VWP CIA Summary - [INSERT PROJECT NAME HERE]

09/13/2021

# 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.

### 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.

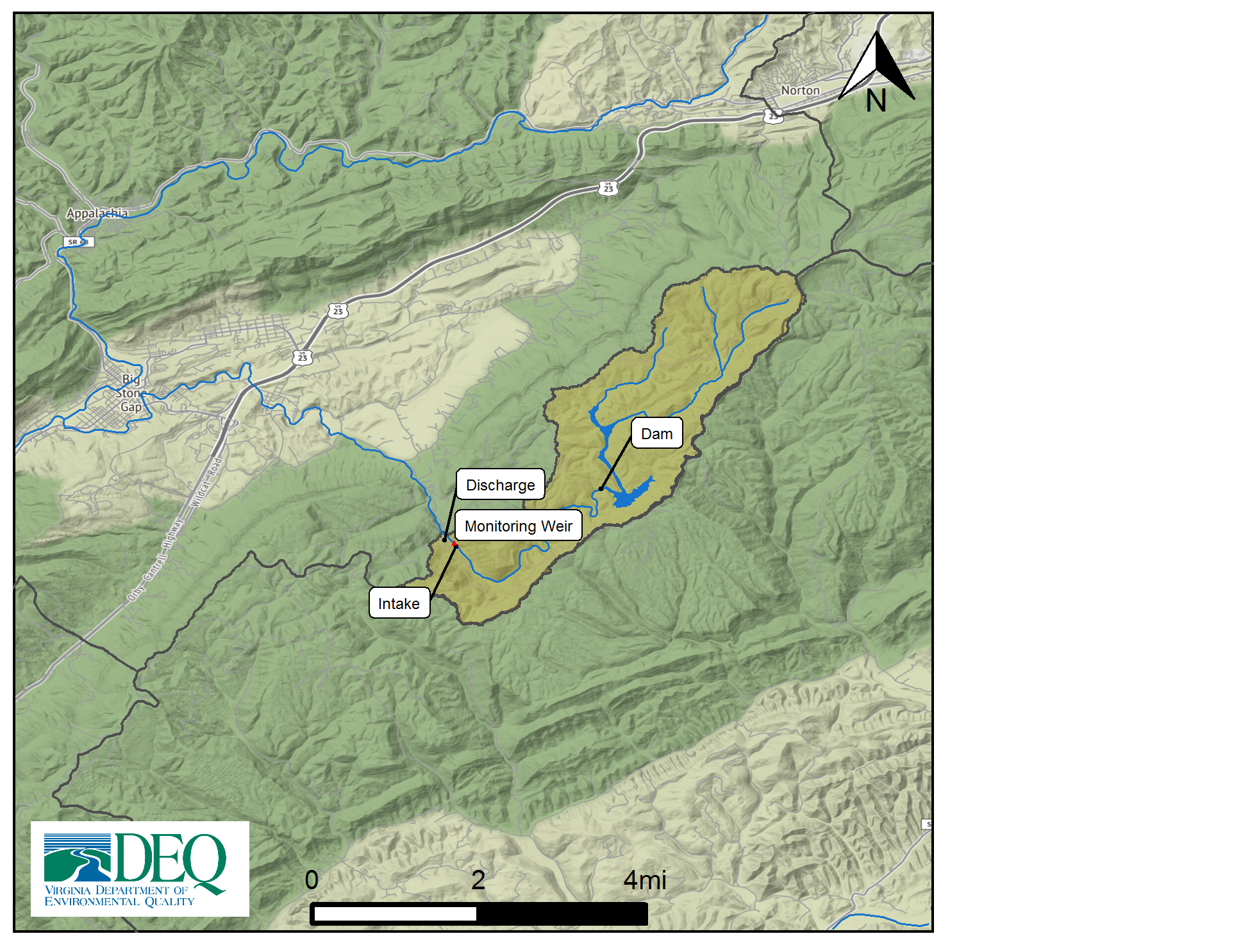
# Project Introduction

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



# Model Overview and Scenario Descriptions

**River Model Description** The “South Fork Powell River - Below Big Cherry Reservoir” model segment is located just east of the town of Big Stone Gap in Wise County in southwest Virginia. The South Fork Powell River joins the Powell River downstream within the town of Big Stone Gap. This model segment has a drainage area of 8.2 square miles, and contains the intake structure which is located approximately 3 miles downstream of the Big Cherry Dam (The monitoring weir and discharge structure are also located within this same model segment, shortly downstream of the intake).

**Facility & Intake Model Description** Big Cherry Dam on the South Fork Powell River is modeled as an on-stream impoundment with an upstream contributing area of 5.54 square miles. The model simulates the stream below Big Cherry Dam including the withdrawal that supplies the Big Stone gap water treatment plant, down through the outfall of the wastewater treatment plant return flow. Analysis of cumulative impacts is based on the net diversion *after* the treated wastewater is discharged back into the stream. The safe yield of the intake is listed as 3.2 mgd from a study published in 2001 (3.2 mgd is equivalent to the permit annual withdrawal limit of 1168 mg/yr). Additional note: The data for the study was collected in 1997, which predates the drought period of 1999-2002.

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:

* **Draft Alternative #1** (3.2 mgd & 90% Flow-by) - The 90% Flow-by scenario is modeled with an annual withdrawal limit of 1168 mg/yr (3.2 mgd) and a flowby of 90%. This scenario is designed to simulate operations using the permit withdrawal limit, combined with the DWR standard guidance of the intake not withdrawing more than 10% instantaneous flow.
* **Draft Alternative #XX** (2.8 mgd Annual Limit & 90% Flow-by) - This scenario is modeled with an annual withdrawal limit of 2.8 mg/yr (1022 mgd) and a flowby of 90%.
* **Draft Alternative #2** (3.2 mgd & 40% Flow-by) - The 80% Flow-by scenario is modeled with an annual withdrawal limit of 1168 mg/yr (3.2 mgd) and a flowby of 80%. This scenario is designed to simulate operations using the permit withdrawal limit, combined with a flowby that ensures the intake does not withdraw more than 20% instantaneous flow.
* **Total Permitted w/ Point Source** (Total Permitted + Point Source) - This scenario is modeled with an annual withdrawal limit of 1168 mg/yr (3.2 mgd) and a static flowby of 0.5 mgd (as outlined in the permit). This scenario is designed to simulate total permitted operations as outlined in the permit, with the only addition being the consideration of net % change to flow after return flow from point source.

# Intake Site Description & Current Estimated Stream Flows

**Table 1:** Modeled monthly current flow statistics for South Fork Powell River 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 105.4 cfs.

| **Month** | **Min** | **5%** | **10%** | **25%** | **30%** | **50%** | **Mean** |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Jan | 55.9 | 83.6 | 105.4 | 183.3 | 204.9 | 289.4 | 404.2 |
| Feb | 87.6 | 142.9 | 183.8 | 244.2 | 266.3 | 371.3 | 569.4 |
| Mar | 79.5 | 136.2 | 170.2 | 264.8 | 293.0 | 385.6 | 533.4 |
| Apr | 35.5 | 77.5 | 100.7 | 159.3 | 177.9 | 258.7 | 388.9 |
| May | 15.2 | 59.2 | 79.0 | 110.2 | 121.5 | 179.7 | 271.2 |
| Jun | 6.6 | 25.2 | 36.1 | 69.7 | 76.7 | 111.5 | 192.9 |
| Jul | 3.2 | 29.6 | 39.8 | 59.4 | 65.8 | 87.0 | 124.1 |
| Aug | 12.4 | 26.6 | 33.5 | 51.3 | 58.3 | 85.0 | 126.0 |
| Sep | 2.1 | 11.0 | 21.0 | 42.8 | 49.9 | 74.4 | 127.8 |
| Oct | 4.3 | 22.6 | 29.6 | 43.5 | 49.3 | 85.9 | 132.2 |
| Nov | 1.6 | 20.0 | 26.9 | 56.6 | 74.0 | 155.8 | 223.0 |
| Dec | 24.8 | 44.9 | 70.6 | 135.5 | 169.1 | 242.0 | 349.7 |

NULL demand\_url

# 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.

* **Draft Alternative #1** - The full demand of 3.2 mgd can be met at nearly all times in the simulated period when combined with a 90% flowby (The maximum 30 day potential unmet demand is 0.00 mgd). This scenario results in a reduced number of days of remaining storage in the Big Cherry Reservoir during the simulated drought of record (13 days of remaining storage).
* **Draft Alternative #XX** - Outcomes from the particular set of operational rules and scenario conditions. Ex: The 90% flow-by scenario results in more flexibility to pump under extremely dry conditions, as compared to the current static MIF permit condition. As a result, the operation is able to meet offstream need during all simulated periods, with a small amount of water remaining during the lowest simulated flow.
* **Draft Alternative #2** - The full demand of 3.2 mgd can be met at nearly all times in the simulated period when combined with an 80% flowby (The maximum 30 day potential unmet demand is 0.00 mgd). Compared to the 90% flowby, this scenario results in an increased number of days of remaining storage in the Big Cherry Reservoir during the simulated drought of record (72 days of remaining storage).
* **Total Permitted w/ Point Source** - This scenario is intended to be used as a point of comparison for the following alternatives which utilize a “percent of flow” style flowby. Due to the size of the demand in the existing permit relative to flows in the South Fork Powell River and due to the consideration of net % change to flow after return flow from point source, the full demand of 3.2 mgd can be met at all times in the simulated period when combined with the static 0.5 mgd flowby (The maximum 30 day potential unmet demand is 0.00 mgd). This scenario results in plenty of days of remaining storage in the Big Cherry Reservoir during the simulated drought of record (99 days of remaining storage).

## Conclusion

Overall, remodeling to consider a net % change to flow (after the point source return flow) has improved the outlook across all scenarios examined, and supports moving towards a “percent of flow” flowby approach. When modeling as a net % change in flow, the reservoir is not chronically drawn down as was shown in previous model results.

With the current permit operations and a limit of 3.2 mgd they likely wouldn’t be able to meet a 90% flowby and retain 60 days remaining storage in the reservoir during the drought of record. However a flowby closer to 80% would likely be effective at maintaining storage levels and ensuring they can sustainably meet demand during dry periods while still better preserving the natural flow regime over a static 0.5 mgd flowby approach. This project may also be able to get to a 90% flowby by reducing demands from 3.2 mgd to around 3.0 mgd, and/or by including drought triggers in the permit to help maintain storage levels in the reservoir during dry periods (this permit doesn’t currently have drought triggers in place). Additionally, this facility has emergency connections with neighboring towns which may be sufficient to maintain supply during times of extreme drought. Note that demand is projected to decline according to water supply plan.

# Cumulative Impact Analysis

This 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 percent total consumptive use 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). Estimates for richness change are also 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 calcualtions 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>). 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.

## Stats Comparison Table:

| **Description** | **3.2 mgd & 90% Flow-by** | **2.8 mgd Annual Limit & 90% Flow-by** | **3.2 mgd & 40% Flow-by** | **Total Permitted + Point Source** |
| --- | --- | --- | --- | --- |
| runid | 6011 | 6012 | 6013 | 6014 |
| River Segment Model Statistics: |  |  |  |  |
| Name | South Fork Powell River - Below Big Cherry Reservoir | South Fork Powell River - Below Big Cherry Reservoir | South Fork Powell River - Below Big Cherry Reservoir | South Fork Powell River - Below Big Cherry Reservoir |
| Flow Out (cfs) | 7.63 | 7.59 | 7.59 | 7.49 |
| Minimum Days of Storage Remaining | NA | NA | NA | NA |
| 30 Day Low Flow (cfs) | 3.02 | 4.64 | 4.52 | 3.37 |
| 90 Day Low Flow (cfs) | 3.83 | 5.01 | 4.99 | 3.48 |
| Consumptive Use Fraction | 0.06 | 0.06 | 0.06 | 0.06 |
| Cumulative Withdrawal (mgd) | 3.2 | 3.18 | 3.2 | 3.2 |
| Cumulative Point Source (mgd) | 2.88 | 2.87 | 2.88 | 2.88 |
| Richness Change (abs) | -0.38 | -0.38 | -0.38 | -0.39 |
| Richness Change (%) | -1.64 | -1.64 | -1.65 | -1.67 |
| Facility Model Statistics: |  |  |  |  |
| Name | BIG STONE GAP WTP:Powell River | BIG STONE GAP WTP:Powell River | BIG STONE GAP WTP:Powell River | BIG STONE GAP WTP:Powell River |
| base\_demand\_mgy | NA | 1,167.19 | 1,167.19 | NA |
| wd\_mgy | NA | 1,162.08 | 1,167.13 | NA |
| unmet\_demand\_mgy | NA | 5.41 | 0.37 | NA |
| Requested Demand (mgd) | NA | 3.2 | 3.2 | NA |
| Withdrawal Met (mgd) | 3.2 | 3.18 | 3.2 | 3.2 |
| Point Source (mgd) | 2.88 | 2.87 | 2.88 | 2.88 |
| Maximum 30 day potential unmet demand (mgd) | 0 | 0.12 | 0 | 0 |

# Reservoir Storage Plots:

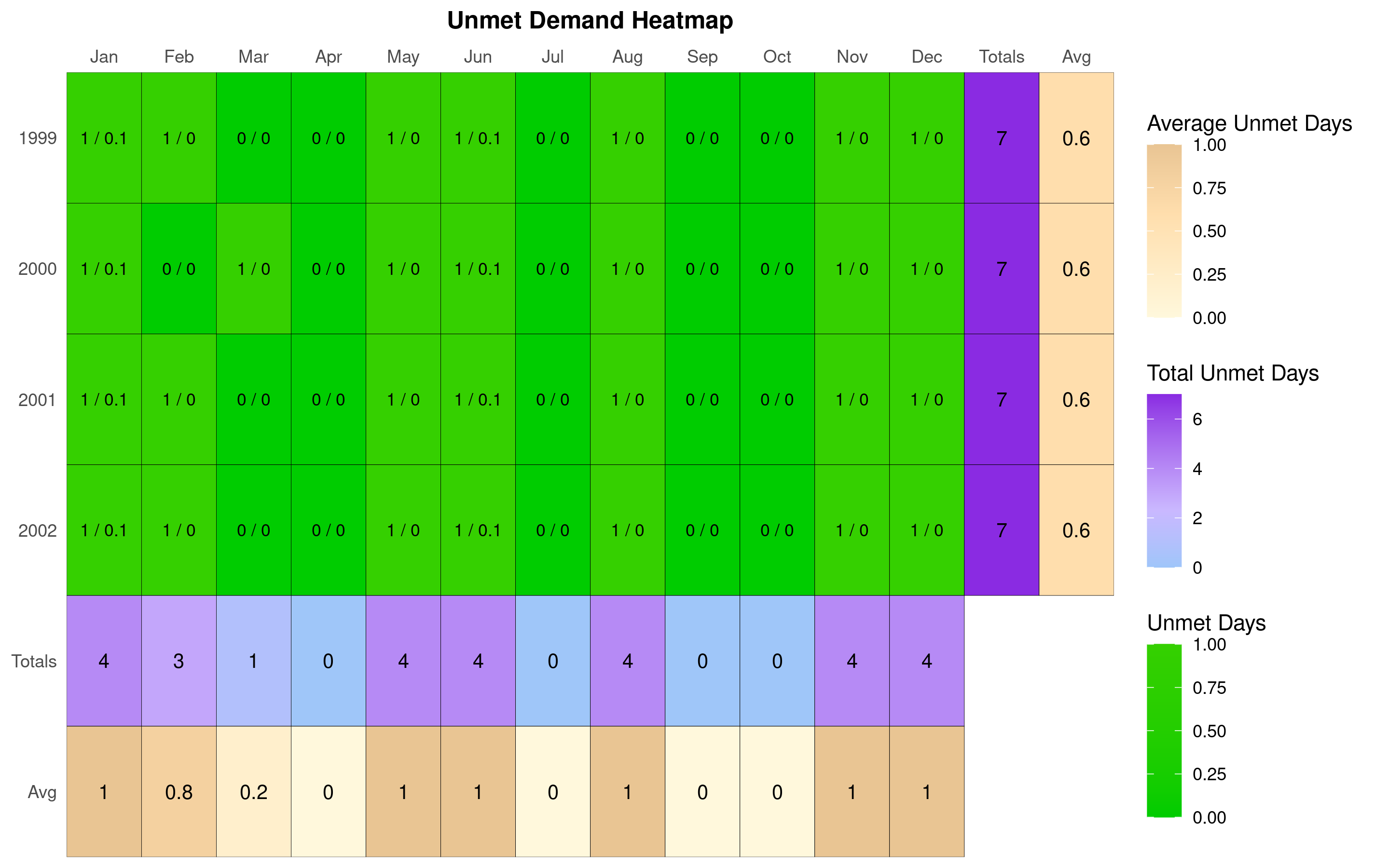
The following reservoir storage plots depict changes in reservoir storage under each scenario (indicated in black), as well as simulated inflow to the reservoir (blue), simulated outflow from the reservoir (green), and system demand for the given scenario (red). For water supply reservoirs, a minimum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

[1] “No riverseg impoundment for run id 6011” [1] “No riverseg impoundment for run id 6012” [1] “No riverseg impoundment for run id 6013” [1] “No riverseg impoundment for run id 6014”

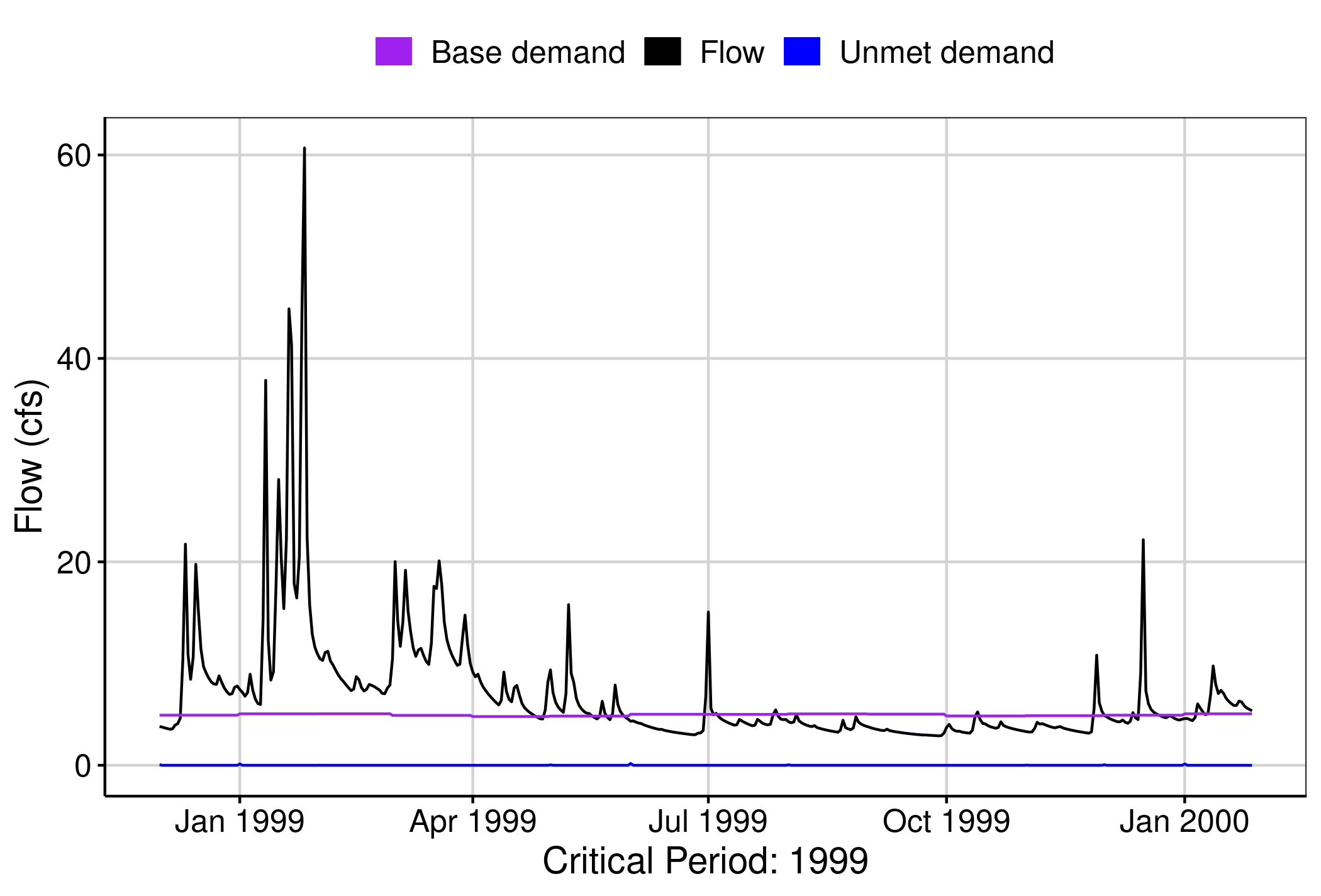
# Unmet Demand Plots:

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). Heatmaps also show the amount of unmet demand for each month [Unmet Days / Amount (mgd)]. Hydrographs are shown for the period of the simulation with greatest unmet demand.

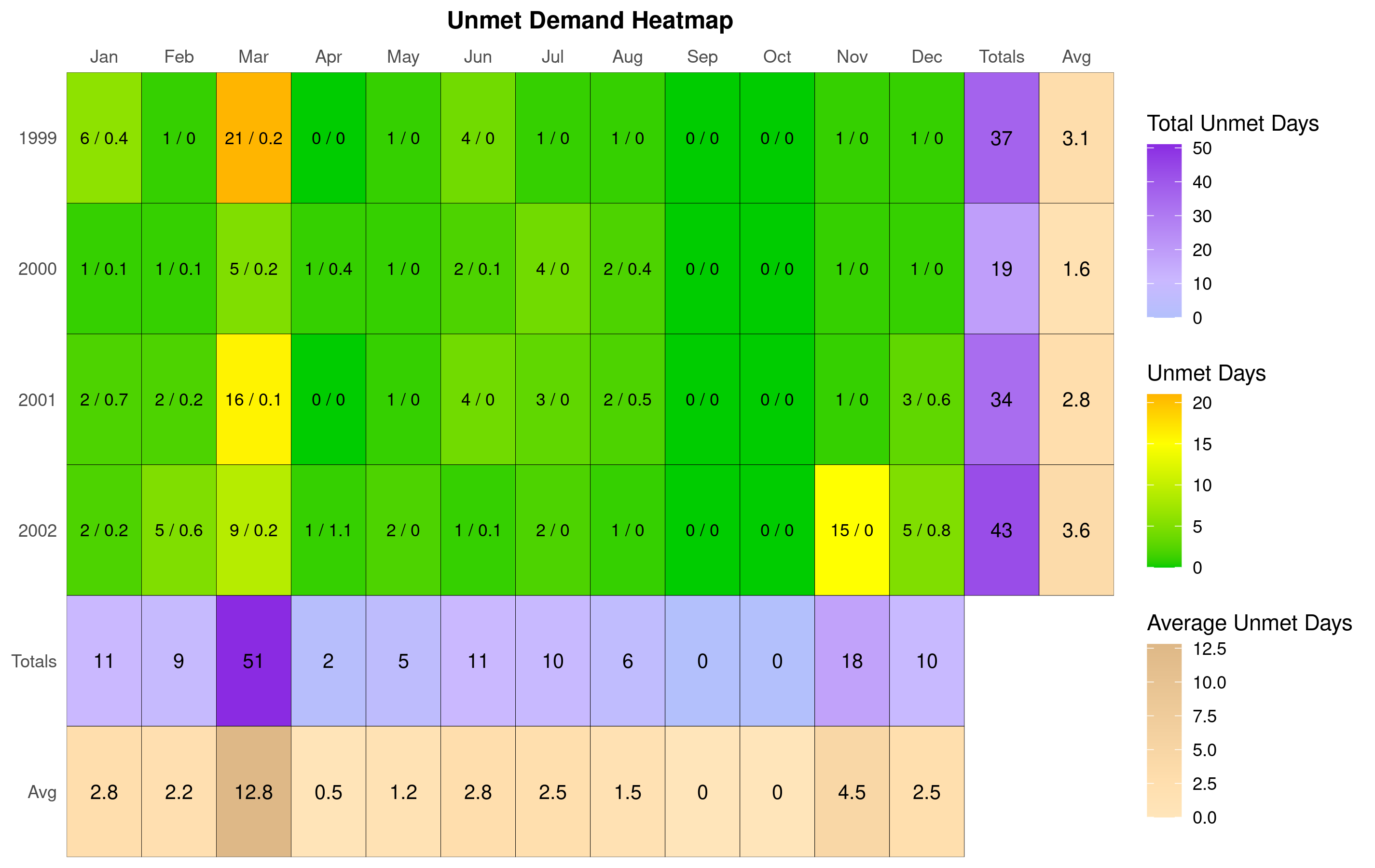
## Heatmap: 3.2 mgd & 90% Flow-by



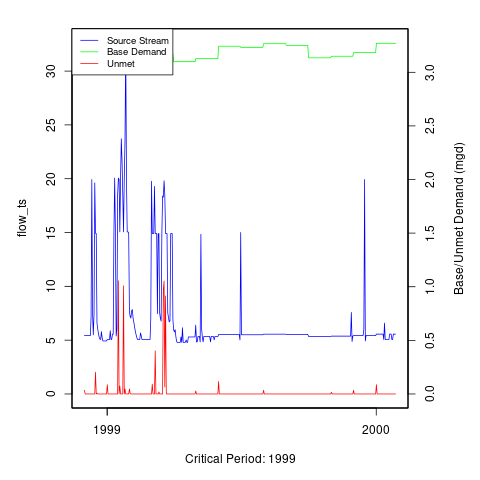
## Hydrograph: 3.2 mgd & 90% Flow-by

 [1] “No local facility impoundment for 3.2 mgd & 90% Flow-by”

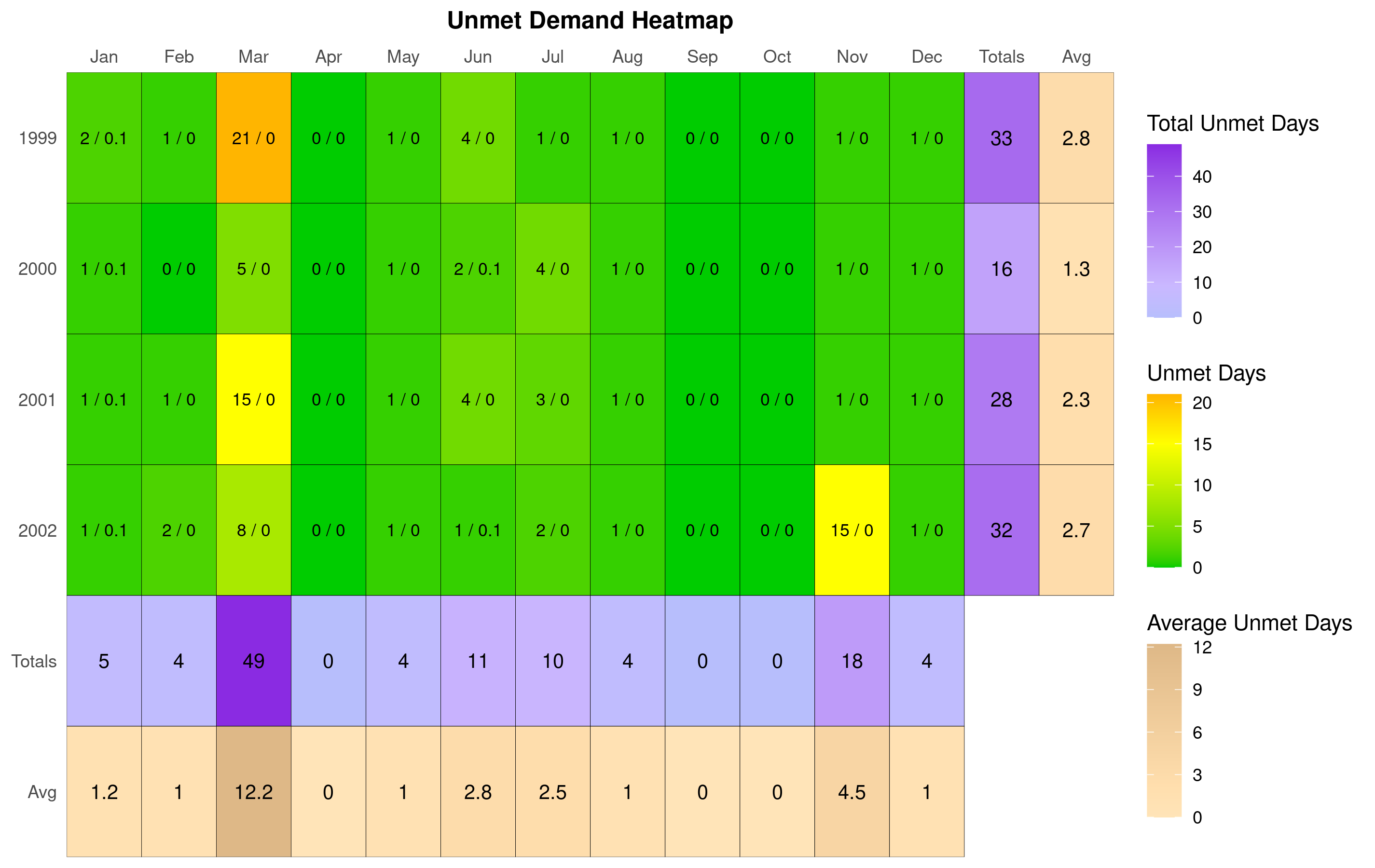
## Heatmap: 2.8 mgd Annual Limit & 90% Flow-by



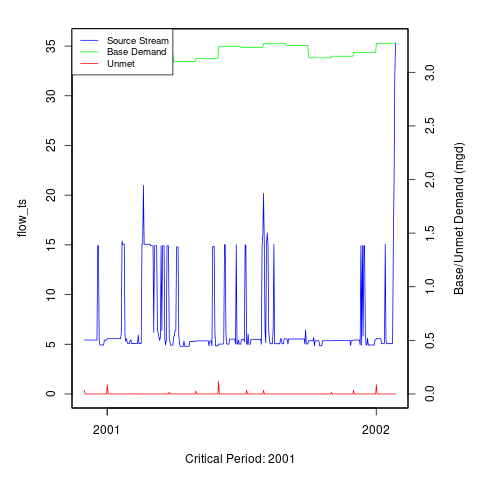
## Hydrograph: 2.8 mgd Annual Limit & 90% Flow-by

 [1] “No local facility impoundment for 2.8 mgd Annual Limit & 90% Flow-by”

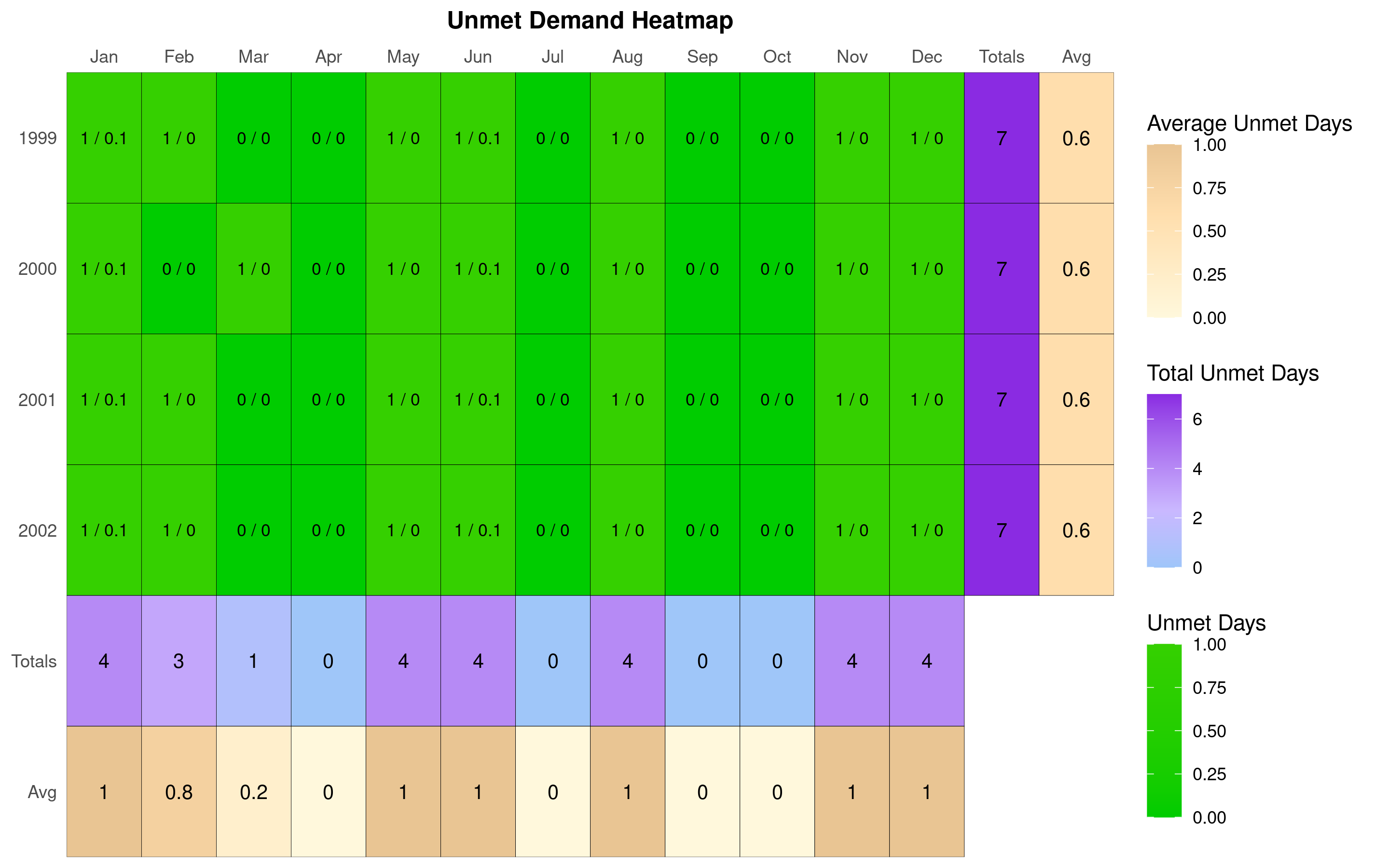
## Heatmap: 3.2 mgd & 40% Flow-by



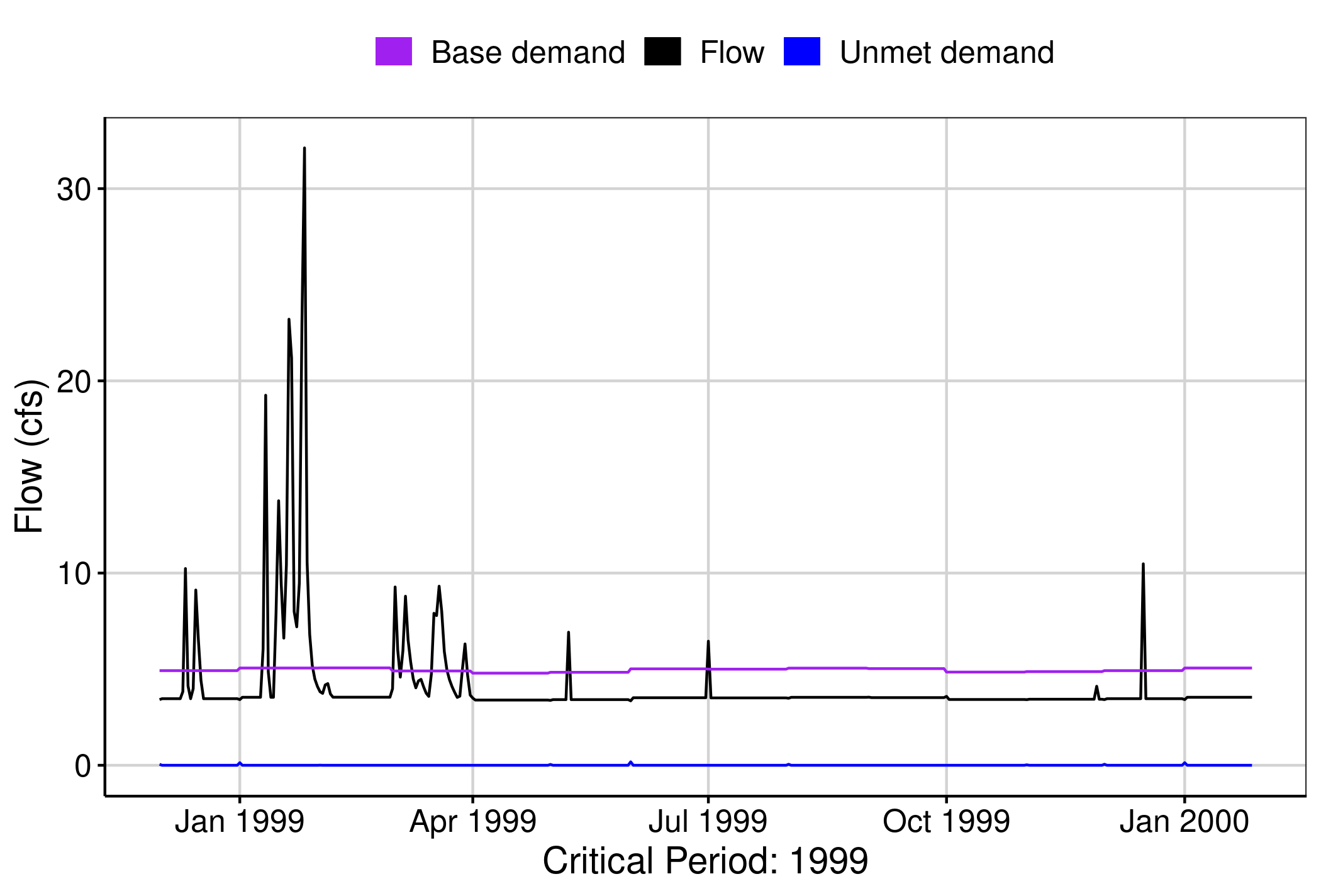
## Hydrograph: 3.2 mgd & 40% Flow-by

 [1] “No local facility impoundment for 3.2 mgd & 40% Flow-by”

## Heatmap: Total Permitted + Point Source



## Hydrograph: Total Permitted + Point Source

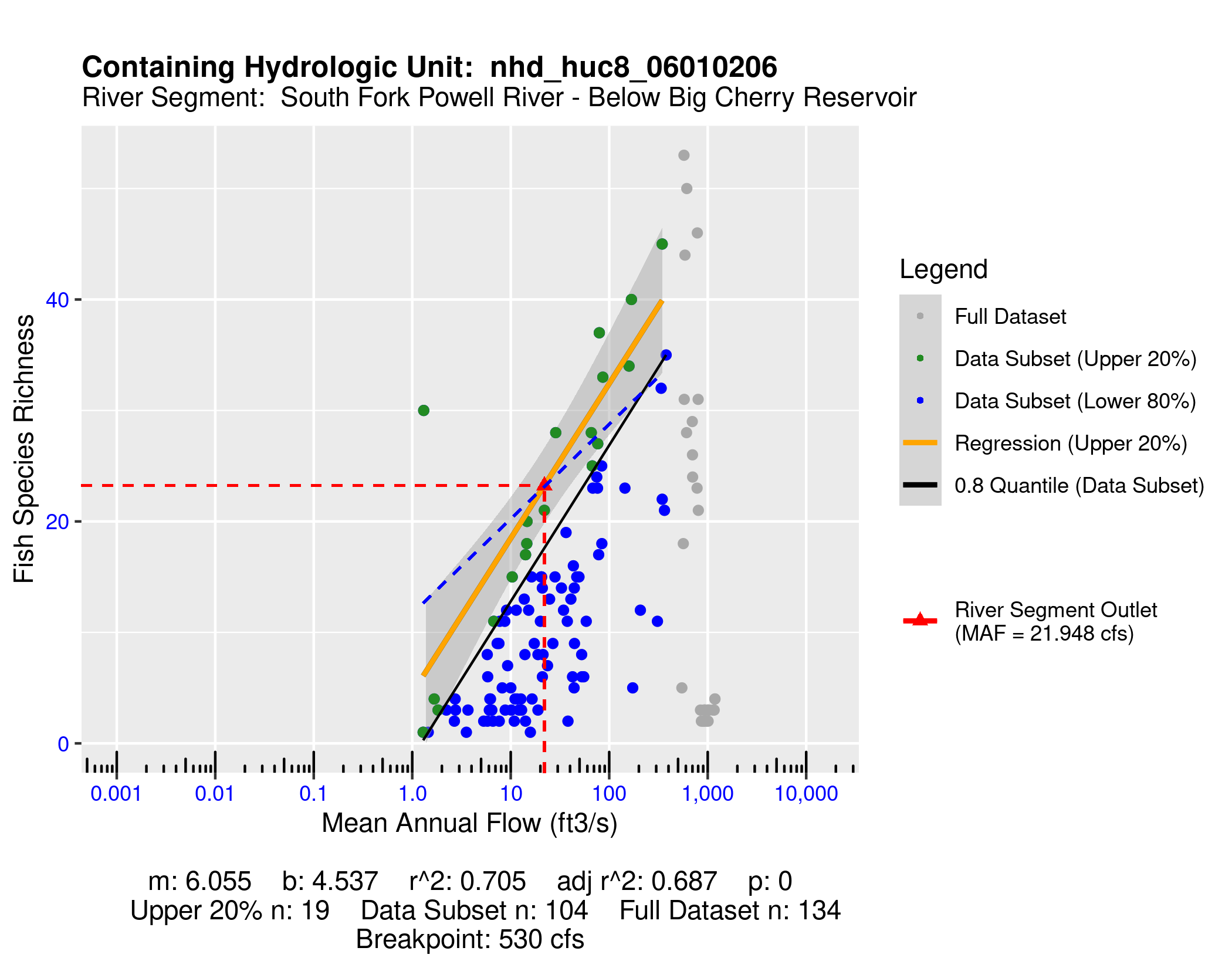
 [1] “No local facility impoundment for Total Permitted + Point Source”

# 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.

In order to calculate river segment-level richness change, elfgen is first used to produce 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 6.1. Stats Comparison Table are derived from this flow-ecology relation.



## Habitat (If Applicable):