

Please let me know if there are any additions or revisions. Otherwise, we will implement this strategy immediately.

Thanks

Bill Mawyer
Executive Director
Rivanna Authorities
695 Moores Creek Lane
Charlottesville, Va 22902
bmawyer@rivanna.org
434-977-2970 ext. 103

Other Assumptions

- Urban system demand = 10 mgd (annual average)
  - Includes NF, which is interconnected with main system (0.5 mgd to come from NF WTP)
- No gated operations at BC, but also no minimum release, both of which would have minimal impact
- No longer consider channel loss in Mechums or Moomans
  - Embedded in the gage flows which form the inflow development
  - Channel loss not well documented
- No longer assume Chris Greene will release water to supplement flows at NF intake
- Updated net evaporation timeseries driven by more regional evap drought studies
- Drought ("Water Supply") triggers
  - No activation of drawdown triggers unless total storage < 90% (therefore, no forecasts are needed)
  - Must be implemented in sequence
  - Waiting period only between drawdown phases 2 and 3 (28 days)
  - No waiting period between lifting stages

Reliability Metrics

- Safe yield (out of scope)
  - In the past, for the RWSA system, has always assumed no WTP production constraints (minimum or maximum)
  - Always ignored a monthly demand pattern
  - Always ignored demand reductions and a minimum reserve (“operational yield” like 60 days of supply)
  - Other systems like AWRA have included these adjustments
- Frequency, severity, and duration of drought restrictions
- Frequency of hitting certain storage levels

Memorandum

To: File
From: Jennifer Whitaker, Chief Engineer
Date: September 6, 2016
Re: Safe Yield Summary

No.	Scenario	Calculated Safe Yield (mgd)	Reference
1	2004 Urban System Safe Yield – Without any Upgrades • Total Useable Storage 1,589 MG • (RM-465, SF-800, SH-324) • Historical Voluntary Flow Releases	12.8	1,2,3
2	2004 Predicted 2055 Safe Yield – Without any Upgrades • Total useable Storage 989 MG • (RM-465, SF-200, SH-324) • Historical Voluntary Flow Releases	8.8	2
3	2004 Predicted 2055 Urban System Safe Yield – With all Upgrades • Total Useable Storage 2,713 MG • (RM-2,189, SF-200, SH-324) • New SF to RM Pipeline • Dam Spillway Height 686 (Equal to current 683 Ft. Volume) • New VWP Permitted Release Requirements	18.7	6, 7
4	2014 Urban System Safe Yield –With Phs. 1 Dam and no Pipeline • Total Useable Storage 2,755 MG • (RM-1549, SF-882, SH-324 MG) • New VWP Permitted Release Requirements • No New SF to RM Pipeline • Dam to Height 671 Ft.	16.2	3
5	2014 Urban System Safe Yield – With Phs. 1 Dam and Pipeline • Total Useable Storage 2,755 MG • (RM-1549, SF-882, SH-324 MG) • New VWP Permitted Release Requirements • New SF to RM Pipeline • Dam Spillway Height 671 Ft. • Does Not Account for Future Loss at SFRR	19.1	3,5
6	2014 Urban System Safe Yield – With Pipeline and Phs.2 Dam Raise • Total Useable Storage 3,395 MG • (RM-2189, SF-882, SH-324 MG) • New VWP Permitted Release Requirements • New SF to RM Pipeline • Dam Spillway Height 683 Ft. • Does Not Account for Future Loss at SFRR	21.5	4,5,8
7	2016 Urban System Safe Yield – With Pipeline and Phs.2 Dam Raise and Loss of Volume at SFRR • Total Useable Storage 2,713 MG • (RM-2189, SF-200, SH-324 MG) • New VWP Permitted Release Requirements • New SF to RM Pipeline • Dam Spillway Height 683 Ft.	19.0	8

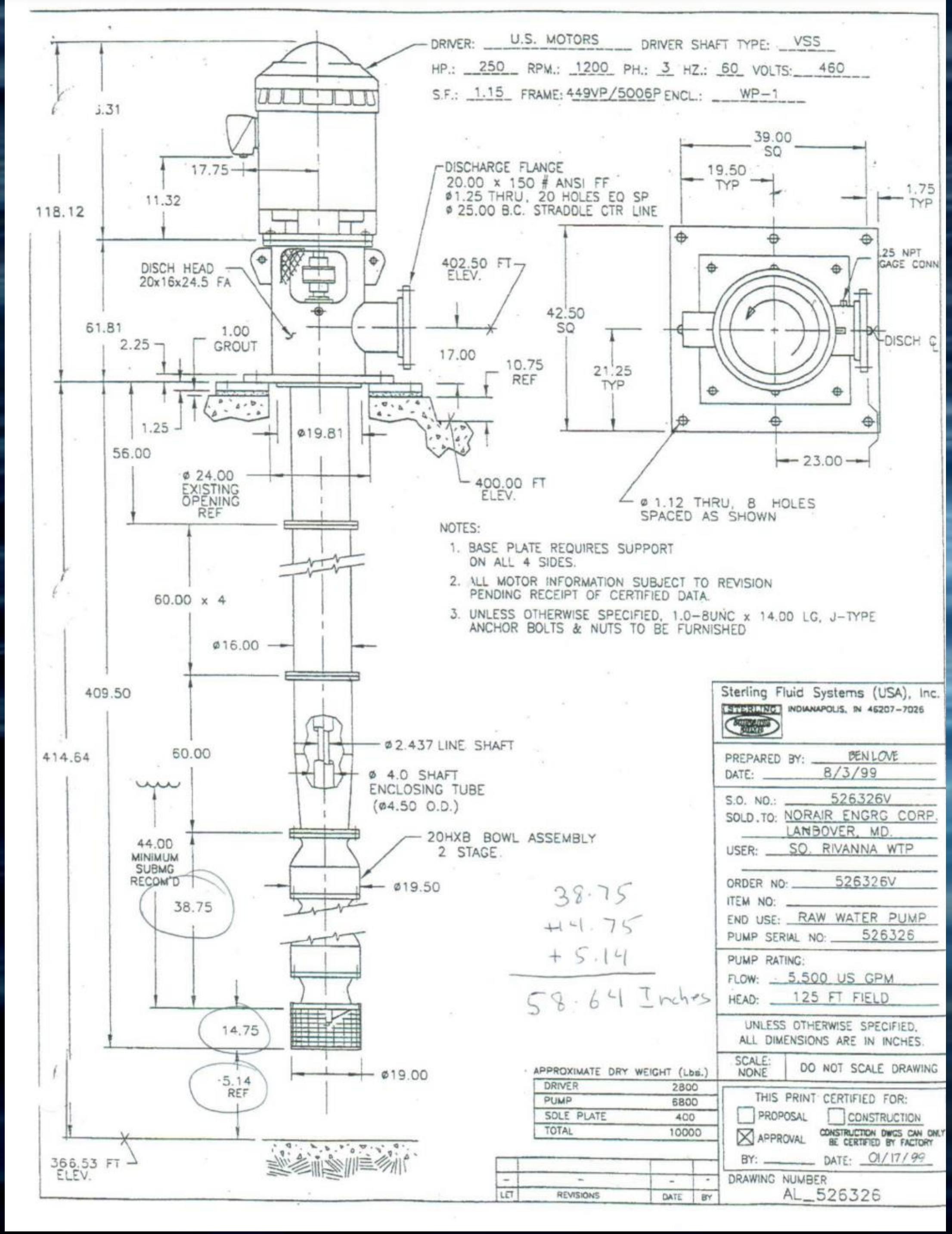
HYDROLOGICS

South Fork

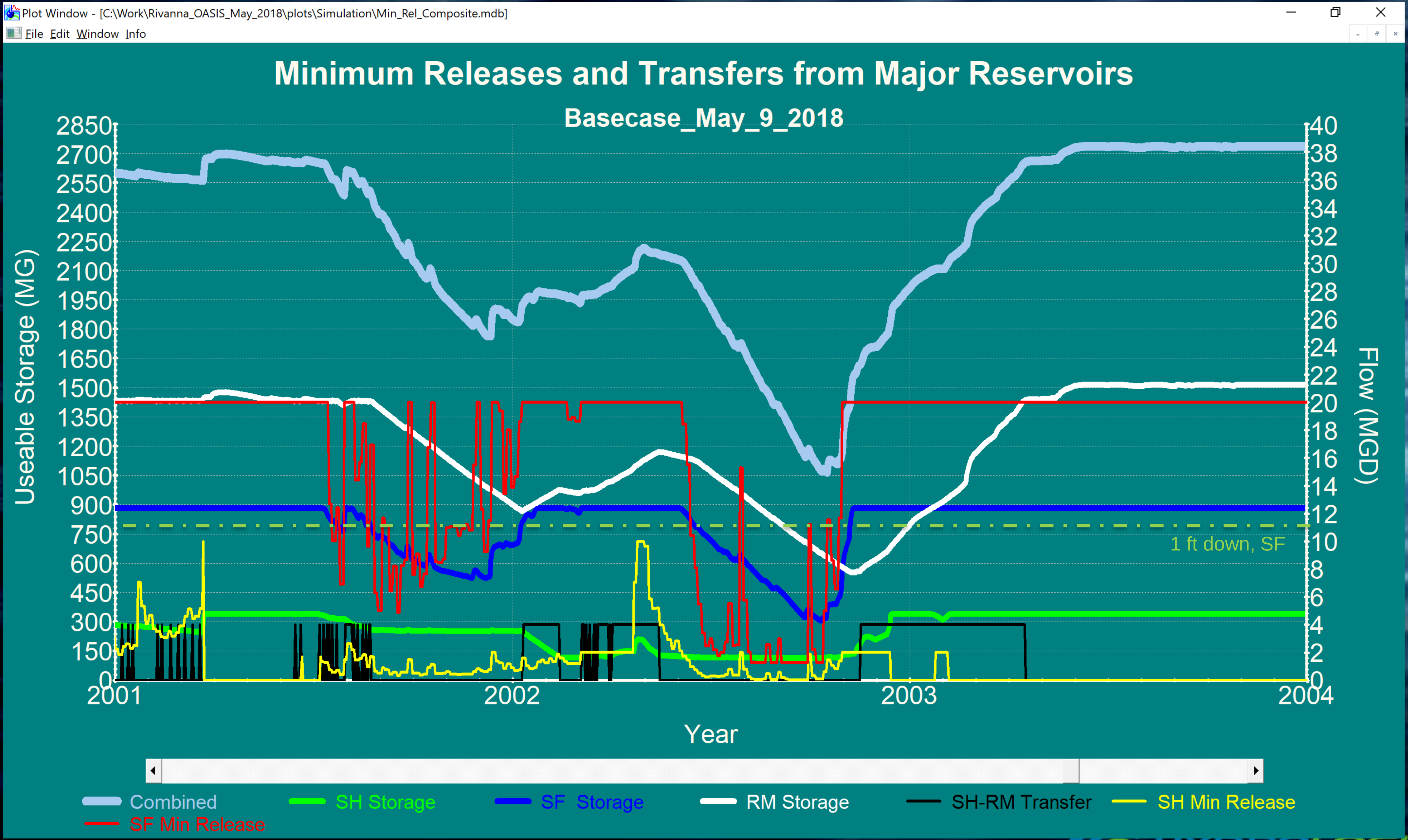
- From Andrea:

  "I talked to Dave about the attached scan of the raw water pump at SFRR. The surface elevation of SFRR is 382'. The bottom elevation as shown on the chamber is 366.53 ft. The 58.64 inches shown on the drawing is how much water has to be in the chamber to keep the pump submersed. Therefore water has to be at elevation of 371.42' (366.53+4.89 ft.(58.64 inches)). During last fall Dave was able to place temporary pumps in the hydro plant intake (elevation 341(?)) and pump that water over to keep the raw water pumps submerged. Obviously that is not the best water and was a challenge to treat, but could and would be done again. So basically, we can still use the 883 mg useable capacity, but know we would prefer not to get below elevation 371."

This is equal to 563 MG total, or 563/1282 = 44% total
This is also equal to 563/882 = 64% useable

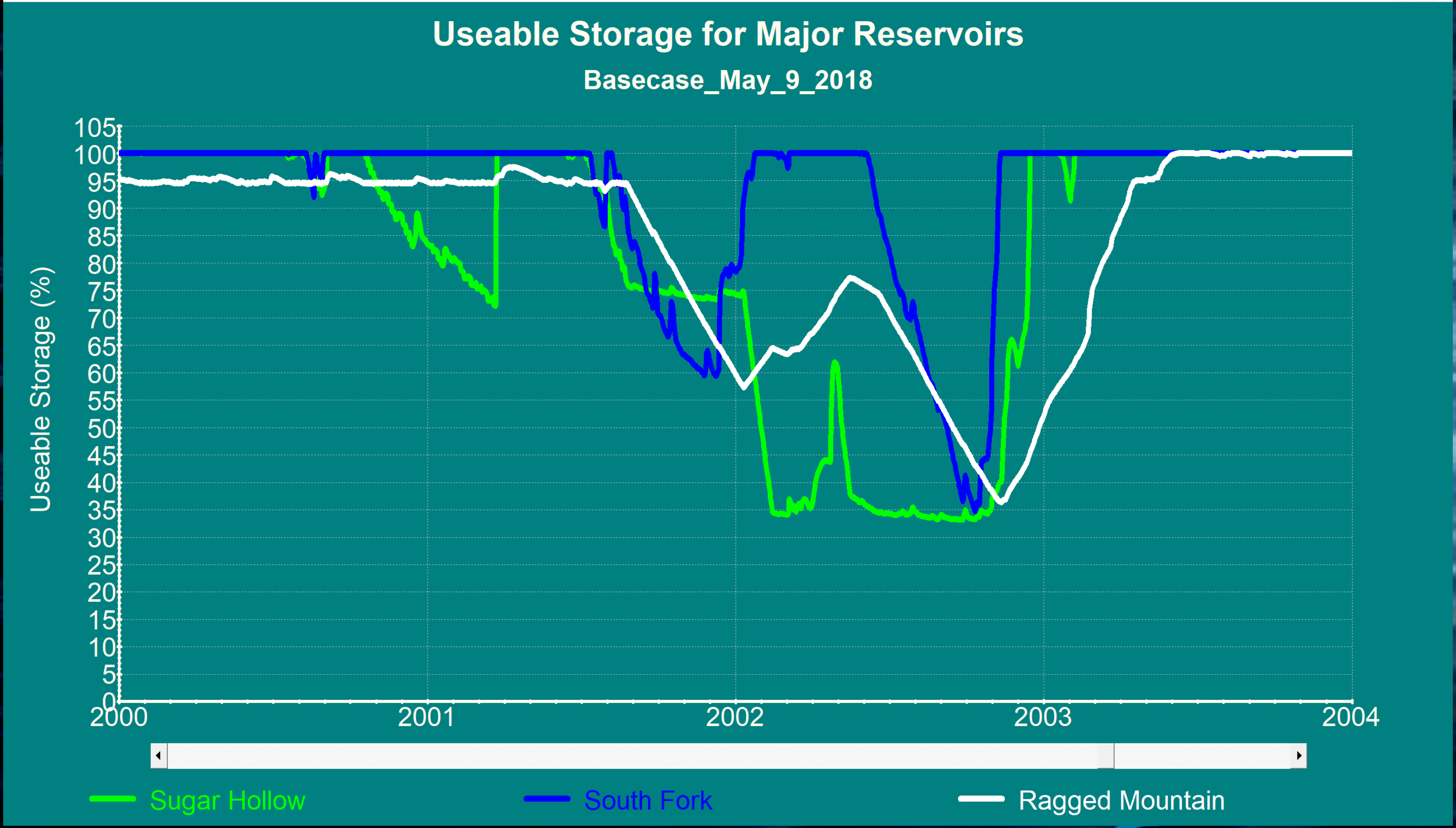


Results

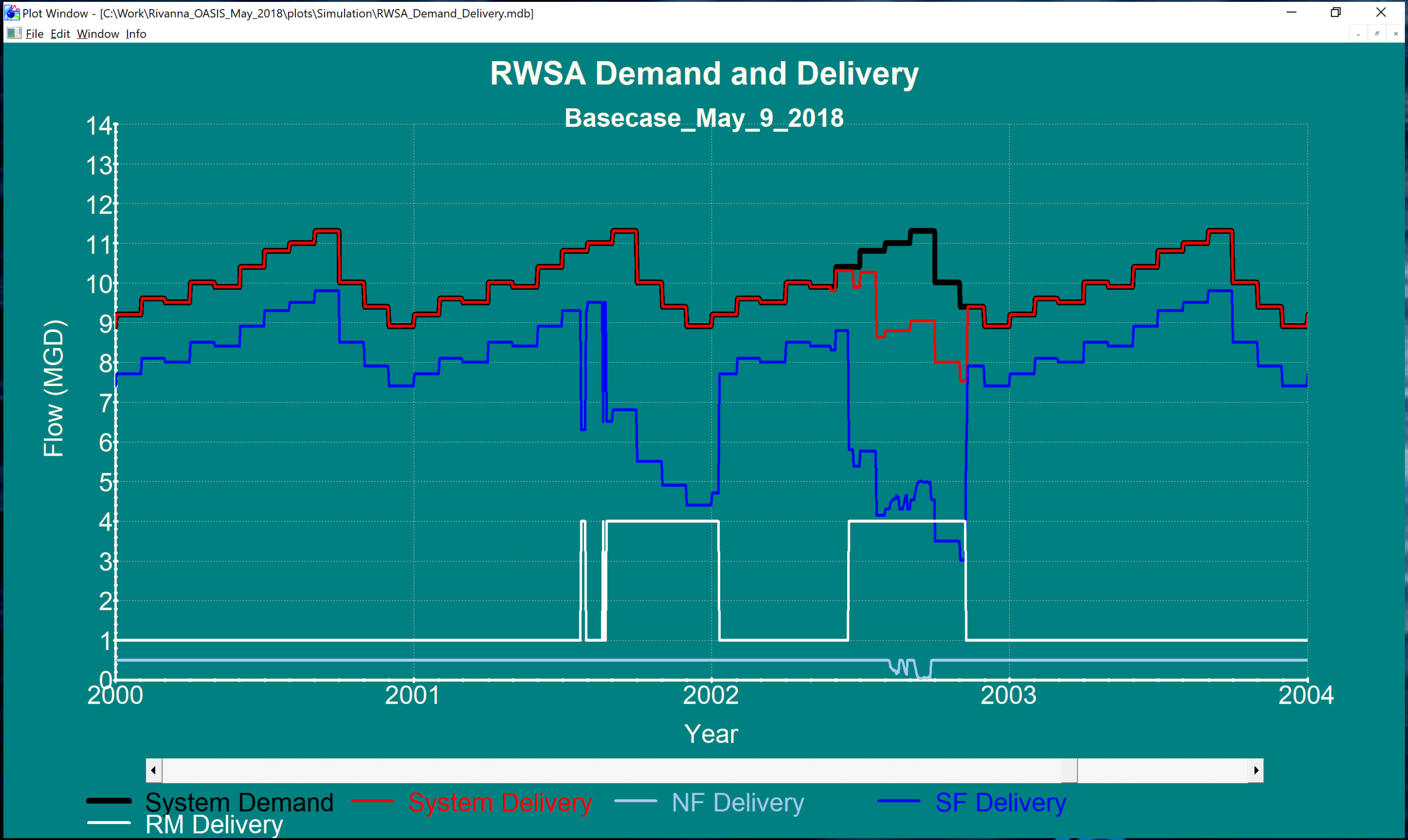

Plot Window - [C:\Work\Rivanna_OASIS_May_2018\plots\Simulation\Min_Rel_Composite.mdb]
File Edit Window Info
Minimum Releases and Transfers from Major Reservoirs
Basecase_May_9_2018
Useable Storage (MG)
2850
2700
2550
2400
2250
2100
1950
1800
1650
1500
1350
1200
1050
900
750
600
450
300
150
0
Flow (MGD)
40
38
36
34
32
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0
1 ft down, SF
2001
2002
2003
2004
Year
Combined
SH Storage
SF Storage
RM Storage
SH-RM Transfer
SH Min Release
SF Min Release

Plot Window - [C:\Work\Rivanna_OASIS_May_2018\plots\Simulation\Major_Res_Useable_pct.mdb]

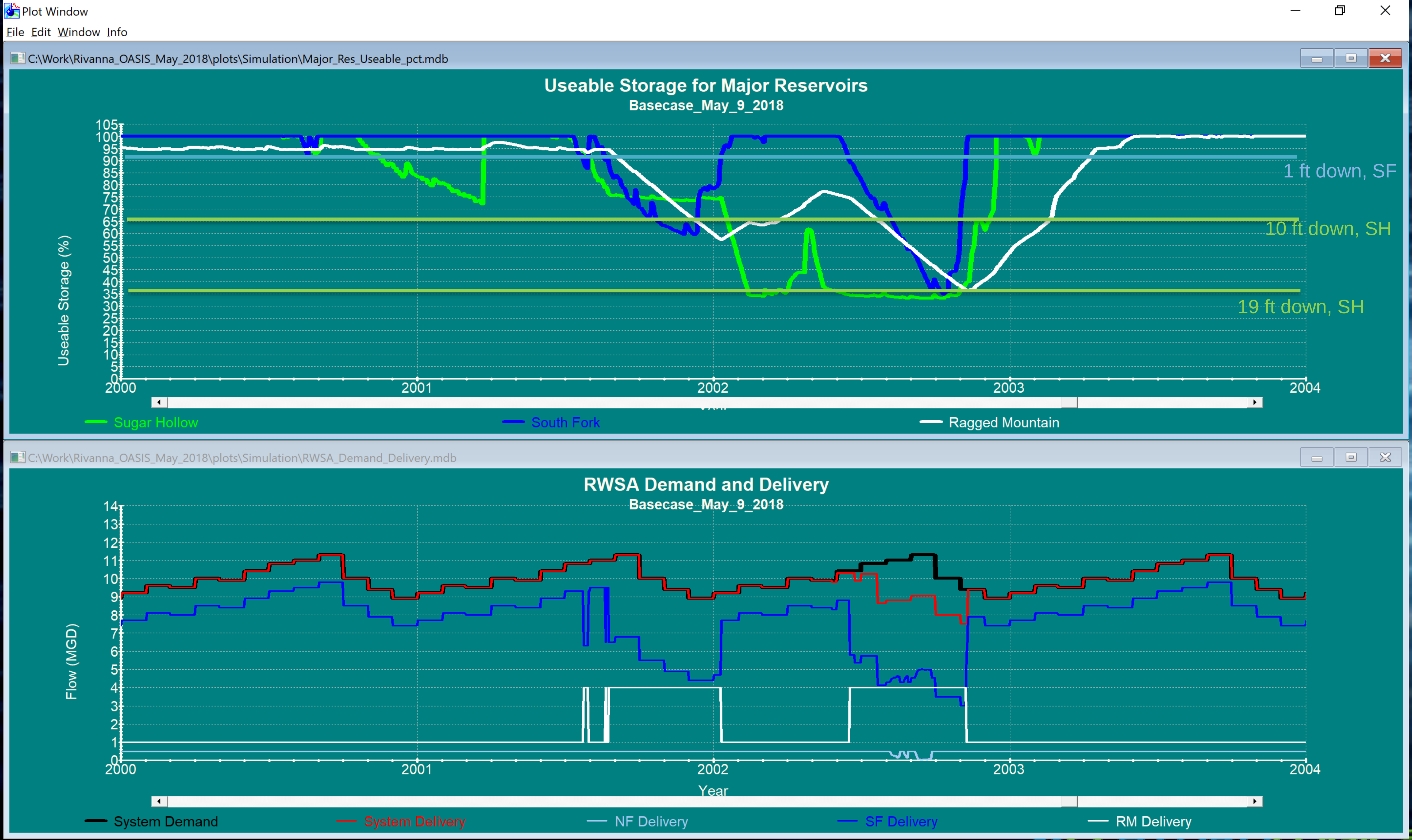
File Edit Window Info

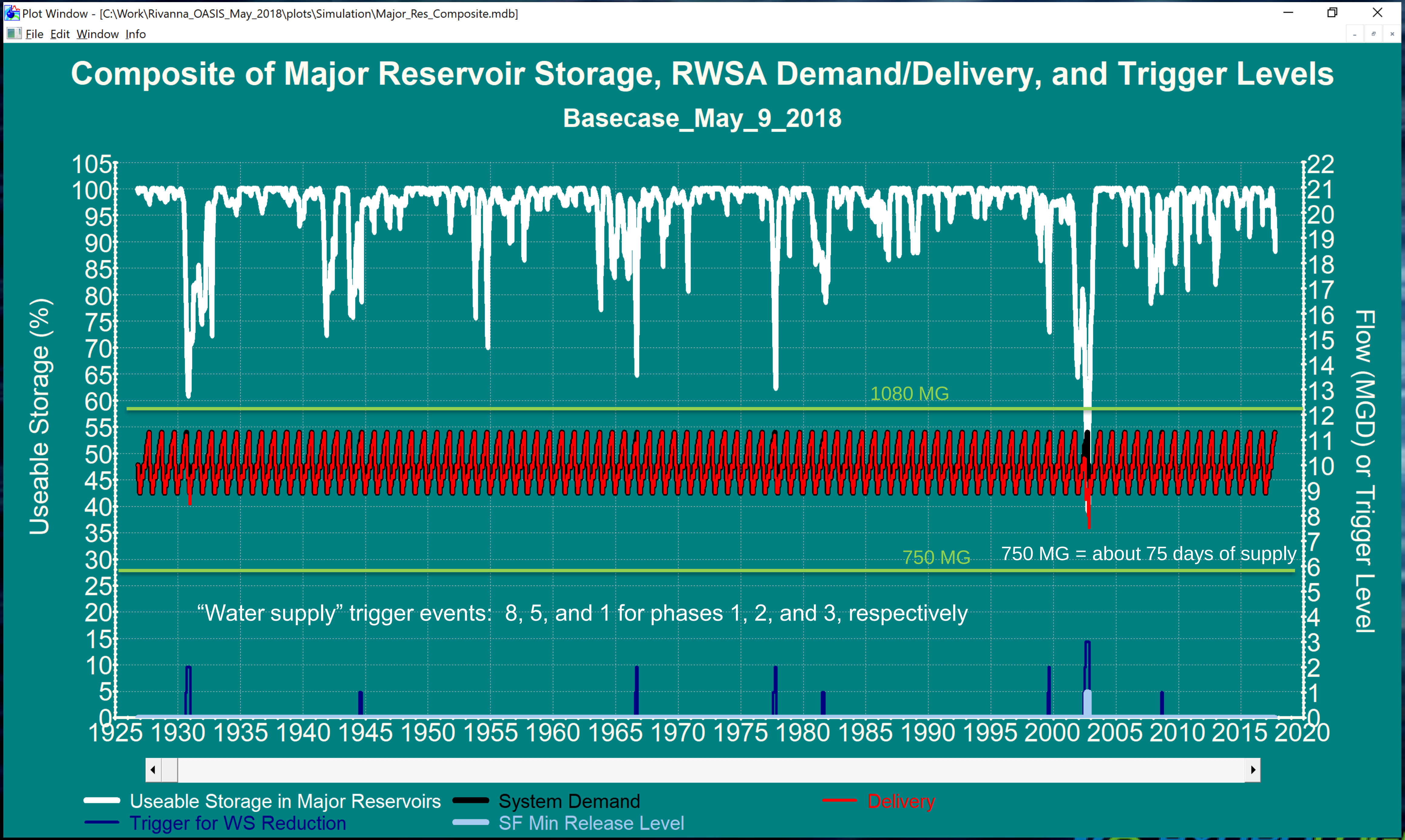


HYDROLOGICS



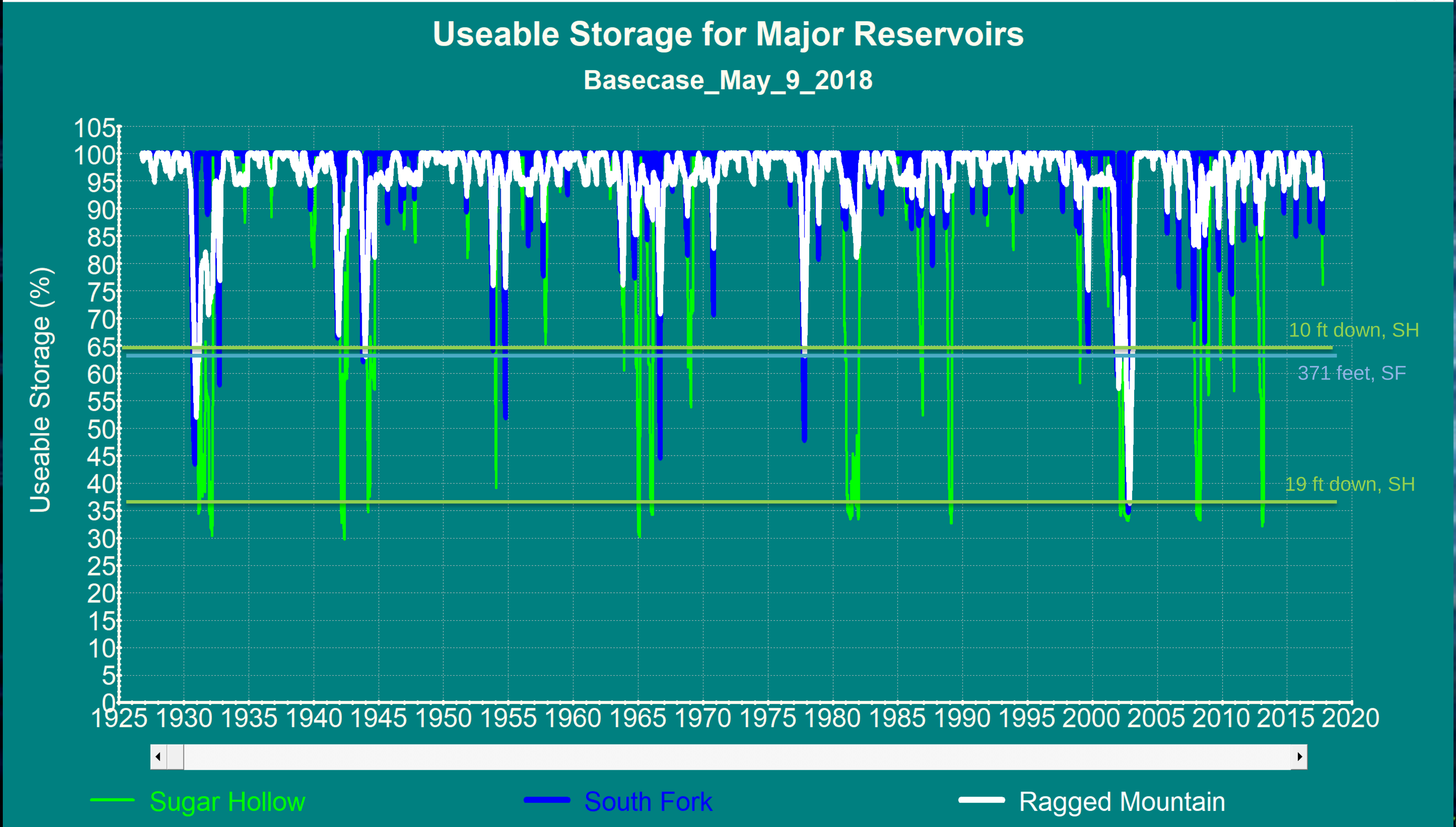
HYDROLOGICS

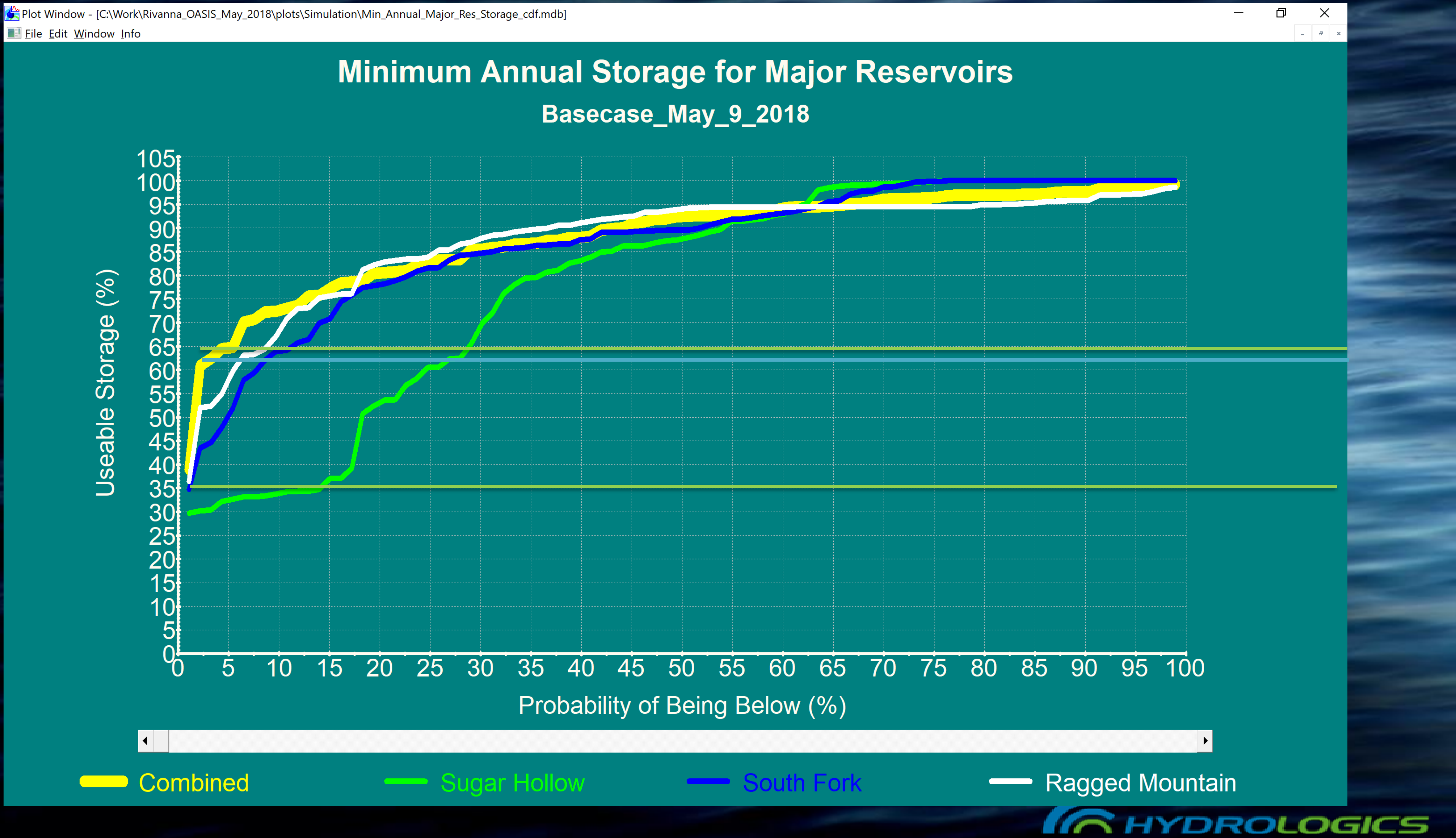

Plot Window
File Edit Window Info
C:\Work\Rivanna_OASIS_May_2018\plots\Simulation\Major_Res_Useable_pct.mdb
Useable Storage for Major Reservoirs
Basecase_May_9_2018
Useable Storage (%)
1 ft down, SF
10 ft down, SH
19 ft down, SH
2000
2001
2002
2003
2004
Sugar Hollow
South Fork
Ragged Mountain
C:\Work\Rivanna_OASIS_May_2018\plots\Simulation\RWSA_Demand_Delivery.mdb
RWSA Demand and Delivery
Basecase_May_9_2018
Flow (MGD)
Year
System Demand
System Delivery
NF Delivery
SF Delivery
RM Delivery


Plot Window - [C:\Work\Rivanna_OASIS_May_2018\plots\Simulation\Major_Res_Composite.mdb]
File Edit Window Info
Composite of Major Reservoir Storage, RWSA Demand/Delivery, and Trigger Levels
Basecase_May_9_2018
Useable Storage (%)
Flow (MGD) or Trigger Level
1080 MG
750 MG
750 MG = about 75 days of supply
"Water supply" trigger events: 8, 5, and 1 for phases 1, 2, and 3, respectively
1925 1930 1935 1940 1945 1950 1955 1960 1965 1970 1975 1980 1985 1990 1995 2000 2005 2010 2015 2020
Useable Storage in Major Reservoirs
System Demand
Delivery
Trigger for WS Reduction
SF Min Release Level

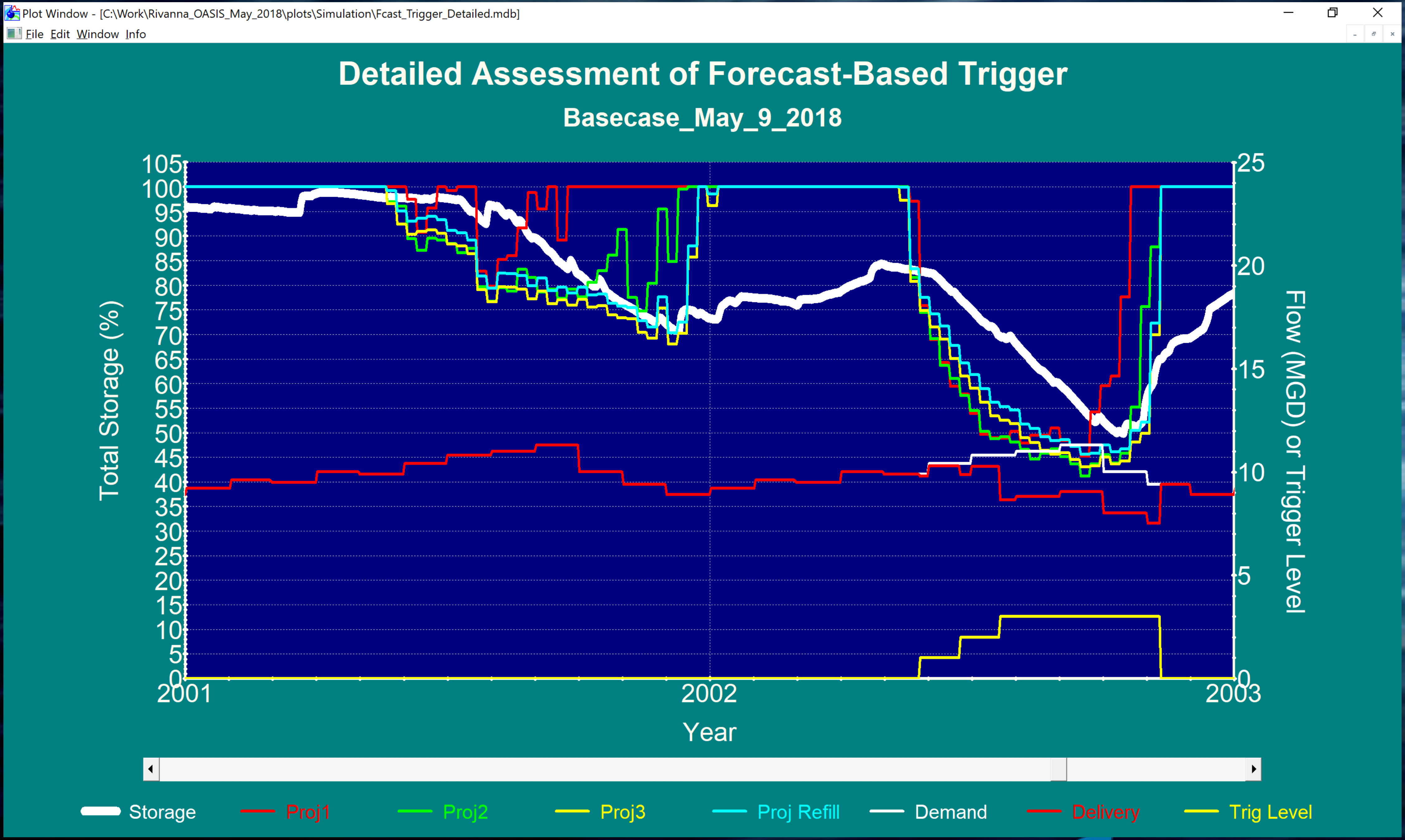
Plot Window - [C:\Work\Rivanna_OASIS_May_2018\plots\Simulation\Major_Res_Useable_pct.mdb]

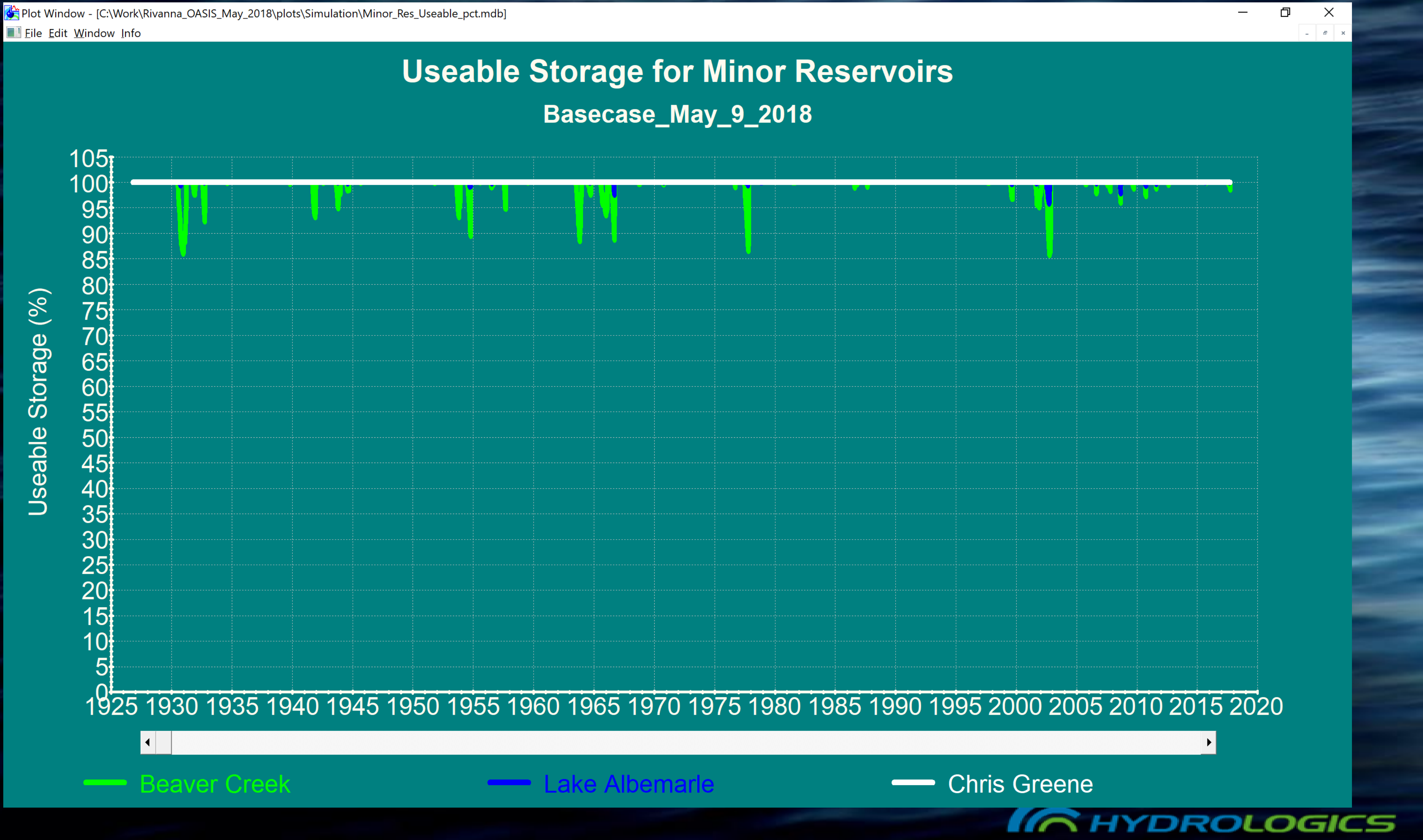
File Edit Window Info





Plot Window - [C:\Work\Rivanna_OASIS_May_2018\plots\Simulation\Min_Annual_Major_Res_Storage_cdf.mdb]
File Edit Window Info
Minimum Annual Storage for Major Reservoirs
Basecase_May_9_2018
Useable Storage (%)
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85
90
95
100
105
Probability of Being Below (%)
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85
90
95
100
Combined
Sugar Hollow
South Fork
Ragged Mountain
HYDROLOGICS


Plot Window - [C:\Work\Rivanna_OASIS_May_2018\plots\Simulation\Fcast_Trigger_Detailed.mdb]
File Edit Window Info
Detailed Assessment of Forecast-Based Trigger
Basecase_May_9_2018
Total Storage (%)
105
100
95
90
85
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
Flow (MGD) or Trigger Level
25
20
15
10
5
0
2001
2002
2003
Year
Storage
Proj1
Proj2
Proj3
Proj Refill
Demand
Delivery
Trig Level

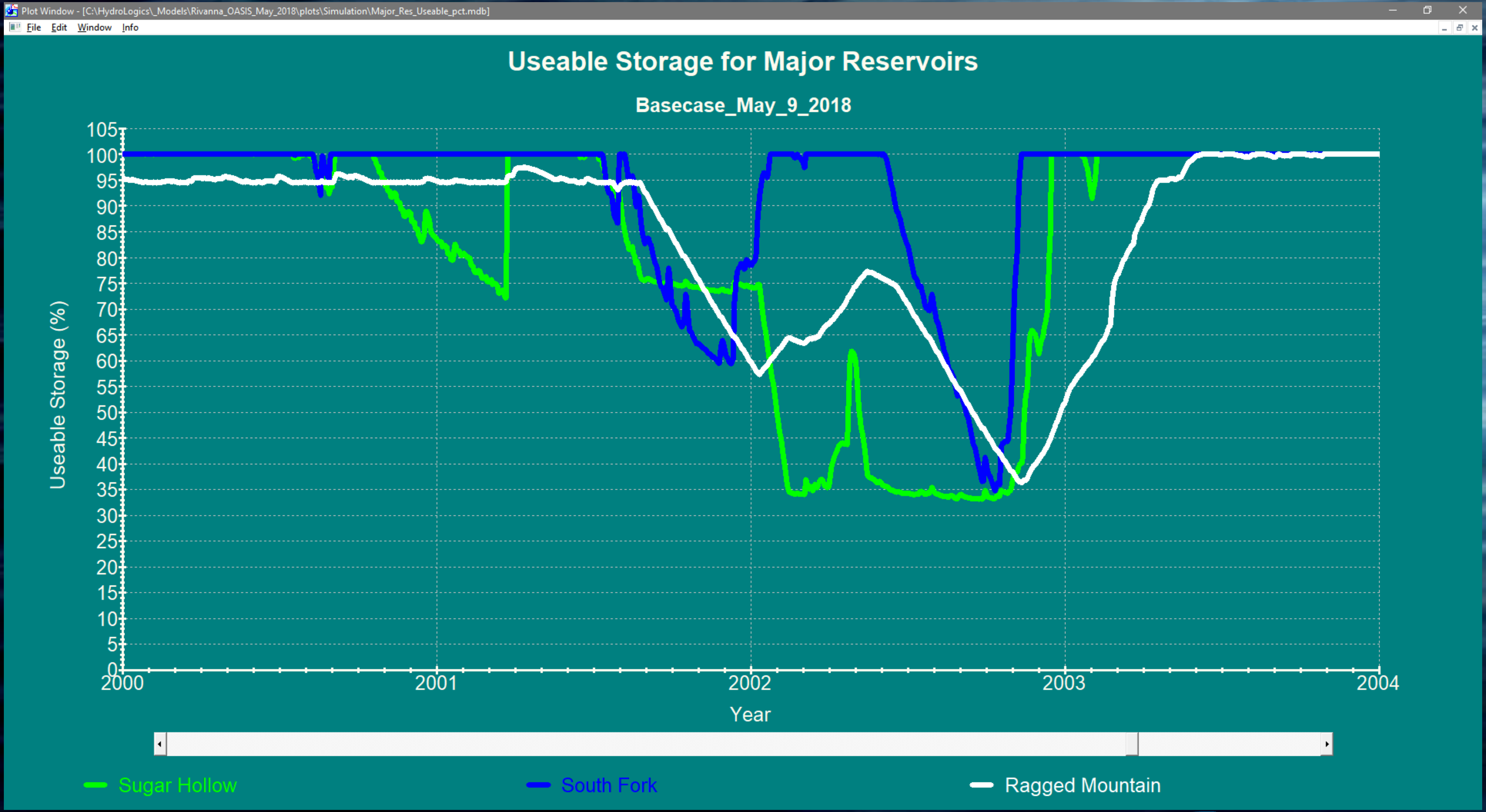

Plot Window - [C:\Work\Rivanna_OASIS_May_2018\plots\Simulation\Minor_Res_Useable_pct.mdb]
File Edit Window Info
Useable Storage for Minor Reservoirs
Basecase_May_9_2018
Useable Storage (%)
105
100
95
90
85
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
1925 1930 1935 1940 1945 1950 1955 1960 1965 1970 1975 1980 1985 1990 1995 2000 2005 2010 2015 2020
Beaver Creek
Lake Albemarle
Chris Greene
HYDROLOGICS

Evaluate Alternative Thresholds for SH/RM Transfer and SF/RM Production

- Considerations
  - Minimize SF spill, which is wasted water. This would mean bring down SF more, RM less. However, minimize SF drawdown since operationally difficult below 371 feet (64% useable). Therefore, RM needs to be drawn down more.
  - Maintain similar storage among reservoirs in the worst droughts
  - Adjustment to policy might be motivated by WQ and/or production cost, but right now focused on reliability

HYDROLOGICS

Basecase (1.0 feet for SF)

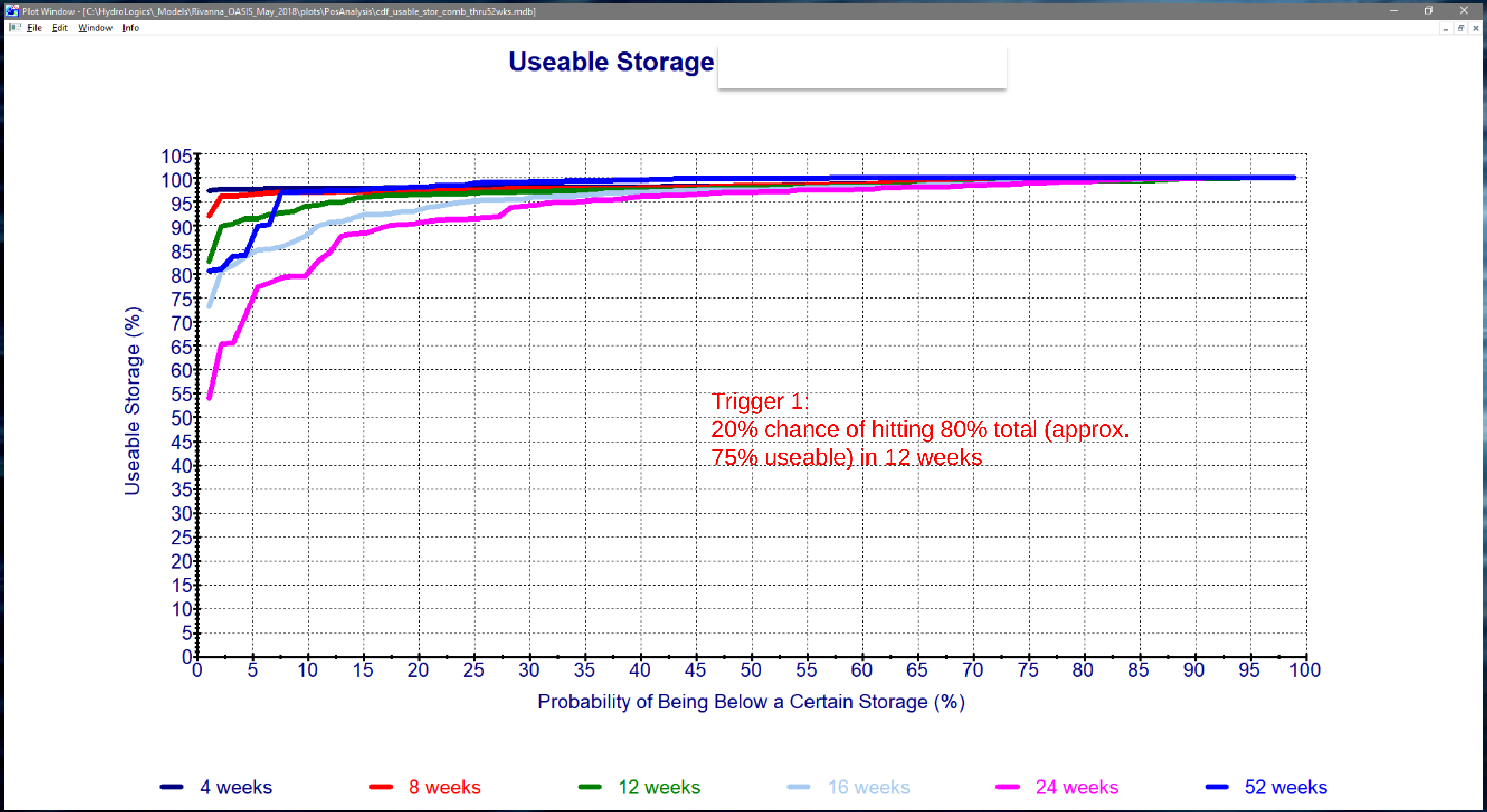


HYDROLOGICS

Alternative 1 : Use 2.5 feet for SF

Alternative 2: Use 5 feet for SF

Forecast Around May 1, 2018

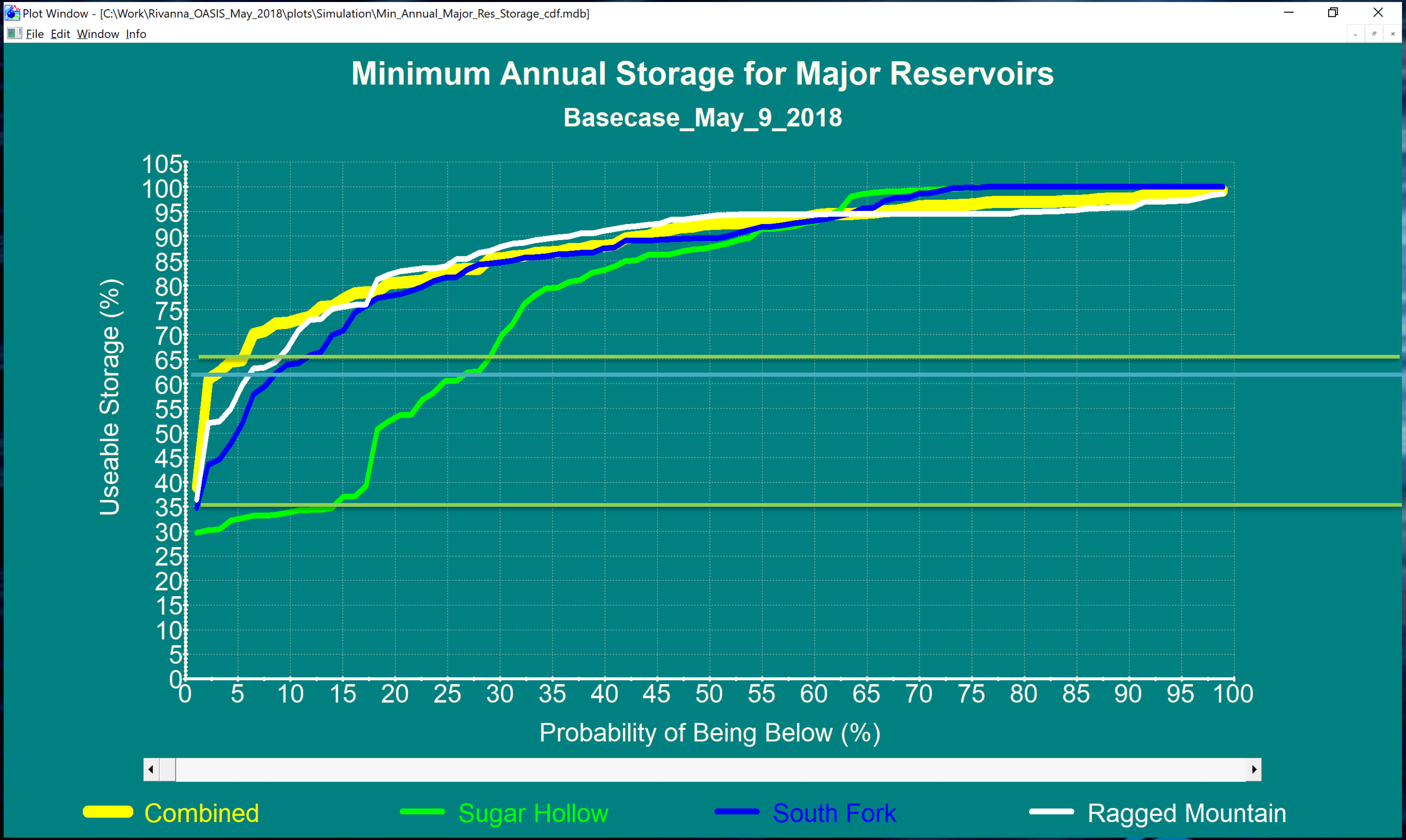


HYDROLOGICS

Impact of Higher System Demands

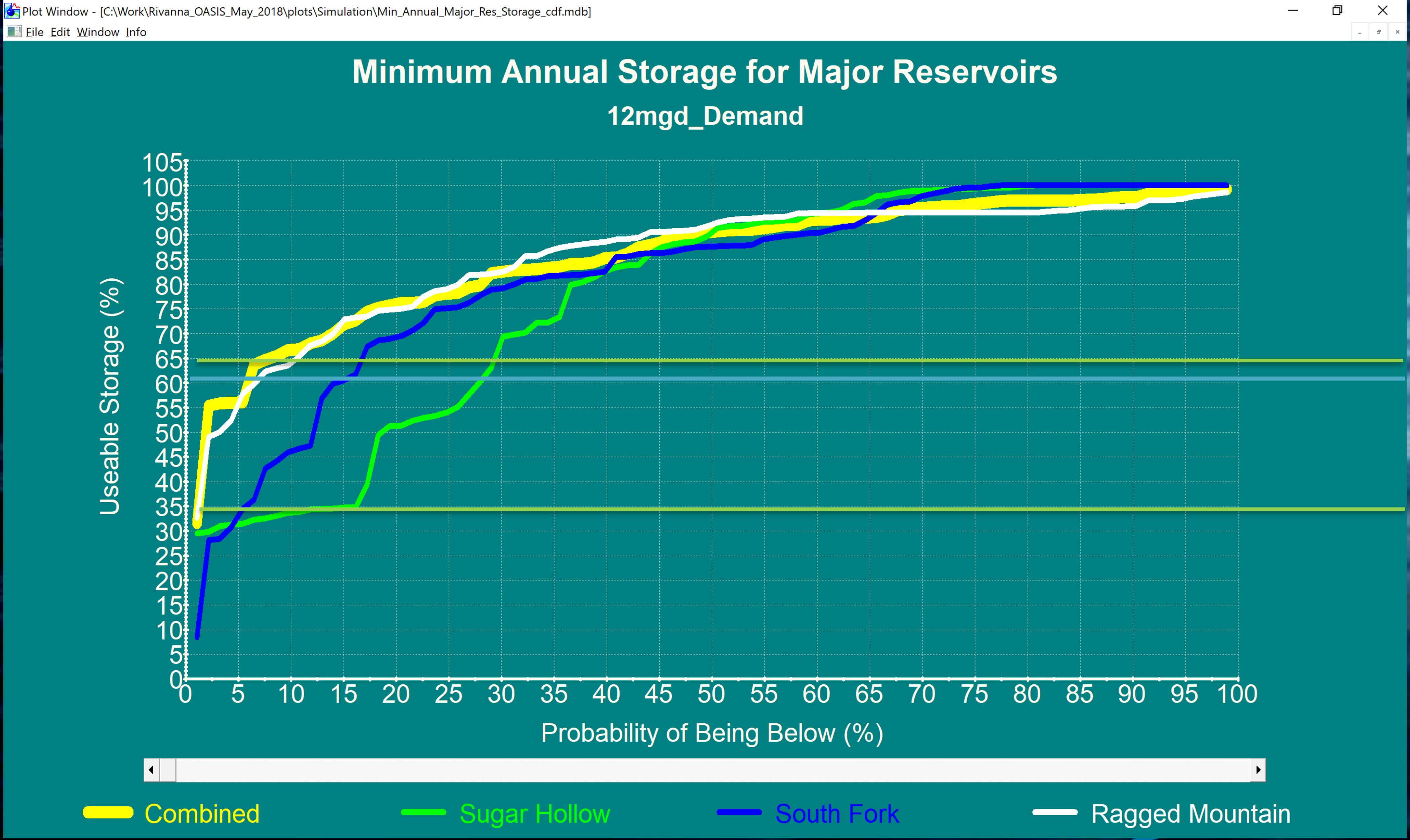
- Basecase: 10 mgd (annual average)
- Alternatives: 12 and 14 mgd
- Operating rules not adjusted for these alternative demands

10 mgd (showed earlier)



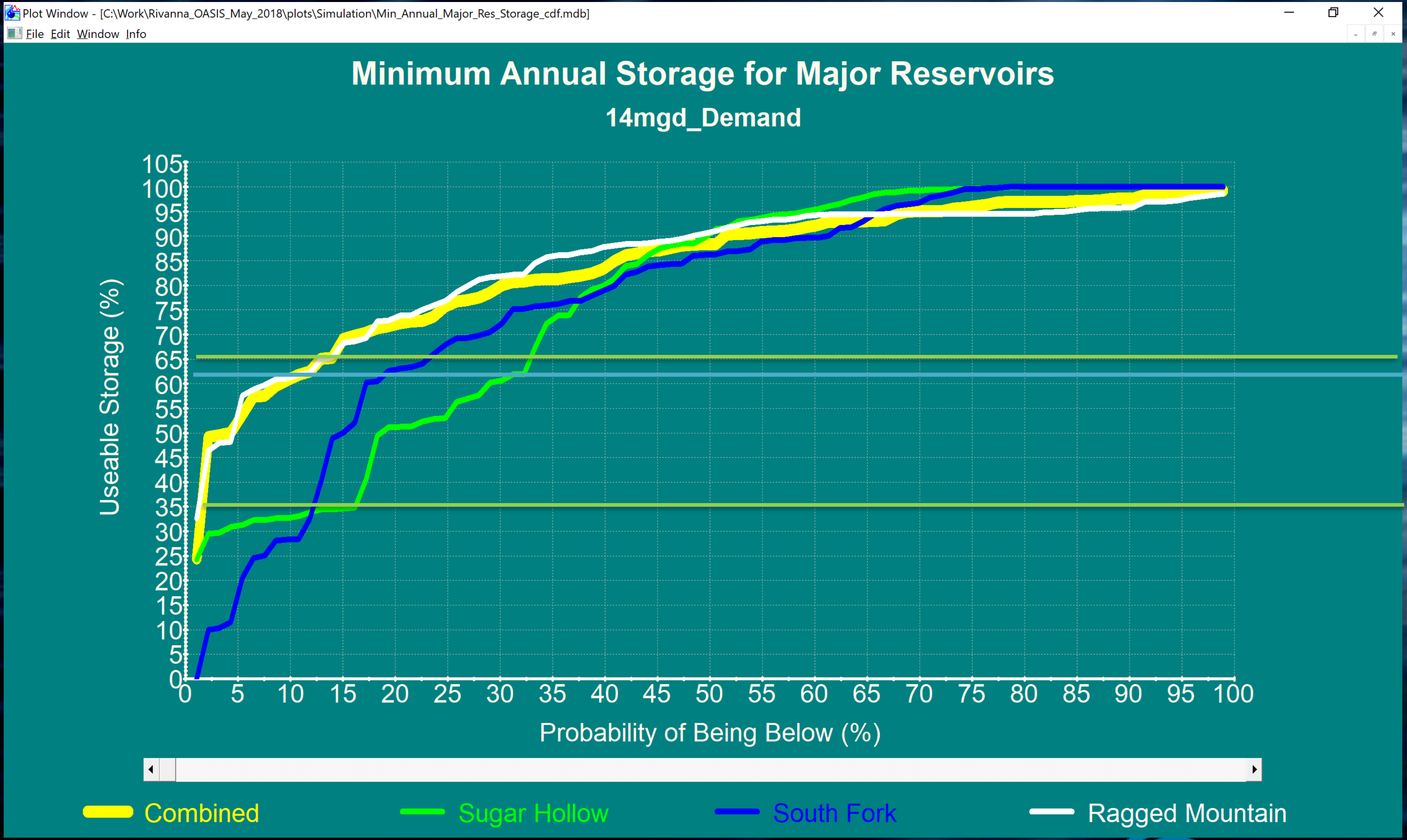
HYDROLOGICS

12 mgd

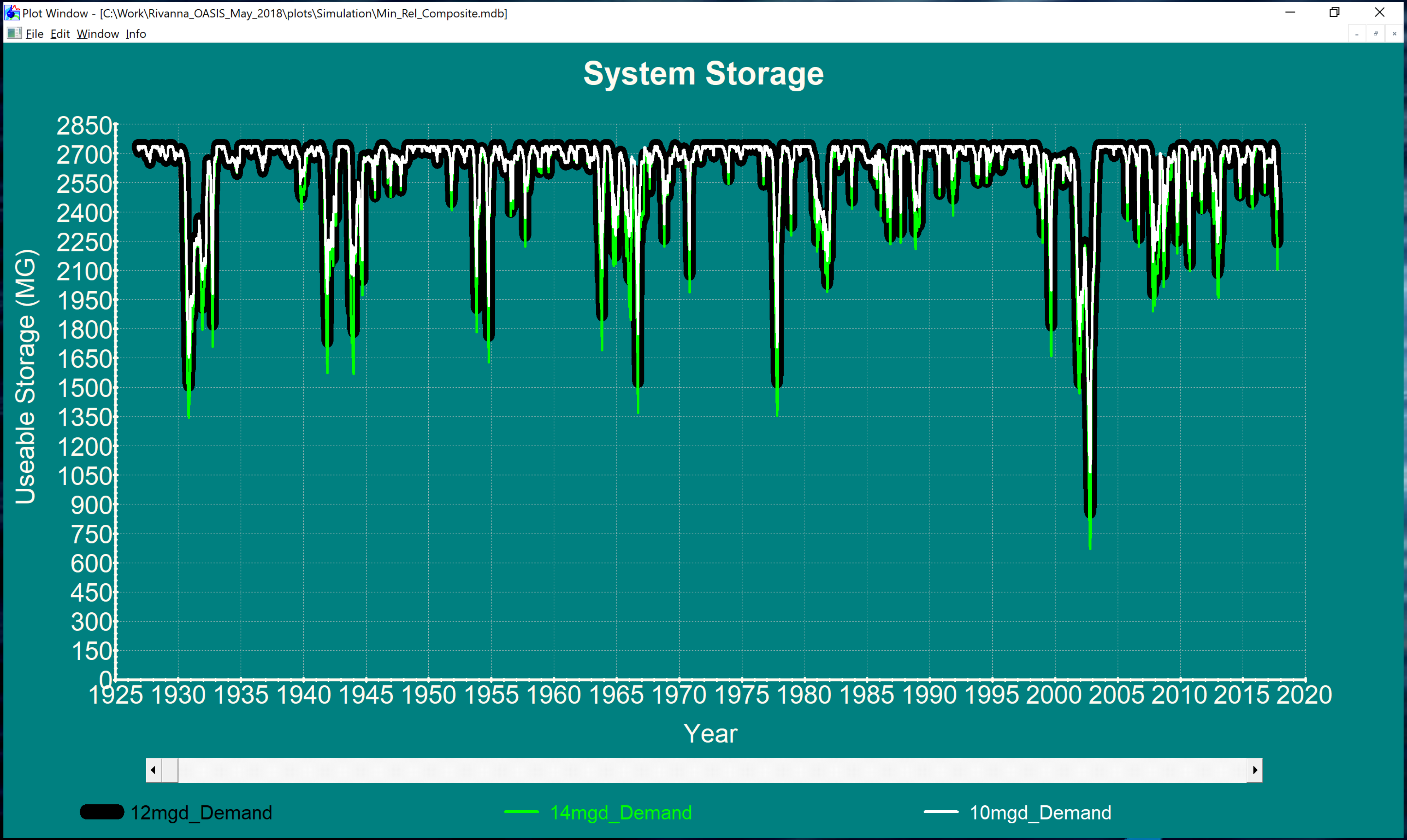


HYDROLOGICS

14 mgd



Plot Window - [C:\Work\Rivanna_OASIS_May_2018\plots\Simulation\Min_Annual_Major_Res_Storage_cdf.mdb]
File Edit Window Info
Minimum Annual Storage for Major Reservoirs
14mgd_Demand
Useable Storage (%)
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85
90
95
100
105
Probability of Being Below (%)
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100
Combined
Sugar Hollow
South Fork
Ragged Mountain



HYDROLOGICS

Impact of Higher System Demands

- Look at other measures of reliability
- 12 mgd is the highest demand that can be supported based on the next slide
  - 60 day reserve is targeted by DEQ as preliminary guidance; higher demands would not meet that
  - Trigger 1 activation at 13 mgd is excessive

Scenario (Annual Average Demand)	Useable Storage Reserve in Critical Drought (% and in terms of days of supply remaining)	Stage 1 Trigger Activation (# of years)	Stage 2 Trigger Activation (# of years)	Stage 3 Trigger Activation (# of years)	MIF Reductions at South Fork (# of years)	Activation of Emergency Pumps (# of years)
10 mgd ADD	38% and 105 days	8	5	1	1	10
11 mgd ADD	35% and 90 days	11	7	4	2	12
12 mgd ADD	30% and 70 days	14	9	5	5	15
13mgd ADD	25% and 50 days	24	17	8	8	15

HYDROLOGICS

Next Steps

- Update drought plan
  - Triggers (total vs. useable storage), drawdown and refill
  - Waiting period between restrictions (reduce from 28 to 14 days), although minimum storage in worst drought only increases by a few %
  - Frequency of restrictions
  - Other (like operating policies)
  - Triggers should work over a range of future demands
- Update permit before next renewal (in 2022?)
  - New inflow calculations for making minimum releases
  - Submit inflow documentation to DEQ with references to “unregulated”, not “unimpaired”, after review by RWSA
- Update demand pattern for urban system based on recent data?
- Coordinate with DEQ on proposed changes
- Safe yield planning (not in this scope)
- Alternative hydrology (not in this phase)
  - Currently maintaining a margin of safety (e.g., 20% useable storage in urban system) to deal with droughts that may be worse than those in the historic record
  - Can look at climate-adjusted hydrology, paleo-data, or extended rainfall records

Appendix H: FWIS Complete Table

Reservoir	Common Name	Scientific Name	Conservation Status	VA Wildlife Action Plan Tier
Sugar Hollow	James spinymussel	*Parvaspina collina*	Federal Endangered; State Endangered	Ia
Sugar Hollow	Virginia big-eared bat	*Corynorhinus townsendii virginianus*	Federal Endangered; State Endangered	IIa
Sugar Hollow	Madison cave isopod	*Antrolana lira*	Federal Threatened; State Threatened	IIc
Sugar Hollow	Northern long-eared bat	*Myotis septentrionalis*	Federal Threatened; State Threatened	Ia
Sugar Hollow	Yellow lance	*Elliptio lanceolata*	Federal Threatened; State Threatened	IIa
Sugar Hollow	Atlantic pigtoe	*Fusconaia masoni*	Federal Protected; State Threatened	Ia
Sugar Hollow	Bewick's wren	*Thryomanes bewickii*	State Endangered	
Sugar Hollow	Brook floater	*Alasmidonta varicosa*	State Endangered	Ib
Sugar Hollow	Eastern tiger salamander	*Ambystoma tigrinum*	State Endangered	IIa
Sugar Hollow	Little brown bat	*Myotis lucifugus*	State Endangered	Ia
Sugar Hollow	Tri-colored bat	*Perimyotis subflavus*	State Endangered	Ia
Sugar Hollow	Appalachian grizzled skipper	*Pyrgus wyandot*	State Threatened	Ia
Ragged Mountain	Green floater	*Lasmigona subviridis*	State Threatened	IIa
Sugar Hollow	Loggerhead shrike	*Lanius ludovicianus*	State Threatened	Ia
Sugar Hollow	Madison cave amphipod	*Stygobromus stegerorum*	State Threatened	Ib
Sugar Hollow	Migrant loggerhead shrike	*Lanius ludovicianus migrans*	State Threatened	

Sugar Hollow	Peregrine falcon	*Falco peregrinus*	State Threatened	Ia
Sugar Hollow	Spotted turtle	*Clemmys guttata*	Collection Concerned	IIIa
Sugar Hollow	Timber rattlesnake	*Crotalus horridus*	Collection Concerned	IVa
Sugar Hollow	Brook trout	*Salvelinus fontinalis*	None Listed	IVa
Sugar Hollow	Mottled duskywing butterfly	*Erynnis martialis*	None Listed	IIIc
Sugar Hollow	Short-billed dowitcher	*Limnodromus griseus*	None Listed	IVa
North Fork	Allegheny crayfish	*Faxonius obscurus*	None Listed	IVc
Ragged Mountain	Allegheny woodrat	*Neotoma magister*	None Listed	IVa
Ragged Mountain	American black duck	*Anas rubripes*	None Listed	IIa
North Fork	American brook lamprey	*Lampetra appendix*	None Listed	IVc
Ragged Mountain	American eel	*Anguilla rostrata*	None Listed	IIIa
Ragged Mountain	American woodcock	*Scolopax minor*	None Listed	IIa
Ragged Mountain	Appalachia darter	*Percina gymnocephala*	None Listed	IVc
Ragged Mountain	Appalachian cottontail	*Sylvilagus obscurus*	None Listed	IVa
Sugar Hollow	Bank swallow	*Riparia riparia*	None Listed	IIIc
Sugar Hollow	Barn owl	*Tyto alba pratincola*	None Listed	IIIa
Sugar Hollow	Belted kingfisher	*Megaceryle alcyon*	None Listed	IIIb
Sugar Hollow	Black-and-white warbler	*Mniotilta varia*	None Listed	IVa
Ragged Mountain	Black-billed cuckoo	*Coccyzus erythropthalmus*	None Listed	IIb
Sugar Hollow	Blue Ridge springsnail	*Fontigens orolibas*	None Listed	IIIc
Sugar Hollow	Brown thrasher	*Toxostoma rufum*	None Listed	IVa
Sugar Hollow	Canada warbler	*Cardellina canadensis*	None Listed	IVb
Sugar Hollow	Carolina lance	*Elliptio angustata*	None Listed	IVc

Sugar Hollow	Cave pseudoscorpion	*Apochthonius coecus*	None Listed	IIb
Sugar Hollow	Cerulean warbler	*Setophaga cerulea*	None Listed	IIa
Sugar Hollow	Chimney swift	*Chaetura pelagica*	None Listed	IVb
Sugar Hollow	Common ribbonsnake	*Thamnophis saurita saurita*	None Listed	IVa
Sugar Hollow	Cow Knob salamander	*Plethodon punctatus*	None Listed	Ic
Sugar Hollow	Creeper	*Strophitus undulatus*	None Listed	IVa
Sugar Hollow	Diana fritillary	*Speyeria diana*	None Listed	IVc
Sugar Hollow	Dunlin	*Calidris alpina hudsonia*	None Listed	IVa
Sugar Hollow	Early hairstreak butterfly	*Erora laeta*	None Listed	IVc
Sugar Hollow	Eastern hog-nosed snake	*Heterodon platirhinos*	None Listed	IVc
Sugar Hollow	Eastern mud salamander	*Pseudotriton montanus montanus*	None Listed	IVa
Sugar Hollow	Eastern red bat	*Lasiurus borealis*	None Listed	IVa
Sugar Hollow	Eastern small-footed myotis	*Myotis leibii*	None Listed	Ia
Sugar Hollow	Eastern spotted skunk	*Spilogale putorius putorius*	None Listed	IVc
Sugar Hollow	Eastern kingbird	*Tyrannus tyrannus*	None Listed	IVa
Sugar Hollow	Eastern meadowlark	*Sturnella magna*	None Listed	IVa
Sugar Hollow	Eastern spadefoot	*Scaphiopus holbrookii*	None Listed	IVc
Sugar Hollow	Eastern towhee	*Pipilo erythrophthalmus*	None Listed	IVa
Sugar Hollow	Eastern whip-poor-will	*Antrostomus vociferus*	None Listed	IIIa
Sugar Hollow	Eastern wood-pewee	*Contopus virens*	None Listed	IVb
Sugar Hollow	Field sparrow	*Spizella pusilla*	None Listed	IVa

Sugar Hollow	Fisher	*Martes pennanti pennanti*	None Listed	IVc
Sugar Hollow	Frosted elfin butterfly	*Callophrys irus*	None Listed	IVc
Sugar Hollow	Golden eagle	*Aquila chrysaetos*	None Listed	Ia
Sugar Hollow	Golden-winged warbler	*Vermivora chrysoptera*	None Listed	Ia
Sugar Hollow	Grasshopper sparrow	*Ammodramus savannarum pratensis*	None Listed	IVa
Sugar Hollow	Gray catbird	*Dumetella carolinensis*	None Listed	IVa
Sugar Hollow	Greater scaup	*Aythya marila*	None Listed	IVa
Sugar Hollow	Green heron	*Butorides virescens*	None Listed	IVb
Sugar Hollow	Hoary elfin butterfly	*Callophrys polius*	None Listed	IVc
Sugar Hollow	Hoary bat	*Lasiurus cinereus*	None Listed	IVa
Sugar Hollow	Jefferson salamander	*Ambystoma jeffersonianum*	None Listed	IVa
Sugar Hollow	Kentucky warbler	*Geothlypis formosa*	None Listed	IIIa
Sugar Hollow	King rail	*Rallus elegans*	None Listed	IIb
Sugar Hollow	Least bittern	*Ixobrychus exilis exilis*	None Listed	IIIa
Sugar Hollow	Longear sunfish	*Lepomis megalotis*	None Listed	IVb
Sugar Hollow	Long-tailed (rock) shrew	*Sorex dispar*	None Listed	IVc
Sugar Hollow	Marsh wren	*Cistothorus palustris*	None Listed	IVa
Sugar Hollow	Monarch butterfly	*Danaus plexippus*	None Listed	IIIa
Sugar Hollow	Northern metalmark butterfly	*Calephelis borealis*	None Listed	IVc
Sugar Hollow	Northern pygmy clubtail dragonfly	*Lanthus parvulus*	None Listed	IVc
Sugar Hollow	Northern rough-winged swallow	*Stelgidopteryx serripennis*	None Listed	IVc
Sugar Hollow	Northern saw-whet owl	*Aegolius acadicus*	None Listed	Ic

Sugar Hollow	Northern bobwhite	*Colinus virginianus*	None Listed	IIIa
Sugar Hollow	Northern flicker	*Colaptes auratus*	None Listed	IVb
Sugar Hollow	Northern harrier	*Circus hudsonius*	None Listed	IIIa
Sugar Hollow	Northern pinesnake	*Pituophis melanoleucus melanoleucus*	None Listed	Ia
Sugar Hollow	Notched rainbow	*Villosa constricta*	None Listed	IIIa
Sugar Hollow	Pearl dace	*Margariscus margarita*	None Listed	IVb
Sugar Hollow	Queen snake	*Regina septemvittata*	None Listed	IVa
Sugar Hollow	Red crossbill	*Loxia curvirostra*	None Listed	IIIc
Sugar Hollow	Regal fritillary	*Speyeria idalia idalia*	None Listed	Ia
Sugar Hollow	Roughhead shiner	*Notropis semperasper*	None Listed	Ib
Sugar Hollow	Ruffed grouse	*Bonasa umbellus*	None Listed	IIIa
Sugar Hollow	Rusty blackbird	*Euphagus carolinus*	None Listed	IVb
Sugar Hollow	Seep mudalia snail	*Leptoxis dilatata*	None Listed	IVc
Sugar Hollow	Silver redhorse	*Moxostoma anisurum*	None Listed	IIIc
Sugar Hollow	Silver-haired bat	*Lasionycteris noctivagans*	None Listed	IVa
Sugar Hollow	Slimy sculpin	*Cottus cognatus*	None Listed	IVc
Sugar Hollow	Smooth greensnake	*Opheodrys vernalis*	None Listed	IIIa
Sugar Hollow	Snapping turtle	*Chelydra serpentina*	None Listed	IVb
Sugar Hollow	Southeastern fox squirrel	*Sciurus niger niger*	None Listed	IIIa
Sugar Hollow	Swainson's warbler	*Limnothlypis swainsonii*	None Listed	IIc
Sugar Hollow	Triangle floater mussel	*Alasmidonta undulata*	None Listed	IVa
Sugar Hollow	Two-spotted skipper butterfly	*Euphyes bimacula*	None Listed	IVc
Sugar Hollow	Virginia rail	*Rallus limicola*	None Listed	IVa

Sugar Hollow	Wood thrush	*Hylocichla mustelina*	None Listed	IVb
Sugar Hollow	Woodland box turtle	*Terrapene carolina carolina*	None Listed	IIIa
Sugar Hollow	Yellow-billed cuckoo	*Coccyzus americanus*	None Listed	IIIa
Sugar Hollow	Yellow-breasted Ccat	*Icteria virens virens*	None Listed	IVa
Sugar Hollow	Yellow-crowned night-heron	*Nyctanassa violacea violacea*	None Listed	IIa

RIVANNA WATER & SEWER AUTHORITY
695 Moores Creek Lane | Charlottesville, Virginia 22902-9016
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August 14, 2020

Joe Grist
Scott Kudlas
Office of Water Supply
Department of Environmental Quality
P.O. Box 1105
Richmond, VA 23218

Re: Request for Minor Modification to Virginia Water Protection (VWP) Individual Permit No. 06-1574, Ragged Mountain Expansion Project, Albemarle County, Virginia

Dear Mr. Kudlas:

The Rivanna Water and Sewer Authority (RWSA) is requesting a Minor Modification of VWP Permit No. 06-1574. This request is being made pursuant to 9 VAC 25-210-180. As stated in Section B of this code, a VWP permit may be modified upon the request of the permittee...., "When new information becomes available about the project or activity covered by the VWP permit, including project additions or alterations, that was not available at VWP permit issuance and would have justified the application of different VWP permit conditions at the time or permit issuance."

RWSA is requesting that the methodology used to estimate natural inflow to Sugar Hollow Reservoir be modified. The VWP Individual Permit for the Urban System includes definitions of terms in Part I, Section F (page 8). "Natural inflow" for Sugar Hollow is defined as:

> *"Natural inflow," when used with respect to Sugar Hollow Reservoir, is the daily mean discharge rate listed by the United States Geological Survey for the Mechums River near White Hall, Virginia (USGS stream gage 02031000), multiplied by the factor of 0.19 (to compensate for the difference in drainage area), and converted from cubic feet per second to millions of gallons per day by multiplying by a factor of 0.65.*

New information has become available which indicates that the USGS Moormans River near Free Union, VA gage (USGS stream gage 02032250) correlates more closely with natural inflow to Sugar Hollow. Data to support this request is provided in the attached Technical Memorandum. RWSA requests to edit the definition to:

> *"Natural inflow," when used with respect to Sugar Hollow Reservoir, is the unregulated daily mean discharge rate listed by the United States Geological Survey for the Moormans River near Free Union, Virginia (USGS stream gage 02032250), multiplied by the factor of 0.226 (to compensate for the difference in drainage area), and converted from cubic feet per second to millions of gallons per day by multiplying by a factor of 0.65.*

As you requested, we will submit the fee form and check after we hear from you concerning the request. Please call with any questions you may have.

Sincerely,

William I. Mawyer, Jr., P.E.
Executive Director

Attachments: Technical Memorandum – Summary of Sugar Hollow Inflow Analysis, July 23, 2020

C: Vincent Pero, U.S. Army Corps of Engineers

October 2, 2020

Location: Virtual via GoToWebinar

Subject: Urban VWP Pre-Application Meeting

Attendees: Stavros Calos, *ACSA*

Joseph Grist, Trevor Lawson, Shana Moore, *Virginia DEQ*

Amy Ewing, Scott Smith, *Virginia DWR*

Megan Fitzgerald, *U.S. EPA*

Jay Woodward, *Virginia MRC*

Roberta Rhur, *Virginia DCR*

Steve Kvech, Taylor Valencia, *Virginia Department of Health*

Anne Coates, *TJSWCD*

Andrea Bowles, Victoria Fort, Jennifer Whitaker, *RWSA*

Sarah Busch, Aaron Duke, Steve Nebiker, Reed Palmer, Ben Wright, *Hazen and Sawyer*

The purpose of this meeting was to discuss the RWSA's Urban Water System Virginia Water Protection (VWP) permit renewal with the agencies involved with the permit application review. The goals of the meeting were to familiarize the regulatory bodies with the Urban Water System and proposed Community Water Supply Plan elements and to review key supporting information associated with the upcoming JPA / VWP Permit submittal.

Project Goals and Review of the Existing System

1. DEQ opened the meeting by reminding participants that all agencies at the meeting have until December 1, 2020, or 60 days, to provide written comments to RWSA about their upcoming JPA/VWP permit renewal.
2. Hazen staff began the presentation by describing the meeting's goals and explaining key definitions that were used throughout the presentation. The discussion shifted to an overview of the existing Urban Water System and an overview of how the Urban Water System will function after implementation of the Community Water Supply Plan (CWSP) elements planned for the upcoming permit term.
3. Hazen staff described the active RWSA projects that were components of the prior VWP permit approval and the status of the other planned elements outlined in the CWSP, including the upgrades occurring at the Observatory WTP, the South Rivanna WTP, and the RMR to Observatory WTP and RMR to SRR pipelines.

31430-005

Demand Forecast

1. Hazen described the population and unit demand (water use intensity) trends associated with the historically flat water demand for the Urban Water System over the past decade. It is anticipated that the dramatic declines in water use intensity observed over the past two decades will not be sustained in the upcoming decades. As a result, it is forecast that (continued) steadily increasing population and employment growth will begin to drive increases in finished water demand over the upcoming 15-year permit term.
2. Hazen and RWSA discussed the COVID-19 response in the region and noted that the Urban Water System has seen an increase of 5-20% in residential water demand. However, even though classes were not in session, water demand at the University of Virginia has not decreased significantly. DEQ would like to understand the potential for greater incorporation of COVID-19 water demand values because there will potentially be lasting impacts on the water system in terms of increases in residential demand, but also potential decreases due to the closure of businesses in the area. RWSA staff spoke of an unrelenting building boom continuing in the Urban Water System service area despite the pandemic.

System Yield

1. Hazen detailed the evaluation process for the system yield by defining the Theoretical Yield (no operational constraints), which is limited solely by the available supply of raw water; the Operational Yield, which is the yield available when the treatment and conveyance capacity constraints are taken into account as well as drought management plan cutbacks to water use; and the Protective Reservoir Yield, which is calculated similarly to the Operational Yield, but incorporates a 60-day reserve storage per DEQ guidance. Minimum In-stream Flow (MIF) requirements are factored in for all the yield scenarios. Hazen showed that implementation of the RMR to SRR pipeline and filling RMR to its full level of 683 feet will greatly increase the resiliency and reliability of the system by increasing the operational yield to 21.4 mgd. The large increase in yield is realized by making more efficient use of the supply sources. The Virginia Department of Health (VDH) asked if Hazen and RWSA could describe in more detail how the current plant improvement projects will increase the safe yield to 15.1 mgd.
    - Hazen described that the Observatory WTP production will be less restrictive. A minimum production level will no longer be required, and additional treatment capacity will be added. This change will provide more flexibility regarding when to draw from SRR and RMR and will therefore increase yield.

Minimum In-stream Flow (MIF) Protocol

1. Hazen reviewed the MIF protocol that is described in the current VWP permit. This protocol releases a percent of the inflow to Sugar Hollow and South Rivanna and is tied to storage levels in the system. RWSA is considering potential adjustments to the MIF with the VWP Permit renewal including caps, percent of inflow levels, crediting SRR for potentially decommissioning the North Rivanna WTP, and adding additional drought mitigation measures like the "R25" concept with guidance from DEQ. These are designed to help with reservoir refill and overall

system reliability under current and future demand conditions, while also balancing the benefit of downstream flows in the rivers.

Inflow Calculation Methodology

1. RWSA proposes adjustments to the inflow calculation methodology to more accurately reflect the inflow to the reservoirs. This would help prevent excess releases that can lead to overdrafting of the reservoirs and delayed refill. In comparison to the method in the current permit, the updated methodology uses gages that are more reflective of the watersheds that the reservoirs are in.
    - For example, the previous method had the inflow calculations for SHR tied to the Mechums gage, which is in a different watershed than the Moormans River on which SHR is located. RWSA is proposing to use the gage downstream of SHR at Free Union to better estimate inflow to the reservoir. The inflow calculation would be based on the proposed DEQ method that would apply during non-spill periods. This method relies on differences between measured outflows from the dam and the Free Union gage, adjusted for drainage area to the head of the lake. To facilitate operational compliance, RWSA suggests that the minimum releases be calculated and made when SHR is slightly below full since spill cannot be measured.
    - Similar inflow calculation adjustments are proposed for SRR, with the proposed approach utilizing a back-calculated inflow based on the downstream gage.

Adjustments to MIF Protocol

1. Hazen discussed the inflow calculation methodology updates by comparing inflows and simulated storage under various MIF scenarios. For example, the impact of discontinuing the North Fork WTP and the impact of the water surplus on SRR storage and releases due to this closure were discussed. RWSA described in further detail why the North Fork WTP is under consideration for decommissioning.

Resource Assessments and Mitigations

1. Hazen indicated that RWSA would continue to comply with the resource assessments and mitigation requirements established under the existing permit for the remaining infrastructure to be constructed. RWSA would continue to seek to avoid and minimize impacts to the extent practicable, for example directional drilling for stream crossings. Targeted resource assessments for the James spinymussel would be conducted for all in-stream work, and time of year restrictions on construction would be followed when necessary for the Indiana bat and other species. DWR and Nature Conservancy resources on anadromous fish species were reviewed for the Rivanna River basin, which indicated no “confirmed” or “potential” anadromous fisheries in the vicinity of the proposed projects. Therefore, no changes to intake infrastructure (e.g. screens) are planned, consistent with the current permits.

Questions and Discussion

1. VDH asked for Hazen and RWSA to expand on how the safe yield for the North Fork WTP is determined and if this safe yield is separate from the overall safe yield withdrawal capacity. Currently, RWSA holds three different permits for each of their water treatment plants.
    - Hazen clarified that North Fork was assumed to be a part of the combined system, which helps offset the system demand by 0.5 mgd to 2 mgd, if looking at the full capacity available. If water is available in the Rivanna River, the water will be delivered to offset the demand met from the South Rivanna River by the Observatory WTP.
    - VDH further detailed that the North Fork WTP intake has never had a withdrawal permit from DEQ making it difficult for VDH to identify the limiting source capacity for the North Fork WTP intake.
    - RWSA added that the North Fork WTP abandonment study, which is 50-75% complete, will likely provide more clarity on how to resolve some of VDH's concerns and how to proceed with the WTP.

2. The Virginia Department of Wildlife Resources (DWR, formerly DGIF) described that there is potential for anadromous fish and other endangered species along in the project areas that may require time of year restrictions for in-stream work. DWR would like to make sure that they will have details about the proposed buildout for the pipeline to understand the level of tree removal and avoidance for Indiana bat habitat. In addition, they would recommend geotechnical analysis for all boring related activity to prevent frac-outs. The agency staff on the call did not have any questions, but plan to coordinate with others at the agency regarding the potential for endangered species along the SRR-RMR pipeline route and in-stream flow needs.

3. The Virginia Marine Resources Commission (VMRC) plans to coordinate with DWR and DCR with regard to the proposed reservoir pool levels. Regarding the RMR to SRR pipeline, VMRC staff noted that the agency prefers to see trenchless methods (boring) employed for stream crossings rather than open cut (ditching) methods. However, all crossings of jurisdictional streams (defined as having 5 square miles of drainage or larger) would require VMRC permits, regardless of method. When the total construction cost for in-stream work or crossings of jurisdictional streams exceeds $500,000, the agency requires permit approval at a commission hearing. If there is any public objection to the project, the hearing would be a Page 1 formal briefing, but if there are no objections, the hearing would be a Page 2 (consent) item.
    - VMRC would like a copy of the presentation. *Note to readers: DEQ sent out a copy to all attendees following the meeting on October 2nd.*

4. The Virginia Department of Conservation and Recreation (DCR) discussed the potential for karst topography in the borings, but otherwise DWR and VMRC discussed the points that DCR would like to see addressed.

5. The U.S. Environmental Protection Agency (EPA) added that it is beneficial to provide as much information as possible for the alternatives analysis to show the description of what alternatives were considered leading to a discussion of the mitigation proposed.

- Hazen clarified that the permit renewal is for the continuation of the projects originally permitted and that the alternatives have been extensively analyzed. Hazen confirmed there is no new information that would suggest RWSA abandon the significant investment in the CWSP made to date.
- RWSA asked if it would be useful for Hazen and RWSA to summarize the mitigation completed in the permit support document. EPA agreed that a summary of the prior alternatives analysis would be sufficient, and it would be helpful to have a concise summary of the mitigation completed for the program.

6. The Thomas Jefferson Soil and Water Conservation District (TJSWCD) did not have any questions at this time.

Appendix K – Previous Actions Related to the Proposed Work

Agency	Action/Activity	Permit/Project number, including any non-reporting Nationwide permits previously used (e.g., NWP 13)	Date of Action
VA DEQ	Issued VWP Permit	06-1574	February 11, 2008
COE	Issued Section 404 Permit	06-V1574	June 3, 2008
VA DEQ	Major Modification VWP Permit	06-1574	December 28, 2011
COE	Modification of Dam Construction	056-1574; NAO-2006-03002	January 31, 2012
COE	Time extension to June 3, 2023	056-1574; NAO-2006-03002	May 14, 2018
State	Pre-application Panel Meeting		August 10, 2020
State and Federal	Pre-application Panel Meeting		October 2, 2020

Conceptual Stream & Wetland Mitigation Plan

Albemarle County, Virginia

Prepared for **Rivanna Water & Sewer Authority**
695 Moores Creek Lane
Charlottesville, VA 22902-9016

Prepared by Vanasse Hangen Brustlin, Inc.
Transportation, Land Development, Environmental Services
351 McLaws Circle, Suite 3
Williamsburg, Virginia 23185

December, 2006

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Introduction

The purpose of this document is to outline the conceptual mitigation plan proposed to offset impacts to jurisdictional streams and wetlands that will occur via the implementation of the Rivanna Water and Sewer Authority's (RWSA) "Community Water Supply Project." The project history, alternatives analysis, and proposed action (expansion of Ragged Mountain Reservoir) are presented in detail in Joint Permit Application 06-1574 and the associated Permit Support Document, dated May 17, 2006.

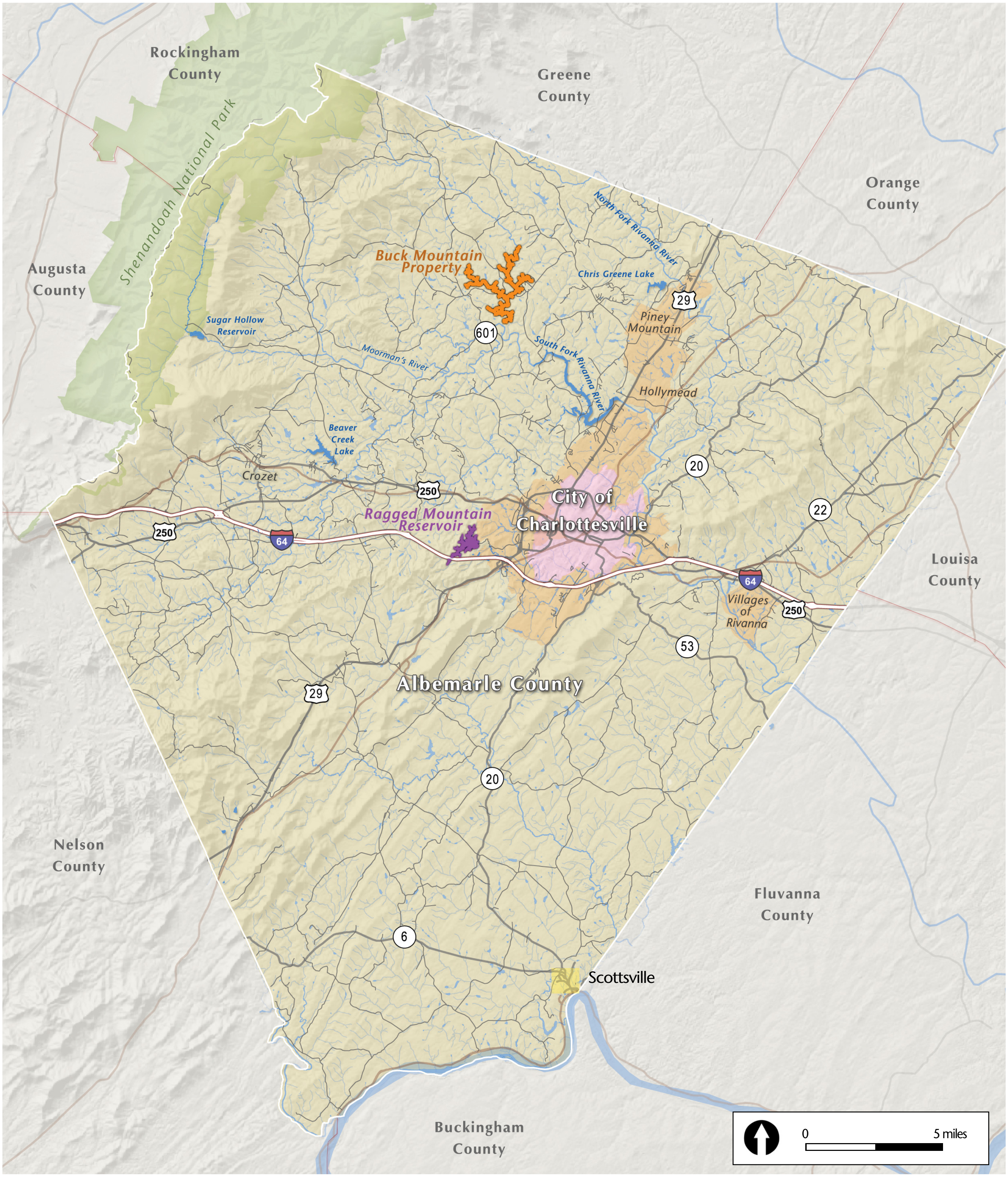
The expansion of Ragged Mountain Reservoir (Figure 1) will inundate 14,033 linear feet of low-order stream channel located above existing dams. An additional 402 linear feet will be filled for the construction of the new dam and for improvements to the Interstate 64 embankment at the southern limit of Ragged Mountain Reservoir, resulting in a total stream impact of 14,435 linear feet. Reservoir expansion will also impact 0.81 acres of forested wetlands, 0.07 acres of scrub-shrub wetlands, and 1.73 acres of emergent wetlands, all of which are located above or immediately downstream of the principal (lower) dam. To compensate for these effects, RWSA has identified a viable, expansive stream mitigation site within the Buck Mountain Creek watershed. Candidate sites for wetland mitigation were also identified around the fringe of the projected new pool elevation at Ragged Mountain Reservoir and on agricultural land nested within an urban setting in the floodplain of Moores Creek just southeast of the City of Charlottesville.

Regulatory Considerations

■

Streams

To determine the level of stream impact for mitigation purposes, the RWSA implemented stream assessment methodologies developed by the U.S. Army Corps of Engineers (COE) and the Virginia Department of Environmental Quality (DEQ). The respective methodologies are called the "Stream Attribute Assessment Methodology" (SAAM) and the "Stream Impact and Compensation Manual" (SICAM). Both SAAM and SICAM are field protocols that evaluate certain characteristics of streams by scoring various physical parameters, such as riparian buffer, in-



Community Water Supply Project

City of Charlottesville and Albemarle County, Virginia

Conceptual Stream and Wetland Mitigation Plan

Vanasse Hangen Brustlin, Inc. Gannett Fleming

Figure 1

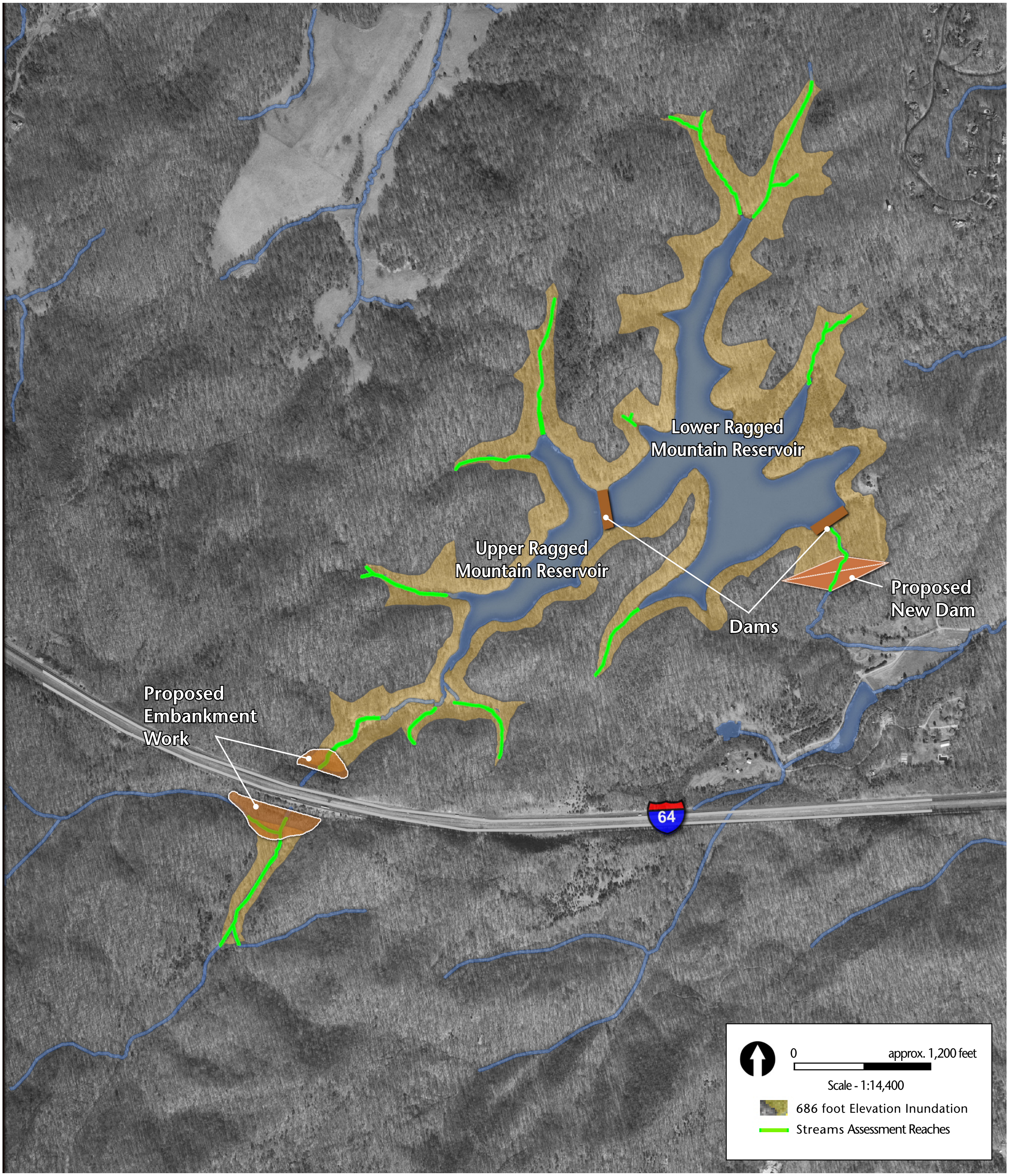
Location of Ragged Mountain Reservoir & Buck Mountain Creek Potential Mitigation Site

stream habitat, channel alteration, and channel condition. Lengths of stream channel displaying consistent characteristics are referred to as Stream Assessment Reaches (SARs), and may vary in length from less than 100 feet to well over 1000 feet. The total score for each SAR is referred to as the Reach Condition Index (RCI). For SAAM, the SAR multiplied by the RCI yields the Total Stream Credit Units (TSCU), or degree of indicated compensation. This is a dimensionless unit, and not linear footage. SICAM performs the same calculation to achieve the Compensation Requirement (CR), yet includes a second factor called a Stream Quality Factor (SQF) which indicates additional compensation for high-quality streams. The units for the CR are linear feet.

It is important to note that, while SAAM and SICAM measure certain parameters relevant to stream condition, they do not evaluate other characteristics that profoundly affect the ability of a stream to perform beneficial environmental functions. For example, neither SAAM nor SICAM take into account whether stream channels are situated above existing impoundments such as Ragged Mountain Reservoir. Thus, we believe these methodologies significantly overvalue headwater and low-order stream segments that are hydrologically isolated from a larger downstream ecosystem via impoundments.

Nevertheless, as tools to assist in evaluating the stream compensation that may be appropriate for the Community Water Supply Project, both SAAM and SICAM were applied to the streams at Ragged Mountain Reservoir that would be impacted by reservoir expansion (Figure 2). The average RCI per linear foot using the SAAM method was 5.14 out of a possible 6.0 points, suggesting overall high stream quality. Similar results were obtained via SICAM, resulting in an average RCI of 6.16 of a possible 7.0 points. Completed field forms for each individual SAR are provided on the compact disk within the rear pocket of this report.

Approximately 14,435 linear feet of stream will be permanently impacted by the expansion of Ragged Mountain Reservoir, resulting in a TSCU of 74,152 using the SAAM protocol (Table 1). Because stream quality at Ragged Mountain Reservoir is so high, the average SQF for SICAM is 1.49. Therefore, the total length of mitigation indicated by this method is this value multiplied by the impacted stream length, or 21,509 linear feet (Table 1).



Rivanna Water & Sewer Authority — Serving Charlottesville and Albemarle County, Virginia

Community Water Supply Project
City of Charlottesville and Albemarle County, Virginia

Conceptual Stream and Wetland Mitigation Plan

Figure 2
Stream Assessment Reaches:
Ragged Mountain Reservoir

VHB Vanasse Hangen Brustlin, Inc.   Gannett Fleming

TABLE 1.
Ragged Mountain Reservoir Stream Assessment
Conceptual Wetland Stream Mitigation Plan
Rivanna Water and Sewer Authority

Stream Name/Sar #	SAR Length (ft)	SAAM RCI	Total Stream Credit Units (TSCU)	SICAM RCI	Stream Quality Factor (SQF)	Impact Factor (IF)	Compensation Requirement (CR)
A SAR 1	2020	5.52	11150	6.5	1.5	1	3030
A SAR 3	532	4.86	2586	6.5	1.5	1	798
A SAR 4	682	4.32	2946	6.3	1.5	1	1023
A1 SAR1	730	5.58	4073	7	1.6	1	1168
A2 SAR1	250	5.63	1408	7	1.6	1	400
A3 SAR1	458	5.86	2684	7	1.6	1	732.8
A4 SAR1	393	5.45	2142	6.3	1.5	1	589.5
A5 SAR1	184	5.82	1071	7	1.6	1	294.4
A5 SAR2	303	1.51	458	3.2	1.2	1	363.6
A5 SAR3	453	4.81	2179	6.3	1.5	1	679.5
A6 SAR1	189	5.55	1049	6.3	1.5	1	283.5
A6 SAR2	85	5.45	463	6.3	1.5	1	127.5
A6 SAR3	139	5.91	821	7	1.6	1	222.4
A6 SAR4	179	4.25	761	4.7	1.3	1	232.7
$A6_1$ SAR1	229	5.71	1308	7	1.6	1	366.4
A7 SAR1	239	6	1434	7	1.6	1	382.4
A7 SAR2	104	4.1	426	4.3	1.3	1	135.2
A7 SAR3	144	4.08	588	5	1.3	1	187.2
LA SAR1	200	5.09	1018	6.5	1.5	1	300
LA-1 SAR1	104	3.85	400	5.8	1.5	1	156
LA-1 SAR2	0	3.6	0	3.9	1.3	1	0
LB SAR1	318	5.76	1832	7	1.6	1	508.8
LB SAR2	303	5.03	1524	6.3	1.5	1	454.5
LC SAR1	811	5.64	4574	6.3	1.5	1	1216.5
LC-1 SAR1	20	3.94	79	5.8	1.5	1	30
LD SAR1	303	5.82	1763	7	1.6	1	484.8
LE SAR1	318	4.57	1453	5.5	1.3	1	413.4
LE SAR2	592	5.04	2984	5.8	1.5	1	888
LE SAR3	209	4.96	1037	6.5	1.5	1	313.5
LE-1 SAR1	45	5.63	253	7	1.6	1	72
UA SAR1	0	5.52	0	7	1.6	1	0
UA SAR2	408	5.35	2183	7	1.6	1	652.8
UA SAR3	164	4.76	781	5.8	1.5	1	246
UA SAR4	378	4.57	1727	5.8	1.5	1	567
UA SAR5	363	4.84	1757	5.9	1.5	1	544.5
LF SAR1	418	5.71	2387	7	1.6	1	668.8
LF SAR2	194	5.66	1098	6.5	1.5	1	291
LF SAR3	313	5.54	1734	7	1.6	1	500.8
LF SAR4	488	4.61	2250	5.1	1.3	1	634.4
LF-1 SAR1	124	5.18	642	6.5	1.5	1	186
LG-SAR1	1049	4.89	5130	4.2	1.3	1	1363.7
TOTAL	**14435**		**74152**				**21509**

streams assessed that will not be impacted

Wetlands

The expansion of Ragged Mountain Reservoir will result in impacts to forested, scrub-shrub, and emergent wetland areas. Each of these wetland types has a recommended compensation ratio of 2:1, 1.5:1, and 1:1, respectively. Some of these wetlands will be replaced naturally as wetland vegetation becomes reestablished in suitable areas at the new reservoir pool elevation. The wetland area initially impacted and compensation acreage is provided in Table 2, below.

TABLE 2. Standard Mitigation – Wetlands
Conceptual Stream and Wetland Mitigation Plan
Rivanna Water & Sewer Authority - Community Water Supply Project

Impacted Wetland Type	Impact Area (acres)	Standard Mitigation Ratio	Standard Mitigation Area (acres)
Forested	0.81	2 : 1	1.62
Scrub-Shrub	0.07	1.5 : 1	0.11
Emergent	1.73	1 : 1	1.73
TOTAL	2.61	--	3.46

It should be noted that the majority of the wetlands that will be impacted developed around the fringe of the existing reservoir on sediments left exposed as the elevation of the upper pool was lowered for safety reasons.

Mitigation Plan

Mitigation Site Selection Process

To identify potentially suitable sites for stream and wetland compensatory mitigation, RWSA solicited input from the public, the City of Charlottesville, Albemarle County, and state and federal regulatory agencies, including the U.S. Fish & Wildlife Service (USFWS), and Virginia Department of Game and Inland Fisheries (DGIF). In addition, the RWSA team utilized aerial photography, soil surveys, National Wetland Inventory mapping, City and County property records, and field reconnaissance to identify sites with the highest potential to provide adequate wetland and stream mitigation to offset the impacts associated with the Ragged Mountain expansion project.

Through this process, more than fifty individual sites were identified. Each site was evaluated based on the following criteria:

1. Potential for success, based on landscape position, contributing watershed, soil conditions and anticipated construction expenses (*i.e.* degree of grading required, access issues, etc.);

2. Potential for successful property acquisition, with consideration given to the number of property owners affected;

3. Size of the parcels compared to the anticipated wetland and stream compensation requirements determined through the SAAM and SICAM methodologies and standard COE and DEQ mitigation ratios, and;

4. Ability to replace impacted wetland and stream values on a function for function basis.

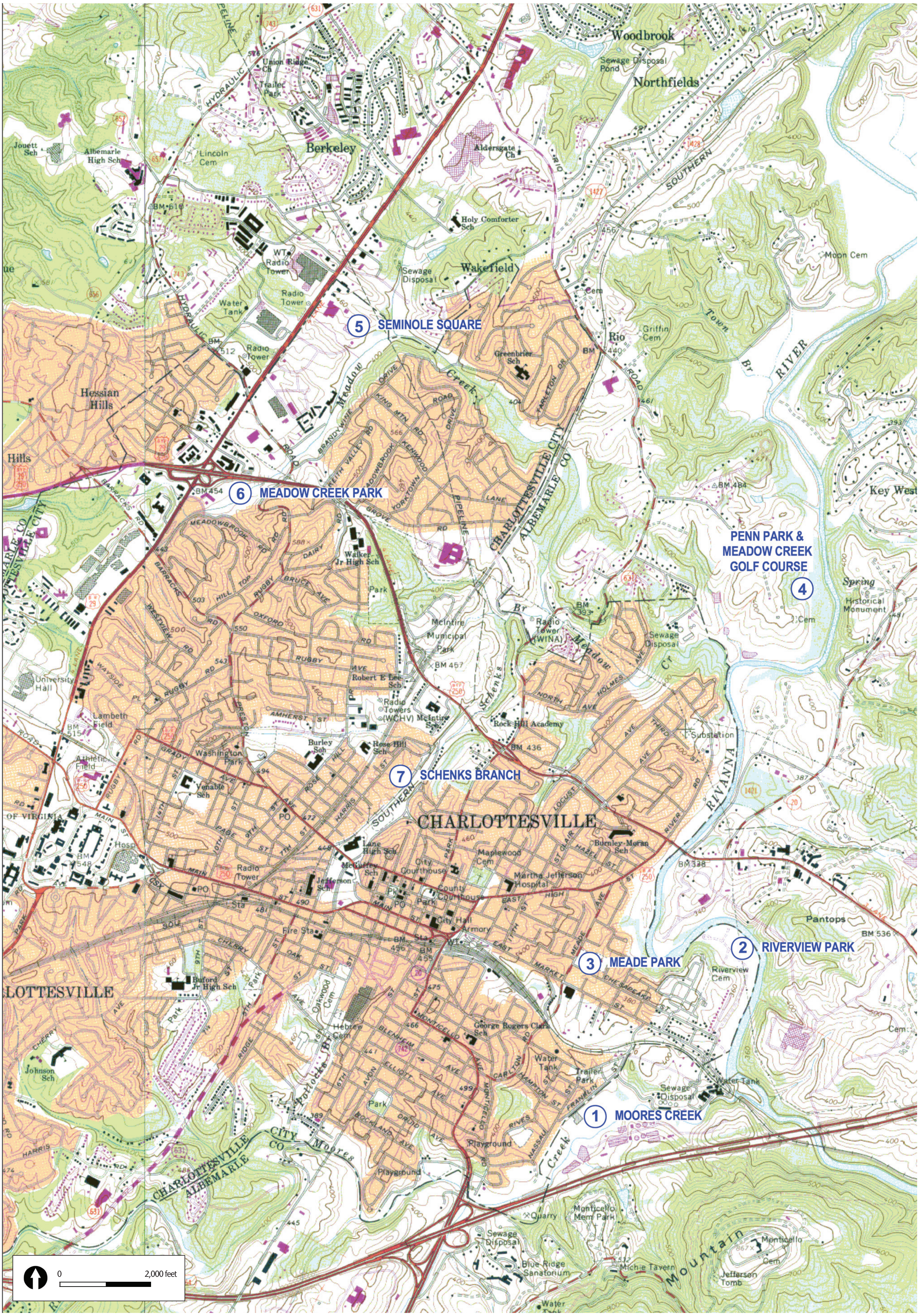
This screening process resulted in the identification of seven potential wetland compensation sites and seven stream compensation sites. On March 9, 2006, VHB scientists conducted field visits of the seven potential wetland mitigation sites (Figure 3). The results of this work are summarized in a March 15, 2006 memorandum, which concluded that the most viable site for wetland compensation was a site located in the floodplain for Moores Creek, near the Charlottesville Stockyard on Franklin Street. A copy of the memorandum is provided as Appendix A.

The potential stream mitigation sites fell into two categories:

1. rural stream restoration sites, generally located in upper watersheds on larger tracts of agricultural land, including land in the Buck Mountain watershed already owned by RWSA, and;

2. urban stream restoration sites, generally consisting of short reaches within the City that would require multiple sites and acquisition of numerous private properties to meet compensation goals.

In April, 2006, RWSA conducted a pre-application meeting with state and federal agencies to determine which category was most likely to meet regulatory goals and objectives. To facilitate the discussion, a conceptual plan for the Buck Mountain Creek property was presented.



Community Water Supply Project
City of Charlottesville and Albemarle County, Virginia

Conceptual Stream and Wetland Mitigation Plan

Vanasse Hangen Brustlin, Inc. Gannett Fleming

Figure 3
Potential Wetland Mitigation Sites

This plan included the preservation of existing riparian buffers as well as the enhancement of riparian areas currently in agricultural use by replanting and select fencing to keep livestock out of stream channels. Several locations for potential urban stream restoration projects were also discussed (Figure 4). Over the course of the meeting, state and federal regulatory agencies expressed a strong preference for the rural stream alternative and specifically, use of the Buck Mountain Creek property as a basis for mitigation planning. This preference was based on an assessment that the rural stream approach had the greatest potential to replace lost stream values in kind, and that a project in the Buck Mountain Creek watershed would protect and enhance habitat for the James spinymussel, a federally listed endangered species.

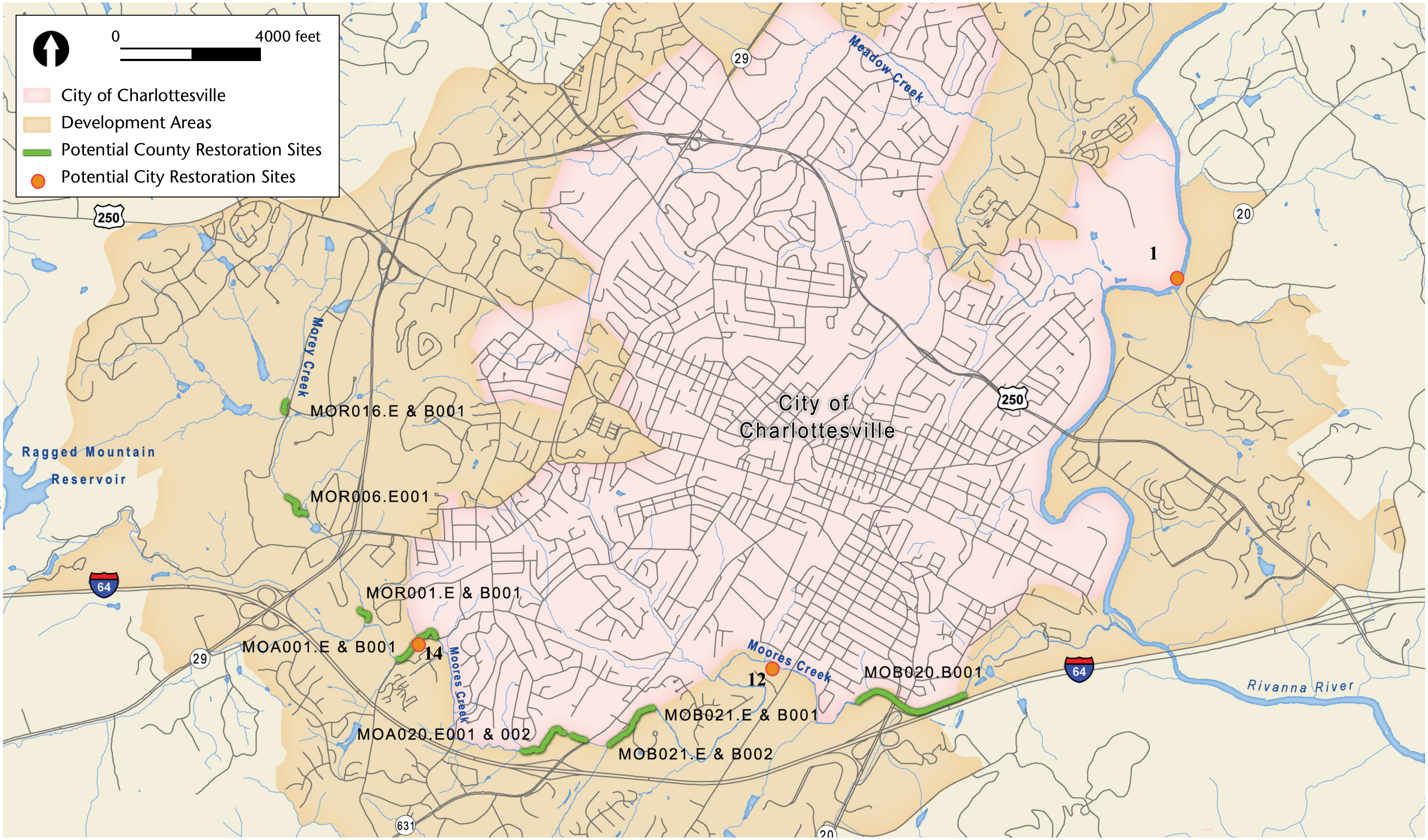
Based on the results of the inter-agency meeting, the RWSA proceeded with the development of a conceptual stream mitigation plan for the Buck Mountain Creek property. A conceptual plan for wetland mitigation within the Moores Creek floodplain just south of Franklin Street was also initiated. Subsequent discussions with the DEQ, the DGIF, the USFWS, and the COE indicated that these concepts could adequately compensate for project related impacts. Accordingly this document presents these concepts in more complete detail for agency acceptance as part of the Joint Permit Application process. Once the relevant state and federal permits are issued, final design plans for the mitigation areas will be prepared for these projects.

■

Stream Mitigation at Buck Mountain Creek

In the late 1970's, the RWSA identified the Buck Mountain Creek watershed as a potential location for a new drinking water reservoir (Figure 1). RWSA began acquiring property within the watershed in anticipation of eventual construction. By the mid 1990's, all required land had been secured.

However, in the course of a comprehensive evaluation of all water-supply options, less environmentally damaging and more practicable alternatives were identified. One consideration was that Buck Mountain Creek is known habitat for a federally-listed endangered species, the James spinymussel. Though the Buck Mountain Reservoir project has not been built, the land originally acquired by RWSA (over 1,300 acres) presents the unique opportunity for watershed-scale mitigation. Furthermore, mitigation activities within this area would improve habitat for the James spinymussel in lower Buck Mountain



Community Water Supply Project
City of Charlottesville and Albemarle County, Virginia

Conceptual Stream and Wetland Mitigation Plan

Vanasse Hangen Brustlin, Inc.   Gannett Fleming

Figure 4
Potential Urban Stream Restoration Sites

Creek via diminished erosion and sedimentation. Such measures would also improve water quality in the South Fork Rivanna River and the downstream reservoir, where excessive sedimentation is a recognized problem.

Land Use

The limits of the property owned by the RWSA for the Buck Mountain Reservoir are depicted in Figure 5. This area will hereafter be referred to as the "Buck Mountain Project Area." More than half of the land use is considered agricultural – a mix of cropland and ranching. This land use is typical of the region. Based on Albemarle County zoning designations and a review of aerial photography, the remainder of the watershed is also predominantly in agricultural use.

Row cropping within the Buck Mountain Project Area appears to be predominantly no-till practice, chiefly for hay. Many floodplain terrace areas were found to be in fallow and perhaps out of rotation for more than one growing season. Localized recreational farming was also noted.

Component Streams & Initial Fieldwork

In addition to Buck Mountain Creek, three principal tributary streams are located within the Buck Mountain Project Area (Figure 5). Elk Run merges with Buck Mountain Creek from the east near the center of the Project Area. Piney Creek joins Buck Mountain Creek from the west just above the VA-665 bridge. Piney Creek itself has a tributary near the western limit of the Project Area named Burruss Branch.

In February, 2006, RWSA contracted Gannett Fleming and Vanasse Hangen Brustlin, Inc. (VHB) to perform a cursory field evaluation of stream mitigation potential at the Buck Mountain Creek site. Thirty-two lesser tributaries were identified as contributing to the four principal streams within the Project Area. A great number of these streams are not depicted on United States Geological Survey topographic series mapping. Figure 5 graphically depicts all field-confirmed streams.

Initial field reconnaissance determined that a number of pristine stream corridors are located within RWSA property and are suitable for preservation. Channel condition is relatively undisturbed and the riparian buffer consists of mature and extensive forestland. Where stream segments flow through cleared agricultural lands, the level of

Community Water Supply Project
City of Charlottesville and Albemarle County, Virginia

Conceptual Stream and Wetland Mitigation Plan

VHB Vanasse Hangen Brustlin, Inc. Gannett Fleming

Figure 5
Buck Mountain Project Area

farming activity and methods practiced have in general resulted in far less stream impact than typically seen in areas of more intense, commercial farming. Such segments are amenable to buffer re-establishment and enhancement. Localized areas of bank instability were also identified, chiefly in areas of intense cattle grazing south of VA-665. These areas consist of steep, eroded, and unvegetated banks with little riparian cover; areas that would benefit from "Stream Enhancement Level II (after SICAM) consisting of direct measures to increase bank stabilization and in-stream habitat coupled with riparian planting.

Based on these favorable preliminary findings, the support of the regulatory agencies, and the considerable amount of property already under RWSA ownership, the "Buck Mountain Creek Potential Mitigation Site" became the sole candidate for compensatory stream mitigation and the subject of a formal evaluation applying both SAAM and SICAM methodologies.

Methodology for Formal Evaluation

In September, 2006, VHB scientists assessed over 75,000 linear feet of stream channel within the Buck Mountain Project Area. Due to the considerable size of the project area, the entire length of some stream segments could not be evaluated directly. For example, relatively small, headwater streams were not exhaustively traced to their origin. Many of these streams are relatively pristine and stable, and thus relatively easy to score remotely. They were classified based on field observations coupled with high-resolution airphoto interpretation in an office setting within a GIS project.

The length of the individual Stream Assessment Reaches (SARs) varied greatly within the Buck Mountain Project Area. The characteristics of the stream channel are generally uniform within each SAR, with endpoints being dictated by a distinct change in channel morphology, substrate materials, bank stability, riparian vegetation, and so on. Seventy-two SARs were delimited on the thirty-two streams identified. The average SAR length was just over 1,000 feet.

Field personnel executed the more laborious SAAM protocol first. Identifying and selecting appropriate bankfull indicators with which to determine bank-height ratio could be somewhat time consuming. SICAM was completed immediately thereafter, as many of the metrics are similar to those used in SAAM. A representative location was photodocumented for each SAR.

All SARs on the principal streams (Buck Mountain Creek, Piney Creek, Burruss Branch, and Elk Run) were labeled with a prefix corresponding to the initials for the stream name, then in alpha-numeric fashion proceeding downstream to the confluence with a larger stream (Figure 6). For example, the uppermost SAR for Burruss Branch is called "BB-A1", followed immediately downstream by "BB-B1." Occasionally, the alpha component of a SAR will be reused repeatedly while the numeric component increases by a factor of one. For example, between Piney Creek SARs PC-B1 and PC-D1 are three individual SARS named PC-C1, PC-C2, and PC-C3. This is a reflection of more refined field analysis since the time SARs were roughly approximated by the initial fieldwork in February, 2006.

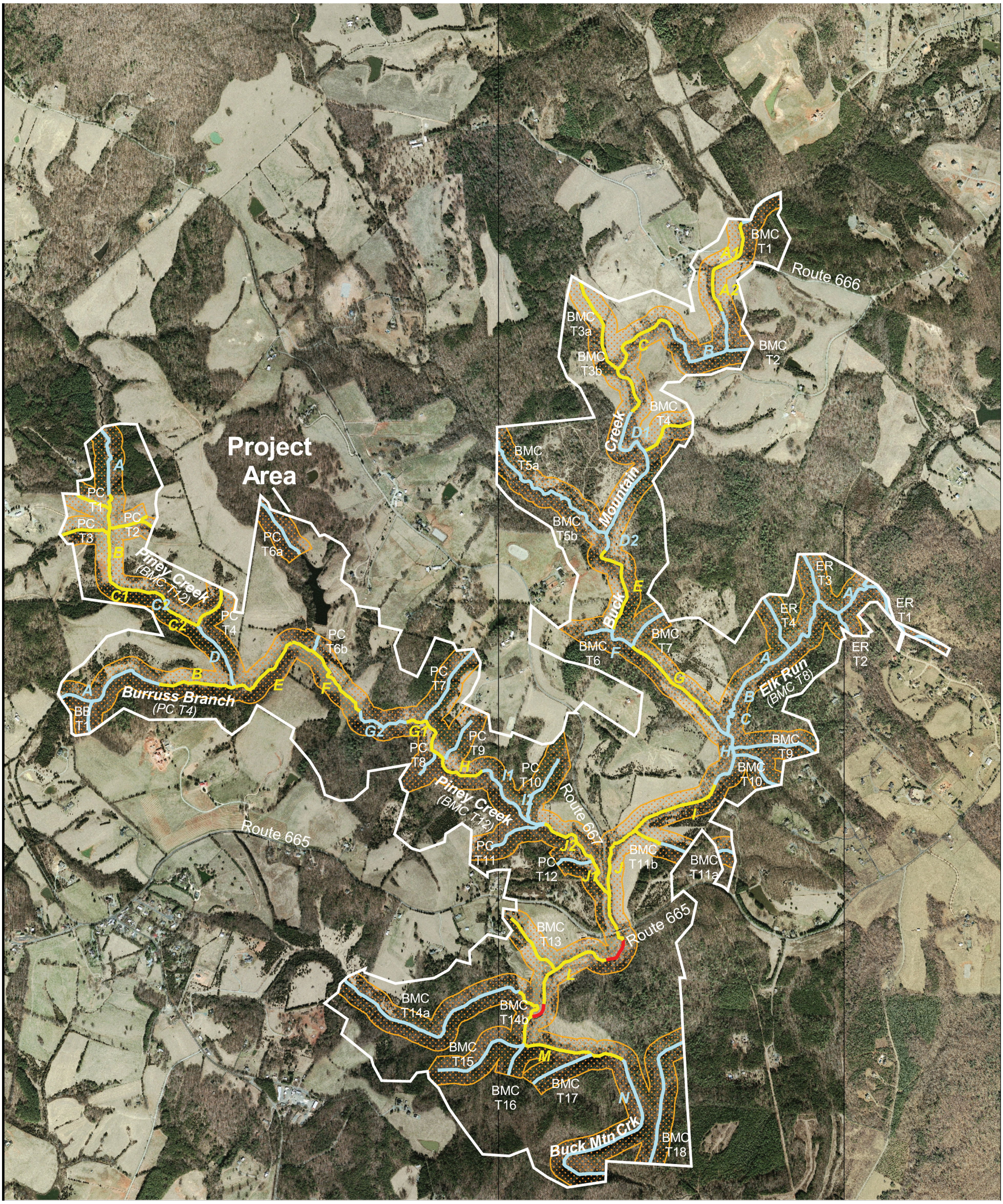
Tributary streams are also labeled with the initials of the principal stream and in alpha-numeric fashion proceeding downstream starting with the letter "T". For example, the uppermost tributary of Piney Creek is labeled PC-T1. The principal streams are also accounted for using this labeling system. For example, Elk Run also represents tributary eight to Buck Mountain Creek, or BMC-T8. Tributaries immediately above and below Elk Run are thus BMC-T7 and BMC-T9, respectively (Figure 6).

Existing Conditions

Individual field forms for each SAR evaluated at the Buck Mountain Project Area are provided on the compact disk in the rear pocket of this report. A summary of the results for SAAM are provided in Table 3. SICAM results for Buck Mountain Creek, Elk Run, and their tributaries are provided in Table 4, while data for Piney Creek and Burruss Branch are present in Table 5. With regards to SAAM, RCI scores ranged from a relatively rare value of 1.34 within a degraded portion of upper Piney Creek (PC-B1) to 6.00 (the maximum score) for BMC-T16. The weighted average RCI for the 72 SARs is 4.09 out of a maximum of 6.0, from:

$$\frac{\text{SUM of 72 TSCUs}}{\text{TOTAL SAR LENGTH}}$$

This indicates that the overall condition of streams within the Buck Mountain Project Area is favorable. In fact, 26 of the 72 SARs have scores of 5.0 or higher. These streams all flow within relatively intact forest cover and are either headwater segments that have experienced relatively little or no impact or have successfully re-stabilized following a period of disturbance in the past, or are larger 2nd and 3rd-order



Stream Preservation
Stream Bank Enhancement Level I
Stream Bank Enhancement Level II
200 foot Preservation or Enhanced Riparian Buffer
M Segment Label: Principal Stream
PC T5a Segment Label: Tributary Stream

0 2,000 feet

Community Water Supply Project
City of Charlottesville and Albemarle County, Virginia

Conceptual Stream and Wetland Mitigation Plan

Figure 6
Buck Mountain Creek Watershed: Proposed Mitigation Plan

Vanasse Hangen Brustlin, Inc. Gannett Fleming

TABLE 3.
Results of SAAM Approach: Buck Mountain Project Area

Community Water Supply Project
Rivanna Water and Sewer Authority

SAR ID	SAR Length (ft)	SAAM RCI	Total Stream Credit Units (TSCU)	Mitigation Approach	Preservation RCI w/ 200 ft Buffer	TSCUs w/ 200 ft Buffer	RCI w/ 200 ft Buffer Enhancement	RCI of Enhancement Mitigation Lift	Total Stream Credit Units (TSCUs)
PC-B1	1326	1.37	1817	E1	--	--	2.26	0.89	1180
BMC-T11b	427	1.50	641	E1	--	--	3.3	1.80	769
BMC-T13	1030	1.68	1730	E1	--	--	3.21	1.53	1576
BB-B1	1138	1.95	2219	E1	--	--	2.69	0.74	842
BMC-T3b	638	1.97	1257	E1	--	--	2.72	0.75	479
BMC-L1	1831	2.03	3717	E1	--	--	3.78	1.75	3204
BMC-L2	500	2.03	1015	E2	--	--	5.22	3.19	1595
BMC-T3a	811	2.03	1646	E1	--	--	3.8	1.77	1435
PC-A1	1026	2.27	2329	P	2.73	2800.98	--	--	560
BMC-T4	901	2.31	2081	E1	--	--	2.89	0.58	523
BMC-T14b	595	2.38	1416	E1	--	--	3.48	1.10	655
PC-G2	851	2.44	2076	P	3.21	2731.71	--	--	546
BMC-M1	1917	2.52	4831	E1	--	--	3.94	1.42	2722
PC-C1	516	2.67	1378	E1	--	--	4.04	1.37	707
BMC-I1	528	2.85	1505	E1	--	--	4.1	1.25	660
PC-E1	1172	2.93	3434	E1	--	--	4.3	1.37	1606
PC-F1	1540	2.94	4528	E1	--	--	4.69	1.75	2695
BMC-D2	1312	2.97	3897	P	3.41	4473.92	--	--	895
PC-J1	1176	3.11	3657	E1	--	--	4.76	1.65	1940
PC-C3	592	3.17	1877	E1	--	--	4.55	1.38	817
PC-D1	1077	3.27	3522	P	4.21	4534.17	--	--	907
PC-I1	1346	3.33	4482	P	4.27	5747.42	--	--	1149
PC-G1	548	3.40	1863	E1	--	--	4.64	1.24	680
BMC-C1	2089	3.44	7186	E1	--	--	4.77	1.33	2778
BMC-I2	1260	3.52	4435	E1	--	--	4.94	1.42	1789
PC-H1	1196	3.54	4234	E1	--	--	4.86	1.32	1579
PC-J2	451	3.57	1610	E1	--	--	4.81	1.24	559
BMC-G1	1531	3.66	5603	E1	--	--	5.16	1.50	2297
BB-A1	1725	3.74	6452	P	4.5	7762.5	--	--	1553
BMC-T14a	3145	3.81	11982	P	4.65	14624.25	--	--	2925
BMC-J1	1289	3.92	5053	E1	--	--	5.07	1.15	1482
BMC-T5b	665	3.98	2647	P	4.85	3225.25	--	--	645
BMC-E1	1427	4.08	5822	E1	--	--	5.22	1.14	1627
BMC-A2	967	4.09	3955	E1	--	--	5.73	1.64	1586
BMC-A1	593	4.14	2455	E1	--	--	5.31	1.17	694
PC-T2	808	4.33	3499	E1	--	--	6.08	1.75	1414
BMC-F1	461	4.34	2001	P	534	246174	--	--	49235
PC-T1	542	4.43	2401	E1	--	--	6.18	1.75	949
PC-C2	379	4.51	1709	P	5.41	2050.39	--	--	410
PC-T3	722	4.54	3278	E1	--	--	6	1.46	1054
BMC-N1	2965	4.57	13550	P	5.57	16515.05	--	--	3303
BMC-T5a	1712	4.67	7995	P	5.52	9450.24	--	--	1890
BMC-B1	1728	4.74	8191	P	5.69	9832.32	--	--	1966
BMC-D1	1383	4.79	6625	P	5.71	7896.93	--	--	1579
BMC-T6	413	4.87	2011	P	5.63	2325.19	--	--	465
PC-T4	706	4.92	3474	E1	--	--	5.93	1.01	713
ER-B1	330	4.95	1634	P	5.75	1897.5	--	--	380
BMC-H1	1290	5.00	6450	P	5.95	7675.5	--	--	1535
ER-C1	667	5.05	3368	P	5.85	3901.95	--	--	780
PC-T6b	252	5.10	1285	P	5.75	1449	--	--	290
PC-T8	439	5.13	2252	P	6.03	2647.17	--	--	529
BMC-T17	952	5.35	5093	P	6.25	5950	--	--	1190
BMC-T7	694	5.44	3775	P	6.34	4399.96	--	--	880
BMC-T9	1228	5.44	6680	P	6.34	7785.52	--	--	1557
BMC-T11a	648	5.44	3525	P	6.34	4108.32	--	--	822
PC-T6a	985	5.45	5368	P	6.45	6353.25	--	--	1271
PC-T7	1271	5.45	6927	P	6.35	8070.85	--	--	1614
PC-T9	730	5.46	3986	P	6.37	4650.1	--	--	930
ER-T1	1324	5.53	7322	P	6.33	8380.92	--	--	1676
BMC-T1	738	5.54	4089	P	6.54	4826.52	--	--	965
BMC-T10	879	5.54	4870	P	6.54	5748.66	--	--	1150
PC-T12	568	5.63	3198	P	6.53	3709.04	--	--	742
BMC-T2	331	5.63	1864	P	6.53	2161.43	--	--	432
ER-A1	2814	5.63	15843	P	6.53	18375.42	--	--	3675
BMC-T15	1490	5.72	8523	P	6.72	10012.8	--	--	2003
BB-T1	472	5.73	2705	P	6.73	3176.56	--	--	635
PC-T10	1082	5.73	6200	P	6.73	7281.86	--	--	1456
PC-T11	918	5.73	5260	P	6.73	6178.14	--	--	1236
ER-T2	334	5.73	1914	P	6.73	2247.82	--	--	450
ER-T3	719	5.73	4120	P	6.73	4838.87	--	--	968
ER-T4	868	5.73	4974	P	6.73	5841.64	--	--	1168
BMC-T18	2007	5.90	11841	P	6.9	13848.3	--	--	2770
BMC-T16	490	6.00	2940	P	7	3430	--	--	686
Totals	**75475**								**142422**

Key: P = Preservation
E1 = Enhancement Level I
E2 = Enhancement Level II

Note: RCI = Reach Condition Index
SARs in italics were assessed in-office.

Preservation TSCUs:	99818
Enhancement Level I TSCUs:	41009
Enhancement Level II TSCUs:	1595

TABLE 4.
Results of SICAM Approach: Buck Mountain Creek and Elk Run

Community Water Supply Project
Rivanna Water and Sewer Authority

SAR ID	SAR Length (ft)	SICAM RCI	Channel Condition	Stream Evolution Model	Mitigation Approach	Initial Preservation Ratio	% Enhanced	% Preserved	Credit Ratio	Buffer Re-establishment?	Final Credit Ratio	Buffer Width	Buffer A_F (200 ft)	Legal Mech. Instituted?	Watershed AF	Rare or T & E Species or Community Improved?	T & E A_F	Presence of Community Related Constraints (Few/Many)	Constraints AF	Livestock Exclusion?	Livestock Exclusion A_F	Adjusted CC (ft)
BMC-A1	593	5.1	Marginal	Late 3, Early 4	E1	10	40%	60%	7.5	Yes	7.30	200	0.2	No	0	Yes	0.2	Few	0	No	0	114
BMC-A2	967	4.5	Marginal	Late 3, Early 4	E1	10	80%	20%	5	Yes	5	200	0.2	No	0	Yes	0.2	Few	0	No	0	294
BMC-B1	1728	5.5	Marginal	Late 3, Early 4	P	10	0%	100%	10	No	10	200	0.2	No	0	Yes	0.2	Few	0	No	0	242
BMC-C1	2089	4.5	Marginal	Late 3, Early 4	E1	10	70%	30%	5.63	Yes	5.28	200	0.2	No	0	Yes	0.2	Few	0	No	0	554
BMC-D1	1383	5.5	Marginal	Late 3, Early 4	P	10	0%	100%	10	No	10	200	0.2	No	0	Yes	0.2	Few	0	No	0	194
BMC-D2	1312	5.5	Marginal	Late 3, Early 4	P	10	0%	100%	10	No	10	200	0.2	No	0	Yes	0.2	Few	0	No	0	184
BMC-E1	1427	5.5	Marginal	Late 3, Early 4	E1	10	25%	75%	8.44	No	8.44	200	0.2	No	0	Yes	0.2	Few	0	No	0	237
BMC-F1	461	5.5	Marginal	Late 3, Early 4	P	10	0%	100%	10	No	10	200	0.2	No	0	Yes	0.2	Few	0	No	0	65
BMC-G1	1531	5.1	Marginal	Late 3, Early 4	E1	10	100%	0%	3.75	Yes	3.25	200	0.2	No	0	Yes	0.2	Few	0	No	0	660
BMC-H1	1290	5.5	Marginal	Late 3, Early 4	P	10	0%	100%	10	No	10	200	0.2	No	0	Yes	0.2	Few	0	No	0	181
BMC-I1	528	4	Marginal	Late 3, Early 4	E1	10	50%	50%	6.88	No	6.88	200	0.2	No	0	Yes	0.2	Few	0	No	0	108
BMC-I2	1260	3.3	Marginal	Late 3, Early 4	E1	15	75%	25%	6.56	Yes	6.19	200	0.2	No	0	Yes	0.2	Few	0	No	0	285
BMC-J1	1289	4.5	Marginal	Late 3, Early 4	E1	10	50%	50%	6.88	Yes	6.63	200	0.2	No	0	Yes	0.2	Few	0	No	0	272
BMC-L1	1831	2.1	Marginal	Late 3, Early 4	E1	15	100%	0%	3.75	Yes	3.25	200	0.2	No	0	Yes	0.2	Few	0	Yes	0.3	958
BMC-L2	500	2.1	Marginal	Late 3, Early 4	E2	15	100%	0%	2.00	Yes	2.00	200	0.2	No	0	Yes	0.2	Few	0	Yes	0.3	425
BMC-M1	1917	2.9	Marginal	Late 3, Early 4	E1	15	60%	40%	8.25	No	8.25	200	0.2	No	0	Yes	0.2	Few	0	Yes	0.3	395
BMC-N1	2965	6.5	Suboptimal	Late 4	P	5	0%	100%	5	No	5	200	0.2	No	0	Yes	0.2	Few	0	No	0	830
BMC-T1	738	6.5	Suboptimal	Late 4	P	5	0%	100%	5	No	5	200	0.2	No	0	Yes	0.2	Few	0	No	0	207
BMC-T2	331	6.5	Suboptimal	Late 4	P	5	0%	100%	5	No	5	200	0.2	No	0	Yes	0.2	Few	0	No	0	93
BMC-T3a	811	2.1	Poor	Late 2, Early 3	E1	15	100%	0%	3.75	Yes	3.25	200	0.2	No	0	Yes	0.2	Few	0	No	0	349
BMC-T3b	638	2.6	Poor	Late 2, Early 3	E1	15	60%	40%	8.25	Yes	7.95	200	0.2	No	0	Yes	0.2	Few	0	No	0	112
BMC-T4	901	3.2	Poor	Late 2, Early 3	E1	15	35%	65%	11.06	Yes	10.89	200	0.2	No	0	Yes	0.2	Few	0	No	0	116
BMC-T5a	1712	6.5	Suboptimal	Late 4	P	5	0%	100%	5	No	5	200	0.2	No	0	Yes	0.2	Few	0	No	0	479
BMC-T5b	665	5.8	Marginal	Late 3, Early 4	P	5	0%	100%	5	No	5	200	0.2	No	0	Yes	0.2	Few	0	No	0	186
BMC-T6	413	5.4	Marginal	Late 3, Early 4	P	10	0%	100%	10	No	10	200	0.2	No	0	Yes	0.2	Few	0	No	0	58
BMC-T7	694	6.5	Suboptimal	Late 4	P	5	0%	100%	5	No	5	200	0.2	No	0	Yes	0.2	Few	0	No	0	194
BMC-T9	1228	6.5	Suboptimal	Late 4	P	5	0%	100%	5	No	5	200	0.2	No	0	Yes	0.2	Few	0	No	0	344
BMC-T10	879	6.5	Suboptimal	Late 4	P	5	0%	100%	5	No	5	200	0.2	No	0	Yes	0.2	Few	0	No	0	246
BMC-T11a	648	6.5	Suboptimal	Late 4	P	5	0%	100%	5	No	5	200	0.2	No	0	Yes	0.2	Few	0	No	0	181
BMC-T11b	427	1.3	Poor	Late 2, Early 3	E1	20	100%	0%	3.75	Yes	3.25	200	0.2	No	0	Yes	0.2	Few	0	No	0	184
BMC-T13	1030	2.1	Poor	Late 2, Early 3	E1	15	75%	25%	6.56	Yes	6.19	200	0.2	No	0	Yes	0.2	Few	0	Yes	0.3	283
BMC-T14a	3145	5.5	Suboptimal	Late 4	P	10	0%	100%	10	No	10	200	0.2	No	0	Yes	0.2	Few	0	No	0	440
BMC-T14b	595	2.2	Poor	Late 2, Early 3	E1	15	50%	50%	9.38	No	9.38	200	0.2	No	0	Yes	0.2	Few	0	Yes	0.3	108
BMC-T15	1490	6.5	Suboptimal	Late 4	P	5	0%	100%	5	No	5	200	0.2	No	0	Yes	0.2	Few	0	No	0	417
BMC-T16	490	7	Optimal	5	P	5	0%	100%	5	No	5	200	0.2	No	0	Yes	0.2	Few	0	No	0	137
BMC-T17	952	6.7	Optimal	5	P	5	0%	100%	5	No	5	200	0.2	No	0	Yes	0.2	Few	0	No	0	267
BMC-T18	2007	6.5	Suboptimal	Late 4	P	5	0%	100%	5	No	5	200	0.2	No	0	Yes	0.2	Few	0	No	0	562
ER-A1	2814	6.5	Suboptimal	Late 4	P	5	0%	100%	5	No	5	200	0.2	No	0	Yes	0.2	Few	0	No	0	788
ER-B1	330	5.1	Marginal	Late 3, Early 4	P	10	0%	100%	10	No	10	200	0.2	No	0	Yes	0.2	Few	0	No	0	46
ER-C1	667	5.1	Marginal	Late 3, Early 4	P	10	0%	100%	10	No	10	200	0.2	No	0	Yes	0.2	Few	0	No	0	93
ER-T1	1324	6.1	Suboptimal	Late 4	P	5	0%	100%	5	No	5	200	0.2	No	0	Yes	0.2	Few	0	No	0	371
ER-T2	334	6.5	Suboptimal	Late 4	P	5	0%	100%	5	No	5	200	0.2	No	0	Yes	0.2	Few	0	No	0	94
ER-T3	719	6.5	Suboptimal	Late 4	P	5	0%	100%	5	No	5	200	0.2	No	0	Yes	0.2	Few	0	No	0	201
ER-T4	868	6.5	Suboptimal	Late 4	P	5	0%	100%	5	No	5	200	0.2	No	0	Yes	0.2	Few	0	No	0	243
Totals	**49921**																					**12796**

Key:
P = Preservation
E1 = Enhancement Level I
E2 = Enhancement Level II
CC = Compensation Credit

Note:
A_F = Adjustment Factor
SARs in italics were assessed in-office.
Initial Preservation Ratio is based solely on primary mitigation approach for that SAR
Adjusted Credit Ratio incorporates the percentage of the SAR riparian area to be enhanced versus preserved
The Final Credit Ratio incorporates an adjustment if buffer re-establishment is involved
Preservation Cretit Ratios correlate to the SAR RCI score

Total CCs using current calculations (All SARs):	19672
Preservation CCs (All SARs):	10149
Enhancement Level I CCs (All SARs):	9098
Enhancement Level I ICCs (All SARs):	425

TABLE 5.
Results of SICAM Approach: Piney Creek and Burruss Branch

Community Water Supply Project
Rivanna Water and Sewer Authority

SAR ID	SAR Length (ft)	SICAM RCI	Channel Condition	Stream Evolution Model	Mitigation Approach	Initial Preservation Ratio	% Enhanced	% Preserved	Adjusted Credit Ratio	Buffer Re-establishment?	Final Credit Ratio	Buffer Width	Buffer A_F (200 ft)	Legal Mech. Instituted?	Watershed A_F	Rare or T & E Species or Community Improved?	T & E A_F	Presence of Community Related Constraints (Few/Many)	Constraints A_F	Livestock Exclusion?	Livestock Exclusion A_F	Adjusted CC (ft)
BB-A1	1725	5.1	Marginal	Late 3, Early 4	P	10	0%	100%	10	No	10	200	0.2	No	0	Yes	0.2	Few	0	No	0	242
BB-B1	1138	3.4	Marginal	Late 3, Early 4	E1	15	75%	25%	6.56	Yes	6.19	200	0.2	No	0	Yes	0.2	Few	0	Yes	0.3	313
BB-T1	472	7	Optimal	5	P	5	0%	100%	5	No	5	200	0.2	No	0	Yes	0.2	Few	0	Yes	0.3	160
PC-A1	1026	4	Poor	Late 2, Early 3	P	10	0%	100%	10	No	10	200	0.2	No	0	Yes	0.2	Few	0	No	0	144
PC-B1	1326	1.3	Poor	Late 2, Early 3	E1	20	100%	0%	3.75	Yes	3.25	200	0.2	No	0	Yes	0.2	Few	0	Yes	0.3	694
PC-C1	516	3.4	Marginal	Late 3, Early 4	E1	15	50%	50%	9.38	Yes	9.13	200	0.2	No	0	Yes	0.2	Few	0	Yes	0.3	96
PC-C2	379	6.2	Suboptimal	Late 4	P	5	0%	100%	5	No	5	200	0.2	No	0	Yes	0.2	Few	0	Yes	0.3	129
PC-C3	592	3.4	Marginal	Late 3, Early 4	E1	15	50%	50%	9.38	Yes	9.13	200	0.2	No	0	Yes	0.2	Few	0	Yes	0.3	110
PC-D1	1077	4.4	Marginal	Late 3, Early 4	P	10	0%	100%	10	No	10	200	0.2	No	0	Yes	0.2	Few	0	No	0	151
PC-E1	1172	3.8	Marginal	Late 3, Early 4	E1	10	50%	50%	6.88	Yes	6.63	200	0.2	No	0	Yes	0.2	Few	0	No	0	248
PC-F1	1540	3.3	Marginal	Late 3, Early 4	E1	15	100%	0%	3.75	Yes	3.25	200	0.2	No	0	Yes	0.2	Few	0	No	0	663
PC-G2	851	3.6	Marginal	Late 3, Early 4	P	15	0%	100%	15	No	15	200	0.2	No	0	Yes	0.2	Few	0	No	0	79
PC-G1	548	4.8	Marginal	Late 3, Early 4	E1	10	55%	45%	6.5625	No	6.56	200	0.2	No	0	Yes	0.2	Few	0	No	0	117
PC-H1	1196	4.1	Marginal	Late 3, Early 4	E1	10	50%	50%	6.88	Yes	6.63	200	0.2	No	0	Yes	0.2	Few	0	No	0	253
PC-I1	1346	5.1	Marginal	Late 3, Early 4	P	10	0%	100%	10	No	10	200	0.2	No	0	Yes	0.2	Few	0	No	0	188
PC-J2	451	5.1	Marginal	Late 3, Early 4	E1	10	40%	60%	7.5	Yes	7.30	200	0.2	No	0	Yes	0.2	Few	0	Yes	0.3	105
PC-J1	1176	4	Marginal	Late 3, Early 4	E1	10	100%	0%	3.75	No	3.75	200	0.2	No	0	Yes	0.2	Few	0	No	0	439
PC-T1	542	4.6	Marginal	Late 3, Early 4	E1	10	100%	0%	3.75	Yes	3.25	200	0.2	No	0	Yes	0.2	Few	0	Yes	0.3	284
PC-T2	808	3.6	Marginal	Late 3, Early 4	E1	15	100%	0%	3.75	Yes	3.25	200	0.2	No	0	Yes	0.2	Few	0	Yes	0.3	423
PC-T3	722	3.6	Marginal	Late 3, Early 4	E1	15	70%	30%	7.125	Yes	6.78	200	0.2	No	0	Yes	0.2	Few	0	Yes	0.3	181
PC-T4	706	4.1	Marginal	Late 3, Early 4	E1	10	25%	75%	8.44	Yes	8.31	200	0.2	No	0	Yes	0.2	Few	0	Yes	0.3	144
PC-T6a	985	6.2	Suboptimal	Late 4	P	5	0%	100%	5	No	5	200	0.2	No	0	Yes	0.2	Few	0	No	0	276
PC-T6b	252	5.2	Suboptimal	Late 4	P	10	0%	100%	10	No	10	200	0.2	No	0	Yes	0.2	Few	0	No	0	35
PC-T7	1271	6.5	Suboptimal	Late 4	P	5	0%	100%	5	No	5	200	0.2	No	0	Yes	0.2	Few	0	No	0	356
PC-T8	439	6.5	Suboptimal	Late 4	P	5	0%	100%	5	No	5	200	0.2	No	0	Yes	0.2	Few	0	No	0	123
PC-T9	730	6.1	Suboptimal	Late 4	P	5	0%	100%	5	No	5	200	0.2	No	0	Yes	0.2	Few	0	No	0	204
PC-T10	1082	6.5	Suboptimal	Late 4	P	5	0%	100%	5	No	5	200	0.2	No	0	Yes	0.2	Few	0	No	0	303
PC-T11	918	6.5	Suboptimal	Late 4	P	5	0%	100%	5	No	5	200	0.2	No	0	Yes	0.2	Few	0	No	0	257
PC-T12	568	6.5	Suboptimal	Late 4	P	5	0%	100%	5	No	5	200	0.2	No	0	Yes	0.2	Few	0	No	0	159
Totals	**25554**																					**6876**

Key: P = Preservation
E1 = Enhancement Level I
E12= Enhancement Level II
CC = Compensation Credit

Note: A_F = Adjustment Factor
SARs in italics were assessed in-office.
Initial Preservation Ratio is based solely on primary mitigation approach for that SAR
Adjusted Credit Ratio incorporates the percentage of the SAR riparian area to be enhanced versus preserved
The Final Credit Ratio incorporates an adjustment if buffer re-establishment is involved
Preservation Cretit Ratios correlate to the SAR RCI score

Total CCs using current calculations (All SARs)	19672
Preservation CCs (All SARs):	10149
Enhancement Level I CCs (All SARs):	9098
Enhancement Level I ICCs (All SARs):	425

streams flowing within forested corridors that are in the final stages of the evolutionary channel adjustment process associated with changes in their flow regime (*e.g.* upstream land clearing for agriculture). The process of channel evolution will be described in greater detail in the following section *Mitigation Approaches: Stream Enhancement*.

Those SARs receiving lower RCI scores are typically found along the principal streams Piney Creek, Burruss Branch, and Buck Mountain Creek. Scores are relatively diminished primarily because of an inadequate riparian buffer. Other metrics routinely scoring lower include sedimentation and bank-height ratio.

Not surprisingly, SICAM results were very similar, with RCI scores ranging from 1.3 to 7.0 for the same two reaches described above. The weighted average RCI was also moderately high, at 4.98 out of a possible 7.0 points.

Proposed Mitigation Approaches

Stream Preservation

Stream preservation is proposed for those streams in the Buck Mountain Project Area achieving high RCI scores and situated within intact forest cover. Preservation reaches are denoted by blue linework on Figure 6. Many of these stream segments are analogous to those that would be impacted by the proposed expansion of Ragged Mountain Reservoir (*i.e.* relatively pristine, first and second-order streams). A conservation area ("riparian buffer") of an average width of 400-foot wide will be established around these streams (on average, 200 feet from both stream banks, though buffer widths in some areas many vary as described below). This easement is depicted on Figure 6 as a transparent orange zone, and will be preserved in its current state in perpetuity.

Stream Enhancement
Level I

Though the principal streams all have reaches that have been significantly incised, the root cause of this downcutting (*i.e.* land clearing and channel straightening) occurred in the distant past. In the absence of direct channel manipulation, the vast majority of these streams have recovered such that vegetation now covers most of the banks and commonly extends to the waterline. Mature, mast-producing trees such as sycamore (*Platanus occidentalis*) can be seen at numerous locations at the toe of the bank along the lower Buck Mountain Creek main stem. This degree of bank stability is particularly impressive because bedrock constitutes the chief substrate material over significant lengths of Buck Mountain Creek. In such a setting, erosional forces are more apt to attack less cohesive bank materials. The fact that this is a rare occurrence suggests the streams have adjusted their dimension, pattern, and profile to approach equilibrium with the hydrologic regime of their watersheds.

The SICAM Channel Condition metric is akin to the "Channel Evolution Model" developed by Schumm, Harvey and Watson (1984). The model consists of five sequential stages of evolution, the first being Stage 1: Stable Channel Configuration, which refers to the stream in its natural, undisturbed state. With the introduction of change within the contributing watershed (*e.g.* increase in impermeable surface area, land clearing, etc.), streams generally proceed down a 4-stage path from Stage 1. These are:

- **Stage 2: Incision**
    - entrenchment, downcutting
    - streambank slopes vertical at toe
- **Stage 3: Widening**
    - slumping banks
    - erosion on inside of meander bends
- **Stage 4: Stabilizing**
    - slumped material not eroding
    - slumped material being colonized by vegetation
    - predictable sinuous course & floodplain developing
- **Stage 5: Stable**
    - as per Stage 1, but having abandoned floodplain terrace

The status of each SAR along this progression is provided in Tables 4 and 5. Overall, most stream segments in the Buck Mountain Project Area have reached late Stage 3 to early Stage 4 or beyond, and therefore are nearing the endpoint in their evolution towards a stable configuration. In fact, an inadequate riparian buffer is the chief shortcoming for those streams coursing through agricultural areas. The mitigation approach proposed is therefore Enhancement Level I: the re-establishment or augmentation of the riparian buffer immediately adjacent to these streams.

Stream segments about which such planting will occur are depicted as yellow lines on Figure 6. Planting will extend to cover the full width of the riparian buffer, with woody tree species installed on 10-foot centers in areas of cropland or fallow field and infilling gaps in existing tree or shrub coverage in areas with patchy riparian vegetation. One-gallon stock will be used, protected from herbivory by tree tubes. A preliminary species list is provided in Table 6.

As all forms of agricultural or other land-clearing practices would be excluded from this riparian buffer, the natural regeneration of tree species via the surrounding, mature canopy would therefore be encouraged, augmenting planted stock. In areas where cattle grazing and watering was observed, cattle exclusion fences will be installed to promote bank stability and recruitment of common riparian species such as tag alder (*Alnus serrulata*) and sycamore. This will be particularly helpful in the uppermost portion of Piney Creek as well as Buck Mountain Creek below VA-665.

Compatibility of Stream Enhancement Level I & Existing Land Use

It is noted that many of the tracts within the Buck Mountain Project Area are leased and in a variety of agricultural uses. Many areas of active farming and pasturing approach within 50 feet or less from the banks of Buck Mountain and Piney Creeks. Farm access roads and stream fords also lie within the proposed riparian buffer. In response to community requests, the RWSA has met with several tenants to better understand the extent to which the proposed Stream Enhancement Level I would affect the continuation of their farming practices and land-access issues. The RWSA proposes the following provisions based on concerns expressed by leaseholders at a public hearing held on November 2, 2006 in Charlottesville and at follow-up, onsite meetings:

1. The average width of the re-established riparian buffer will be approximately 200 feet extending landward from the top of both stream banks. However, widths may be reduced in a limited number of areas as determined on a case-by-case basis where:

    a. A 200-foot buffer would significantly diminish existing agricultural land (*e.g.* narrow pasture or farm fields that follow the stream course in bottomland areas);
    b. The continued existing use with a narrower buffer will not compromise water-quality objectives, and;
    c. The total scope of the proposed mitigation project remains sufficient to meet regulatory approval (*i.e.* where possible, the width of the riparian buffer will be extended beyond 200 feet, to compensate for reductions in buffer width elsewhere). Further, if appropriate following more detailed inspections, additional Stream Enhancement I areas could be

identified. The intent is that as the project becomes better defined, the scope of work continues to satisfy the SAAM and SICAM compensation requirements, and the water quality objectives are satisfied

2. the RWSA may propose to improve existing stream crossings and/or install a limited number of new, stabilized stream crossings for activities such as horseback riding, supervised cattle movement, hunting where permitted by RWSA, or similar activities, and;

3. Existing access paths may be maintained and a limited number of new access paths may be permitted within easement areas, where protection is provided against erosion or other degradation of water quality.

It should be noted that a number of public roads intersect the proposed 200-foot buffer (Figure 5). Specifically, these are:

- Route 665, which bisects lower Buck Mountain Creek;
- Route 667, which runs along the west bank of Buck Mountain Creek and crosses Piney Creek just north of the intersection with Route 665, and;
- Route 666, which crosses Buck Mountain Creek near the northern limit of the Project Area.

Accordingly, the area of these roads, their embankments, and so on will not be included in the total acreage of riparian re-establishment, nor will such areas be subject to any restrictive covenant related to this mitigation plan. All private, serviceable roads will be similarly discounted in terms of acreage, though they may be captured within the conservation easements and subject to certain limitations on improvements (*i.e.* gravel road cannot be paved, roads cannot be expanded, etc.). Other such exempted utilities include, but may not be restricted to, pipelines, overhead power and telephone lines, and drain fields.

Stream Enhancement Level II

Limited areas suitable for more intensive Enhancement Level II were identified. Two such reaches are located on Buck Mountain Creek: just downstream of the VA-665 bridge (~200 feet), and at the confluence with BMC-T14b (~300 feet). Active slumping and eroding, near-vertical banks were noted at these locations, identified by red linework on Figure 6.

Enhancement Level II will address bank instabilities via the regrading of vertical bank sections and the installation of bank-defense structures such as vanes, root wads, or imbricated revetments. Such features will also promote in-stream habitat. The implementation of grade-control measures is not warranted in the Buck Mountain Project Area as downcutting is bedrock limited.

Priority I, II, or III stream restoration (Rosgen, 1995) is considered unwarranted within the Buck Mountain Project Area. Restoration practices would involve the clearing of existing vegetation and earthmoving, both of which would likely induce greater instability within both the stream and adjacent riparian areas – particularly over the short term. Freshly graded areas planted with relatively juvenile tree species would be vulnerable to erosion during storms.

TABLE 6. Proposed Plant List – Riparian Zone, Buck Mountain Project Area
Conceptual Stream and Wetland Mitigation Plan
Rivanna Water & Sewer Authority - Community Water Supply Project

Stratum	Wetland Species	Upland Species
Tree	Sycamore (*Platanus occidentalis*) River birch (*Betula nigra*) Black gum (*Nyssa sylvatica*) Willow oak *(Quercus phellos)* Silver maple (*Acer saccharinum*) Green ash (*Fraxinus pennsylvanica*) Slippery elm (*Ulmus rubra*)	Black Walnut (*Juglans nigra*) Bitternut hickory (*Carya cordiformis*) Pignut hickory (*Carya glabra*) Scarlett oak (*Quercus coccinea*) Chestnut oak (*Quercus prinus*) Persimmon (*Diospyros virginiana*) White oak (*Quercus alba*) Northern red oak (*Quercus rubra*) American beech (*Fagus grandifolia*), Sassafras (*Sassafras albidum*) Sourwood (*Oxydendrum arboretum*) American holly (*Ilex opaca*)
Scrub-Shrub	Spicebush (*Lindera benzoin*) Brookside alder (*Alnus serrulata*) Box elder (*Acer negundo*) Elderberry (*Sambucus canadensis*) Arrow-wood (*Viburnum dentatum*)	Eastern red cedar (*Juniperus virginiana*) Witch Hazel (*Hamamelis virginiana*) Coral berry (*Symphoricarpos orbiculatus*)

Anticipated Mitigation Lift

Within the Buck Mountain Project Area, 75,475 linear feet of stream are available for compensatory mitigation. The three mitigation approaches described above break down quantitatively as follows:

- Stream Preservation: 44,708 linear feet, or 59%;
- Stream Enhancement Level I: 30,267 linear feet, or 40%, and;
- Stream Enhancement Level II: 500 feet, or <1%.

SAAM

With regards to the SAAM method, this three-pronged approach results in generous mitigation credit. A total of 142,422 TSCU are generated, almost twice the indicated level of 74,152 TSCU. This is a result of the relative weighting the SAAM protocol places on the preservation of undisturbed natural areas, particularly if buffers are adopted beyond 100 feet in width. The details of the calculation of mitigation credit are provided in Table 3. To determine the mitigation lift associated with preservation reaches, an updated RCI and subsequent TSCU value was calculated based on the increase of the riparian buffer from the 100 feet evaluated in the field to the 200 feet being incorporated in a conservation easement. This essentially doubles the Condition Index (CI) for the Riparian Areas metric. For example, consider the 985-foot SAR named PC-T6a in Table 3. Its RCI value is 5.45, and it has a perfect CI for Riparian Areas of 1.0. Preserving an additional 100 feet on both sides of the stream boosts the CI to 2.0, for an RCI total of 6.45. The lift in TSCUs is calculated by multiplying the SAR length by the new RCI and dividing by a fixed factor of 5 (preservation ratio of 5:1):

$$(SAR * RCI_{preserved}) / 5 = \text{TSCUs of lift from preservation}$$

In this example,

$$(985 * 6.45) / 5 = 1{,}271 \text{ TSCUs}$$

For enhancement reaches, the RCI was updated to reflect enhancement of those portions of the assessed 100-foot buffer along each stream bank requiring plantings. A new RCI was then calculated to reflect the riparian buffer enhancement increased to 200 feet. A subsequent RCI lift was calculated for enhancement SARs by subtracting the original RCI from the new value. The resulting TSCUs are therefore the product of the lift value and the SAR length:

$$(RCI_{enhancement} - RCI_{existing}) * SAR = \text{TSCU of lift from enhancement}$$

To calculate mitigation lift for the relatively limited, 500-foot total length of Stream Enhancement in Buck Mountain Creek below VA-665, the CIs of three metrics were increased based on the predicted improvement in their condition in response to the installation of bank stability measures and in-stream habitat features. The two areas suitable for Enhancement Level II were consolidated into one SAR for the calculation of mitigation lift, included in Table 3 as BMC-L2.

It should be noted that the degree of mitigation lift using the SAAM methodology was not determined using the standard Form 3 of the COE-provided Excel spreadsheet, but rather based on the calculation of TSCUs arising from the various mitigation approaches described above. For a project of this size, one that involves multiple impact areas and even more plentiful mitigation reaches, it is impractical to assign a specific segment of stream mitigation towards a specific impact area. This issue was voiced by numerous members of the environmental consulting community during the May, 2006 “Stream Methodologies Public Meeting” in Williamsburg. Form 3 is useful for smaller projects impacting relatively few stream segments and for which such direct compensation is more applicable.

SICAM

The Compensation Credits (CC) arising from the application of the SICAM protocol are on a par with the impacts assessed by that method. While 21,509 linear feet of mitigation were indicated by the stream assessment at Ragged Mountain Reservoir, 19,672 linear feet are available at the Buck Mountain Creek site according to this assessment protocol. The discrepancy between the two protocols is related chiefly to the value attributed to the preservation of undisturbed natural areas. While SAAM employs a 5:1 credit ratio to all streams worthy of preservation, SICAM employs a credit ratio linked to the RCI of the candidate stream, ranging from 5:1 to 20:1. The ratio applied to each of the SARs can be seen in Tables 4 and 5.

In contrast, Stream Enhancement Level I has a corresponding base credit ratio of 3.75:1. Many of the candidate SARs do not require 100% enhancement mitigation (*i.e.* riparian planting along each bank for the entire length of the SAR). Therefore, for these SARs, a percentage of the reach to be enhanced versus the percentage that only needs to be preserved was determined. These percentages are included in Tables 4 and 5. Based on this percentage breakdown, an updated credit ratio was attributed to each SAR. Additionally, in actively farmed (cleared) areas where buffer re-establishment will be required, the base credit ratio can be lowered to 3.25:1. For the minor segments of Stream Enhancement Level II below VA-665, the base credit ratio for improving stream-bank stability is 2.25:1. Installing in-stream structures or improving habitat lowers the ratio to 2:1. The final credit ratios provided in Tables 4 and 5 are determined by the relative percentage of the SAR being preserved versus that enhanced, and the degree of the enhancement effort. As per the SAAM calculations, the two areas of Stream Enhancement Level II have been consolidated into one SAR named BMC-L2 (Table 4).

The SICAM manual outlines five potential adjustment factors (AFs) that can affect the final adjusted compensation credits for each SAR. For the Buck Mountain Creek Mitigation Site, all SARs received the AF for habitat improvement for the federally-listed endangered James spinymussel, as well as the AF for increasing the preserved or enhanced riparian buffer from 100 feet to 200 feet. Additionally, some reaches received an additional AF for cattle exclusion when there was observed evidence of recent cattle activity within that SAR. SARs eligible for these AFs are noted as such in Tables 4 and 5.

Summary

In the present application, VHB believes that the SAAM and SICAM protocols significantly overstate the amount of compensatory mitigation needed to offset fully the impacts of expanding Ragged Mountain Reservoir. The impacted segments at Ragged Mountain Reservoir are part of a relatively small aquatic ecosystem isolated by existing dams. In contrast, the proposed mitigation area in the lower Buck Mountain Creek watershed represents a far larger, more complex, and higher-order stream environment. The scope of the mitigation approach thus offers a great opportunity to accomplish environmental benefit not only within its boundaries but within downstream stream reaches. This is an inherent benefit of watershed-scale restoration. The proposed mitigation site contains headwaters and significant tributaries to lower Buck Mountain Creek - a stream containing the listed James spinymussel. By comparison, the impacted streams at Ragged Mountain Reservoir support only lower trophic species and are hydrologically isolated from downstream reaches and have been for many years. Furthermore, they are much smaller headwater streams with arguably less intrinsic value from a broader ecosystem perspective. This fact has been acknowledged by representatives of the USFWS and DGIF.

Unlike the SAAM method, SICAM employs a quantitative “Impact Factor” to determine the degree to which streams will be affected based on the type of project. All streams at Ragged Mountain Reservoir will be inundated by the establishment of a lacustrine environment. The Impact Factor thus used was the highest, or a value of 1, indicating a complete loss of stream function. Though the Ragged Mountain Reservoir scenario (*i.e.* inundation of previously isolated stream reaches) is not addressed as a SICAM impact type, it would be unreasonable not to take these important factors into account in interpreting and applying the results.

Wetland Mitigation

As previously discussed, two potential wetland mitigation sites have been identified to compensate for impacts at Ragged Mountain Reservoir. The Moores Creek Wetland Restoration Site (Figure 3) is located in the floodplain of Moores Creek adjacent to the RWSA office in Charlottesville. The second site is actually at Ragged Mountain Reservoir, where emergent wetland areas are expected to develop above the new pool elevation after construction of the new dam.

Moores Creek Proposed Wetland Restoration Site

The proposed Moores Creek Wetland Restoration Site is bordered by Franklin Street to the north and by Moores Creek to the south. The site currently serves as a livestock pasturing area and is adjacent to property with a barn for the periodic auctioning of domestic animals for purchase. The Moores Creek site was identified by the City of Charlottesville and Albemarle County as having potential for wetland mitigation due to continuing agricultural land use in a floodplain setting and adverse effects on water quality caused by animal waste transmitted to Moores Creek during overbank flood events. Furthermore, the site is located within a well-established urban area. Thus, the development of a wetland mitigation site in such a setting offers particular value as wildlife habitat while forestalling further encroachment into natural areas.

A detailed analysis of the Moore's Creek Wetland Restoration Site performed by VHB included a review of existing topographic mapping, soils survey data, City of Charlottesville watershed and stormwater drainage mapping, and National Wetlands Inventory mapping. On-site field data were collected to assist in quantifying site design and hydrologic performance. Field data collected during the site visit included the following items:

- surveyed floodplain cross sections;
- soil-profile descriptions and hydric-soil determinations;
- descriptions of existing vegetative communities;
- identification of significant surface and groundwater hydrologic inputs, and;
- existing wetlands and ditch mapping.

Results

The County Soil Survey indicates three primary soil types associated with the floodplain. The conceptual plan for the Moores Creek site (Figure 7) includes features described in the following points:

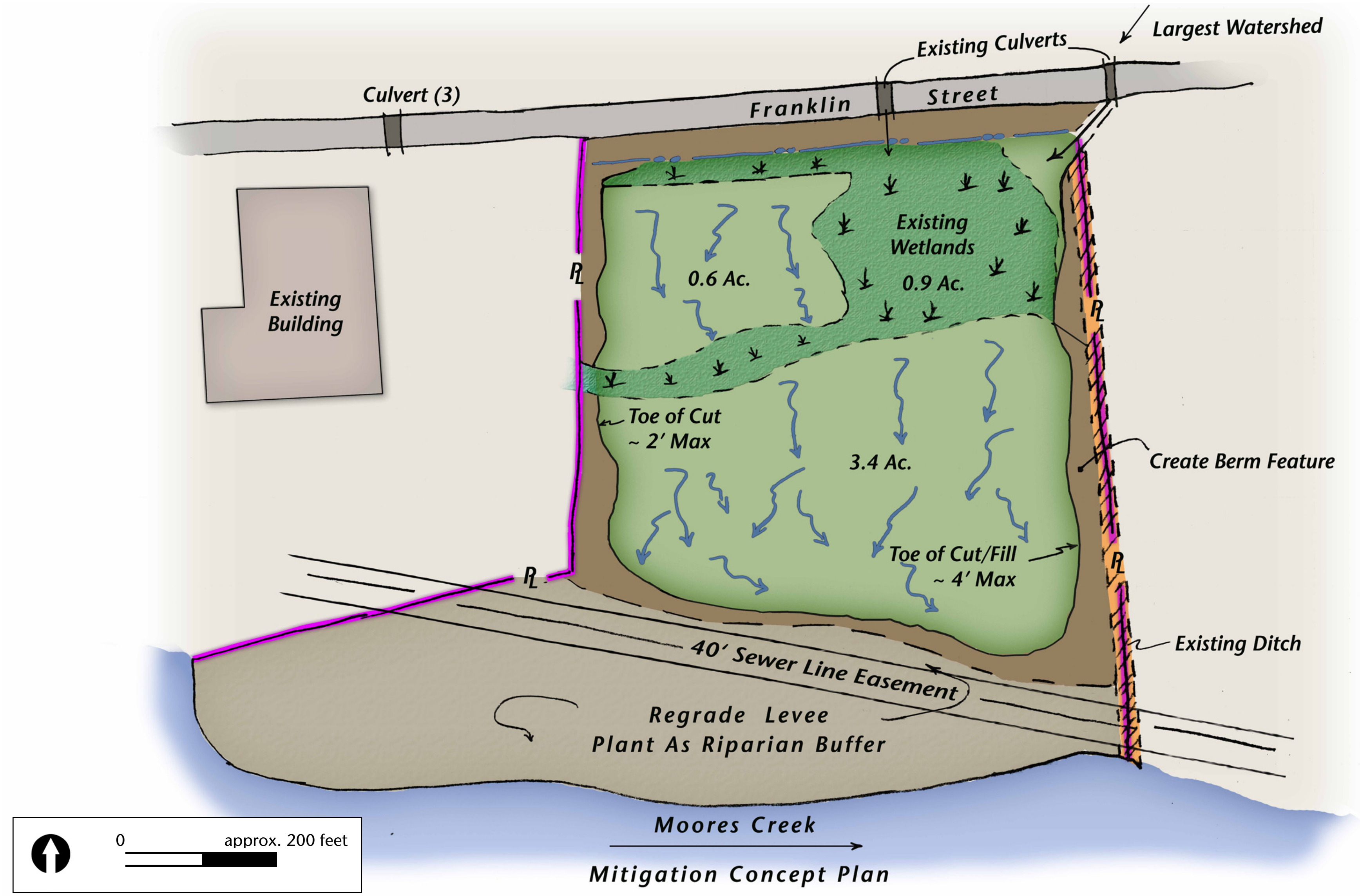
- **Buncombe loamy sand** – The Buncombe loamy sand occurs as a coarse textured levee to Moores Creek. This soil is less favorable for wetland restoration due to its high permeability.

- **Riverview-Chewacla complex** – This soil comprises the majority of the mitigation area found between the Moores Creek levee and Franklin Street. Soil borings confirmed a silt loam to silty clay loam throughout all soil profiles suitable for wetland restoration.

- **Toccoa fine sandy loam** – The Toccoa fine sandy loam is mapped immediately adjacent to the Moores Creek channel. Our field investigations, however, yielded a soil texture coarser than a sandy loam, more consistent with the Buncombe soil type.

Upland and wetland community types were clearly observed and identified within the proposed mitigation area (Figure 7). Wetlands consist of a ditch immediately south of and parallel to Franklin Street that serves to capture and convey runoff to an emergent flat. Water from the emergent system simplifies to a single channel that connects to a ditch that bisects the floodplain between Franklin Street and Moores Creek. Vegetation in this area consists of emergent species such as soft rush (*Juncus effusus*) and tearthumb (*Polygonum* spp.) with scattered alder (*Alnus serulata*) stems along the ditch edge.

Soils in the wetlands were confirmed as the Riverview-Chewacla complex, containing chroma values of 1 and 2 with numerous redoximorphic features and thus confirming their hydric status. Uplands occur in the southern half of the site within areas mapped as the



Mitigation Concept Plan

Community Water Supply Project

City of Charlottesville and Albemarle County, Virginia

Conceptual Stream and Wetland Mitigation Plan

Rivanna Water & Sewer Authority — Serving Charlottesville and Albemarle County, Virginia

Vanasse Hangen Brustlin, Inc. Gannett Fleming

Figure 7
Moore's Creek Proposed Wetland Restoration Site: Conceptual Plan

Riverview-Chewacla complex, Buncombe, and Toccoa soil types. The presence of soil chroma 3 and 4 soils indicate non-hydric soils are present. Vegetation includes common floodplain species such as American sycamore (*Platanus occidentalis*), green ash (*Fraxinus pennsylvanica*), and box elder (*Acer negundo*).

Topography within the Moores Creek site is relatively flat as revealed by several strategic floodplain cross sections taken from Franklin Street to Moores Creek during the field data collection process. Maximum elevation difference across most of the proposed wetland mitigation area is within the +/- 0.4 feet range; hence, grading to achieve uniform dispersion of water will be minimal.

High-resolution topographic mapping of the watershed provided by Albemarle County verifies a total drainage area of approximately 28 acres of residential/commercial land contributing runoff to approximately 0.9 acres of existing wetlands and 4.0 acres of proposed wetlands. In addition to runoff conveying to the site from areas to the north of Franklin Street, overbank flooding from Moores Creek will also contribute to the manifestation of jurisdictional hydrology.

In addition to surface runoff, hillside/groundwater seepage contributes significantly to the site as evidenced by standing water in the north and south Franklin Street ditches during the extremely dry months of July and August 2006. An existing wetland in the northwest corner of the site and the presence of reversible hydrologic modifications (*i.e.* ditches) testify to the presence of a high seasonal water table and land-use problems associated with surplus moisture.

Conceptual Design

The conceptual plan for the Moores Creek Site is provided in Figure 7. Runoff entering the site through the culverts under Franklin Street as well as hillside seepage entering the ditch south of the street would be directed to the lower elevations of the site via an interconnected system of shallow swales (mitigation channels). A berm feature would be installed along the west side of the east drainage ditch to maximize water retention in the proposed wetland area. The lower end of the proposed wetland is where the soils change from a silt loam to sandy loam texture, and are thus less conducive to wetland restoration. Where appropriate, topsoil will be stockpiled for later redistribution across the graded mitigation site The on-site natural levee will be slightly regraded to allow Moores Creek floodwaters more frequent access to the floodplain / mitigation area. Exclusion fencing will be installed where necessary in insure that domestic animals on neighboring land do not enter the mitigation site. A preliminary plant list for the mitigation site is provided in Table 7.

Detailed pre-construction hydrologic and geotechnical studies will be conducted at the onset of the formal design process. The requirements for post-construction monitoring will be specified in a dedicated Wetland Monitoring Plan that will accompany the submission of final design plans to the COE and DEQ. Performance criteria will comply with the joint guidance from these agencies, such as the Annotated COE-DEQ Mitigation Requirements (COE 2004) or its future equivalent.

The proposed Moores Creek Wetland Restoration Site will offer increased water quality function for Moores Creek via the cessation of domestic animal grazing and increased residence time for floodwaters. Flood abatement will also be augmented via increased capacity within the floodplain. Lastly, the project will greatly improve community aesthetics and provide a viewshed more consistent with the surrounding urban/suburban environment. The total amount of credit that could be developed at this site is estimated at 4.0 acres of forested wetlands, which surpasses the recommended 3.46 acres indicated by standard regulatory mitigation ratios.

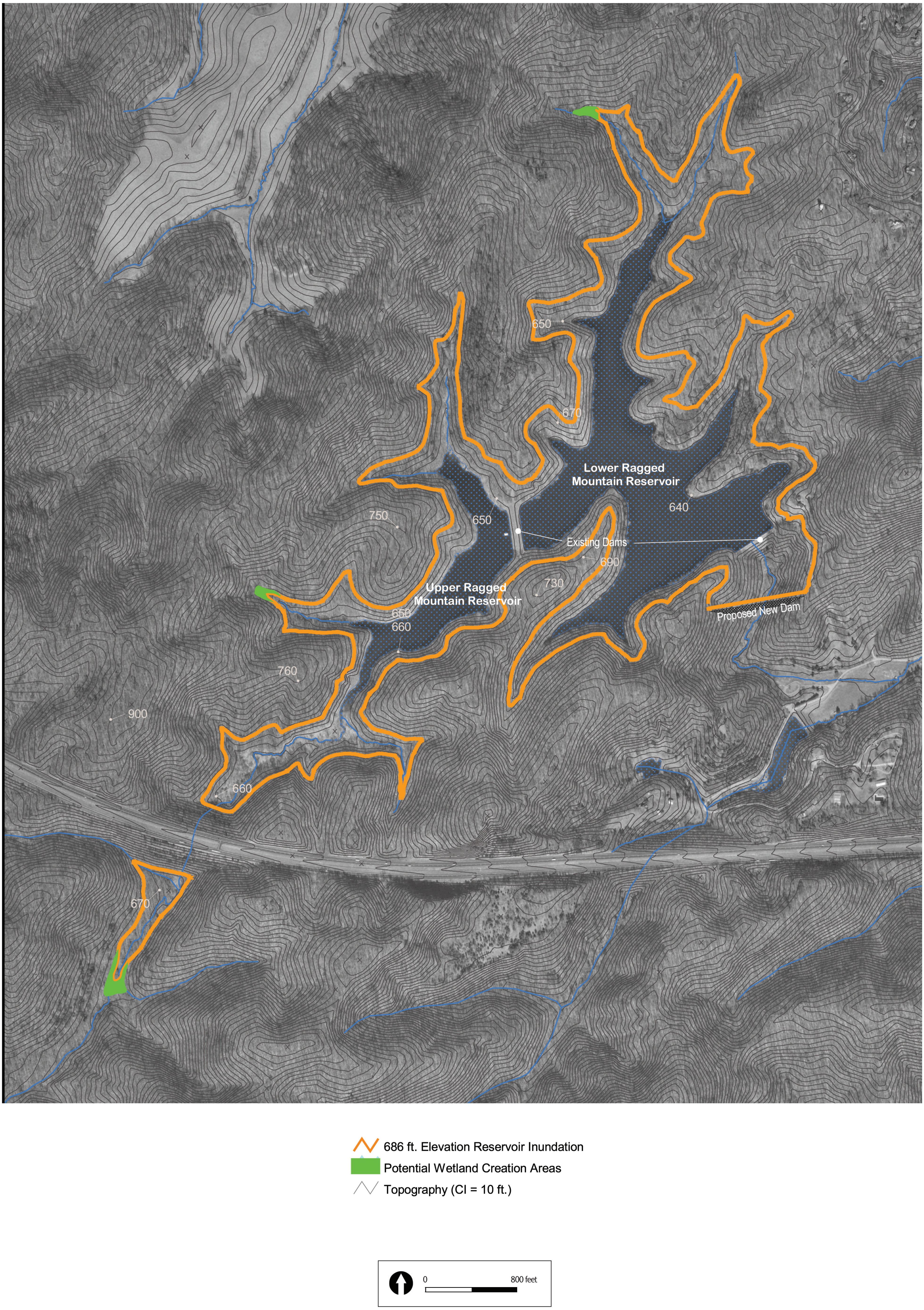
TABLE 7. Proposed Plant List – Moores Creek Wetland Mitigation Site
Conceptual Stream and Wetland Mitigation Plan
Rivanna Water & Sewer Authority - Community Water Supply Project

Stratum	Species
Tree	Sycamore (*Platanus occidentalis*) River birch (*Betula nigra*) Willow oak *(Quercus phellos)* Pin oak (*Quercus palustris*) Green ash (*Fraxinus pennsylvanica*) Slippery elm (*Ulmus rubra*)
Scrub-Shrub	Spicebush (*Lindera benzoin*) Brookside alder (*Alnus serrulata*) Arrow-wood (*Viburnum dentatum*)

Fringe Wetlands at Ragged Mountain Reservoir

A careful review of the topography immediately above the projected new pool elevation at Ragged Mountain Reservoir (686 ft) identified three relatively low-gradient stream valleys where it is extremely likely that wetland habitat will become established near the new pool elevation. These locations are depicted in Figure 8. While no active construction work is proposed, the potential for passive wetland development at Ragged Mountain Reservoir is estimated at about 1 acre. Coupled with the 4.0 acres of wetland restoration at the Moores Creek Site, the standard mitigation for wetland impacts is exceeded by about 1.5 acres. This is in addition to other wetlands that will undoubtedly be re-established naturally around the narrow fringe of the reservoir at the new pool elevation.

This aspect of the mitigation plan is presented for agency consideration. However, it is not relied upon at this time because it is not necessary to achieve standard mitigation goals. For this reason, long-term monitoring, reporting, and potential remediation will not be applied to these sites.



Community Water Supply Project
City of Charlottesville and Albemarle County, Virginia

Conceptual Stream and Wetland Mitigation Plan

Vanasse Hangen Brustlin, Inc. Gannett Fleming

Figure 8
Ragged Mountain Reservoir:
Potential Fringe Wetlands at New Pool Elevation

Summary and Conclusions

The conceptual mitigation plan for the RWSA Community Water Supply Project involves three discrete components located in the same hydrologic unit code and relatively close to the impact area at Ragged Mountain Reservoir. Stream impacts will be compensated via an unusual, watershed-scale stream preservation and enhancement project within the Buck Mountain Creek catchment. The level of compensation offered greatly exceeds the recommendations of the SAAM protocol and approximates the linear footage recommended by the SICAM methodology. In meetings with VHB, the DEQ has indicated that a minor deficit in footage is not critical given the considerable scope and rarity of watershed-scale mitigation and the fact that the application of SICAM is a somewhat subjective endeavor. Furthermore, the degree of compensation credit available in the Buck Mountain Project Area is particularly impressive given that the calculation of stream impact at Ragged Mountain Reservoir does not take into account that channels to be inundated by the expansion of reservoir are already hydrologically and ecologically isolated from the down-gradient stream. In light of this, the tabulation of the mitigation requirements is very conservative and thus the proposed compensation plan is considered to be a generous offering.

Significant benefits will arise from the preservation and enhancement of streams within the Buck Mountain Project area and the replanting of some 200 acres of riparian corridor. These include safeguarding habitat for the federally-listed endangered James spinymussel and diminishing siltation to the South Fork Rivanna River Reservoir. Many of the streams proposed for preservation within the Buck Mountain Project Area are first and second-order streams and thus are analogous to those that will be impacted at Ragged Mountain Reservoir.

The restoration of wetlands at the proposed Moores Creek Wetland Restoration Site will provide functions and values beyond those of the impacted wetlands, including water quality, habitat, and flood abatement. Wetland creation at Ragged Mountain Reservoir will also provide on-site, in-kind mitigation for impacts to existing reservoir fringes flooded by the expansion project.

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Appendix A

Memorandum:
Compensatory Wetland Site Selection Process

Transportation
Land Development
Environmental
Services

Vanasse Hangen Brustlin, Inc.

351 McLaws Circle, Suite 3
Williamsburg, Virginia 23185
757 220-0500
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Memorandum

To: Andrea Terry

Date: March 15, 2006

Project No.: 31671.01

From: R. Timothy Davis, Randy Sewell

Re: Potential Wetland Mitigation Sites for Rivanna Water and Sewer Authority

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This memorandum is a summary of our findings resulting from site visits to 7 properties on March 9, 2006. The purpose of our work was to evaluate each site for potential wetland mitigation to compensate for proposed wetland impacts resulting from the Ragged Mountain reservoir expansion. The subject sites were identified by City of Charlottesville staff (Figure 1) and brought to the attention of the Rivanna Water and Sewer Authority (RWSA) and VHB. Names of the sites visited are given below:

1. The Stockyard (livestock auction property)
2. Meade Park
3. Riverview Park
4. Meadowcreek Golf Course (Pen Park)
5. Meadowcreek Gardens
6. Seminole Square
7. Schenks Branch along McIntire Road

VHB evaluated each site using criteria important to the restoration/creation of wetlands. The criteria applied include the following:

- Landscape position supports wetlands (fluvial bottoms, hydric flats, etc.),
- Adequate sources of hydrologic input (stormwater runoff, stream flow, groundwater, hillside seeps) are evident, and
- Site exhibits evidence of historic drainage or water control practices such as ditching, hillside diversions, rerouting and/or channelizing streams, and berming or diking for the purpose of minimizing hydrologic input to the bottom land.

<u>The Stockyard</u>

This ± 32 acre site lies in the historic floodplain of Moores Creek and is currently used for holding and grazing livestock (Figure 2). The site occurs at the base of a substantial sloping hillside currently occupied by homes, businesses, and paved roads. Runoff from the hillside is directed into the site at multiple locations via the storm drainage network. Most of this runoff is conveyed by agricultural ditches around the perimeter of the site or directly across the site to Moores Creek. Depositional features and rack lines observed along Moores Creek suggest that out of bank flows occasionally make a significant hydrologic contribution to the site. In addition, groundwater seeps were observed at several locations creating wetlands at extreme ends of the site.

The landscape position and surface water inputs indicate the Stockyard has high potential for wetland mitigation. Water from the storm drainage outfall pipes along Franklin Road and the groundwater seep currently ditched around the site can easily be captured and dispersed uniformly across the site through a system of interconnected channels. Moores Creek could also be restored and reconnected to the floodplain to provide for more frequent and natural flooding of the potential mitigation site. The presence of approximately 2 to 3 acres of existing wetlands on the site also provides a clear indication that expanding the size of the wetlands is certainly possible.

Meade Park

Meade Park comprises a small public park with a ball field and swimming pool (Figure 3). A small stream flowing through the center of the park enters a culvert underneath a road next to the swimming pool, and exits onto adjacent private property. The limited space offered by the site due to topography, infrastructure, and multiple land ownership, and the earthwork necessary as part of any restorative design suggests low potential for achieving substantial wetland mitigation.

Riverview Park

Riverview Park comprises an upland portion of the gently sloping terrace to the Rivanna River (Figure 4). While the landscape position of this parcel is promising for wetland mitigation, no significant surface or ground water inputs were observed. With no apparent sufficient hydrologic inputs, the use of this site for mitigation would require extensive excavation to lower the ground surface near the existing water table – an expensive and impracticable design concept. As such, we view Riverview Park as having little wetland mitigation potential.

Meadowcreek Golf Course

A portion of the Meadowcreek Golf Course property includes another stretch of floodplain to the Rivanna River. Unlike Riverview Park, this floodplain is receiving strong groundwater seep from the hillside toe that is saturating and inundating a significant portion of the floodplain. This seep corresponds to the National Wetlands Inventory digitized green line on Figure 5. In order to create a viable mitigation site, uplands within the floodplain, consisting of scattered mounds and the river levee, would need to be cleared and graded to match neighboring wetland elevations. This practice is not advisable given the high quality and character of the wetland currently occupying the site that would be disturbed. Therefore, it is our view that this site should remain in its current wooded condition, and that it can serve as a reference wetland for future wetland mitigation projects.

In addition to the forested floodplain, we were directed to a short reach of the Rivanna River where the river bank is exposed and eroding adjacent to a pond and golf course green at the southern end of the course. Discussions focused on whether this site presented a stream restoration opportunity for the RWSA project. The conclusion reached was that the work required to stabilize the riverbank would be expensive and constitute more of a stabilization project rather than a restoration, and hence, mitigation credit would be minimal. That said, the river bank is actively eroding and will ultimately undermine a portion of the golf course if left untreated.

Meadowcreek Gardens

Meadowcreek Gardens comprises another City-owned park bisected by Meadow Brook (Figure 6). Most of the site is currently forested with an adjacent clearing reserved for community gardening. The National Wetlands Inventory (NWI) indicates the presence of a rather large wetland in the center of the floodplain. During our inspection, we noticed an abandoned man-made channel at this location that contained stained leaves but no surface flow or wetlands. We also observed in the wooded portion of the site what appears to be old headwalls from an historic bridge crossing of the man-made channel.

The Meadowcreek Gardens site is comprised entirely of uplands with the exception of the man-made ditch. No surface water inputs are present other than the main stem of Meadow Brook, which appears to be relatively entrenched at this location. Efforts to restore wetlands at this site would either require extensive restoration of Meadow Brook to re-connect the channel to the floodplain, or clearing and excavation of the uplands to lower the floodplain. In either event, the cost associated with these concepts appears to be prohibitive. Therefore, we do not recommend further consideration of this site for mitigation.

Seminole Square

Behind Seminole Square lies a stretch of City-owned property that includes the steep forested hillside sloping down to the floodplain of Meadow Brook (Figure7). It appears that the majority of the floodplain to Meadow Brook at this location is privately owned. As such, the City-owned property does not offer any mitigation potential because of the poor landscape position.

An inspection of Meadow Brook revealed that this reach of stream channel is highly unstable due to excessive urban runoff causing severe streambank and streambed erosion. It is our view that the City should consider efforts to restore this reach of channel in combination with restoring highly degraded upstream reaches. Stream corridor restoration should be conducted from upstream to downstream and should include watershed stormwater retrofits, where practicable, to properly manage stormwater.

Schenks Branch along McIntire Road

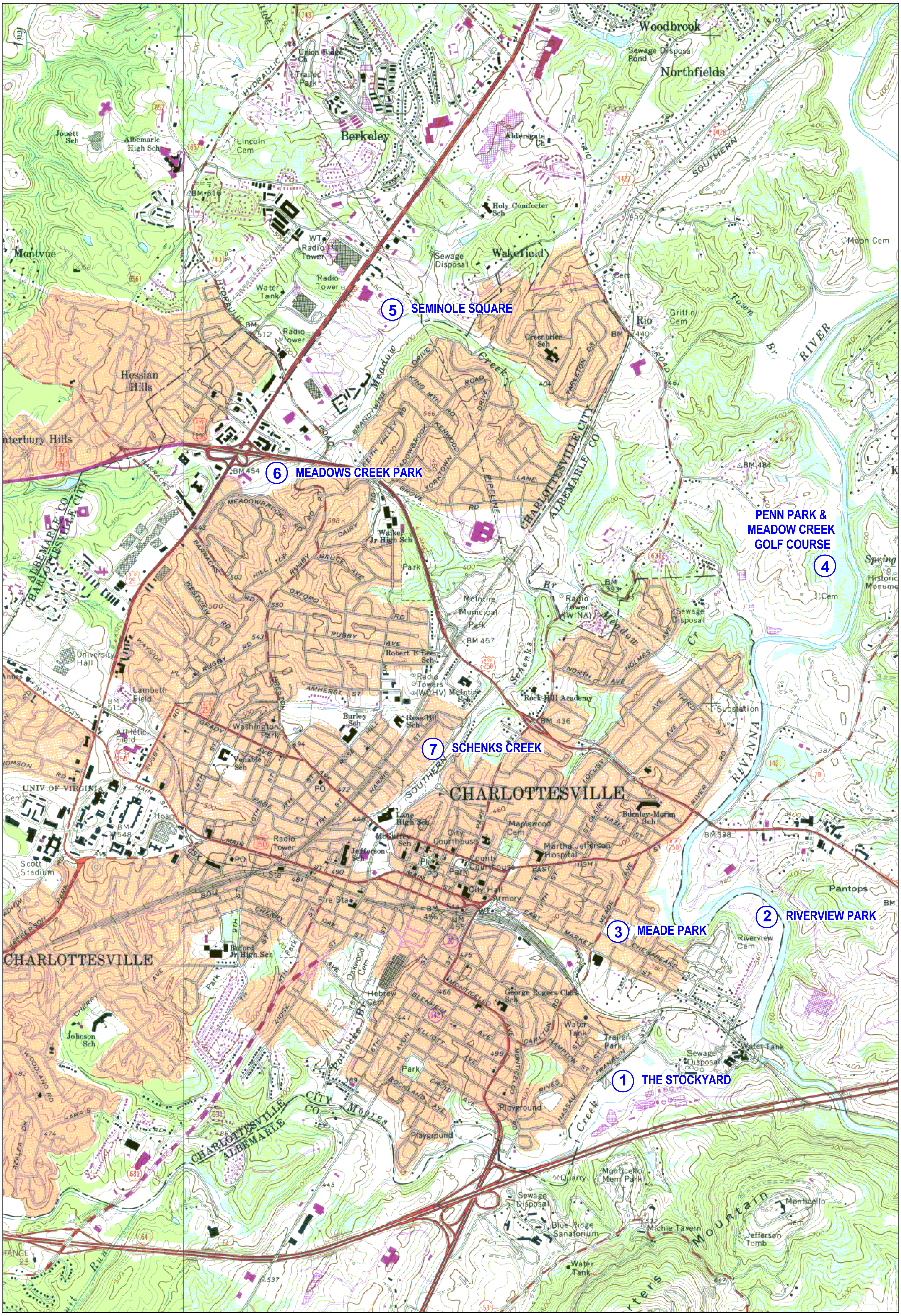
This narrow corridor beside McIntire Road was reviewed for potential wetland mitigation (Figure 8). It was discovered that this reach of Schenks Branch is severely entrenched with exposed bedrock in the channel bottom. The only property available to potentially perform any wetland mitigation would be the cleared, grassy area between the stream channel and the road. This grassy area is very near in elevation to McIntire Road, and also contains a sewer line and other possible underground infrastructure. Consideration of raising the bed of Schenks Branch to re-connect the stream to the floodplain would jeopardize the roadway and sewer line. Therefore, this area is not practicable for wetland mitigation.

The other side of the channel (west side) consists of a steep hillside leading up to a concrete plant, and does not offer wetland restoration potential. The bank of the west side of the channel is severely eroded as the stream attempts to widen and meander, causing the ends of stormwater outfall pipes to dislodge and drop into the channel. Given the condition of this stretch of Schenks Branch, the City should consider future restoration in order to stabilize the system to prevent continued degradation, loss of infrastructure and the transfer of erosive energy to downstream areas.

Summary

VHB evaluated 6 sites within the City of Charlottesville municipal boundaries and 1 site bordering the City of Charlottesville municipal boundary line (the Stockyard property) for wetland and stream mitigation potential. Based upon a cursory review of each site, we believe the Stockyard has the greatest potential to serve as a combined wetland and stream mitigation site for the impacts associated with the Ragged Mountain Reservoir project. The other 6 sites do not appear to be good mitigation candidates because they possess less than ideal landscape position, lack sufficient hydrologic inputs, or require excessive grading.

The Stockyard site appears to have high mitigation potential because it offers the ideal landscape position, sufficient hydrologic inputs, and minimal grading requirements to establish appropriate wetland topography. The restoration would provide a diversity of wildlife habitat, and significantly improve water quality in Moores Creek by removing the current livestock operation and filtering urban runoff from the developed hillside and out of bank flows from Moores Creek. A portion of Moores Creek could also be restored to reconnect with its historic floodplain and meander naturally through the site in a self maintaining form. It is our recommendation, therefore, that the RWSA continue pursuing the Stockyard as a candidate for wetland and stream mitigation.



0 2000 Feet

Vanasse Hangen Brustlin, Inc.

Community Water Supply Project
Charlottesville, Virginia

Figure 1
Potential Mitigation Sites

Figure 2 - The Stockyard
Parcel Boundaries
Roadways
Wetlands
Study Area
0
415 Feet
Moore's Creek
FRANKLIN ST
CARLTON AVE
CARLTON RD
MEADOW WAY
BURGESS LN
LEAKE LN
E MARKET ST
RANDOLPH ST
MIDLAND ST
VINE ST
HAMPTON ST
NASSAU ST
FLORENCE RD
MASON ST
CAMI LN
BROADWAY ST
N MOORES CREEK LN
MOORES CREEK LN
I-64 W
I-64 E

Figure 3 - Meade Park

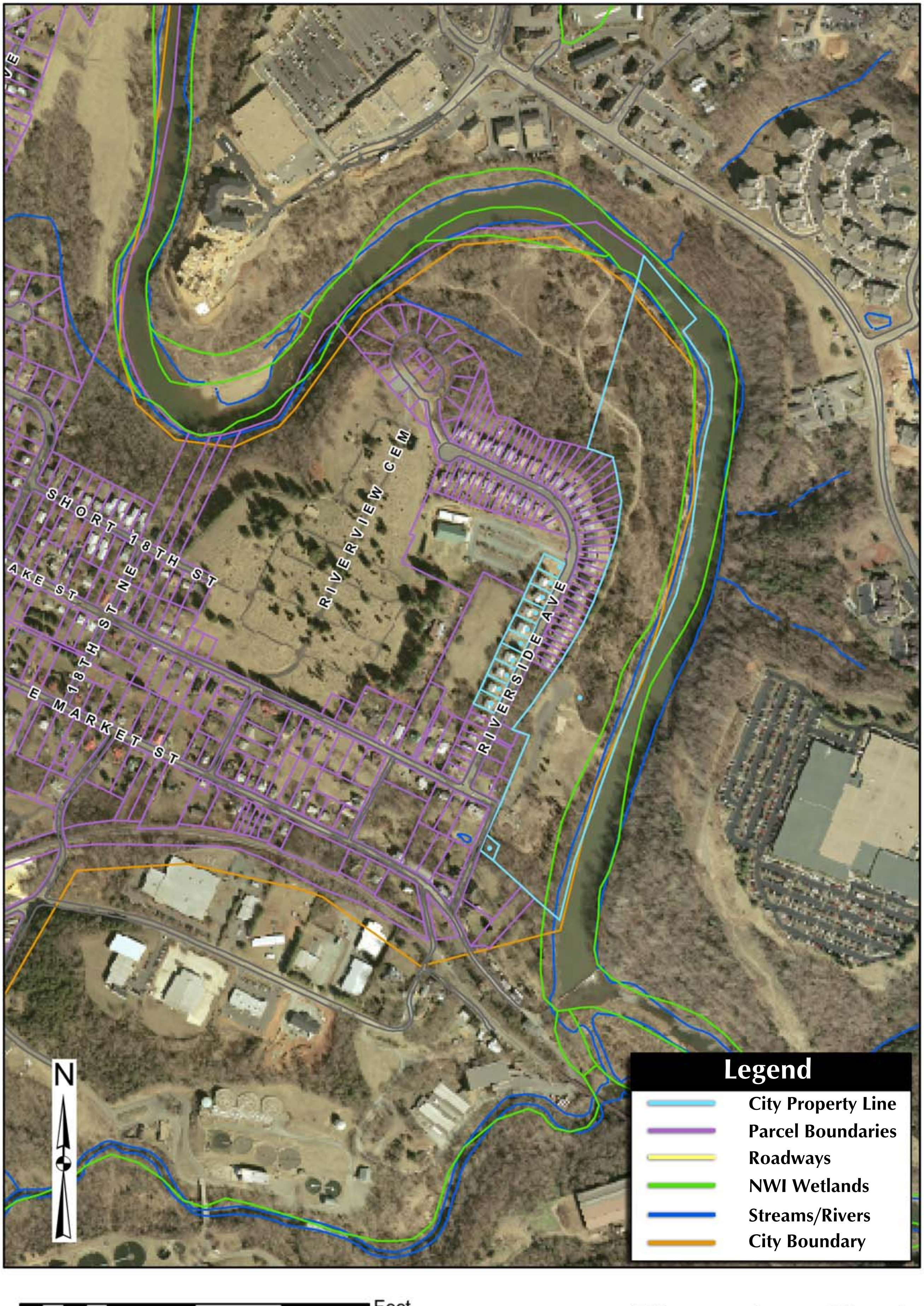


Figure 4 - Riverview Park

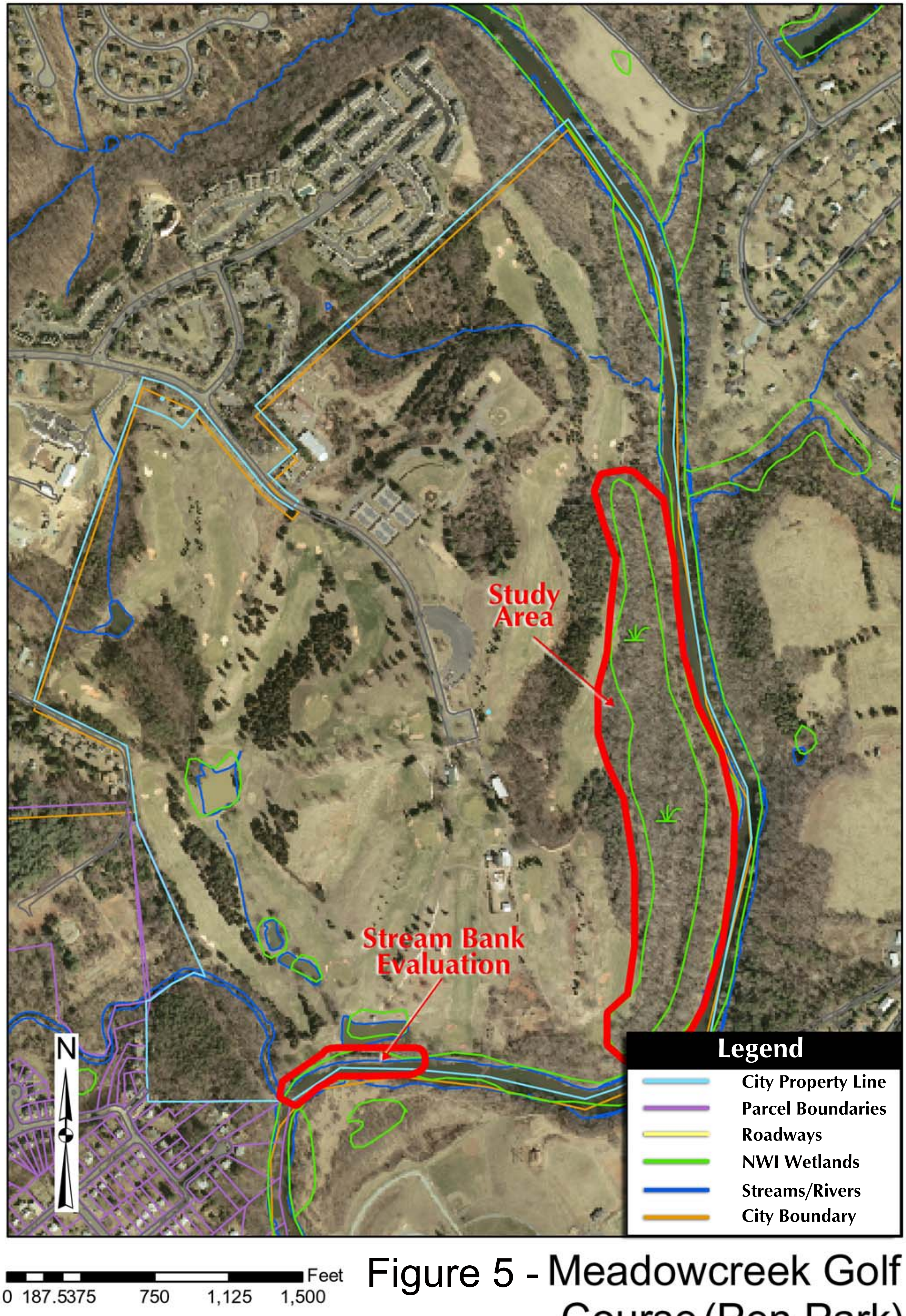


Figure 5 - Meadowcreek Golf Course (Pen Park)

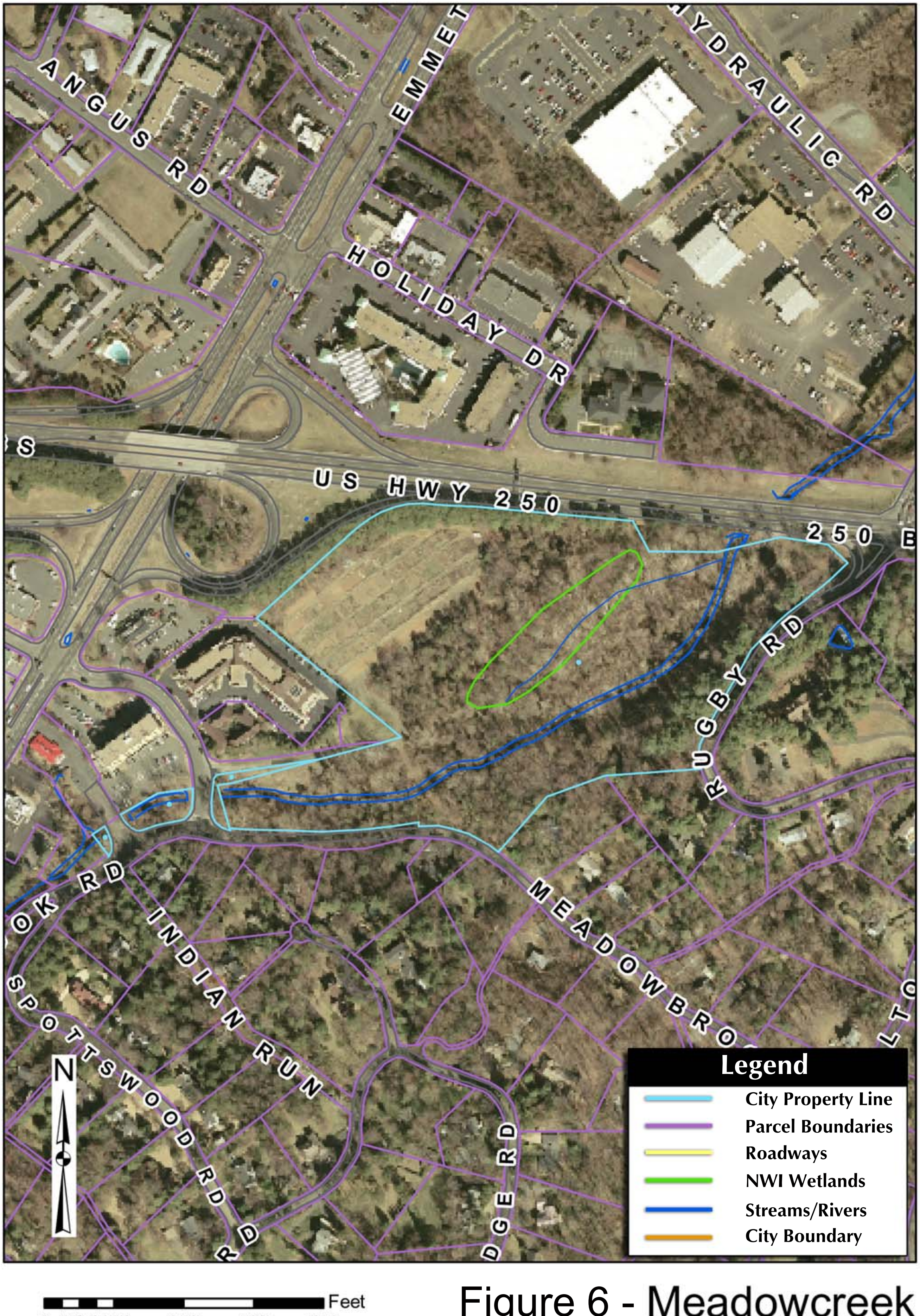


Figure 6 - Meadowcreek Gardens

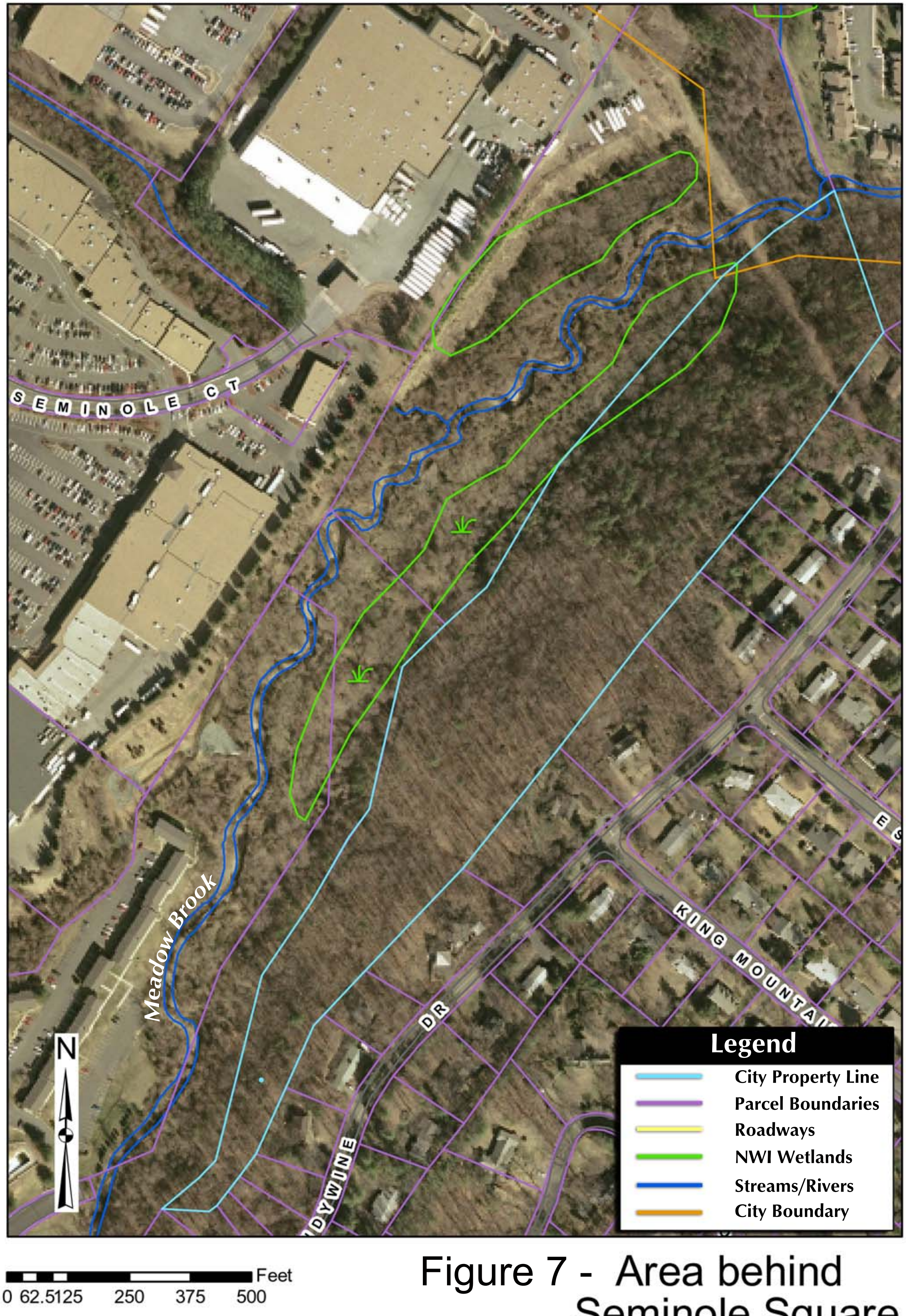


Figure 7 - Area behind Seminole Square

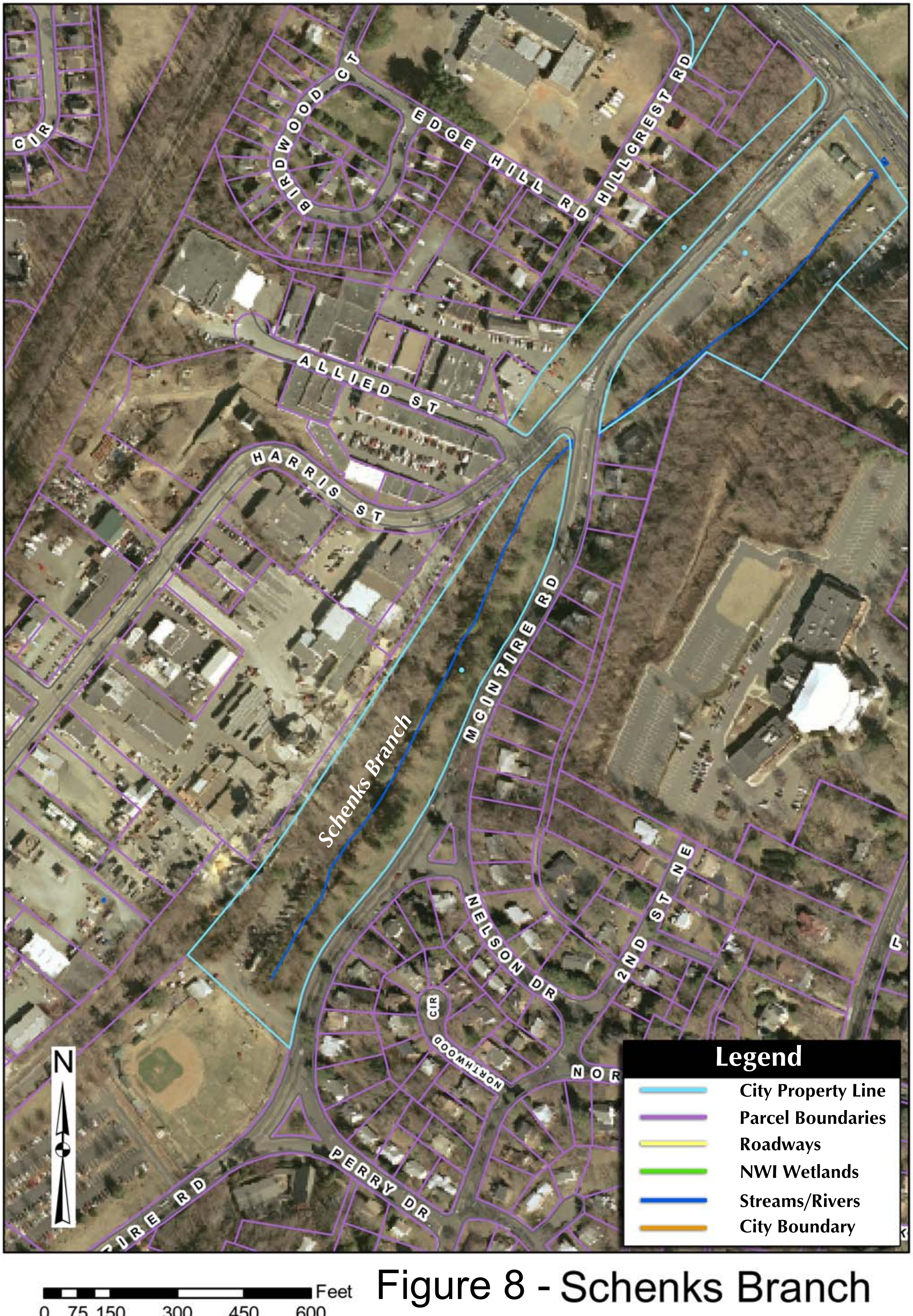


Figure 8 - Schenks Branch along McIntire Road