VWP CIA Summary - [INSERT PROJECT NAME HERE]

09/26/2022

# Project Introduction

The Spring Creek golf course manages an inline impoundment on Spring Branch (Spring Creek Lake), where they source water for irrigation of the facility. They also have an intake on Camp Creek Lake, which is an impoundment on Camp Creek that receives inflow from Spring Branch below the outlet of Spring Creek Lake. Prior to the year 2016, Spring Creek Lake intake was the primary source of water, with withdrawals from Camp Creek Lake used as a backup source of water when Spring Creek Lake drew down. However, since 2016, reported demands have been entirely from Camp Creek, indicating that the facility is now operating in reverse fashion, with Camp Creek as primary, and Spring Creek Lake as a backup. The current permit provides the ability to pump up to 47.5 million gallons per year, it should be noted that demands during the entire reporting history of this facility have only reached a maximum of 25.6 mgy, or 54% of the demand simulated in this scenario.

## Location Map

*No location map available for this facility model*

# Model Overview and Scenario Descriptions

**River Model Description** River segment model overview not provided.

**Facility & Intake Model Description** This simulation represents two impoundments: Camp Creek Lake, which receives inflow from Camp Creek, and Spring Creek Lake, which impounds the area above the facility, and releases into Camp Creek Lake. The modeling analysis has been conducted to use Camp Creek Lake as a primary source of water, with supplemental water from Spring Creek lake when flow into Camp Creek is insufficient to supply all demands for the facility.

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 Rules with 47 MGY “Drought Year” demand.** (Current Permit, 47 MGY) - A “maximum drought year” withdrawal of 47 million gallon per year total demand is simulated, distributed monthly according to the pattern of use over the period from 2017-2021. In order to maintain lake storage, and downstream flows from Camp Creek Lake (CCL), the intake on CCL is modeled to allow withdrawal of up to 0.435mgd when the surface of the pond is 0.2 feet above the top of the riser structure, and limited to 10% of the modeled inflow to the lake once the lake surface has dropped below this level. When the allowable withdrawal from CCL is insufficient to meet all demands, water is pumped from Spring Creek Lake (SCL). Spring Creek Lake is modeled with a tiered release, which requires 60% of inflow to be released when the SCL is full, and 90% of inflow to be released when the lake is down to 60% of storage. This effectively allows more pumping from SCL during times of plentiful water, and also minimize flow impacts during drought.
* **Proposed Permit, 30 MGY base demand, 90% flow-by at CCL, Tiered SCL.** (30 MGY, 90% Flow-By) - A 30 million gallon per year total demand is simulated, distributed monthly according to the pattern of use over the period from 2017-2021. The intake on Camp Creek is modeled to allow withdrawal of 10% of the modeled inflow to the lake regardless of lake level in order to maintain lake storage, and downstream flows. When the allowable withdrawal from Camp Creek lake is insufficient to meet all demands, water is pumped from Spring Creek Lake (SCL). Spring Creek Lake is modeled with a tiered release, which requires 60% of inflow to be released when the SCL is full, and 90% of inflow to be released when the lake is down to 60% of storage. This effectively allows more pumping from SCL during times of plentiful water, and also minimize flow impacts during drought.

## Table of Modeled Demand Limits:

| **Description** | **Current Permit, 47 MGY** | **30 MGY, 90% Flow-By** |
| --- | --- | --- |
| Average Daily Volume (MGD) | 0.13 | 0.08 |
| Peak Day Volume (MGD) | 1.00 | 1.00 |
| Maximum Annual Volume (MG) | 47.00 | 30.00 |

**Historical Intake Flows and Drought Flow Indicators**

The VAHydro model is used to estimate flows at the project intake, including the impact of all cumulative withdrawals and discharges upstream of the intake location and are presented in Table 1. The Virginia Drought Assessment and Response Plan[[1]](#footnote-22) employs non-exceedance flow percentiles as indicators of drought conditions at particular stream-gaging stations used to monitor drought conditions. Representative daily streamflows above the 25th percentile for return flow frequency represent normal conditions with respect to drought. Representative daily streamflows between the 10th and 25th percentiles represent drought watch conditions. Representative daily streamflows between the 5th and 10th percentiles represent drought warning conditions. Representative daily streamflows below the 5th percentile indicate drought emergency conditions.

| **Month** | **Min** | **5%** | **10%** | **25%** | **30%** | **50%** | **Mean** |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Jan | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Feb | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Mar | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Apr | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| May | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Jun | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Jul | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Aug | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Sep | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Oct | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Nov | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Dec | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

**Table 1:** Modeled monthly current flow statistics for Spring Creek Lake & Camp Creek Lake 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 percent of flows that do *not* exceed the given value. For example, the “25%” states that only 25% 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 25% column states that 25% of flows within the month of January would be less than 0 cfs.

# Results

## Summary

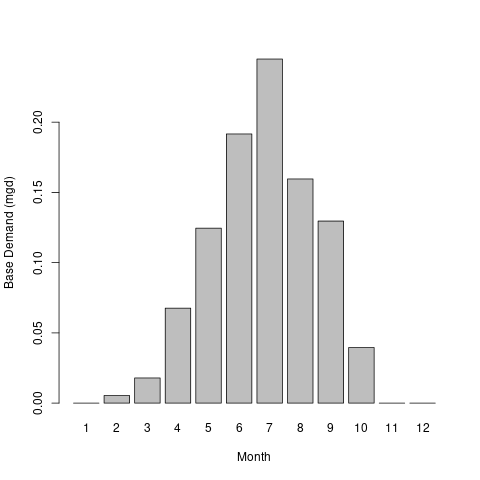
Presented below are 2 scenarios to examine the alternatives for this permit re-issuance. A summary of how permit rules affect available water for this permit, and how this operation may impact instream beneficial uses, and other downstream water withdrawals is presented.

* **Current Permit Rules with 47 MGY “Drought Year” demand.** - The original permit requested a “drought year” demand of 47 mgy, which is feasible under all circumstances, due to the allowance for drawing down Camp Creek impoundment until the water surface nears the top of the riser structure. However, this allowance results in times where allowable pumping exceeds inflows, resulting in negligible flow leaving the Camp Creek impoundment (see “Hydrograph: Dry Period” in section 3.4 for this scenario).
* **Proposed Permit, 30 MGY base demand, 90% flow-by at CCL, Tiered SCL.** - The modeled average annual demand of 30 MGY is viable under all conditions with the exception of summer 2014, when Spring Creek Lake was simulated as being empty for an entire month. Despite one month of unmet demand, total demand met for the year still account for 26.1 MGY, approximately 80% of the 30 mgd requested demand. Reported withdrawals from Spring Creek Lake in 2014 were 25.3 MGY, 0.8 MGY less than the maximum potential simulated during that year. This indicates that the maximum water need in a drought year can be met by this set of permit conditions based on historical reported demands.

## Conclusion

* **Proposed Permit, 30 MGY base demand, 90% flow-by at CCL, Tiered SCL.** - Given a maximum reported demand of 25.6 MGY since 2010, this scenario, with an annual limit of 30 mgy represents both the most reasonable assessment of potential maximum annual demand, and a set of rules which permits the the facility to meet all historic demands during the most severe drought simulated. The permitted maximum allows for a 15% greater maximum withdrawal than has been reported by this facility during 34 out 25 years simulated, indicating a significant margin of safety under all but the most extreme historical drought conditions.

## Facility Base Demand Before Conservation: Proposed Permit, 30 MGY base demand, 90% flow-by at CCL, Tiered SCL.



## Detailed Cumulative Impact Analysis

The following “Summary of Results” 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.

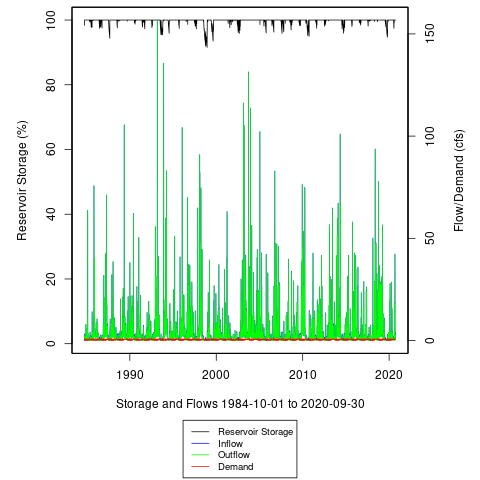
### Summary of Results:

| **Description** | **Current Permit, 47 MGY** | **30 MGY, 90% Flow-By** |
| --- | --- | --- |
| River Segment Model Statistics: | Camp Creek | Camp Creek |
| Flow Out (cfs) - (i.e mean flow) | 3.02 | 3.13 |
| Minimum Days of Storage Remaining | 49.33 | 0 |
| 30 Day Low Flow (cfs) (i.e drought flow) | 0 | 0.05 |
| 90 Day Low Flow (cfs) (i.e drought flow) | 0 | 0.22 |
| Consumptive Use Fraction | 0.17 | 0.09 |
| Cumulative Withdrawal (MGD) | 0.14 | 0.08 |
| Cumulative Point Source (MGD) | 0 | 0 |
| Withdrawal (MGD) | 0.25 | 0.12 |
| Point Source (MGD) | 0 | 0 |
| Facility Model Statistics: | Spring Creek Golf Club:Camp Creek | Spring Creek Golf Club:Camp Creek |
| Base Demand (MGY) | 46.97 | 29.98 |
| Withdrawal (MGY) | 46.95 | 29.83 |
| Unmet Demand (MGY) | 0.02 | 0.15 |
| Requested Demand (MGD) | 0.13 | 0.08 |
| Withdrawal Met (MGD) | 0.13 | 0.08 |
| Point Source (MGD) | 0 | 0 |
| Groundwater Demand (MGD) | 0 | 0 |
| Maximum 30 day potential unmet demand (MGD) | 0.02 | 0.1 |

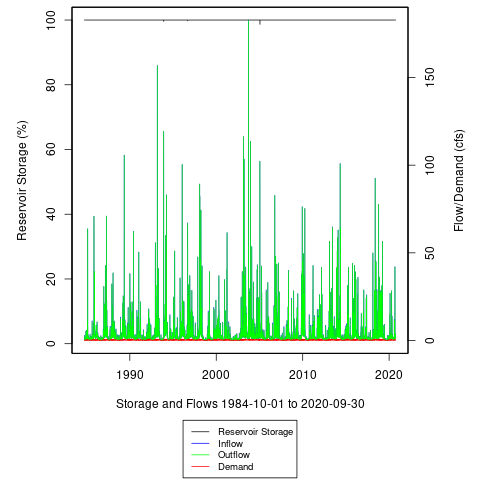
### Analysis of Reservoir Storage:

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.

#### Reservoir Storage: Current Permit, 47 MGY



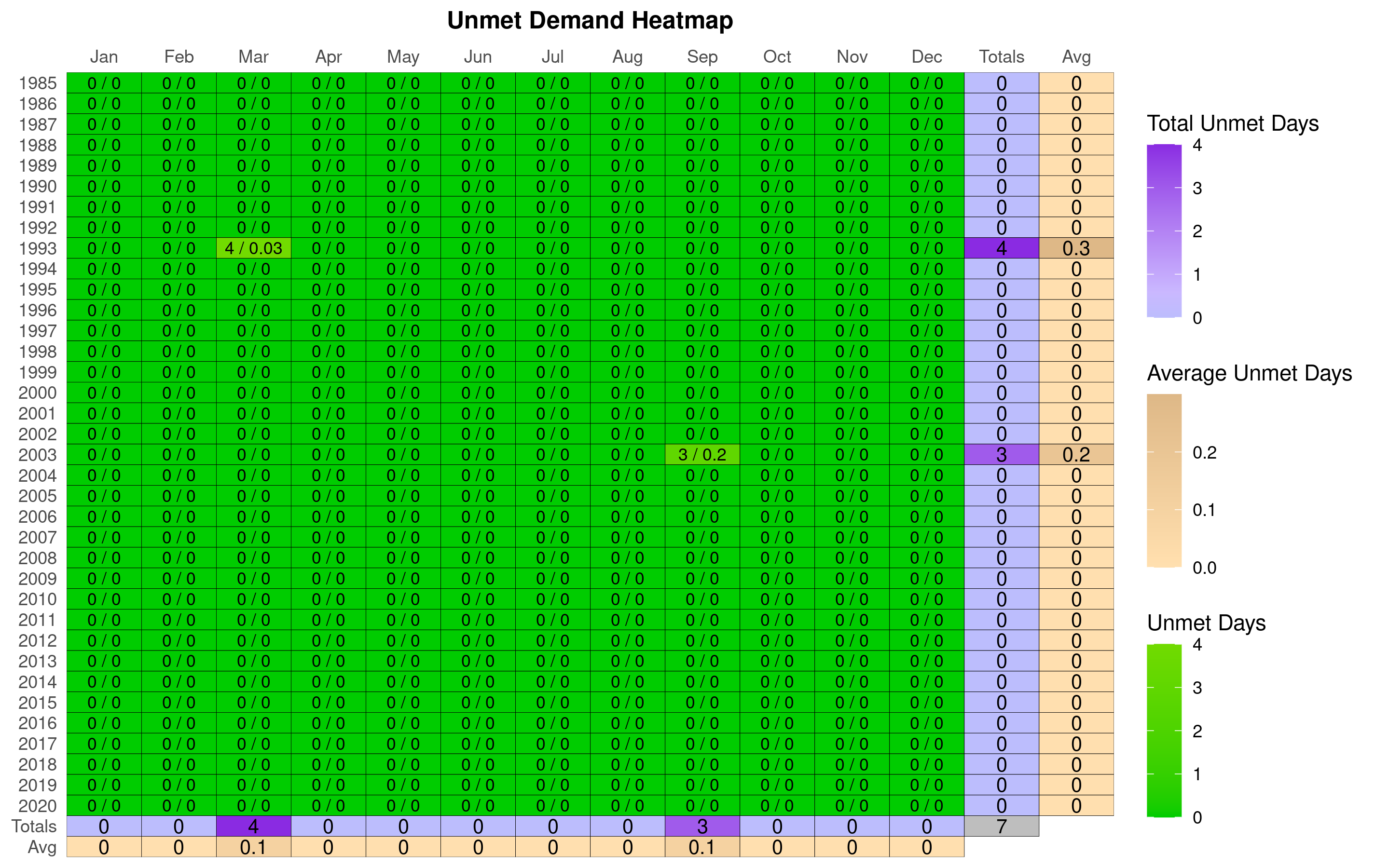
#### Reservoir Storage: 30 MGY, 90% Flow-By



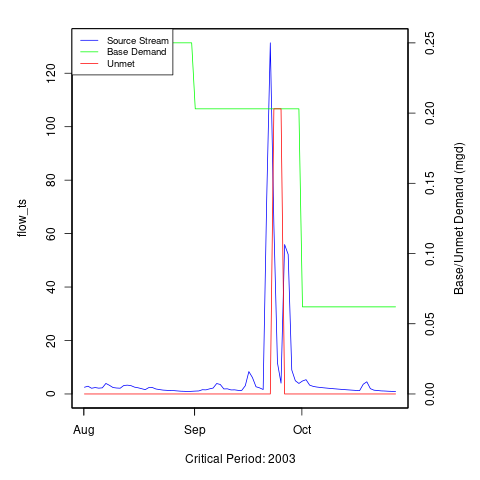
### Analysis of Potential Unmet Demand at the River Intake:

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.

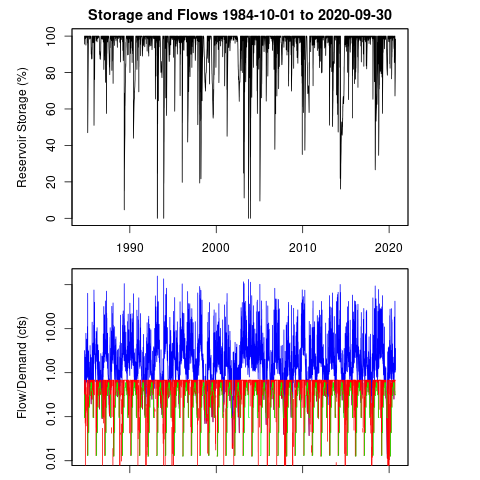
#### Heatmap: Current Permit, 47 MGY



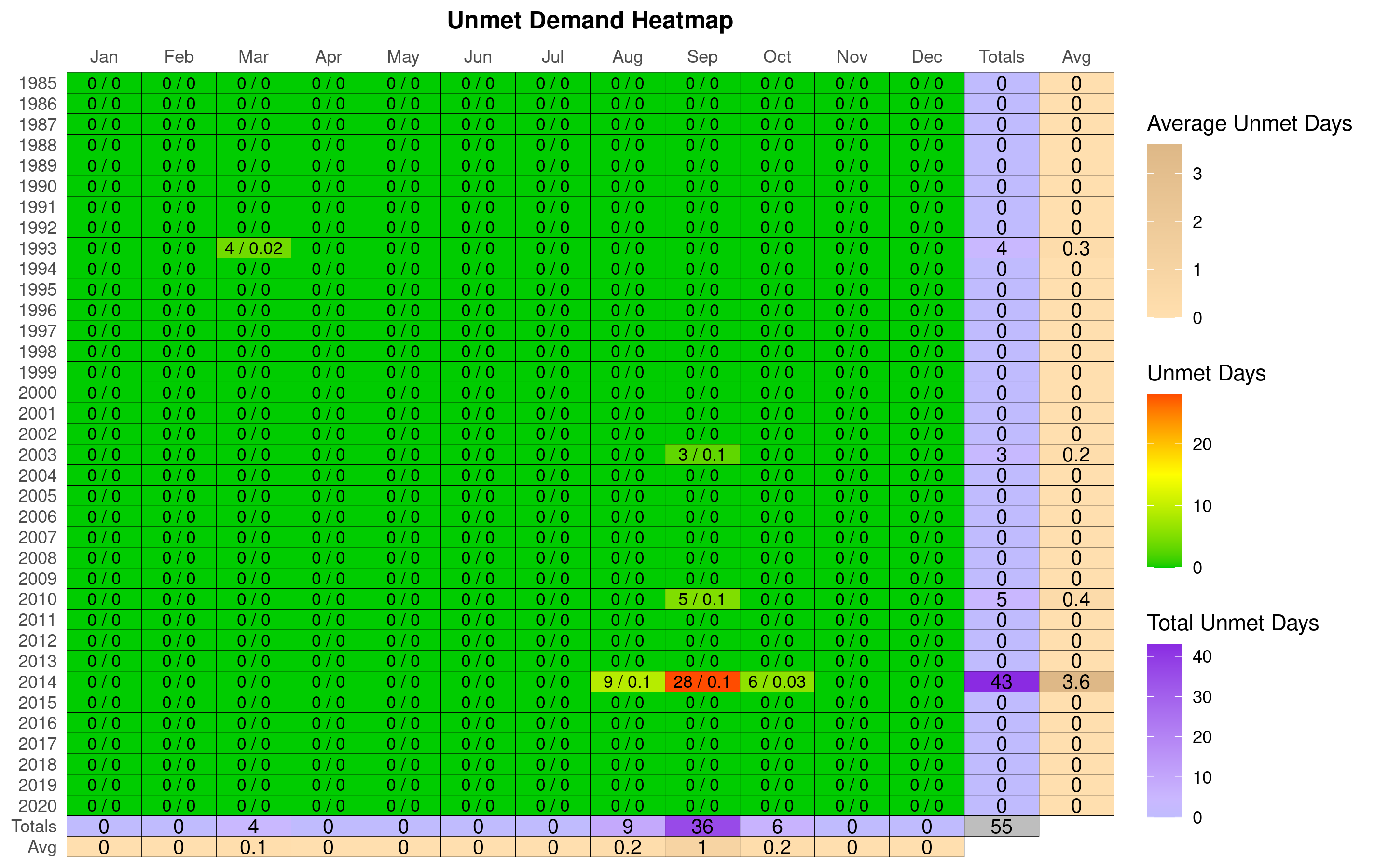
#### Hydrograph: Current Permit, 47 MGY



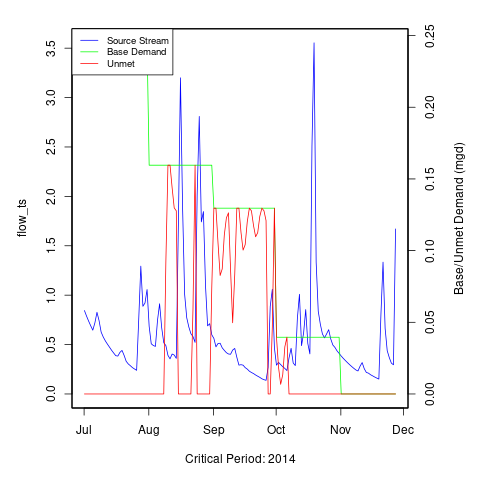
#### Reservoir Storage: Current Permit, 47 MGY



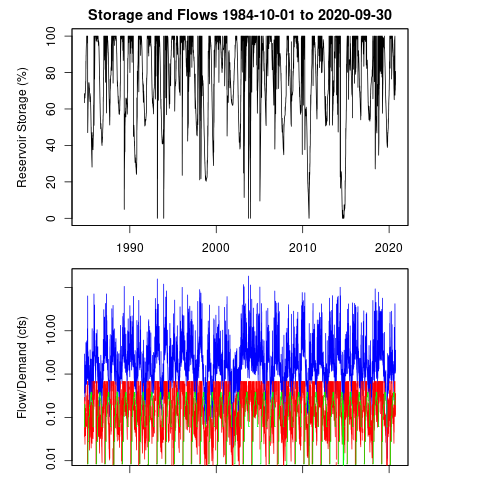
#### Heatmap: 30 MGY, 90% Flow-By



#### Hydrograph: 30 MGY, 90% Flow-By

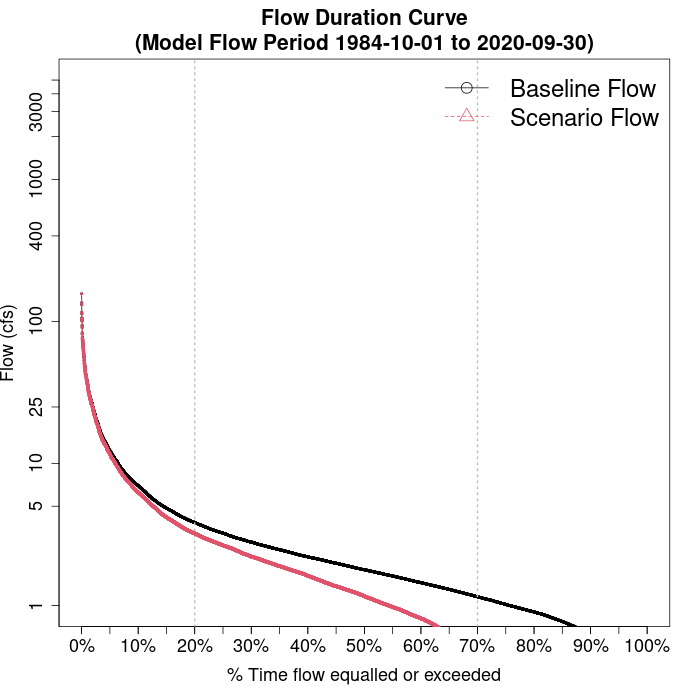


#### Reservoir Storage: 30 MGY, 90% Flow-By

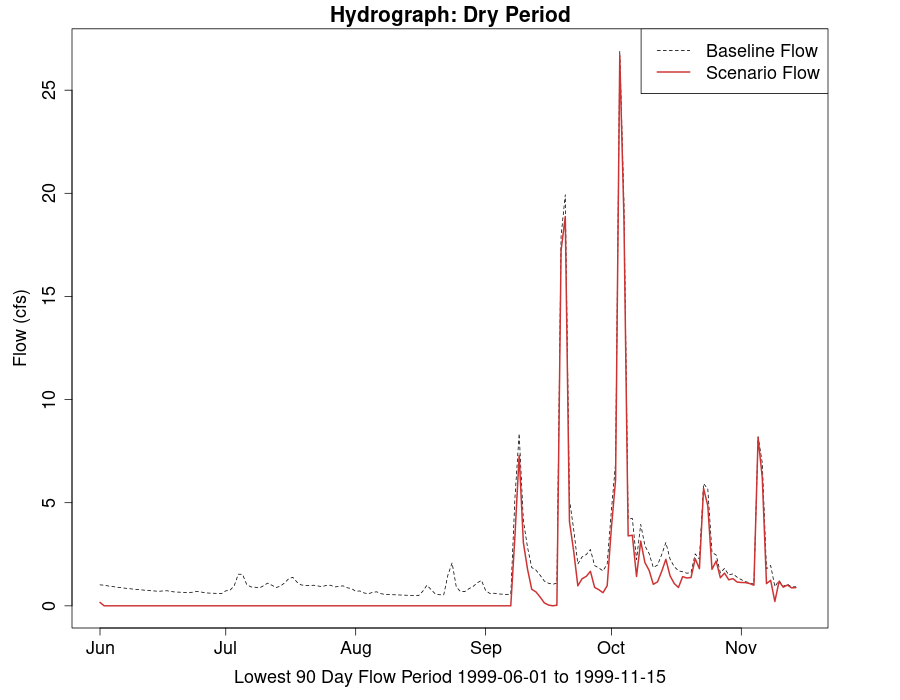


### Additional Model Flow Plots:

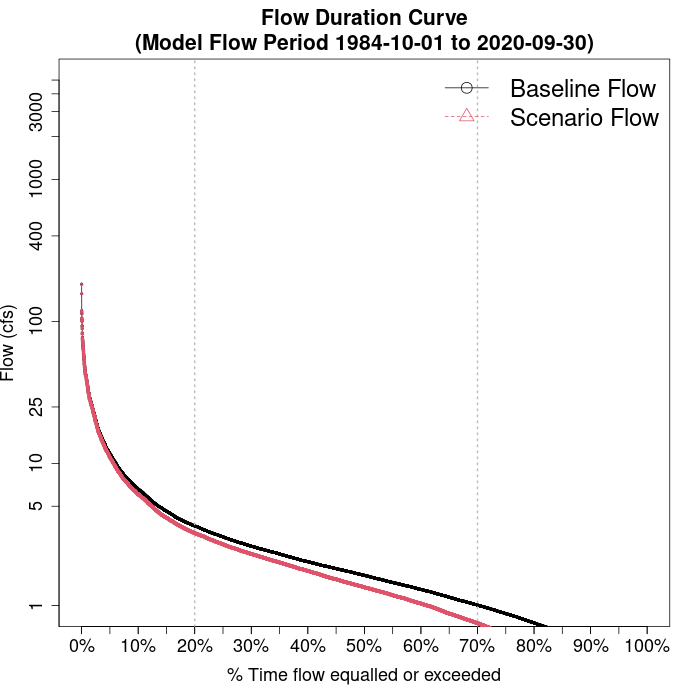
#### Current Permit, 47 MGY :



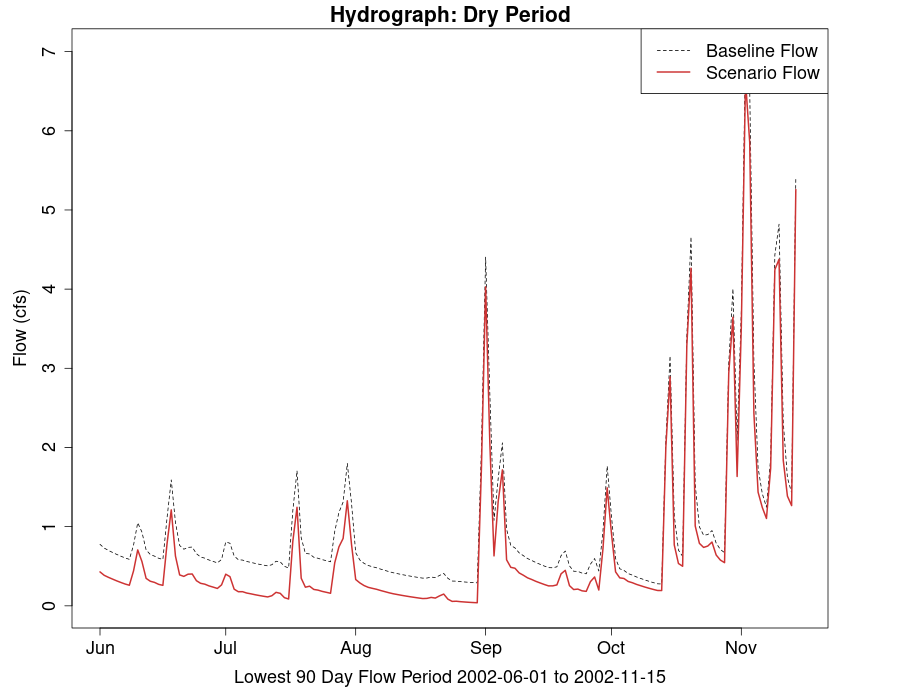
#### Current Permit, 47 MGY :



#### 30 MGY, 90% Flow-By :



#### 30 MGY, 90% Flow-By :



# VAHydro Model:

## Appendix B - VAHydro

The comprehensive VAHydro hydrologic model is used by the DEQ Office of Water Supply to evaluate instream and off-stream beneficial uses for non-tidal surface water withdrawals throughout Virginia. This model also simulates streamflow with inputs such as precipitation, climate, land use, and topography, as well as local data collected through DEQ water supply planning and reporting programs, which includes all known withdrawals and discharges, as well as operational rules of Virginia Water Protection (VWP) permits and major hydrologic features such as reservoirs.

The VAHydro model is built on the rainfall-evaporation-runoff (RER) time-series from the Chesapeake Bay Model Phase 6[[2]](#footnote-86). The VAHydro model simulates conditions from 1984-2014 in the Chesapeake Bay watershed drainage, and 1984-2005 in the rivers flowing outside of the Chesapeake Bay watershed. 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.

## Cumulative Impact Analysis (CIA)

DEQ assesses water supply sustainability through Cumulative Impact Analysis (CIA). CIA is a modeling and analysis approach that takes into account the varied hydrologic processes occurring throughout a river network (including meteorological 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.

### Glossary of Cumulative Impact Modeling Terms

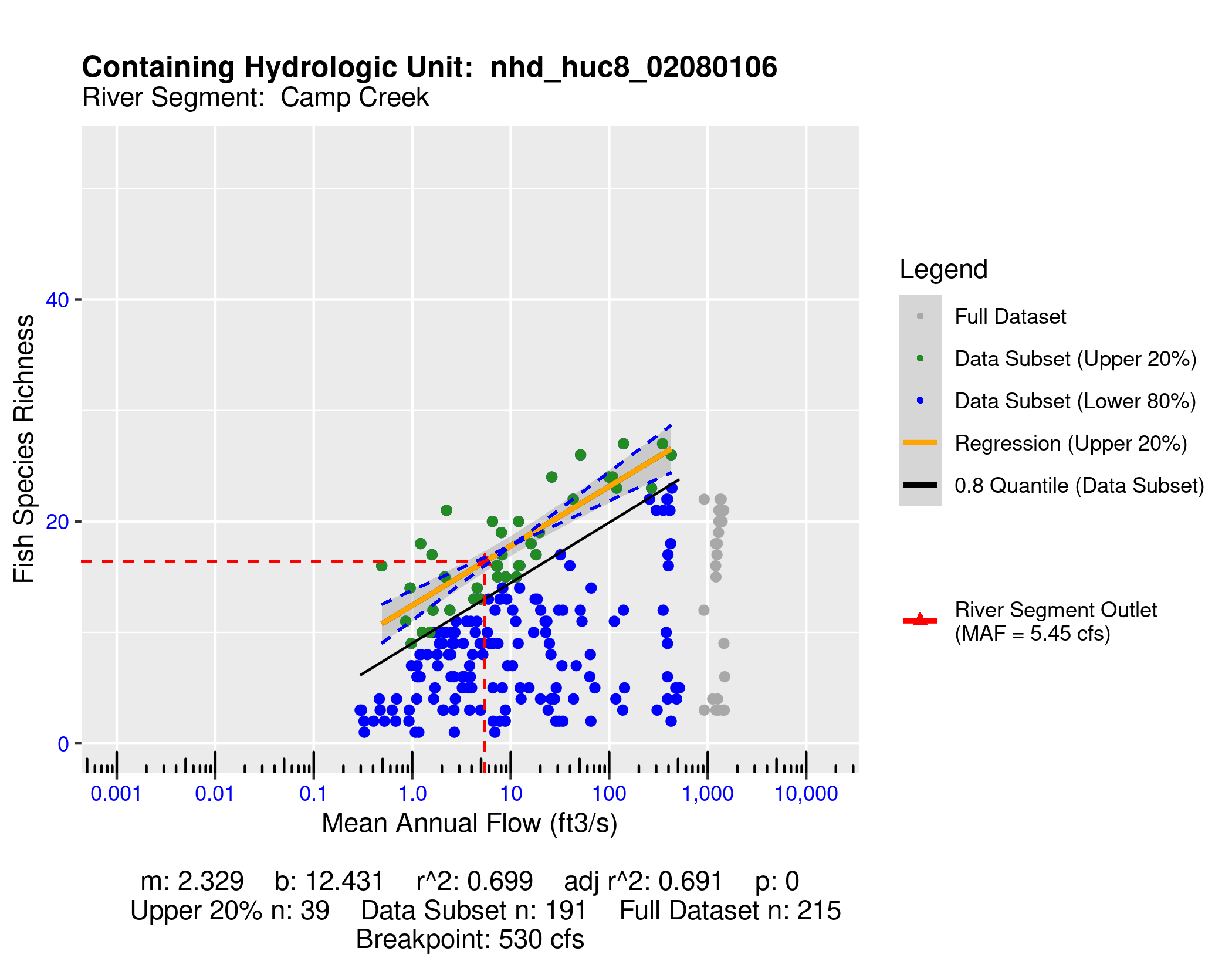
* 30 Day Low Flow (l30): Describes the lowest consecutive 30 day average daily streamflow over the simulation period. This metric is a representation of a short-term, or acute drought.
* 90 Day Low Flow (l90): Represents the lowest consecutive 90 day average daily streamflow over the simulation period. This would represent a prolonged drought.
* Base Demand / Requested Demand: The demand simulated for a facility/intake prior to any reductions due to conservation, depleted storage, or adherence to Minimum Instream Flow operational rules (MIF). In this document, *Base Demand* is expressed as *MGY*, and Requested Demand is given in *MGD*.
* CFS: Cubic Feet Per Second, a common unit of measuring stream flow.
* Consumptive Use Fraction (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.
* Cumulative Withdrawal: The amount of water withdrawn by all intakes in a given river segment sub-watershed, and all upstream sub-watersheds. See also: *Cumulative Withdrawal*.
* Days of Storage Remaining: For reservoir models, the quotient of the volume of water in a reservoir divided by the daily rate of withdrawal, calculated at each time step of the entire simulation period.
* Maximum 30 day potential unmet demand (MGD): The largest difference between *Requested Demand* and *Withdrawal Met* that results during a continuous 30-day simulation period.
* MGD: Millions of Gallons per Day, a common unit of measuring withdrawal and discharge.
* MGY: Millions of Gallons per Year, a common unit for expressing annual facility demand.
* Minimum Days of Storage Remaining: The minimum simulated *Days of Storage Remaining* in a reservoir.
* Point Source: Water returned to the stream as treated wastewater.
* Withdrawal: The amount of water withdrawn by a single facility, or the total amount of water withdrawn within a single simulated river segment sub-watershed. See also: *Cumulative Withdrawal*.
* Withdrawal Met: The amoiunt of requested demand that was met, on average, throughout the entire simulation period.
* Unmet Demand: The difference between *Base Demand* and *Withdrawal Met*, on average, throughout the entire simulation period.

# Appendix A - 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[[3]](#footnote-96). Note: elfgen methodology only applicable for watersheds < 800 cfs mean annual flow.

| **Description** | **Current Permit, 47 MGY** | **30 MGY, 90% Flow-By** |
| --- | --- | --- |
| Consumptive Use (%) |  | 600 |
| Consumptive Use Fraction | 0.17 | 0.09 |
| Cumulative Withdrawal (MGD) | 0.14 | 0.08 |
| Richness Change (abs) | -0.43 | -0.22 |
| Richness Change (%) | -2.62 | -1.32 |

## Habitat (If Applicable):

# Appendix C - Nearby Users Table:

|  | **Location** | **Sub-Watershed** | **MP Type** | **MP Name** | **MP 5-yr Avg Use (MGY)** | **Facility Name** | **Facility 5-yr Avg Use (MGY)** | **Facility 2040 Use (MGY)** | **30 MGY, 90% Flow-By: base\_demand\_mgy** |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 1 | Downstream | Camp Creek | intake | Impoundment located on Camp Creek | 22.39 | Spring Creek Golf Club | 22.39 | 22.16 | 29.98 |
| 2 | Downstream | Camp Creek | intake | In Line Irrigation Lake on Spring Branch | 0.00 | Spring Creek Golf Club | 22.39 | 22.16 | 29.98 |

1. [Virginia Drought Assessment and Response Plan](https://www.deq.virginia.gov/home/showpublisheddocument/5115/637490843054630000), developed by the Drought Response Technical Advisory Committee in response to Executive Order #39, March 28, 2003. [↑](#footnote-ref-22)
2. [Chesapeake Bay Program Phase 6 Model](https://www.chesapeakebay.net/documents/Phase_6_Modeling_Tools_1-page_factsheet_12-18-17.pdf). [↑](#footnote-ref-86)
3. Kleiner et al: <https://onlinelibrary.wiley.com/doi/full/10.1111/1752-1688.12876> & Rapp et al: <https://onlinelibrary.wiley.com/doi/full/10.1111/1752-1688.12877> [↑](#footnote-ref-96)