VWP CIA Summary - [INSERT PROJECT NAME HERE]

10/29/2021

# VAHydro Model:

## VAHydro

The comprehensive VAHydro hydrologic model is used to evaluate potential impacts to surface water supply and other beneficial uses (including aquatic life), for withdrawal projects that have applied for a Virginia Water Protection (VWP). The VAHydro model simulates streamflow with inputs such as precipitation, climate, land use, and topography, as well as local data collected through Local and Regional Water Supply Plans and reported water use submitted to DEQ through the Annual Water Withdrawal Reporting program. The VAHydro model includes all known withdrawals and discharges, as well as operational rules of VWP permits and major hydrologic features such as reservoirs.

The VAHydro model is built on rainfall-evaporation-runoff (RER) time-series from the Chesapeake Bay Model Phase 6 which runs from 1984-2014 in the Chesapeake Bay watershed drainage, and 1984-2005 in the rivers flowing outside of the Chesapeake Bay watershed, aka the “southern rivers.” The VAHydro model features high-resolution hydrologic subsections called “river segments” (over 600 river segments in total), roughly the size of HUC 10 hydrologic units, with additional high-resolution segments added for VWP modeling projects as needed.

## CIA

DEQ assesses water supply sustainability through Cumulative Impact Analysis (CIA) modeling. CIA is a modeling and analysis approach that takes into account the varied hydrologic process occurring throughout a river network (including meteorology and human water use). By simulating a daily water balance for every individual river segment within a watershed, DEQ is able to evaluate the potential “cumulative impact” of all streamflow changes occurring upstream and downstream of any location within the river system, as well as the downstream impact of a specific proposed or permitted surface water withdrawal.

The goal of the following analysis is to estimate the potential impacts of the proposed water withdrawal upon existing beneficial uses, including both in-stream and off-stream uses. In addition, cumulative impacts from all existing withdrawals are included in the evaluation.

# Project Introduction

This project consists of an existing water intake constructed in the 1960’s with an upgrade in the early 1980’s. The Town owns and operates the Big Cherry Dam located approximately 3 miles upstream from the intake structure. The Town’s water treatment plant operators control the amount of water discharging the dam into the Powell River and all of the stream by-pass flow to meet the previous permit requirements of 4.0 MOD of maximum withdrawal and 0.50 MGD of by-pass flow. This is always true unless the dam is overflowing exceeding the amount of water required from various rainfall events. Therefore, the existing/proposed maximum withdrawal amounts will not have an impact on the stream in terms of rates, volumes, frequency, etc. This is a daily activity as it serves the existing water treatment plant.

Permit: Big Cherry Dam, 01-0688  
Permit Dates: 2003-08-23 to 2018-08-22

* **Annual Withdrawal Limit** = 1168 mg/yr (3.2 mgd)
  + (historically they withdraw ~2 mgd on average)
* **Daily Withdrawal Limit** = 4 mgd
* **Flow-by** = 0.5 mgd

## Location Map

*No location map available for this facility model*

# Model Overview and Scenario Descriptions

**River Model Description** The Rappahannock River at Fredericksburg VA is simulated by the base Chesapeake Bay Program model Phase 6. Model mean flow calibration is within 40 cfs, or 1.5% of the USGS gage flows for the period 1984-2015. The Phase 6 model over-simulates the low flows (the bottom 5-25% of flows) by approximately 80 cfs during this period, so all intake flows in this reach are adjusted by -40 cfs to accommodate for some of this error, then an additional margin of safety is added for “remaining days of storage” calculations. Sources of model error may be due to under-representation of impoundments in headwater tributaries, over-simplification of sub-surface hydrogeology, incomplete withdrawal data in the model inputs, errors in point source model flows, and gage calibration errors during low-flows. Future versions of the model will be evaluated for improved calibration in this part of the watershed.

**Facility & Intake Model Description** Facility intake model overview not provided.

The following model scenarios were simulated in order to determine the most effective means of meeting the project need and all other in-stream beneficial uses:

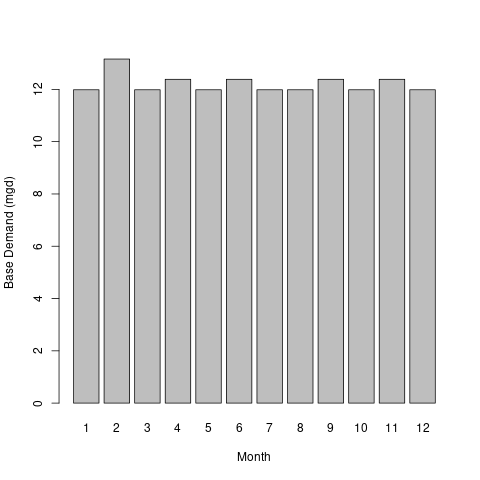
* **Current permit conditions** (Current Permit) - This scenario includes reservoir capacities, demands and flow-by rules for the original VWP permit for Rocky Pen Run. This scenario includes a tiered flow-by based on month and remaining storage, as a well as a monthly tiered release from the impoundment to maintain flows in Rocky Pen Run.

# Intake Site Description & Current Estimated Stream Flows

**Table 1:** Modeled monthly current flow statistics for un-named intake in cubic feet per second (cfs). Columns show the minimum (Min) and average (Mean) modeled flow, and a range of non-exceedance flow percentiles, that is, the column header indicates the percent of flows that do *not* exceed the given value. For example, the “10%” states that only 10% of flows in the given month are expected to be less than the indicated value, and therefore, 90% of the flows in that month are expected to be greater than the given value. For example, in the table below the 10% column states that 10% of flows within the month of January would be less than 510.4 cfs.

| **Month** | **Min** | **5%** | **10%** | **25%** | **30%** | **50%** | **Mean** |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Jan | 227.1 | 379.0 | 510.4 | 837.6 | 971.5 | 1,471.1 | 2,060.7 |
| Feb |  |  |  |  |  |  |  |
| Mar | 119.4 | 435.9 | 661.1 | 1,090.8 | 1,243.7 | 1,824.2 | 2,752.5 |
| Apr | 207.0 | 388.9 | 535.9 | 956.1 | 1,079.7 | 1,626.9 | 2,263.0 |
| May | 183.5 | 381.1 | 494.0 | 765.3 | 825.8 | 1,303.9 | 1,983.8 |
| Jun | 51.3 | 231.4 | 335.6 | 599.1 | 673.8 | 978.8 | 1,257.0 |
| Jul | 51.7 | 129.8 | 169.9 | 354.2 | 396.1 | 632.7 | 847.8 |
| Aug | 27.9 | 89.4 | 128.1 | 282.6 | 335.9 | 482.2 | 638.5 |
| Sep | 16.2 | 96.4 | 140.9 | 207.6 | 243.9 | 396.5 | 1,006.7 |
| Oct | -1.8 | 81.1 | 149.9 | 310.4 | 368.9 | 624.6 | 1,147.8 |
| Nov | 13.7 | 98.3 | 177.3 | 444.7 | 491.2 | 986.5 | 1,462.2 |
| Dec | 56.5 | 284.5 | 406.5 | 817.4 | 916.9 | 1,441.7 | 2,056.6 |

## Facility Base Demand Before Conservation: Current Permit



# Model Results Summary

Four scenarios are presented below to examine the alternatives for this permit re-issuance. A summary of how permit rules affect available water for this permit, and how this operation may impact instream beneficial uses, and other downstream water withdrawals is presented.

* **Current permit conditions** - The Rocky Pen Run model was simulated from 1984-2014, using current permit rules and a static demand of 12.2 MGD from the WTP, and a 2-year refill limit of 10.44 BG in order to facilitate faster refill after drawdown. The model estimates that the remaining storage reaches a minimum of 876MG, or approximately 71 days remaining at a demand of 12.2 mgd. Based on a simulation of modellow-flow error in this watershed, it is estimated that there would an additional 15 days where pumping would be curtailed during the critical drought period, suggesting that the actual remaining storage during this time period would be closer to 56 days of demand at 12.2 MGD.

## Conclusion

* **NULL** - Preferred scenario, 600 , conclusions not provided.

# Cumulative Impact Analysis

The following table summarizes the cumulative impacts to flows, aquatic life, and off-stream demand for the project. The section entitled “River Segment Model Statistics” contains mean flows (Flow Out), and drought flows (30 and 90 Day Low Flow), as well as an estimated Consumptive Use Fraction (See description below) as a result of all withdrawals (Cumulative Withdrawal) and discharges (Cumulative Point Source) in the watershed. Minimum Days of Storage Remaining describes the number of days of remaining storage available during the driest period of the model simulation (applicable to impoundment models only). Total Number of Days with Storage < 50% describes the number of days in the simulation in which reservoir levels fall below 50% of full storage. The section entitled “Facility Model Statistics” shows the withdrawals, return flows (Point Source), and the model estimate for potential unmet demand due to demands exceeding the allowable withdrawal at the intake based on the cumulative conditions in the watershed and the flow-by rules in effect. There will be one or more columns in this table representing each scenario considered for this analysis.

## Glossary of Cumulative Impact Modeling Terms

* Consumptive Use (CU): This is calculated as a fraction of modeled Flow, so it is CU = 1.0 - (Flow / Flow\_Baseline), where Flow\_Baseline = (Flow + WD - PS), and WD and PS are the total cumulative withdrawals and point source discharges above the point in the stream. In other words, for calculating baseline flow, we take modeled outflow from the river, add the withdrawals back in, and subtract the point source in order to estimate a baseline flow balance. This almost always ends up being a higher number than the modeled Flow out, so it tells us the fraction of baseline flow that is consumed. Occasionally there are water transfers and point sources from groundwater, or point sources that cross watershed boundaries that can make the CU fraction in some watersheds negative, i.e. Flow > Flow\_Baseline.

## Stats Comparison Table:

| **Description** | **Current Permit** |
| --- | --- |
| runid | 400 |
| River Segment Model Statistics: | Rappahannock River @ Fall Line |
| Flow Out (cfs) | 1,675.28 |
| Minimum Days of Storage Remaining | NA |
| 30 Day Low Flow (cfs) | 75.62 |
| 90 Day Low Flow (cfs) | 188.8 |
| Consumptive Use Fraction | 0.05 |
| Cumulative Withdrawal (mgd) | 62.07 |
| Cumulative Point Source (mgd) | 8.74 |
| Facility Model Statistics: | Lake Mooney WTP:Rocky Pen Run |
| Base Demand (mgy) | 4,455.66 |
| Withdrawal (mgy) | 4,455.66 |
| Unmet Demand (mgy) | 0 |
| Requested Demand (mgd) | 12.21 |
| Withdrawal Met (mgd) | 12.21 |
| Point Source (mgd) | 10.5 |
| Maximum 30 day potential unmet demand (mgd) | 0 |

# Reservoir Storage Plots:

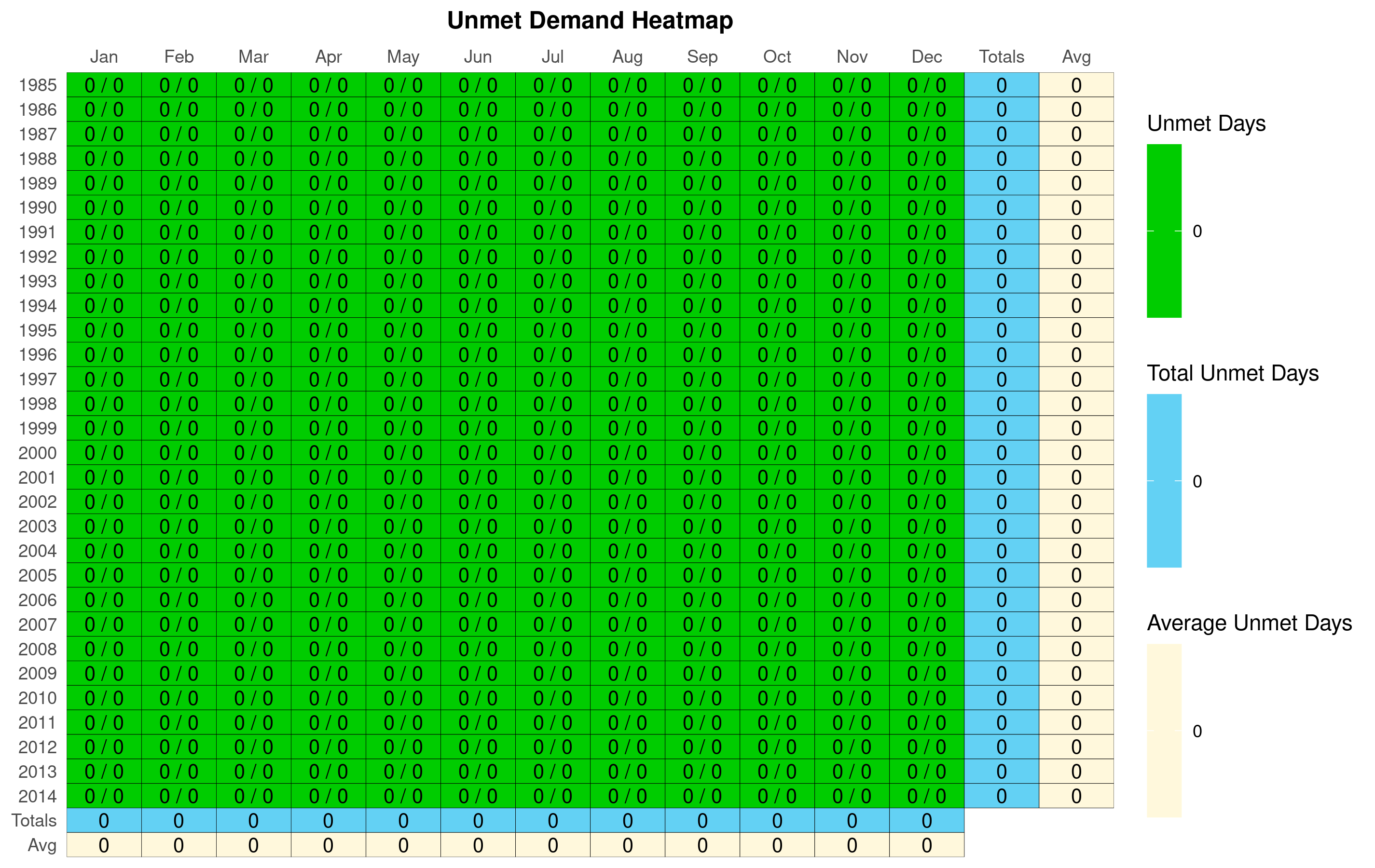
The following reservoir storage plots depict changes in reservoir storage under each scenario (indicated in black), as well as simulated inflow to the reservoir (blue), simulated outflow from the reservoir (green), and system demand for the given scenario (red). For water supply reservoirs, a minimum of 60 days of remaining storage over the course of the simulation is recommended. System demand varies seasonally.

[1] “No active impoundment found for run id runid\_400”

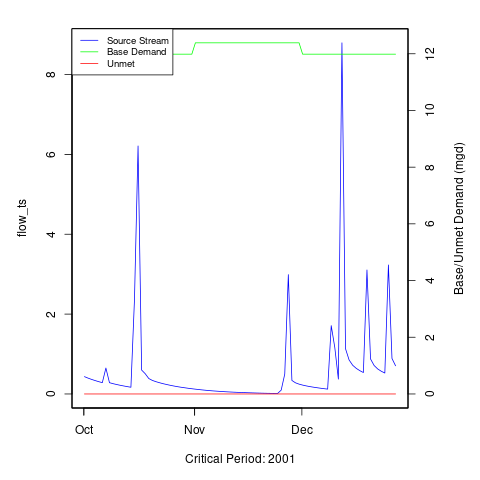
# Unmet Demand Plots:

Heatmaps are data plotting tools that help visualize data as magnitudes of color intensity. The following heatmaps depict the number of days with unmet demands for each month of the simulation (due to demands exceeding allowable withdrawal at the intake based on the cumulative conditions in the watershed and the flow-by rules in effect). The heatmap cells show the amount of unmet demand for each month [Number of Unmet Days & Amount (mgd)]. Hydrographs are shown for the period of the simulation with greatest unmet demand.

## Heatmap: Current Permit



## Hydrograph: Current Permit

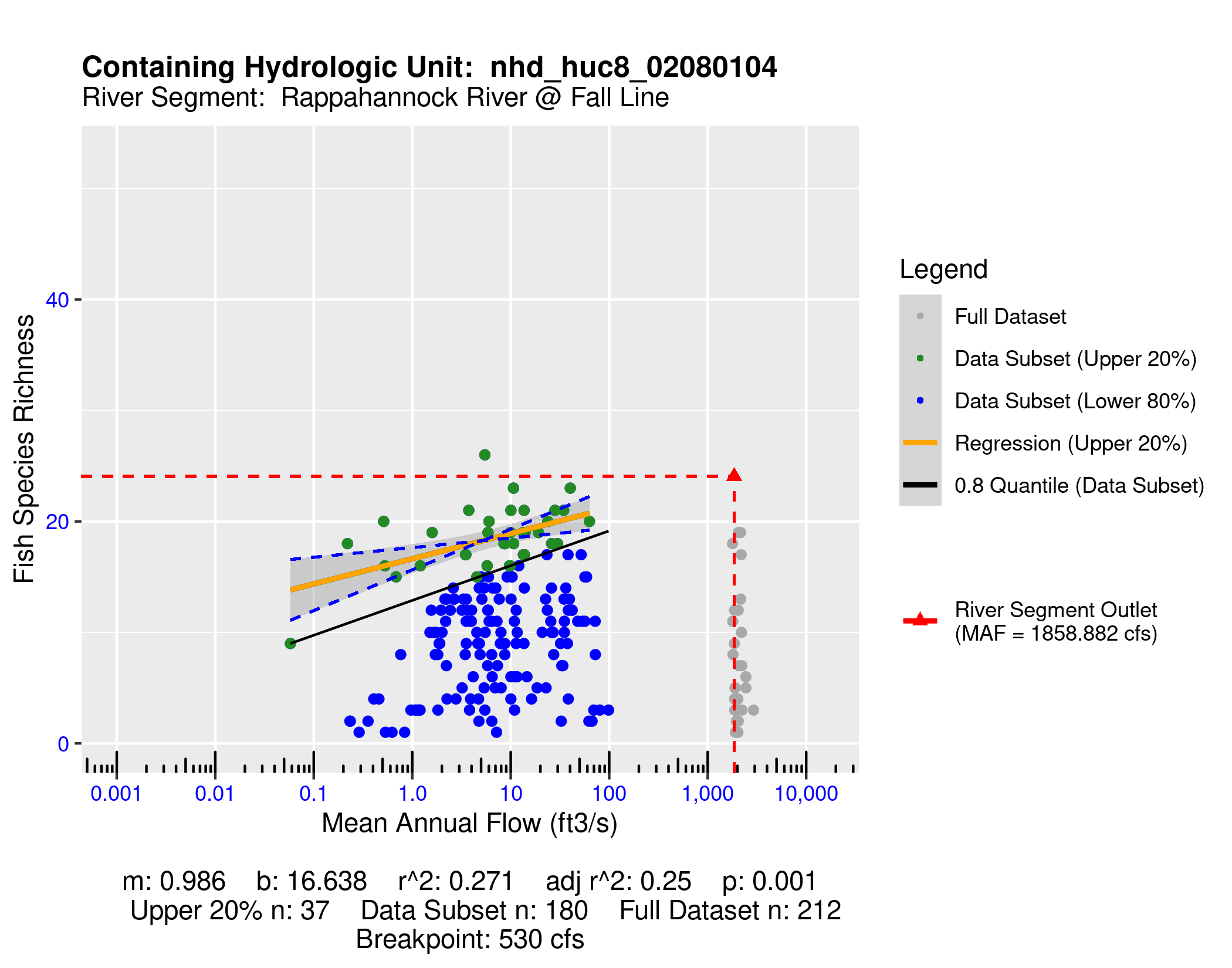
 [1] “No local facility impoundment for Current Permit”

# Ecological Impacts Assessment:

## Elfgen:

In response to a need for better environmental flow metrics, DEQ has developed a new framework for characterizing relations between streamflow and aquatic organism species richness. Part of an evolving approach to managing environmental flows for maintaining aquatic life; this methodology builds on existing minimum instream ow approaches, allowable withdrawals as a percentage of flow, and extensive flow-habitat studies. For the first time this new framework may allow quantification of potential species loss resulting from flow change, and may offer an improved understanding of aquatic life risk variability due to geographic location, stream size and local scale.

This new flow-ecology framework referred to as “elfgen” (*pronounced elf-jen*) derives its name from Ecological Limit Function (ELF) generation (*ELF-gen*). In order to calculate river segment-level richness change, elfgen is first used to produce ELFs, or relations between stream flow and species richness at the HUC 8 scale (See plot below). This is achieved using long term datasets for both ecological and hydrologic data. Ecological data (Fish species richness) is sourced from the VAHydro-EDAS dataset. Hydrologic data (Average Annual Flow) is sourced from the National Hydrography Dataset Plus. The Richness Change values presented in the table below are derived from this flow-ecology relation.



## Richness Change Metric Table:

Estimates for richness change are presented both as an absolute number of species (Richness Change (abs)) and as a percentage of the total number of species present (Richness Change (%)). Richness change calculations are derived from the estimated percent total consumptive use (For additional details on “elfgen” methodology, see <https://onlinelibrary.wiley.com/doi/full/10.1111/1752-1688.12876>).

| **Description** | **Current Permit** |
| --- | --- |
| River Segment Model Statistics: | Rappahannock River @ Fall Line |
| Consumptive Use Fraction | 0.05 |
| Cumulative Withdrawal (mgd) | 62.07 |
| Richness Change (abs) | -0.05 |
| Richness Change (%) | -0.2 |

## Habitat (If Applicable):