RSEA Hydrology and Allocation Baseline

REV 1.0.3

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Please Note:

The RSEA Water Working Group and RSEA PT are currently developing the RSEA Water Current Condition Report (CCR). Current condition reports provide an overview of the current state or condition of individual values in relation to selected indicators and their respective reporting units. Reports generated by the RSEA Project Team will contain information pertaining to the indicators and methods used to assess the current condition, results for each indicator, descriptive maps and a summary of the assessment results. The vision and goals associated with the valued components continues to evolve and both the protocols and reports are expected to change as work continues.

The limitations of the tool should be addressed where possible (for example, how FLNRORD's shallow groundwater licenses are incorporated) and the issues in e-licensing that Fathom identified would ideally be addressed to improve the reliability.

The adequacy of the model for the South of the Peace River may need further engagement with First Nations

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Executive Summary

Fathom Scientific Ltd. (FSL) has developed a Geospatial Multiple Regression model (GMRm) at the request of the Regional Strategic Environmental Assessment (RSEA) working group. We have worked closely with the Water Working Group to develop hydrological statistics (hydro-stats) and allocation estimates that capture the most sensitive times and conditions for making water related resource decisions. This report presents the methodology, collectively referred to as FSL-2020, in a fully transparent and reproducible manner (Section 2), describes model performance (Section 4.2), and describes the results of several validation[1] exercises undertaken (Section 4.2).

In this study, we generate the necessary geospatial variables for all 4618 FreshWater Atlas (FWA) assessment polygons in the RSEA study area (220,132 km^2), then generate the 27 hydro-stats for all 4618 sites. The hydro-stat is attached to 3 shape files: 1. the FWA assessment polygon, 2. the Upstream Drainage Area (UDA), and 3. the Drainage Point (DP) with the largest UDA. These can be referenced by either the FWA_ID or the FSL_ID (aka OGC_FID). Any user can also check the results using the methodology described in this document.

Once the models were verified for operation, we completed several validation[2] exercises against both WSC records and North East Water Tool (NEWT) (Omineca Water Tool (OWT)) results. In the process, this study has provided an independent validation exercise of the NEWT (OWT) results, as well as presenting an alternate water availability model that can be used for ungauged basins in the region.

NEWT (OWT) both use the methodology described in Chapman (2018) and are currently used by the Oil & Gas Commission (OGC) to inform Water Allocation decisions. Comparing similar hydrological statistics (hydro-stats) in Table 34, for 17 of the 21 validation sites (80%ile) [3], we found that:

- the NEWT estimate of Mean Annual unit-area Runoff (MAR) was high by +1.2%, compared to +1.1% for the FSL-2020 model. According to Table 35, this is within the stated 5.5% Mean Bias Error (MBE) reported in Chapman (2018), and agrees with the 1.1% MBE for FSL-2020.
- The Mean Monthly Discharge (MMD) values for both models were close to measured, the 80%ile Nash Sutcliffe Efficiency (NSE) for NEWT was 86.9% and 95.1% for FSL-2020. The NSE metric tends to favour high flows though, so we also considered %Difference of winter low flows.

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[1] We use the term "Validation" in this report because we compare the model performance to uncertainty specifications in order to evaluate the model performance. We also worked with the client to determine model fit-for-purpose. We determined that it is performing within specifications, to the users requirements. It is therefore validated in this respect, but not without limitations. See Section 5.1.6 for limitations. We also use the K-Fold Cross-Validation method to determine model robustness. We acknowledge that "Validation" often implies evaluation of model performance by a third-party against unseen data, which is not the case. See Beven (2013) and Wikipedia (2020) for further references.

[2] FSL-2020 represents a modeling approach. Each hydro-stat has its own "Model", which is a simple multiple regression equation. There are a total of 162 "Models" each with the same form.

[3] Excluding anomalous stations like Teeter and short-term records like that at St John and Petitot, along with a 4th station of poor quality match.

- The winter low flows from NEWT were 14% higher than the measured WSC flows on average for the 80%ile sites, while they were within 0.1% on average for FSL-2020. Two notable exceptions from the validation exercises were Blueberry River (HZ6) and Adsett Creek (HZ4), at which both models overestimated winter low flows.

While model results are close, the FSL-2020 has higher performance metrics in each of the three examples above. Overall, it was our impression that NEWT was overestimating winter flows and that the model results should be adjusted by at least the reported +5.5% MBE. This would bring the low flow estimates closer to measured. It must be stressed that this assessment is based on a small percentage (17 out of 95) of the possible validation sites in the study and further work would need to be completed to justify this adjustment. It is also based on winter flow measurements, which have "significant uncertainty … under ice, whether in real-time or in historical published values[4]". Improved monitoring of winter low flows and monitoring in a greater number of watersheds are needed to better predict winter low flows and evaluate the impacts of allocation during the winter low flow season.

Beyond the Mean Annual Discharge (MAD) and Mean Monthly Discharge (MMD), we also developed models for the Summer (Jun-Sep) 7 day average Q with a 10 year return period as a fraction of MAD (S-7Q10/MAD), the Annual 7-Q10/MAD (A-7Q10/MAD) and the A-30Q10, along with Monthly Q10/MAD (MmmQ10/MAD) for each month. We did this for 6 Hydrological Zones (HZ) defined in Obedkoff (2000) and again used in Ahmed (2015) in the RSEA study region. For each HZ, 27 models were developed (MAD, A-7Q10/MAD, S-7Q10/MAD, 12x%MD, 12xMmmQ10)[5], generating 162 models in total. These models were validated against WSC station data, as well as regionalization results presented in extensive mapping products. In total 48 maps were generated, only a selection is included in this report, the others are available on the accompanying data product.

Monthly mean and low flow estimates were compared to the volume of water allocated through water licenses and short-term use approvals. For each surface water authorization, instantaneous monthly demand and total annual volumes were calculated, based on the volume of water allocated and the water license purpose. For water licenses with an Oil & Gas purpose, environmental flow needs requirements were modeled. Water allocations were summed by upstream drainage area and compared to the flow estimates at the downstream point in each assessment polygon.

One complicating factor in developing the allocation model was the lack of digitized records on Environmental Flow Needs (EFN) conditions on STUAs.

[4] Pers.Comm. (2020) with Dave Hutchinson (Manager WSC, B.C.), January 15, 2020

[5] We did not develop a regression model for the A-30Q10/MAD. Instead, we created a model for the A-7Q10/MAD, the Min Monthly10Q, and found the relationship between these and the A-30Q10/MAD at each validation site, which was very reliable with an R2 of 0.9974, shown in Figure 1. The A-30Q10/MAD is 6%larger than the A-7Q10/MAD and 10%smaller than the min Monthly 10Q.

Where available in the Water License database, sophisticated EFN conditions were implemented based on modeled Q10 low flow values.

- We recommend adding EFN conditions to digital records, to improve the reliability of demand estimates in future models. At a minimum, for STUAs and licenses, we recommend including a MAX_DIVERSION_RATE field that identifies the maximum instantaneous diversion. Also, we recommend adding two fields, identifying the beginning and end of the period of allowed use (e.g. for irrigation licenses, the beginning of the period may be May 1, and the end of the period may be October 31).
- We also noted that many water licenses in the BC database had a value of '0' in the quantity field and, upon review of the actual water license, was determined to be in error. Similarly, superseded licenses were still in the provincial database. We recommend the provincial database be reviewed and updated.
- In the MFLNRORD STUA database, we noted that the allocated volume and units were blank for 1167 out of 1260 records so these allocations were assumed to be 0 in this study. We recommend these fields be updated.
- Many of the EFN conditions for water licenses were unclear, as detailed in Section 3.7. We recommend they be clarified.

Allocation results were also similar to NEWT (OWT) except in a few key areas. Typically, the annual allocated volume between the two models were very close, however the NEWT may be underestimating instantaneously allocated flows on a monthly basis. NEWT could improve estimates by capturing seasonal variability, EFNs, and considering max instantaneous diversion rates. There were a few instances in the validation exercises where an OGC Short Term Use Approval (STUA) was not captured by NEWT. Overall the FSL-2020 Allocation results were close to NEWT, but more conservative.

We combine the water availability and allocation data in Appendix A showing the results for all 4618 FWA assessment polygons. A summary of %Allocation statistics are summarized in Table 44 for all assessment polygons (comparable to land surface area) and Table 45 for all assessment polygons with a Point of Diversion (PoD) count greater than zero in their UDA, totaling 1074 assessment polygons. From Table 45, we can see that

- The low-flow period occurs in winter in 84% of the catchments, summer in 3%, and could occur in winter or summer in 13%.
- 11.3% of those catchments with a PoD Count >0 have a maximum monthly %allocation of >20% (more than 20% of the mean monthly flow is allocated).
- The 95%ile of those assessment polygons %Allocation of Mean Annual Discharge (MAD) is 3.91% (5% of the catchments have more than 3.91% of their MAD allocated).
- From a drought management perspective, an important finding is that 18.8% of those 1074 catchments have more than 100% of their A- 30Q10 allocated without EFN protection.

The %Allocated results can be seen in the associated mapping products for Maximum Monthly% Allocated (MAP600), %MAD Allocated (MAP601), PoD Count (MAP602), %A-30Q10 Allocated (MAP603), and A-30Q10%Allocated showing larger Water Management Units (MAP604).

From these mapping products, we can see that HZ4 and HZ6 show the greatest risk and possible environmental stress based on the combination of estimated low flows and allocations. From the validation exercises completed in this study, Blueberry River (Table 21 and Table 38) and Pouce Coupe (Table 26 and Table 36) were flagged for both further desktop investigation and possibly winter flow measurements. This is because,

- There is a large discrepancy between modeled and measured low winter flows at Blueberry and a large percentage of A-30Q10 may be already allocated, and
- Pouce Coupe has very low A-30Q10 flow and already the allocation just in BC is greater than 100% of the A-30Q10 while over half the watershed is in Alberta where we did not sum allocation amounts.

Allocation Validation exercises were only completed on 8 catchments, but of these:

- Blueberry River,
- Upper Blueberry River,
- Pouce Coupe River,
- Manson River,
- Atunatche Creek, and
- Meadows Creek,

all showed potential allocations exceeding 20% of 30Q10 values. According to Table 45, 361 FWA assessment catchments have allocations exceeding 20% of the A-30Q10 and 183 catchments have allocations exceeding 100% of the A-30Q10/MAD. Bear in mind that many of these catchments are on the same river/creek so this could be interpreted as the number of reaches with a risk of over-allocation.

It is generally recognized that winter flow measurements on these systems are subject to large uncertainty due to the difficulty in measuring less than 1%Mean Annual Discharge (MAD) below ice. However, there are allocations that are also near this threshold and therefore demand higher level of effort and investment in making these critical measurements. Alternate methods and locations for measurements should be investigated, and the frequency of winter measurements should be increased to support sound allocation decisions in this area. There may be more systems subject to the same stresses as Blueberry and Pouce Coupe, but they were not analyzed in the detailed validation exercises of this study.

Only dugout water use from OGC licenses was considered in this study[6] which is a limitation. In future work, it is recommended that groundwater demand be

[6] This is because the dugout water source is defined differently in the water license applications procedures for the different agencies. The OGC definition of the dugout water source includes surface water sources, whereas the MFLNRORD definition of a dugout water source does not include surface water sources.

considered and dugout water sources be included from both agencies. In addition, it is recommended that the dugout water source is defined consistently by both agencies.

We understand that Allocation and Water Management decisions are multi-layered, sophisticated, and ever-changing and that water managers are doing a commendable job balancing stakeholder interests, human resources, and environmental stewardship. The NEWT (OWT) and the current study provide a starting point for those decisions and can inform the prioritization of watersheds for further study. There is always more that we can do, and deciding the most effective way to manage our shared resources is the purpose of this study. We look forward to hearing how we can continue this important effort.

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ACRONYMS AND ABBREVIATIONS

A-7Q10	Annual 7day average discharge with 10 year return period
A-7Q10/MAD	A-7Q10 expressed as percentage of MAD
A-30Q10	Annual 30day average discharge with 10 year return period
A-3Q10/MAD	A-7Q10 expressed as percentage of MAD
DA	Drainage Area
DEM	Digital Elevation Model
EFN	Environmental Flow Needs
GIS	Geographic Information System
GMRm	Geospatial Multiple Regression model
hydro-stat	Hydrological Statistic (such as MAD, MAR, %MD)
HZ	Hydrological Zone
MAD	Mean Annual Discharge
MAR	Mean Annual unit-area Runoff
MmmQ10	Monthly average Q with 10 year return period
%MD	%Monthly Distribution (percent of flow within a month)
PDF	Probability Distribution Function
Q	Standard nomenclature for discharge or flow
S-7Q10	Summer (June-September) 7day discharge with 10 year return period
S-7Q10/MAD	S-7Q10 expressed as percentage of MAD
SRTM	Shuttle Radar Topography Mission
STEYX	Standard error in the estimate of the hydrological variable (Y) as a function of the regression model (X).
STUA	Short Term Use Approval
UDA	Upstream Drainage Area
WL	Water License
WSC	Water Survey of Canada

1 INTRODUCTION

The Saulteau First Nations, acting on behalf of the Regional Strategic Environmental Assessment (RSEA), has contracted Fathom Scientific Ltd. to develop a transparent and defensible hydrology model for the Northeast of British Columbia identified in MAP100 as the RSEA Comprehensive Study Area. Furthermore, we have been contracted to create a tally of all water allocations within each watershed and compare that to the estimated water availability.

This report builds on analysis presented in "South Coast Stewardship Baseline (Brem, Fraser Valley South, Toba, Upper Lillooet) REV 1.0" (Sentlinger & Metherall 2016). This new work follows the approach outlined in that study to determine the volume of water allocated, by month and annually, within each of the 4618 Fresh Water Atlas (FWA) assessment polygons in the RSEA study area, and their associated Upstream Drainage Area (UDA).

The work occurred in 2 parts:

1. Part 1 work was to collect and QA/QC existing data. This included GIS and hydrometric data, as well as existing water license and authorization allocations. The GIS and hydrometric data was for the entire RSEA Comprehensive Study area.

2. Part 2 work was to develop multi-variate linear regression models to estimate key watershed hydrological statistics (hydro-stats) and compare these to the summary water allocation stats.

The key hydrologic variables to be estimated per the contract terms of reference were Mean Annual Discharge (MAD), Mean Monthly Discharges (MMD) and annual 7-day low flow variables. We chose Annual 7day Discharge with 10 year return period (A-7Q10), Summer (June-September) 7Q10 (S-7Q10) to model since these were present in our primary data source. The primary data sources used for hydrometric data was Ashfaque Ahmed's "Streamflow in the Lower Mainland and Vancouver Island" (Ahmed, 2015) and Bill Obedkoff's "Streamflow in the Omineca-Peace Region" (Obedkoff 2000). Neither of these sources list the 30Q10 as a derived hydro-stat, but we have generated an estimate of it from the A-7Q10 and Minimum Monthly Q: 10 year Return Period (Min MmmQ10), described below. The study area is designated in MAP100 as "RSEA Study Area".

Two independent modeling tasks were undertaken.

1. Estimate water availability using a multiple regression hydrological model and,
2. Estimate water allocation from water licenses and Short Term Use Approvals (STUA).

2 HYDROLOGY METHODOLOGY

The RSEA comprehensive study area is large (220,132 km^2) and diverse, ranging from and diverse, ranging from Unlike NEWT (Chapman 2018) and other models, we did not employ a water balance model. We rely on geospatial statistics and multiple regression analysis to determine each hydro-stat independently. It is not a physical model, although physical variables are used. For example, the amount of May runoff is not determined by the average temperature and precipitation in the previous winter, rather it's determined by the regression between regional %May Distribution values and unchanging variables such as median elevation, precipitation, solar exposure, and slope. In Sentlinger & Metherall (2016), we found this to be a very efficient way to model hydro-stats that is far more robust than conventional watershed modeling in ungauged basins, based on professional experience.

In a water balance model, accounting is kept of water entering and leaving a gridded cell. Chapman (2018) gives this as:

$$RO_{pred} = P - ET$$

where RO_{pred} is the predicted annual runoff (mm), P is the annual precipitation (mm) from PRISM, and ET is the annual evapotranspiration (mm) based on the same PET model results described above, but adjusted. The water balance approach provides some assurance that no water is lost or created, and ideally flows are not negative. However, Chapman goes on to say that "the analysis of the residuals from the basic water balance model indicated the presence of systematic patterns in the unexplained annual runoff." They then develop a multivariate regression model for the residuals based on geospatial variables and "[t]he multivariate regression adjustment in annual runoff, to account for some of the error or uncertainty in the residuals, significantly improved the accuracy of the annual runoff model." From our perspective, if the final estimate of MAR is from a multivariate regression model, there is no advantage of using a water balance model. We don't understand the difference between this approach and a GMRm as we employed in this study, since the constraint of water accounting is void.

The benefit of the Geospatial Multiple Regression model (GMRm) as we've implemented it, is an estimate of Standard Error on each independent variable, allowing the practitioner to understand the uncertainty on each prediction. In a way, it's very similar to the method proposed by Obedkoff in his work in BC, relating all hydro-stats to the two most influential geospatial stats: median elevation and drainage area. Our method follows and extends this approach. It is a similar approach taken by USGS in Alaska in the study "Estimating annual high-flow statistics and monthly and seasonal low-flow statistics for ungaged sites on streams in Alaska and conterminous basins in Canada" (Wiley & Curran, 2003). One limitation of this approach is that predicted points, such as %Monthly Distribution of August flow, will fall on either side of the regression line and where this value is low it can be estimated to be negative. We've applied a minimum flow of Zero constraint, but this example does highlight the limitation.

Regardless of the approach taken, so long as both are valid, they can be used to cross-validate each other, and a more formal comparison of model results are presented in Section 4.2.

2.1 Hydrologic Variables

There are a number of ways to model the target variables. We've chosen to model normalized variables, where the intention is that these normalized values allow the comparison of corresponding normalized values for different datasets in a way that eliminates the effects of certain coarse influences. For instance, instead of modeling Mean Annual Discharge (MAD), which would necessarily include the Drainage Area (DA) as an independent variable, we've modeled the Mean Annual unit-area Runoff (MAR) instead. The MAR is the MAD divided by the drainage area and multiplied by 1000x to achieve units of $l/s/km^2$. It is dimensionally equivalent to runoff in mm/year[7]. Normalized variables are useful when graphically depicting regional trends on maps. We generally use the term Upstream Drainage Area (UDA) to signify the cumulative catchment upstream of a Drainage Point (DP), as opposed to the more ambiguous Drainage Area, which may be used to indicate the area of a hydrological unit not necessarily draining to a single point.

Furthermore, instead of modeling MMD, which would again use DA, we've followed Obedkoff (2000) and modeled the % Monthly Distributions (%MD) of flows. Each month is represented by the percent (expressed as a decimal value instead of fraction) of the total flow that occurs in that month, so the sum of all months is 100 (as per Obedkoff 2000 and Ahmed 2015). This approach avoids error associated with estimating the total flow and only captures the mechanisms that determine the timing of flows.

To convert the %MD to monthly average flow, in m^3/s, use:

$$MeanMonthlyQ_i = \%MD_i * MAD * \frac{365}{Days_i} \quad (1)$$

where $Days_i$ is the number of days in the *i*th month.

In Sentlinger (2015), we found that the S-7Q10/MAD was a useful variable for characterizing the vulnerability of a watershed to extraction of water during summer low flows[8]. It's a meaningful, scalable, unitless metric. In the RSEA study area, we found the S-7Q10/MAD was almost always larger than the A-7Q10/MAD, which occurred in late winter (Feb-Mar) in most catchments.

The RSEA Water Working Group requested to have a monthly indicator of low flows, so in addition to the mean monthly flow, we also developed the monthly Q10 low flow divided by MAD, or MmmQ10/MAD where Mmm is meant to

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[7] While the runoff of the UDA of a DP is a single value, it is the result of numerous spatially varying processes upstream; we only estimate, or measure, the integrated response at the DP. However, as the DPs go higher into the watershed the predictor variables change, such as median elevation and precipitation, and therefore the response variable, i.e. MAR, will also change i.e.increase.

[8] This study focused on the South Coast maritime region with rain dominated and transitional catchments compared to the current study which involves primarily snow dominated catchments.

designate a 3 letter month such as Jan30Q10. This is based on a Log-Normal Probability Distribution Function (PDF) for average monthly flows. We also chose the minimum value from the 12 estimates of MmmQ10 as indicator annual 30Q10. This typically occurred in the winter.

For all validation[9] exercises, we calculated the A-30Q10/MAD from raw WSC validated daily data using a Log Normal PDF. To do this, we calculated a running 30 day average and took the minimum annual value. We then fitted a log normal PDF of these values and the 1:10 year exceedance value. We compared this to the A-7Q10/MAD and the minimum MmmQ10/MAD and found it was generally slightly larger than the 7Q10/MAD and slightly smaller than the minimum MmmQ10/MAD. The comparisons are shown in Figure 1. We've estimated the A-30Q10 for all catchments based on the average of these two relationships:

A-30Q10/MAD = Average (A-7Q10/MAD*1.0581, Min Mmm30Q10/MAD*0.8976)

This resulted in a slope of 1.0012 and an R^2 of 0.9974, shown in Figure 1. The resulting Standard Error in Y as a function of X (STEYX) is 0.0041. If the A-30Q10/MAD is 10%, by this method, the 95% confidence uncertainty is ±0.82% so 9.18% to 10.82% of MAD. We used this proxy because neither Ahmed nor Obedkoff, which we used as our primary QA/QC'd curated dataset, generated A-30Q10 values and generating this hydro-stat from raw WSC was not within this project's scope. We trained the model on catchment sizes ranging from 103 km2 to 10,000 km2 with similar results. **Future studies could generate the A-30Q10/MAD from all raw WSC datafiles or confirm the validity of this proxy estimate.**

2.2 Data Sources

There are two main types of hydrological data used in this study, Flow Data and GIS data.

2.2.1 Streamflow Data

Many of our estimates of MAD, MMD, S-7Q10, and A-7Q10 relied on data from Ahmed (2015) which was collected at long-term (>20 year) streamflow stations monitored by the Water Survey of Canada (WSC) between 1976 and 2011. It is a rigorous, quality controlled, and normalized data summary used as a standard in British Columbia. In the few instances where Ahmed did not include a station included in Obedkoff (2000), we used the Obedkoff value.

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[9] We use the term "Validation" in this report because we compare the model performance to uncertainty specifications to evaluate the model performance and determine it is performing within specifications. It is therefore validated in this respect, but not without limitations. See Section 5.1.6 for limitations. We also use the K-Fold Cross-Validation method to determine model robustness. We acknowledge that "Validation" often implies evaluation of model performance by a third-party against unseen data, which is not the case.

We've chosen to work in the Hydrologic Zones defined in Ahmed (2015). Descriptions of each zone refer to the Biogeoclimatic classification (BCMOF 1998) and Obedkoff (1998):

- Zone 3 - Northern Rocky Mountains: Obedkoff 1997 breaks this zone into two zone, which coincide with our grouping of 3N and South.
    - 3N: Liard Basin is classified as Boreal White and Black Spruce, subzone dry and submaritime. According to BC Surficial geology, this region may have significant karst geology, which may result in some losing, and gaining, reaches.
    - 3S: North Central Interior: Spruce-Willow-Birch subzone moist and cool. *To the west, the Northern Rocky Mountains zone is bounded by the Rocky Mountain Trench, and to the east by the western edge of the Great Plains. Unlike the Rockies to the south, these mountains are not in the rain shadow of another range to the west, with this resulting in higher precipitation relative to surrounding zones. The geology is made of sedimentary rocks, similar to the Great Plains to the west, but the orogeny that formed the mountains also faulted and tilted the strata, creating a more permeable region than the plains. (Obedkoff 1998)*
- Zone 4 – Northern Interior Plains: Boreal White and Black Spruce, subzone wet and moist. *The most distinctive in the province, the Northeast Plains zone is part of the Great Plains that make up most of the Prairies and US Midwest. The zone lies in the rainshadow of the Rocky Mountains, keeping the zone relatively dry. The continental air masses that dominate the region make for cold winters; yet the warm summers create uplift for convective storms that lead to the precipitation maximums during the summer months. The geology of the region also differs greatly from the rest of the province. The flat land of the zone contrasts with the mountains and hills that dominate the rest of the province. The bedrock is sedimentary, but unlike other locations in the province that are of sedimentary origin, the Great Plains zone has not been tilted or faulted, leaving large slabs of shale that do not allow for much permeation into lower strata. There are three groundwater sources in the region, a shallow aquifer in the unconsolidated sediments laid during glaciation, a confined aquifer below the shale, and a bedrock aquifer (Obedkoff 1998).*
- Zone 6 - Southern Interior Plains: Boreal White and Black Spruce, subzone wet and moist. (Same description as Northern Interior Plains from Obedkoff (1998)).
- Zone 7 - Southern Rocky Mountain Foothills: Engleman Spruce and Subalpine Fir, subzone wet and cool-cold. (Same description as Zone 3S from Obedkoff (1998))
- Zone 8 - Nechako Plateau: A diverse mixture of Subboreal Spruce, Engleman Spruce, and Subalpine Fir ranging from wet and cool to very cold.

- Zone 12 - McGregor Basin: The same as Zone 7 but with higher peaks and lower valleys.

- Zone 13 - Upper Fraser Basin: Biogeoclimatic conditions not considered.

These seven zones are characterized by similar catchment characteristics within each HZ. They capture different hydrologic mechanisms and provide a means to classify typical responses within each zone. Ahmed (2015) states,

> *"The most practical approach for estimating streamflow characteristics at ungauged sites involves the use of regional procedures and techniques based on hydrologic zones. A hydrologic zone is defined as an area where runoff characteristics are homogeneous and where data collected in the region can be reasonably extrapolated to estimate characteristics at ungauged sites to an acceptable degree of accuracy. A hydrologic zone is typically identified on a map on the basis of physiographic features and/or a statistical study of hydrologic data."*

Ahmed and Obedkoff used only Non-Regulated WSC data as indicated in the WSC record. Ahmed states:

> *The hydrometric stations (data) included in the analyses met the following criteria:*
>
> *• natural flow (or flow with minor regulation);*
> *• minimum 12 years of substantially complete monthly flow data (with a few exceptions); and*
> *• Measured instantaneous discharge.*

Dave Hutchinson (2020) provided this definition of regulated: "The record designation Natural (or non-regulated) is applied only if the monthly mean value and/or the maximum instantaneous value is increased or decreased by 10% from that of the natural regime". Based on this definition, we can assume that the flow records used in this report have not been modified by more than 10% of mean monthly flow. If they have been reduced by this much or more, then the model results are conservative (i.e. lower than natural).

2.2.2 GIS Data

Beyond having the flow statistics contained within Obedkoff (2003) and Ahmed (2015), we need GIS-derived statistics to complete the analysis, which required having drainage area polygons.

The spatial data sources used to derive catchment characteristics are as follows:

1. Digital Elevation Model (DEM): In Sentlinger (2015) we used elevation data primarily provided by GeoBase and the 1:50k Canadian Digital Elevation Data (CDED). This data is very good for BC: we have found that elevation contours are within 10m of BC Terrain Resource Inventory Mapping (TRIM) contours. However, it is very time consuming and data-intensive to process for larger areas. For this study, we chose to use a coarser gridded Shuttle Radar Topography Mission (SRTM) DEM. It has recently become available at 30m for most

of the globe, but we chose to derive watershed characteristics from a coarser (500m) resolution product because, 1. it's much faster to process and 2. there were no significant differences with parameters previously derived from the higher resolution CDED product. Several layers are derived from the DEM:

a. The hillshade image (using an azimuth of 180° and altitude of 45° with shadows, a.k.a. Solar Exposure),

b. Slope in % (rise/run),

c. Median Elevation,

2. Glacier coverage: We used the 1:50k NTS glacier coverage database

3. PRISM Annual Precipitation: Produced by the Oregon Climate Center (Daly 2002). This regression model uses data from local long-term meteorological stations along with DEM data to estimate the local (1km² pixels) precipitation. We only considered annual precipitation since Sentlinger & Metherall (2016) found no significant predictive power was gained going to monthly precipitation estimates.

4. Annual Potential Evapo-Transpiration (PET) (Trabucco 2009): This variable is globally available and takes into account solar radiation and temperature.

We investigated Bio-geoclimatic Zones and Surficial Geology, as they did in Moore (2012) and Trubilowicz (2013), however both datasets were constrained to BC and many of the catchments in the study area originate outside of BC. We therefore left these possibly valuable predictor variables for future studies when they can be expanded outside of BC.

2.2.2.1 Freshwater Atlas Assessment Watershed

The BC Freshwater Atlas database is a very useful, accurate, and comprehensive dataset based on 1:20k mapping of water features. We used it for several purposes:

- mapping of lakes, rivers, streams, and
- determination of upstream drainage areas (UDA) of assessment watersheds.

Once the multivariate regression model is developed, the predictive variables must be defined for the Upstream Drainage Area (UDA) for every assessment watershed in the study (4618 in total). Defining the UDA for every assessment watershed is not trivial; the assessment units are not necessarily hydrologically valid catchments, but rather "management units" unrelated to drainage, which renders this task very time-consuming. For a full discussion of the issues around defining the UDA, see Sentlinger (2015).

In order to define predictive variables that properly represent the flow through the assessment polygon, it was necessary to first process the DEM for the region with a hydrological model to determine Drainage Points (DPs) and UDAs. We then chose the largest UDA for each assessment watershed as being representative of that assessment watershed.

2.3 Multivariate Regression Model

In this section, we describe the relationship between the predictor variables and the hydro-stat being modeled. When we describe the relationship we use these arbitrary guidelines:

- a very strong relationship is with an R^2>0.80
- a strong relationship is between 0.50 and 0.80
- a moderate relationship is between 0.20 and 0.50
- a weak relationship between 0.05 and 0.20
- and a non-existent relationship below 0.05.

A GeoSpatial Multiple Regression model (GMRm) has being developed to estimate the various streamflow stats, as per Sentlinger & Metherall (Sentlinger & Metherall, 2016). This includes Monthly Distribution (%MD), Mean Annual unit-Runoff MAR), Summer (Jun-Sep) 7Q10/MAD, Annual 7Q10/MAD, and MmmQ10/MAD. The Monthly average 10 year return period flow is not technically a running 30 day average, it's essentially a 30 day average centered on each calendar month. The results of all models are shown in Table 1 to Table 7. In total, 162 models have been developed and the results of each model pasted into these tables. The tables are then applied to the assessment polygons for the 4618 study catchments in the RSEA study area.

To apply these models to a study catchment, first the geospatial stats were calculated for the UDA of the DP in the assessment polygon. Next, the regression equation for the hydro-stat of interest and the corresponding HZ was used to calculate the hydro-stat for that DP.

We generated maps for the predictor variables and HZs. The maps in the 100 series are now:

1. 100: WSC Stations- Shows location of WSC stations used in study, along with unused stations, validations sites, and anomalous stations.
2. 101: PRISM Annual Precip-Shows annual precipitation.
3. 102: Potential EvapoTranspiration-Shows annual PET.
4. 103: Slope-Shows slope as a percent.
5. 104: Hydrological Zone and Solar Exposure: Shows the HZ to which the WSC has been assigned (for example if a WSC has its DA primarily in a zone different than where it is located) overlaid on the solar exposure (modidifed hillshade) image.
6. 105: Elevation- Shows the elevation.

These can be used to help understand the regional variability and results of the modeling. While WSC Stations and HZ are not predictor variable, they help understand how the models were trained and applied.

2.3.1 Predictor Variables

The predictor variables used in the multivariate model were chosen based on available data, parameters we found to be significant from Sentlinger&Metherall (2016), and discussions with colleagues and with Ministry of Forests, Lands, Natural Resources and Rural Development (FLNRORD) staff. We were able to delineate catchments for all 108 WSC stations in Ahmed (2015). We were therefore able to determine predictor variables for each of them. Predictor variables were:

- Median Elevation ('Med.Elev.') in mASL calculated from FWA UDAs and SRTM DEM and verified against Ahmed (2015).

- Glacier Coverage ('Glc') expressed as a % of DA: derived from the NTS glacier coverage polygons

- Annual Precipitation ('Precip') in mm/year: the average annual precipitation over a catchment polygon from PRISM.

- Annual Potential Evapo-Transpiration ('PET') in mm/year: "Potential Evapo-Transpiration (PET) is a measure of the ability of the atmosphere to remove water through Evapo-Transpiration (ET) processes[10] (Trabucco, 2009) describes the PET as:

  Monthly average PET (mm/month) according to the Hargreaves method requires monthly average geo-datasets of 1) mean temperature (Tmean, C°); 2) daily temperature range (TD, C°) and 3) extra-terrestrial radiation (RA, radiation on top of atmosphere expressed in mm/month as equivalent of evaporation), as shown below
  *PET = 0.0023 * RA * (Tmean + 17.8) * TD0.5 (mm / month)* (2)

  TD is an effective proxy to describe the effect of cloud cover on the quantity of extra-terrestrial radiation reaching the land surface and, as such, it describes more complex physical processes with easily available climate data at high resolution.

- Drainage Area ('DA') in km^2 taken from Ahmed (2015) and verified by FWA UDAs.

- Solar Exposure ("SolExp") in % of maximum: as a surrogate variable in order to capture the effect of shadows, slope, and aspect together, a hillshade image was derived with shadows. The azimuth setting was 180° (due south) and the altitude was 45°. The maximum value is 255 and each raster cell received a value between 0-255 depending on it's solar exposure.

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[10] . The FAO introduced the definition of PET as the ET of a reference crop under optimal conditions, having the characteristics of well-watered grass with an assumed height of 12 centimeters, a fixed surface resistance of 70 seconds per meter and an albedo of 0.23." (Trabucco, 2009)

- Average Slope ('Slope') in %: the average slope between adjacent pixels over a catchment polygon

We began by looking at the single regression results between all predictor variables for each of the 7 zones for MAR, S-7Q10/MAD, and A-7Q10/MAD. These are shown in Figure 12 to Figure 32. Because there are 21 figures, only salient features are summarized below. For detailed observations, please see the notes under each figure.

Only a single FWA catchment was included in HZ 13, which we learned after developing the first 15 models. The Low Flow stats were therefore not developed. We also realized that the northern catchments in HZ3 were unique from those in the South (below BCAlbers N1,600,000 or roughly Geddes Creek). And lastly, both HZ7 and HZ12 were relatively sparsely sampled and generally were in clusters in Figure 12 to Figure 32, so we grouped them. Therefore the 6 HZ discussed primarily are 3N, 3S, 4, 6, 7+12, and 8. We found that we could satisfactorily develop models for Zone 3N and 3S together for most hydro-stats except low-flow stats. Looking at MAP104, we can see that those WSC stations with a significant portion of their drainage area in the Yukon have been designated HZ 3N. When assigning a HZ to the FWA assessment polygons a threshold of N1,600,000m BC Albers was used between 3N and 3S. In the end, only A-7Q10/MAD is different between the 2 zones, but we retain the division for future iterations and analysis.

We note that Obedkoff (1998) originally defined this region as Zone 4: Liard Basin with this description:

> *The Liard Basin zone is bounded to the west and south by the Cassiar and Rocky mountains, and to the East by the Liard River. The western part of the zone is the flat Liard Plains; the eastern part is made of the fading Rocky Mountains or Liard Plateau. Precipitation is consistent throughout the zone, and similar to that of the Great Plains to the east. Permeability is better in the western part of the zone; the eastern part of the zone contains the shales of the plains.*

The zone was subsequently redefined and merged with southern regions as subzone p in Obedkoff (2000), then redefined as Zone 3 in Ahmed (2015). We believe our analysis suggests it should remain as a subzone and it's defined as 3N in this report.

We considered developing a single model for all zones, but the current approach of deriving response variables (hydro-stats) for each Hydrological Zone (HZ) integrates inherent biogeoclimatic and surficial variables within the regionalization. Figure 12 to Figure 32, discussed below, show that no predictor variables cover the entire range of HZ and hydro-stats. Only regionalization can group the data into clusters with significant correlations.

2.3.2 S-7Q10/MAD Predictor Variables

The Jun-Sep Summer-7Q10/MAD hydro-stat is not necessarily the lowest flow in the RSEA study area; more often the low flow period is winter. However, summer may be the period of greatest biological activity and critical life stages of biota; it may also coincide with the most active human activity and resource extraction. Therefore it is still considered a critical flow parameter.

Figure 12 shows the relationship between S-7Q10/MAD and DA. A Strong (R^2>0.5) positive relationship is seen in HZ 4 and 7. The slope is positive but weak to moderate with DA in the other HZ and is on of the chosen predictor variables in each HZ model for both A-7Q10/MAD and S-7Q10/MAD (except HZ6) according to Table 1 to Table 7.

From Table 1 to Table 7, we see that PET (Figure 15) and %Slope[11] (Figure 18) and Glaciation (Figure 14) are also significant predictor variables. Glaciers are not prevalent in the study area, but where they exist they almost always have a positive influence on the S-7Q10/MAD. They occupy more than 1% of the catchment in 6 of the 103 WSC study catchments, and occurs as non-zero value in 45 of the 103 WSC study catchments. The Glacier variable is used in 12 of the 62 models, which is an indicator of its relative importance.

There is no analogous low-flow stat for Chapman (2018).

2.3.3 MAR Predictor Variables

The MAR is correlated with PRISM Annual Precipitation in most zones, shown in Figure 21. Some zones have glacier and this almost always is a significant predictor variable where they exist, shown in Figure 24. PET is negatively correlated in Figure 23 in most zones.

In Table 1 to Table 7 we see high R^2 for MAR in all zones. We have not completed a significance test on the predictor variables and leave this endeavor to future iterations of the models. The validation results in Section 4.2 show that the models are working within uncertainty bounds. Our predictor variables are similar to those used by NEWT (Chapman 2018) however, there are some key differences:

1. We develop models for each HZ, although Chapman does develop two regression models for the Northern Interior Plains and the Southern Interior Plains based on the zonation from Obedkoff (2000).
2. Chapman employs a water balance approach using Precip and PET, which is essentially a linear process, whereas we develop multivariate regression modes using a robust 2/3 training approach (described in Section 2.3.6).
3. In addition to Drainage Area, Precip, PET, and Elevation used by Chapman, we also consider Glaciation, Slope and Solar Exposure.

[11] While Median Elevation, %Slope, and PRISM Precipitation are all highly correlated, they are still independent variables. For example, a high elevation plateau can have both low PPT and low %Slope. In general, the regression modeling technique used eliminates multi-collinearity problems by considering the min R2 and only keeping the highest Min R2 model out of 30 iterations of a randomly chosen 2/3 training set.

2.3.4 A-7Q10/MAD Predictor Variables

The Annual 7Q10/MAD is the lowest 7 day average low flow, derived from Ahmed (2015). It can be difficult to model because it can occur in either the later summer or late winter. In general, the low flow period is in late winter in the RSEA study area.

There is a strong positive relationship between Drainage Area and A-7Q10/MAD for most catchments except Zone 3S, 3N, and 6, shown in Figure 26. There is a weak negative correlation in Zone 3N to elevation, primarily driven by Geddes, Smith, and Teeter. Zone 3N shows a weak positive correlation to PET, Zone 12 a strong positive correlation, and Zone 4 a strong negative correction to PET shown in Figure 29.

There is no analogous low-flow hydro-stat for Chapman (2018) or incorporated into NEWT (OWT).

2.3.5 MmmQ10/MAD Predictor Variables

In this study, we undertook a low-flow modeling exercise to achieve monthly low flow estimates. In addition to the Summer 7Q10 (S-Q10) and Annual 7Q10 (A-7Q10) estimates already modeled and readily available in both Ahmed and Obedkoff Inventories, we also derived monthly 10 year return period average flows. These are labeled as MmmQ10. Like other hydro-stats, we modeled the normalized value, MmmQ10/MAD. In order to leverage the Quality Controlled (QC'd) and curated data available within the Ahmed datasets, we used only monthly flow reported therein[12]. This exercise resulted in an additional 72 (6 zones x 12 months) models. These models are documented in Table 1 to Table 6[13]. For both %MD and MmmQ10/MAD models Zones 3N and 3S have been combined.

To get the MmmQ10, for each station record in Ahmed, we developed a Log Normal Probability Distribution Function (PDF) and found the 1:10 year exceedance (10th percentile). This was added to the database as the MmmQ10. We divided by MAD to get the final hydro-stat for modeling. Two examples are shown in Figure 36 and Figure 37. In Figure 36, Kwadacha River in Zone 3 has a very predictable hydrograph and a normal distribution of monthly flows worked just as well as a log-normal distribution. However, when more variance was seen in the monthly distributions, as at Chuchinka shown in Figure 37, the normal distribution no longer was adequate. These records tended to have a skewed distribution with more monthly flows at the lower end with few high monthly

[12] To add a different hydro stat, such as a minimum running 30 day average assigned to each month, would require going back to the original raw daily data and all the Data QC and curation already undertaken by Ahmed and Obedkoff. As a proxy value, we derived the A-30Q10 for all stations in the validation exercise. We then derived an A-30Q10 value from the relationship between Min MmmQ10 and A-7Q10.

[13] We realized early on that only a single study catchment is in Zone 13. While we developed 15 of the models, we stopped there.

flows. Using a Log Normal distribution ensured that the MmmQ10 was always above the minimum recorded MM Q[14].

In addition to these new hydro-stats, we've also added two new stats to every model: AVG and STDEV. This is to give the user a sense of the average value of the hydro-stat and the natural standard deviation of the value within the zone. Compare the STDEV to the STEYX value in each model to determine the improvement of the model over simply assuming the AVG value and STDEV within a zone. The reduction in uncertainty of the hydro-stat is directly proportional to the strength of the correlation, and hence the R^2 value. The columns STEYX% and STDEV% convert these values to % of the AVG and are colour coded to show largest (Red) to lowest (Green).

2.3.6 Model Selection

We considered 2 factors when recommending a model for a Zone and a hydro-stat. The first is correlation strength. This is the resulting Adjusted R^2 between the measured and predicted variable. A maximum of 7 variables were considered. Beginning with the strongest predictor, variables were added stepwise to a multiple linear regression model and the variable which increased the adjusted R^2 by the most was kept until 3 variables were chosen. We found in Sentlinger & Metherall (2016) that 3 variables gave the highest Min R2 values, as discussed below. The Adjusted R^2 is used to give consideration the sample size compared to the number of variables. Adjusted R^2 is given by:

$$R^2 adjusted = 1 - \frac{(1-R^2)(N-1)}{N-p-1} \qquad (3)$$

where p is the number of predictor variables and N is the total sample size. This implies that as p approaches N+1, the adjusted R^2 is very negative; conversely if N>>p, then the adjusted $R^2 \sim R^2$.

The second factor we considered was model robustness. The perennial challenge with developing regression models is that the best model will use all of the samples in the training dataset. However, this leaves the user with no "validation" period to test the robustness of the model. We have developed what we believe is a reliable surrogate for model robustness without sacrificing model accuracy. This is a modified k-fold cross-validation evaluation method.

In this approach, 2/3 of the samples are used in the training dataset, but these samples are randomly chosen and altered for 30 iterations. Figure 33 demonstrates this approach for Zone 7+12: S-7Q10/MAD. In this case, 10 of the 15 samples are randomly chosen and the model is trained 30 times (iterations). The R^2, Adj.R^2 , and model coefficients all use 15/15 samples. The Avg_R^2 is the average R^2 of the 30 iterations using only 10 samples. The Min R^2 is the minimum R^2 from the 30 iterations. The SD_R^2 is the standard deviation in the R^2 of the 30 iterations. Higher R^2 values are achievable when 3 variables are used. With 4+ variables, the

[14] These are Logarithmic plots and often the monthly Q using a normal distribution was negative and does not plot.

model is at risk of being under-conditioned and prone to large error depending on the training set. Model 14 was chosen for this hydro-stat-HZ combination as per Table 5.

Not all models used 3 variables. If better Adj R^2 and Min R^2 occurred with fewer variables, those models were chosen as per Figure 34. In this test, the 2-variable model 8 outperformed the 3+variable models due to its higher Min R^2 value. This is reflected in Table 4.

A diagram of model operation is shown in Figure 35. To reiterate, the model choice is made from performance metrics after training the particular model being considered with 2/3 of the datapoints, sampled randomly, 30 times. The model that gives the highest MinR2, Adj R2, and the fewest number of variables, is the model chosen for a given HZ and hydro-stat. That model is then retrained with all of the datapoints and those R2 and coefficients are reported in the HZ Summary table and used to derive the hydro-stat for a given FWA Assessment Polygon, DP, and UDA within that HZ.

This sensitivity analysis was performed for each hydro-stat+HZ model. Although we checked, using the 11 WSC sites in HZ3N was only significantly better for A-7Q10/MAD than using all HZ3 stations. In most other hydro-stats, Teeter, Smith, Geddes, and Grayling in HZ3N were excluded and considered anomalous and Raspberry in HZ4.

After developing the first 15 models for HZ13 (12x%MD+MAR+S-7Q10/MAD+A-7Q10/MAD) we realized HZ13 only contained a single FWA assessment Polygon in the RSEA study area so no further was done for it, but it's contained in this report for posterity.

2.3.7 Model Implementation

For each FWA Assessment polygon, the 7 predictor variables are multiplied by the 7 factors + Intercept for the hydro-stat and HZ. If this is negative, it is set to zero. These results are presented in the associated electronic files based on the models in Table 1 to Table 6.

A worked example for Kechika-Boya MAR is shown below, compare to results in Table 15:

1. From the associated mapping files for FWA Assessment Polygons and Drainage Points, we find the nearest DP with a similar DA to the published Kechika-Boya WSC station. The WSC DA is 11,276 km^2 and the nearest DP is for FWA 18361 with a DA of 11,004.
2. This DP occurs in Zone 3S.
3. According to Table 2 for Zone 3S, MAR uses Med.Elev. and Glc. Taking the intercept and coefficients from Table 2, and the Geospatial stats from the shp file entitled "merged_20191029.shp", we get the following table:

C:\gsentlin\FATHOM_SCI\CUSTOMERS\RSEA\Data\Validation\[Worked_Examples_V0.1.xlsx]Kechika Boya 2020-01-06 6:36

Intercept	MedElev (mASL)	GLC (%)	PPT (mm)	PET (mm)	DA (km2)	SolExp (%)	Slope (%)
	1457	0.0097	696.2	522.5	11004	0.690	17.97
-8.4	1.56E-02	1.44E+02					

Calculated MAR (L/s/km2)	15.8
STEYX (L/s/km2)	1.76
95%Conf. (L/s/km2)	3.52
Max (L/s/km2)	19.3
Min (L/s/km2)	12.2
WSC MAR (L/s/km2)	13.0
Diff (L/s/km2)	-2.8
Sig Diff @ 95%?	FALSE

Kechika Boya worked example for MAR

Notes

A] Using FWA_ID DP 18361 in Zone 3S

B] From HZ Summary Table for 3S, MAR uses only Med.Elev. and Glc.

Ver 0.1

MAR = -8.4 + 1457*(1.56E-02)+0.0097*(1.44E+02)+0+0+0+0+0 = 15.8

The STEYX (l/s/km²) on MAR is 1.76 l/s/km², from Table 2. The 2*STEYX (95% confidence) limit is 3.52 l/s/km², which, if subtracted from 15.8, is 12.2 l/s/km². The WSC MAR from Ahmed (2018) is 13.0 l/s/km². Given that 13.0 l/s/km² is within the 95% confidence interval, it is not significantly different.

To calculate MAD, use:

MAD = 15.8 l/s/km² * 11,004 km²/ 1000 (L/m³) = 173.8 m³/s

Another worked example is below for January flow for the same catchment, Kechika-Boya.

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Intercept	MedElev (mASL)	GLC (%)	PPT (mm)	PET (mm)	DA (km2)	SolExp (%)	Slope (%)
	1457	0.0097	696.2	522.5	11004	0.690	17.97
5.8	-3.24E-03		9.79E-04				

Calculated Jan %MD	1.75
STEYX (%MD)	0.84
95%Conf. (%MD)	1.68
Max (%MD)	2.59
Min (%MD)	0.07
WSC Jan %MD	1.90
Diff (%MD)	0.15
Sig Diff @ 95%?	FALSE

Kechika Boya worked example for January Q

Notes

A] Using FWA_ID DP 18361 in Zone 3S

B] From HZ Summary Table for 3S, Jan%MD uses only Med.Elev. and PPT.

Ver 0.1

%MD = 5.8 + 1457*(-3.24E-03)+0+696.2*(9.79E-0.04)+0+0+0+0 = 1.75

To calculate the flow at this site in January, use Equation (1) and a MAD of 17.3m³/s from above. Also use the %MD Correction from Section 4.1.1, which can be found by summing all the %MD values, or looking up FWA_ID 18361 in the spreadsheet called "Stewardship_Baseline" in the file "WaterRightsLicenses_UDA_V12.9.1_forReport", which is equal to 99.998 (you must divide by 100 if not using the %MD correction factor because the %MD values are in percent, ie. 1.75 is 1.75%).

January Q = 1.75 * 173.8 m³/s * 365 days /31 days /99.998 = 35.8 m³/s

Which agrees with the January flow in Table 15. The keen observer will note that the 95% confidence interval of 1.68% is very close to the actual value of 1.75%, meaning we can be 95% confident the true value is greater than 0.07% and 2.59%. While this appears to be nearly ±100% of the value, the caution is justified given how low the true value is, and the amount of unexplained regional variability in the value.

2.3.7.1 Extrapolation of regression models outside of the training range

In each of Table 1 to Table 6, below each predictor variable are the Min and Max values used in the training set. We've implemented the same extrapolation methods here as described in "Extrapolation of Multiple Regression Hydrological Results" (Sentlinger, 2017). In that method, if the FWA Assessment Polygon Geospatial Stat is above 115% of the Max or below 85% of the Min, then the GeoSpatial stat is replaced by either 115%Max or 85%Min. This is expected to reduce error associated with extrapolation of the result. It's difficult to know how effective this is at reducing error because all WSC are within the training range. We can say that the extreme values of %MD were reduced to reasonable (0>%MD>100) values. We recommend adding this to list of validation exercises for future work.

2.3.7.2 Anomalous Stations

Anomalous stations in MAP 100 are Geddes, Teeter, Smith, Grayling in Zone 3N (shown in Figure 6) and Raspberry in Zone 4 (Figure 8). Often the hydro-stats from these stations could not be adequately explained from regression analysis. Cursory investigations into the record quality indicated that they are all long-term high quality records indicative of true hydrological conditions in those regions. We did note that Geddes, Smith, and Teeter are all lower elevation, smaller DA catchments, shown in Figure 26 and Figure 27. We also note that The strongest relationship is with PET, shown in Figure 29. The A-7Q10/MAD hydro-stat is the only model that uses a separate model for 3N and includes Teeter and Smith.

Usually, these 5 stations are omitted from the regression as anomalous and we were not able to determine conclusively the reason for their anomalous status, nor find models to satisfactorily explain them (besides A7Q10/MAD). We recommend further work on these 5 stations to better understand the hydrology and update the models to include them. We also note that NEWT was not successful at modeling either the MAR or MMD for Teeter, shown in Table 13. In fact, both FSL-2020 and NEWT estimate significantly higher MAR values with significantly lower low flows.

Karst caused by the erosion of carbonaceous bedrock (Figure 39) may be a factor resulting in the lower than expected values of MAR at these sites. This region is known to have significant karst features (Figure 40). Duplicate hydrometric stations further up or downstream on these systems could help to determine if karst is a significant contributor to the anomaly.

3 WATER ALLOCATION MODELLING METHODOLOGY

The following summarizes the approach taken to estimate net instantaneous water demand on a monthly basis in the RSEA study area.

3.1 Download data

- Information on water licenses was obtained by downloading the 'Water Rights Licenses – Public' dataset from the BC Data Catalogue (current to August 28, 2019)[15].
- Information on short term water use permits was obtained from two sources:
  - Water Approvals issued by the MFLNRORD were obtained from the 'Water Approval Points' dataset available on the BC Data Catalogue (current to August 28, 2019)[16].
  - Water Approvals issued by the OGC were obtained from the 'Short Term Use of Water (Permitted)' available on the BC Oil and Gas Commission Open Data Portal (current to August 28, 2019)[17]

3.2 Review data

Water Licenses

- The number of water licenses in the MFLNRORD dataset was compared to the number of water licenses shown on the NEWT website. Several licenses were inspected to assess consistency.
- Licenses were reviewed and active surface water licenses with a value of '0' in the quantity field were flagged. It was found that there are 88 active surface water licenses with a value of zero in the quantity field.
  - For several licenses, the e-licensing database was queried and the actual license reviewed. In these cases, the 0 was a typo (e.g. an irrigation license with an allocation of 120,000m^3/year). An update to the water license database was deemed outside the scope of this work, so all licenses were not investigated. However, in areas of water stress, it is recommended that the digital water authorizations datasets are compared to the water authorizations PDFs, as missing license and Short Term Use Approval information ***has the potential to under-estimate water demand***.
- All licenses for O&G purposes were reviewed in order to flag licenses that had EFN conditions. Data sources included the e-licensing database and information provided by OGC staff. In cases where there was an inconsistency between the allocated volume in the license PDF and the allocated volume in the MFLNRORD dataset, this was noted so that the most appropriate information

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15 https://catalogue.data.gov.bc.ca/dataset/water-rights-licences-public

16 https://catalogue.data.gov.bc.ca/dataset/water-approval-points

17 https://data-bcogc.opendata.arcgis.com/datasets/fcc52c0cfb3e4bffb20518880ec36fd0_0

could be used in the demand modelling (in several cases, the O&G licenses had complex conditions or EFN restrictions, so a single value in the Quantity field did not fully reflect the licensed allocation). In cases where water licenses had been superseded, this was also identified so that the most current EFN restrictions would be considered in the demand modelling.

Short-Term Use Approvals

- Short-term use approvals in the dataset downloaded from the Open Data Portal were compared to the OGC short term use approvals available on the BC Data Catalogue. This included a comparison of the number and content of records and attributes, to ensure that the dataset used in the study contained the most available attribute information.
- MFLNRORD Regional Water Authorizations and GIS staff were contacted[18] to ensure that the most up-to-date information on MFLNRORD short-term use approvals was used.

3.3 Select records for analysis

- All three spatial datasets were clipped to the RSEA comprehensive area shapefile.
  - Boundary areas were inspected to ensure that there were no allocations just outside the study area that should be included
  - The number of allocations was compared to the number shown in NEWT
- Select current allocations:
  - Water Licenses: Select licenses where LCNC_STTS=Current
  - OGC Short Term: Select approvals where STATUS = Active
  - MFLNRORD Short Term: Select approvals where APP_STATUS=Current
- Select surface water sources:
  - Water Licenses: Select licenses where PODSUBTYPE=POD
  - OGC Short Term: Select approvals where WATER_SO_1= Lake/Pond OR WATER_SO_1= Water Source Dugout OR WATER_SO_1= Water Source Dugout= Stream/River
  - MFLNRORD Short Term: Select all approvals as there is no attribute to differentiate groundwater from surface water sources. The 'Source' attribute is blank for 97% of records. The remainder are surface water sources. To be conservative, it was assumed that these were surface water sources (for many applications, it does not make sense to drill a well for short-term use, so a surface water source would be more likely).

[18] Phil Krausakops (Senior Licensed Authorizations Specialist – Water), July 2, 2019 and Stafford Read (Omineca Geospatial Services Team Lead), July 2, 2019.

- Allocations were spatially joined to the FWA polygons so that they can be summarized by FWA

3.4 Convert allocation quantities to a standard flow rate units of m^3/s

- Water Licenses: The water license data shows allocated volumes for daily, monthly, or annual time periods. Each water record has a 'Quantity Flag' attribute which identifies how the total quantity is assigned across multiple points of diversion for a particular licence and purpose use (e.g. T - Total demand for purpose, one POD; M - Maximum licensed demand for purpose, multiple PODs, quantity at each POD unknown; D - Multiple PODs for purpose, quantities at each are known, PODs on different aquifers; P - Multiple PWDs for purpose, quantities at each are known, PODs on same aquifer). To adjust the Quantity based on the Quantity Flag, a Quantity_Divisor was calculated as follows:
    - T: Quantity_Divisor=1
    - M: Quantity_Divisor=the count of the number of PODs for consumptive water license purposes with the same license number
    - P: Quantity_Divisor=1
    - D: Quantity_Divisor=1

  The adjusted quantity at each POD was calculated as:

  Adjusted_Quantity = Quantity/Quantity_Divisor

  The Adjusted_Quantity was then converted to standard units by multiplying the adjusted volume allocated ("Adjusted_Quantity") by a unit conversion factor (based on the "Units" field) to convert the volume allocated to m^3/s.

    - For records where there was an EFN cutoff, this step was excluded, as extractions for those licenses vary with flows.
- OGC Short Term: This data set shows allocated volume using two fields: Approved Total Volume and Approved Volume per Day. Where an Approved Volume per Day value was available (for surface water sources this was not zero or blank), then the m^3/s value was assumed to be Volume per Day divided by the number of seconds in a day. This was the case for 118 out of 1443 records. Where an Approved Volume per Day was not available (dugout was sources, or 1325 out of 1443 records), then the m^3/s was calculated as the Approved Total Volume multiplied by a monthly coefficient: the Corrected RSEA Average Runoff %MD. These coefficients are shown in the final row of Table 9 and in Figure 2. All Allocations coefficients, albeit cluttered are shown in Figure 3. EFN conditions in short term use approvals were not considered
- MFLNRORD Short Term: This dataset shows allocated volume in units of m^3/s or m^3/day. The allocated volume and units were blank for 1167 out of 1260 records so these allocations were assumed to be 0. For the 93 records

where a volume and units were available, all volumes were converted to m^3/s.

  - Comment: The 1167 records for which there was no information available were held by organizations that have the potential to use large volumes of water (O&G, pulp mills, irrigation). Not including allocations used by these users ***has the potential to under-estimate demands***.

3.5 Categorize water licenses into consumptive and non-consumptive uses based on licensed use

- Water Licenses: Water licenses for storage, conservation, snow-making, power-generation, land improvement, and fish hatchery purposes were assumed to non-consumptive. All other licenses were assumed to be consumptive.
- OGC Short Term: All approvals assumed to be consumptive.
- MFLNRORD Short Term: All approvals assumed to be consumptive.

3.6 For each water allocation, assign monthly allocation and return coefficients for each month of the year based on the allocation purpose.

Monthly allocation coefficients represent the fraction of flow being consumed, and monthly return coefficients represent the fraction of flow being returned to the river. Coefficients were assigned based on the license purpose. Where possible, allocation and return coefficients were used from previous work (Sentlinger & Metherall, 2016).

This step was not taken for licenses with EFN conditions, as estimated withdrawals for those licenses were based on flow conditions. The steps taken to address licenses with EFN conditions are described in Section 3.7.

***'Mapping' Water Allocation Purposes*:** In recent years, the MFLNRORD has updated the water license 'Purpose' categories and the units in which many water licenses are expressed. Because of this, the water license purposes in the study area did not match the water license purposes in prior work (Sentlinger & Metherall 2016). In many cases these licenses were not expressed in similar units as in the past (in prior work, the units in which water licenses were expressed provided meaning in interpreting variations in water license use). Therefore, additional work was conducted to map these new purpose categories to the older purpose categories. A review of the current water license data showed that water license units have been updated and licenses are now generally expressed in the same units, so it was assumed that the 'units' no longer provide information on the yearly distribution of use. Because of this, the units were no longer applied as a consideration in the assignment of allocation and return coefficients.

Generally, the mapping of Purposes was fairly straightforward. For example, the older category "CAMPS & PUB FACIL: WORK C" was now "02I37 - Camps & Pub

Facil: Work Camps” in the Water License dataset and “Work Camps” in the short term dataset. Some were less obvious. For example, “Bottle Sales” became “00C - Waterworks: Sales”.

New Water License Purposes: Some water licenses purposes did not match those used in Sentlinger & Metherall, so background research was conducted to determine appropriate monthly allocation and return coefficients. Generally, these allocations were for industrial purposes. The following ‘new’ purposes were found in the water license dataset:

- 02I06 - Misc Ind'l: Dewatering
- 02I23 - O & G: Oil Fld Inject. (non-deep GW)
- 02I23 - O&G: Oil Fld Inject (non-deep GW)
- 02I24 - Misc Ind'l: Overburden Disposal
- 05B - Mining: Washing Coal
- 05E - O & G: Hydrlc Frctrg (non-deep GW)
- 05F - O & G: Hydrlc Frctrg (deep GW)
- 05H - O & G: Drilling
- 08B - Aquifer Storage: NP

The following ‘new’ purposes were found in the short term approval dataset:

- Equipment (02139)
- Oil and Gas Purpose
- Oil Field Injection (includes Hydraulic Fracturing)

After consulting with OGC Hydrologist Suzan Lapp and MFLNRORD representatives[19] it was determined that these purposes had unpredictable variations in use. For example, Oil and Gas demands tended to be more influenced by economic market conditions than seasons. Therefore, for the new purposes, a consistent yearly distribution of use was assumed.

Comment: *This has the potential to both under-estimate and over-estimate instantaneous demand*.

The monthly allocation and return coefficients for each license purpose are shown in Table 8 to Table 12.

3.7 Estimate mean monthly allocation for water licenses with EFN requirements

Several O&G licenses have EFN restrictions. The EFN restrictions vary with each license. The approach to addressing the conditions is outlined below.

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[19] Pers.Comm. (2019) with Phil Krausakops (Senior Licensed Authorizations Specialist – Water), July 2, 2019. Stafford Read (Omineca Geospatial Services Team Lead), July 2, 2019 and Liia Schilds (Senior Authorizations Technologist – Water), Nov 22, 2019

Note: Many of these licenses with EFN restrictions provided details on where and how streamflow should be measured. For the purposes of this study, demand estimates were based on estimates of flow provided by modelled data at the most downstream point in the FWA polygon.

- ***EFN Condition 1 - Restricted Periods:*** Several licenses had restrictions based on time of year. In months where extractions were not allowed, the estimated monthly extraction value was set to 0.
- Because the water demand is estimated monthly, if a water extraction is allowed for half of a month (this was the case for two licenses: C134054 and C134471), then the maximum amount that can be diverted in that month is assumed. An example is shown below for License C134471:

"Daily withdrawal will not exceed a rate of 8,000 cubic metres per day during the period of November 1 to April 15, and 12,000 cubic metres per day during the period of April 16 to October 31."

- Modelled extraction: In the above example, for the month of April, an extraction of 12,000 cubic meters per day would be assumed.
- Comment: ***This has the potential to over-estimate water demand.*** However, this approach was deemed the most reasonable given the monthly time-step, as the opposite approach (assuming no extraction for that month), has the potential to under-estimate demand at a high-consequence time of year.

- ***EFN Condition 2 – Low Flow Cut-Off:*** For licenses with a low-flow cutoff, it was assumed that no extraction was happening when estimated flows were at or below the flow cut-off. An example of a low-flow cutoff is described below for License 500662:

"e. Water diversion is not permitted when discharge is less than 1.90 m^3/s"

- Modelled extraction: In the above example, the extraction would be $0m^3/s$ for any month with a Mean Monthly instantaneous flow estimate of less than $1.9m^3/s$.

- ***EFN Condition 3 – Maximum Pumping Rate:*** For licenses with maximum pumping rates, the maximum pumping rate was the default value. In cases where the instantaneous max multiplied by the number of seconds in a year is greater than the maximum diversion, the maximum pumping rate is still used. An example of a maximum pumping rate is shown below for license C132688:

"Max 0.01249 cubic metres per second (394,000 cubic metres per year) at a rate not to exceed 40 litres per second"

- Modelled extraction: In the above example, the instantaneous demand is estimated to be 40 litres per second.
- Comment: ***This may over-estimate instantaneous demand.***

- ***EFN Condition 4 – Maximum Daily Diversion:*** For licenses that did not have a maximum pumping rate, but do have a maximum daily diversion, the instantaneous demand was assumed to be the daily rate divided by the number of seconds in a day. An example is shown below for License C134471:

"Daily withdrawal will not exceed a rate of 8,000 cubic metres per day during the period of November 1 to April 15, and 12,000 cubic metres per day during the period of April 16 to October 31."

- Modelled extraction: In the above example, the instantaneous demand in March is estimated to be 0.092592593m^3/s.
- Comment: ***This has the potential to under-estimate instantaneous demand.***

- ***EFN Condition 5 – Low Flow Cut-Off Ranges that Specify Max Pumping Rates:*** For licenses with low flow 'ranges', which specify maximum instantaneous diversions, the maximum instantaneous diversion was assumed:
- An example of these flow ranges is shown below for License 501076:

"The authorization holder is required to implement the following Environmental Flow Needs requirements for Bissette Creek:

- *When discharge is greater than 1.5 m^3/s, limit diversions to no more than 0.15 m^3/s.*
- *When discharge is 1.0 - 1.5 m^3/s, limit diversions to no more than 0.10 m^3/s*
- *When discharge is 0.5 - 1.0 m^3/s, limit diversions to no more than 0.05 m^3/s*
- *Water diversion is not permitted when discharge is less than 0.5 m^3/s*

Water Diversions must never result in discharge immediately upstream of the POD to fall below these Environmental Flow Needs thresholds.

- *Modelled extraction: In the above example, the estimated extraction is 0.10m^3/s for a month where the discharge is between 1.0 and 1.5 m^3/s.*
- *Comment: This approach is assumed to provide a reasonable estimate of instantaneous demand.*

- ***EFN Condition 6 – Low Flow Cut-Off Ranges that Specify Max Daily Diversions***: For the one license with low flow 'ranges', that specifies a maximum daily diversion and no maximum instantaneous, the maximum instantaneous diversion was assumed, as the license reads as if the maximum diversion rate still applies. This approach was chosen as it most accurately reflects the risk to aquatic health (as it is assumed that the same pumping rate would be used in both low flow and high flow conditions, unless a variable pumping rate is specified). An example of these flow ranges is shown below for License 500662:

"e) The maximum quantity of water which may be diverted and used for Oil and Gas purposes is 1,100,000m3/year at a rate not to exceed 0.116m³/s.

…

n) The maximum rates of diversion under the licence vary according to the discharge of the Kiskatinaw River as follows:

a. When discharge is greater than 3.5 m³/s, no more than 10,000 m3/day

b. When discharge is 2.51 – 3.50 m³/s, no more than:

i. 10,000 m3/day during any period in which all other holder of Water Sustainability Act authorizations issued by the Commission to divert water from the Kiskatinaw River confirm by written notice to the Commission that they will not be withdrawing water under those authorizations,

ii. 4,320 m3/day if the licence holder becomes aware that during the period specified in a notice under i, those other authorization holders are withdrawing or have withdrawn water under their authorizations,

iii. 10,000 m3/day during any period in which there are no other Water Sustainability Act authorizations issued by the Commission to divert water from the Kiskatinaw River,

iv. 4,320 m3/day during all other periods.

c. When discharge is 2.01 – 2.50 m³/s, no more than:

i. 4,320 m3/day during any period in which all other holder of Water Sustainability Act authorizations issued by the Commission to divert water from the Kiskatinaw River confirm by written notice to the Commission that they will not be withdrawing water under those authorizations,

ii. 500 m3/day if the licence holder becomes aware that during the period specified in a notice under i, those other authorization holders are withdrawing or have withdrawn water under their authorizations,

iii. 4,320 m3/day during any period in which there are no other Water Sustainability Act authorizations issued by the Commission to divert water from the Kiskatinaw River,

iv. 500 m3/day during all other periods.

d. When discharge is 1.90 - 2.00 m³/s, no more than 500 m3/day

e. Water diversion is not permitted when discharge is less than 1.90 m³/s"

- Modelled extraction: In the above example, the estimated extraction is 0.116m³/s if the flow is greater than or equal to 1.9m³/s.
- Comment: This is a conservative approach and may over-estimate demand at some times during the day. However, unless there has been a misinterpretation of the license, it likely provides a better indication of potential impacts to aquatic health.

- ***EFN Condition 7 – EFN Restrictions Dependent on Other Users:*** For licenses where EFN restrictions vary based on agreements with other users, the agreements with other users are not considered, as it is beyond the scope of this work to identify interacting license conditions.

3.8 For licenses without EFN restrictions, estimate mean monthly allocation

- The mean monthly allocation, expressed in m^3/s, was determined for each licence. This was calculated by multiplying the licensed allocation expressed in m^3/s by the relevant allocation coefficient for the month.

3.9 For licenses without EFN restrictions, estimate mean monthly return

- The mean monthly return flow, expressed in m^3/s, was determined for each licence. This was calculated by multiplying the licensed allocation expressed in m^3/s by the relevant return coefficient for the month.

3.10 For all licenses, estimate net monthly allocation

- The net monthly allocation, expressed in m3/s, was then determined by subtracting the mean monthly return from the mean monthly allocation. In some cases the net monthly allocation was negative because there were months where the return flow was greater than the allocated flow. For example with snow making, water is primarily extracted in November, December, January, and February and water would be returning to the stream as snow melted in March, April, May, and June. Therefore, in the spring months the net allocation would be negative (and the input to stream flow, positive). A similar scenario occurs with water licenses having an irrigation purpose. In the month of January, more water is returned than is taken from a stream by a license for irrigation purposes and so watersheds with a significant amount of irrigation use show negative allocations in January.

3.11 For all licenses, estimate net annual allocation

- The net annual allocation, expressed in m^3/year, was then determined as:

Net Annual Allocation = Total Annual Allocation - Total Annual Allocation * Annual Percent Returned

- where the Annual Percent Returned is the 'Total' Column in Table 2, divided by 12

4 RESULTS

The results of the modeling are presented in Maps and in validation results. The Tables contain all the individual assessment catchment details.

In total, 4618 assessment catchments were characterized for the predictor variables and then model results generated for all 27 hydro-stats. Maps were generated for each hydro-stat so that the user can see visually how the hydro-stat varies across the study area and across HZs. We compared the %MD values for all 6 zones in Figure 4.

Comparing these to the %MD in the Ahmed inventory in Figure 5, we can see general trends that agree:

- Zones 4 & 6 have the lowest winter flows while Zones 3N & 8 have the highest with respect to MAD.
  - This agrees with results in Maps 301, 302, 303, and 202.
- Zones 6 & 8 have large April & May flows while Zones 3S & 3N have lower April flows.
  - This agrees with Map 304 & Map 305
- Zone 8, Zone 6, & Zone 7+12 have the lowest late summer flows while Zone 4 & 3 have the largest
  - This agrees with Map 308 & 309 & 201.

The map series 2xx, 3xx, and 4xx summarize the model output. In general, we want to see smoothness across a Hydrological Zone and also smooth transitions between HZs. A smooth transition in any particular value validates the model to some degree since the hydro-stat is derived independently within each zone. Where there are hard lines between HZ, likely a weak model is in place, but that should be reflected in the uncertainty analysis, and the average for the HZ should reflect the true average.

Circles in the maps are Drainage Points (DPs) or the lowest point within each assessment polygon. We've made the size of each circle dependent on the UDA. Similarly for the WSC triangles. So a triangle and circle side by side of the same size and colour indicates a good match. Note that often a small tributary will join a major river and its DP will be smaller and a different colour than the mainstem. As another mode of validation, larger rivers should keep the same colour as they travel between HZs, like the Liard River from Zone 3 to Zone 4, and the Peace River from Zone 8 to Zone 6.

4.1 Hydrology Regionalization

MAP200 shows the results of MAR in the RSEA study region. Runoff goes from very low (1-5 $l/s/km^2$) in the northeast to 45 in the south. The "Obedkoff Runoff" isolines were derived completely independently but show a reasonable match with our MAR results. There are two areas of green, higher MAR value in Zone 3, but according to MAP105 these are areas of higher elevation. Also MAP101, which shows PRISM Precipitation derived completely independently but based on elevation, indicates that this area has more precipitation. Compare triangular WSC records to circles of the same size.

MAP201 shows the S-7Q10/MAD. This map shows what is expected for each Zone: large late summer flows in the mountains and lower late summer flows in the plains. Notice that where large rivers originate outside of a zone, the river (large circles) maintain the colour of their headwaters. Note that Solar Exposure is a predictive variable for Zone 3 which may lead to unusual results in very small catchments if that catchment only faces one direction (like a hillslope). As expected, DA is a predictor variable in all Zones except 6, where PET and Median Elevation are better predictors

MAP202 shows the A-7Q10/MAD. This is generally the winter low flow except in Zone 8, where it could be in the Summer. Like S-7Q10/MAD, this map shows DA as a positive predictor variable (the larger the circle, the greener the colour compared to nearby smaller circles), except in Zone 3N, where it is slightly negative. It is unknown why it would be negative, except that we know that Geddes, Smith, Teeter all have relatively large A-7Q10/MAD values and are smaller catchments. They are also lower median elevation catchments which also results in lower PET values. We can see the negative DA relationship in Figure 26 and the positive relationship in Figure 29. We recommend revisiting this relationship in future studies along with further investigation into understanding the anomalous stations indicated on MAP100.

MAP203 shows the HZ to which each DP is assigned (and thereby derives its model values). Each DP is assigned to the HZ in which it falls. It could be argued that the DP should be assigned to the HZ where the centroid of it's UDA falls, be we did not do that.

MAP204 shows the A-30Q10. This is a linear function of the A-7Q10 and the Minimum MmmQ10, described in Section 4.2.2.4.

MAP205 shows the Winter-MmmQ10. This is the minimum winter monthly Q with a 10 year return period. MAP201, MAP202, MAP204, and MAP205 use the same colour symbology to allow easier comparison of model results.

4.1.1 %MD Correction Factor

If we sum all monthly %MD values for each of the 4618 FWA Assessment Catchments, they should sum to 100 to be physically realistic. However, each %MD is derived independently from one and other so sum to unity is not built into the GMRm. The average of all these sums is 98% for all 4618 FWA Assessment Catchments. To correct for this small bias, the %MD for each month is divided by the sum of all 12 %MD values for a given FWA Assessment Catchment. These values are shown in the spreadsheet called "Stewardship_Baseline" in the file "WaterRightsLicenses_UDA_V12.9.1_forReport".

4.2 Validation/Evaluation/Verification of Hydrology Model Results

Model validation/evaluation/verification exercises were undertaken by comparing model results from the nearest DP to the WSC record. Given the sparsity of data in the study area, all WSC were used in the model training set. As discussed in Section 2.3.6, the robustness of the model was determined in an alternate fashion (k-fold cross-validation), but we don't have independent long-term datasets for validation. It could be argued this is model verification and model evaluation, but the model does perform within the specific uncertainty (confidence) intervals. For a full discussion of model validation vs evaluation vs verification, see relevant literature in the references (Beven (2013) and Wikipedia).

4.2.1 Validation of NEWT (OWT)

In each validation exercise, contained in Table 13 to Table 33, we also compare hydro-stats to those derived in the NorthEast Water Tool (NEWT) and Omineca Water Tool (OWT), which, to the author's knowledge, use the same methodology described in Chapman (2018). These tools do not generate low-flow stats, nor do they provide uncertainty estimates on each hydro-stat. They do provide general performance metrics in Chapman (2018) which are reflected in the footnotes of every NEWT report:

The hydrologic modeling study conducted in this region employed a water balance approach to estimate runoff in ungauged basins. The model used 45 watersheds with hydrometric gauges, and included detailed information on watershed climate, evapotranspiration, topography, vegetation and land cover. The model was calibrated using stream flow measurements from the Water Survey of Canada, and validated using a leave-one-out cross validation. Error metrics calculated for the entire model domain are: Mean error = 5.5%, Median Error = 3.7%, Mean Absolute Error = 16.1%, Watersheds within +/- 20% = 77.8%.

It's not clear how to interpret these error values or apply them to the NEWT modeling results, however. Is the MAD/MAR value ±5.5%, ±3.7%, or ±16.1%? The uncertainty on the monthly distribution is also not made clear in Chapman (2018). Comparing NEWT results in the validation exercises shown in Table 13 show errors in MAR up to 27%, but closer to 5.5% on average. The monthly error (%Diff) often exceeds ±100% in the low flow months.

4.2.2 Validation Tables and Charts

The following sub-sections describe the components and methods of the validation tables and charts.

4.2.2.1 Performance Metrics

In our validation exercise, we calculate the error on each hydro-stat. Note that all %Diff calculations use the form:

$$\%Diff = \frac{Modeled}{Measured} - 1 \quad (4)$$

Also note that the STEYX values are constant for each Zone in the model units (i.e., %MD, %MAD, and MAR), although they translate to unique values when applied to a given watershed. In Table 13 to Table 33, row 14 labeled "STEYX" in each table is taken from the appropriate table (Table 1 to Table 7) for the given Zone, while row 16 labeled "STEYX x 2" is row 14 multiplied by 2 to get the 95% confidence interval, and translated to a physical unit.

4.2.2.2 Validation Exercise Charts

Below each table are 3 charts.

- The chart on the left is the comparison of mean monthly discharge (MMD) from the WSC record, NEWT, and FSL-2020. The FSL-2020 hydrograph shows error bars with 2 standard deviations (95% confidence interval). The y-axis is logarithmic to focus on low flows.
- The center chart shows just the %MD (in %) and the error bars are 1 standard deviation (representing 67% confidence). The y-axis is logarithmic to focus on low flows.
- The chart on the right is zoomed in on the low flows with the y-axis being linear. The FSL-2020 low flow stats are compared to the WSC stats.

Please note that negative error bars values cannot be shown on a logarithmic plot and have been clipped to positive values.

The MMD error bars do not include the error in the MAD, however (remember from Equation 1, the %MD is multiplied by the MAD to get MMD). If the error in the MAD is added, in quadrature, with the error in the %MD, there are no significant differences in MMD, however the resulting error is relatively large, approaching ±60% in some months. While the error due to %MD alone may be too small to include all deviation from measured in the validation exercise, if the error on the measured values were to be included, there would likely be no significant difference. These preliminary results indicate a reasonable match and are adequate for water allocation modeling, in consideration of the stated uncertainty.

4.2.2.3 Model Values and Uncertainty

Each validation table (Table 13 to Table 33) contains the model derived values, usually expressed as %MAD, converted to m^3/s, and then compared to both the original WSC values, in m^3/s, and to those derived from either the NorthEast Water Tool (NEWT) or the Omineca Water Tool (OWT). The output of these 2 tools is available online from Foundry Spatial Ltd.[20]. It is not known if the NEWT (OWT) hydrological results are hydrological model results, or simply the derived hydro-stats for each WSC station. That is, the NEWT and OWT values for a WSC site may not be a true representation of the model efficiency for ungauged basins.

[20] Not to be confused with Fathom Scientific Ltd (FSL) sharing the same acronym.

Although the FSL-2020 models are trained on the validation sites, the results are a true representation of the model efficiency for the training set.

For each WSC station, we found the nearest FWA Assessment Polygon and extracted the hydro-stats from the models along with the Drainage Area (DA). The WSC record hydro-stats were scaled to the FWA Assessment Polygon DA linearly and values compared.

Below each model results are the uncertainty (STEYX[21]) results for the zone from which the model is derived. These are reported in model values, not to be confused with %uncertainty. For example, considering Kechika-Boya (10BB002) River in Zone 3S (Table 15) if the STEYX value for the A-7Q10/MAD is reported as 0.019 in Table 2 for Zone 3S, this is in units of %MAD and it does not represent 1.9% of the A-7Q10/MAD value. When converted to m^3/s, we get $3.02m^3/s$ (0.019*160 = 3.02) and multiplied by 2x to get 95% confidence we get 6.05 m^3/s. The estimate of A-7Q10/MAD for this catchment is 12%MAD and the MAD is 160 m^3/s, therefore the estimated A-7Q10 is $19.5m^3/s$. When compared to the derived value in Ahmed of $17.3m^3/s$, this is only a difference of 2.2 m^2/s, which is much smaller than the stated uncertainty of $6.05m^3/s$ therefore they are not significantly different at 95% confidence and the row labeled "FSL 95% SigDiff?" is FALSE.

4.2.2.4 A-30Q10

We calculated the A-30Q10 values for each validation record, shown on row 7 on the far right of each validation table. These are derived from the original WSC record and haven't undergone any QA/QC beyond what WSC provides as validated data. These should be compared to the A-7Q10 and minimum MmmQ10 values. In general, the A-30Q10 is slightly larger than the 7Q10 and slightly lower than the minimum MmmQ10. We found the relationship between these two models quite stable, shown in Figure 1. In fact, we were able to estimate the A-30Q10 with an R2 of 0.994 based on an average of the regression value A-7Q30 from the other hydro-stats.

4.2.2.5 Nash-Sutcliffe Efficiency

We also calculated the Nash Sutcliffe Efficiency (NSE) between the MMD of the WSC and each of the models NEWT (OWT) and FSL-2020. The NSE is shown on the left side of each table and discussed in Section 4.2.9 and Equation 5.

4.2.3 Zone 3N: Northern Rocky Mountains-North: Availability Validation

Table 13 shows the results for Teeter Creek (10BE009). Teeter, Smith, Geddes, and to a lesser degree Trout, all show truncated freshets, and therefore lower MADs

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[21] STEYX is shorthand for Standard Error in Y as a function of X. It is similar to standard deviation, but represents the variance of the modeled results about the regression line between modeled and measured results.

than the regional expectation. Therefore all hydro-stats that are divided by MAD appear over-estimated. Interestingly, using the regional MAR from the model results in reasonable low flow estimates shown in these figures, even though MAD and freshet are underestimated. The NEWT results show much lower winter low flows, again suggesting that Teeter creek is regionally anomalous. The range of low flow values (30Q10, A-7Q10, S-7Q10) flank the WSC values, and signal to the user that more in depth study is required.

4.2.4 Zone 3S: Northern Rocky Mountains-South: Availability Validation

Table 14 shows the results from the Ingenika (07EA004) River in Zone 3S. The models are both close to the measured, with FSL-2020 slightly underestimating winter flows. The 7Q10 and MmmQ10 results are very close.

Table 15 shows the results from the Kechika-Boya (10BB002) River in Zone 3S. Here we get much more encouraging results with all three models agreeing very closely. Especially encouraging is the plot on the right of the low flow estimates. Not only are measured and modeled results very close, but the A-7Q10 results are slightly below the MM30Q10 estimates for the lowest flow months in the winter.

Table 16 shows the results for Ospika (07EB002) River in Zone 3S. MAR is slightly low at 15.9 vs 18.5 $l/s/km^2$. Despite this, the low flow values are all very close to the WSC measured values from Ahmed. Not significant differences occurred.

4.2.5 Zone 4: Northern Interior Plains: Availability Validation

Table 17 shows the results for Adsett Creek (10CD005). Like the NEWT, FSL-2020 overestimates flows in the late winter, especially February. However, it would be very difficult to measure flows during this time. What appears like a large difference in February of 304%, is actually only a difference of 10 Litres/second. Adsett A-7Q10 and A-30Q10 are both Zero. These results are considered good. 2 out of the 27 errors are significant.

We wanted to investigate the northeast of Zone 4, which has no long-term gauge sites in either Ahmed or Obedkoff. Investigation revealed that the area is primarily the Petitot River, which has a short-term WSC record on it spanning 7 discontinuous years but with only 2 of those years being validated. The validation results are shown in Table 18**.**

For Petitot, the results are inconclusive. The black line from WSC shows what appears to be an attenuated hydrograph compared to both FSL and NEWT. Investigation revealed only 2 of the 7 years were validated and those 2 years were closer to the modeled results. No further comparison or QA/QC of the Petitot River data was undertaken.

4.2.6 Zone 6: Southern Interior Plains: Availability Validation

Validation efforts focused on Zone 6 because of the activity in this region. We performed validation on all of the Ahmed WSC records within this zone + the short term record at St John Creek (07FD004). Although Beaverlodge, Chinchaga, and Redwillow were included in the Zone 6 training data, they are in Alberta and so there is no comparable FWA Assessment Polygon to compare to.

Table 19 shows the results for Alces (07FD004). In general the results are excellent, but the MmmQ10/MAD in late summer show some error, and the S-7Q10/MAD is high. In this case, NEWT is overpredicting the winter low-flow months.

Table 20 shows the results for Beatton (07FC001) River in Zone 6 and again shows an excellent match. NEWT is overpredicting the winter low-flow months.

Table 21 shows the results for Blueberry River (07FC003). While the shape of the hydrographs are similar, the low flow months are being overestimated by both FSL-2020 and NEWT. It may be that Blueberry is anomalous for this region. The NEWT report shows several water licenses but no significant withdrawals during low flow months. WSC lists this site as Natural (no significant withdrawals or regulation). Looking at the monthly average flows from Ahmed, 1980, 1995, 2001, 2006, and 2007 were all unusually low winter flows. Table 38 shows this study's investigations into allocations. Up to 0.100 m^3/s is estimated to be withdrawn in the winter flow months, while the difference between the monthly flow between WSC and both FSL-2020 and NEWT is 0.20 in January. It is possible that 0.2 m^3/s is being withdrawn since 1964 when both the WSC station began and licenses appeared on the creek. However, after speaking to Dave Hutchinson with WSC and Suzan Lapp of OGC, the discrepancy may be attributed to measurement error in the winter flows resulting in the lower measured WSC flows. It still remains a flagged catchment due to this uncertainty and large number (53) of allocation PoDs in the watershed. We recommend measurements at this site be improved during the winter.

Table 22 shows the results for Halfway-Farrell[22](07FA006) River in Zone 6. The FSL-2020 model results are slightly high for April, slightly outside the 95% confidence limit. The low flow estimates are excellent.

Table 23 shows the results for Halfway River above Graham River (07FA003). Like Halfway-Farrell downstream, the results are excellent.

Table 24 shows the results for Kiskatinaw (07FA003). MAR is a bit high which has resulted in overestimates for Mar, May, and Sep, otherwise the %MDs look good.

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[22] This was incorrectly labeled Halfway-Graham (07FA006) in Ahmed. Although it is below Graham River, 07FA006 is named Halfway River near Farrell Creek and 07FA003 is Halfway River above Graham River.

Table 25 shows the results for Moberly (07FB008). The MAR is a bit low this time, but otherwise other hydro-stats look good.

Table 26 shows the results for Pouce Coupe (07FD007). Although the hydrograph looks quite ragged, FSL-2020 matches pretty well. Looking at the source data, it's the most monthly variance we've seen in any record in this study. NEWT appears to be overestimating the winter flow.

Table 27 shows the results for St John (07FD004) Creek. This station record only has 13 years with data and only 8 complete years. It's inconclusive whether the FSL-2020 model is representing that watershed very well due to the inherent error in the short-term measured record. We can see that at least FSL-2020 matches the NEWT results well, although both overpredict winter flows compared to the short term record. There are many months with Zero recorded flow in the WSC record and the FSL-2020 A-7Q10 is very close to Zero. However the S-7Q10/MAD is 4%MAD. Again the results are inconclusive with only 8 complete years of data.

4.2.7 Zone 8: Nechako Plateau Availability Validation

Table 28 shows the results for Muskeg (08kC003) River in Zone 8. All results are excellent, except Oct-Nov, although nothing is outside of the 95% confidence interval. The 30Q10 for August is much lower than measured. In this case, the low flow period is in the summer and the OWT is overpredicting mean flows.

Table 29 shows the results for Nation River near Fort St. James (08kC003) River in Zone 8. Results are good in the winter, but overestimated in the summer, similar to NEWT. The S-7Q10 is slightly overestimated along with the monthly 30Q10 in the summer. Note that the uncertainty in those months is also high, so the model is working to within defined uncertainty bounds.

Table 30 shows the results for Chuchinka Creek in Zone 8. Our estimate of MAR is a bit low, 13.7 $l/s/km^2$ vs the measured 15.8 $l/s/km^2$. The monthly distribution factors are close except in the highly variable late summer again. A-7Q10 and 30Q10 values are close, but the S-7Q10 is overestimated in FSL-2020, although not significantly at 95% confidence. NEWT is overpredicting summer flows.

4.2.8 Zone 7+12: Southern Rocky Mountain Foothills/MacGregor Basin: Availability Validation

Table 31 shows the results for Murray-Wolverine (07FB006) River in Zone 7. The winter months are lower than measured, as is the S-7Q10.

Table 32 shows the results for Muller (08KB006) Creek in Zone 12. This is the smallest catchment with the highest MAR considered. All FSL results are excellent. We are slightly overestimating the A-7Q10 and winter 30Q10 values, but not significantly ($0.22m^3/s$ compared to $0.34m^3/s$). NEWT is overestimating winter and summer flows.

Table 33 shows the results for Pine (07FB001) Creek in Zone 7. Most results are excellent and NEWT and FSL results are close. There are 4 months in the MmmQ10 results which are slightly overestimated and significantly different at 95% confidence, March, April, June and July.

4.2.9 Summary of Water Availability Validation Exercises

In general, the matches between FSL-2020 predicted hydro-stats and the measured WSC are excellent with only 30 of the 459 measured hydro-stats outside of the 95% confidence intervals. This is a bit larger (6.5%) than the 5% exceedance allowed by the 95% confidence regime[23]. This is considered very good, as it demonstrates the statistics of the uncertainty are also accurate.

In general the FSL-2020 low-flow stats are falling on the conservative (low) side of measured. However, there are two stations where this is very much the opposite, Blueberry in HZ6 and Adsett in Zone 4, in which both NEWT (OWT) and FSL-2020 overestimate the Jan-Mar low flows. We've taken the average %difference between Jan-Mar low flows and (excluding Adsett, Blueberry, Petitot and St John) the average difference between FSL-2020 and WSC is 0.4%. The average difference between NEWT (OWT) and WSC is +14% (low flows are overestimated). If Blueberry, Adsett, Petitot and St John are included, the % difference is +19% for FSL-2020 and +46% for NEWT (OWT). These averages are for the validation exercises only and summarized in Table 34.

Similarly, the %Difference between FSL-2020 MAR and WSC MAR is +5.1% while it is +7.9% for NEWT (OWT) MAR. The largest outliers in this validation set in MAR are Teeter, Petitot, St John and PouceCoupe (NEWT)/Kiskatinaw(FSL-2020). If these four are excluded, the %Difference between FSL-2020 MAR and WSC MAR is +1.1% while it is +1.2% for NEWT (OWT) MAR.

In general the FSL-2020 monthly flows are closer to the observed WSC record than the NEWT results. NEWT (OWT) tends to overpredict low flows. One common metric to measure model performance is the Nash Sutcliffe Efficiency, given by :

$$NSE = 1 - \frac{\sum_{t=1}^{T}\left(Q_m^t - Q_o^t\right)^2}{\sum_{t=1}^{T}\left(Q_o^t - \overline{Q}_o\right)^2} \quad (5)$$

The NSE is similar to R2, but it includes the impact of bias. It essentially compares the model's ability to explain the variability of the dataset and compares it to the average of all the values, asking "how much better is this model at predicting variance than simply taking the average?". A value of 0% suggests it's no better than the mean. A value of 100% suggests it's perfect. A negative value suggests it's worse than the mean. Like R2, it does give more weight to the larger values, i.e. freshet flows. It doesn't compare %difference as we've done for the low flow months above

[23] That is excluding Petitot where 12 of the 15 are significantly different, but the measured values are not considered accurate as only 2 of the 7 years are validated currently. Also excluding Teeter which is considered a special case.

Where the FSL-2020 results diverge from the measured, interestingly they often agree with the NEWT results (Blueberry, Adsett). If the four largest outliers (Petitot, St John, Teeter, Kiskatinaw) are excluded, the average NSE of the validation exercises for FSL-2020 is 95.1% while it is 86.9% for NEWT.

We've prepared a table similar to that in Chapman (2018) to compare to the NEWT model, shown in Table 35. Accompanying figures for 3 modeled hydro-stats are shown below Table 35 and the analogous figure from Chapman (2018) is reproduced on the right. While the FSL-2020 results appear to be more accurate, we are not comparing apples to apples. We considered modeled 95 WSC stations, whereas Chapman (2018) modeled only 45. For this table we used the equation:

$$\text{Mean Bias Error} = (\text{Predicted} - \text{Measured}) / \text{Average}(\text{Predicted, Measured}) \qquad (6)$$

We chose this method as opposed the %Diff equation in (4) because where the measured was Zero or near Zero, the %Diff error was unreasonably large. We don't know how Chapman (2018) calculated MBE. Given these two discrepancies, we can't say that the NEWT and FSL-2020 error estimates for MAR are significantly different.

4.3 Uncertainty Mapping and Gap Analysis

We've prepared an uncertainty and gap analysis. The results are displayed in the Uncertainty maps series, 5xx. Each map is currently paired; the first is the hydro-stat for each WSC Triangle and DP circle. For example, this is MAR in l/s/km² in MAP500. However, the STEYX for each zone, also in l/s/km², colours all of the assessment polygons. The WSC Triangles are twice as large as on other maps to allow the user to see the coverage of monitoring stations. Because there is only 1 value per hydro-stat per zone, the entire zone is one colour. It's difficult to interpret these maps and the relative uncertainty, so the second of the pair of maps shows the STEYX/hydro-stat and in %Uncertainty. Unfortunately, many hydro-stat values are zero (due to very low value and model error). Dividing by zero results in infinity, so these values have been set to 1,000,000.

1. 500: This map shows the MAR and STEYX in MAR. Zone 8 in the Southwest has the highest uncertainty of 3.16 l/s/km² but not the highest AVG MAR, as show in Tables 1-7. The lowest STEYX occurs in Zone 6 in the Southeast, which has an AVG MAR of 4.45 l/s/km².
2. 501: Combining the STEYX with the AVG MAR we arrive at this map which shows a lot of green. In this map the DP circles and the assessment polygons have both been coloured by %STEYX in MAR while the WSC Triangles remain with the value of MAR. Lots of green is good, showing %Uncertainty of <15% (or <30% at the 95% confidence interval). As expected Zone 6 is predominantly green, while Zone 8 is yellow, indicating uncertainty of 20-50%. According to Table 6, in the lower left, there are 22 stations in this region, which is good coverage. But the consistently low R2 values, and resulting higher STEYX values%, suggests better predictor variables are required for this zone. Smaller pockets of Red indicating very large uncertainty are typically associated with very small catchments; there

are no large red circles, except one at the northern border. Of more concern is the larger yellow circles in Zone 7 and 8.

3. 502: This map shows the uncertainty in A-7Q10/MAD much like map 500. This time the lowest STEYX values are in the Zone 4 and the highest are again in Zone 8.
4. 503: Because the A-7Q10/MAD values are so low in Zone 4, primarily for smaller catchments, we see predominantly orange (±50%-100%) in Zone 4 for smaller catchments, but larger catchments are green (±1-10%). Zone 6 shows orange to red for both small and medium size catchments. Zones 7+12 and 8 show moderate uncertainty in this hydro-stat (±15%-50%) and Zone 3 shows the lowest uncertainty. From this analysis, Zone 6 is in the greatest need of additional monitoring, or better modeling, followed by smaller catchments in Zone 4. This tends to be because the A-7Q10 values are so low in this zone. This recommendation would need to be tempered with resource demand in these zones.
5. 504: This map shows the uncertainty in S-7Q10/MAD. The largest STEYX is in Zone 8 in the southeast, but Zone 4 in the northwest is equally large.
6. 505: This map really shows where the deficiency lies in our current modeling, in Zone 4 in the Northwest. This is a combination of sparse data that is poorly modeled, along with very low S-7Q10/MAD values for all of the northwest. Unfortunately, as discussed in the Model Validation, section, Petitot River in this region only has a few years of validated data and does not show particularly low late summer flows. The analysis is correct in suggesting this is a blind spot. Similarly, the center of Zone 6 shows significant uncertainty along with very low S-7Q10/MAD values. Likewise, Table 4 shows some of the lowest late summer flows in this zone and the largest relative uncertainties in the late summer months.

This analysis currently suggests that Zone 4 in the northwest, Zone 6 in the east, and Zone 8 in the Southwest contain the largest modeling/data gaps for low-flows.

4.4 Allocation Modeling Results

The assumptions and methodologies developed in Section 3 were applied to every UDA in the RSEA Study. The results are available as a table, including 27 hydro-stats, monthly and annual Mean Monthly Allocations, monthly and annual 30Q10 Allocations based on EFNs, and %Allocated for each month. This data is available as an electronic file, but also presented in map format in Maps 601, Map 602, and Map 603. The latter map shows the %allocated for each FWA Assessment polygon for A-30Q10 flow conditions.

4.4.1 Allocation Validation

We conducted several validation exercises for the allocations, much like we did for the hydro-stats, shown in Table 36 to Table 43. While we don't have measured results for the amounts withdrawn, we can compare to NEWT and OWT results. To determine which catchments to investigate, we started with the catchments showing the largest %Allocation where the %Allocation within a month is Monthly

Allocation / MMD. Where the MMD is zero, we acknowledge this could be model error or actual, in either case it indicates that the catchment is sensitive to any allocations.

Several MFLNRORD water licenses have EFNs. To capture the sensitivity of the WL to current flow, we've also tabled a row called "MmmQ10 MNFLNRORD License (EFN)." For this entry, the MmmQ10 was input to the WL-EFN model and the allocation results tabled. The Sum Allocation and monthly total allocation values use only the MMD Allocation values, not the MmmQ10 values.

In each table, the %Monthly allocation values have been colour coded from Lowest to Highest of both the FSL-2020 allocation and NEWT (or OWT). Similar coloured cells in the two models (FSL vs NEWT/OWT) represent similar results. Please note that the FSL-2020 monthly allocations flow represent the likely withdrawal rate stipulated by the water license type (based on estimates of seasonal distribution of use), WL conditions (e.g. for OGC licenses with a maximum withdrawal rate), and where applicable, maximum daily use (for STUAs). For most licenses, NEWT (and OWT) use a different approach such that the average of all monthly allocations is equal to the annual allocation divided by the number of seconds in a year. However, this is not always the case.

- The cell labeled "Vol. NEWT (m3/s)" is the volume reported in NEWT
- The cells labeled "Inst. Vol (m3/s)" is the instantaneous rate reported in the monthly columns converted to total volume per year.
- The cell labeled "Inst. Vol: Lic.Vol(%)" is the ratio of these two.

In some cases, the average of monthly allocations in FSL-2020, multiplied by the number of seconds in a year, will likely exceed the annual allocation volume however, because it's an estimate of maximum likely withdrawal rate at any given time within that month.

In the lower right of each table block, three low flow metrics are compared to allocations: %A-30Q10, %A-7Q10, and %S-7Q10. In the two Annual flow conditions, the allocation from the month with the lowest MmmQ10 value (indicated in the top right by Min Mmm and the month in which it occurs) is divided by the hydro-stat. This assumes the EFNs are in full effect during the low flow period. For S-7Q10, the allocation associated with the lowest MmmQ10 in June-September is divided by the S-7Q10.

The final row of the table compares the FSL-2020 allocated value to the NEWT/OWT allocation and expressed as a percentage.

Beside the monthly diversion rate is the total allocated volume per year in m^3. Below this and to the right is the volume divided by the number of seconds per year. Compare this to the average monthly diversion rate. Often the monthly average diversion rate will be larger because the average diversion rate can theoretically exceed the annual divided by #of seconds.

Below each table is the results in chart form, with the y-axis being logarithmic. To the right is a screen capture from Map 200 showing the colour from the Mean

Annual Runoff, the UDA for the study site, and allocation PoDs. The symbology is depicted in MAP602 (Triangle MFLNRORD WL, Circle MNFLNRORD STUA, Star OGC STUA).

4.4.2 Zone 6: Southern Interior Plains: Allocation Validation

Most of the vulnerable sites were in Zone 6 which has both the most allocation and the lowest low flows compared to MAD.

Table 36 shows the results for Pouce Coupe. From the map screen grab, we can see that much of Pouce Coupe is in Alberta and we therefore have not captured all PoDs. The allocation values are 0.047 m^3/s on average for NEWT while the FSL-2020 allocations are lower in the winter and higher in the summer, but average out to 0.0842m^3/s. The allocated volume/s/year agrees with NEWT of 0.05m^3/s which is 1.1% of MAD. In the low flow category (lower right) the instantaneous allocated Q could be up to Infinity% (ie #Div/0!) of the low flow stat because all three low flow stats (min Mmm30Q10, A-30Q10, and S-7Q10) are zero. Note that the sum of the Inst. Volumes in NEWT is close to, 93%, of the total allocated annual volume.

Table 37 shows the allocation validation results for Kiskatinaw River in Zone 6. There are 5 licenses over 14 PoDs in both NEWT and FSL-2020. FSL-2020 estimates an average of 0.019 m^3/s while NEWT estimates 0.01m^3/s in each month. However, where the inst. allocation rate sums to 40,554 m^3/year in FSL-2020, it sums to 31,536 m^3 while the allocated volume in NEWT is only listed as 20,656 m^3/year. Again, the A-30Q10 and A-7Q10 is estimated to be Zero, so this system should be flagged as high risk of over-allocation during low flow periods, which can occur in Winter or Summer.

Table 38 shows the results for Blueberry. The total allocated volume from FSL-2020 is 1,606,316 m^3, while it is 1,666,591 m^3 from NEWT, which is close. However, since the MAD from NEWT is larger, 9.23 m^3/s, than FSL-2020, 8.75 m^3/s, the ratio of %MAD Allocated is 96%. The Inst. Vol. rates are also very close, 0.097 m^3/s compared to 0.089 m^3/s, which is 109%. Up to 82% of the A-30Q10 value could be allocated.

Table 39 shows the results for Upper Blueberry. FSL-2020 and NEWT results are very close for Mmm Inst. Allocations, but because the estimate of MAD for FSL-2020 is a bit higher, the %Allocations are a bit lower. The total allocated volumes are very close.

Table 40 shows the validation results for Unnamed Creek in Zone 6. This is a very simple study with 9,700 m^3/year allocated and an average Diversion Rate equal to the Volume/s/year. In the NEWT report, the same allocated volume is reported but zero monthly inst. diversion rates. It is important to note that the FSL-202 allocations are based on data downloaded on August 28, 2019, whereas the NEWT results are from December 2019, so there may be some variation in the water authorizations.

4.4.3 Zone 7+12 Southern Rocky Mountain Foothills/MacGregor Basin: Allocation Validation

Table 41 shows the results for Atunatche in Zone 7. The estimated OGC STUAs instantaneous Q could account for up to 8% of MAD, but the licensed volume is only 0.06%. The estimated OGC STUA inst. diversion rate could be up to 39% of the Winter Low Flow in February in an average year, or up to 156% in a 30Q10 event. OWT lists Zero STUAs.

4.4.4 Zone 8: Nechako Plateau Allocation Validation

Table 42 shows the results for Manson River in Zone 8. The OWT MFLNRORD licenses are equal for both models, but the STUAs in FSL-2020 are significantly larger, and not included in the OWT, resulting in a large discrepancy. The STUAs could result in 22% of the flow in the winter and 46% during a 30Q10 event.

Table 43 shows the results for Meadows Creek in Zone 8. Again this is a simple catchment with only 4 MFLNRORD WLs. Both FSL-2020 and OWT agree, but the allocated flow could be up to 168% of the A-30Q10 which likely occurs in the winter.

4.4.5 Summary of Allocated

There is good general agreement between NEWT/OWT and FSL-2020. However differences exist. In a few cases, STUAs were not captured by the NEWT/OWT resulting in a potential underestimation of allocated flow. In both cases, the likely instantaneous diversion rate within a given month would often exceed the annual allocated volume if continuing at that rate. In most cases, the ratio of FSL-2020 Annual Allocated Volume close to that of NEWT/OWT. There was one case where the allocated flow volumes were equal, but OWT assigned zero monthly diversion rate. At Atunatche Creek in Zone 8, FSL-2020 estimated up to 38% of the winter low flows but OWT has zero allocations listed.

The closeness of the results in the large catchments of Pouce Coupe and Kiskatinaw validates both models to some degree. Hydrological estimates for the validation catchments were very close, generally no significant difference at 95% confidence interval. Further reconciliation of the allocation results are beyond the scope of this project.

Table A-1 in the appendix includes all FWA assessment polygons for which the PoD count was >0. We have summed all the %allocation values for each of the 3 allocation categories. The table has been sorted by FWA_ID, but also shows the OGC_FID. There are 6 summary columns:

- Max (%Allocated): This is the maximum of the mean monthly allocation values.
- Count: The PoD count for the UDA associated with this FWA Assessment Polygon
- %Alloc_MAD: The % of MAD allocated

- Min30Q10 Mmm: The month in which the minimum MmmQ10 occurs.
- MinMMD Mmm: The month in which the mean monthly Q occurs
- W/S LowQ: Depending on the previous columns, this column indicates the low flow period. If the Min30Q10 Mmm occurs in Summer, while the min monthly flow occurs in Winter, or vice-versa, this column reads W,S.
- %Alloc_A-30Q10: Taking the EFN Adjusted %Allocated in the month in which the Min30Q10 occurs and dividing by the A-30Q10. When A-30Q10 is zero, a value of 10000 is assigned.
- Code: This is a shorthand code to indicate the relationship between the FWA_ID and the UDA. They are:
    - OPA: The border of the UDA extends outside the Project Area
    - OBC: The border of the UDA extends outside of BC
    - EDA: We've determined this to be an erroneous UDA requiring further attention. Usually this is because the UDA is much smaller than the FWA Assessment Polygon
    - UDA: The UDA looks valid.

5 DISCUSSION

In all, 162 hydro-stat models were developed (27 for each Zone, 6 Zones). Analysis indicates they are performing within the stated uncertainty. The upstream drainage catchments were processed for key parameters and the 162 regression models applied. The validation exercises above indicate that the models are performing well, at least as well as the NEWT hydrology model if not more accurately and more conservatively especially during winter low flow periods. Where a model results in a negative value, a natural result of any regression model, we've set the result to zero.

A very detailed Allocation model has been developed and applied to the same 4618 assessment catchments and UDAs. The validation exercise comparing results to NEWT and OWT confirm that, while there are differences in interpretation, the allocation model values are very close.

5.1.1 Watershed Scale Validation Results

We chose several small to medium size watersheds to validate the allocation data against and to compare to NEWT. In general the agreement between NEWT and FSL were good, although there were some missing STUA allocations that were missing from NEWT. We also noted that %Allocation in several months were greater than 5%, notably:

- Pouce Coupe River
- Blueberry River
- Upper Blueberry River
- Manson River

- Atunatche Creek
- Meadows Creek

In general, the allocated water is greater than 20%of the 30Q10 and should be monitored closely in drought conditions.

5.1.2 Licensed Allocations and Net Availability

We've created a few summary tables and maps to give the reader a sense of the spatial distribution and probability distribution of %Allocations.

Table 44 shows some summary statistics for all 4618 FWA Assessment Polygons. From this table we can see that 97% of the assessment polygons have <20% Max Mmm allocations. This includes the 3544 polygons with Zero allocations.

Table 45 shows the stats for just the 1074 FWA assessment polygons which have a UDA PoD count greater than zero. Of these, 84% have a low flow period during the Winter. 3% have their low flow in the Summer and 13% have an indefinite low flow period. 88.7% have a Max Mmm %Alloc less than 20% and 0.4% have a Max Mmm %Alloc >1000%. The %Alloc MAD stats are less startling with the 95%ile being 2.96%MAD. The %Alloc A-30Q10 is a bit more alarming with 20% of the allocations exceeding 81.42% of the estimated A-30Q10 value. The 95%ile value requires explanation; when the A-30Q10 is estimated to be zero, the Allocation/Zero is a Div/0 error so we've replaced these error values with 100000%. The same is true in Table 44 when the A-7Q10 is zero. Most assessment polygon counts exceeding a threshold are the same between Table 44 and Table 45, except A-30Q10 for this reason. 116 of the 477 (477-116 = 361) polygons have a PoD count of Zero and an A-30Q10 of Zero.

In each of the summary maps, only those FWA Assessment Polygons with a PoD count > 0 have been coloured and the size of each DP is proportional to the #of PoDs in the UDA.

Map 600 shows the Maximum Mmm %Allocation value. Where the estimated monthly flow was zero, this value has been replaced by 10000. This is the case on the Peace River in Zone 6

Map 601 shows the %of MAD allocated for each UDA. Zone 6 shows the most colour.

Map 602 shows the Pod Count and again Zone 6 is the most thoroughly utilized.

The %Alloc A-30Q10 stats can be seen spatially in Map 603. This map shows the %allocated for every FWA polygon with a Point of Diversion Count>0. The colour is a function of both %allocated but also availability. From this Map, the reader can see the sensitivity to allocation in Zone 6 in particular, as well as Zone 4. This is both due to resource allocation pressures, as well as low flow availability in the low flow months, i.e. winter in these zone.

Map 604 is the same as Map 603 but with the larger FWA Watershed Groups overlaid.

5.1.3 Groundwater Use

Estimations of groundwater demand were outside the scope of this project. This is not a conservative approach and limits the results. It is recommended that any future assessments of water supply and demand in the region consider groundwater authorizations, especially shallow groundwater use. This would provide more realistic and conservative results and ensure consistency with the WSA.

5.1.4 Dugout Use

Demand from dugouts were only partially considered in this project, due to the exclusion of groundwater demand. The WWG recommended that dugout water use authorized by the OGC be included and dugout use authorized by MFLNRORD be excluded. This is because the dugout water source is defined differently in the water license applications procedures for the different agencies. The OGC definition of the dugout water source includes surface water sources, whereas the MFLNRORD definition of a dugout water source does not include surface water sources. In future work, it is recommended that groundwater demand be considered and dugout water sources be included from both agencies. In addition, it is recommended that the dugout water source is defined consistently by both agencies.

5.1.5 Climate Change

This modeling exercise does not include climate change results. However, each hydro-stats includes model uncertainty. If the user wanted to implement a conservative estimate of the hydro-stat based on climate change, they could take the 95% confidence limit. Often, for low flows, this results in a zero or negative value.

A more detailed study would be needed to assess how climate change would affect water availability in individual watersheds. Complex processes that may affect water availability include melting permafrost and changes in glacier area and volume

5.1.6 Limitations of Water Availability and Allocation Models and of Model Validation

Models are wrong, by definition. However, we can validate the model performance with metrics. We have reported the uncertainty on every variable derived by the 162 independent models and our validation exercises have shown that model results are close to the 95%confidence mark. However, the model has not been fully validated against independent datasets. This is partly because the dataset is so sparse in the northeast, we felt it was prudent to use all available data to train the models, rather than leaving some out. We did use a modified k-fold cross-validation method to choose the best model, however, which efficiently helps to choose the most robust model.

The water availability model limitations, which also apply to NEWT (OWT), are as follows:

1. There was no independent validation data that was not used in the training of the models
2. The uncertainty estimates of the regression equation apply only the domain of the training set (range of predictor variables). Out side of this domain is extrapolation and the uncertainty would only increase.
3. Implicit in this domain problem, is the tendency for gauging stations to be situated on larger, lower elevation catchments. Therefore, smaller and higher elevation catchments will often be estimated by extrapolation.
4. We did not include any groundwater influences in the models, although those may be implicit in the choice of predictor variables such as slope.
5. We did not constrain low flow values to pass through the origin, therefore when a predicted low-flow value is negative, we have simply set these to zero.
6. We did not include the effect of water diversions on the low flow values. All stations used are listed as "Natural", which by definition implies no more than 10% of the natural monthly mean flow is diverted (Hutchinson 2020).

The water allocation limitations, which also apply to NEWT (OWT), are as follows:

1. Not all EFN conditions on STUAs were implemented
2. Groundwater licenses were not considered, except shallow dugout licenses for O&G

5.1.7 Intended Purpose of Modeling Results

The results of this modeling are intended to provide an independent regional estimates of water availability and allocation, at the time of writing. It is not intended to be the sole source of information when making water allocation decisions or infrastructure design. Users of these models and results are reminded to consider the associated uncertainty.

5.1.8 Further Work

In the future, this project would benefit from further work in both water availability modeling and allocation estimation.

5.1.8.1 Further Availability Modeling

a. Surficial, Bio-geoclimatic, or Aquifer Mapping as predictor variables in the GMRm. This would require data spanning into Yukon and

Alberta and our currently available datasets are limited to the BC border. We hope this work would improve low-flow modeling results in all regions

b. Low-Flow scaling factors drawn from the lowest point in the training dataset (or 15%lower, for example) to the origin such that negative model results don't occur. Again, this would reduce the uncertainty around low-flow results.
c. Integration of temperature influences and climate change impacts in a physically justifiable manner. This would allow decision makers to make more robust decisions resilient to climate change impacts.
d. Interpolation to a weekly or daily timescale. This would allow decision makers to assign a finer granularity to allocation decisions.
e. Investigate and improve regression modeling results at anomalous WSC stations Geddes, Teeter, Smith, Grayling, and Raspberry. This will improve all results in Zone 3 and Zone 4.
f. Implementation of the GMRm in an interactive GIS manner, much like we did for the South Coast region in the Watershed Information Tool (WIT). This would allow users to access the results of this work in an interactive and more efficient manner.
g. Further testing of multivariate regression significance, independence, covariance, normalcy, and multi-collinearity. These factors may influence the predictor variables used for each model, or explain why certain models performed better than others. This may refine the model results, improve accuracy, reduce uncertainty, and make the work more defensible.
h. Further testing of validity of method used for extrapolation of hydro-stats. This work may make the model results more accurate, reduce uncertainty, and make the work more defensible.
i. More detailed groundwater use modeling including shallow groundwater (dugout) use. This will improve estimates of allocations.

5.1.8.2 Further Allocation Modeling

Update water authorization dataset to improve allocation modelling. Recommended updates include:

a. Add information on EFN conditions to digital records, to improve reliability of demand estimates in future models. At a minimum, for STUAs and licenses, include a MAX_DIVERSION_RATE field that identifies the maximum instantaneous diversion.
b. Also, add two fields, identifying the beginning and end of the period of allowed use (e.g. for irrigation licenses, the beginning of the period may be May 1, and the end of the period may be October 31)
c. In sensitive areas, review water licenses to ensure consistency to spatial and digital dataset, and update model to consider max instantaneous demand.

6 CONCLUSIONS AND RECOMMENDATIONS

This report includes derivation of the cumulative allocated flow, expressed annually and on a monthly basis, for the 4618 watersheds in RSEA study area. This report also includes development of several regression models for estimating hydrological statistics (aka hydro-stats) such as Mean Annual unit Runoff (MAR), Mean Annual Discharge (MAD), %Monthly Distribution (%MD), Mean Monthly Discharge (MMD), Summer 7Q10, Annual 7Q10, and Monthly 30Q10. In order to do so, we utilized measured streamflow data from throughout RSEA Study Area, thus completing and validating 162 models, 27 in each of the 6 hydrological zones as defined in Obedkoff (2000) and Ahmed (2015). Our validation exercises suggest these models are operating within the stated error limits.

Gap analysis has suggested that HZ 6 and HZ 4 both require more monitoring or better modeling results. This is based on the ratio between the low flow uncertainty compared to the estimated low flows. HZ 6 also happens to be the area with the most intense resource development is occurring. Specifically, winter monitoring should focus on the Blueberry River to confirm or validate the WSC record, which is significantly lower than the modeling results from both FSL and NEWT. The Pouce Coupe has significant resource development, and while the current allocation is less than 6% of the low monthly winter flows, the A-30Q10, S-7Q10, and A-7Q10 are all estimated to be zero from this model and measured to be 0.11%MAD.

With respect to winter low flow measurements, Dave Hutchinson (manager for BC WSC) has suggested significant uncertainty exists for low flow measurements in the winter. Based on discussions with him, we have determined several ways uncertainty can be reduced:

1. Recession hydrology modeling that could be undertaken to improve winter low flow estimates.
2. Redundant stations could be established on the same watercourse and flow estimates compared to ascertain the uncertainty.
3. More frequent measurements in the winter would also help reduce the uncertainty.
4. Where there is sufficient mixing, dilution gauging can be used under ice for low cost measurements, possibly by local communities.
5. Side-looking or upward looking hydro-acoustic stations could be established for continuous flow measurement under ice.

This all takes more investment, but where allocations approach availability, such as on the Blueberry, the investment would seem warranted. Some of that investment could be from private entities and would be good value if the allocation licenses reflected the true uncertainty in the water availability.

These 162 regression models are applicable to all 4618 FreshWater Atlas (FWA) Assessment, and thus could presumably be utilized for the purposes of Water Allocation activities. However, in order for these regression model results to be applicable, the user must ensure the Upstream Drainage Area (UDA) is similar to that of the study catchment. This can be done by comparing the UDA for the study site to that of the assessment polygon's.

It must be emphasized that hydro-stats presented in this report, and water allocations, may not use the same drainage area that a user of this report is studying. Users of the hydro-stats contained within this document, and described by the regression models, are cautioned to use only model results from a Drainage Area similar in size to the study DA on the same watercourse. If they have access to the UDA GIS layer, they could look up the FWA Assessment Polygon ID to confirm the correct area.

In order to validate the model output, we compared model estimates to both WSC measured data and NEWT (OWT) output available online from Foundry Spatial Ltd. All results were comparable (generally not significantly different at 95% confidence), however FSL-2020 appears to better model low flows. In the few instances where winter low flows were over estimated (for example Blueberry River (07FC003)) the difference could not be explained by upstream licensed/approved diversions. In that specific case, both NEWT and FSL-2020 gave similar winter low flow estimates.

We are limited by the training datasets from WSC which tend to focus on larger and lower elevation watersheds. Where hydro-stats have been extrapolated outside of the training set range (i.e. to higher median elevations or smaller catchments) the results should be carefully considered. The source geospatial variables are included in the file "merged_20191029.shp." This file has all UDAs and DP ID to link back to FWA_ID. The range of training data is shown beneath each predictor variable for each HZ in Table 1 to Table 7.

Our recommendations regarding water licenses and short term use approvals are:

1. Water Licenses: EFN conditions should include a max instantaneous diversion rate. Currently some conditions identify max daily withdrawals, and some identify max instantaneous withdrawals. In some of the cases where a license has an EFN condition and a max daily withdrawal, the license stipulates a max instantaneous rate that is greater than the available flow in the river at the time of EFN conditions. An EFN restriction that specifies a max instantaneous withdrawal would have a better chance of protecting aquatic health. This would also allow better water demand modelling in the future.
2. Short Term Use Approvals: all authorizations should specify a max instantaneous rate, in addition to a max total volume. Currently, several STUAs identify a max withdrawal over two years. Further clarity is needed regarding daily and/or instantaneous maximums, in order to protect aquatic health. This would also allow better water demand modelling in the future.

In summary, the FSL 2020 flow models for the RSEA study area in the northeast of BC are performing well, within the stated uncertainty, and are comparable to the NEWT model outputs. The Allocation estimates generally agree with NEWT estimates, but offer a finer and more detailed monthly accounting. The addition of low-flow hydro-stats to the model output indicate that many watersheds may be overallocated during low flow periods.

7 ACKNOWLEDGEMENTS

We would like to thank Ron Ptolemy of BC Ministry of Environment for his review and comment on the results with comparison to his HydroMaster database. Thanks to Jaime Cathcart of Knight Piesold Ltd for insight and direction on the various hydro-stats and peer-review letter. Thanks to Dan Moore on suggestions for improving the correlation model. Thanks to Nick Page for providing sound council on the project.

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TABLES

Table 1: Zone 3N: Northern Rocky Mountains-North- Multiple-Regression Hydrological Models

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Zone 3N	Model#	**#Variables**	Intercept	Med.Elev. (1/m)	Glc (1/%)	Precip (1/mm)	PET (1/mm)	DA (1/km2)	SolExp (1/%)	Slope (1/%)	**R2**	**AdjR2**	**STEYX**[A]	**AVG**	**STDEV**	**STEYX%**	**STDEV%**
MAR ($l/s/km^2$)	12	**2**	-8.4	1.56E-02	1.44E+02						83%	82%	**1.76**	**12.35**	**4.20**	**14%**	**34%**
A-7Q10/MAD	8	**2**	-1.42				3.18E-03	-6.62E-07			98%	97%	**0.014**	**0.181**	**0.084**	**8%**	**46%**
S-7Q10/MAD	14	**3**	7.89				-4.08E-03	1.85E-06	-7.58E+00		70%	66%	**0.067**	**0.535**	**0.177**	**13%**	**33%**
Jan (%MD)	8	**2**	5.79	-3.24E-03		9.79E-04					32%	28%	0.84	2.13	0.91	39%	43%
Feb (%MD)	14	**3**	6.94	-5.30E-03		6.36E-04				1.00E-01	54%	49%	0.69	1.76	0.94	39%	53%
Mar (%MD)	14	**3**	7.71	-6.14E-03		8.85E-04				1.19E-01	57%	52%	0.74	1.85	1.04	40%	56%
Apr (%MD)	15	**3**	-0.26	-6.05E-03			1.82E-02			9.60E-02	81%	79%	0.76	2.70	1.57	28%	58%
May (%MD)	13	**2**	-135.34					-1.31E-05	2.14E+02		30%	26%	2.37	13.29	2.67	18%	20%
Jun (%MD)	14	**3**	-3.92	3.66E-02		-1.04E-02				-8.31E-01	58%	53%	3.65	26.11	5.47	14%	21%
Jul (%MD)	9	**2**	5.32	1.11E-02		-1.88E-03					54%	50%	2.00	18.64	2.94	11%	16%
Aug (%MD)	14	**3**	108.01		1.34E+02				-1.39E+02	-8.04E-02	50%	44%	1.26	10.62	1.94	12%	18%
Sep (%MD)	14	**3**	72.09		4.38E+01				-8.93E+01	-1.09E-01	17%	9%	1.10	8.58	1.11	13%	13%
Oct (%MD)	5	**1**	9.47	-1.84E-03							10%	7%	1.18	7.06	1.17	17%	17%
Nov (%MD)	14	**3**	9.73	-6.16E-03	-2.78E+01					1.63E-01	49%	44%	0.71	3.76	1.09	19%	29%
Dec (%MD)	8	**2**	9.10	-5.99E-03						1.17E-01	53%	50%	0.77	2.84	1.10	27%	39%
Jan (30Q10/MAD)	7	**1**	0.61				-8.73E-04				22%	19%	0.034	0.162	0.038	21%	24%
Feb (30Q10/MAD)	17	**3**	3.34		-1.77E+00	-3.15E-04			-4.28E+00		32%	24%	0.038	0.147	0.045	26%	31%
Mar (30Q10/MAD)	9	**2**	1.46			-2.34E-04			-1.69E+00		22%	15%	0.028	0.133	0.032	21%	24%
Apr (30Q10/MAD)	9	**2**	3.11			-4.91E-04			-3.76E+00		33%	27%	0.046	0.174	0.055	26%	31%
May (30Q10/MAD)	8	**2**	1.28	1.55E-04						-4.47E-02	31%	26%	0.267	0.870	0.316	31%	36%
Jun (30Q10/MAD)	8	**2**	-1.34	3.39E-03						-7.05E-02	60%	57%	0.361	2.178	0.561	17%	26%
Jul (30Q10/MAD)	12	**2**	-0.26	1.18E-03	1.12E+01						73%	71%	0.170	1.344	0.324	13%	24%
Aug (30Q10/MAD)	14	**3**	3.97	-6.72E-04			-5.71E-03			5.09E-02	62%	58%	0.139	0.813	0.222	17%	27%
Sep (30Q10/MAD)	14	**3**	3.06	-5.63E-04			-3.88E-03			2.55E-02	44%	37%	0.099	0.646	0.129	15%	20%
Oct (30Q10/MAD)	14	**3**	2.25	-4.71E-04			-2.50E-03			1.38E-02	29%	21%	0.087	0.519	0.102	17%	20%
Nov (30Q10/MAD)	14	**3**	4.23			-3.21E-04	-1.07E-03		-4.56E+00		27%	18%	0.060	0.293	0.069	20%	23%
Dec (30Q10/MAD)	8	**2**	0.85			-2.01E-04	-9.88E-04				22%	16%	0.050	0.211	0.056	24%	26%
Number of Samples[D]	29		Min	897	0%	516	481	209	68%	5	10%	7%				8%	13%
			Max	1644	4%	827	568	104355	72%	22	98%	97%				40%	58%

NOTES

A] Note that the Standard Error is not %error in the variable. If we are estimating the monthly distribution of flows as % of the total flow, the STEYX is the uncertainty in the estimate of this value. For example if the estimated flow in January is 5% of the total flow, and the STEYX is 0.1%, then the estimate is 5.0%+/-0.1%. Similarly for MAR the STEYX is in the units of the variable, which is $l/s/km^{2.}$

B) Orange cells contain R^2 values less than 0.80.

C) The Min and Max define the training range of the model. Beyond these values is extrapolation.

D) For most models 29 samples are used and applied to all of Zone 3, in several cases Geddes, Smith, and Teeter are excluded. In the case of A-7Q10/MAD only these northern catchments are included in 3N,

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Table 2: Zone 3S: Northern Rocky Mountains-South- Multiple-Regression Hydrological Models

Zone 3S	Model#	#Variables	Intercept	Med.Elev. (1/m)	Glc (1/%)	Precip (1/mm)	PET (1/mm)	DA (1/km2)	SolExp (1/%)	Slope (1/%)	R2	AdjR2	STEYX[A]	AVG	STDEV	STEYX%	STDEV%
MAR ($l/s/km^2$)	12	**2**	-8.4	1.56E-02	1.44E+02						83%	82%	**1.76**	**12.35**	**4.20**	**14%**	**34%**
A-7Q10/MAD	11	**2**	1.16					1.82E-06	-1.54E+00		36%	29%	**0.019**	**0.106**	**0.023**	**18%**	**22%**
S-7Q10/MAD	14	**3**	7.89				-4.08E-03	1.85E-06	-7.58E+00		70%	66%	**0.067**	**0.535**	**0.177**	**13%**	**33%**
Jan (%MD)	8	**2**	5.79	-3.24E-03		9.79E-04					32%	28%	0.84	2.13	0.91	39%	43%
Feb (%MD)	14	**3**	6.94	-5.30E-03		6.36E-04				1.00E-01	54%	49%	0.69	1.76	0.94	39%	53%
Mar (%MD)	14	**3**	7.71	-6.14E-03		8.85E-04				1.19E-01	57%	52%	0.74	1.85	1.04	40%	56%
Apr (%MD)	15	**3**	-0.26	-6.05E-03			1.82E-02			9.60E-02	67%	63%	0.58	2.50	1.08	23%	43%
May (%MD)	13	**2**	-135.34					-1.31E-05	2.14E+02		30%	26%	2.37	13.29	2.67	18%	20%
Jun (%MD)	14	**3**	-3.92	3.66E-02		-1.04E-02				-8.31E-01	58%	53%	3.65	26.11	5.47	14%	21%
Jul (%MD)	9	**2**	5.32	1.11E-02		-1.88E-03					54%	50%	2.00	18.64	2.94	11%	16%
Aug (%MD)	14	**3**	108.01		1.34E+02				-1.39E+02	-8.04E-02	50%	44%	1.26	10.62	1.94	12%	18%
Sep (%MD)	14	**3**	72.09		4.38E+01				-8.93E+01	-1.09E-01	17%	9%	1.10	8.58	1.11	13%	13%
Oct (%MD)	5	**1**	9.47	-1.84E-03							10%	7%	1.18	7.06	1.17	17%	17%
Nov (%MD)	14	**3**	9.73	-6.16E-03	-2.78E+01					1.63E-01	49%	44%	0.71	3.76	1.09	19%	29%
Dec (%MD)	8	**2**	9.10	-5.99E-03						1.17E-01	53%	50%	0.77	2.84	1.10	27%	39%
Jan (30Q10/MAD)	7	**1**	0.61				-8.73E-04				22%	19%	0.034	0.162	0.038	21%	24%
Feb (30Q10/MAD)	17	**3**	3.34		-1.77E+00	-3.15E-04			-4.28E+00		32%	24%	0.038	0.147	0.045	26%	31%
Mar (30Q10/MAD)	9	**2**	1.46			-2.34E-04			-1.69E+00		22%	15%	0.028	0.133	0.032	21%	24%
Apr (30Q10/MAD)	9	**2**	3.11			-4.91E-04			-3.76E+00		33%	27%	0.046	0.174	0.055	26%	31%
May (30Q10/MAD)	8	**2**	1.28	1.55E-04						-4.47E-02	31%	26%	0.267	0.870	0.316	31%	36%
Jun (30Q10/MAD)	8	**2**	-1.34	3.39E-03						-7.05E-02	60%	57%	0.361	2.178	0.561	17%	26%
Jul (30Q10/MAD)	12	**2**	-0.26	1.18E-03	1.12E+01						73%	71%	0.170	1.344	0.324	13%	24%
Aug (30Q10/MAD)	14	**3**	3.97	-6.72E-04			-5.71E-03			5.09E-02	62%	58%	0.139	0.813	0.222	17%	27%
Sep (30Q10/MAD)	14	**3**	3.06	-5.63E-04			-3.88E-03			2.55E-02	44%	37%	0.099	0.646	0.129	15%	20%
Oct (30Q10/MAD)	14	**3**	2.25	-4.71E-04			-2.50E-03			1.38E-02	29%	21%	0.087	0.519	0.102	17%	20%
Nov (30Q10/MAD)	14	**3**	4.23			-3.21E-04	-1.07E-03		-4.56E+00		27%	18%	0.060	0.293	0.069	20%	23%
Dec (30Q10/MAD)	8	**2**	0.85			-2.01E-04	-9.88E-04				22%	16%	0.050	0.211	0.056	24%	26%
Number of Samples[D]	29		Min	897	0%	516	481	209	68%	5	10%	7%				11%	13%
			Max	1644	4%	827	568	104355	72%	22	83%	82%				40%	56%

NOTES

A] Note that the Standard Error is not %error in the variable. If we are estimating the monthly distribution of flows as % of the total flow, the STEYX is the uncertainty in the estimate of this value. For example if the estimated flow in January is 5% of the total flow, and the STEYX is 0.1%, then the estimate is 5.0%+/-0.1%. Similarly for MAR the STEYX is in the units of the variable, which is $l/s/km^2$.

B) Orange cells contain R^2 values less than 0.80.

C) The Min and Max define the range applicability of the model. Beyond these values is extrapolation.

D) For most models 29 samples are used and applied to all of Zone 3, in several cases Geddes, Smith, and Teeter are excluded. In the case of A-7Q10/MAD only these northern catchments are included in 3N,

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Table 3: Zone 4: Northern Interior Plains- Multiple-Regression Hydrological Models

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Zone 4	Model#	#Variables	Intercept	Med.Elev. (1/m)	Glc (1/%)	Precip (1/mm)	PET (1/mm)	DA (1/km2)	SolExp (1/%)	Slope (1/%)	R2	AdjR2	STEYX[A]	AVG	STDEV	STEYX%	STDEV%
MAR (l/s/km^2)	14	**3**	5.50	5.21E-03		-1.06E-02				6.16E-01	98%	96%	**0.47**	**7.94**	**2.98**	**6%**	**38%**
A-7Q10/MAD	12	**2**	0.00		3.24E+00			1.11E-06			100%	100%	**0.0019**	**0.033**	**0.047**	**6%**	**140%**
S-7Q10/MAD	17	**3**	-1.83		5.14E+01		3.04E-03	7.02E-06		0.027339813	99%	98%	**0.030**	**0.231**	**0.233**	**13%**	**101%**
Jan (%MD)	14	**3**	18.62	-2.40E-03			-2.75E-02	5.66E-06			96%	93%	0.16	0.65	0.73	24%	113%
Feb (%MD)	8	**2**	5.28				-8.42E-03	6.86E-06			96%	94%	0.13	0.49	0.57	26%	117%
Mar (%MD)	11	**2**	20.75					1.19E-05	-2.92E+01		88%	83%	0.21	0.62	0.56	35%	91%
Apr (%MD)	1	**1**	5.88							-2.71E-01	94%	93%	0.26	3.82	0.99	7%	26%
May (%MD)	1	**1**	-58.70				1.35E-01				85%	82%	2.33	19.91	5.55	12%	28%
Jun (%MD)	15	**3**	-117.46	5.65E-02			1.69E-01			-8.49E-01	94%	90%	0.98	21.32	3.77	5%	18%
Jul (%MD)	9	**2**	730.84	-1.06E-02					-1.00E+03		70%	58%	2.58	21.02	4.35	12%	21%
Aug (%MD)	9	**2**	388.36				4.38E-02		-5.74E+02		85%	80%	1.01	12.94	2.44	8%	19%
Sep (%MD)	14	**3**	304.37	-2.68E-02			-1.46E-01		-2.70E+02		39%	-7%	1.01	7.87	1.19	13%	15%
Oct (%MD)	14	**3**	235.48	-3.00E-02			-1.97E-01		-1.31E+02		97%	95%	0.27	4.46	1.49	6%	33%
Nov (%MD)	12	**2**	1.05		8.41E+01			2.31E-05			82%	74%	0.50	1.75	1.09	29%	62%
Dec (%MD)	11	**2**	8.12				-1.25E-02	1.11E-05			88%	83%	0.35	1.01	0.93	34%	92%
Jan (30Q10/MAD)	8	**2**	2.32					1.40E-06	-3.29E+00		95%	93%	0.016	0.050	0.063	31%	126%
Feb (30Q10/MAD)	8	**2**	2.16					1.27E-06	-3.07E+00		95%	93%	0.014	0.044	0.057	32%	130%
Mar (30Q10/MAD)	8	**2**	1.90					1.28E-06	-2.69E+00		96%	94%	0.013	0.040	0.057	32%	141%
Apr (30Q10/MAD)	15	**3**	8.78				-2.09E-03		-1.05E+01	-1.64E-02	63%	36%	0.054	0.105	0.082	51%	78%
May (30Q10/MAD)	13	**2**	-32.80			1.83E-03			4.68E+01		86%	81%	0.081	0.930	0.203	9%	22%
Jun (30Q10/MAD)	8	**2**	4.11	1.80E-03			-7.23E-03				94%	92%	0.177	1.312	0.693	13%	53%
Jul (30Q10/MAD)	10	**2**	43.67				-9.01E-03		-5.35E+01		89%	85%	0.206	0.947	0.582	22%	61%
Aug (30Q10/MAD)	14	**3**	76.36	-5.67E-03			-3.56E-02		-7.21E+01		98%	97%	0.053	0.471	0.347	11%	74%
Sep (30Q10/MAD)	14	**3**	39.78	-3.05E-03			-2.19E-02		-3.45E+01		99%	99%	0.025	0.313	0.268	8%	86%
Oct (30Q10/MAD)	8	**2**	7.23	-1.01E-03			-1.05E-02				95%	93%	0.044	0.219	0.181	20%	83%
Nov (30Q10/MAD)	8	**2**	4.43	-6.55E-04			-6.46E-03				92%	88%	0.033	0.107	0.106	31%	99%
Dec (30Q10/MAD)	10	**2**	1.94				-3.05E-03			-1.15E-02	97%	96%	0.015	0.069	0.080	22%	116%
Number of Samples	8		Min	555	0%	444	515	109	69%	1	39%	-7%				5%	15%
			Max	1189	1%	659	619	118523	71%	12	100%	100%				51%	141%

NOTES

A] Note that the Standard Error is not %error in the variable. If we are estimating the monthly distribution of flows as % of the total flow, the STEYX is the uncertainty in the estimate of this value. For example if the estimated flow in January is 5% of the total flow, and the STEYX is 0.1%, then the estimate is 5.0%+/-0.1%. Similarly for MAR the STEYX is in the units of the variable, which is l/s/km$^{2.}$

B) Orange cells contain R^2 values less than 0.80.

C) The Min and Max define the range applicability of the model. Beyond these values is extrapolation.

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Table 4: Zone 6: Southern Interior Plains- Multiple-Regression Hydrological Models

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Zone 6	Model#	**#Variables**	Intercept	Med.Elev. (1/m)	Glc (1/%)	Precip (1/mm)	PET (1/mm)	DA (1/km2)	SolExp (1/%)	Slope (1/%)	**R2**	**AdjR2**	**STEYX**[A]	**AVG**	**STDEV**	**STEYX%**	**STDEV%**
MAR ($l/s/km^2$)	14	**3**	19.33			1.30E-02	-3.88E-02			3.56E-01	98%	97%	**0.23**	**4.45**	**2.83**	**5%**	**64%**
A-7Q10/MAD	9	**2**	0.15				-2.51E-04			6.77E-03	87%	84%	**0.013**	**0.021**	**0.035**	**63%**	**166%**
S-7Q10/MAD	8	**2**	1.11	2.62E-04			-2.06E-03				85%	81%	**0.047**	**0.079**	**0.114**	**59%**	**143%**
Jan (%MD)	13	**2**	-3.04				4.82E-03			1.63E-01	94%	92%	0.14	0.67	0.52	21%	78%
Feb (%MD)	13	**2**	-2.78				4.42E-03			1.30E-01	93%	92%	0.11	0.53	0.41	21%	77%
Mar (%MD)	19	**4**	-90.05			1.97E-03	1.58E-02		1.13E+02	2.35E-01	97%	94%	0.08	0.93	0.42	9%	45%
Apr (%MD)	11	**2**	20.04					-4.09E-04		-1.41E+00	91%	88%	1.92	10.92	5.97	18%	55%
May (%MD)	9	**2**	536.27						-7.10E+02	-2.24E+00	91%	89%	2.19	27.00	7.01	8%	26%
Jun (%MD)	13	**2**	28.47	-1.96E-02						2.22E+00	80%	74%	3.05	21.05	6.46	15%	31%
Jul (%MD)	8	**2**	-0.16	1.67E-02				2.98E-04			85%	81%	1.30	16.60	3.21	8%	19%
Aug (%MD)	9	**2**	43.77				-6.06E-02	2.93E-04			80%	74%	1.37	7.80	2.85	18%	37%
Sep (%MD)	15	**3**	-226.68	5.19E-03		-3.82E-04			3.26E+02		78%	66%	0.51	6.47	1.02	8%	16%
Oct (%MD)	8	**2**	1.62	1.92E-03						7.51E-02	53%	40%	0.59	3.73	0.81	16%	22%
Nov (%MD)	9	**2**	-2.77			7.60E-03				8.67E-02	88%	84%	0.29	1.80	0.78	16%	43%
Dec (%MD)	9	**2**	-1.43			3.38E-03				1.27E-01	92%	90%	0.20	1.02	0.65	19%	64%
Jan (30Q10/MAD)	3	**1**	-0.02							1.11E-02	91%	90%	0.014	0.033	0.043	42%	131%
Feb (30Q10/MAD)	9	**2**	0.01			-3.44E-05				9.74E-03	81%	77%	0.018	0.033	0.039	55%	120%
Mar (30Q10/MAD)	1	**1**	-0.01							1.05E-02	94%	94%	0.010	0.032	0.040	33%	128%
Apr (30Q10/MAD)	16	**3**	-13.69	4.56E-04			2.35E-03		1.72E+01		92%	88%	0.024	0.255	0.078	9%	31%
May (30Q10/MAD)	14	**3**	9.58	-4.78E-03		1.17E-02	-1.75E-02				77%	66%	0.168	0.805	0.331	21%	41%
Jun (30Q10/MAD)	8	**2**	7.80			4.35E-03	-1.52E-02				96%	95%	0.128	0.773	0.628	17%	81%
Jul (30Q10/MAD)	16	**3**	1.31				-2.28E-03	2.37E-05		8.86E-02	98%	97%	0.065	0.406	0.422	16%	104%
Aug (30Q10/MAD)	16	**3**	0.83				-1.39E-03	1.36E-05		2.54E-02	96%	94%	0.036	0.155	0.161	23%	104%
Sep (30Q10/MAD)	15	**3**	1.62			-9.25E-05	-2.49E-03			1.71E-02	85%	79%	0.062	0.112	0.152	55%	137%
Oct (30Q10/MAD)	8	**2**	1.08				-1.71E-03			1.60E-02	87%	83%	0.046	0.102	0.120	45%	117%
Nov (30Q10/MAD)	15	**3**	0.51			2.09E-04	-9.67E-04			9.97E-03	92%	88%	0.023	0.070	0.075	32%	108%
Dec (30Q10/MAD)	1	**1**	-0.01							1.46E-02	90%	89%	0.019	0.049	0.057	39%	116%
Number of Samples	11		Min	712	0%	452	545	295	70%	1.4	53%	40%				5%	16%
			Max	1273	0%	657	653	15561	71%	11.4	98%	97%				63%	166%

NOTES

A] Note that the Standard Error is not %error in the variable. If we are estimating the monthly distribution of flows as % of the total flow, the STEYX is the uncertainty in the estimate of this value. For example if the estimated flow in January is 5% of the total flow, and the STEYX is 0.1%, then the estimate is 5.0%+/-0.1%. Similarly for MAR the STEYX is in the units of the variable, which is $l/s/km^{2}$.

B) Orange cells contain R^2 values less than 0.80.

C) The Min and Max define the range applicability of the model. Beyond these values is extrapolation.

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Table 5: Zone 7+12:Southern Rocky Mountain Foothills/MacGregor Basin- Multiple-Regression Hydrological Models

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Zone 7+12	Model#	#Variables	Intercept	Med.Elev. (1/m)	Glc (1/%)	Precip (1/mm)	PET (1/mm)	DA (1/km2)	SolExp (1/%)	Slope (1/%)	R2	AdjR2	STEYX[A]	AVG	STDEV	STEYX%	STDEV%
MAR (l/s/km^2)	1	**1**	-22.80			4.30E-02					92%	91%	**2.87**	**14.72**	**7.98**	**20%**	**54%**
A-7Q10/MAD	14	**3**	-0.05	2.15E-05		7.53E-05		5.21E-06			75%	68%	**0.023**	**0.067**	**0.045**	**35%**	**67%**
S-7Q10/MAD	14	**3**	-0.16	2.22E-04	5.63E+00			1.42E-05			92%	89%	**0.040**	**0.196**	**0.135**	**21%**	**69%**
Jan (%MD)	8	**2**	0.42			9.54E-04		3.78E-05			58%	51%	0.30	1.51	0.45	20%	30%
Feb (%MD)	8	**2**	0.27			7.59E-04		3.76E-05			60%	53%	0.26	1.18	0.39	22%	33%
Mar (%MD)	8	**2**	0.66			6.98E-04		4.49E-05			61%	54%	0.27	1.54	0.42	18%	27%
Apr (%MD)	16	**3**	-191.11				6.44E-02	-8.43E-05	2.29E+02		73%	65%	1.51	6.67	2.81	23%	42%
May (%MD)	14	**3**	29.21	-2.49E-03	-1.97E+02			-2.86E-04			62%	50%	2.60	23.79	4.03	11%	17%
Jun (%MD)	14	**3**	365.69	-1.47E-02			-1.82E-01		-3.06E+02		73%	65%	2.51	25.52	4.64	10%	18%
Jul (%MD)	14	**3**	-58.82			-1.98E-02	1.34E-01			9.00E-01	67%	57%	1.68	15.00	2.80	11%	19%
Aug (%MD)	16	**3**	-12.58		1.65E+02	-4.37E-03	3.79E-02				65%	54%	1.16	7.08	1.87	16%	26%
Sep (%MD)	9	**2**	-24.56	6.91E-03			3.68E-02				81%	78%	0.49	5.98	1.09	8%	18%
Oct (%MD)	14	**3**	7.65	-2.05E-03		6.22E-03	-8.66E-03				84%	79%	0.64	5.96	1.52	11%	26%
Nov (%MD)	8	**2**	1.13	-9.51E-04		3.83E-03					64%	57%	0.70	3.69	1.11	19%	30%
Dec (%MD)	16	**3**	1.43	-8.01E-04		1.39E-03		3.92E-05			51%	36%	0.38	1.99	0.52	19%	26%
Jan (30Q10/MAD)	9	**2**	0.00			8.27E-05		4.78E-06			60%	53%	0.030	0.102	0.046	30%	46%
Feb (30Q10/MAD)	9	**2**	-0.01			7.36E-05		4.78E-06			65%	59%	0.026	0.085	0.043	31%	51%
Mar (30Q10/MAD)	9	**2**	0.00			6.44E-05		4.89E-06			65%	59%	0.026	0.083	0.042	31%	50%
Apr (30Q10/MAD)	14	**3**	-1.69			1.73E-04	2.91E-03	4.56E-06			72%	64%	0.052	0.262	0.095	20%	36%
May (30Q10/MAD)	11	**2**	1.02			1.88E-03				-8.43E-02	46%	35%	0.285	1.693	0.372	17%	22%
Jun (30Q10/MAD)	8	**2**	12.27				-1.78E-02	5.42E-05			49%	39%	0.411	1.728	0.551	24%	32%
Jul (30Q10/MAD)	14	**3**	9.13	8.36E-04				3.15E-05	-1.37E+01		68%	58%	0.214	0.772	0.363	28%	47%
Aug (30Q10/MAD)	18	**3**	8.06	1.16E-03			8.13E-03		-2.01E+01		86%	81%	0.098	0.378	0.250	26%	66%
Sep (30Q10/MAD)	18	**3**	2.99	8.61E-04			5.73E-03		-1.04E+01		85%	81%	0.066	0.276	0.167	24%	60%
Oct (30Q10/MAD)	10	**2**	3.68			5.18E-04			-5.58E+00		84%	81%	0.067	0.307	0.158	22%	52%
Nov (30Q10/MAD)	12	**2**	-0.12			3.14E-04		7.93E-06			87%	85%	0.039	0.215	0.104	18%	48%
Dec (30Q10/MAD)	15	**3**	1.74			1.18E-04			-2.50E+00		71%	62%	0.032	0.134	0.057	24%	43%
Number of Samples	14		Min	942	0	623	548	38	69%	5	46%	35%				8%	17%
			Max	1475	0	1438	630	17956	71%	23	92%	91%				35%	69%

NOTES

A] Note that the Standard Error is not %error in the variable. If we are estimating the monthly distribution of flows as % of the total flow, the STEYX is the uncertainty in the estimate of this value. For example if the estimated flow in January is 5% of the total flow, and the STEYX is 0.1%, then the estimate is 5.0%+/-0.1%. Similarly for MAR the STEYX is in the units of the variable, which is l/s/km$^{2.}$

B) Orange cells contain R^2 values less than 0.80.

C) The Min and Max define the range applicability of the model. Beyond these values is extrapolation.

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Table 6: Zone 8 Nechako Plateau- Multiple-Regression Hydrological Models

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Zone 8	Model#	**#Variables**	Intercept	Med.Elev. (1/m)	Glc (1/%)	Precip (1/mm)	PET (1/mm)	DA (1/km2)	SolExp (1/%)	Slope (1/%)	**R2**	**AdjR2**	**STEYX[A]**	**AVG**	**STDEV**	**STEYX%**	**STDEV%**
MAR ($l/s/km^2$)	14	**3**	70.96			2.65E-02	-6.06E-02		-5.90E+01		83%	80%	**3.16**	**11.70**	**6.48**	**27%**	**55%**
A-7Q10/MAD	1	**1**	0.07					1.54E-05			47%	45%	**0.059**	**0.112**	**0.079**	**52%**	**70%**
S-7Q10/MAD	11	**2**	0.02					3.59E-05		0.011481787	62%	58%	**0.101**	**0.231**	**0.160**	**44%**	**69%**
Jan (%MD)	8	**2**	20.81	-6.76E-03			-1.78E-02				59%	55%	0.79	2.45	1.20	32%	49%
Feb (%MD)	8	**2**	15.75	-5.64E-03			-1.24E-02				62%	58%	0.67	1.99	1.07	34%	54%
Mar (%MD)	10	**2**	8.26	-4.95E-03		-5.69E-04					74%	71%	0.69	2.49	1.31	28%	53%
Apr (%MD)	14	**3**	-165.84	1.57E-02			2.60E-01	-8.66E-04			82%	79%	3.96	9.78	9.08	40%	93%
May (%MD)	14	**3**	43.27				-3.61E-03	-1.66E-03		-1.11E+00	67%	61%	5.67	25.85	9.60	22%	37%
Jun (%MD)	8	**2**	176.93				-2.43E-01			-4.76E-01	79%	77%	4.30	22.03	9.15	20%	42%
Jul (%MD)	14	**3**	43.35				-6.01E-02	7.76E-04		4.05E-01	75%	71%	2.90	12.11	5.68	24%	47%
Aug (%MD)	14	**3**	-1.52				3.28E-03	6.24E-04		4.23E-01	62%	56%	2.35	6.27	3.72	38%	59%
Sep (%MD)	9	**2**	1.08					2.97E-04		2.91E-01	67%	63%	1.38	4.69	2.33	29%	50%
Oct (%MD)	15	**3**	-8.11			3.20E-03	1.44E-02			2.04E-01	60%	53%	0.96	5.07	1.47	19%	29%
Nov (%MD)	11	**2**	7.83	-4.49E-03		1.86E-03					58%	54%	0.84	4.29	1.27	20%	30%
Dec (%MD)	8	**2**	27.01	-8.12E-03			-2.47E-02				66%	62%	0.76	2.93	1.27	26%	43%
Jan (30Q10/MAD)	8	**2**	0.33	-1.82E-04				1.32E-05			51%	45%	0.070	0.173	0.097	41%	56%
Feb (30Q10/MAD)	18	**3**	1.09	-3.57E-04			-9.14E-04	1.12E-05			55%	47%	0.067	0.161	0.097	42%	60%
Mar (30Q10/MAD)	8	**2**	0.40	-2.40E-04				9.65E-06			55%	47%	0.067	0.161	0.097	42%	60%
Apr (30Q10/MAD)	15	**3**	-4.81			8.53E-04	7.54E-03	-1.75E-05			80%	76%	0.145	0.386	0.313	38%	81%
May (30Q10/MAD)	10	**2**	2.55					-9.13E-05		-6.38E-02	40%	34%	0.560	1.688	0.707	33%	42%
Jun (30Q10/MAD)	11	**2**	13.25				-1.90E-02	4.69E-05			90%	89%	0.277	1.641	0.853	17%	52%
Jul (30Q10/MAD)	16	**3**	10.24				-5.59E-03	8.54E-05	-8.96E+00		85%	83%	0.208	0.837	0.532	25%	64%
Aug (30Q10/MAD)	9	**2**	-0.07					5.79E-05		3.73E-02	65%	61%	0.203	0.448	0.335	45%	75%
Sep (30Q10/MAD)	18	**3**	0.31	-3.09E-04				3.10E-05		2.73E-02	65%	59%	0.125	0.325	0.207	39%	64%
Oct (30Q10/MAD)	8	**2**	0.16					1.77E-05		9.34E-03	38%	32%	0.096	0.296	0.119	32%	40%
Nov (30Q10/MAD)	8	**2**	2.49	-6.46E-04			-2.48E-03				57%	53%	0.064	0.256	0.095	25%	37%
Dec (30Q10/MAD)	14	**3**	1.33	-3.87E-04			-1.20E-03	1.17E-05			58%	51%	0.064	0.197	0.096	33%	49%
Number of Samples	22		Min	678	0%	563	552	11	55%	1	38%	32%				17%	29%
			Max	1522	3%	919	692	14212	71%	26	90%	89%				52%	93%

NOTES

A] Note that the Standard Error is not %error in the variable. If we are estimating the monthly distribution of flows as % of the total flow, the STEYX is the uncertainty in the estimate of this value. For example if the estimated flow in January is 5% of the total flow, and the STEYX is 0.1%, then the estimate is 5.0%+/-0.1%. Similarly for MAR the STEYX is in the units of the variable, which is $l/s/km^{2.}$

B) Orange cells contain R^2 values less than 0.80.

C) The Min and Max define the range applicability of the model. Beyond these values is extrapolation.

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Table 7: Zone 13 Upper Fraser Basin- Multiple-Regression Hydrological Models

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Zone 13	Model#	**#Variables**	Intercept	Med.Elev. (1/m)	Glc (1/%)	Precip (1/mm)	PET (1/mm)	DA (1/km2)	SolExp (1/%)	Slope (1/%)	**R2**	**AdjR2**	**STEYX[A]**	**AVG**	**STDEV**
MAR ($l/s/km^2$)	9	**2**	-10.15		9.02E+01	2.84E-02					93%	91%	**1.91**		
A-7Q10/MAD	8	**2**	0.35	-1.48E-04				4.75E-06			76%	69%	**0.012**		
S-7Q10/MAD	14	**3**	0.88	5.53E-04				3.63E-05	-2.30E+00		91%	86%	**0.031**		
Jan (%MD)	1	**1**	5.04	-1.95E-03							83%	82%	0.14		
Feb (%MD)	1	**1**	3.79	-1.46E-03							83%	81%	0.11		
Mar (%MD)	9	**2**	3.97	-1.54E-03				4.21E-05			89%	86%	0.09		
Apr (%MD)	13	**2**	14.93	-6.69E-03	3.30E+00						96%	95%	0.21		
May (%MD)	14	**3**	-26.39					-4.30E-04	6.60E+01	-2.03E-01	65%	49%	1.64		
Jun (%MD)	8	**2**	-63.55						1.52E+02	-5.80E-01	67%	58%	2.86		
Jul (%MD)	14	**3**	42.06	1.28E-02			2.05E-02		-8.07E+01		70%	57%	1.34		
Aug (%MD)	9	**2**	10.93			-1.37E-02				8.77E-01	65%	56%	2.68		
Sep (%MD)	11	**2**	60.58				-3.53E-03		-7.40E+01		52%	40%	0.97		
Oct (%MD)	9	**2**	14.36	-6.11E-03		1.93E-03					87%	83%	0.34		
Nov (%MD)	14	**3**	-7.48	-2.42E-03		1.53E-03	2.34E-02				92%	88%	0.22		
Dec (%MD)	14	**3**	-6.55	-7.96E-04		4.11E-04	1.68E-02				90%	85%	0.14		
Jan (30Q10/MAD)															
Feb (30Q10/MAD)															
Mar (30Q10/MAD)															
Apr (30Q10/MAD)															
May (30Q10/MAD)															
Jun (30Q10/MAD)															
Jul (30Q10/MAD)															
Aug (30Q10/MAD)															
Sep (30Q10/MAD)															
Oct (30Q10/MAD)															
Nov (30Q10/MAD)															
Dec (30Q10/MAD)															
Number of Samples	11		Min	1490	0%	680	533	136	66%	8	52%	40%			
			Max	2017	20%	1512	597	6886	71%	30	96%	95%			

NOTES

A] Note that the Standard Error is not %error in the variable. If we are estimating the monthly distribution of flows as % of the total flow, the STEYX is the uncertainty in the estimate of this value. For example if the estimated flow in January is 5% of the total flow, and the STEYX is 0.1%, then the estimate is 5.0%+/-0.1%. Similarly for MAR the STEYX is in the units of the variable, which is $l/s/km^{2}$.

B) Orange cells contain R^2 values less than 0.80.

C) The Min and Max define the range applicability of the model. Beyond these values is extrapolation.

Ver 0.9

Table 8: Allocation Co-efficients 1/2

PURPOSE - RSEA	m1	m2	m3	m4	m5	m6	m7	m8	m9	m10	m11	m12	Sum
Water License Purposes													
00A - Waterworks: Local Provider	0.85	0.85	0.85	0.85	0.95	1	1.5	1.5	1.1	0.85	0.85	0.85	12.00
00B - Waterworks (other than LP)	0.85	0.85	0.85	0.85	0.95	1	1.5	1.5	1.1	0.85	0.85	0.85	12.00
00C - Waterworks: Sales	0.85	0.85	0.85	0.85	0.95	1	1.5	1.5	1.1	0.85	0.85	0.85	12.00
01A - Domestic	1	1	1	1	1	1	1	1	1	1	1	1	12.00
02A - Pulp Mill	1	1	1	1	1	1	1	1	1	1	1	1	12.00
02B - Processing & Mfg: Processing	1	1	1	1	1	1	1	1	1	1	1	1	12.00
02C - Cooling	1	1	1	1	1	1	1	1	1	1	1	1	12.00
02D - Comm. Enterprise: Enterprise	1	1	1	1	1	1	1	1	1	1	1	1	12.00
02E - Pond & Aquaculture	1	1	1	1	1	1	1	1	1	1	1	1	12.00
02F - Lwn, Fairway & Grdn: Watering	0	0	0	1.2	2.4	2.4	2.4	2.4	1.2	0	0	0	12.00
02G - Fresh Water Bottling	1	1	1	1	1	1	1	1	1	1	1	1	12.00
02I02 - Camps & Pub Facil: Non-Work Camps	1	1	1	1	1	1	1	1	1	1	1	1	12.00
02I08 - Transport Mgmt: Dust Control	1	1	1	1	1	1	1	1	1	1	1	1	12.00
02I12 - Misc Ind'l: Fire Protection	1	1	1	1	1	1	1	1	1	1	1	1	12.00
02I21 - Camps & Pub Facil: Institutions	1	1	1	1	1	1	1	1	1	1	1	1	12.00
02I23 - O&G: Oil Fld Inject (non-deep GW)	1	1	1	1	1	1	1	1	1	1	1	1	12.00
02I24 - Misc Ind'l: Overburden Disposal	1	1	1	1	1	1	1	1	1	1	1	1	12.00
02I25 - Camps & Pub Facil: Public Facility	1	1	1	1	1	1	1	1	1	1	1	1	12.00
02I27 - Misc Ind'l: Sediment Control	1	1	1	1	1	1	1	1	1	1	1	1	12.00
02I30 - Ice & Snow Making: Snow	3	3	0	0	0	0	0	0	0	0	3	3	12.00
02I31 - Livestock & Animal: Stockwatering	0.95	0.95	0.95	0.95	1.05	1.07	1.08	1.08	1.07	0.95	0.95	0.95	12.00
02I33 - Vehicle & Eqpt: Truck & Eqp Wash	1	1	1	1	1	1	1	1	1	1	1	1	12.00
02I35 - Waterworks: Water Delivery	0.85	0.85	0.85	0.85	0.95	1	1.5	1.5	1.1	0.85	0.85	0.85	12.00
02I37 - Camps & Pub Facil: Work Camps	1	1	1	1	1	1	1	1	1	1	1	1	12.00
02I39 - Vehicle & Eqpt: Mine & Quarry	1	1	1	1	1	1	1	1	1	1	1	1	12.00
02I46 - Transport Mgmt: Road Maint.	1	1	1	1	1	1	1	1	1	1	1	1	12.00
03B - Irrigation: Private	0	0	0	0	0	3.6	3.6	3.6	1.2	0	0	0	12.00
04A - Land Improve: General	1	1	1	1	1	1	1	1	1	1	1	1	12.00
05B - Mining: Washing Coal	1	1	1	1	1	1	1	1	1	1	1	1	12.00
05C - Mining: Processing Ore	1	1	1	1	1	1	1	1	1	1	1	1	12.00
05D - Mining: Placer	1	1	1	1	1	1	1	1	1	1	1	1	12.00
05E - O & G: Hydrlc Frctrg (non-deep GW)	1	1	1	1	1	1	1	1	1	1	1	1	12.00
05H - O & G: Drilling	1	1	1	1	1	1	1	1	1	1	1	1	12.00

Table 9: Allocation Co-efficients 2/2

PURPOSE - RSEA	m1	m2	m3	m4	m5	m6	m7	m8	m9	m10	m11	m12	Sum
07A - Power: Residential	1	1	1	1	1	1	1	1	1	1	1	1	12.00
07C - Power: General	1	1	1	1	1	1	1	1	1	1	1	1	12.00
08A - Stream Storage: Non-Power	1	1	1	1	1	1	1	1	1	1	1	1	12.00
08A - Stream Storage: Non-Power (O&G)	1	1	1	1	1	1	1	1	1	1	1	1	12.00
08B - Aquifer Storage: NP	1	1	1	1	1	1	1	1	1	1	1	1	12.00
11A - Conservation: Storage	1	1	1	1	1	1	1	1	1	1	1	1	12.00
11B - Conservation: Use of Water	1	1	1	1	1	1	1	1	1	1	1	1	12.00
11C - Conservation: Construct Works	1	1	1	1	1	1	1	1	1	1	1	1	12.00
12A - Stream Storage: Power	1	1	1	1	1	1	1	1	1	1	1	1	12.00
WSA01 - Domestic (WSA01)	1	1	1	1	1	1	1	1	1	1	1	1	12.00
WSA02 - Camps & Public Facilities	1	1	1	1	1	1	1	1	1	1	1	1	12.00
WSA03 - Commercial Enterprise	1	1	1	1	1	1	1	1	1	1	1	1	12.00
WSA05 - Greenhouse & Nursery	0	3/25	3/25	6/25	1 1/5	1 17/25	2 22/25	2 22/25	2 1/25	18/25	3/25	0	12.00
WSA07 - Misc Indust	1	1	1	1	1	1	1	1	1	1	1	1	12.00
WSA07 - Misc Indust	1	1	1	1	1	1	1	1	1	1	1	1	12.00
WSA08 - Livestock & Animal	0.95	0.95	0.95	0.95	1.05	1.07	1.08	1.08	1.07	0.95	0.95	0.95	12.00
WSA09 - Processing & Manufacturing	1	1	1	1	1	1	1	1	1	1	1	1	12.00
WSA10 - Well Drill/Transprt Mgmt	1	1	1	1	1	1	1	1	1	1	1	1	12.00
WSA12 - Vehicle & Equipment	1	1	1	1	1	1	1	1	1	1	1	1	12.00
WSA13 - Industrial Waste Mgmt	1	1	1	1	1	1	1	1	1	1	1	1	12.00
Short Term Use Approval Purposes													
Equipment (02139)	1	1	1	1	1	1	1	1	1	1	1	1	12.00
Fire Protection	1	1	1	1	1	1	1	1	1	1	1	1	12.00
Industrial	1	1	1	1	1	1	1	1	1	1	1	1	12.00
Oil and Gas Purpose	1	1	1	1	1	1	1	1	1	1	1	1	12.00
Oil Field Injection (includes Hydraulic Fracturing)	1	1	1	1	1	1	1	1	1	1	1	1	12.00
Other Water Purpose	1	1	1	1	1	1	1	1	1	1	1	1	12.00
Pressure Testing and Flushing	1	1	1	1	1	1	1	1	1	1	1	1	12.00
Road Maintenance	1	1	1	1	1	1	1	1	1	1	1	1	12.00
Storage - Non Power (08A)	1	1	1	1	1	1	1	1	1	1	1	1	12.00
Well Drilling	1	1	1	1	1	1	1	1	1	1	1	1	12.00
Work Camps	1	1	1	1	1	1	1	1	1	1	1	1	12.00
Unspecified	1	1	1	1	1	1	1	1	1	1	1	1	12.00
OGC DUGOUTS	0.24	0.12	0.24	0.72	2.40	2.88	2.04	1.08	0.84	0.72	0.36	0.36	12.00

Table 10: Monthly Return Co-efficients 1/3

PURPOSE - RSEA	m1	m2	m3	m4	m5	m6	m7	m8	m9	m10	m11	m12	Total
Water License Purposes													
02I21 - Camps & Pub Facil: Institutions	0	0	0	0	0	0	0	0	0	0	0	0	0.00
02I02 - Camps & Pub Facil: Non-Work Camps	0	0	0	0	0	0	0	0	0	0	0	0	0.00
02I25 - Camps & Pub Facil: Public Facility	0	0	0	0	0	0	0	0	0	0	0	0	0.00
02I37 - Camps & Pub Facil: Work Camps	0	0	0	0	0	0	0	0	0	0	0	0	0.00
WSA02 - Camps & Public Facilities	0	0	0	0	0	0	0	0	0	0	0	0	0.00
02D - Comm. Enterprise: Enterprise	0	0	0	0	0	0	0	0	0	0	0	0	0.00
WSA03 - Commercial Enterprise	0	0	0	0	0	0	0	0	0	0	0	0	0.00
11C - Conservation: Construct Works	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	12.00
11A - Conservation: Storage	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	12.00
11B - Conservation: Use of Water	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	12.00
02C - Cooling	0	0	0	0	0	0	0	0	0	0	0	0	0.00
01A - Domestic	0	0	0	0	0	0	0	0	0	0	0	0	0.00
WSA01 - Domestic (WSA01)	0	0	0	0	0	0	0	0	0	0	0	0	0.00
02G - Fresh Water Bottling	0	0	0	0	0	0	0	0	0	0	0	0	0.00
WSA05 - Greenhouse & Nursery	0	0	0	0	0	0	0	0	0	0	0	0	0.00
02I30 - Ice & Snow Making: Snow	0	0	3	3	3	3	0	0	0	0	0	0	12.00
WSA13 - Industrial Waste Mgmt	0	0	0	0	0	0	0	0	0	0	0	0	0.00
03B - Irrigation: Private	0.06	0.06	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.06	0.06	1.20
04A - Land Improve: General	0	0	0	0	0	0	0	0	0	0	0	0	0.00
02I31 - Livestock & Animal: Stockwatering	0	0	0	0	0	0	0	0	0	0	0	0	0.000 00
02F - Lwn, Fairway & Grdn: Watering	0	0	0	0.12	0.12	0.18	0.18	0.24	0.24	0.12	0	0	1.20
05D - Mining: Placer	0	0	0	0	0	0	0	0	0	0	0	0	0.00
05C - Mining: Processing Ore	0	0	0	0	0	0	0	0	0	0	0	0	0.00
02I12 - Misc Ind'l: Fire Protection	1/4	1/4	1/4	1/4	1/4	1/4	1/4	1/4	1/4	1/4	1/4	1/4	3.00
02I27 - Misc Ind'l: Sediment Control	0	0	0	0	0	0	0	0	0	0	0	0	0.00
02E - Pond & Aquaculture	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	3.00
07C - Power: General	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	12.00

Table 11: Monthly Return Co-efficients 2/3

PURPOSE - RSEA	m1	m2	m3	m4	m5	m6	m7	m8	m9	m10	m11	m12	Total
07A - Power: Residential	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	12.00
WSA09 - Processing & Manufacturing	0	0	0	0	0	0	0	0	0	0	0	0	0.00
02A - Pulp Mill	0	0	0	0	0	0	0	0	0	0	0	0	0.00
08A - Stream Storage: Non-Power	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	12.00
12A - Stream Storage: Power	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	12.00
02I08 - Transport Mgmt: Dust Control	0	0	0	0	0	0	0	0	0	0	0	0	0.00
02I46 - Transport Mgmt: Road Maint.	0	0	0	0	0	0	0	0	0	0	0	0	0.00
WSA12 - Vehicle & Equipment	0	0	0	0	0	0	0	0	0	0	0	0	0.00
02I33 - Vehicle & Eqpt: Truck & Eqp Wash	0	0	0	0	0	0	0	0	0	0	0	0	0.00
00B - Waterworks (other than LP)	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	1.20
00A - Waterworks: Local Provider	0	0	0	0.12	0.12	0.18	0.18	0.24	0.24	0.12	0	0	1.20
02I35 - Waterworks: Water Delivery	0	0	0	0	0	0	0	0	0	0	0	0	0.00
02B - Processing & Mfg: Processing	0	0	0	0	0	0	0	0	0	0	0	0	0.00
02I06 - Misc Ind'l: Dewatering	0	0	0	0	0	0	0	0	0	0	0	0	0.00
02I23 - O&G: Oil Fld Inject (non-deep GW)	0	0	0	0	0	0	0	0	0	0	0	0	0.00
02I24 - Misc Ind'l: Overburden Disposal	0	0	0	0	0	0	0	0	0	0	0	0	0.00
00C - Waterworks: Sales	0	0	0	0	0	0	0	0	0	0	0	0	0.00
02I39 - Vehicle & Eqpt: Mine & Quarry	0	0	0	0	0	0	0	0	0	0	0	0	0.00
05B - Mining: Washing Coal	0	0	0	0	0	0	0	0	0	0	0	0	0.00
05E - O & G: Hydrlc Frctrg (non-deep GW)	0	0	0	0	0	0	0	0	0	0	0	0	0.00
05F - O&G: Hydrlc Frctrg (deep GW)	0	0	0	0	0	0	0	0	0	0	0	0	0.00
05H - O & G: Drilling	0	0	0	0	0	0	0	0	0	0	0	0	0.00
08B - Aquifer Storage: NP	1	1	1	1	1	1	1	1	1	1	1	1	12.00
WSA07 - Misc Indust	0	0	0	0	0	0	0	0	0	0	0	0	0.00
WSA08 - Livestock & Animal	0	0	0	0	0	0	0	0	0	0	0	0	0.00
WSA10 - Well Drill/Transprt Mgmt	0	0	0	0	0	0	0	0	0	0	0	0	0.00
WSA07 - Misc Indust	0	0	0	0	0	0	0	0	0	0	0	0	0.00
08A - Stream Storage: Non-Power (O&G)	1	1	1	1	1	1	1	1	1	1	1	1	12.00

Table 12: Monthly Return Co-efficients 3/3

PURPOSE - RSEA	m1	m2	m3	m4	m5	m6	m7	m8	m9	m10	m11	m12	Total
Short-Term Use Approvals													
Equipment (02139)	0	0	0	0	0	0	0	0	0	0	0	0	0.00
Oil and Gas Purpose	0	0	0	0	0	0	0	0	0	0	0	0	0.00
Oil Field Injection (includes Hydraulic Fracturing)	0	0	0	0	0	0	0	0	0	0	0	0	0.00
Other Water Purpose	0	0	0	0	0	0	0	0	0	0	0	0	0.00
Pressure Testing and Flushing	0	0	0	0	0	0	0	0	0	0	0	0	0.00
Well Drilling	0	0	0	0	0	0	0	0	0	0	0	0	0.00
Work Camps	0	0	0	0	0	0	0	0	0	0	0	0	0.00
Fire Protection	0	0	0	0	0	0	0	0	0	0	0	0	0.00
Storage - Non Power (08A)	1	1	1	1	1	1	1	1	1	1	1	1	12.00
Road Maintenance	0	0	0	0	0	0	0	0	0	0	0	0	0.00
Industrial	0	0	0	0	0	0	0	0	0	0	0	0	0.00
Unspecified	0	0	0	0	0	0	0	0	0	0	0	0	0.00

Table 13: Availability Validation Results for Teeter (10BE009) Creek in Zone 3N

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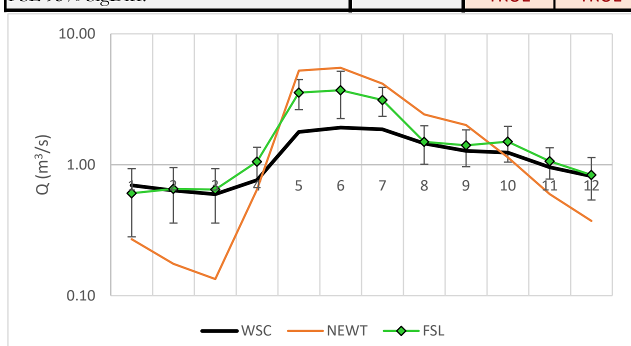
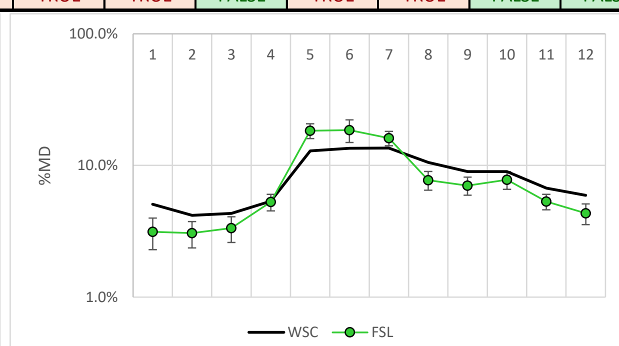
Teeter (10BE009)	DA (km^2)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	MAR	MAD	A-7Q10	S-7Q10
MEAN MONTHLY Q		%MD												(l/s/km²)	(m³/s)	(%MAD)	(%MAD)
Ahmed WSC (32years data)	210	5.1%	4.2%	4.3%	5.4%	12.9%	13.5%	13.5%	10.5%	9.0%	9.0%	6.7%	5.9%	5.6	1.17	29%	66%
		Q (m³/s)														(m³/s)	(m³/s)
WSC Scaled to FWA ID. 8480	**210**	**0.70**	**0.635**	**0.59**	**0.76**	**1.78**	**1.92**	**1.86**	**1.45**	**1.28**	**1.24**	**0.96**	**0.82**	**5.6**	**1.17**	**0.34**	0.77
NEWT (2019)	210	0.27	0.175	0.13	0.65	5.2	5.5	4.2	2.4	2.01	1.14	0.60	0.37	9.0	1.90	WSC 30Q10	
Nash Sutcliffe Eff.= -1111%	%Diff	-61%	-72%	-77%	-15%	194%	186%	123%	67%	58%	-8%	-38%	-54%	63%	63%	**0.37**	
		%MD												(l/s/km²)	(m³/s)	(%MAD)	(%MAD)
FSL (2020) FWA ID. 8480	210	3.1%	3.1%	3.3%	5.3%	18.4%	18.6%	16.1%	7.7%	7.0%	7.8%	5.3%	4.3%	7.8	1.64	32%	22%
		Q (m³/s)														(m³/s)	(m³/s)
FSL (2020) FWA ID. 8480	210	0.606	0.654	0.65	1.05	3.5	3.7	3.1	1.49	1.41	1.50	1.06	0.84	7.8	1.64	0.521	0.36
Nash Sutcliffe Eff.= -202%	%Diff	-13%	3%	9%	38%	100%	93%	67%	3%	10%	21%	11%	2%	40%	40%	52%	-66%
For Zone 3N		%MD												(l/s/km²)	(m³/s)	(%MAD)	(%MAD)
STEYX	210	0.8%	0.7%	0.7%	0.8%	2.4%	3.6%	2.0%	1.3%	1.1%	1.2%	0.7%	0.8%	1.76	0.37	1.4%	6.7%
		Q (m³/s)												%	%	(m³/s)	(m³/s)
STEYX x 2	210	0.33	0.30	0.29	0.30	0.92	1.46	0.77	0.49	0.44	0.46	0.29	0.30	45%	45%	0.05	0.22
FSL 95% SigDiff?		FALSE	FALSE	FALSE	FALSE	TRUE	TRUE	TRUE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	TRUE	TRUE
30Q10 MONTHLY Q		%MAD												Notes: 95%confidence error bars extending below negative in logarithmic plot are not shown. Only 1 sigma error bars shown in comparison of %MD plot. Error bars not shown on Low Flow comparison plot			
Ahmed WSC (32years data)	210	36.9%	35.5%	35.1%	48.3%	87.5%	88.6%	75.6%	74.3%	72.5%	66.6%	55.3%	46.1%				
MIN M-Q10 (m³/s) 0.410		Q (m³/s)															
WSC Scaled to FWA ID. 8480	**210**	**0.431**	**0.415**	**0.410**	**0.564**	**1.023**	**1.035**	**0.884**	**0.868**	**0.848**	**0.779**	**0.647**	**0.538**				
		%MAD															
FSL (2020) FWA ID. 8480	210	13.6%	6.4%	10.1%	10.0%	94.1%	138.3%	96.4%	72.4%	64.0%	55.3%	16.6%	18.5%				
MIN M-Q10 (m³/s) 0.105		Q (m³/s)															
FSL (2020) FWA ID. 8480	210	0.223	0.105	0.165	0.164	1.545	2.270	1.583	1.189	1.051	0.908	0.273	0.304				
%Diff		-48%	-75%	-60%	-71%	51%	119%	79%	37%	24%	17%	-58%	-44%				
For Zone 3N		%MD												Notes: While the %MD are expressed as % of the annual flow and as a percentage, ie 24 is 24% as per Ahmed and Obedkoff, the 30Q10/MAD is expressed as a fraction of MAD, i.e.0.24 is 24%			
STEYX	210	3.4%	3.8%	2.8%	4.6%	26.7%	36.1%	17.0%	13.9%	9.9%	8.7%	6.0%	5.0%				
		Q (m³/s)															
STEYX x 2	210	0.113	0.125	0.093	0.151	0.876	1.186	0.559	0.457	0.324	0.286	0.197	0.165				
FSL 95% SigDiff?		TRUE	TRUE	TRUE	TRUE	FALSE	TRUE	TRUE	FALSE	FALSE	FALSE	TRUE	TRUE				





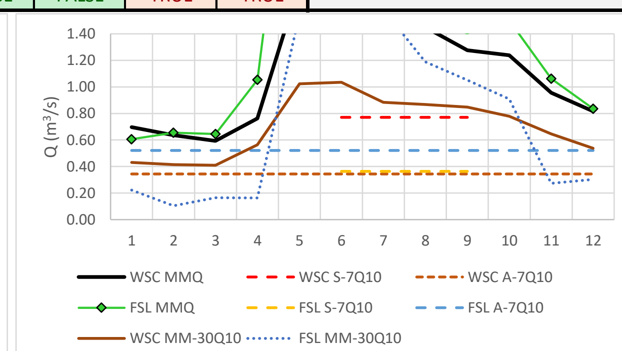


Table 14: Availability Validation Results for Ingenika (07EA004) River in Zone 3S

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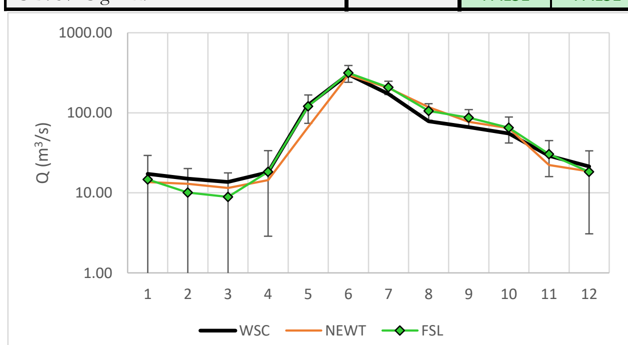
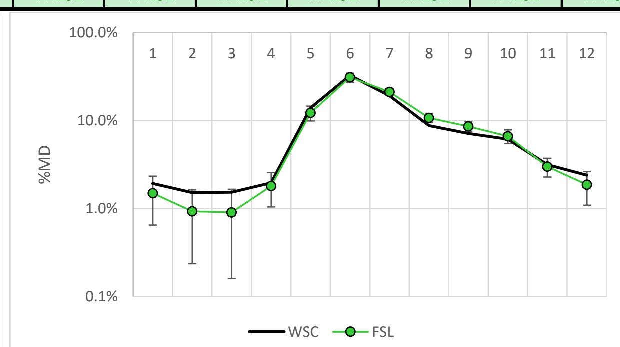
2020-01-31 10:35

Ingenika (07EA004)	DA (km²)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	MAR	MAD	A-7Q10	S-7Q10
MEAN MONTHLY Q		%MD												(l/s/km²)	(m³/s)	(%MAD)	(%MAD)
Ahmed WSC (38 years data)	4,145	1.9%	1.5%	1.5%	1.9%	14.0%	32.5%	19.1%	8.7%	7.1%	6.1%	3.1%	2.4%	14.31	59.3	11.5%	45.0%
34969		*Q (m³/s)*														(m³/s)	(m³/s)
WSC Scaled to 5051	**5,329**	**17.27**	**15.03**	**13.70**	**18.09**	**125.43**	**301.75**	**171.68**	**78.54**	**65.96**	**55.08**	**29.06**	**21.39**	**14.31**	**76.3**	**8.7933**	34.33
NEWT (2019)	5,208	13.61	12.97	11.55	14.39	66.2	296.5	203.3	117.5	77.0	64.3	22.2	18.6	14.73	76.702	WSC 30Q10	
Nash Sutcliffe Eff.= 92%	%Diff	-21%	-14%	-16%	-20%	-47%	-2%	18%	50%	17%	17%	-24%	-13%	3%	1%	**8.070**	
		%MD												(l/s/km²)	(m³/s)	(%MAD)	(%MAD)
FSL (2020) 5051	5,329	1.5%	0.9%	0.9%	1.8%	12.2%	30.9%	21.1%	10.7%	8.5%	6.6%	3.0%	1.9%	15.71	83.7	10.9%	48.0%
		Q (m³/s)														(m³/s)	(m³/s)
FSL (2020) 5051	5,329	14.68	10.12	8.90	18.33	120.41	314.53	208.23	105.26	86.93	65.27	30.48	18.31	15.7	83.7	9.14	40.22
Nash Sutcliffe Eff.= 97%	%Diff	-15%	-33%	-35%	1%	-4%	4%	21%	34%	32%	18%	5%	-14%	10%	10%	4%	7%
For Zone 6		%MD												(l/s/km²)	(m³/s)	(%MAD)	(%MAD)
STEYX	5,329	0.8%	0.7%	0.7%	0.8%	2.4%	3.6%	2.0%	1.3%	1.1%	1.2%	0.7%	0.8%	0.23	1.20	1.3%	4.7%
		Q (m³/s)												%	%	(m³/s)	(m³/s)
STEYX x 2	5,329	15	10	9	15	47	74	39	25	22	23	15	15	3%	3%	2.22	7.80
FSL 95% SigDiff?		FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	TRUE	FALSE	FALSE	FALSE	FALSE	TRUE	TRUE	FALSE	FALSE
30Q10 MONTHLY Q		%MAD												Notes: 95%confidence error bars extending below negative in logarithmic plot are not shown. Only 1 sigma error bars shown in comparison of %MD plot. Error bars not shown on Low Flow comparison plot.			
Ahmed WSC (38 years data)	4,145	18.2%	15.5%	14.6%	16.2%	78.0%	275.5%	137.0%	69.4%	58.5%	49.3%	27.9%	21.0%				
MIN M-Q10 (m³/s) 11.1550		*Q (m³/s)*															
WSC Scaled to 5051	**5,329**	**13.850**	**11.819**	**11.155**	**12.39**	**59.52**	**210.18**	**104.54**	**52.96**	**44.61**	**37.60**	**21.292**	**16.013**				
		%MAD															
FSL (2020) 5051	5,329	14.7%	15.1%	12.6%	15.9%	76.0%	268.7%	156.3%	75.2%	55.3%	42.7%	27.3%	18.2%				
MIN M-Q10 (m³/s) 10.55		*Q (m³/s)*															
FSL (2020) 5051	5,329	12.31	12.61	10.55	13.30	63.66	224.97	130.84	62.99	46.29	35.77	22.89	15.23				
%Diff		-11%	7%	-5%	7%	7%	7%	25%	19%	4%	-5%	8%	-5%				
For Zone 6		%MD												Notes: While the %MD are expressed as % of the annual flow and as a percentage, ie 24 is 24% as per Ahmed and Obedkoff, the 30Q10/MAD is expressed as a fraction of MAD, i.e.0.24 is 24%			
STEYX	5,329	3.4%	3.8%	2.8%	4.6%	26.7%	36.1%	17.0%	13.9%	9.9%	8.7%	6.0%	5.0%				
		Q (m³/s)															
STEYX x 2	5,329	5.8	6.4	4.8	7.7	44.7	60.5	28.5	23.3	16.5	14.6	10.0	8.4				
FSL 95% SigDiff?		FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE				





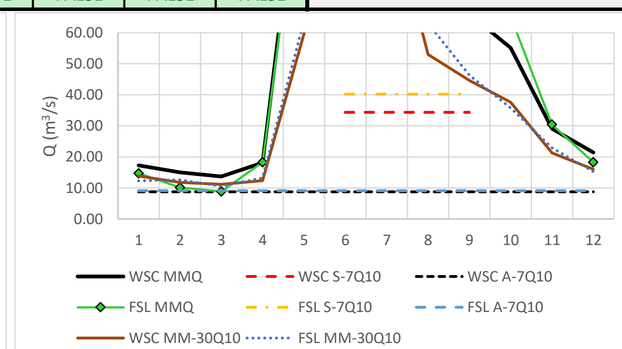


Table 15: Availability Validation Results for Kechika-Boya (10BB002) River in Zone 3S

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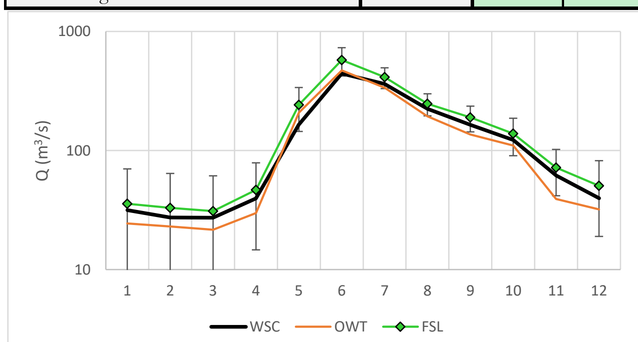
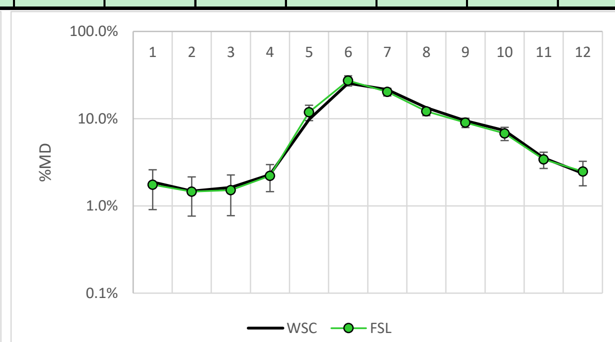
Kechika-Boya (10BB002)	DA (km^2)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	MAR	MAD	A-7Q10	S-7Q10
MEAN MONTHLY Q							%MD							($l/s/km^2$)	(m^3/s)	(%MAD)	(%MAD)
Ahmed WSC (19 years data)	11,276	1.9%	1.5%	1.6%	2.3%	9.8%	25.5%	21.5%	13.3%	9.5%	7.3%	3.5%	2.4%	13.0	146	12.6%	68%
							Q (m^3/s)									(m^3/s)	(m^3/s)
WSC Scaled to FWA ID. 18361	**11,004**	**32**	**27**	**27**	**40**	**165**	**443**	**362**	**224**	**164**	**123**	**62**	**40**	**13.0**	**143**	**18.0**	97.7
OWT (2019)	11,004	24	23	22	30	208	471	337	193	136	110	39	32	12.3	135.87	WSC 30Q10	
Nash Sutcliffe Eff.= 97%	%Diff	-22%	-16%	-21%	-25%	26%	6%	-7%	-14%	-17%	-10%	-37%	-19%	-5%	-5%	**19.5**	
							%MD							($l/s/km^2$)	(m^3/s)	(%MAD)	(%MAD)
FSL (2020) FWA ID. 18361	11,004	1.746%	1.5%	1.5%	2.2%	11.8%	27.2%	20.2%	12.1%	9.0%	6.8%	3.4%	2.5%	15.8	173	12%	55%
							Q (m^3/s)									(m^3/s)	(m^3/s)
FSL (2020) FWA ID. 18361	11,004	36	33	31	47	242	575	413	247	190	139	72	51	15.8	173	21.1	95.41
Nash Sutcliffe Eff.= 87%	%Diff	13%	20%	13%	18%	46%	30%	14%	10%	15%	13%	16%	27%	21%	21%	17%	-20%
For Zone 3S							%MD							($l/s/km^2$)	(m^3/s)	(%MAD)	(%MAD)
STEYX	11,004	0.8%	0.7%	0.7%	0.8%	2.4%	3.6%	2.0%	1.3%	1.1%	1.2%	0.7%	0.8%	1.76	19.41	1.9%	6.7%
							Q (m^3/s)							%	%	(m^3/s)	(m^3/s)
STEYX x 2	11,004	34	31	30	32	97	154	82	52	46	48	30	32	22%	22%	6.55	23.32
FSL 95% SigDiff?		FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE
30Q10 MONTHLY Q							%MAD							Notes: 95%confidence error bars extending below negative in logarithmic plot are not shown. Only 1 sigma error bars shown in comparison of %MD plot. Error bars not shown on Low Flow comparison plot			
Ahmed WSC (19 years data)	11,276	17%	15%	15%	20%	64%	227%	179%	122%	81%	60%	35%	22%				
MIN M-Q10 (m^3/s) 21.534							Q (m^3/s)										
WSC Scaled to FWA ID. 18361	**11,004**	**25**	**22**	**22**	**29**	**91**	**324**	**256**	**175**	**115**	**86**	**50**	**31**				
							%MAD										
FSL (2020) FWA ID. 18361	11,276	15.7%	14.7%	13.3%	17.4%	70.6%	233.4%	156.9%	92.2%	66.9%	50.9%	29.9%	19.7%				
MIN M-Q10 (m^3/s) 23.132							Q (m^3/s)										
FSL (2020) FWA ID. 18361	10,543	27	25	23	30	123	405	272	160	116	88	52	34				
%Diff		10%	16%	7%	5%	35%	25%	6%	-8%	1%	3%	3%	9%				
For Zone 3S							%MD							Notes: While the %MD are expressed as % of the annual flow and as a percentage, ie 24 is 24% as per Ahmed and Obedkoff, the 30Q10/MAD is expressed as a fraction of MAD, i.e.0.24 is 24%			
STEYX	10,543	3.4%	3.8%	2.8%	4.6%	26.7%	36.1%	17.0%	13.9%	9.9%	8.7%	6.0%	5.0%				
							Q (m^3/s)										
STEYX x 2	10,543	12	13	10	16	93	125	59	48	34	30	21	17				
FSL 95% SigDiff?		FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE				





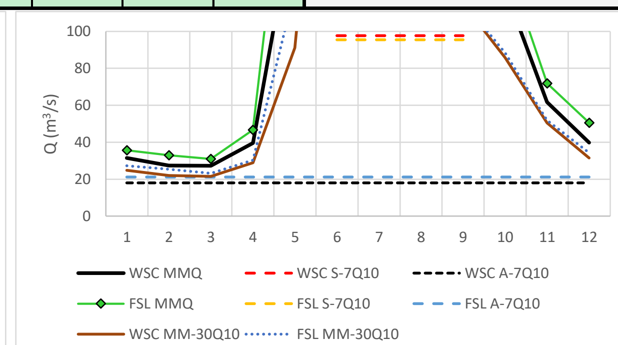


Table 16: Availability Validation Results for Ospika (07EB002) River in Zone 3S

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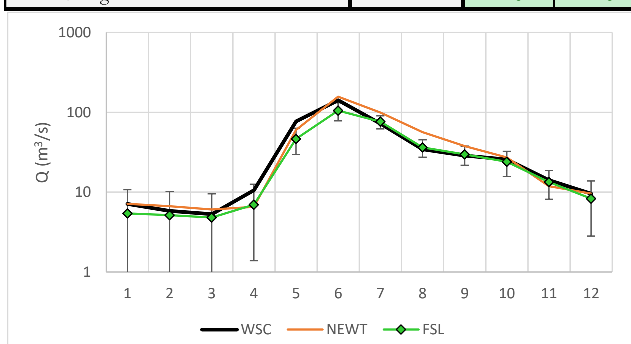
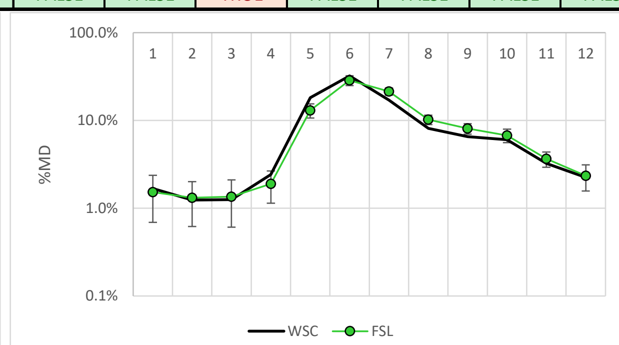
Ospika (07EB002)	DA (km^2)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	MAR	MAD	A-7Q10	S-7Q10
MEAN MONTHLY Q		%MD												($l/s/km^2$)	(m^3/s)	(%MAD)	(%MAD)
Ahmed WSC (30 years data)	2,193	1.7%	1.2%	1.2%	2.4%	18.1%	32.2%	17.0%	8.1%	6.5%	6.0%	3.2%	2.2%	18.5	40.5	10.5%	36%
		Q (m^3/s)														(m^3/s)	(m^3/s)
WSC Scaled to FWA ID. 12677	**1,954**	**7**	**6**	**5**	**11**	**77**	**141**	**72**	**34**	**29**	**26**	**14**	**10**	**18.5**	**36.1**	**3.78**	12.97
NEWT (2019)	2,079	7	7	6	7	60	157	99	56	38	27	12	10	19.5	40.595	WSC 30Q10	
Nash Sutcliffe Eff.= 90%	%Diff	1%	15%	15%	-38%	-22%	11%	37%	64%	31%	6%	-16%	1%	6%	12%	**3.96**	
		%MD												($l/s/km^2$)	(m^3/s)	(%MAD)	(%MAD)
FSL (2020) FWA ID. 12677	1,954	1.5%	1.3%	1.4%	1.9%	13.0%	28.5%	21.3%	10.2%	8.1%	6.7%	3.6%	2.3%	15.5	30.238	10%	52%
		Q (m^3/s)														(m^3/s)	(m^3/s)
FSL (2020) FWA ID. 12677	1,954	5	5	5	7	46	105	76	36	30	24	13	8	15.5	30.238	3.00	15.74
Nash Sutcliffe Eff.= 88%	%Diff	-23%	-11%	-9%	-34%	-40%	-26%	5%	5%	4%	-6%	-5%	-13%	-16%	-16%	-21%	45%
For Zone 3S		%MD												($l/s/km^2$)	(m^3/s)	(%MAD)	(%MAD)
STEYX	1,954	0.8%	0.7%	0.7%	0.8%	2.4%	3.6%	2.0%	1.3%	1.1%	1.2%	0.7%	0.8%	1.63	3.18	1.9%	6.7%
		Q (m^3/s)												%	%	(m^3/s)	(m^3/s)
STEYX x 2	1,954	5	5	5	6	17	27	14	9	8	8	5	5	21%	21%	1.14	4.06
FSL 95% SigDiff?		FALSE	FALSE	FALSE	FALSE	TRUE	TRUE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE
30Q10 MONTHLY Q		%MAD												Notes: 95%confidence error bars extending below negative in logarithmic plot are not shown. Only 1 sigma error bars shown in comparison of %MD plot. Error bars not shown on Low Flow comparison plot			
Ahmed WSC (30 years data)	2,193	15%	13%	12%	17%	118%	259%	127%	62%	47%	38%	25%	18%				
MIN M-Q10 (m^3/s) 4.25		Q (m^3/s)															
WSC Scaled to FWA ID. 12677	**1,954**	**5**	**5**	**4**	**6**	**43**	**94**	**46**	**22**	**17**	**14**	**9**	**6**				
		%MAD															
FSL (2020) FWA ID. 12677	1,954	16%	15%	13%	16%	62%	242%	154%	101%	70%	52%	29%	20%				
MIN M-Q10 (m^3/s) 3.89		Q (m^3/s)															
FSL (2020) FWA ID. 12677	1,954	5	5	4	5	19	73	47	31	21	16	9	6				
%Diff		-10%	-3%	-8%	-17%	-56%	-22%	2%	37%	25%	14%	-3%	-4%				
For Zone 3S		%MD												Notes: While the %MD are expressed as % of the annual flow and as a percentage, ie 24 is 24% as per Ahmed and Obedkoff, the 30Q10/MAD is expressed as a fraction of MAD, i.e.0.24 is 24%			
STEYX	1,954	3.4%	3.8%	2.8%	4.6%	26.7%	36.1%	17.0%	13.9%	9.9%	8.7%	6.0%	5.0%				
		Q (m^3/s)															
STEYX x 2	1,954	2	2	2	3	16	22	10	8	6	5	4	3				
FSL 95% SigDiff?		FALSE	FALSE	FALSE	FALSE	TRUE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE				





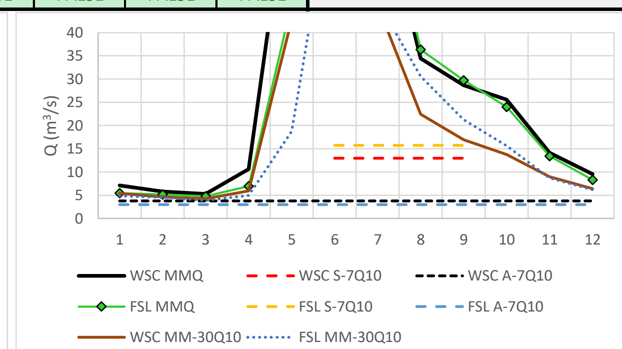


Table 17: Availability Validation Results for Adsett (10CD005) Creek in Zone 4

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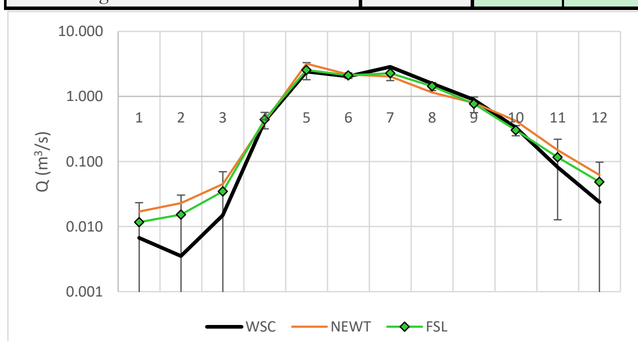
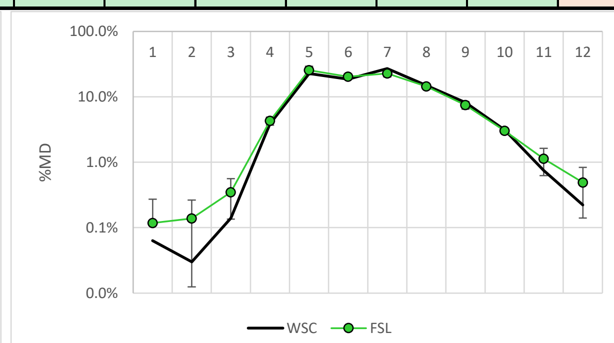
Adsett (10CD005)	DA (km^2)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	MAR	MAD	A-7Q10	S-7Q10
MEAN MONTHLY Q		%MD												(l/s/km^2)	(m^3/s)	(%MAD)	(%MAD)
Ahmed WSC (13 years data)	109	0.1%	0.0%	0.1%	3.8%	22.7%	18.6%	26.9%	14.9%	8.1%	3.1%	0.7%	0.2%	7.8	0.85	0.0%	6%
		Q (m^3/s)														(m^3/s)	(m^3/s)
WSC Scaled to FWA ID. 11022	**116**	**0.01**	**0.004**	**0.01**	**0.42**	**2.41**	**2.04**	**2.86**	**1.58**	**0.89**	**0.33**	**0.08**	**0.02**	**7.8**	**0.90**	**0.000**	0.05
NEWT (2019)	116	0.02	0.023	0.05	0.41	3.2	2.2	2.0	1.2	0.80	0.42	0.15	0.06	7.6	0.88	WSC 30Q10	
Nash Sutcliffe Eff.= 88%	%Diff	153%	552%	203%	-2%	32%	6%	-29%	-27%	-11%	27%	84%	162%	-2%	-3%	**0.000**	
		%MD												(l/s/km^2)	(m^3/s)	(%MAD)	(%MAD)
FSL (2020) FWA ID. 11022	116	0.1%	0.1%	0.3%	4.3%	25.6%	20.3%	22.7%	14.4%	7.5%	3.0%	1.1%	0.5%	7.3	0.85	0.14%	16%
		Q (m^3/s)														(m^3/s)	(m^3/s)
FSL (2020) FWA ID. 11022	116	0.012	0.015	0.03	0.44	2.6	2.1	2.3	1.44	0.77	0.30	0.12	0.05	7.3	0.85	0.001	0.13
Nash Sutcliffe Eff.= 97%	%Diff	75%	333%	135%	5%	6%	3%	-21%	-9%	-14%	-9%	43%	106%	-6%	-6%	#DIV/0!	156%
For Zone 4		%MD												(l/s/km^2)	(m^3/s)	(%MAD)	(%MAD)
STEYX	116	0.2%	0.1%	0.2%	0.6%	3.7%	1.0%	2.6%	1.0%	1.0%	0.3%	0.5%	0.3%	0.47	0.05	0.2%	9.2%
		Q (m^3/s)												%	%	(m^3/s)	(m^3/s)
STEYX x 2	116	0.01	0.02	0.03	0.13	0.75	0.20	0.52	0.20	0.21	0.05	0.10	0.05	13%	13%	0.00	0.16
FSL 95% SigDiff?		FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	TRUE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE
30Q10 MONTHLY Q		%MAD												Notes: 95%confidence error bars extending below negative in logarithmic plot are not shown. Only 1 sigma error bars shown in comparison of %MD plot. Error bars not shown on Low Flow comparison plot			
Ahmed WSC (13 years data)	109	0.1%	0.1%	0.1%	2.1%	86.8%	84.8%	56.3%	22.5%	12.3%	8.9%	1.7%	0.2%				
MIN M-Q10 (m^3/s) 0.0007		Q (m^3/s)															
WSC Scaled to FWA ID. 11022	**116**	**0.0010**	**0.0007**	**0.0009**	**0.0187**	**0.7828**	**0.7648**	**0.5077**	**0.2027**	**0.1105**	**0.0804**	**0.0152**	**0.0017**				
		%MAD															
FSL (2020) FWA ID. 11022	116	1.6%	1.3%	0.9%	4.0%	100.2%	92.8%	66.6%	15.1%	7.7%	7.1%	2.1%	0.0%				
MIN M-Q10 (m^3/s) 0.00		Q (m^3/s)															
FSL (2020) FWA ID. 11022	116	0.014	0.011	0.008	0.034	0.850	0.788	0.565	0.128	0.065	0.060	0.017	0.000				
%Diff		1290%	1422%	798%	80%	9%	3%	11%	-37%	-41%	-25%	15%	-100%				
For Zone 4		%MD												Notes: While the %MD are expressed as % of the annual flow and as a percentage, ie 24 is 24% as per Ahmed and Obedkoff, the 30Q10/MAD is expressed as a fraction of MAD, i.e.0.24 is 24%			
STEYX	116	1.6%	1.4%	1.3%	5.4%	8.1%	17.7%	20.6%	5.3%	2.5%	4.4%	3.3%	1.5%				
		Q (m^3/s)															
STEYX x 2	116	0.027	0.024	0.022	0.091	0.138	0.300	0.350	0.089	0.043	0.074	0.056	0.026				
FSL 95% SigDiff?		FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	TRUE	FALSE	FALSE	FALSE				





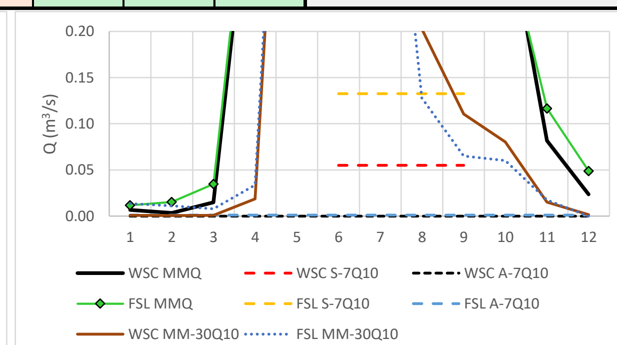


Table 18: Availability Validation Results for Petitot (10DA001) River in Zone 4

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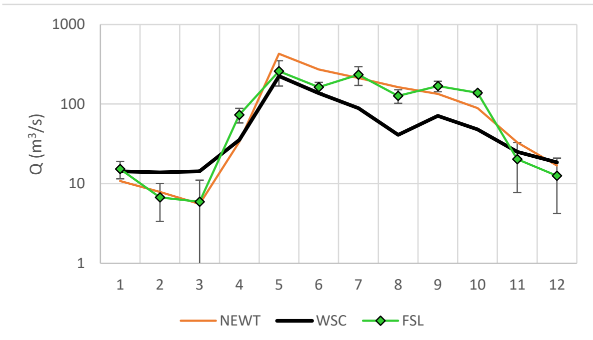
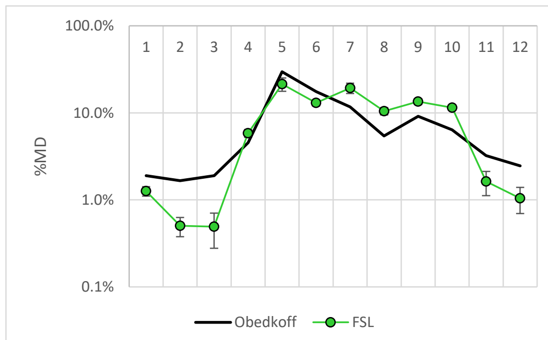
Petitot (10DA001)	DA (km^2)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	MAR	MAD	A-7Q10	S-7Q10
		%MD												(l/s/km^2)	(m^3/s)	(%MAD)	(%MAD)
WSC (5 years data)	22,400	1.9%	1.7%	1.9%	4.5%	29.8%	17.6%	11.7%	5.4%	9.1%	6.4%	3.2%	2.5%	2.9	64.3	1.1%	11%
		m^3/s														(m^3/s)	(m^3/s)
Scaled to FWA ID. 9526	**22,269**	**14**	**14**	**14**	**35**	**224**	**137**	**88**	**41**	**71**	**48**	**25**	**19**	**2.9**	**63.962**	**0.70**	7.04
NEWT (2019)	22,269	11	8	6	34	428	271	213	163	134	89	33	17	5.3	118		
Nash Sutcliffe Eff.= -117%	%Diff	-24%	-43%	-61%	-5%	91%	98%	141%	298%	88%	84%	31%	-9%	84%	84%		
		%MD												(l/s/km^2)	(m^3/s)	(%MAD)	(%MAD)
FSL (2020) FWA ID. 23731	22,269	1.3%	0.5%	0.5%	5.9%	21.4%	13.0%	19.3%	10.5%	13.5%	11.5%	1.6%	1.0%	4.6	103	2.61%	6.97%
		m^3/s														(m^3/s)	(m^3/s)
FSL (2020) FWA ID. 23731	22,269	15	7	6	73	259	163	233	127	168	138	20	13	4.6	103	2.68	7.15
Nash Sutcliffe Eff.= -12%	%Diff	7%	-52%	-59%	106%	15%	19%	164%	209%	136%	187%	-19%	-32%	60%	60%	280%	-37%
For Zone 4		%MD												(l/s/km^2)	(m^3/s)	(%MAD)	(%MAD)
STEYX	22,269	0.2%	0.1%	0.2%	0.6%	3.7%	1.0%	2.6%	1.0%	1.0%	0.3%	0.5%	0.3%	0.47	10.47	0.19%	9.2%
		m^3/s												%	%	(m^3/s)	(m^3/s)
STEYX x 2	22,269	4	3	5	15	90	25	62	24	25	7	13	8	20%	20%	0.38	18.80
FSL 95% SigDiff?		FALSE	TRUE	TRUE	TRUE	FALSE	TRUE	TRUE	TRUE	TRUE	TRUE	FALSE	FALSE	TRUE	TRUE	TRUE	FALSE





Notes: The black line from WSC shows what appears to be an attenuated hydrograph compared to both FSL and NEWT. Investigation revealed only 2 of the 7 years were validated and those 2 years were closer to the modeled results. No further comparison or QA/QC of the Petitot River data was undertaken.

Table 19: Availability Validation Results for Alces (07FD004) River in Zone 6

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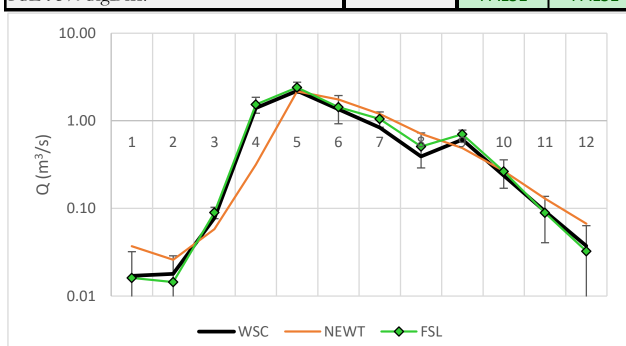
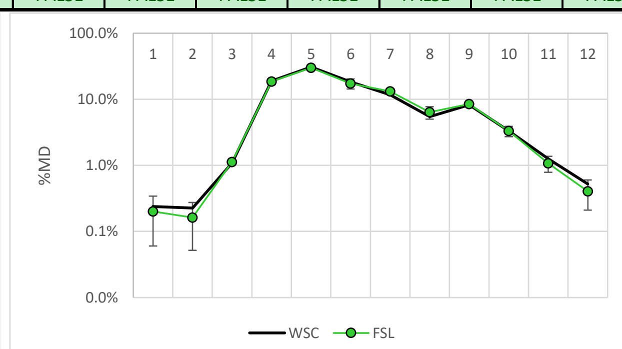
Alces (07FD004)	DA (km^2)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	MAR	MAD	A-7Q10	S-7Q10
MEAN MONTHLY Q		*%MD*												($l/s/km^2$)	(m^3/s)	(%MAD)	(%MAD)
Ahmed WSC (30 years data)	295	0.2%	0.2%	1.1%	18.9%	30.8%	18.3%	11.7%	5.5%	8.2%	3.3%	1.3%	0.5%	1.8	0.5	0.0%	0.0%
		Q (m^3/s)														(m^3/s)	(m^3/s)
WSC Scaled to FWA ID. 9427	**340**	**0.02**	**0.02**	**0.08**	**1.40**	**2.20**	**1.35**	**0.83**	**0.39**	**0.61**	**0.24**	**0.09**	**0.04**	**1.8**	**0.6**	**0.00**	0.00
NEWT (2019)	313	0.04	0.03	0.06	0.32	2.2	1.8	1.2	0.7	0.49	0.27	0.13	0.07	1.9	0.6	WSC 30Q10	
Nash Sutcliffe Eff.= 71%	%Diff	117%	45%	-25%	-77%	-2%	29%	44%	81%	-20%	13%	40%	79%	8%	0%	**0.00**	
		%MD												($l/s/km^2$)	(m^3/s)	(%MAD)	(%MAD)
FSL (2020) FWA ID. 9427	340	0.2%	0.2%	1.1%	18.5%	30.0%	17.3%	13.1%	6.4%	8.5%	3.3%	1.1%	0.4%	2.0	0.7	0.0%	3%
		Q (m^3/s)														(m^3/s)	(m^3/s)
FSL (2020) FWA ID. 9427	340	0.02	0.01	0.09	1.53	2.4	1.4	1.1	0.51	0.70	0.26	0.09	0.03	2.0	0.7	0.00	0.02
Nash Sutcliffe Eff.= 98%	%Diff	-6%	-19%	16%	10%	9%	6%	26%	30%	15%	11%	-4%	-13%	12%	12%	#DIV/0!	#DIV/0!
For Zone 6		%MD												($l/s/km^2$)	(m^3/s)	(%MAD)	(%MAD)
STEYX	340	0.1%	0.1%	0.1%	1.9%	2.2%	3.1%	1.3%	1.4%	0.5%	0.6%	0.3%	0.2%	3.16	1.07	5.9%	10.1%
		Q (m^3/s)												%	%	(m^3/s)	(m^3/s)
STEYX x 2	340	0.02	0.01	0.01	0.32	0.35	0.51	0.21	0.22	0.08	0.09	0.05	0.03	316%	316%	0.08	0.14
FSL 95% SigDiff?		FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	TRUE	FALSE	TRUE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE
30Q10 MONTHLY Q		*%MAD*												Notes: 95%confidence error bars extending below negative in logarithmic plot are not shown. Only 1 sigma error bars shown in comparison of %MD plot. Error bars not shown on Low Flow comparison plot			
Ahmed WSC (30 years data)	295	0.4%	0.4%	0.6%	32.6%	60.4%	46.0%	9.1%	1.8%	1.2%	1.4%	0.9%	1.0%				
MIN M-Q10 (m^3/s) 0.0023		*Q (m^3/s)*															
WSC Scaled to FWA ID. 9427	**340**	**0.0023**	**0.0023**	**0.0034**	**0.1980**	**0.3672**	**0.2798**	**0.0552**	**0.0112**	**0.0071**	**0.0083**	**0.0057**	**0.0061**				
		%MAD															
FSL (2020) FWA ID. 9427	340	0.0%	0.6%	0.0%	33.4%	73.3%	43.6%	2.2%	0.9%	4.7%	4.2%	2.0%	0.6%				
MIN M-Q10 (m^3/s) 0.00		*Q (m^3/s)*															
FSL (2020) FWA ID. 9427	340	0.00	0.00	0.00	0.23	0.50	0.30	0.01	0.01	0.03	0.03	0.01	0.00				
%Diff		-93%	75%	-92%	15%	36%	6%	-73%	-48%	349%	243%	139%	-33%				
For Zone 6		%MD												Notes: While the %MD are expressed as % of the annual flow and as a percentage, ie 24 is 24% as per Ahmed and Obedkoff, the 30Q10/MAD is expressed as a fraction of MAD, i.e.0.24 is 24%			
STEYX	340	1.4%	1.8%	1.0%	2.4%	16.8%	12.8%	6.5%	3.6%	6.2%	4.6%	2.3%	1.9%				
		Q (m^3/s)															
STEYX x 2	340	0.0	0.0	0.0	0.0	0.2	0.2	0.1	0.0	0.1	0.1	0.0	0.0				
FSL 95% SigDiff?		FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE				





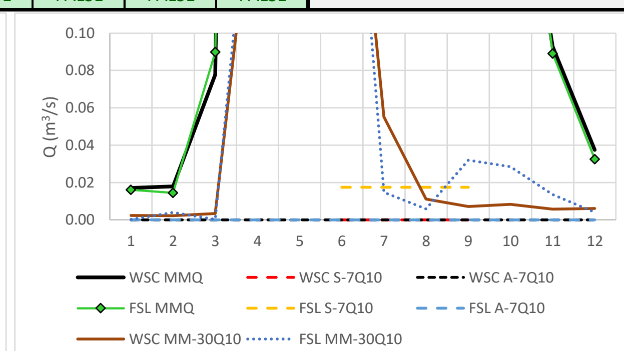


Table 20: Availability Validation Results for Beatton (07FC001) River in Zone 6

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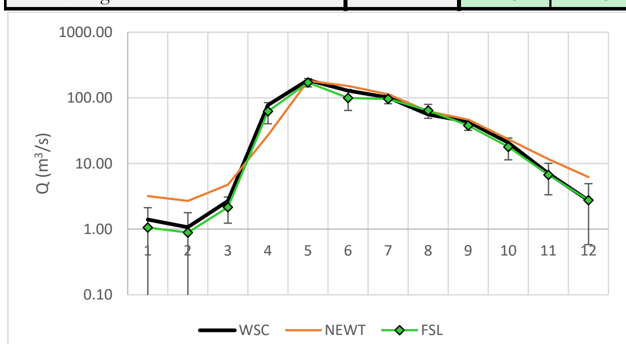
Beatton (07FC001)	DA (km^2)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	MAR	MAD	A-7Q10	S-7Q10
MEAN MONTHLY Q		%MD												(l/s/km^2)	(m^3/s)	(%MAD)	(%MAD)
Ahmed WSC (36 years data)	15,561	0.2%	0.2%	0.4%	12.0%	30.1%	19.9%	16.2%	8.9%	6.7%	3.3%	1.1%	0.4%	3.4	53.1	0.3%	6%
		Q (m^3/s)														(m^3/s)	(m^3/s)
WSC Scaled to FWA ID. 7618	**15,507**	**1.40**	**1.07**	**2.69**	**77.45**	**187.45**	**128.31**	**101.29**	**55.80**	**43.38**	**20.72**	**7.05**	**2.75**	**3.4**	**53.0**	**0.14**	3.03
NEWT (2019)	15,550	3.20	2.69	4.76	27.00	182.0	152.0	113.0	62.3	46.60	23.40	11.60	6.19	3.4	53.2	WSC 30Q10	
Nash Sutcliffe Eff.= 92%	%Diff	129%	152%	77%	-65%	-3%	18%	12%	12%	7%	13%	65%	125%	0%	0%	**0.17**	
		%MD												(l/s/km^2)	(m^3/s)	(%MAD)	(%MAD)
FSL (2020) FWA ID. 7618	15,507	0.2%	0.1%	0.4%	10.8%	30.9%	17.3%	17.3%	11.5%	6.6%	3.2%	1.2%	0.5%	3.0	47.2	0.7%	7%
		Q (m^3/s)														(m^3/s)	(m^3/s)
FSL (2020) FWA ID. 7618	15,507	1.06	0.89	2.16	62.27	171.8	99.4	96.1	64.12	37.81	17.94	6.71	2.75	3.0	47.2	0.33	3.19
Nash Sutcliffe Eff.= 96%	%Diff	-24%	-17%	-20%	-20%	-8%	-23%	-5%	15%	-13%	-13%	-5%	0%	-11%	-11%	136%	18%
For Zone 6		%MD												(l/s/km^2)	(m^3/s)	(%MAD)	(%MAD)
STEYX	15,507	0.1%	0.1%	0.1%	1.9%	2.2%	3.1%	1.3%	1.4%	0.5%	0.6%	0.3%	0.2%	3.16	49.02	5.9%	10.1%
		Q (m^3/s)												%	%	(m^3/s)	(m^3/s)
STEYX x 2	15,507	1.1	0.9	0.9	22	24	35	14	15	5.9	6.6	3.4	2.2	208%	208%	5.53	9.53
FSL 95% SigDiff?		FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE
30Q10 MONTHLY Q		*%MAD*															
Ahmed WSC (36 years data)	15,561	1%	1%	1%	22%	100%	84%	49%	21%	10%	8%	4%	2%				
MIN M-Q10 (m^3/s) 0.2755		*Q (m^3/s)*															
WSC Scaled to FWA ID. 7618	**15,507**	**0.41**	**0.28**	**0.42**	**11.85**	**52.86**	**44.53**	**25.92**	**11.19**	**5.19**	**4.11**	**2.28**	**1.02**				
		%MAD															
FSL (2020) FWA ID. 7618	15,507	1%	1%	1%	22%	110%	76%	47%	25%	10%	8%	5%	1%				
MIN M-Q10 (m^3/s) 0.28		*Q (m^3/s)*															
FSL (2020) FWA ID. 7618	15,507	0.29	0.49	0.28	10.19	52.14	36.07	22.14	11.97	4.69	3.81	2.13	0.65				
%Diff		-30%	79%	-34%	-14%	-1%	-19%	-15%	7%	-10%	-7%	-6%	-36%				
For Zone 6		%MD															
STEYX	15,507	1.4%	1.8%	1.0%	2.4%	16.8%	12.8%	6.5%	3.6%	6.2%	4.6%	2.3%	1.9%				
		Q (m^3/s)															
STEYX x 2	15,507	1.3	1.7	1.0	2.2	15.8	12.1	6.1	3.4	5.8	4.4	2.1	1.8				
FSL 95% SigDiff?		FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE				

Notes: 95%confidence error bars extending below negative in logarithmic plot are not shown. Only 1 sigma error bars shown in comparison of %MD plot. Error bars not shown on Low Flow comparison plot

Notes: While the %MD are expressed as % of the annual flow and as a percentage, ie 24 is 24% as per Ahmed and Obedkoff, the 30Q10/MAD is expressed as a fraction of MAD, i.e.0.24 is 24%



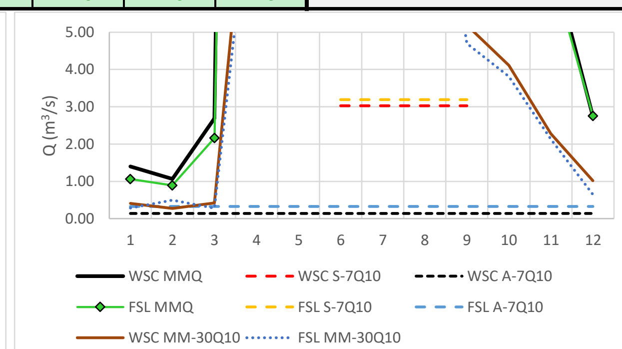


Table 21: Availability Validation Results for Blueberry (07FC003) River in Zone 6

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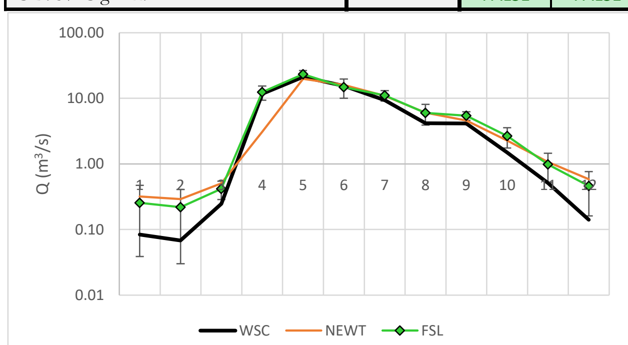
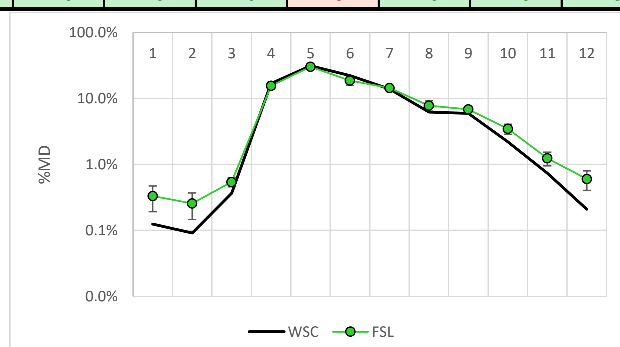
Blueberry (07FC003)	DA (km^2)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	MAR	MAD	A-7Q10	S-7Q10
MEAN MONTHLY Q		%MD												($l/s/km^2$)	(m^3/s)	(%MAD)	(%MAD)
Ahmed WSC (50 years data)	1,772	0.1%	0.1%	0.4%	16.8%	31.3%	22.1%	13.9%	6.2%	5.9%	2.2%	0.7%	0.2%	2.87	5.1	0.1%	0.2%
FSL_ID:35636		Q (m^3/s)														(m^3/s)	(m^3/s)
WSC Scaled to FWA ID. 7746	**2,000**	**0.08**	**0.07**	**0.25**	**11.70**	**21.11**	**15.44**	**9.40**	**4.18**	**4.13**	**1.49**	**0.51**	**0.14**	**2.87**	**5.7**	**0.0039**	0.01
NEWT (2019)	1,789	0.32	0.29	0.50	3.07	19.8	16.0	10.9	6.0	4.6	2.3	1.1	0.6	3.06	5.48	WSC 30Q10	
Nash Sutcliffe Eff.= 85%	%Diff	281%	328%	105%	-74%	-6%	4%	16%	44%	11%	52%	109%	316%	7%	-4%	**0.003**	
		%MD												($l/s/km^2$)	(m^3/s)	(%MAD)	(%MAD)
FSL (2020) FWA ID. 7746	2,000	0.3%	0.3%	0.5%	15.6%	30.2%	18.7%	14.4%	7.8%	6.8%	3.5%	1.2%	0.6%	3.27	6.5	1.2%	7.8%
		Q (m^3/s)														(m^3/s)	(m^3/s)
FSL (2020) FWA ID. 7746	2,000	0.25	0.22	0.42	12.37	23.24	14.86	11.09	5.99	5.44	2.66	0.99	0.46	3.3	6.5	0.08	0.51
Nash Sutcliffe Eff.= 97%	%Diff	204%	220%	69%	6%	10%	-4%	18%	44%	32%	79%	92%	228%	14%	14%	1928%	3316%
For Zone 6		%MD												($l/s/km^2$)	(m^3/s)	(%MAD)	(%MAD)
STEYX	2,000	0.1%	0.1%	0.1%	1.9%	2.2%	3.1%	1.3%	1.4%	0.5%	0.6%	0.3%	0.2%	0.23	0.45	1.3%	4.7%
		Q (m^3/s)												%	%	(m^3/s)	(m^3/s)
STEYX x 2	2,000	0.2	0.2	0.1	3.1	3.4	4.8	2.0	2.1	0.8	0.9	0.5	0.3	14%	14%	0.17	0.61
FSL 95% SigDiff?		FALSE	FALSE	TRUE	FALSE	FALSE	FALSE	FALSE	FALSE	TRUE	TRUE	TRUE	TRUE	FALSE	FALSE	FALSE	FALSE
30Q10 MONTHLY Q		%MAD												Notes: 95%confidence error bars extending below negative in logarithmic plot are not shown. Only 1 sigma error bars shown in comparison of %MD plot. Error bars not shown on Low Flow comparison plot. 3 years of 50 had a 30Q10 of 0.00 which could not be modeled in a log normal distribution.			
Ahmed WSC (50 years data)	1,772	0.3%	0.2%	0.3%	21.8%	92.3%	48.5%	11.2%	3.5%	1.4%	2.4%	1.8%	0.8%				
MIN M-Q10 (m^3/s) 0.0126		Q (m^3/s)															
WSC Scaled to FWA ID. 7746	**2,000**	**0.016**	**0.013**	**0.015**	**1.25**	**5.29**	**2.78**	**0.64**	**0.20**	**0.08**	**0.14**	**0.103**	**0.045**				
		%MAD															
FSL (2020) FWA ID. 7746	2,000	1.5%	1.8%	1.4%	22.9%	84.1%	73.9%	21.9%	8.9%	11.2%	9.3%	5.2%	2.5%				
MIN M-Q10 (m^3/s) 0.09		Q (m^3/s)															
FSL (2020) FWA ID. 7746	2,000	0.10	0.12	0.09	1.50	5.49	4.83	1.43	0.58	0.73	0.60	0.34	0.17				
%Diff		504%	859%	530%	20%	4%	74%	122%	193%	788%	338%	228%	273%				
For Zone 6		%MD												Notes: While the %MD are expressed as % of the annual flow and as a percentage, ie 24 is 24% as per Ahmed and Obedkoff, the 30Q10/MAD is expressed as a fraction of MAD, i.e.0.24 is 24%			
STEYX	2,000	1.4%	1.8%	1.0%	2.4%	16.8%	12.8%	6.5%	3.6%	6.2%	4.6%	2.3%	1.9%				
		Q (m^3/s)															
STEYX x 2	2,000	0.2	0.2	0.1	0.3	2.2	1.7	0.8	0.5	0.8	0.6	0.3	0.3				
FSL 95% SigDiff?		FALSE	FALSE	FALSE	FALSE	FALSE	TRUE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE				





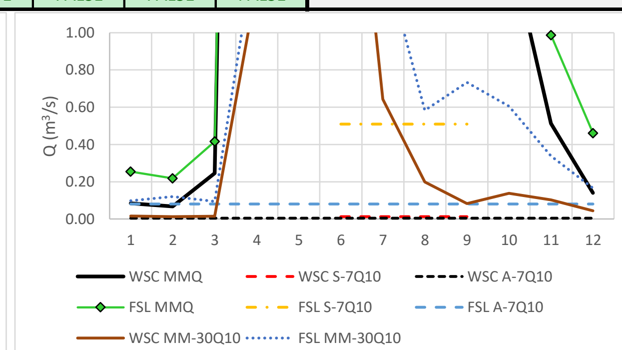


Table 22: Availability Validation Results for Halfway River near Farrell Creek (07FA006) in Zone 6

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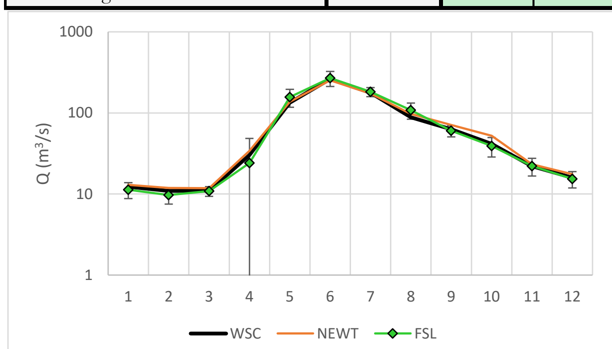
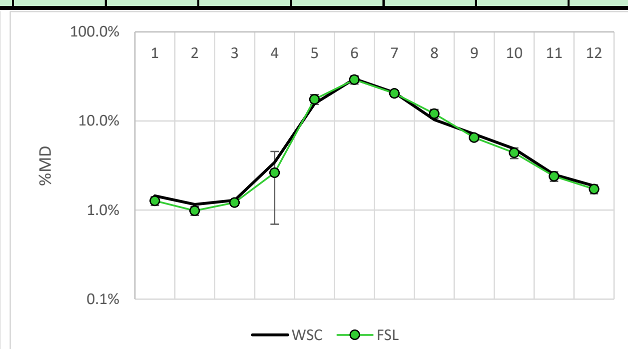
Halfway-Farrell (07FA006)	DA (km²)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	MAR	MAD	A-7Q10	S-7Q10
MEAN MONTHLY Q		%MD												(l/s/km²)	(m³/s)	(%MAD)	(%MAD)
Ahmed WSC (28 years data)	9,342	1.4%	1.2%	1.3%	3.4%	15.6%	29.6%	20.8%	10.3%	7.1%	4.9%	2.5%	1.9%	7.8	72.6	9.6%	30%
FSL_FID: 32385		Q (m³/s)														(m³/s)	(m³/s)
WSC Scaled to FWA ID. 8401	**9,346**	**12**	**11**	**11**	**30**	**134**	**262**	**178**	**88**	**63**	**42**	**22**	**16**	**7.8**	**72.593**	**7.00**	21.53
NEWT (2019)	9,351	13	12	12	34	137	252	173	97	71	52	23	18	8.0	74.7	WSC 30Q10	
Nash Sutcliffe Eff.= 99%	%Diff	6%	9%	8%	13%	3%	-4%	-3%	10%	13%	25%	5%	10%	3%	3%	**7.37**	
		%MD												(l/s/km²)	(m³/s)	(%MAD)	(%MAD)
FSL (2020) FWA ID. 8401	9,346	1.3%	1.0%	1.2%	2.6%	17.5%	29.0%	20.4%	12.1%	6.5%	4.4%	2.4%	1.7%	8.1	76.012	7%	22%
		Q (m³/s)														(m³/s)	(m³/s)
FSL (2020) FWA ID. 8401	9,346	11	10	11	24	157	268	182	108	60	39	22	15	8.1	76.012	5.19	16.54
Nash Sutcliffe Eff.= 99%	%Diff	-8%	-11%	-1%	-20%	17%	2%	3%	23%	-4%	-6%	0%	-4%	5%	5%	-26%	-27%
For Zone 6		%MD												(l/s/km²)	(m³/s)	(%MAD)	(%MAD)
STEYX	9,346	0.1%	0.1%	0.1%	1.9%	2.2%	3.1%	1.3%	1.4%	0.5%	0.6%	0.3%	0.2%	0.23	2.11	1.3%	4.7%
		Q (m³/s)												%	%	(m³/s)	(m³/s)
STEYX x 2	9,346	2.5	2.2	1.5	24	39	56	23	24	9.5	10.6	5.4	3.5	6%	6%	2.01	7.08
FSL 95% SigDiff?		FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE
30Q10 MONTHLY Q		%MAD												Notes: 95%confidence error bars extending below negative in logarithmic plot are not shown. Only 1 sigma error bars shown in comparison of %MD plot. Error bars not shown on Low Flow comparison plot			
Ahmed WSC (28 years data)	9,342	12%	12%	11%	20%	101%	180%	104%	43%	33%	30%	20%	16%				
MIN M-Q10 (m³/s) 7.80		Q (m³/s)															
WSC Scaled to FWA ID. 8401	**9,346**	**8.8**	**8.4**	**7.8**	**14.7**	**73.6**	**130.5**	**75.7**	**31.5**	**23.8**	**22.0**	**14.9**	**11.5**				
		%MAD															
FSL (2020) FWA ID. 8401	9,346	9.1%	8.3%	8.7%	17.5%	122.7%	163.3%	108.8%	41.6%	31.6%	26.6%	17.2%	12.6%				
MIN M-Q10 (m³/s) 6.31		Q (m³/s)															
FSL (2020) FWA ID. 8401	9,346	6.9	6.3	6.6	13.3	93.3	124.2	82.7	31.6	24.0	20.2	13.1	9.6				
%Diff		-21%	-25%	-15%	-10%	27%	-5%	9%	0%	1%	-8%	-12%	-17%				
For Zone 6		%MD												Notes: While the %MD are expressed as % of the annual flow and as a percentage, ie 24 is 24% as per Ahmed and Obedkoff, the 30Q10/MAD is expressed as a fraction of MAD, i.e.0.24 is 24%			
STEYX	9,346	1.4%	1.8%	1.0%	2.4%	16.8%	12.8%	6.5%	3.6%	6.2%	4.6%	2.3%	1.9%				
		Q (m³/s)															
STEYX x 2	9,346	2.1	2.7	1.6	3.6	25.5	19.4	9.9	5.5	9.4	7.0	3.4	2.9				
FSL 95% SigDiff?		FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE				





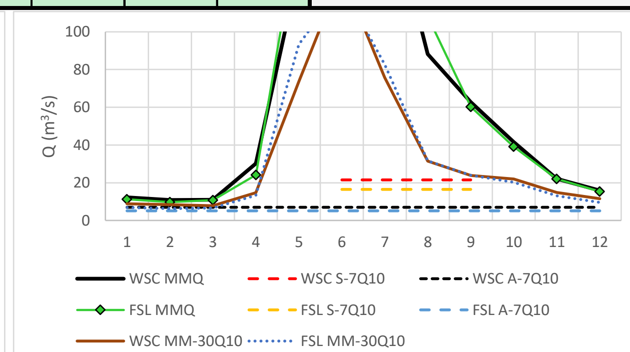


Table 23: Availability Validation Results for Halfway River above Graham River (07FA003) in Zone 6

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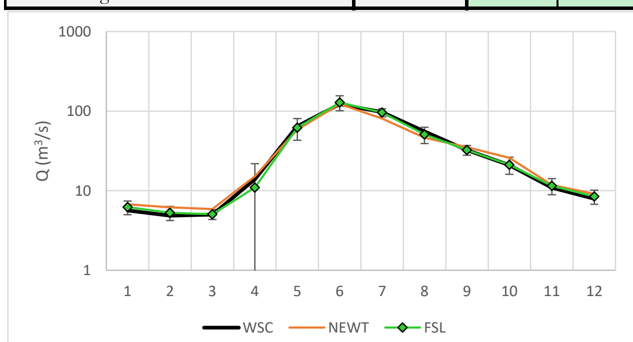
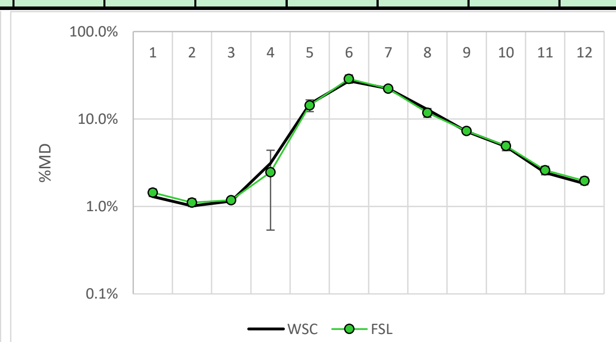
Halfway (07FA003)	DA (km²)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	MAR	MAD	A-7Q10	S-7Q10
MEAN MONTHLY Q		*%MD*												(l/s/km²)	(m³/s)	(%MAD)	(%MAD)
Ahmed WSC (22 years data)	3,763	1.3%	1.0%	1.1%	3.1%	14.8%	27.3%	22.3%	12.8%	7.2%	4.8%	2.4%	1.8%	9.8	36.7	8.0%	31%
		Q (m³/s)														(m³/s)	(m³/s)
WSC Scaled to FWA ID. 18168	**3,782**	**6**	**5**	**5**	**14**	**64**	**122**	**97**	**56**	**32**	**21**	**11**	**8**	**9.8**	**36.930**	**2.95**	**11.38**
NEWT (2019)	3,764	7	6	6	15	59	123	81	46	35	26	12	9	9.4	35.5	WSC 30Q10	
Nash Sutcliffe Eff.= 98%	%Diff	20%	27%	17%	9%	-9%	0%	-17%	-17%	9%	23%	8%	16%	-3%	-4%	**3.03**	
		%MD												(l/s/km²)	(m³/s)	(%MAD)	(%MAD)
FSL (2020) FWA ID. 18168	3,782	1.4%	1.1%	1.2%	2.5%	14.3%	28.7%	22.2%	11.8%	7.3%	4.9%	2.6%	2.0%	9.7	36.638	9%	32%
		Q (m³/s)														(m³/s)	(m³/s)
FSL (2020) FWA ID. 18168	3,782	6	5	5	11	62	128	96	51	32	21	12	8	9.7	36.638	3.13	11.65
Nash Sutcliffe Eff.= 100%	%Diff	10%	9%	2%	-21%	-4%	5%	-1%	-9%	1%	1%	6%	7%	-1%	-1%	6%	3%
For Zone 6		%MD												(l/s/km²)	(m³/s)	(%MAD)	(%MAD)
STEYX	3,782	0.1%	0.1%	0.1%	1.9%	2.2%	3.1%	1.3%	1.4%	0.5%	0.6%	0.3%	0.2%	0.23	0.85	1.3%	4.7%
		Q (m³/s)												%	%	(m³/s)	(m³/s)
STEYX x 2	3,782	1.2	1.1	0.7	11	19	27	11	12	4.6	5.1	2.6	1.7	5%	5%	0.97	3.41
FSL 95% SigDiff?		FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE
30Q10 MONTHLY Q		*%MAD*												Notes: 95%confidence error bars extending below negative in logarithmic plot are not shown. Only 1 sigma error bars shown in comparison of %MD plot. Error bars not shown on Low Flow comparison plot			
Ahmed WSC (22 years data)	3,763	12%	12%	11%	20%	101%	180%	104%	43%	33%	30%	20%	16%				
MIN M-Q10 (m³/s) 3.97		*Q (m³/s)*															
WSC Scaled to FWA ID. 18168	**3,782**	**4.5**	**4.3**	**4.0**	**7.5**	**37.4**	**66.4**	**38.5**	**16.0**	**12.1**	**11.2**	**7.6**	**5.9**				
		%MAD															
FSL (2020) FWA ID. 18168	3,782	11.0%	10.0%	10.5%	20.2%	69.1%	199.9%	115.9%	41.5%	40.0%	33.1%	21.2%	15.1%				
MIN M-Q10 (m³/s) 3.65		*Q (m³/s)*															
FSL (2020) FWA ID. 18168	3,782	4.0	3.6	3.9	7.4	25.3	73.2	42.5	15.2	14.7	12.1	7.8	5.5				
%Diff		-10%	-14%	-3%	-1%	-32%	10%	10%	-5%	21%	8%	3%	-6%				
For Zone 6		%MD												Notes: While the %MD are expressed as % of the annual flow and as a percentage, ie 24 is 24% as per Ahmed and Obedkoff, the 30Q10/MAD is expressed as a fraction of MAD, i.e.0.24 is 24%			
STEYX	3,782	1.4%	1.8%	1.0%	2.4%	16.8%	12.8%	6.5%	3.6%	6.2%	4.6%	2.3%	1.9%				
		Q (m³/s)															
STEYX x 2	3,782	1.0	1.3	0.8	1.7	12.3	9.4	4.8	2.6	4.5	3.4	1.7	1.4				
FSL 95% SigDiff?		FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE				





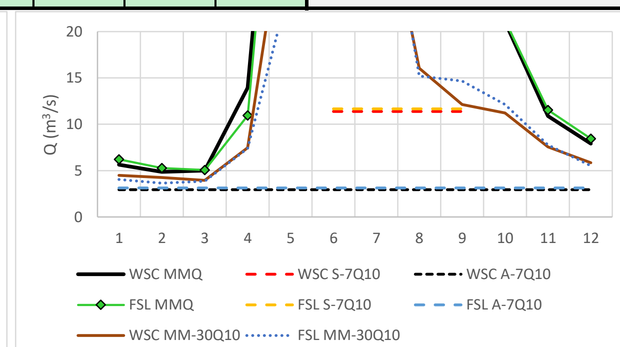


Table 24: Availability Validation Results for Kiskatinaw (07FA003) River in Zone 6

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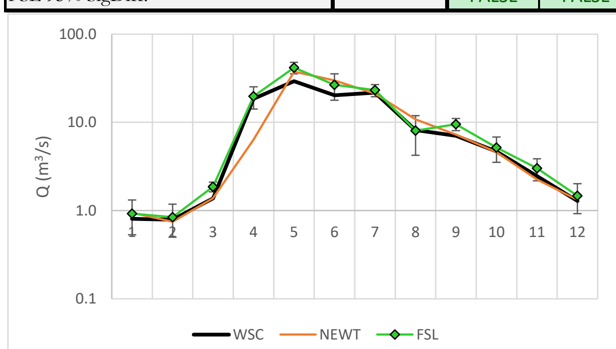
2020-01-31 10:35

Kiskatinaw (07FD001)	DA (km^2)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	MAR	MAD	A-7Q10	S-7Q10
MEAN MONTHLY Q		*%MD*												(l/s/km^2)	(m^3/s)	(%MAD)	(%MAD)
Ahmed WSC (53 years data)	3,635	0.7%	0.6%	1.2%	15.6%	25.6%	17.0%	18.9%	7.1%	5.9%	4.1%	2.1%	1.1%	2.7	9.9	0.8%	3%
		Q (m^3/s)														(m^3/s)	(m^3/s)
WSC Scaled to FWA ID. 6163	**3,582**	**0.8**	**0.8**	**1.4**	**18.5**	**29.4**	**20.2**	**21.8**	**8.2**	**7.1**	**4.7**	**2.5**	**1.3**	**2.7**	**9.75**	**0.076**	0.25
NEWT (2019)	3,597	0.9	0.7	1.4	6.4	37.6	29.8	21.2	10.8	7.3	4.6	2.3	1.3	2.9	10.4	WSC 30Q10	
Nash Sutcliffe Eff.= 72%	%Diff	17%	-5%	0%	-66%	28%	47%	-3%	32%	3%	-2%	-9%	3%	6%	7%	**0.090**	
		%MD												(l/s/km^2)	(m^3/s)	(%MAD)	(%MAD)
FSL (2020) FWA ID. 6163	3,582	0.7%	0.5%	1.3%	13.6%	29.7%	18.4%	16.5%	5.8%	6.6%	3.7%	2.1%	1.0%	3.3	11.9	0.8%	2.2%
		Q (m^3/s)														(m^3/s)	(m^3/s)
FSL (2020) FWA ID. 6163	3,582	0.9	0.8	1.9	19.7	41.6	26.6	23.2	8.1	9.5	5.2	3.0	1.5	3.3	11.9	0.09	0.26
Nash Sutcliffe Eff.= 82%	%Diff	15%	7%	36%	7%	42%	32%	6%	-1%	35%	10%	23%	14%	22%	22%	22%	-13%
For Zone 6		%MD												(l/s/km^2)	(m^3/s)	(%MAD)	(%MAD)
STEYX	3,582	0.1%	0.1%	0.1%	1.9%	2.2%	3.1%	1.3%	1.4%	0.5%	0.6%	0.3%	0.2%	0.23	0.81	1.3%	4.7%
		Q (m^3/s)												%	%	(m^3/s)	(m^3/s)
STEYX x 2	3,582	0.4	0.3	0.2	5.6	6.1	8.8	3.6	3.8	1.5	1.7	0.8	0.5	14%	14%	0.31	1.11
FSL 95% SigDiff?		FALSE	FALSE	TRUE	FALSE	TRUE	FALSE	FALSE	FALSE	TRUE	FALSE	FALSE	FALSE	TRUE	TRUE	FALSE	FALSE
30Q10 MONTHLY Q		*%MAD*												Notes: 95%confidence error bars extending below negative in logarithmic plot are not shown. Only 1 sigma error bars shown in comparison of %MD plot. Error bars not shown on Low Flow comparison plot			
Ahmed WSC (53 years data)	3,635	3%	2%	2%	29%	94%	52%	20%	6%	5%	7%	6%	4%				
MIN M-Q10 (m^3/s) 0.2047		*Q (m^3/s)*															
WSC Scaled to FWA ID. 6163	**3,582**	**0.25**	**0.20**	**0.21**	**2.83**	**9.18**	**5.09**	**1.96**	**0.54**	**0.50**	**0.72**	**0.57**	**0.37**				
		%MAD															
FSL (2020) FWA ID. 6163	3,582	2.4%	2.3%	2.3%	33.4%	83.4%	57.0%	23.8%	7.6%	1.7%	3.7%	4.3%	3.8%				
MIN M-Q10 (m^3/s) 0.20		*Q (m^3/s)*															
FSL (2020) FWA ID. 6163	3,582	0.29	0.27	0.28	3.97	9.92	6.78	2.83	0.90	0.20	0.44	0.51	0.45				
%Diff		15%	34%	28%	40%	8%	33%	45%	67%	-60%	-38%	-10%	21%				
For Zone 6		%MD												Notes: While the %MD are expressed as % of the annual flow and as a percentage, ie 24 is 24% as per Ahmed and Obedkoff, the 30Q10/MAD is expressed as a fraction of MAD, i.e.0.24 is 24%			
STEYX	3,582	1.4%	1.8%	1.0%	2.4%	16.8%	12.8%	6.5%	3.6%	6.2%	4.6%	2.3%	1.9%				
		Q (m^3/s)															
STEYX x 2	3,582	0.3	0.4	0.2	0.6	4.0	3.0	1.5	0.9	1.5	1.1	0.5	0.5				
FSL 95% SigDiff?		FALSE	FALSE	FALSE	TRUE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE				



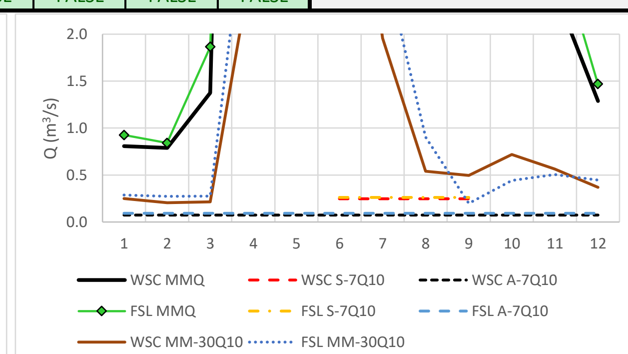


Table 25: Availability Validation Results for Moberly (07FB008) River in Zone 6

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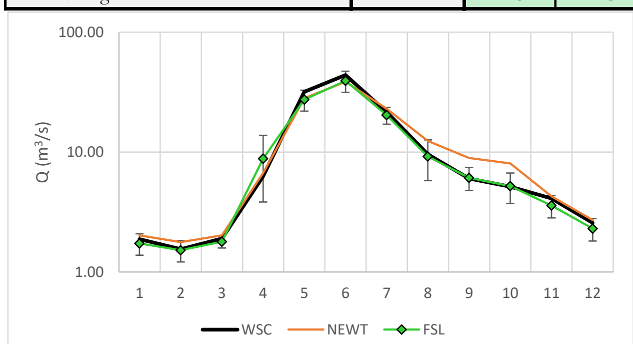
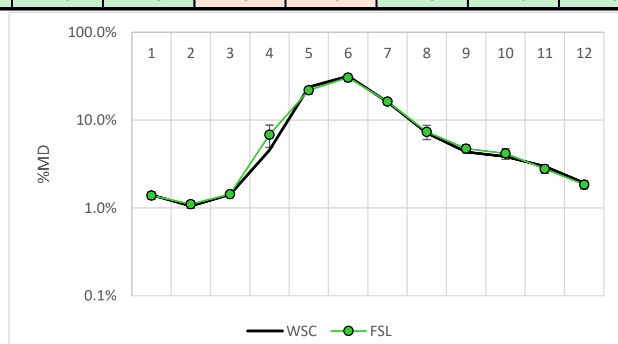
Moberly (07FB008)		DA (km^2)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	MAR	MAD	A-7Q10	S-7Q10
MEAN MONTHLY Q			%MD												(l/s/km^2)	(m^3/s)	(%MAD)	(%MAD)
Ahmed WSC (34 years data)		1,523	1.4%	1.0%	1.4%	4.5%	23.7%	31.6%	16.1%	7.1%	4.3%	3.8%	3.0%	1.9%	7.45	11.4	3.3%	6.8%
			Q (m^3/s)														(m^3/s)	(m^3/s)
WSC Scaled to	FWA ID. 18950	**1,530**	**1.88**	**1.55**	**1.90**	**6.28**	**31.86**	**43.89**	**21.59**	**9.56**	**6.01**	**5.15**	**4.11**	**2.58**	**7.45**	**11.4**	**0.378**	0.78
NEWT (2019)		1,530	2.0	1.8	2.0	6.7	28.1	38.6	23.0	12.4	8.9	8.1	4.3	2.7	7.58	11.6	WSC 30Q10	
Nash Sutcliffe Eff.= 97%		%Diff	7%	15%	6%	6%	-12%	-12%	7%	30%	49%	57%	4%	5%	2%	2%	**0.445**	
			%MD												(l/s/km^2)	(m^3/s)	(%MAD)	(%MAD)
FSL (2020)	FWA ID. 18950	1,530	1.4%	1.1%	1.4%	6.8%	21.9%	30.4%	16.2%	7.3%	4.7%	4.2%	2.8%	1.8%	6.96	10.6	5.3%	9.9%
			Q (m^3/s)														(m^3/s)	(m^3/s)
FSL (2020)	FWA ID. 18950	1,530	1.73	1.52	1.79	8.82	27.39	39.32	20.34	9.20	6.11	5.21	3.59	2.31	7.0	10.6	0.57	1.05
Nash Sutcliffe Eff.= 98%		%Diff	-8%	-2%	-6%	40%	-14%	-10%	-6%	-4%	2%	1%	-13%	-11%	-7%	-7%	50%	45%
For Zone 6			%MD												(l/s/km^2)	(m^3/s)	(%MAD)	(%MAD)
STEYX		1,530	0.1%	0.1%	0.1%	1.9%	2.2%	3.1%	1.3%	1.4%	0.5%	0.6%	0.3%	0.2%	0.23	0.35	1.3%	4.7%
			Q (m^3/s)												%	%	(m^3/s)	(m^3/s)
STEYX x 2		1,530	0.4	0.3	0.2	5	5	8	3	3	1.3	1.5	0.8	0.5	6%	6%	0.28	0.99
FSL 95% SigDiff?			FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	TRUE	TRUE	FALSE	FALSE
30Q10 MONTHLY Q			%MAD												Notes: 95%confidence error bars extending below negative in logarithmic plot are not shown. Only 1 sigma error bars shown in comparison of %MD plot. Error bars not shown on Low Flow comparison plot.			
Ahmed WSC (34 years data)		1,523	6%	6%	6%	15%	125%	238%	82%	22%	9%	10%	10%	8%				
MIN M-Q10 (m^3/s)	0.6462		*Q (m^3/s)*															
WSC Scaled to	FWA ID. 18950	**1,530**	**0.71**	**0.65**	**0.74**	**1.75**	**14.31**	**27.19**	**9.35**	**2.49**	**1.03**	**1.12**	**1.12**	**0.92**				
			%MAD															
FSL (2020)	FWA ID. 18950	1,530	8.4%	7.5%	8.0%	15.4%	169.1%	122.2%	75.0%	23.5%	19.5%	18.4%	13.6%	11.7%				
MIN M-Q10 (m^3/s)	0.80		*Q (m^3/s)*															
FSL (2020)	FWA ID. 18950	1,530	0.90	0.80	0.85	1.64	18.00	13.01	7.98	2.50	2.08	1.96	1.45	1.24				
%Diff			26%	23%	16%	-6%	26%	-52%	-15%	0%	102%	75%	29%	35%				
For Zone 6			%MD												Notes: While the %MD are expressed as % of the annual flow and as a percentage, ie 24 is 24% as per Ahmed and Obedkoff, the 30Q10/MAD is expressed as a fraction of MAD, i.e.0.24 is 24%			
STEYX		1,530	1.4%	1.8%	1.0%	2.4%	16.8%	12.8%	6.5%	3.6%	6.2%	4.6%	2.3%	1.9%				
			Q (m^3/s)															
STEYX x 2		1,530	0.3	0.4	0.2	0.5	3.6	2.7	1.4	0.8	1.3	1.0	0.5	0.4				
FSL 95% SigDiff?			FALSE	FALSE	FALSE	FALSE	TRUE	TRUE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE				





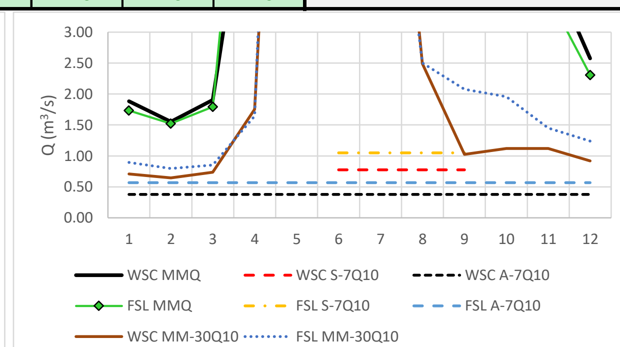


Table 26: Availability Validation Results for Pouce Coupe (07FD007) River in Zone 6

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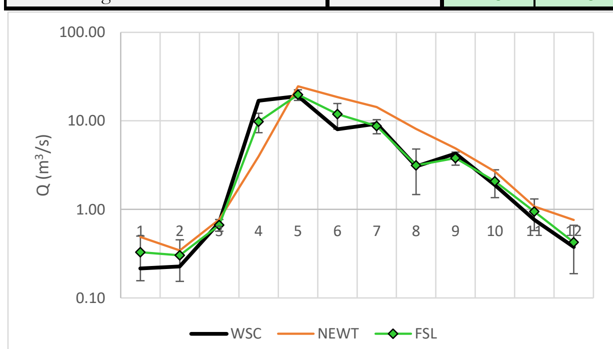
Pouce Coupe (07FD007)	DA (km^2)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	MAR	MAD	A-7Q10	S-7Q10
MEAN MONTHLY Q		%MD												($l/s/km^2$)	(m^3/s)	(%MAD)	(%MAD)
Ahmed WSC (42 years data)	2,862	0.3%	0.3%	1.1%	25.8%	30.1%	12.3%	14.7%	4.8%	6.6%	3.0%	1.2%	0.6%	1.86	5.3	0.3%	1.2%
		Q (m^3/s)														(m^3/s)	(m^3/s)
WSC Scaled to FWA ID. 9380	**2,877**	**0.21**	**0.23**	**0.71**	**16.84**	**18.98**	**8.04**	**9.27**	**3.06**	**4.28**	**1.88**	**0.76**	**0.38**	**1.86**	**5.36**	**0.018**	0.06
NEWT (2019)	2,871	0.5	0.3	0.8	4.0	24.6	18.5	14.3	8.1	4.9	2.7	1.1	0.8	2.4	6.75	WSC 30Q10	
Nash Sutcliffe Eff.= 25%	%Diff	127%	52%	9%	-76%	30%	130%	54%	165%	14%	42%	41%	102%	26%	26%	**0.006**	
		%MD												($l/s/km^2$)	(m^3/s)	(%MAD)	(%MAD)
FSL (2020) FWA ID. 9380	2,877	0.5%	0.4%	1.1%	15.6%	32.3%	18.9%	14.3%	5.1%	6.0%	3.4%	1.5%	0.7%	1.80	5.2	0.0%	0.0%
		Q (m^3/s)														(m^3/s)	(m^3/s)
FSL (2020) FWA ID. 9380	2,877	0.33	0.30	0.67	9.79	19.69	11.89	8.73	3.14	3.80	2.08	0.94	0.43	1.8	5.2	0.00	0.00
Nash Sutcliffe Eff.= 86%	%Diff	53%	34%	-6%	-42%	4%	48%	-6%	3%	-11%	11%	24%	13%	-4%	-4%	-100%	-100%
For Zone 6		%MD												($l/s/km^2$)	(m^3/s)	(%MAD)	(%MAD)
STEYX	2,877	0.1%	0.1%	0.1%	1.9%	2.2%	3.1%	1.3%	1.4%	0.5%	0.6%	0.3%	0.2%	0.23	0.65	1.3%	4.7%
		Q (m^3/s)												%	%	(m^3/s)	(m^3/s)
STEYX x 2	2,877	0	0	0	2	3	4	2	2	1	1	0	0	25%	25%	0.14	0.48
FSL 95% SigDiff?		FALSE	FALSE	FALSE	TRUE	FALSE	TRUE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE
30Q10 MONTHLY Q		%MAD												Notes: 95%confidence error bars extending below negative in logarithmic plot are not shown. Only 1 sigma error bars shown in comparison of %MD plot. Error bars not shown on Low Flow comparison plot. A-7Q10/MAD is from Obedkoff (2000) excluding very low year of 2008			
Ahmed WSC (42 years data)	2,862	1%	1%	1%	32%	51%	17%	2%	1%	1%	2%	2%	1%				
MIN M-Q10 (m^3/s) 0.0281		Q (m^3/s)															
WSC Scaled to FWA ID. 9380	**2,877**	**0.03**	**0.03**	**0.03**	**1.74**	**2.76**	**0.92**	**0.12**	**0.05**	**0.05**	**0.11**	**0.09**	**0.05**				
		%MAD															
FSL (2020) FWA ID. 9380	2,877	1.3%	1.5%	1.3%	29.4%	52.9%	16.3%	11.5%	3.0%	0.0%	0.8%	1.1%	2.3%				
MIN M-Q10 (m^3/s) 0.00		Q (m^3/s)															
FSL (2020) FWA ID. 9380	2,877	0.07	0.08	0.06	1.52	2.74	0.84	0.59	0.16	0.00	0.04	0.06	0.12				
%Diff		133%	185%	91%	-12%	-1%	-8%	407%	195%	-100%	-60%	-35%	149%				
For Zone 6		%MD												Notes: While the %MD are expressed as % of the annual flow and as a percentage, ie 24 is 24% as per Ahmed and Obedkoff, the 30Q10/MAD is expressed as a fraction of MAD, i.e.0.24 is 24%			
STEYX	2,877	1.4%	1.8%	1.0%	2.4%	16.8%	12.8%	6.5%	3.6%	6.2%	4.6%	2.3%	1.9%				
		Q (m^3/s)															
STEYX x 2	2,877	0.1	0.2	0.1	0.2	1.7	1.3	0.7	0.4	0.6	0.5	0.2	0.2				
FSL 95% SigDiff?		FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE				



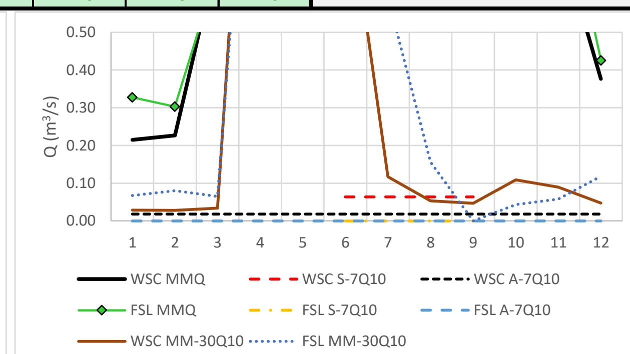


Table 27: Availability Validation Results for St John (07FD004) Creek in Zone 6

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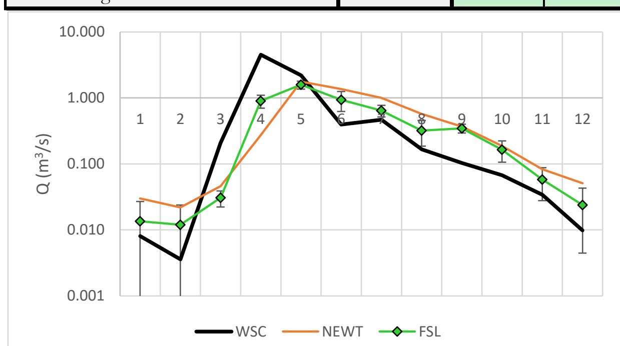
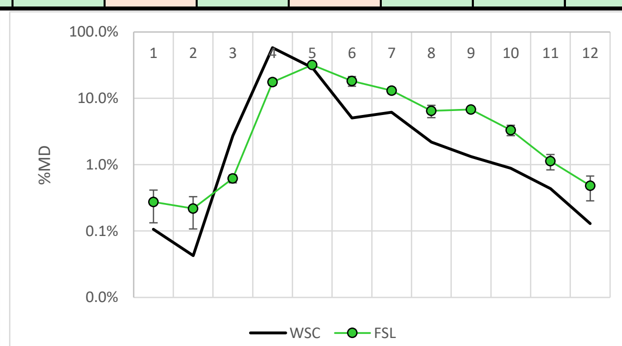
St John (07FD004)	DA (km²)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	MAR	MAD	A-7Q10	S-7Q10
MEAN MONTHLY Q		*%MD*												(l/s/km²)	(m³/s)	(%MAD)	(%MAD)
Ptolemy WSC (13 years data)	201	0.1%	0.0%	2.7%	57.8%	29.0%	5.1%	6.1%	2.2%	1.3%	0.9%	0.4%	0.1%	3.6	0.73	0.0%	0.0%
		Q (m³/s)														(m³/s)	(m³/s)
WSC Scaled to FWA ID. 7629	**177**	**0.01**	**0.00**	**0.21**	**4.53**	**2.20**	**0.40**	**0.47**	**0.17**	**0.10**	**0.07**	**0.03**	**0.01**	**3.6**	**0.6**	0.00	0.00
NEWT (2019)	183	0.03	0.02	0.05	0.27	1.8	1.4	1.0	0.6	0.37	0.19	0.08	0.05	2.6	0.5	WSC 30Q10	
Nash Sutcliffe Eff.= 2%	%Diff	273%	515%	-78%	-94%	-20%	243%	115%	245%	253%	179%	144%	418%	-27%	-25%	**0.00**	
		%MD												(l/s/km²)	(m³/s)	(%MAD)	(%MAD)
FSL (2020) FWA ID. 7629	177	0.3%	0.2%	0.6%	17.5%	31.9%	18.3%	13.0%	6.5%	6.8%	3.3%	1.1%	0.5%	2.4	0.4	0.4%	4%
		Q (m³/s)														(m³/s)	(m³/s)
FSL (2020) FWA ID. 7629	177	0.01	0.01	0.03	0.90	1.6	0.9	0.6	0.32	0.35	0.16	0.06	0.02	2.4	0.4	0.0016	0.0149
Nash Sutcliffe Eff.= 31%	%Diff	68%	235%	-85%	-80%	-28%	136%	38%	93%	233%	145%	70%	142%	-35%	-35%	#DIV/0!	#DIV/0!
For Zone 6		%MD												(l/s/km²)	(m³/s)	(%MAD)	(%MAD)
STEYX	177	0.1%	0.1%	0.1%	1.9%	2.2%	3.1%	1.3%	1.4%	0.5%	0.6%	0.3%	0.2%	3.16	0.56	5.9%	10.1%
		Q (m³/s)												%	%	(m³/s)	(m³/s)
STEYX x 2	177	0.01	0.01	0.01	0.20	0.22	0.31	0.13	0.14	0.05	0.06	0.03	0.02	266%	266%	0.05	0.08
FSL 95% SigDiff?		FALSE	FALSE	TRUE	TRUE	TRUE	TRUE	TRUE	TRUE	TRUE	TRUE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE
30Q10 MONTHLY Q		*%MAD*												Notes: 95%confidence error bars extending below negative in logarithmic plot are not shown. Only 1 sigma error bars shown in comparison of %MD plot. Error bars not shown on Low Flow comparison plot. Less than 10 years are available in the winter months. These values are the min monthly value from Ptolemy.			
Ptolemy WSC (13 years data)	201																
MIN M-Q10 (m³/s) 0.0000		*Q (m³/s)*															
WSC Scaled to FWA ID. 7629	**177**	**0.00**	**0.00**	**0.00**	**0.88**	**0.22**	**0.02**	**0.01**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**				
		%MAD															
FSL (2020) FWA ID. 7629	177	0.7%	1.1%	0.6%	24.3%	79.4%	50.3%	7.7%	2.6%	6.6%	5.7%	3.0%	1.4%				
MIN M-Q10 (m³/s) 0.00		*Q (m³/s)*															
FSL (2020) FWA ID. 7629	177	0.00	0.00	0.00	0.10	0.33	0.21	0.03	0.01	0.03	0.02	0.01	0.01				
%Diff		#DIV/0!	#DIV/0!	#DIV/0!	-88%	50%	959%	170%	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!				
For Zone 6		%MD												Notes: While the %MD are expressed as % of the annual flow and as a percentage, ie 24 is 24% as per Ahmed and Obedkoff, the 30Q10/MAD is expressed as a fraction of MAD, i.e.0.24 is 24%			
STEYX	177	1.4%	1.8%	1.0%	2.4%	16.8%	12.8%	6.5%	3.6%	6.2%	4.6%	2.3%	1.9%				
		Q (m³/s)															
STEYX x 2	177	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.0	0.1	0.0	0.0	0.0				
FSL 95% SigDiff?		FALSE	FALSE	FALSE	TRUE	FALSE	TRUE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE				





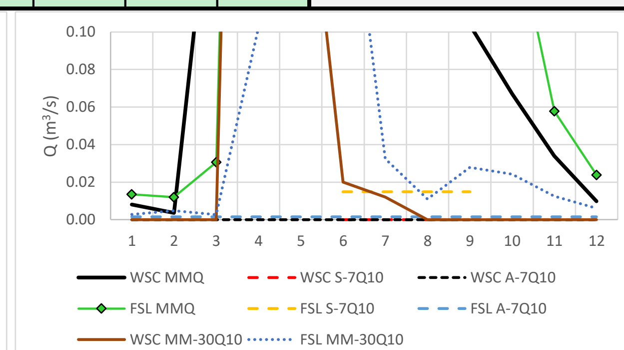


Table 28: Availability Validation Results for Muskeg (08KC003) River in Zone 8

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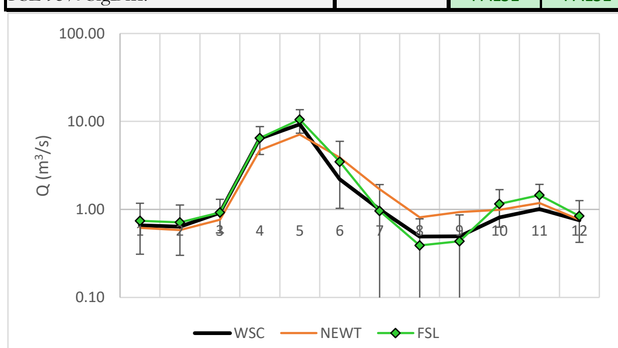
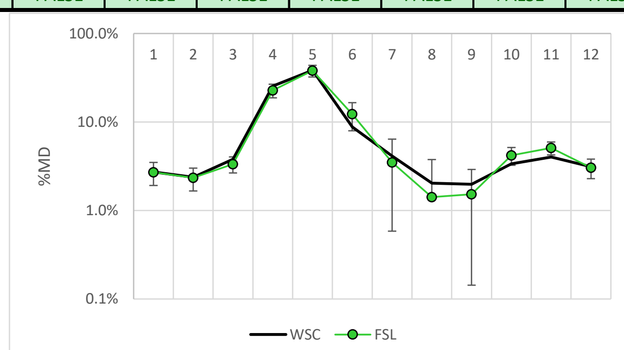
Muskeg (08KC003)	DA (km^2)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	MAR	MAD	A-7Q10	S-7Q10
MEAN MONTHLY Q		%MD												($l/s/km^2$)	(m^3/s)	(%MAD)	(%MAD)
Ahmed WSC (21 years data)	297	2.7%	2.4%	3.8%	25.4%	38.3%	8.8%	4.1%	2.0%	2.0%	3.4%	4.0%	3.1%	7.2	2.1	10.3%	11%
		Q (m^3/s)														(m^3/s)	(m^3/s)
WSC Scaled to FWA ID. 11478	**286**	**0.66**	**0.64**	**0.92**	**6.37**	**9.27**	**2.20**	**1.00**	**0.49**	**0.50**	**0.81**	**1.01**	**0.75**	**7.2**	**2.1**	**0.21**	0.22
NEWT (2019)	290	0.62	0.58	0.76	4.71	7.09	3.89	1.70	0.81	0.94	0.99	1.18	0.77	6.9	2.0	WSC 30Q10	
Nash Sutcliffe Eff.= 87%	%Diff	-7%	-8%	-17%	-26%	-23%	77%	70%	65%	89%	22%	17%	1%	-4%	-2%	**0.24**	
		%MD												($l/s/km^2$)	(m^3/s)	(%MAD)	(%MAD)
FSL (2020) FWA ID. 11478	286	2.7%	2.3%	3.3%	22.7%	37.9%	12.2%	3.5%	1.4%	1.5%	4.2%	5.1%	3.0%	8.2	2.3	7%	5%
		Q (m^3/s)														(m^3/s)	(m^3/s)
FSL (2020) FWA ID. 11478	286	0.74	0.71	0.92	6.47	10.47	3.49	0.96	0.39	0.43	1.16	1.45	0.84	8.2	2.3	0.17	0.12
Nash Sutcliffe Eff.= 96%	%Diff	13%	12%	1%	2%	13%	58%	-4%	-21%	-12%	42%	44%	11%	14%	14%	-18%	-53%
For Zone 8		%MD												($l/s/km^2$)	(m^3/s)	(%MAD)	(%MAD)
STEYX	286	0.8%	0.7%	0.7%	4.0%	5.7%	4.3%	2.9%	2.3%	1.4%	1.0%	0.8%	0.8%	3.16	0.90	5.9%	10.1%
		Q (m^3/s)												%	%	(m^3/s)	(m^3/s)
STEYX x 2	286	0.43	0.41	0.38	2.26	3.13	2.45	0.96	0.39	0.43	0.53	0.48	0.42	77%	77%	0.27	0.47
FSL 95% SigDiff?		FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE
30Q10 MONTHLY Q		%MAD												Notes: 95%confidence error bars extending below negative in logarithmic plot are not shown. Only 1 sigma error bars shown in comparison of %MD plot. Error bars not shown on Low Flow comparison plot			
Ahmed WSC (21 years data)	297	19%	20%	20%	111%	249%	42%	18%	13%	14%	21%	28%	23%				
MIN M-Q10 (m^3/s) 0.2607		*Q (m^3/s)*															
WSC Scaled to FWA ID. 11478	**286**	**0.39**	**0.41**	**0.41**	**2.29**	**5.13**	**0.86**	**0.36**	**0.26**	**0.30**	**0.42**	**0.57**	**0.48**				
		%MAD															
FSL (2020) FWA ID. 11478	286	18%	15%	19%	92%	244%	43%	17%	0%	8%	18%	24%	18%				
MIN M-Q10 (m^3/s) 0.00		*Q (m^3/s)*															
FSL (2020) FWA ID. 11478	286	0.41	0.36	0.44	2.15	5.71	1.00	0.40	0.00	0.20	0.41	0.57	0.41				
%Diff		7%	-13%	7%	-6%	11%	16%	9%	-100%	-33%	-3%	-1%	-13%				
For Zone 8		%MD												Notes: While the %MD are expressed as % of the annual flow and as a percentage, ie 24 is 24% as per Ahmed and Obedkoff, the 30Q10/MAD is expressed as a fraction of MAD, i.e.0.24 is 24%			
STEYX	286	7.0%	6.7%	6.7%	14.5%	56.0%	27.7%	20.8%	20.3%	12.5%	9.6%	6.4%	6.4%				
		Q (m^3/s)															
STEYX x 2	286	0.3	0.3	0.3	0.7	2.6	1.3	1.0	0.9	0.6	0.4	0.3	0.3				
FSL 95% SigDiff?		FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE				





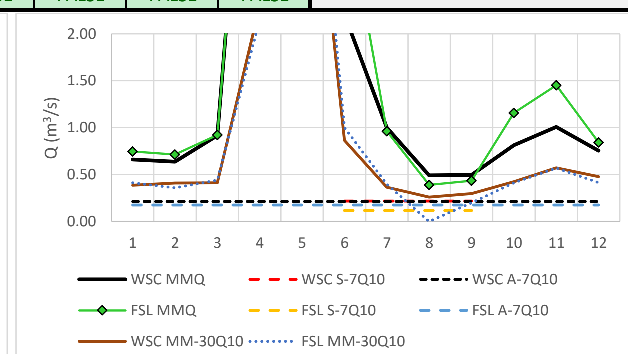


Table 29: Availability Validation Results for Nation-James (07ED001) River in Zone 8

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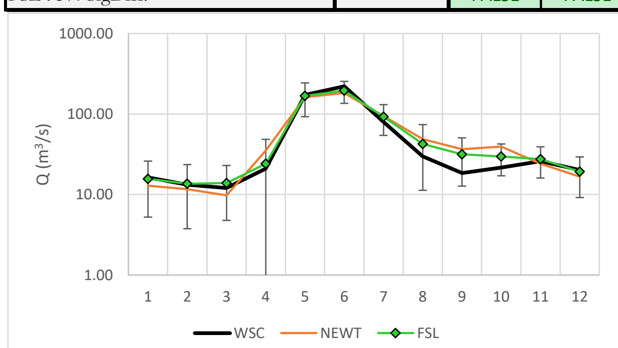
Nation-James (07ED001)	DA (km^2)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	MAR	MAD	A-7Q10	S-7Q10
MEAN MONTHLY Q		%MD												($l/s/km^2$)	(m^3/s)	(%MAD)	(%MAD)
Ahmed WSC (34 years data)	4,356	2.5%	1.9%	1.9%	3.2%	26.9%	33.2%	12.5%	4.7%	2.8%	3.4%	3.9%	3.1%	12.73	55.5	14.7%	19.2%
		Q (m^3/s)														(m^3/s)	(m^3/s)
WSC Scaled to FWA ID. 12027	**4,275**	**16.30**	**13.23**	**12.09**	**20.97**	**172.54**	**220.06**	**80.04**	**29.83**	**18.50**	**21.57**	**25.97**	**20.17**	**12.7**	**54.4**	**7.98**	**10.43**
NEWT (2019)	4,282	12.91	11.64	9.79	35.16	161.29	182.68	94.02	48.72	36.62	39.35	24.08	16.72	13.1	56.3	WSC 30Q10	
Nash Sutcliffe Eff.= 94%	%Diff	-21%	-12%	-19%	68%	-7%	-17%	17%	63%	98%	82%	-7%	-17%	3%	3%	**7.75**	
		%MD												($l/s/km^2$)	(m^3/s)	(%MAD)	(%MAD)
FSL (2020) FWA ID. 12027	4,275	2.4%	1.9%	2.1%	3.5%	25.3%	28.4%	14.0%	6.4%	4.6%	4.5%	4.0%	2.9%	13.2	56.3	14%	27%
		Q (m^3/s)														(m^3/s)	(m^3/s)
FSL (2020) FWA ID. 12027	4,275	15.69	13.66	13.91	24.19	167.44	194.74	92.59	42.43	31.64	29.77	27.58	19.22	13.2	56.3	7.66	15.04
Nash Sutcliffe Eff.= 98%	%Diff	-4%	3%	15%	15%	-3%	-12%	16%	42%	71%	38%	6%	-5%	3%	3%	-4%	39%
For Zone 8		%MD												($l/s/km^2$)	(m^3/s)	(%MAD)	(%MAD)
STEYX	4,275	0.8%	0.7%	0.7%	4.0%	5.7%	4.3%	2.9%	2.3%	1.4%	1.0%	0.8%	0.8%	3.16	13.52	5.9%	10.1%
		Q (m^3/s)												%	%	(m^3/s)	(m^3/s)
STEYX x 2	4,275	10.4	9.9	9.1	24	75	59	38	31	18.9	12.7	11.6	10.1	48%	48%	6.59	11.35
FSL 95% SigDiff?		FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE
30Q10 MONTHLY Q		%MAD															
Ahmed WSC (34 years data)	4,356	20%	17%	16%	18%	172%	233%	90%	30%	21%	25%	29%	24%				
MIN M-Q10 (m^3/s) 8.5350		Q (m^3/s)															
WSC Scaled to FWA ID. 12027	**4,275**	**10.90**	**9.43**	**8.54**	**9.87**	**93.84**	**127.07**	**48.91**	**16.48**	**11.22**	**13.40**	**15.81**	**12.93**				
		%MAD															
FSL (2020) FWA ID. 12027	4,275	18%	17%	16%	26%	166%	211%	95%	47%	30%	31%	27%	22%				
MIN M-Q10 (m^3/s) 9.15		Q (m^3/s)															
FSL (2020) FWA ID. 12027	4,275	10.15	9.81	9.15	14.65	93.34	118.64	53.31	26.57	17.03	17.27	14.97	12.11				
%Diff		-7%	4%	7%	48%	-1%	-7%	9%	61%	52%	29%	-5%	-6%				
For Zone 8		%MD															
STEYX	4,275	7.0%	6.7%	6.7%	14.5%	56.0%	27.7%	20.8%	20.3%	12.5%	9.6%	6.4%	6.4%				
		Q (m^3/s)															
STEYX x 2	4,275	7.9	7.6	7.6	16.3	63.1	31.1	23.5	22.8	14.1	10.8	7.2	7.2				
FSL 95% SigDiff?		FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE				

Notes: 95%confidence error bars extending below negative in logarithmic plot are not shown. Only 1 sigma error bars shown in comparison of %MD plot. Error bars not shown on Low Flow comparison plot

Notes: While the %MD are expressed as % of the annual flow and as a percentage, ie 24 is 24% as per Ahmed and Obedkoff, the 30Q10/MAD is expressed as a fraction of MAD, i.e.0.24 is 24%



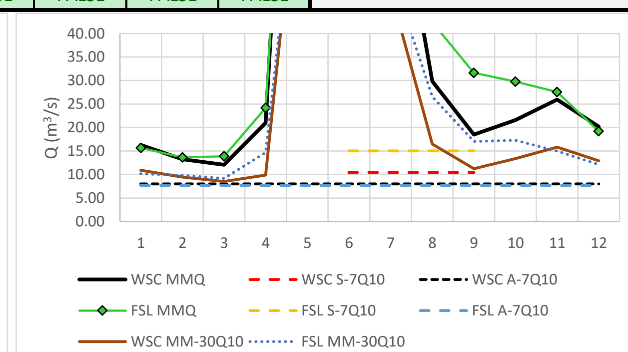


Table 30: Availability Validation Results for Chuchinka (07EE009) River in Zone 8

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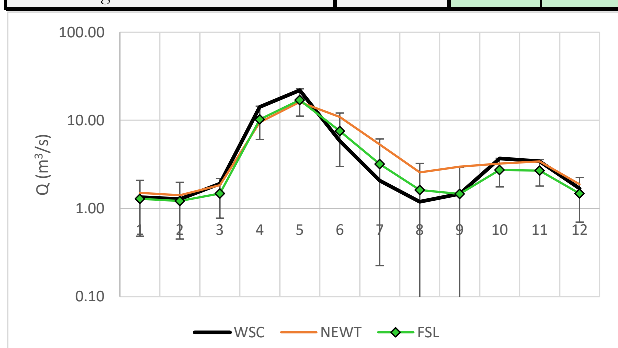
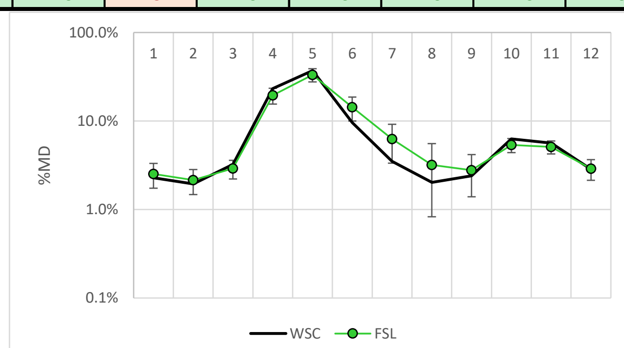
Chuchinka (07EE009)	DA (km^2)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	MAR	MAD	A-7Q10	S-7Q10
MEAN MONTHLY Q		%MD												(l/s/km^2)	(m^3/s)	(%MAD)	(%MAD)
Ahmed WSC (21 years data)	310	2.3%	1.9%	3.2%	23.2%	37.1%	9.6%	3.5%	2.0%	2.4%	6.3%	5.6%	2.8%	15.82	4.9	4.9%	4.6%
		Q (m^3/s)														(m^3/s)	(m^3/s)
WSC Scaled to FWA ID. 37768	**318**	**1.35**	**1.28**	**1.91**	**14.22**	**21.95**	**5.85**	**2.07**	**1.19**	**1.47**	**3.71**	**3.44**	**1.68**	**15.8**	**5.0**	**0.25**	0.23
NEWT (2019)	318	1.51	1.41	1.85	9.51	16.14	10.91	5.32	2.56	2.99	3.24	3.43	1.89	16.0	5.1	WSC 30Q10	
Nash Sutcliffe Eff.= 79%	%Diff	12%	11%	-3%	-33%	-26%	86%	157%	115%	104%	-13%	0%	12%	1%	1%	**0.32**	
		%MD												(l/s/km^2)	(m^3/s)	(%MAD)	(%MAD)
FSL (2020) FWA ID. 37768	318	2.5%	2.1%	2.9%	19.4%	33.2%	14.3%	6.2%	3.2%	2.8%	5.4%	5.1%	2.9%	13.7	4.3	7%	10%
		Q (m^3/s)														(m^3/s)	(m^3/s)
FSL (2020) FWA ID. 37768	318	1.29	1.21	1.48	10.27	16.99	7.55	3.19	1.63	1.47	2.74	2.69	1.48	13.7	4.3	0.33	0.44
Nash Sutcliffe Eff.= 90%	%Diff	-4%	-5%	-23%	-28%	-23%	29%	54%	36%	0%	-26%	-22%	-12%	-14%	-14%	32%	120%
For Zone 8		%MD												(l/s/km^2)	(m^3/s)	(%MAD)	(%MAD)
STEYX	318	0.8%	0.7%	0.7%	4.0%	5.7%	4.3%	2.9%	2.3%	1.4%	1.0%	0.8%	0.8%	3.16	1.00	5.9%	10.1%
		Q (m^3/s)												%	%	(m^3/s)	(m^3/s)
STEYX x 2	318	0.80	0.76	0.70	4.19	5.80	4.55	2.97	1.63	1.46	0.98	0.89	0.78	46%	46%	0.51	0.88
FSL 95% SigDiff?		FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE
30Q10 MONTHLY Q		%MAD												Notes: 95%confidence error bars extending below negative in logarithmic plot are not shown. Only 1 sigma error bars shown in comparison of %MD plot. Error bars not shown on Low Flow comparison plot			
Ahmed WSC (21 years data)	310	12%	11%	14%	113%	223%	44%	16%	7%	10%	20%	27%	17%				
MIN M-Q10 (m^3/s) 0.3388		Q (m^3/s)															
WSC Scaled to FWA ID. 37768	**318**	**0.62**	**0.56**	**0.70**	**5.70**	**11.22**	**2.24**	**0.82**	**0.34**	**0.49**	**1.02**	**1.34**	**0.86**				
		%MAD															
FSL (2020) FWA ID. 37768	318	16%	14%	17%	93%	216%	75%	25%	16%	18%	22%	24%	17%				
MIN M-Q10 (m^3/s) 0.62		Q (m^3/s)															
FSL (2020) FWA ID. 37768	318	0.71	0.62	0.74	4.05	9.36	3.28	1.10	0.71	0.79	0.94	1.04	0.74				
%Diff		14%	10%	6%	-29%	-17%	47%	34%	110%	61%	-8%	-22%	-14%				
For Zone 8		%MD												Notes: While the %MD are expressed as % of the annual flow and as a percentage, ie 24 is 24% as per Ahmed and Obedkoff, the 30Q10/MAD is expressed as a fraction of MAD, i.e.0.24 is 24%			
STEYX	318	7.0%	6.7%	6.7%	14.5%	56.0%	27.7%	20.8%	20.3%	12.5%	9.6%	6.4%	6.4%				
		Q (m^3/s)															
STEYX x 2	318	0.6	0.6	0.6	1.3	4.9	2.4	1.8	1.8	1.1	0.8	0.6	0.6				
FSL 95% SigDiff?		FALSE	FALSE	FALSE	TRUE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE				





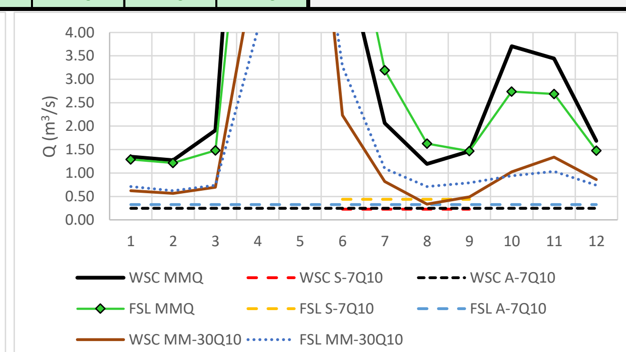


Table 31: Availability Validation Results for Murray-Wolverine (07FB006) River in Zone 7+12

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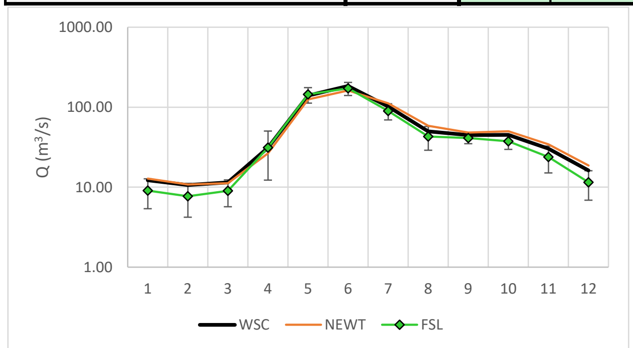
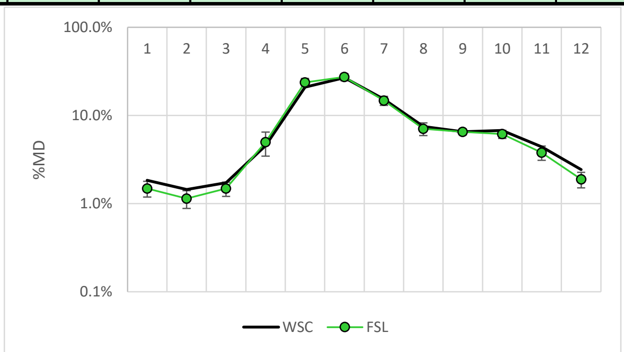
Murray-Wolverine (07FB006)	DA (km^2)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	MAR	MAD	A-7Q10	S-7Q10
MEAN MONTHLY Q		%MD												(l/s/km^2)	(m^3/s)	(%MAD)	(%MAD)
Ahmed WSC (34 years data)	2,366	1.8%	1.4%	1.7%	4.5%	20.9%	26.7%	15.3%	7.5%	6.5%	6.7%	4.4%	2.4%	23.9	56.6	11%	28%
		Q (m^3/s)														(m^3/s)	(m^3/s)
WSC Scaled to FWA ID. 11358	**2,367**	**12.22**	**10.63**	**11.51**	**31.20**	**139.30**	**184.40**	**102.14**	**49.90**	**44.90**	**44.96**	**30.30**	**16.21**	**23.9**	**56.7**	**6.16**	**15.85**
NEWT (2019)	2,403	12.80	10.80	11.20	26.50	125.00	162.00	112.00	58.50	48.20	50.00	34.40	18.70	23.3	56.1	WSC 30Q10	
Nash Sutcliffe Eff.= 97%	%Diff	5%	2%	-3%	-15%	-10%	-12%	10%	17%	7%	11%	14%	15%	-2%	-1%	**6.47**	
		%MD												(l/s/km^2)	(m^3/s)	(%MAD)	(%MAD)
FSL (2020) FWA ID. 11358	2,367	1.5%	1.1%	1.5%	5.0%	23.6%	27.3%	14.7%	7.1%	6.5%	6.1%	3.8%	1.9%	21.9	51.8	6%	21%
		Q (m^3/s)														(m^3/s)	(m^3/s)
FSL (2020) FWA ID. 11358	2,367	9.05	7.69	9.02	31.32	144.19	171.91	89.68	43.09	41.07	37.43	23.87	11.49	21.9	51.8	3.33	11.09
Nash Sutcliffe Eff.= 98%	%Diff	-26%	-28%	-22%	0%	4%	-7%	-12%	-14%	-9%	-17%	-21%	-29%	-9%	-9%	-46%	-24%
For Zone 7+12		%MD												(l/s/km^2)	(m^3/s)	(%MAD)	(%MAD)
STEYX	2,367	0.3%	0.3%	0.3%	1.5%	2.6%	2.5%	1.7%	1.2%	0.5%	0.6%	0.7%	0.4%	2.68	6.35	2.3%	4.0%
		Q (m^3/s)												%	%	(m^3/s)	(m^3/s)
STEYX x 2	2,367	4	3	3	19	32	32	20	14	6	8	9	5	24%	24%	2.42	4.17
FSL 95% SigDiff?		FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	TRUE	FALSE	FALSE	TRUE	TRUE
30Q10 MONTHLY Q		%MAD															
Ahmed WSC (34 years data)	2,366	14%	12%	11%	25%	169%	198%	110%	61%	39%	39%	27%	18%				
MIN M-Q10 (m^3/s) 6.3390		Q (m^3/s)															
WSC Scaled to FWA ID. 11358	**2,367**	**7.92**	**6.64**	**6.34**	**13.93**	**95.86**	**112.43**	**62.59**	**34.44**	**22.26**	**21.93**	**15.26**	**10.15**				
		%MAD															
FSL (2020) FWA ID. 11358	2,367	10%	8%	8%	24%	164%	176%	88%	56%	39%	37%	21%	14%				
MIN M-Q10 (m^3/s) 3.92		Q (m^3/s)															
FSL (2020) FWA ID. 11358	2,367	4.93	4.03	3.92	12.21	84.91	91.33	45.71	29.26	20.23	19.01	11.08	7.06				
%Diff		-38%	-39%	-38%	-12%	-11%	-19%	-27%	-15%	-9%	-13%	-27%	-30%				
For Zone 7+12		%MD															
STEYX	2,367	3.0%	2.6%	2.6%	5.2%	28.5%	41.1%	21.4%	9.8%	6.6%	6.7%	3.9%	3.2%				
		Q (m^3/s)															
STEYX x 2	2,367	3.1	2.7	2.7	5.4	29.5	42.6	22.2	10.2	6.9	6.9	4.0	3.3				
FSL 95% SigDiff?		FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	TRUE	FALSE				

Notes: 95%confidence error bars extending below negative in logarithmic plot are not shown. Only 1 sigma error bars shown in comparison of %MD plot. Error bars not shown on Low Flow comparison plot

Notes: While the %MD are expressed as % of the annual flow and as a percentage, ie 24 is 24% as per Ahmed and Obedkoff, the 30Q10/MAD is expressed as a fraction of MAD, i.e.0.24 is 24%





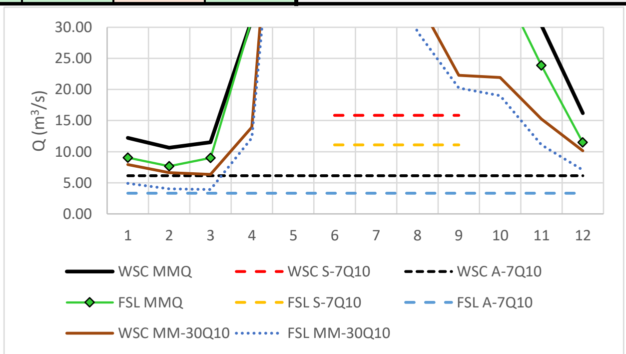


Table 32: Availability Validation Results for Muller (08KB006) Creek in Zone 12

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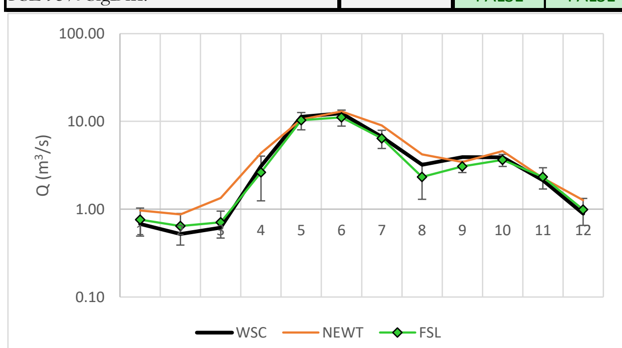
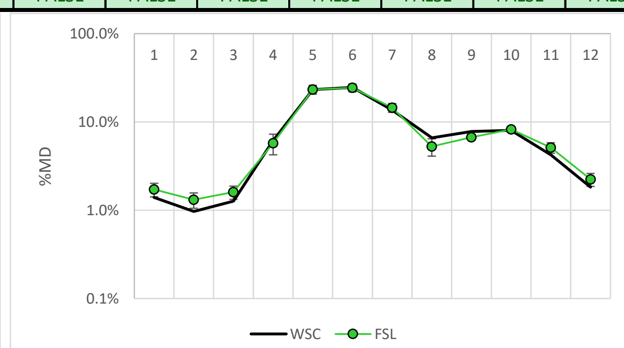
Muller (08KB006)	DA (km²)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	MAR	MAD	A-7Q10	S-7Q10
MEAN MONTHLY Q		*%MD*												(l/s/km²)	(m³/s)	(%MAD)	(%MAD)
Ahmed WSC (33years data)	103	1.4%	1.0%	1.3%	6.1%	23.1%	24.6%	13.6%	6.6%	7.8%	8.0%	4.2%	1.8%	45.5	4.67	5%	19%
		Q (m³/s)														(m³/s)	(m³/s)
WSC Scaled to FWA ID. 4794	91	0.68	0.523	0.62	3.08	11.28	12.39	6.65	3.21	3.93	3.90	2.13	0.89	45.5	4.14	0.22	0.79
NEWT (2019)	102	0.97	0.874	1.34	4.37	10.5	13.0	9.0	4.2	3.45	4.59	2.26	1.27	43.7	4.46	WSC 30Q10	
Nash Sutcliffe Eff.= 94%	%Diff	42%	67%	118%	42%	-7%	5%	35%	31%	-12%	18%	6%	43%	-4%	8%	0.18	
		%MD												(l/s/km²)	(m³/s)	(%MAD)	(%MAD)
FSL (2020) FWA ID. 4794	91	1.7%	1.3%	1.6%	5.7%	23.3%	24.3%	14.5%	5.3%	6.7%	8.2%	5.1%	2.2%	41.4	3.76	8%	19%
		Q (m³/s)														(m³/s)	(m³/s)
FSL (2020) FWA ID. 4794	91	0.762	0.643	0.71	2.63	10.3	11.1	6.4	2.33	3.07	3.64	2.34	0.99	41.4	3.76	0.315	0.72
Nash Sutcliffe Eff.= 98%	%Diff	12%	23%	15%	-14%	-9%	-10%	-4%	-27%	-22%	-7%	10%	11%	-9%	-9%	42%	1%
For Zone 7+12		%MD												(l/s/km²)	(m³/s)	(%MAD)	(%MAD)
STEYX	91	0.3%	0.3%	0.3%	1.5%	2.6%	2.5%	1.7%	1.2%	0.5%	0.6%	0.7%	0.4%	1.63	0.15	1.4%	6.7%
		Q (m³/s)												%	%	(m³/s)	(m³/s)
STEYX x 2	91	0.27	0.25	0.24	1.38	2.30	2.30	1.49	1.03	0.45	0.57	0.64	0.34	8%	8%	0.10	0.51
FSL 95% SigDiff?		FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	TRUE	FALSE	FALSE	FALSE	TRUE	TRUE	FALSE	FALSE
30Q10 MONTHLY Q		*%MAD*												Notes: 95%confidence error bars extending below negative in logarithmic plot are not shown. Only 1 sigma error bars shown in comparison of %MD plot. Error bars not shown on Low Flow comparison plot			
Ahmed WSC (33years data)	103	8.2%	6.5%	5.3%	19.3%	182.1%	178.5%	87.7%	44.0%	36.1%	44.2%	30.0%	13.4%				
MIN M-Q10 (m³/s) 0.2211		*Q (m³/s)*															
WSC Scaled to FWA ID. 4794	91	0.341	0.270	0.221	0.799	7.537	7.391	3.632	1.820	1.495	1.828	1.243	0.555				
		%MAD															
FSL (2020) FWA ID. 4794	91	11.8%	9.6%	9.0%	30.4%	165.5%	158.2%	81.2%	59.0%	42.0%	56.1%	32.2%	17.7%				
MIN M-Q10 (m³/s) 0.34		*Q (m³/s)*															
FSL (2020) FWA ID. 4794	91	0.442	0.363	0.340	1.144	6.228	5.953	3.055	2.219	1.580	2.110	1.211	0.667				
%Diff		30%	34%	54%	43%	-17%	-19%	-16%	22%	6%	15%	-3%	20%				
For Zone 7+12		%MD												Notes: While the %MD are expressed as % of the annual flow and as a percentage, ie 24 is 24% as per Ahmed and Obedkoff, the 30Q10/MAD is expressed as a fraction of MAD, i.e.0.24 is 24%			
STEYX	91	11.8%	9.6%	9.0%	30.4%	165.5%	158.2%	81.2%	59.0%	42.0%	56.1%	32.2%	17.7%				
		Q (m³/s)															
STEYX x 2	91	0.884	0.726	0.680	2.288	12.455	11.906	6.110	4.438	3.160	4.220	2.423	1.335				
FSL 95% SigDiff?		FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE				





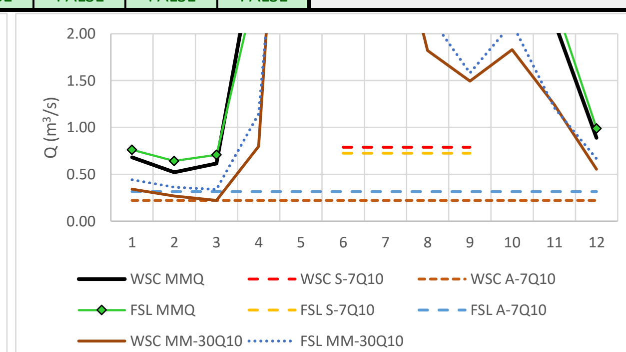


Table 33: Availability Validation Results for Pine (07FB001) River in Zone 7

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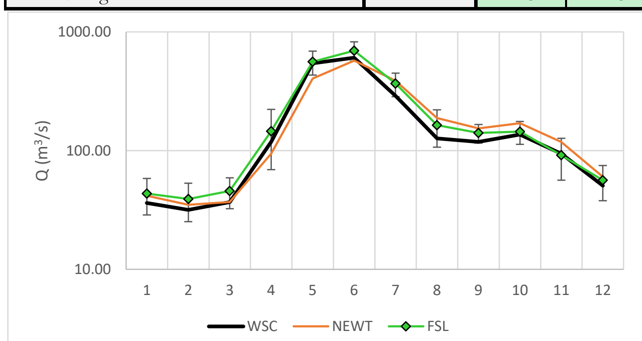
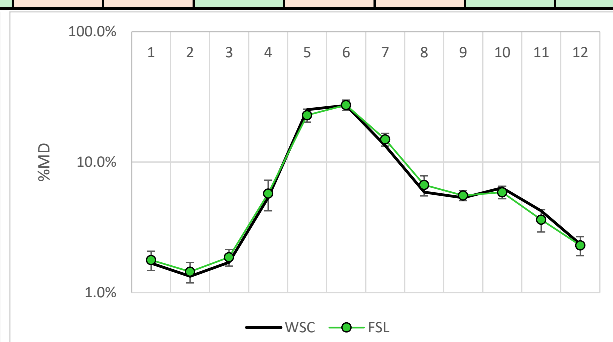
2020-01-31 10:35

Pine (07FB001)	DA (km^2)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	MAR	MAD	A-7Q10	S-7Q10
MEAN MONTHLY Q		%MD												($l/s/km^2$)	(m^3/s)	(%MAD)	(%MAD)
Ahmed WSC (53 years data)	12,126	1.7%	1.3%	1.7%	5.3%	25.2%	27.2%	13.4%	5.9%	5.3%	6.3%	4.2%	2.4%	15.06	182.6	9.9%	25.1%
		Q (m^3/s)														(m^3/s)	(m^3/s)
WSC Scaled to FWA ID. 13204	12,154	36.20	31.78	36.80	118.80	543.47	605.75	288.67	126.93	118.49	136.61	94.02	50.64	15.1	183.0	18.1	45.9
NEWT (2019)	12,201	41.7	35.0	37.0	94.5	404.0	573.0	388.0	188.0	154.0	170.0	118.0	60.3	15.5	189	WSC 30Q10	
Nash Sutcliffe Eff.= 91%	%Diff	15%	10%	1%	-20%	-26%	-5%	34%	48%	30%	24%	25%	19%	3%	3%	17.44	
		%MD												($l/s/km^2$)	(m^3/s)	(%MAD)	(%MAD)
FSL (2020) FWA ID. 13204	12,154	1.8%	1.4%	1.9%	5.7%	22.8%	27.4%	14.9%	6.7%	5.5%	5.9%	3.6%	2.3%	17.17	208.6	10.4%	27.2%
		Q (m^3/s)														(m^3/s)	(m^3/s)
FSL (2020) FWA ID. 13204	12,154	43.57	39.25	45.82	145.89	560.99	694.98	367.11	163.88	140.88	144.47	91.72	56.44	17.2	208.6	21.65	56.77
Nash Sutcliffe Eff.= 96%	%Diff	20%	24%	25%	23%	3%	15%	27%	29%	19%	6%	-2%	11%	14%	14%	20%	8%
For Zone 7+12		%MD												($l/s/km^2$)	(m^3/s)	(%MAD)	(%MAD)
STEYX	12,154	0.3%	0.3%	0.3%	1.5%	2.6%	2.5%	1.7%	1.2%	0.5%	0.6%	0.7%	0.4%	2.68	32.59	2.3%	4.0%
		Q (m^3/s)												%	%	(m^3/s)	(m^3/s)
STEYX x 2	12,154	15	14	13	77	128	127	82	57	25	31	35	19	31%	31%	9.74	16.78
FSL 95% SigDiff?		FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE
30Q10 MONTHLY Q		%MAD												Notes: 95%confidence error bars extending below negative in logarithmic plot are not shown. Only 1 sigma error bars shown in comparison of %MD plot. Error bars not shown on Low Flow comparison plot.			
Ahmed WSC (53 years data)	12,126	13%	11%	11%	27%	203%	196%	82%	37%	29%	34%	26%	17%				
MIN M-Q10 (m^3/s) 19.5944		Q (m^3/s)															
WSC Scaled to FWA ID. 13204	12,154	24.26	20.41	19.59	48.53	370.64	359.14	149.40	67.42	52.24	62.50	48.46	31.14				
		%MAD															
FSL (2020) FWA ID. 13204	12,154	13.4%	11.7%	11.7%	28.5%	172.0%	215.4%	97.2%	31.8%	22.6%	29.0%	26.1%	11.3%				
MIN M-Q10 (m^3/s) 23.58		Q (m^3/s)															
FSL (2020) FWA ID. 13204	12,154	27.91	24.48	24.45	59.55	358.76	449.50	202.69	66.38	47.14	60.47	54.37	23.58				
%Diff		15%	20%	25%	23%	-3%	25%	36%	-2%	-10%	-3%	12%	-24%				
For Zone 7+12		%MD												Notes: While the %MD are expressed as % of the annual flow and as a percentage, ie 24 is 24% as per Ahmed and Obedkoff, the 30Q10/MAD is expressed as a fraction of MAD, i.e.0.24 is 24%			
STEYX	12,154	1.4%	1.8%	1.0%	2.4%	16.8%	12.8%	6.5%	3.6%	6.2%	4.6%	2.3%	1.9%				
		Q (m^3/s)															
STEYX x 2	12,154	5.8	7.4	4.3	9.9	70.0	53.3	27.1	15.0	25.7	19.2	9.4	8.0				
FSL 95% SigDiff?		FALSE	FALSE	TRUE	TRUE	FALSE	TRUE	TRUE	FALSE	FALSE	FALSE	FALSE	FALSE				





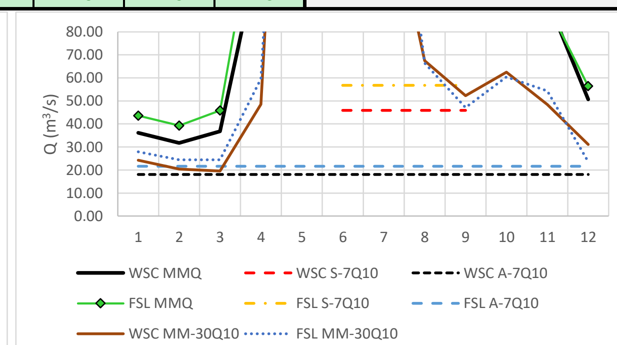


Table 34: Availability Validation Results Summary

Site	Significantly Different = False Count	%Diff FSL_JAN	%Diff FSL_FEB	%Diff FSL_MARCH	%Diff FSL_MAR	%Diff NEWT_JAN	%Diff NEWT_FEB	%Diff NEWT_MARCH	%Diff NEWT_MAR	FSL_NSE	NEWT_NSE
Teeter (10BE009)		-13%	3%	9%		-61%	-72%	-77%			
Kechika-Boya (10BB002)	27	13%	20%	13%	21%	-22%	-16%	-21%	-5%	87%	97%
Ingenika (07EA004)	25	-15%	-33%	-35%	10%	-21%	-14%	-16%	3%	97%	92%
Ospika (07EB002)	24	-23%	-11%	-9%	-16%	1%	15%	15%	6%	88%	90%
Adsett (10CD005)	25				-6%				-2%	97%	88%
Petitot (10DA001)											
Alces (07FD004)	25	-6%	-19%	16%	12%	117%	45%	-25%	8%	98%	71%
Beatton (07FC001)	27	-24%	-17%	-20%	-11%	129%	152%	77%	0%	96%	92%
Blueberry (07FC003)					14%				7%	97%	85%
Halfway-Farrell (07FA006)	27	-8%	-11%	-1%	5%	6%	9%	8%	3%	99%	99%
Halfway (07FA003)	27	10%	9%	2%	-1%	20%	27%	17%	-3%	100%	98%
Kiskatinaw (07FD001)	22	15%	7%	36%		17%	-5%	0%	6%		
Moberly (07FB008)	24	-8%	-2%	-6%	-7%	7%	15%	6%	2%	98%	97%
Pouce Coupe (07FD007)	25	53%	34%	-6%	-4%	127%	52%	9%		86%	25%
St John (07FD004)											
Muskeg (08KC003)	27	13%	12%	1%	14%	-7%	-8%	-17%	-4%	96%	87%
Nation-James (07ED001)	27	-4%	3%	15%	3%	-21%	-12%	-19%	3%	98%	94%
Chuchinka (07EE009)	26	-4%	-5%	-23%	-14%	12%	11%	-3%	1%	90%	79%
Murray-Wolverine (07FB006)	23	-26%	-28%	-22%	-9%	5%	2%	-3%	-2%	98%	97%
Muller (08KB006)	25	12%	23%	15%	-9%	42%	67%	118%	-4%	98%	94%
Pine (07FB001)	23	20%	24%	25%	14%	15%	10%	1%	3%	96%	91%
Sum	429	**Average (80th Percentile)**		**0.4%**	**1.1%**	**Average (80th Percentile)**		**14%**	**1.2%**	**95.1%**	**86.9%**
Total	459	**Average Entire**		**19%**	**5.1%**	**Average Entire**		**46%**	**7.9%**	**72.2%**	**15.4%**
Percent	93.5%										

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NOTES

A] % Diff is (Modeled/Measured - 1) so a negative value indicates and underestimation and positive an overestimation.

B] FSL is the results of the FSL-2020 model and NEWT is either NEWT or OWT from Chapman (2018)

C] NSE is Nash Sutcliffe Efficiency

Ver 0.9

Table 35: Summary of Availability Modeling Results for all Zones- FSL-2020 vs Chapman (2018)

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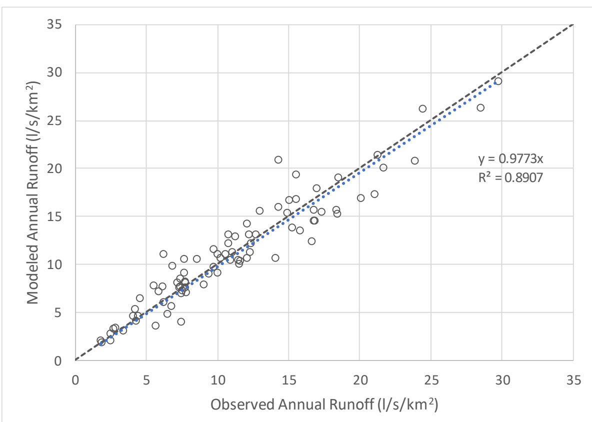
	MBE (%)	MAE (%)	ME (%)	WSC Watershed Count	% of Watersheds within +/- 20% error
FSL (2020) MAR (l/s/km^2)	1.1%	14%	0.5%	95	80%
FSL (2020) S-7Q10/MAD	5.6%	31%	0.7%	95	63%
FSL (2020) A7Q10/MAD	16.6%	37%	3.8%	96	57%
Chapman (2018) MAR (l/s/km^2)	5.5%	16%	3.7%	45	78%

NOTES

A] MBE is Mean Bias Error, MAE is Mean Absolute Error, ME is Median Error.

Ver 0.2



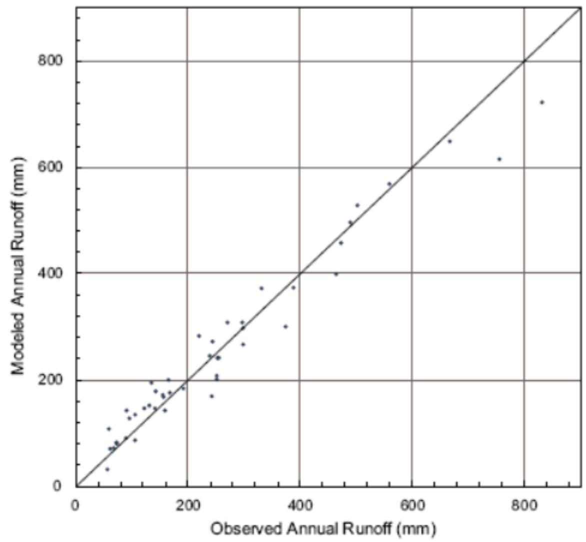
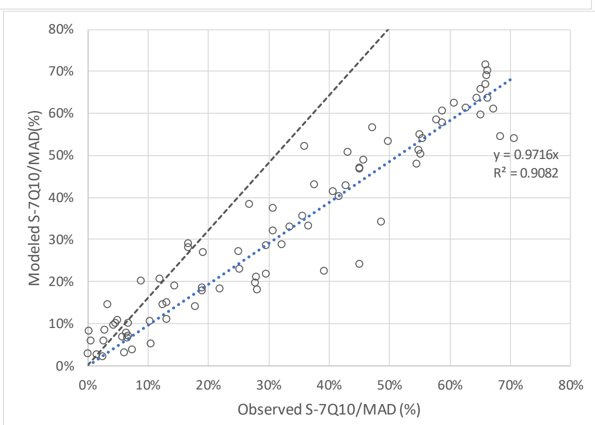


Figure 4 from Chapman (2018) is reproduced here.



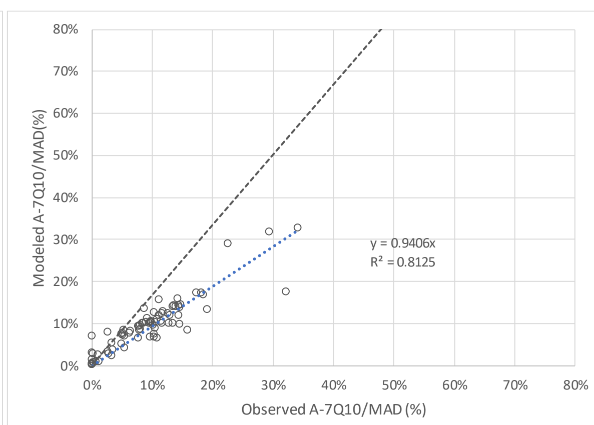


Table 36: Allocation Validation Results for Pouce Coupe River in Zone 6

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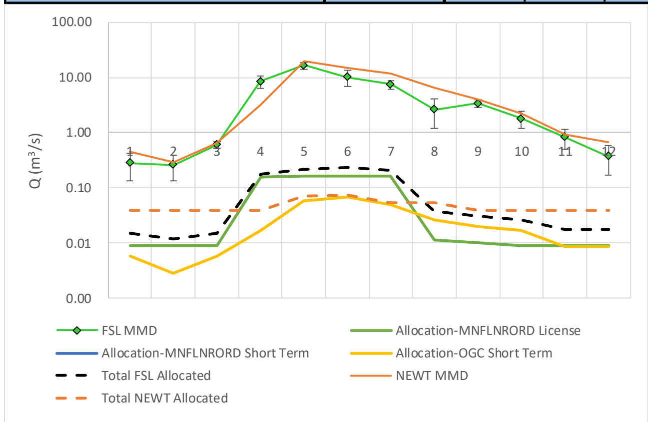
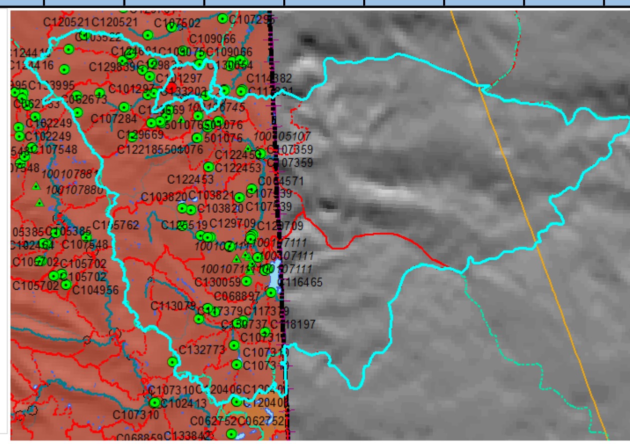
Pouce Coupe River		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	MAR (lps/km^2)	Ann (m^3/s)	A-30Q10	A-7Q10	S-7Q10
MEAN MONTHLY Q	DA (km2)	*Available Q (m^3/s)*														(m^3/s)	(m^3/s)	(m^3/s)
FSL (2020) FWA_ID: 9383	**2,325**	**0.28**	**0.26**	**0.61**	**8.42**	**16.50**	**10.04**	**7.50**	**2.61**	**3.38**	**1.79**	**0.82**	**0.37**	**1.89**	**4.40**	**-**	**-**	**-**
	MmmQ10	**0.06**	**0.07**	**0.06**	**1.36**	**2.22**	**0.83**	**0.48**	**0.11**	**-**	**0.05**	**0.06**	**0.10**			**Min Mmm**	**-**	**Sep**
FSL_FID: 32552	Count	*Allocated Q (m^3/s)*												*Volume (m^3/s)*	*Average Diversion Rate (m^3/s)*			
Allocation-Water License	128	0.009	0.009	0.009	0.160	0.161	0.161	0.161	0.011	0.010	0.009	0.009	0.009	802,351	0.0601			
*MmmQ10 Water License (EFN)**	***MmmQ10***	*0.009*	*0.009*	*0.009*	*0.110*	*0.161*	*0.061*	*0.011*	*0.011*	*0.010*	*0.009*	*0.009*	*0.009*	*802,351*	*0.0351*	**Not used in Sum Allocation*		
Allocation-MNFLNRORD Short Term	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-			
Allocation-OGC Short Term	11	0.006	0.003	0.006	0.017	0.058	0.069	0.049	0.026	0.020	0.017	0.009	0.009	760,844	0.0241			
Sum Allocation FWA_ID: 9383	**139**	**0.015**	**0.012**	**0.015**	**0.177**	**0.219**	**0.231**	**0.211**	**0.037**	**0.031**	**0.026**	**0.018**	**0.018**	**1,563,195**	**0.0842**	*Colour Scaling 0-100%*		
		% Allocated (Colour Scaling Min-Max with NEWT)												Vol/s/yr (m^3/s)	0.050	%A-30Q10	%A-7Q10	%S-7Q10
	DA (km2)	**5.3%**	**4.6%**	**2.5%**	**2.1%**	**1.3%**	**2.3%**	**2.8%**	**1.4%**	**0.9%**	**1.5%**	**2.2%**	**4.8%**	**1.1%**	**1.9%**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**
NEWT MMQ (2019)	2,327	0.44	0.30	0.65	3.19	19.60	15.10	11.70	6.59	3.96	2.19	0.92	0.67	2.4	5.47			
	Count	*Allocated Q (m^3/s)*														*Inst. Vol (m^3/s)*		
NEWT License (2019)	47	0.039	0.039	0.039	0.039	0.039	0.039	0.039	0.039	0.039	0.039	0.039	0.039		0.039	1,229,904		
NEWT Short Term (2019)	2	-	-	-	-	0.03	0.03	0.01	0.01	-	-	-	-	*Vol. NEWT (m3/s)*	0.008	249,660	*Inst. Vol: Lic.Vol(%)*	
Sum Allocation	**49**	**0.039**	**0.039**	**0.039**	**0.039**	**0.072**	**0.073**	**0.053**	**0.053**	**0.039**	**0.039**	**0.039**	**0.039**	**1,588,450**	**0.047**	1,479,564	93%	
		% Allocated (Colour Scaling Min-Max with NEWT/OWT)												Vol/s/yr (m3/s)	0.050			
% Allocated		**8.8%**	**13.1%**	**6.0%**	**1.2%**	**0.4%**	**0.5%**	**0.5%**	**0.8%**	**1.0%**	**1.8%**	**4.3%**	**5.8%**	**0.92%**	**0.86%**			
Allocation % Difference FSL/NEWT		**38%**	**31%**	**38%**	**455%**	**304%**	**316%**	**398%**	**71%**	**78%**	**68%**	**46%**	**46%**	**102%**	**179%**			





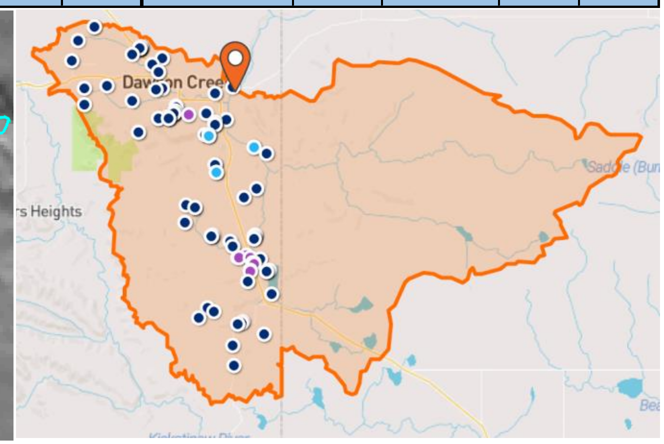


Table 37: Allocation Validation Results for Kiskatinaw River in Zone 6

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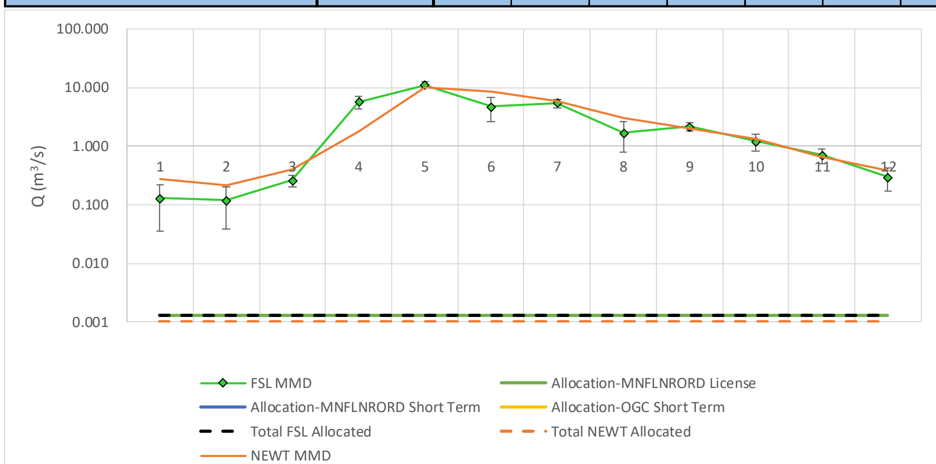
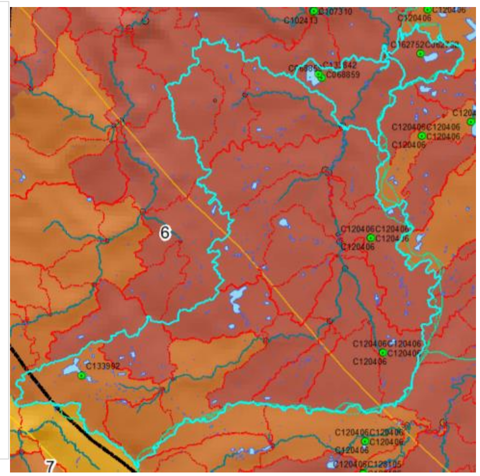
Kiskatinaw River		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	MAR (lps/km^2)	Ann (m^3/s)	A-30Q10	A-7Q10	S-7Q10
MEAN MONTHLY Q	DA (km2)	*Available Q (m^3/s)*														(m^3/s)	(m^3/s)	(m^3/s)
FSL (2020) FWA_ID: 6172	**903**	**0.13**	**0.12**	**0.26**	**5.72**	**11.17**	**4.73**	**5.45**	**1.69**	**2.17**	**1.21**	**0.70**	**0.30**	**3.12**	**2.82**	**-**	**-**	**0.12**
	MmmQ10	**0.02**	**0.02**	**0.02**	**0.92**	**2.33**	**1.95**	**0.13**	**0.02**	**-**	**0.05**	**0.10**	**0.04**			**Min Mmm**	**-**	**Sep**
FSL_FID: 34745	Count	*Allocated Q (m^3/s)*												*Volume (m^3/s)*	*Average Diversion Rate (m^3/s)*			
Allocation-Water License	14	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	40,554	0.0013			
*MmmQ10 Water License (EFN)**	***MmmQ10***	*0.0013*	*0.0013*	*0.0013*	*0.0013*	*0.0013*	*0.0013*	*0.0013*	*0.0013*	*0.0013*	*0.0013*	*0.0013*	*0.0013*	*40,554*	*0.0013*	**Not used in Sum Allocation*		
Allocation-MNFLNRORD Short Term	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-			
Allocation-OGC Short Term	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-			
Sum Allocation FWA_ID: 6172	**14**	**0.0013**	**0.0013**	**0.0013**	**0.0013**	**0.0013**	**0.0013**	**0.0013**	**0.0013**	**0.0013**	**0.0013**	**0.0013**	**0.0013**	**40,554**	**0.0013**	*Colour Scaling 0-100%*		
		% Allocated (Colour Scaling Min-Max with NEWT)												Vol/s/yr (m^3/s)	0.0013	%A-30Q10	%A-7Q10	%S-7Q10
	DA (km2)	**0.99%**	**1.08%**	**0.50%**	**0.02%**	**0.01%**	**0.03%**	**0.02%**	**0.08%**	**0.06%**	**0.11%**	**0.18%**	**0.43%**	**0.05%**	**0.05%**	**#DIV/0!**	**#DIV/0!**	**1.06%**
NEWT MMQ (2019)	903	0.28	0.22	0.39	1.79	10.20	8.44	5.83	3.08	2.03	1.32	0.65	0.39	5.0	4.48			
	Count	*Allocated Q (m^3/s)*														*Inst. Vol (m^3/s)*		
NEWT License (2019)	5	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010		0.001	31,536		
NEWT Short Term (2019)	-	-	-	-	-	-	-	-	-	-	-	-	-	*Vol. NEWT (m3/s)*	0.000	-	*Inst. Vol: Lic.Vol(%)*	
Sum Allocation	**5**	**0.0010**	**0.0010**	**0.0010**	**0.0010**	**0.0010**	**0.0010**	**0.0010**	**0.0010**	**0.0010**	**0.0010**	**0.0010**	**0.0010**	**20,656**	**0.0010**	31,536	153%	
		% Allocated (Colour Scaling Min-Max with NEWT/OWT)												Vol/s/yr (m3/s)	0.00065			
% Allocated		**0.36%**	**0.46%**	**0.26%**	**0.06%**	**0.01%**	**0.01%**	**0.02%**	**0.03%**	**0.05%**	**0.08%**	**0.15%**	**0.26%**	**0.01%**	**0.02%**			
Allocation % Difference FSL/NEWT		**129%**	**129%**	**129%**	**129%**	**129%**	**129%**	**129%**	**129%**	**129%**	**129%**	**129%**	**129%**	**196%**	**129%**			





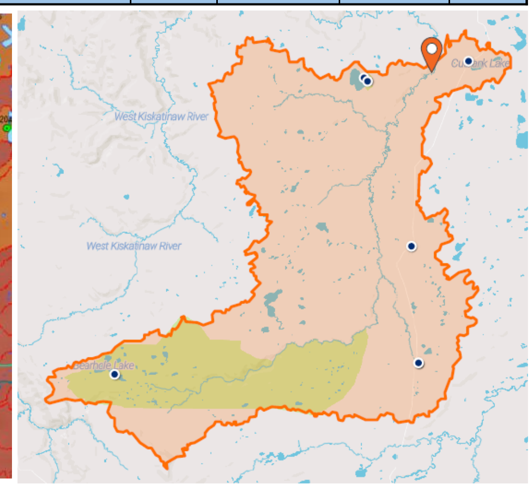


Table 38: Allocation Validation Results for Blueberry River in Zone 6

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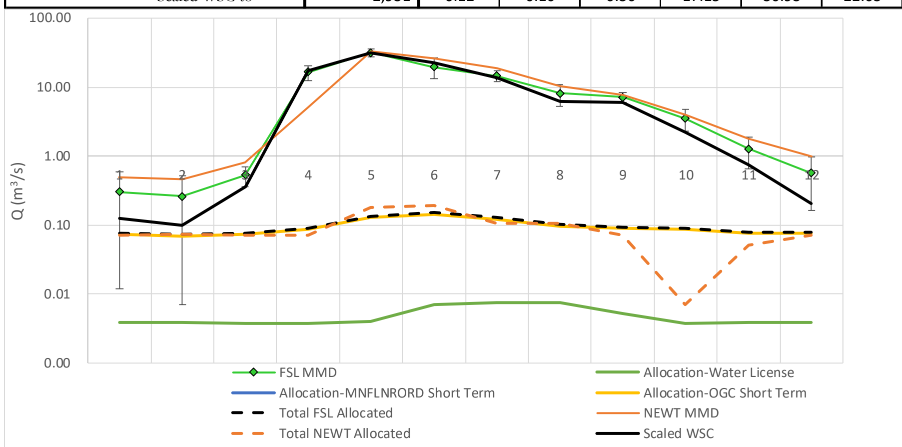
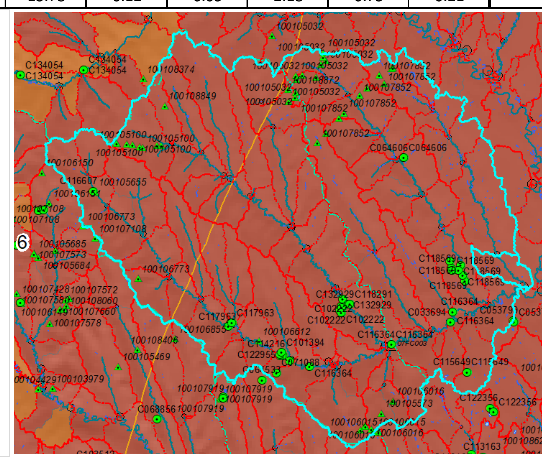
2020-01-08 8:13

Blueberry River		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	MAR (lps/km^2)	Ann (m^3/s)	A-30Q10	A-7Q10	S-7Q10
MEAN MONTHLY Q	DA (km2)	*Available Q (m^3/s)*														(m^3/s)	(m^3/s)	(m^3/s)
FSL (2020) FWA_ID: 7695	**2,931**	**0.30**	**0.26**	**0.53**	**16.65**	**31.84**	**19.73**	**14.60**	**8.10**	**7.13**	**3.47**	**1.27**	**0.56**	**2.98**	**8.75**	**0.09**	**0.08**	**0.55**
	MmmQ10	**0.10**	**0.13**	**0.10**	**1.96**	**7.82**	**5.92**	**1.78**	**0.78**	**0.86**	**0.72**	**0.39**	**0.18**			**Min Mmm**	**0.10**	**Mar**
FSL_FID: 31959	Count	*Allocated Q (m^3/s)*												*Volume (m^3/s)*	*Average Diversion Rate (m^3/s)*			
Allocation-Water License	53	0.0038	0.0038	0.0038	0.0037	0.0040	0.0070	0.0075	0.0074	0.0051	0.0037	0.0038	0.0038	150,494	0.0048			
*MmmQ10 Water License (EFN)**	***MmmQ10***	*0.0038*	*0.0038*	*0.0038*	*0.0037*	*0.0040*	*0.0070*	*0.0075*	*0.0074*	*0.0051*	*0.0037*	*0.0038*	*0.0038*	*150,494*	*0.0048*	**Not used in Sum Allocation*		
Allocation-MNFLNRORD Short Term	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-			
Allocation-OGC Short Term	40	0.072	0.069	0.072	0.085	0.130	0.142	0.120	0.095	0.088	0.085	0.076	0.076	1,455,822	0.092			
Sum Allocation FWA_ID: 7695	**93**	**0.076**	**0.073**	**0.076**	**0.089**	**0.134**	**0.149**	**0.127**	**0.102**	**0.093**	**0.089**	**0.079**	**0.079**	**1,606,316**	**0.0972**	*Colour Scaling 0-100%*		
		% Allocated (Colour Scaling Min-Max with NEWT)												Vol/s/yr (m^3/s)	0.0509	%A-30Q10	%A-7Q10	%S-7Q10
% Allocated	**DA (km2)**	**25.28%**	**28.10%**	**14.35%**	**0.53%**	**0.42%**	**0.76%**	**0.87%**	**1.26%**	**1.31%**	**2.55%**	**6.27%**	**14.09%**	**0.6%**	**1.1%**	**81.72%**	**94.67%**	**18.41%**
NEWT MMQ (2019)	**2,932**	**0.50**	**0.46**	**0.82**	**5.14**	**33.30**	**26.50**	**18.50**	**10.30**	**7.71**	**3.97**	**1.80**	**0.98**	3.1	9.23			
	Count	*Allocated Q (m^3/s)*														*Inst. Vol (m^3/s)*		
NEWT License (2019)	20	0.0050	0.0050	0.0050	0.0050	0.0050	0.0110	0.0100	0.0100	0.0070	0.0050	0.0050	0.0050		0.0065	204,984		
NEWT Short Term (2019)	10	0.066	0.068	0.066	0.066	0.176	0.178	0.097	0.096	0.064	0.002	0.045	0.066	*Vol. NEWT (m3/s)*	0.083	2,601,720	*Inst. Vol: Lic.Vol(%)*	
Sum Allocation	**30**	**0.071**	**0.073**	**0.071**	**0.071**	**0.181**	**0.189**	**0.107**	**0.106**	**0.071**	**0.007**	**0.050**	**0.071**	**1,666,591**	**0.089**	2,806,704	168%	
		% Allocated (Colour Scaling Min-Max with NEWT/OWT)												Vol/s/yr (m3/s)	0.0528			
% Allocated		**14.23%**	**15.90%**	**8.66%**	**1.38%**	**0.54%**	**0.71%**	**0.58%**	**1.03%**	**0.92%**	**0.18%**	**2.78%**	**7.22%**	**0.57%**	**0.96%**			
Allocation % Difference FSL/NEWT		**107%**	**100%**	**107%**	**125%**	**74%**	**79%**	**119%**	**96%**	**131%**	**1268%**	**159%**	**112%**	**96%**	**109%**			
Scaled WSC to	2,931	0.12	0.10	0.36	17.15	30.93	22.63	13.78	6.12	6.05	2.18	0.75	0.21	287%	8.40			





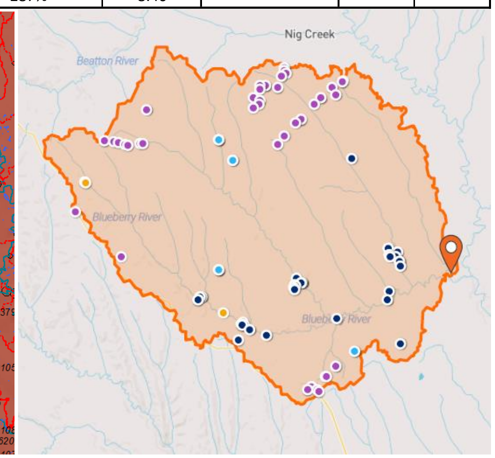


Table 39: Allocation Validation Results for Upper Blueberry River in Zone 6

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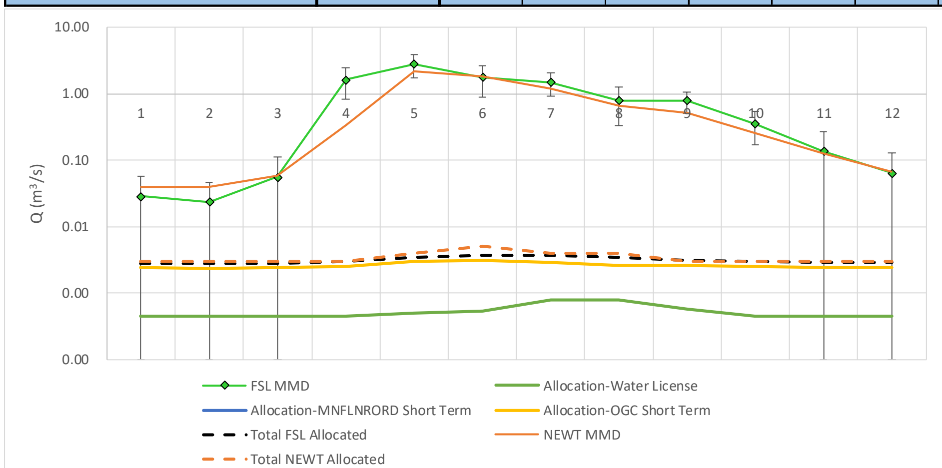
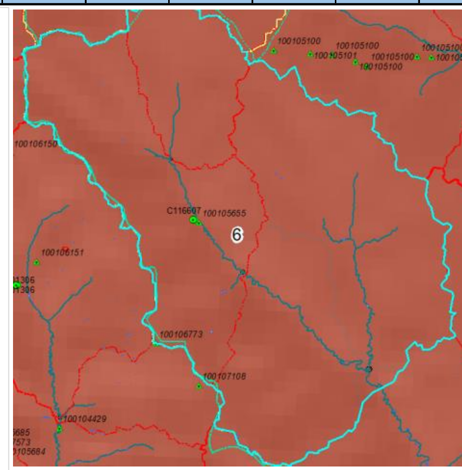
Upper Blueberry River		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	MAR	Ann (m^3/s)	A-30Q10	A-7Q10	S-7Q10
MEAN MONTHLY Q	DA (km2)	*Available Q (m^3/s)*														(m^3/s)	(m^3/s)	(m^3/s)
FSL (2020) FWA_ID: 7753	**211**	**0.03**	**0.02**	**0.06**	**1.63**	**2.83**	**1.77**	**1.50**	**0.79**	**0.79**	**0.36**	**0.14**	**0.06**	**4.0**	**0.83**	**0.014**	**0.014**	**0.105**
	MmmQ10	**0.01**	**0.02**	**0.01**	**0.22**	**0.68**	**0.82**	**0.18**	**0.07**	**0.12**	**0.10**	**0.06**	**0.02**			**Min Mmm**	**0.013**	**Mar**
FSL_FID: 35643	Count	*Allocated Q (m^3/s)*												*Volume (m^3/s)*	*Average Diversion Rate (m^3/s)*			
Allocation-Water License	1	0.00045	0.00045	0.00045	0.00045	0.00050	0.00053	0.00079	0.00079	0.00058	0.00045	0.00045	0.00045	16,593	0.0005			
*MmmQ10 Water License (EFN)**	***MmmQ10***	0.00045	0.00045	0.00045	0.00045	0.00050	0.00053	0.00079	0.00079	0.00058	0.00045	0.00045	0.00045	*16,593*	*0.0005*	**Not used in Sum Allocation*		
Allocation-MNFLNRORD Short Term	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-			
Allocation-OGC Short Term	2	0.00238	0.00235	0.00238	0.00252	0.00300	0.00314	0.00290	0.00262	0.00255	0.00252	0.00242	0.00242	29,000	0.0026			
Sum Allocation FWA_ID: 7753	**3**	**0.0028**	**0.0028**	**0.0028**	**0.0030**	**0.0035**	**0.0037**	**0.0037**	**0.0034**	**0.0031**	**0.0030**	**0.0029**	**0.0029**	**45,593**	**0.0031**	*Colour Scaling 0-100%*		
		% Allocated (Colour Scaling Min-Max with NEWT)												Vol/s/yr (m^3/s)	0.0014	%A-30Q10	%A-7Q10	%S-7Q10
	DA (km2)	**9.90%**	**11.84%**	**5.09%**	**0.18%**	**0.12%**	**0.21%**	**0.25%**	**0.43%**	**0.40%**	**0.83%**	**2.11%**	**4.44%**	**0.17%**	**0.37%**	**19.8%**	**20.7%**	**3.3%**
NEWT MMQ (2019)	**230**	**0.04**	**0.04**	**0.06**	**0.34**	**2.16**	**1.82**	**1.20**	**0.66**	**0.52**	**0.26**	**0.13**	**0.07**	2.7	0.61			
	Count	*Allocated Q (m^3/s)*													*Inst. Vol (m^3/s)*			
NEWT License (2019)	1	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010		0.0010	31,536		
NEWT Short Term (2019)	2	0.0020	0.0020	0.0020	0.0020	0.0030	0.0040	0.0030	0.0030	0.0020	0.0020	0.0020	0.0020	*Vol. NEWT (m3/s)*	0.0024	76,212	*Inst. Vol: Lic.Vol(%)*	
Sum Allocation	3	**0.0030**	**0.0030**	**0.0030**	**0.0030**	**0.0040**	**0.0050**	**0.0040**	**0.0040**	**0.0030**	**0.0030**	**0.0030**	**0.0030**	**45,605**	**0.0034**	107,748	236%	
		% Allocated (Colour Scaling Min-Max with NEWT/OWT)												Vol/s/yr (m3/s)	0.0014			
% Allocated		**7.69%**	**7.69%**	**5.08%**	**0.88%**	**0.19%**	**0.27%**	**0.33%**	**0.60%**	**0.57%**	**1.17%**	**2.36%**	**4.41%**	**0.24%**	**0.56%**			
Allocation % Difference FSL/NEWT		**94%**	**93%**	**94%**	**99%**	**87%**	**73%**	**92%**	**85%**	**104%**	**99%**	**95%**	**95%**	**73%**	**92%**			





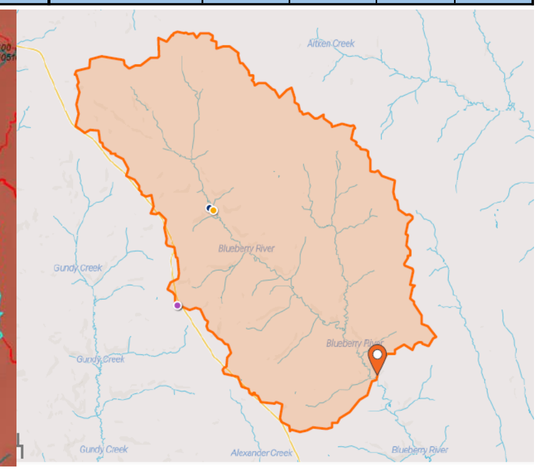


Table 40: Allocation Validation Results for Unnamed Creek in Zone 6

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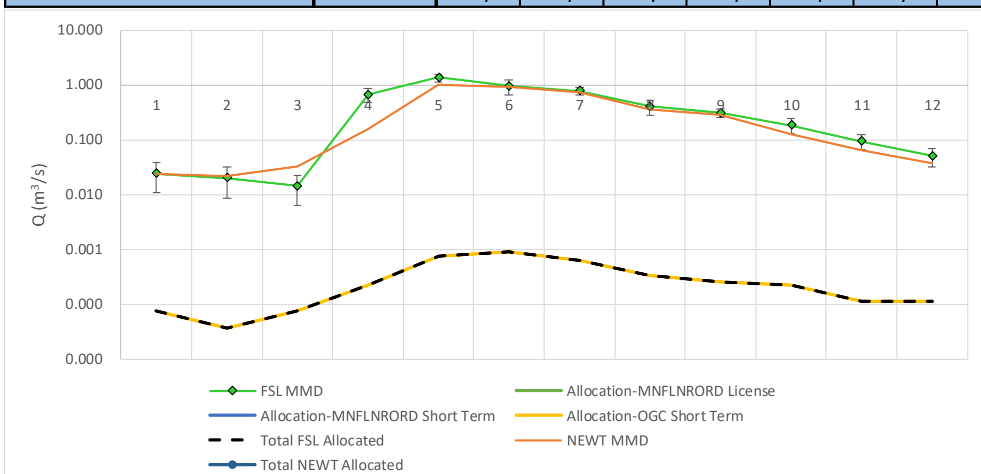
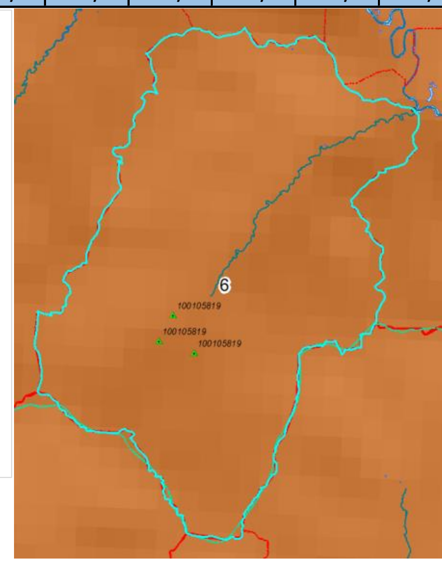
Unnamed Creek		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	MAR (lps/km^2)	Ann (m^3/s)	A-30Q10	A-7Q10	S-7Q10
MEAN MONTHLY Q	DA (km2)	*Available Q (m^3/s)*														(m^3/s)	(m^3/s)	(m^3/s)
FSL (2020) FWA_ID:17577	**71**	**0.024**	**0.020**	**0.014**	**0.663**	**1.351**	**0.938**	**0.774**	**0.402**	**0.309**	**0.182**	**0.093**	**0.050**	**5.7**	**0.40**	**0.013**	**0.012**	**0.068**
	MmmQ10	**0.014**	**0.013**	**0.013**	**0.074**	**0.516**	**0.561**	**0.154**	**0.056**	**0.078**	**0.064**	**0.043**	**0.021**			**Min Mmm**	**0.013**	**Mar**
FSL_FID:26726	Count	*Allocated Q (m^3/s)*												*Volume (m^3/s)*	*Average Diversion Rate (m^3/s)*			
Allocation-Water License	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-			
*MmmQ10 Water License (EFN)**	***MmmQ10***	-	-	-	-	-	-	-	-	-	-	-	-	-	-	**Not used in Sum Allocation*		
Allocation-MNFLNRORD Short Term	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-			
Allocation-OGC Short Term	3	0.00007	0.00004	0.00007	0.00022	0.00074	0.00089	0.00063	0.00033	0.00026	0.00022	0.00011	0.00011	9,700	0.0003			
Sum Allocation FWA_ID:17577	**3**	**0.00007**	**0.00004**	**0.00007**	**0.00022**	**0.00074**	**0.00089**	**0.00063**	**0.00033**	**0.00026**	**0.00022**	**0.00011**	**0.00011**	**9,700**	**0.0003**	*Colour Scaling 0-100%*		
		% Allocated (Colour Scaling Min-Max with NEWT)												Vol/s/yr (m^3/s)	0.0003	%A-30Q10	%A-7Q10	%S-7Q10
% Allocated	**DA (km2)**	**0.31%**	**0.18%**	**0.52%**	**0.03%**	**0.05%**	**0.09%**	**0.08%**	**0.08%**	**0.08%**	**0.12%**	**0.12%**	**0.22%**	**0.08%**	**0.08%**	**0.55%**	**0.61%**	**0.49%**
NEWT MMQ (2019)	**71**	**0.02**	**0.02**	**0.03**	**0.16**	**0.99**	**0.90**	**0.72**	**0.36**	**0.28**	**0.13**	**0.07**	**0.04**	4.4	0.31			
	Count	*Allocated Q (m^3/s)*														*Inst. Vol (m^3/s)*		
NEWT License (2019)	3	-	-	-	-	-	-	-	-	-	-	-	-		-	-		
NEWT Short Term (2019)	3	-	-	-	-	-	-	-	-	-	-	-	-	*Vol. NEWT (m3/s)*	0.000	-	*Inst. Vol: Lic.Vol(%)*	
Sum Allocation	6	-	-	-	-	-	-	-	-	-	-	-	-	9,700	0.000	-	0%	
		% Allocated (Colour Scaling Min-Max with NEWT/OWT)												Vol/s/yr (m3/s)	0.0003			
% Allocated		**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.10%**	**0.00%**			
Allocation % Difference FSL/NEWT		**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**100%**	**#DIV/0!**			





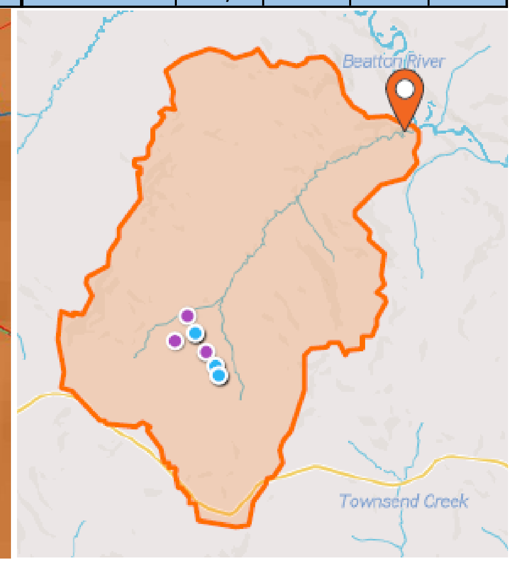


Table 41: Allocation Validation Results for Atunatche Creek in Zone 7

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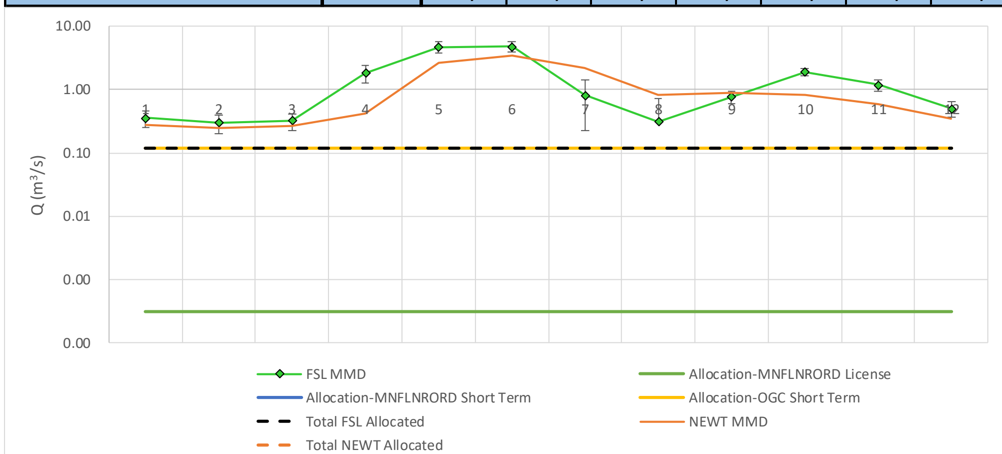
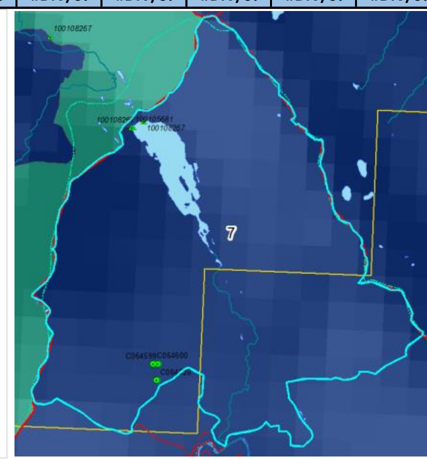
Atunatche Creek		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	MAR (lps/km²)	Ann (m³/s)	A-30Q10	A-7Q10	S-7Q10
MEAN MONTHLY Q	DA (km2)	*Available Q (m³/s)*														(m³/s)	(m³/s)	(m³/s)
FSL (2020) FWA_ID:12955	**30.8**	**0.36**	**0.30**	**0.32**	**1.83**	**4.71**	**4.81**	**0.81**	**0.31**	**0.77**	**1.91**	**1.18**	**0.51**	**48.3**	**1.49**	**0.08**	**0.14**	**0.13**
	MmmQ10	**0.20**	**0.17**	**0.16**	**0.40**	**3.31**	**3.05**	**0.38**	**-**	**-**	**0.81**	**0.59**	**0.21**			**Min Mmm**	**0.000**	**Aug**
FSL_FID:28765	Count	*Allocated Q (m³/s)*												*Volume (m³/s)*	*Average Diversion Rate (m³/s)*			
Allocation-Water License	3	3.16E-04	3.16E-04	3.16E-04	3.16E-04	3.16E-04	3.16E-04	3.16E-04	3.16E-04	3.16E-04	3.16E-04	3.16E-04	3.16E-04	9,956	0.0003			
*MmmQ10 Water License (EFN)**	***MmmQ10***	3.16E-04	3.16E-04	3.16E-04	3.16E-04	3.16E-04	3.16E-04	3.16E-04	3.16E-04	3.16E-04	3.16E-04	3.16E-04	3.16E-04	*9,956*	*0.0003*	**Not used in Sum Allocation*		
Allocation-MNFLNRORD Short Term	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-			
Allocation-OGC Short Term	3	1.17E-01	1.17E-01	1.17E-01	1.17E-01	1.17E-01	1.17E-01	1.17E-01	1.17E-01	1.17E-01	1.17E-01	1.17E-01	1.17E-01	20,400	0.1169			
Sum Allocation FWA_ID:12955	**6**	**0.117**	**0.117**	**0.117**	**0.117**	**0.117**	**0.117**	**0.117**	**0.117**	**0.117**	**0.117**	**0.117**	**0.117**	**30,356**	**0.1172**	*Colour Scaling 0-100%*		
		% Allocated (Colour Scaling Min-Max with NEWT)												Vol/s/yr (m³/s)	0.0010	%A-30Q10	%A-7Q10	%S-7Q10
	DA (km2)	**32.94%**	**38.86%**	**36.30%**	**6.42%**	**2.49%**	**2.44%**	**14.47%**	**37.67%**	**15.27%**	**6.14%**	**9.93%**	**23.19%**	**0.06%**	**7.88%**	**156.0%**	**82.6%**	**93.0%**
OWT MMQ (2019)	**30.8**	**0.28**	**0.25**	**0.27**	**0.42**	**2.62**	**3.51**	**2.20**	**0.82**	**0.89**	**0.82**	**0.58**	**0.35**	35.3	1.09			
	Count	*Allocated Q (m³/s)*																
OWT License (2019)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-			
OWT Short Term (2019)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-			
Sum Allocation	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**			
		% Allocated (Colour Scaling Min-Max with NEWT/OWT)												Vol/s/yr (m3/s)	0.0000			
% Allocated		**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.00%**	**0.0**	**0.00%**			
Allocation % Difference FSL/NEWT		**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**			





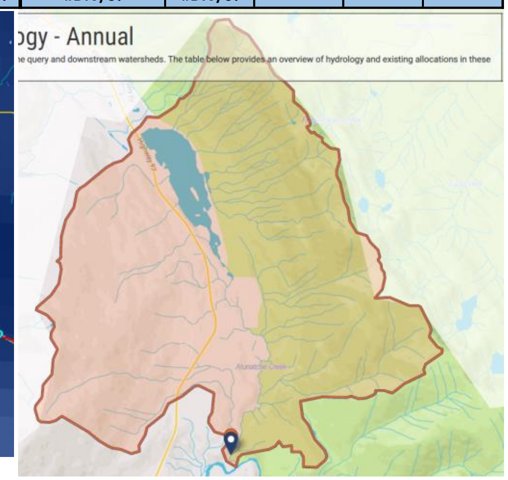


Table 42: Allocation Validation Results for Manson River in Zone 8

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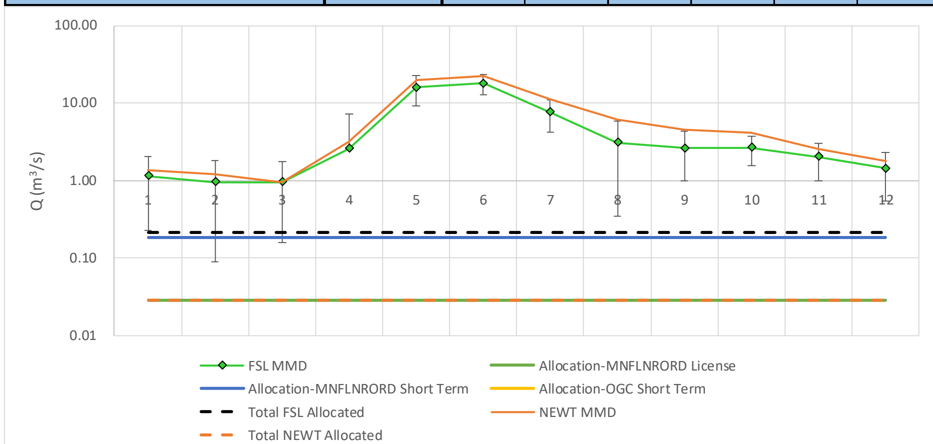
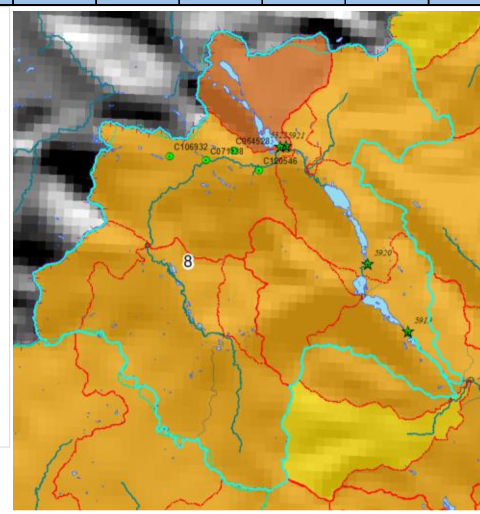
Manson River		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	MAR (lps/km^2)	Ann (m^3/s)	A-30Q10	A-7Q10	S-7Q10
MEAN MONTHLY Q	DA (km2)	*Available Q (m^3/s)*														(m^3/s)	(m^3/s)	(m^3/s)
FSL (2020) FWA_ID: 3454	**395**	**1.13**	**0.95**	**0.95**	**2.55**	**15.81**	**17.89**	**7.53**	**3.05**	**2.62**	**2.65**	**2.00**	**1.42**	**12.39**	**4.90**	**0.46**	**0.37**	**0.82**
	MmmQ10	**0.55**	**0.54**	**0.50**	**0.64**	**8.78**	**10.88**	**3.99**	**1.84**	**1.21**	**1.32**	**1.19**	**0.74**			**Min Mmm**	**0.50**	**Mar**
FSL_FID: 35596	Count	*Allocated Q (m^3/s)*												*Volume (m^3/s)*	*Average Diversion Rate (m^3/s)*			
Allocation-Water License	4	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	894,759	0.0284			
*MmmQ10 Water License (EFN)**	***MmmQ10***	*0.028*	*0.028*	*0.028*	*0.028*	*0.028*	*0.028*	*0.028*	*0.028*	*0.028*	*0.028*	*0.028*	*0.028*	*894,759*	*0.0284*	**Not used in Sum Allocation*		
Allocation-MNFLNRORD Short Term	4	0.185	0.185	0.185	0.185	0.185	0.185	0.185	0.185	0.185	0.185	0.185	0.185	5,834,160	0.1850			
Allocation-OGC Short Term	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-			
Sum Allocation FWA_ID: 3454	**8**	**0.213**	**0.213**	**0.213**	**0.213**	**0.213**	**0.213**	**0.213**	**0.213**	**0.213**	**0.213**	**0.213**	**0.213**	**6,728,919**	**0.2134**	*Colour Scaling 0-100%*		
		% Allocated (Colour Scaling Min-Max with NEWT)												Vol/s/yr (m^3/s)	0.2134	%A-30Q10	%A-7Q10	%S-7Q10
	DA (km2)	**18.87%**	**22.47%**	**22.48%**	**8.38%**	**1.35%**	**1.19%**	**2.83%**	**6.99%**	**8.15%**	**8.06%**	**10.64%**	**15.04%**	**4.36%**	**4.36%**	**46.16%**	**57.20%**	**26.00%**
OWT MMQ (2019)	**395**	**1.34**	**1.20**	**0.94**	**3.16**	**19.79**	**22.23**	**11.26**	**6.03**	**4.47**	**4.10**	**2.51**	**1.76**	16.7	6.59			
	Count	*Allocated Q (m^3/s)*													*Inst. Vol (m^3/s)*			
OWT License (2019)	4	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028		0.0280	883,008		
OWT Short Term (2019)	-	-	-	-	-	-	-	-	-	-	-	-	-	*Vol. NEWT (m3/s)*	0.000	-	*Inst. Vol: Lic.Vol(%)*	
Sum Allocation	**4**	**0.028**	**0.028**	**0.028**	**0.028**	**0.028**	**0.028**	**0.028**	**0.028**	**0.028**	**0.028**	**0.028**	**0.028**	**895,372**	**0.028**	883,008	99%	
		% Allocated (Colour Scaling Min-Max with NEWT/OWT)												Vol/s/yr (m3/s)	0.0284			
% Allocated		**2.09%**	**2.34%**	**2.99%**	**0.89%**	**0.14%**	**0.13%**	**0.25%**	**0.46%**	**0.63%**	**0.68%**	**1.12%**	**1.59%**	**0.43%**	**0.42%**			
Allocation % Difference FSL/NEWT		**762%**	**762%**	**762%**	**762%**	**762%**	**762%**	**762%**	**762%**	**762%**	**762%**	**762%**	**762%**	**752%**	**762%**			





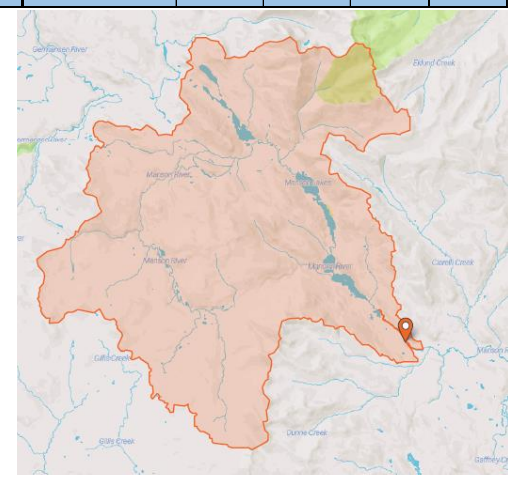


Table 43: Allocation Validation Results for Meadows Creek in Zone 8

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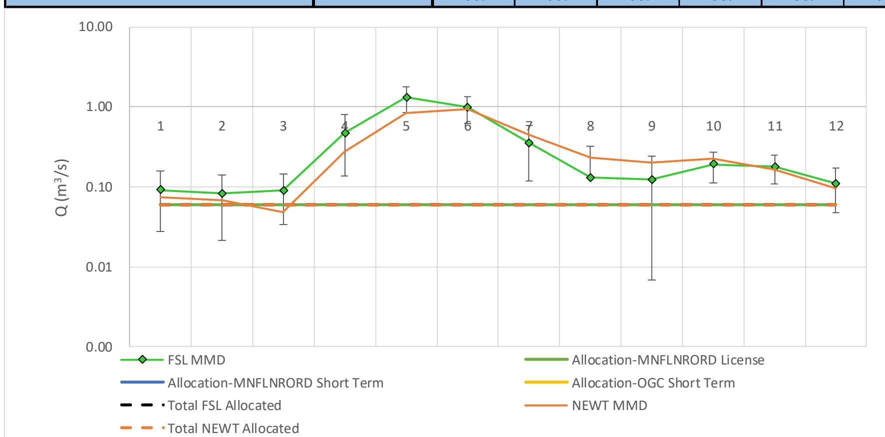
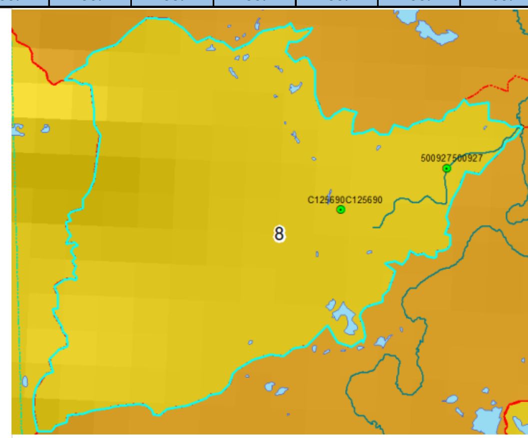
2020-01-08 8:13

Meadows Creek		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	MAR (lps/km^2)	Ann (m^3/s)	A-30Q10	A-7Q10	S-7Q10
MEAN MONTHLY Q	DA (km2)	*Available Q (m^3/s)*														(m^3/s)	(m^3/s)	(m^3/s)
FSL (2020) FWA_ID: 11928	**22.8**	**0.09**	**0.08**	**0.09**	**0.47**	**1.32**	**0.99**	**0.36**	**0.13**	**0.12**	**0.19**	**0.18**	**0.11**	**15.2**	**0.35**	**0.036**	**0.024**	**0.035**
	Mmm 30Q10	**0.05**	**0.04**	**0.05**	**0.19**	**0.73**	**0.53**	**0.20**	**0.06**	**0.05**	**0.08**	**0.09**	**0.06**	**7.8**	**0.18**	**Min Mmm**	**0.043**	**Feb**
FSL_FID: 22909	Count	*Allocated Q (m^3/s)*												*Volume (m^3/s)*	*Average Diversion Rate (m^3/s)*			
Allocation-Water License	4	6.02E-02	6.02E-02	6.02E-02	6.02E-02	6.02E-02	6.02E-02	6.02E-02	6.02E-02	6.02E-02	6.02E-02	6.02E-02	6.02E-02	1,900,000	0.0602			
*MmmQ10 Water License (EFN)**	***Mmm 30Q10***	*6.02E-02*	*6.02E-02*	*6.02E-02*	*6.02E-02*	*6.02E-02*	*6.02E-02*	*6.02E-02*	*6.02E-02*	*6.02E-02*	*6.02E-02*	*6.02E-02*	*6.02E-02*	*1,900,000*	*0.0602*	**Not used in Sum Allocation*		
Allocation-MNFLNRORD Short Term	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-			
Allocation-OGC Short Term	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-			
Sum Allocation FWA_ID: 11928	**4**	**0.060**	**0.060**	**0.060**	**0.060**	**0.060**	**0.060**	**0.060**	**0.060**	**0.060**	**0.060**	**0.060**	**0.060**	**1,900,000**	**0.0602**	*Colour Scaling 0-100%*		
		% Allocated (Colour Scaling Min-Max with NEWT)												Vol/s/yr (m^3/s)	0.0602	%A-30Q10	%A-7Q10	%S-7Q10
	DA (km2)	**66%**	**74%**	**67%**	**13%**	**5%**	**6%**	**17%**	**46%**	**49%**	**32%**	**34%**	**55%**	**17%**	**17.46%**	**168.4%**	**247.8%**	**172.5%**
OWT MMQ (2019)	**22.8**	**0.08**	**0.07**	**0.05**	**0.28**	**0.84**	**0.93**	**0.45**	**0.23**	**0.20**	**0.22**	**0.17**	**0.10**	13.2	0.30			
	Count	*Allocated Q (m^3/s)*																
OWT License (2019)	4	0.060	0.060	0.060	0.060	0.060	0.060	0.060	0.060	0.060	0.060	0.060	0.060		0.0600			
OWT Short Term (2019)	-	-	-	-	-	-	-	-	-	-	-	-	-		0.0000			
Sum Allocation	**4**	**0.060**	**0.060**	**0.060**	**0.060**	**0.060**	**0.060**	**0.060**	**0.060**	**0.060**	**0.060**	**0.060**	**0.060**	**1,901,301**	**0.0600**			
		% Allocated (Colour Scaling Min-Max with NEWT/OWT)												Vol/s/yr (m3/s)	0.0603			
% Allocated		**80%**	**87%**	**122%**	**22%**	**7%**	**6%**	**13%**	**26%**	**30%**	**27%**	**36%**	**63%**	**20%**	**20.00%**			
Allocation % Difference FSL/NEWT		**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**			





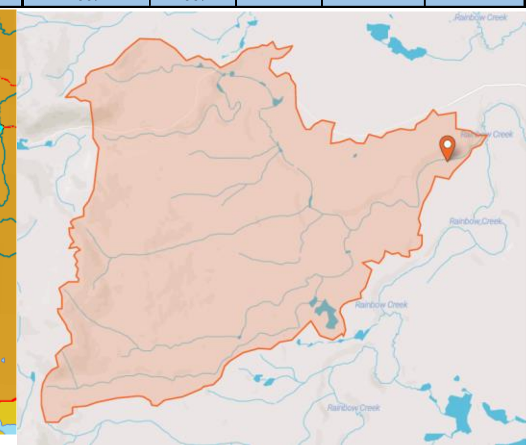


Table 44: Allocation Stats for All FWA Assessment Polygons

C:\gsentlin\FATHOM_SCI\CUSTOMERS\RSEA\Data\[WaterRightsLicenses_UDA_V12.9.1_forReport.xlsx]MMD Summary_Report 2020-01-09 19:37

Count	4618	Count	Percentage	Percentile	%Alloc
Low Q Season	W	3838	83%		
	S	175	4%		
	W,S	605	13%		
Max %Alloc	<0.2	4485	97.1%	20%	0.0%
	>0.2	120	2.6%	50%	0.0%
	>1	34	0.7%	80%	0.0%
	>10	4	0.1%	95%	9.4%
%Alloc MAD	<0.2	4611	99.8%	20%	0.00%
	>0.2	5	0.1%	50%	0.00%
	>1	2	0.0%	80%	0.00%
	>10	0	0.0%	95%	0.56%
%Alloc A-30Q10	<0.2	4141	89.7%	20%	0.00%
	>0.2	477	10.3%	50%	0.00%
	>1	299	6.5%	80%	0.54%
	>10	224	4.9%	95%	614.64%

Notes

A] This is for all 4618 FWA Assesment Polygons

B] Max (%Alloc): This is the maximum of the mean monthly allocation values.

C] %Alloc_MAD: The % of MAD allocated

D] Low Q Season: The month in which the mean monthly Q occurs

E] %Alloc_A-30Q10: Taking the EFN Adjusted %Allocated in the month in which the Min30Q10 occurs and dividing by the A-30Q10. When A-30Q10 is zero, a value of 10000 is assigned.

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Table 45: Allocation Stats for UDAs with PoD Count>0

C:\gsentlin\FATHOM_SCI\CUSTOMERS\RSEA\Data\[WaterRightsLicenses_UDA_V12.9.1_forReport.xlsx]MMD Summary_Report_CountGT0 2020-01-09 19:40

Count	1074	Count	Percentage	Percentile	%Alloc
Low Q Season	W	901	84%		
	S	33	3%		
	W,S	140	13%		
Max %Alloc	<0.2	941	88.7%	20%	0.1%
	>0.2	120	11.3%	50%	1.7%
	>1	34	3.2%	80%	10.3%
	>10	4	0.4%	95%	67.3%
%Alloc MAD	<0.2	1069	99.5%	20%	0.01%
	>0.2	5	0.5%	50%	0.06%
	>1	2	0.2%	80%	0.59%
	>10	0	0.0%	95%	2.96%
%Alloc A-30Q10	<0.2	713	66.4%	20%	0.20%
	>0.2	361	33.6%	50%	6.95%
	>1	183	17.0%	80%	72.73%
	>10	108	10.1%	95%	100000.00%

Notes

A] This is for the 1061 FWA Assesment Polygons with a UDA PoD Count>0.

B] Max (%Alloc): This is the maximum of the mean monthly allocation values.

C] %Alloc_MAD: The % of MAD allocated

D] Low Q Season: The month in which the mean monthly Q occurs

E] %Alloc_A-30Q10: Taking the EFN Adjusted %Allocated in the month in which the Min30Q10 occurs and dividing by the A-30Q10. When A-30Q10 is zero, a value of 10000 is assigned.

Ver 12.9.1

FIGURES

A)

B)

C)

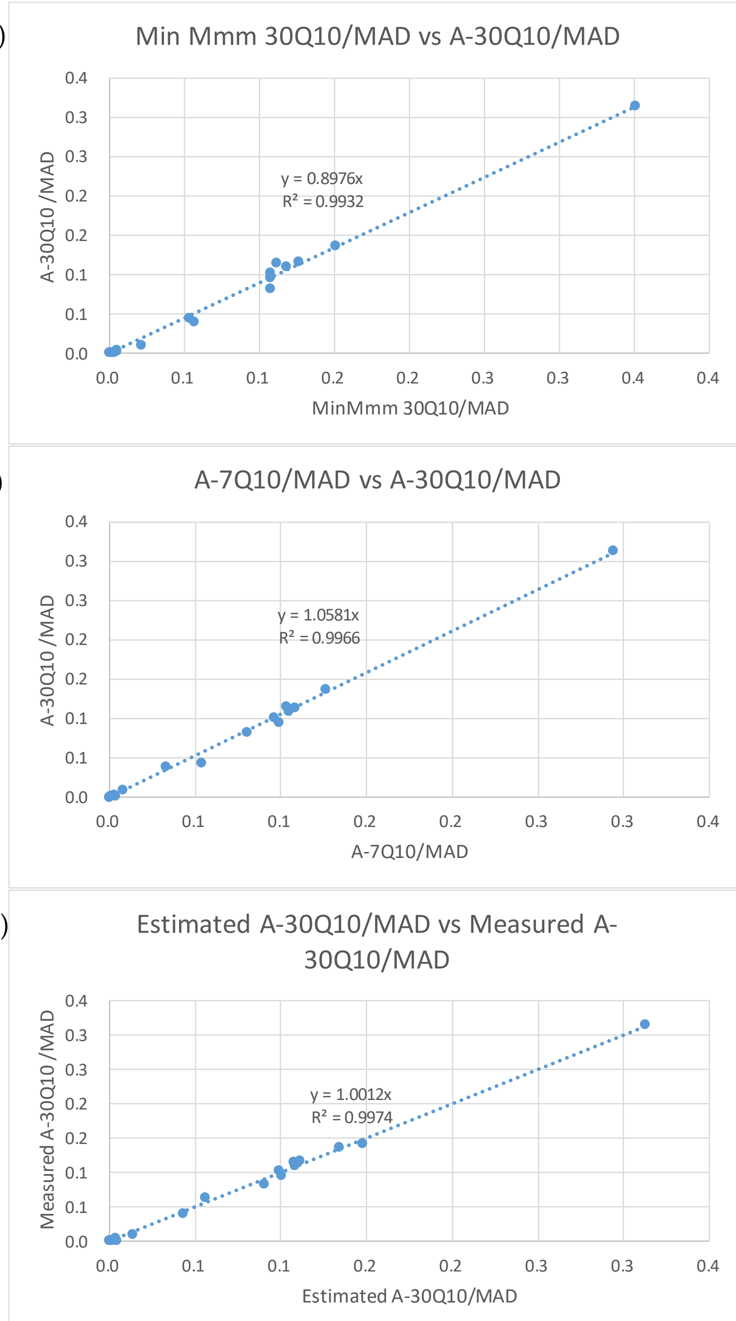


Figure 1: A) Relationship between A-30Q10/MAD and the minimum monthly 30Q10/MAD B) A-7Q10/MAD, and C) the estimated A-30Q10/MAD and the measured

Figure 2: Comparison of Dugout Allocation Coefficients based on Average %MD values for all WSC Stations in RSEA SA, compared to NEWT assumptions.

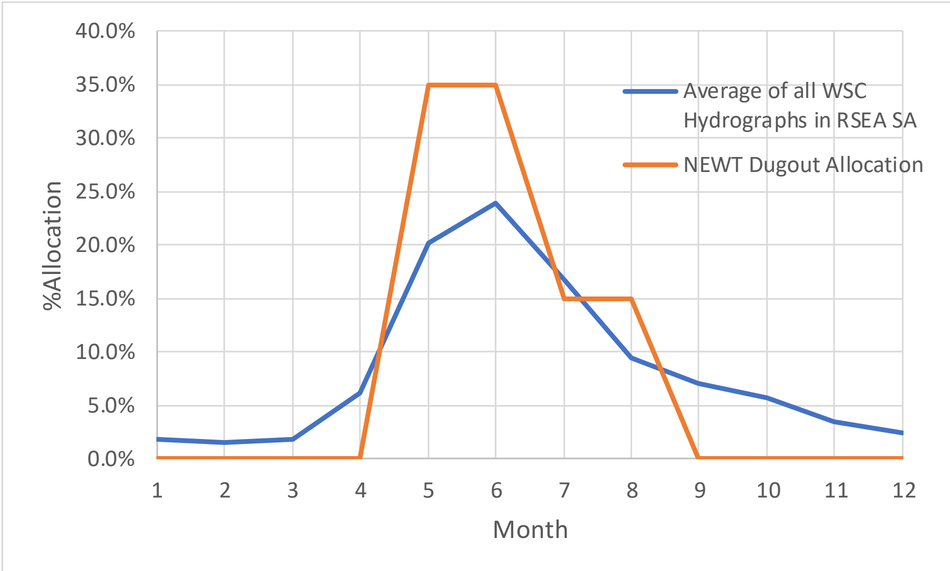


Figure 3: Comparison of All Water License Allocation Coefficients

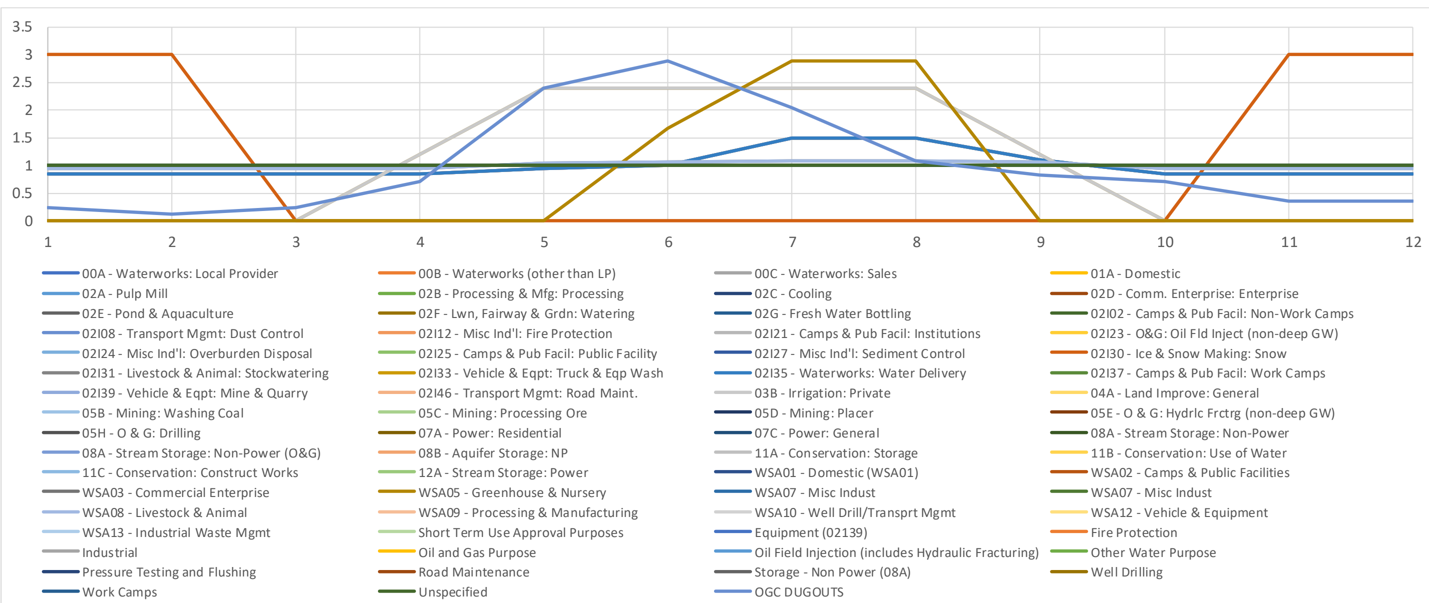


Figure 4: Comparison of Derived %MD Hydrographs: Hydrological Model

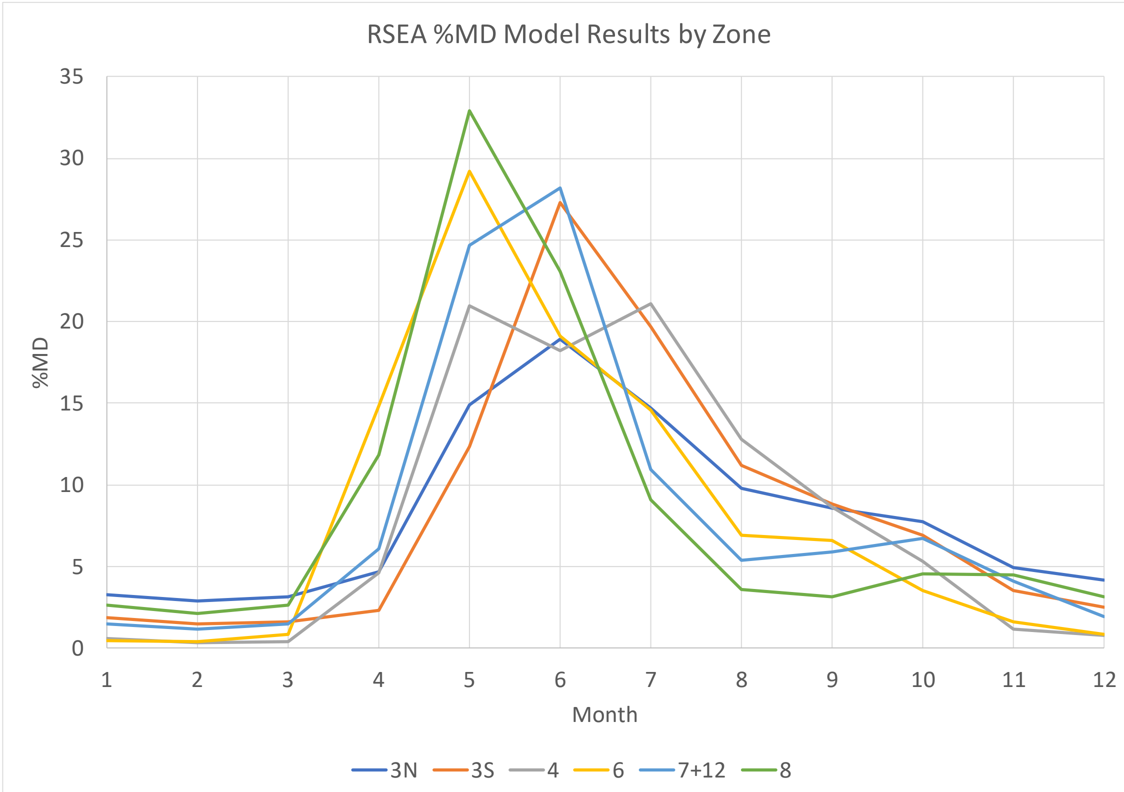


Figure 5: Comparison of Measured WSC %MD Hydrographs: Excluding Outliers

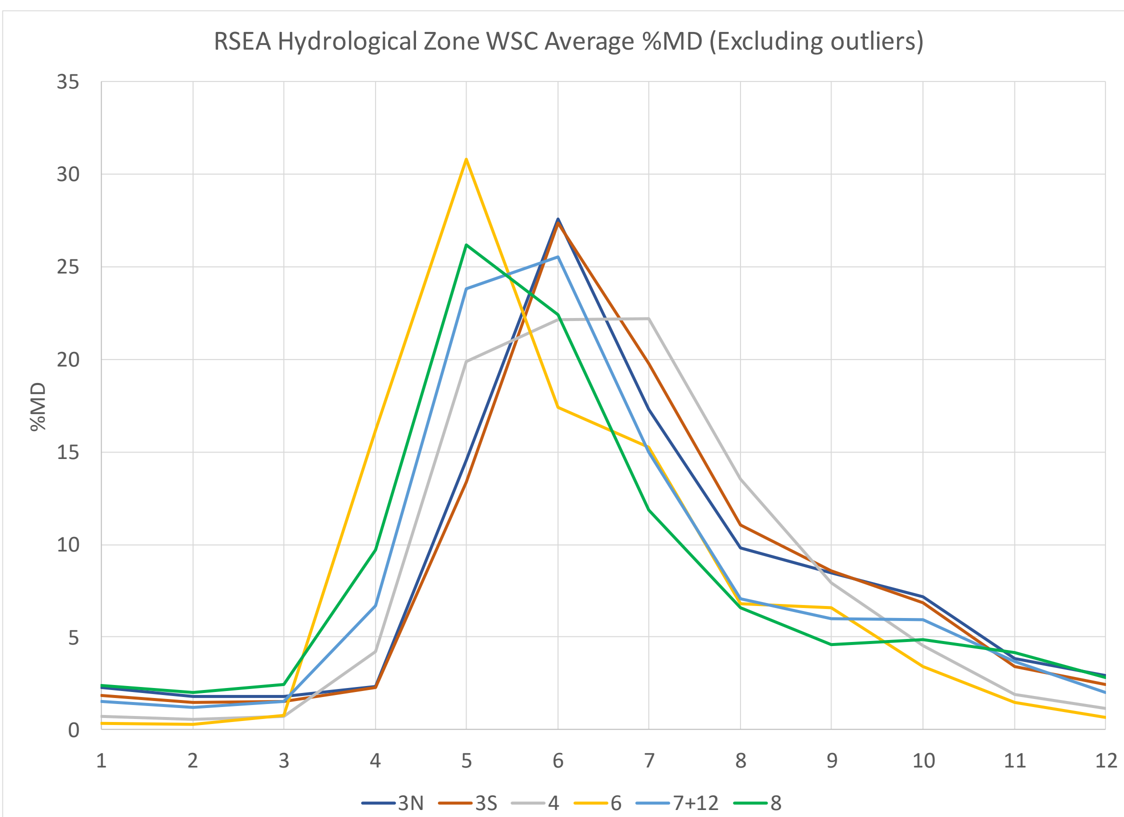


Figure 6: Comparison of Measured %MD Hydrographs: Zone 3N: Northern Rocky Mountains-North

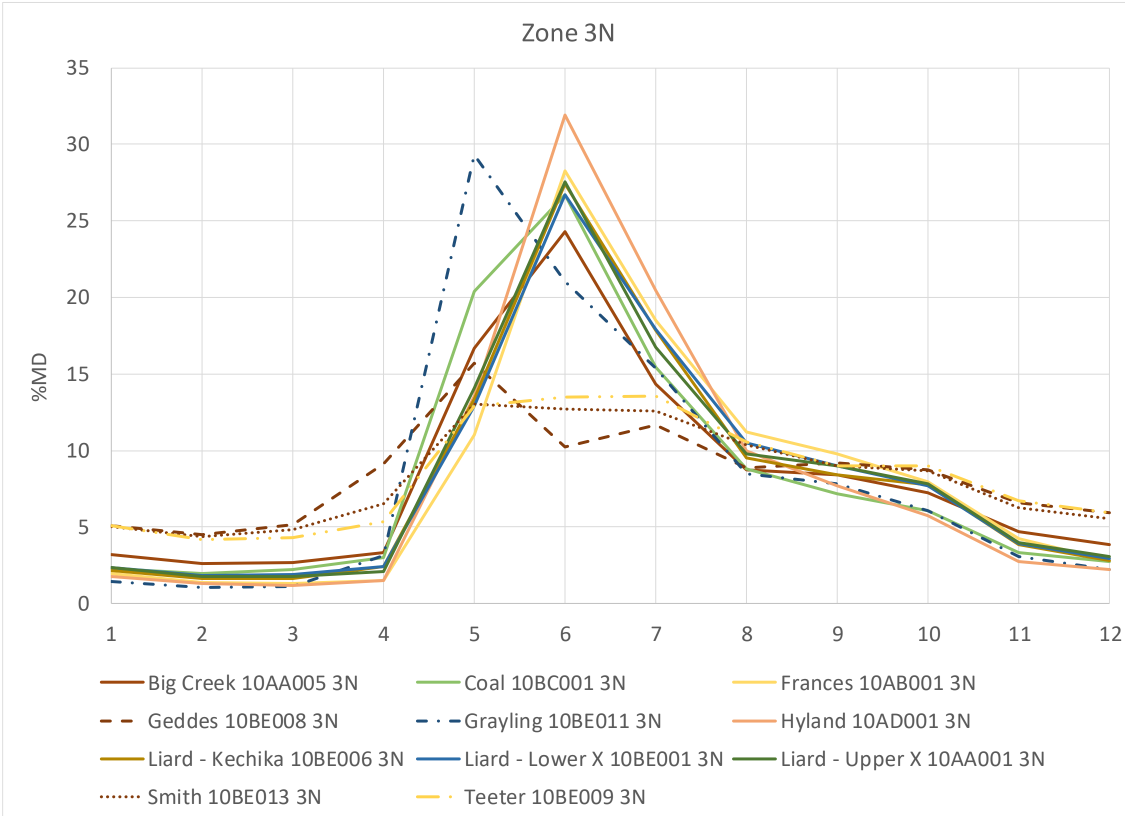


Figure 7: Comparison of Measured %MD Hydrographs: Zone 3S: Northern Rocky Mountains-South

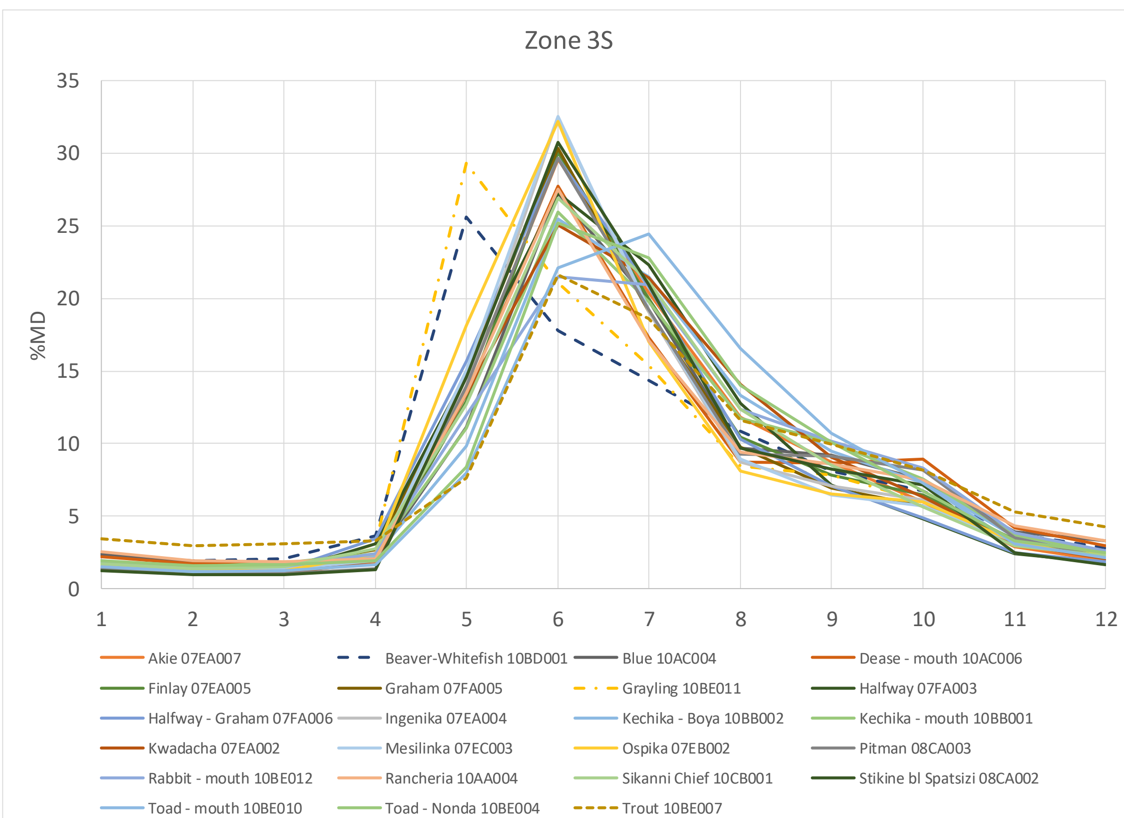


Figure 8: Comparison of Measured %MD Hydrographs: Zone 4: Northern Interior Plains

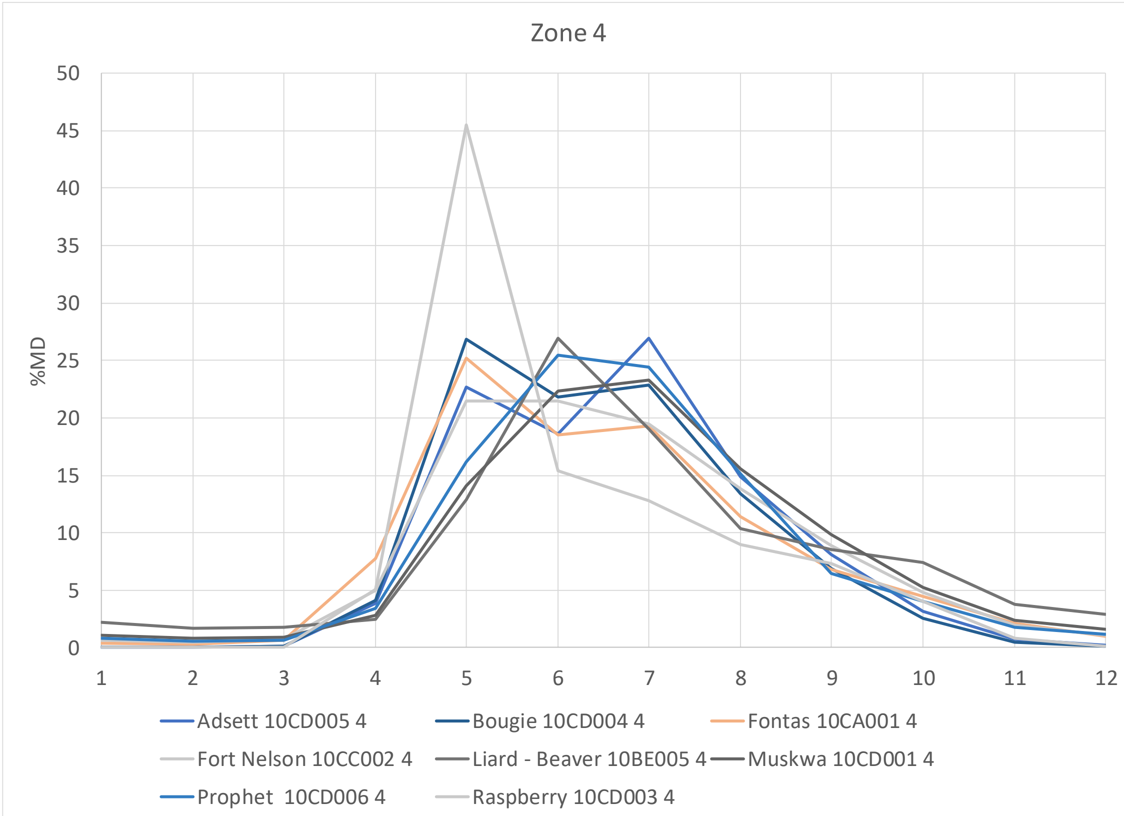


Figure 9: Comparison of Measured %MD Hydrographs: Zone 6: Southern Interior Plains

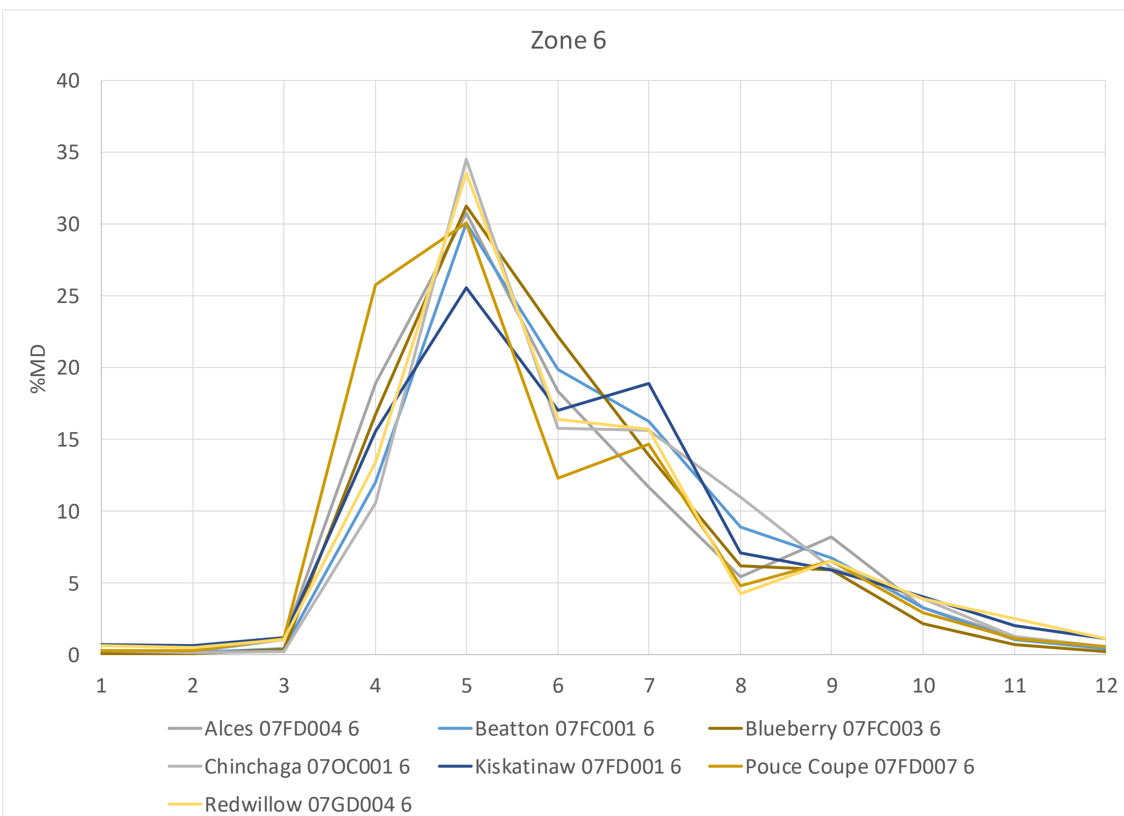


Figure 10: Comparison of Measured %MD Hydrographs: Zone 7+12 Southern Rocky Mountain Foothills/MacGregor Basin

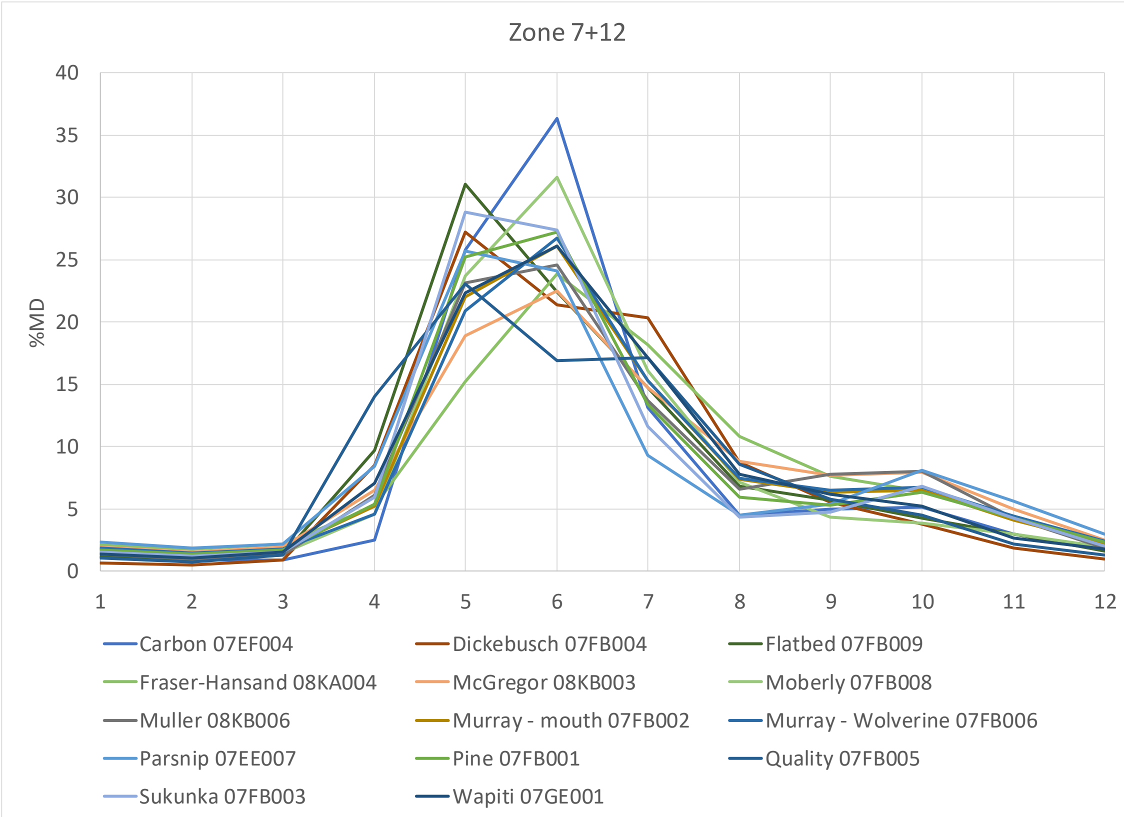
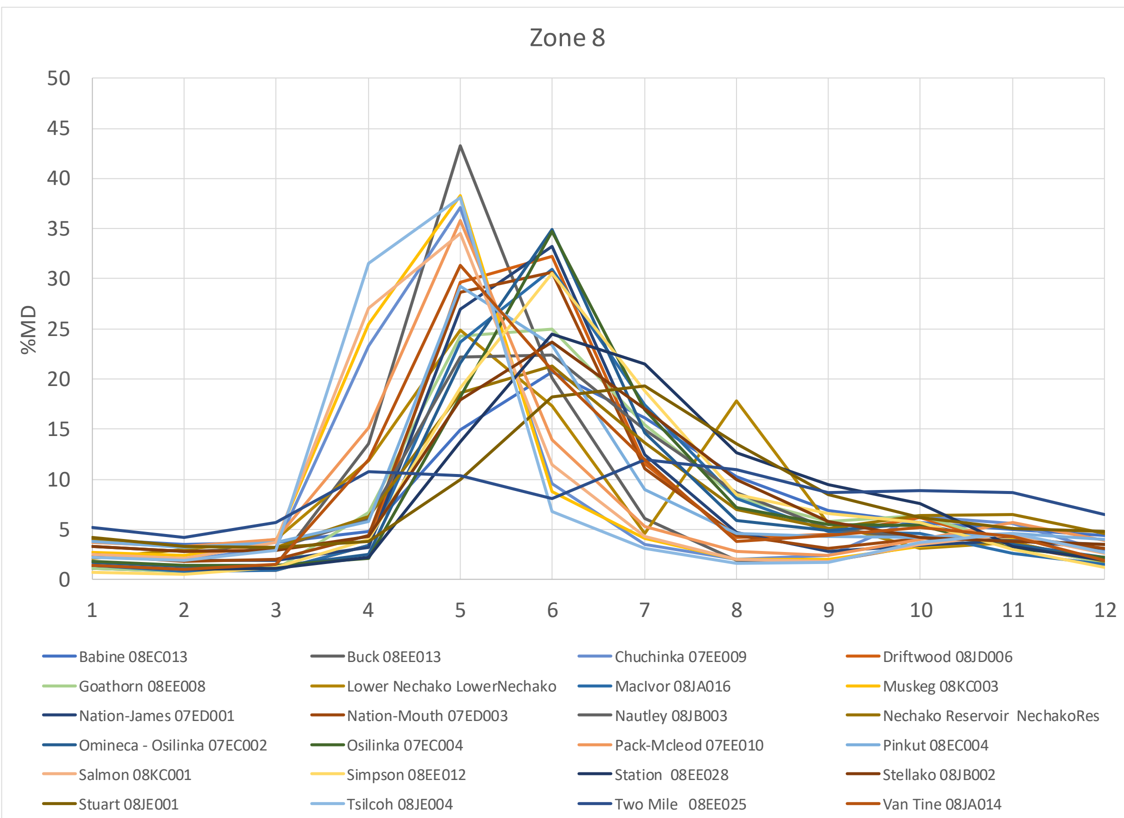
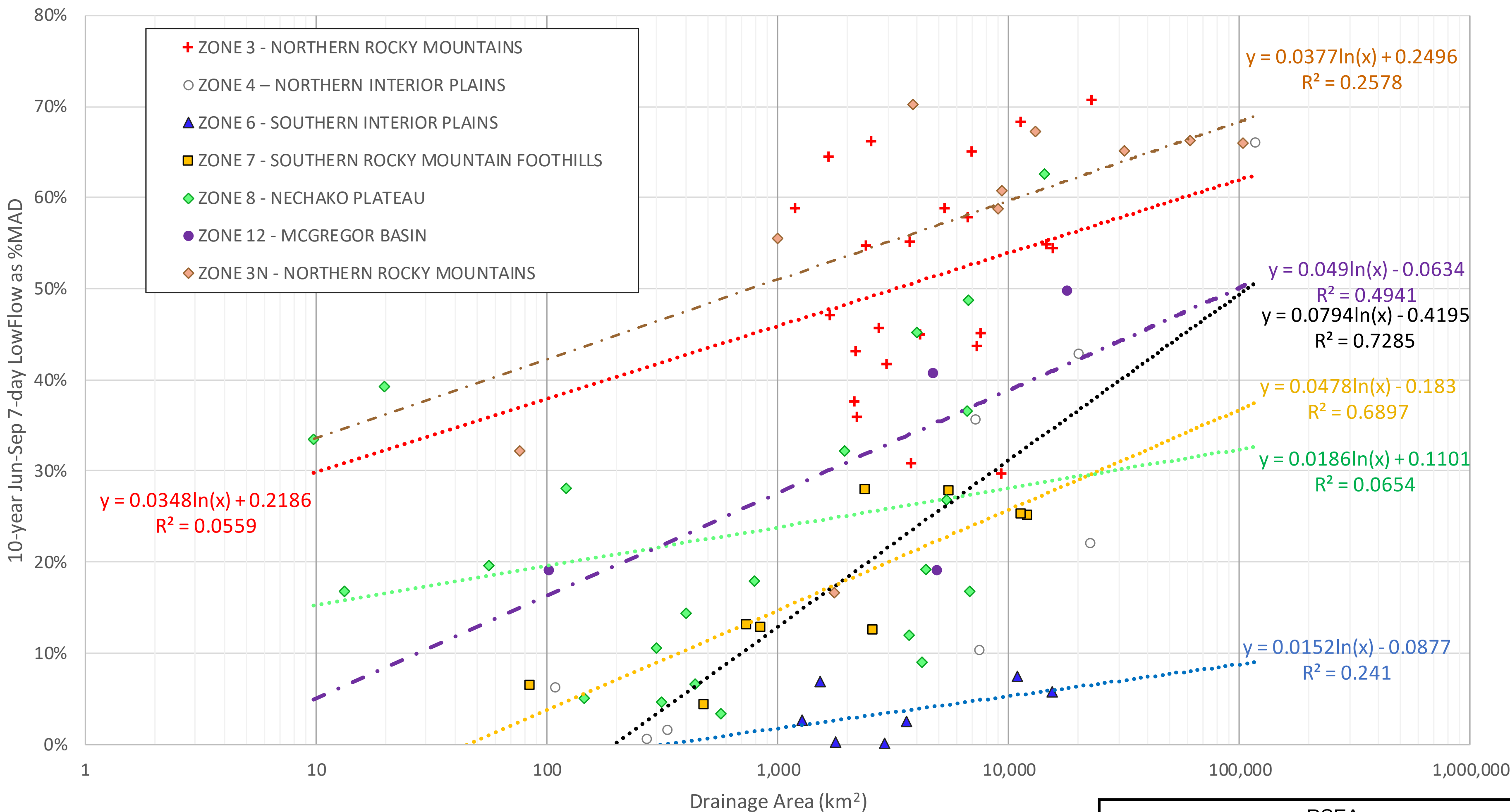


Figure 11: Comparison of Measured %MD Hydrographs: Zone 8-Nechako Plateau

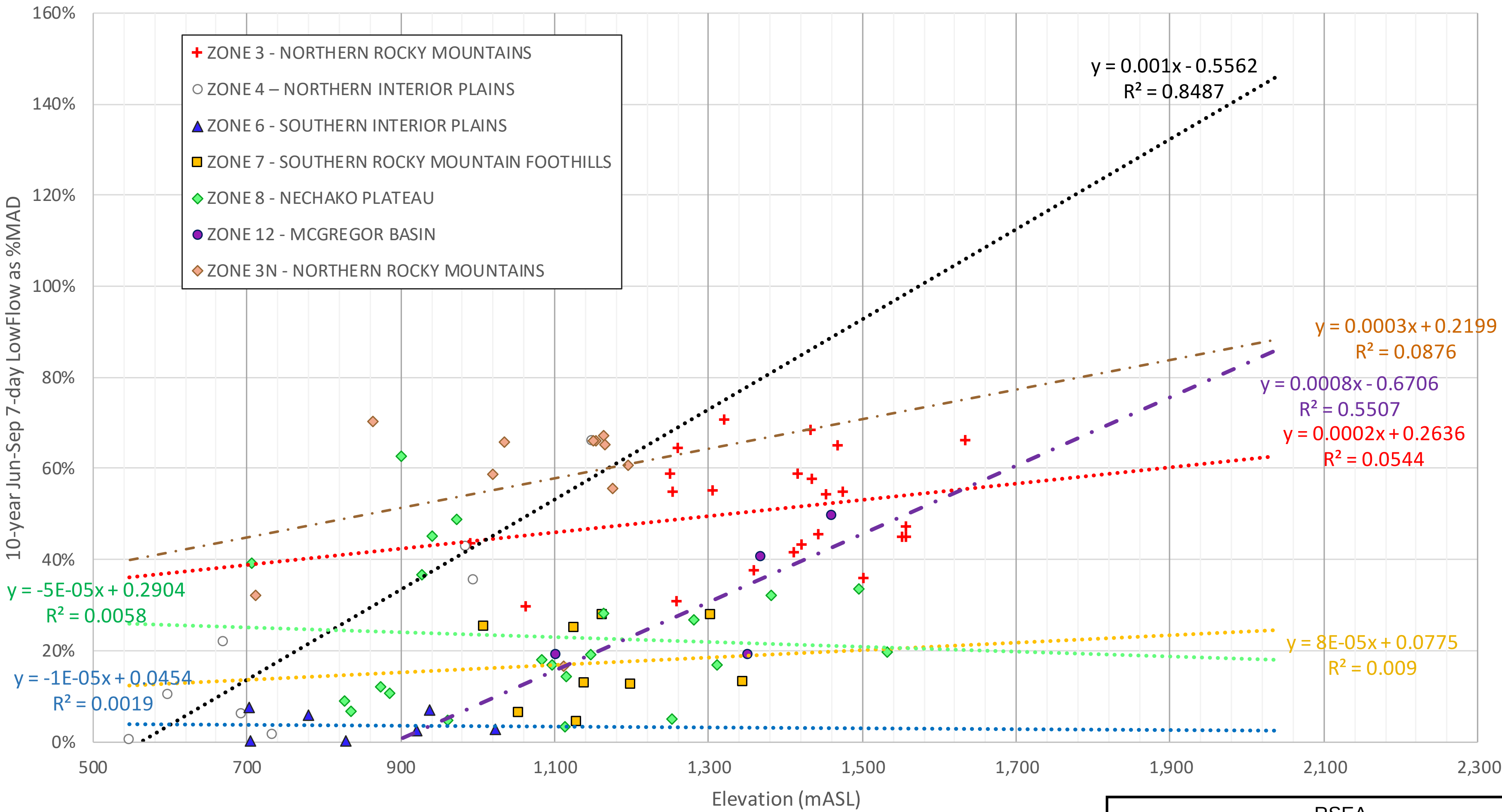




Notes:
1) This figure expresses the 10-year return period Jun-Sep 7-day low flow as %MAD for the 7 regions in Ahmed's "Inventory of Streamflow in the Omineca and Northeast Regions" as a function of Drainage Area.
2) From this figure we can see that the 10-year Jun-Sep 7-day low flow is a much smaller percentage of the MAD for smaller catchments than larger.
3) Both the x-axis and the trend line are logarithmic.

RSEA	
2019 HYDRO-STATS ANALYSIS FOR NE BC	
10-YEAR JUN-SEP 7-DAY LOW FLOW AS %MAD COMPARED TO DRAINAGE AREA	
Fathom Scientific Ltd. Ver 0.6 Nov 12, 2019	**FIGURE 12**

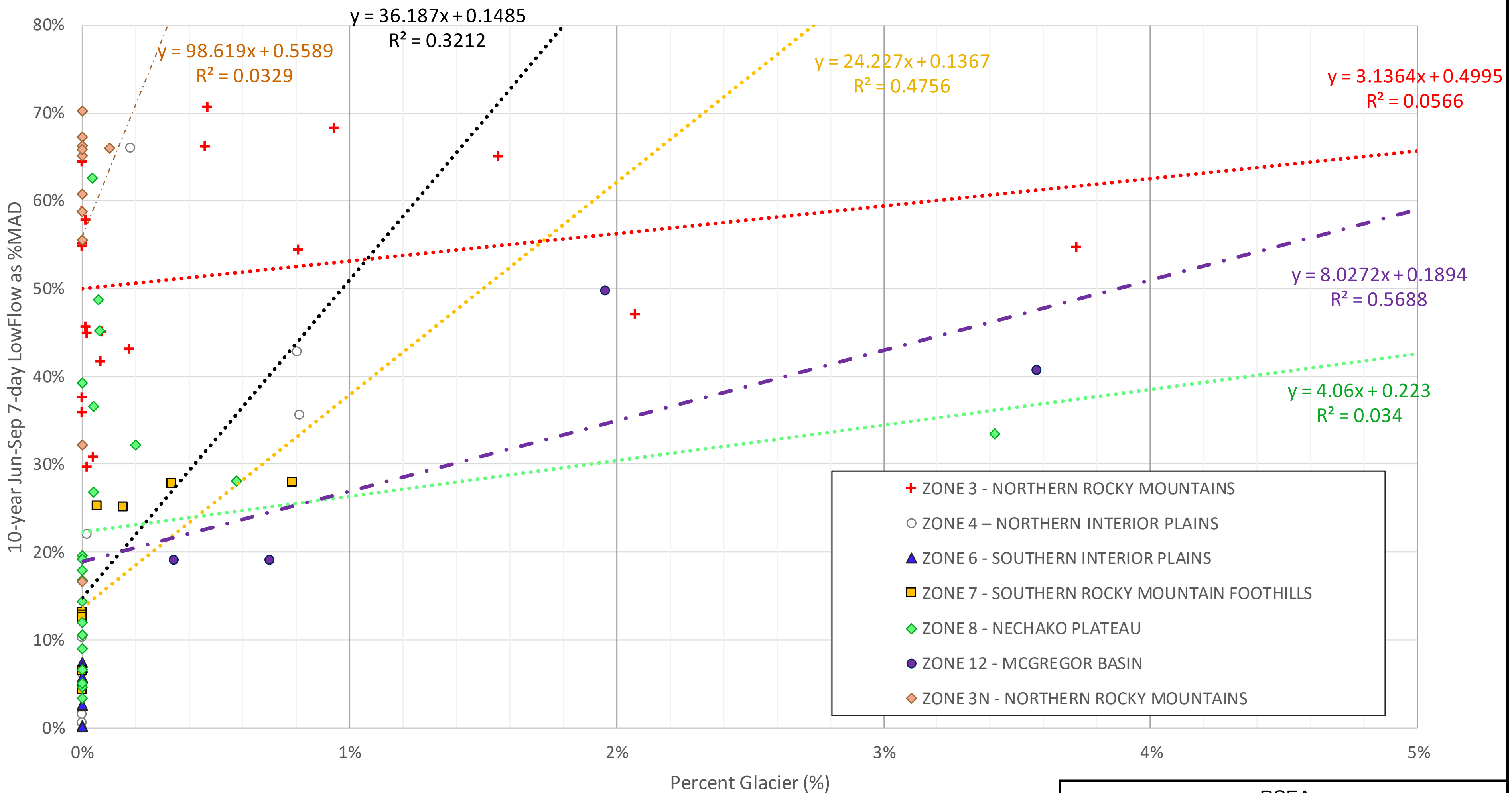
Figure 12: 10- year Jun-Sep 7-Day Low Flow as %MAD Compared to Drainage Area



Notes:
1) This figure expresses the 10-year return period Jun-Sep 7-day low flow as %MAD for the 7 regions in Ahmed's "Inventory of Streamflow in the Omineca and Northeast Regions" as a function of Median Elevation.
2) From this figure we can see that there is a relationship in Zone 4 and Zone 12.

RSEA	
2019 HYDRO-STATS ANALYSIS FOR NE BC	
10-YEAR JUN-SEP 7-DAY LOW FLOW AS %MAD COMPARED TO MEDIAN ELEVATION	
Fathom Scientific Ltd. — Ver 0.6 — Nov 12, 2019	**FIGURE 13**

Figure 13: : 10- year Jun-Sep 7-Day Low Flow as %MAD Compared to Median Elevation



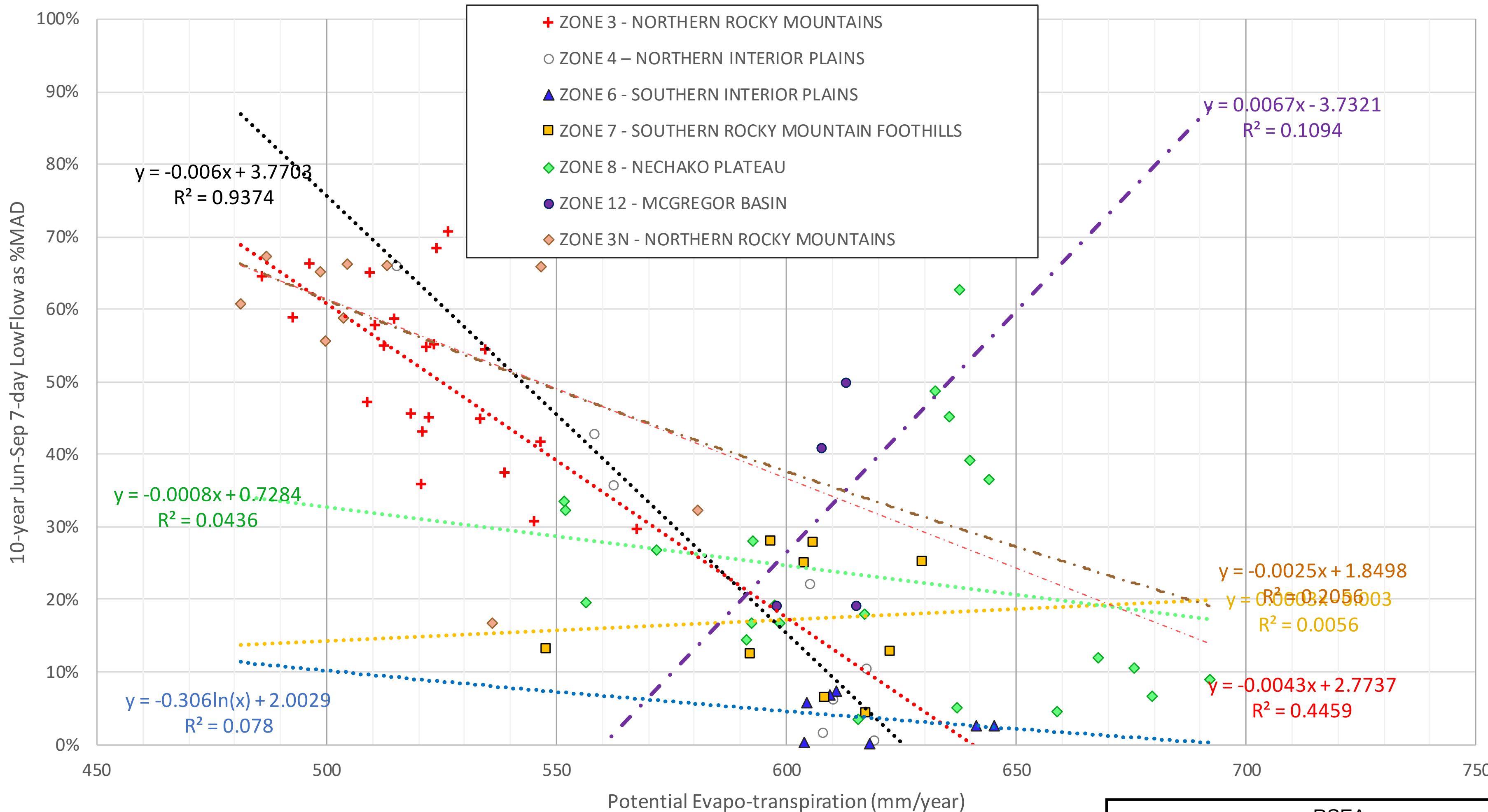
Notes:

1) This figure expresses the 10-year return period Jun-Sep 7-day low flow as %MAD for the 7 regions in Ahmed's "Inventory of Streamflow in the Omineca and Northeast Regions" as a function of Glaciation.

2) From this figure we can see that there is a moderate relationship in Zone 4, Zone 7, and a strong relationship in Zone 12, although the training sets are not large.

RSEA
2019 HYDRO-STATS ANALYSIS FOR NE BC
10-YEAR JUN-SEP 7-DAY LOW FLOW AS %MAD COMPARED TO GLACIATION
Fathom Scientific Ltd. — Ver 0.6 — Jan 3, 2020 — **FIGURE 14**

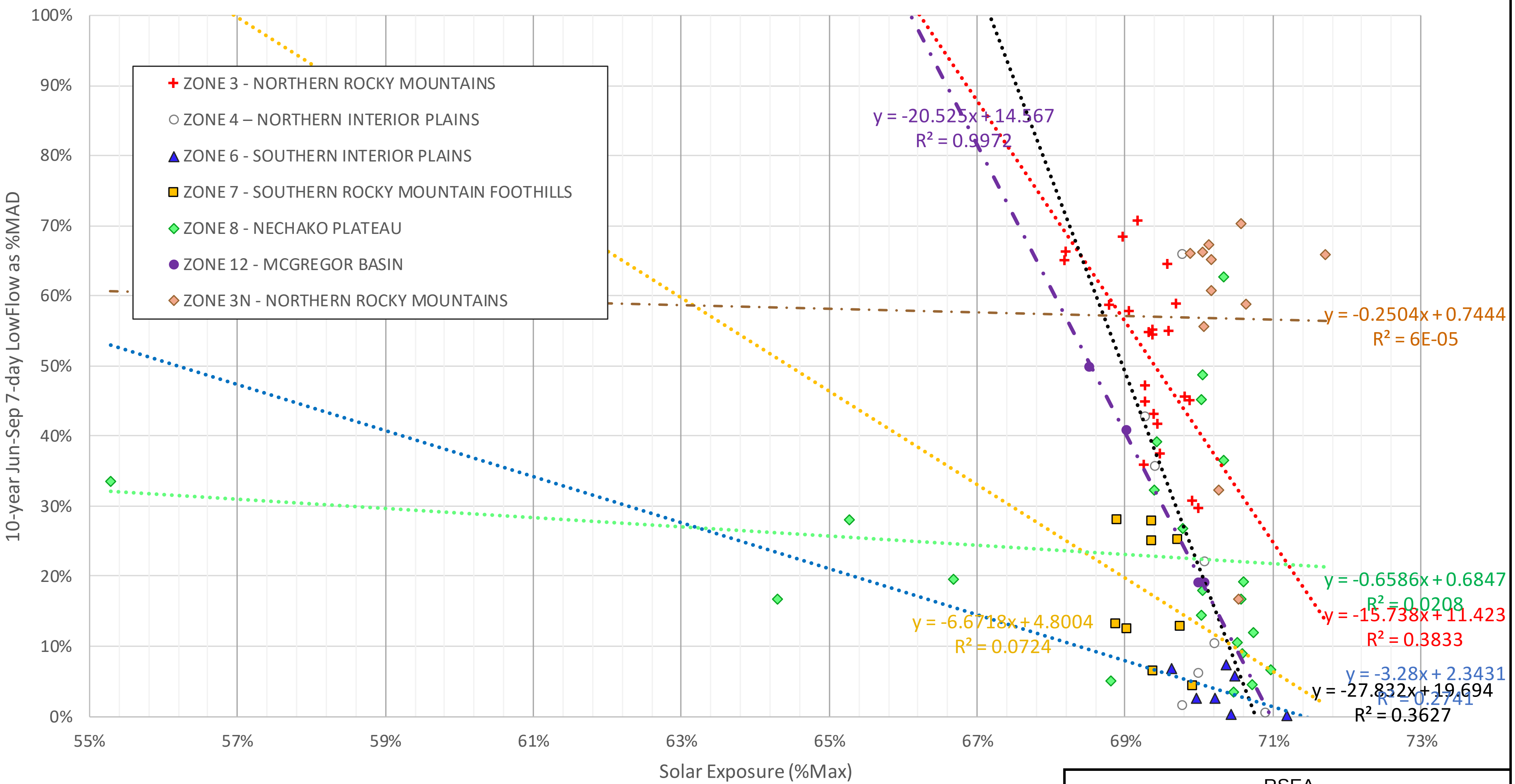
Figure 14: : 10- year Jun-Sep 7-Day Low Flow as %MAD Compared to Glaciation



Notes:
1) This figure expresses the 10-year return period Jun-Sep 7-day low flow as %MAD for the 7 regions in Ahmed's "Inventory of Streamflow in the Omineca and Northeast Regions" as a function of Potential Evapo-transpiration.
2) From this figure we can see that there is no clear relationship in any of the hydrological zones.

RSEA
2019 HYDRO-STATS ANALYSIS FOR NE BC
10-YEAR JUN-SEP 7-DAY LOW FLOW AS %MAD COMPARED TO PET
Fathom Scientific Ltd. — Ver 0.6 — Nov 12, 2019 — **FIGURE 15**

Figure 15: 10- year Jun-Sep 7-Day Low Flow as %MAD Compared to PET



Notes:

1) This figure expresses the 10-year return period Jun-Sep 7-day low flow as %MAD for the 7 regions in Ahmed's "Inventory of Streamflow in the Omineca and Northeast Regions" as a function of hillshade with shadows. The azimuth in this hillshade analysis was set to 180o (due south) and the elevation at 45o from the horizon.

2) From this figure we can see that the 10-year Jun-Sep 7-day low flow is a much smaller percentage of the MAD for catchments with more solar exposure.

RSEA

2019 HYDRO-STATS ANALYSIS FOR NE BC

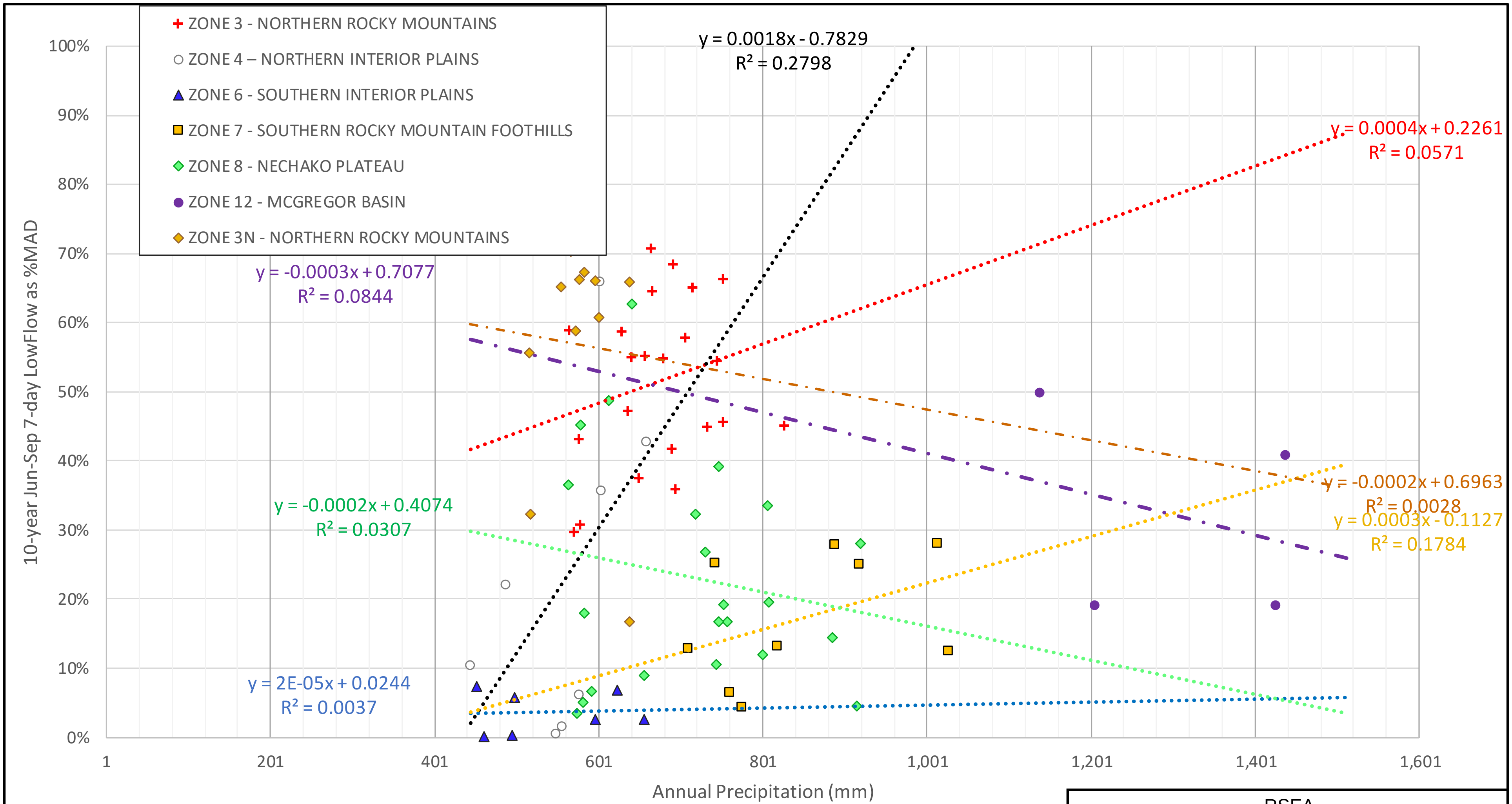
10-YEAR JUN-SEP 7-DAY LOW FLOW AS %MAD COMPARED TO HILLSHADE + SHADOWS

Fathom Scientific Ltd.

Ver 0.6 | Nov 12, 2019

FIGURE 16

Figure 16: 10- year Jun-Sep 7-Day Low Flow as %MAD Compared to Hillshade + Shadows



Notes:

1) This figure expresses the 10-year return period Jun-Sep 7-day low flow as %MAD for the 7 regions in Ahmed's "Inventory of Streamflow in the Omineca and Northeast Regions" as a function of PRISM Precipitation.

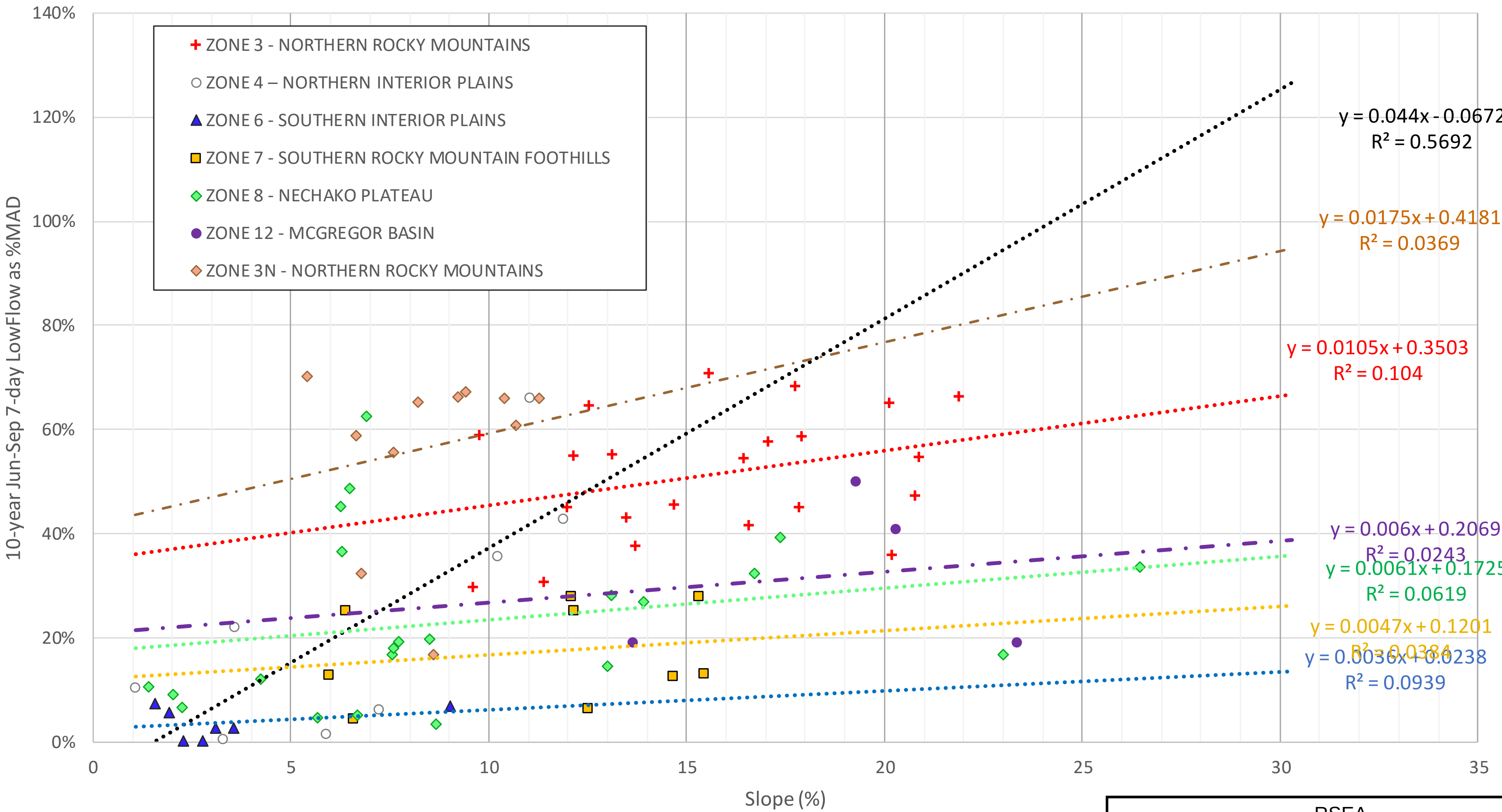
2) From this figure we can see that the 10-year Jun-Sep 7-day low flow is a much smaller percentage of the MAD for lower annual PPT in Zone 7 only

3) Both the x-axis and the trend line are logarithmic.

RSEA
2019 HYDRO-STATS ANALYSIS FOR NE BC
10-YEAR JUN-SEP 7-DAY LOW FLOW AS %MAD COMPARED TO PPT

Fathom Scientific Ltd. | Ver 0.6 | Nov 12, 2019 | **FIGURE 17**

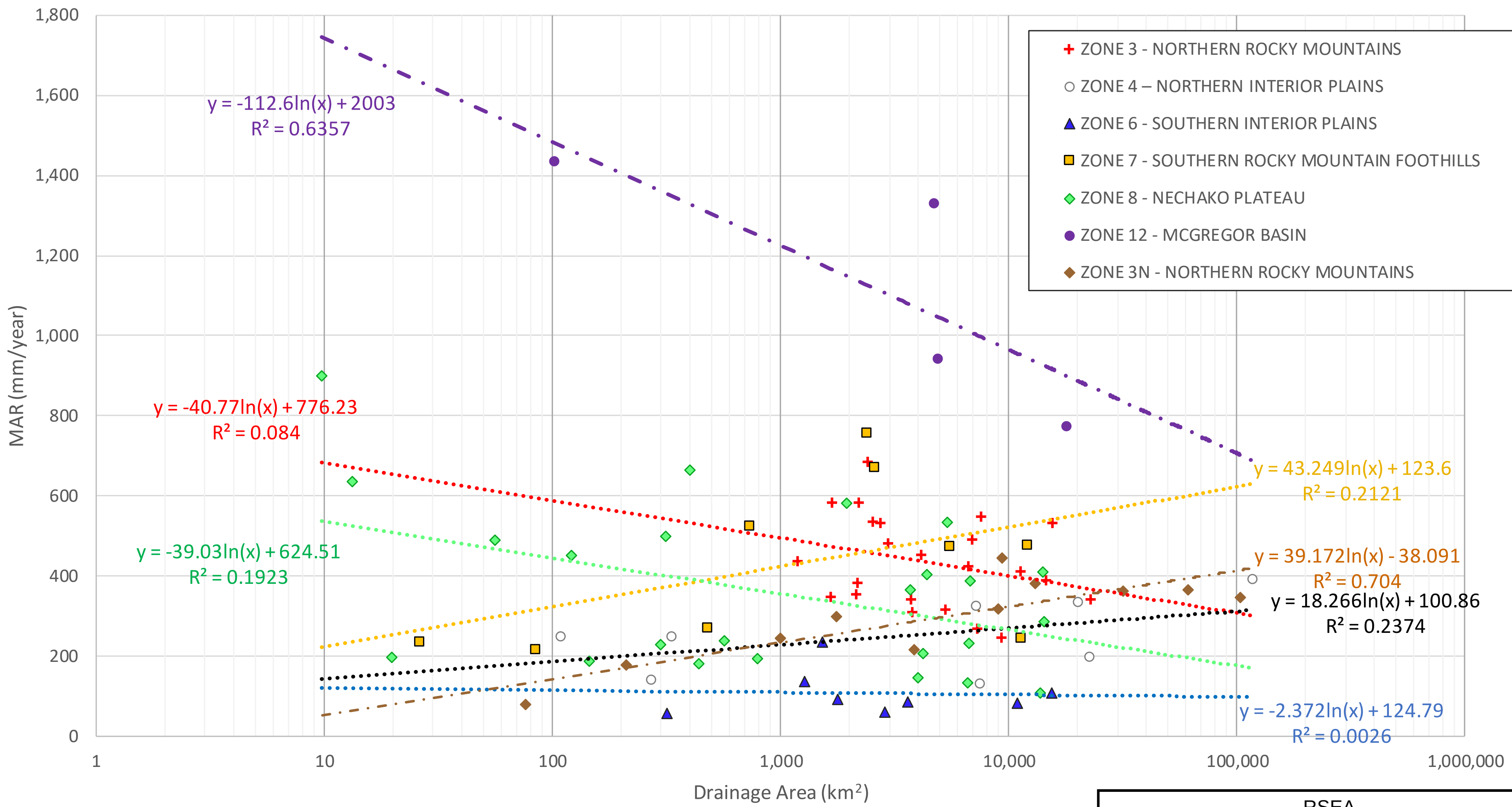
Figure 17: 10- year Jun-Sep 7-Day Low Flow as %MAD Compared to PPT



Notes:
1) This figure expresses the 10-year return period Jun-Sep 7-day low flow as %MAD for the 7 regions in Ahmed's "Inventory of Streamflow in the Omineca and Northeast Regions" as a function of Slope.
2) From this figure we can see that the 10-year Jun-Sep 7-day low flow is a much smaller percentage of the MAD for steeper slopes in Zone 6. The relationship is positive in Zone 4 but insignificant in the other zones.

RSEA	
2019 HYDRO-STATS ANALYSIS FOR NE BC	
10-YEAR JUN-SEP 7-DAY LOW FLOW AS %MAD COMPARED TO SLOPE	
Fathom Scientific Ltd. — Ver 0.6 — Nov 12, 2019	**FIGURE 18**

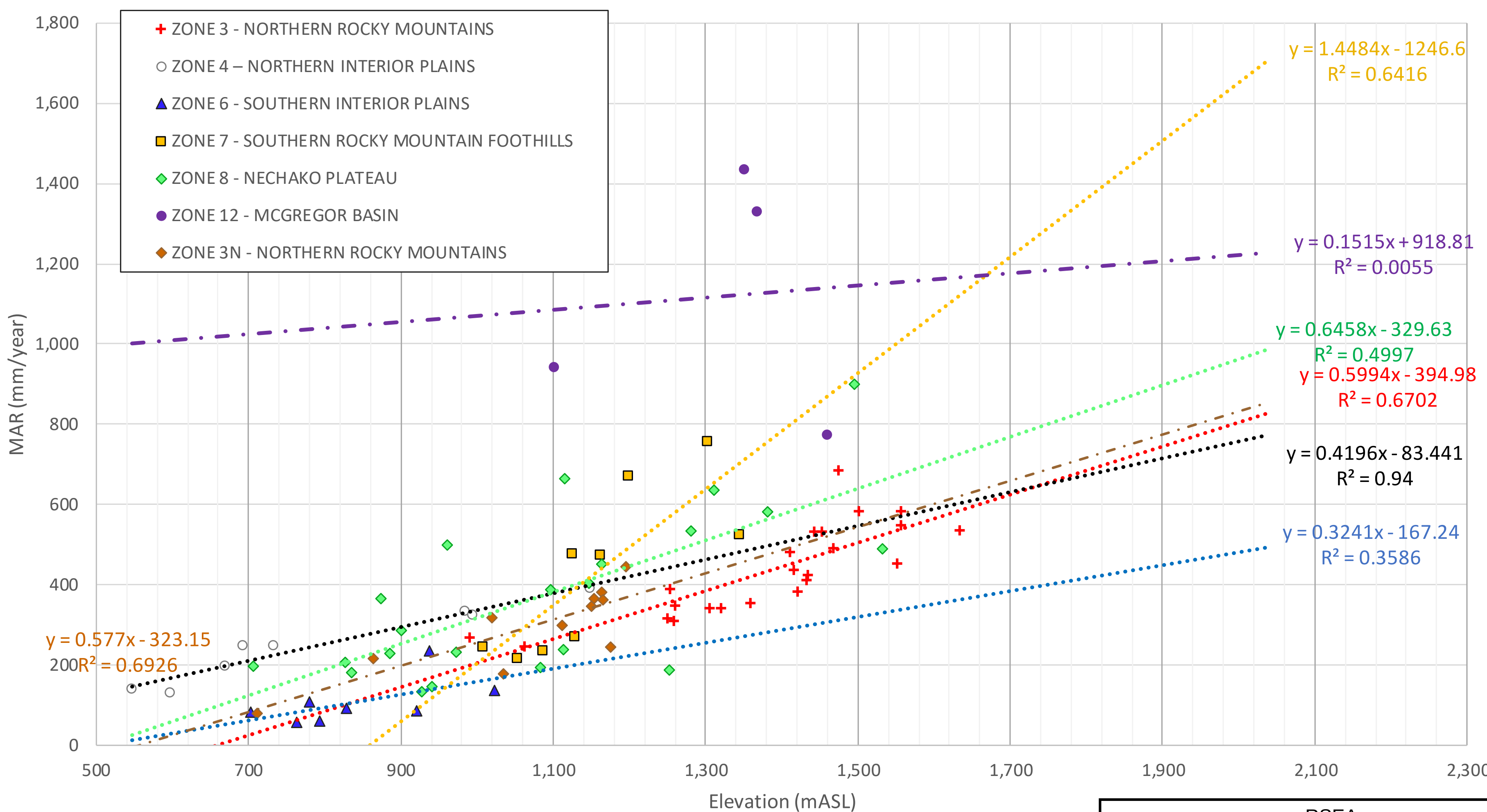
Figure 18: 10- year Jun-Sep 7-Day Low Flow as %MAD Compared to Slope



Notes:
1) This figure expresses the Mean Annual Runoff in mm/year for the 7 regions in Ahmed's "Inventory of Streamflow in the Omineca and Northeast Regions" as a function of Drainage Area.
2) From this figure we can see there are no clear relationships.
3) Both the x-axis and the trend line are logarithmic.

RSEA	
2019 HYDRO-STATS ANALYSIS FOR NE BC	
COMPARISON OF MAR TO DRAINAGE AREA	
Fathom Scientific Ltd. — Ver 0.6 — Jan 5, 2020	**FIGURE 19**

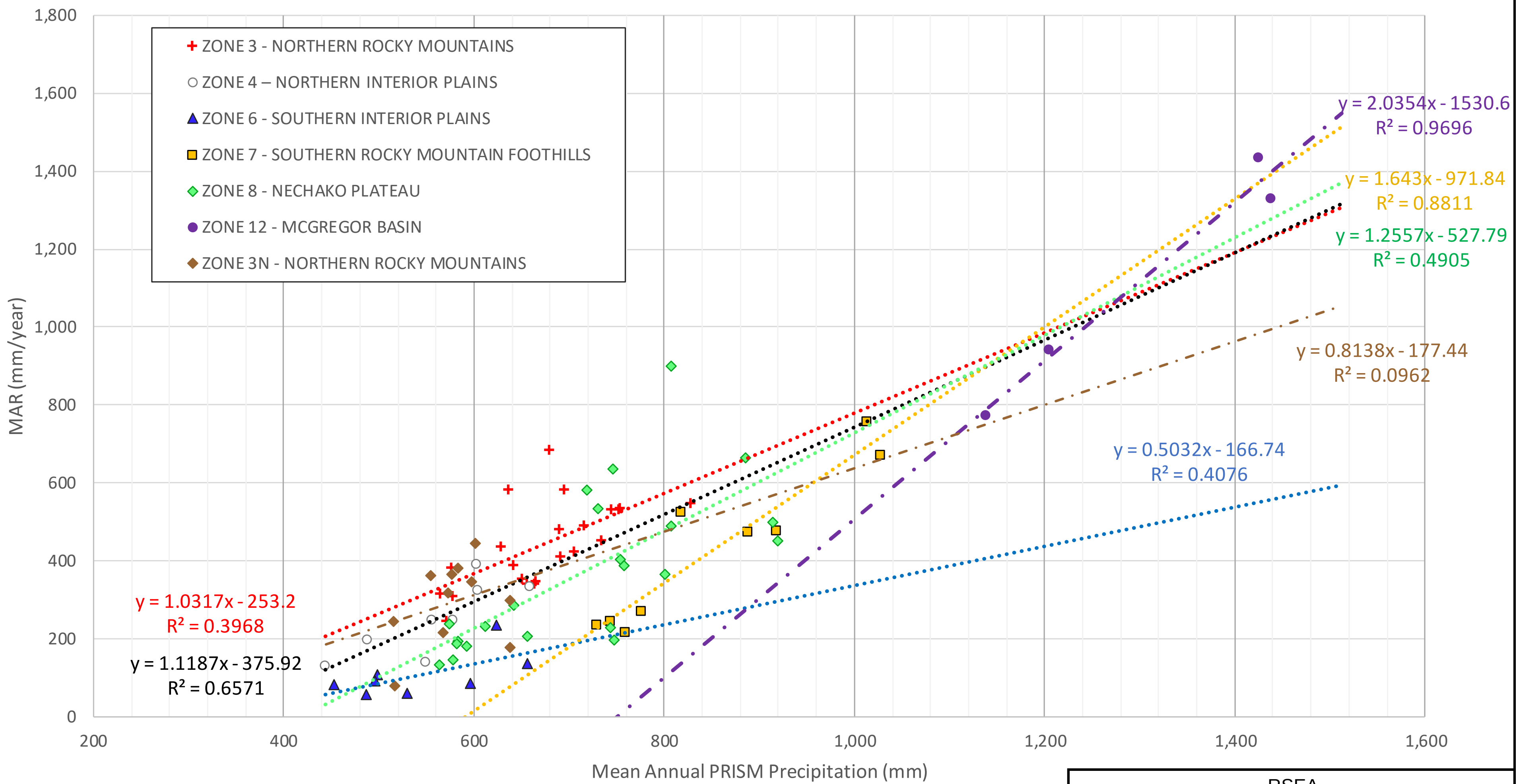
Figure 19: Comparison of MAR to Drainage Area



Notes:
1) This figure expresses the Mean Annual Runoff in mm/year for the 7 regions in Ahmed's "Inventory of Streamflow in the Omineca and Northeast Regions" as a function of Median Elevation.
2) From this figure we can see there is a strong relationship between MAR and Median Elevation in every zone, but for zone 12.

RSEA	
2019 HYDRO-STATS ANALYSIS FOR NE BC	
COMPARISON OF MAR TO MEDIAN ELEVATION (MASL)	
Fathom Scientific Ltd. — Ver 0.6 — Nov 12, 2019	**FIGURE 20**

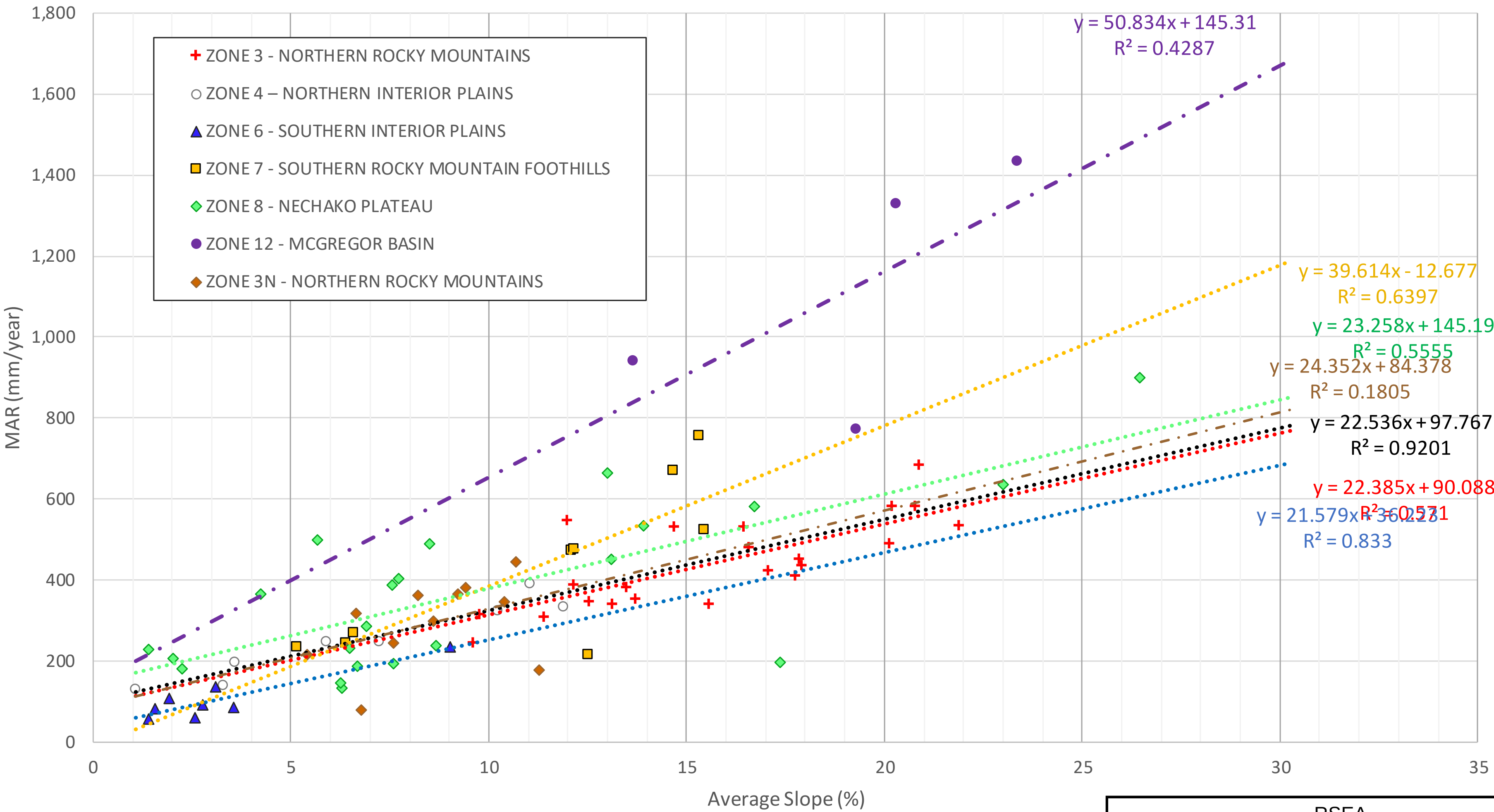
Figure 20: Comparison of MAR to Median Elevation (MASL)



Notes:
1) This figure expresses the Mean Annual Runoff in mm/year for the 7 regions in Ahmed's "Inventory of Streamflow in the Omineca and Northeast Regions" as a function of PRISM Annual PPT.
2) From this figure we can see there is a strong relationship between MAR and PRISM Annual PPT.

RSEA	
2019 HYDRO-STATS ANALYSIS FOR NE BC	
COMPARISON OF MAR TO PRISM PRECIPITATION (MM)	
Fathom Scientific Ltd. — Ver 0.6 — Nov 12, 2019	**FIGURE 21**

Figure 21: Comparison of MAR to PRISM Precipitation (mm)



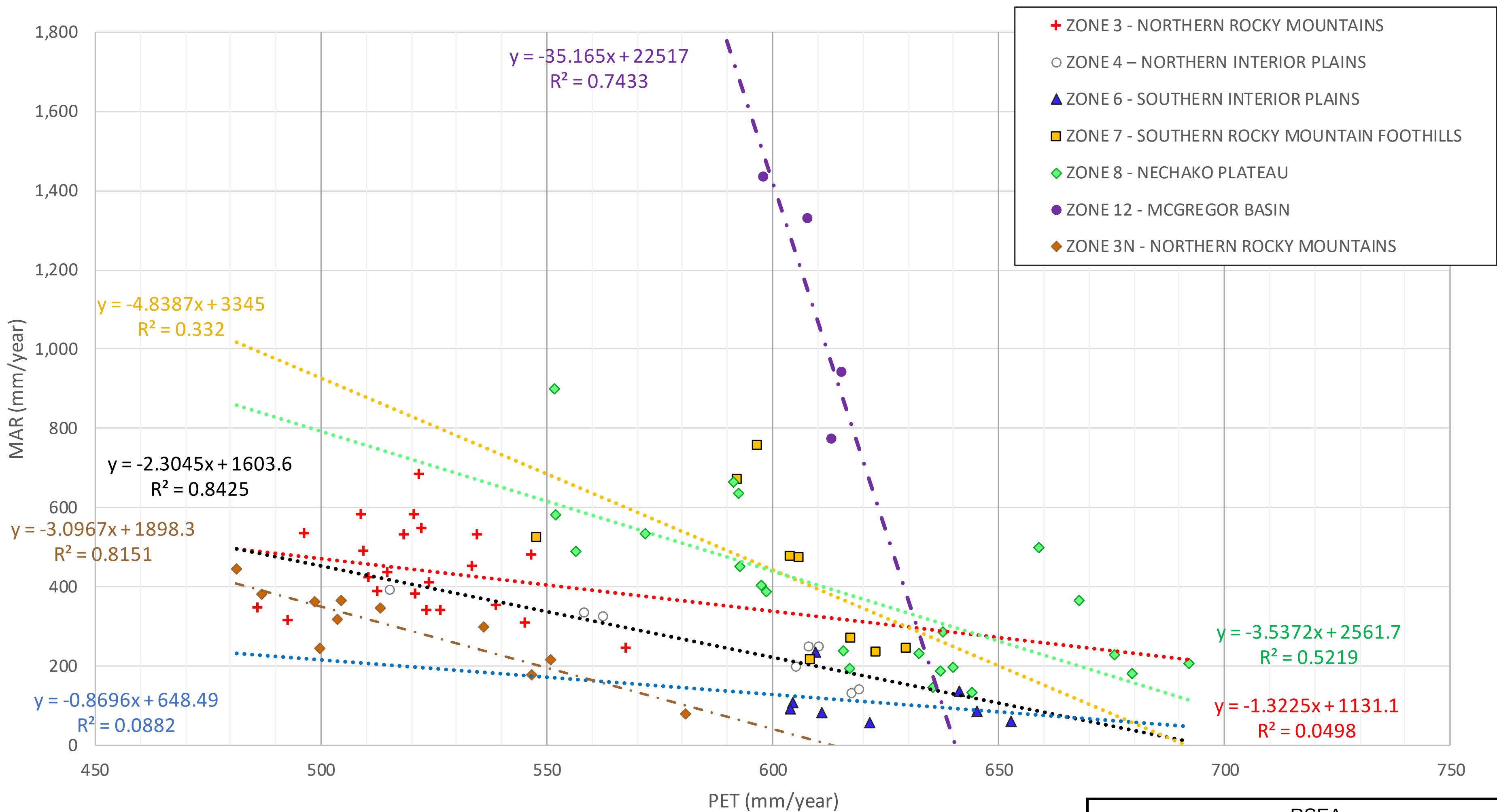
Notes:

1) This figure expresses the Mean Annual Runoff in mm/year for the 7 regions in Ahmed's "Inventory of Streamflow in the Omineca and Northeast Regions" as a function of average slope.

2) From this figure we can see there is a strong relationship between MAR and SLOPE%.

RSEA
2019 HYDRO-STATS ANALYSIS FOR NE BC
COMPARISON OF MAR TO SLOPE (%)
Fathom Scientific Ltd. — Ver 0.6 — Nov 12, 2019 — **FIGURE 22**

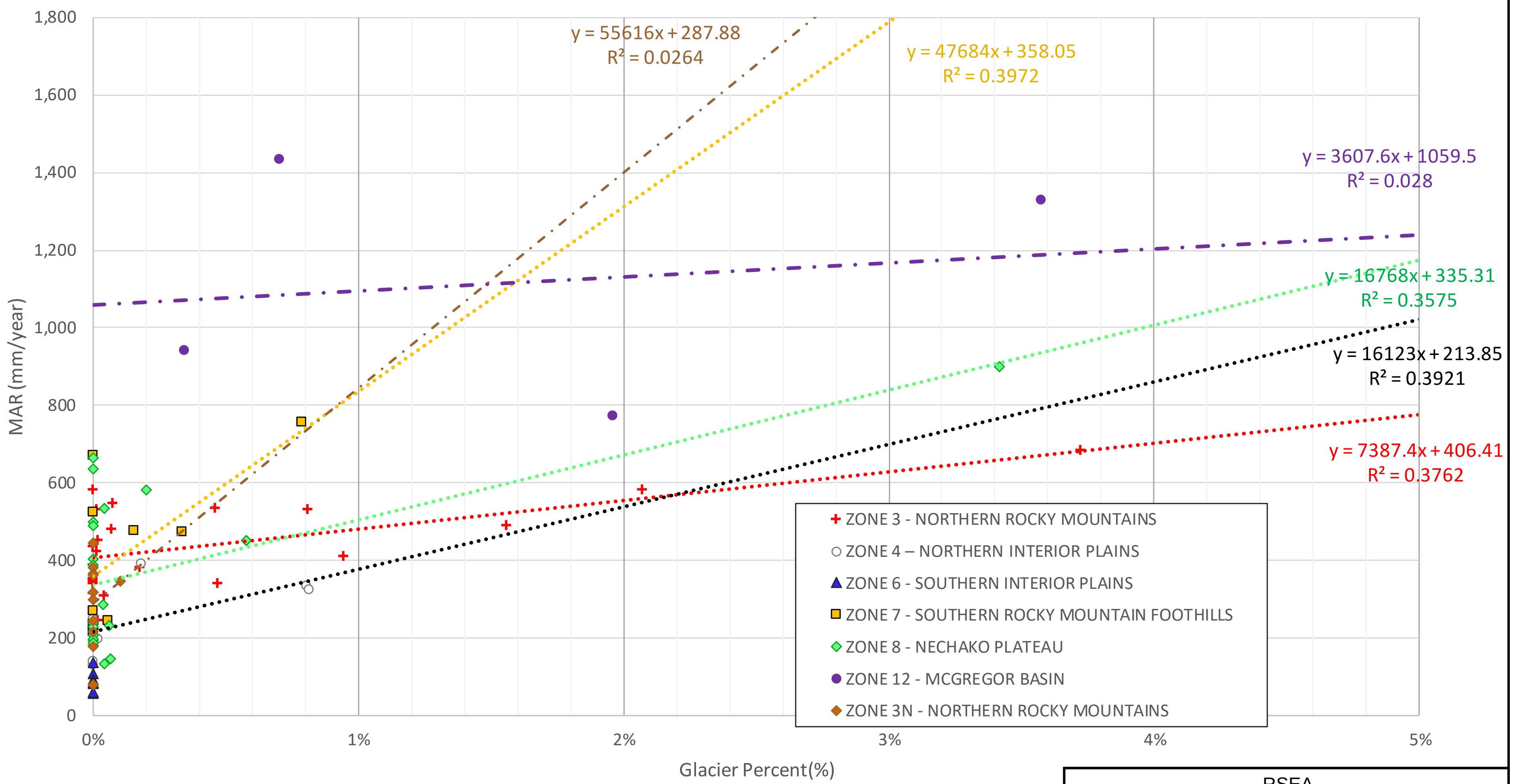
Figure 22: Comparison of MAR to Slope (%)



Notes:
1) This figure expresses the Mean Annual Runoff in mm/year for the 7 regions in Ahmed's "Inventory of Streamflow in the Omineca and Northeast Regions" as a function of PET
2) From this figure we can see there is a strong relationship between MAR and PET.

RSEA
2019 HYDRO-STATS ANALYSIS FOR NE BC
COMPARISON OF MAR TO PET
Fathom Scientific Ltd. — Ver 0.6 — Nov 12, 2019 — **FIGURE 23**

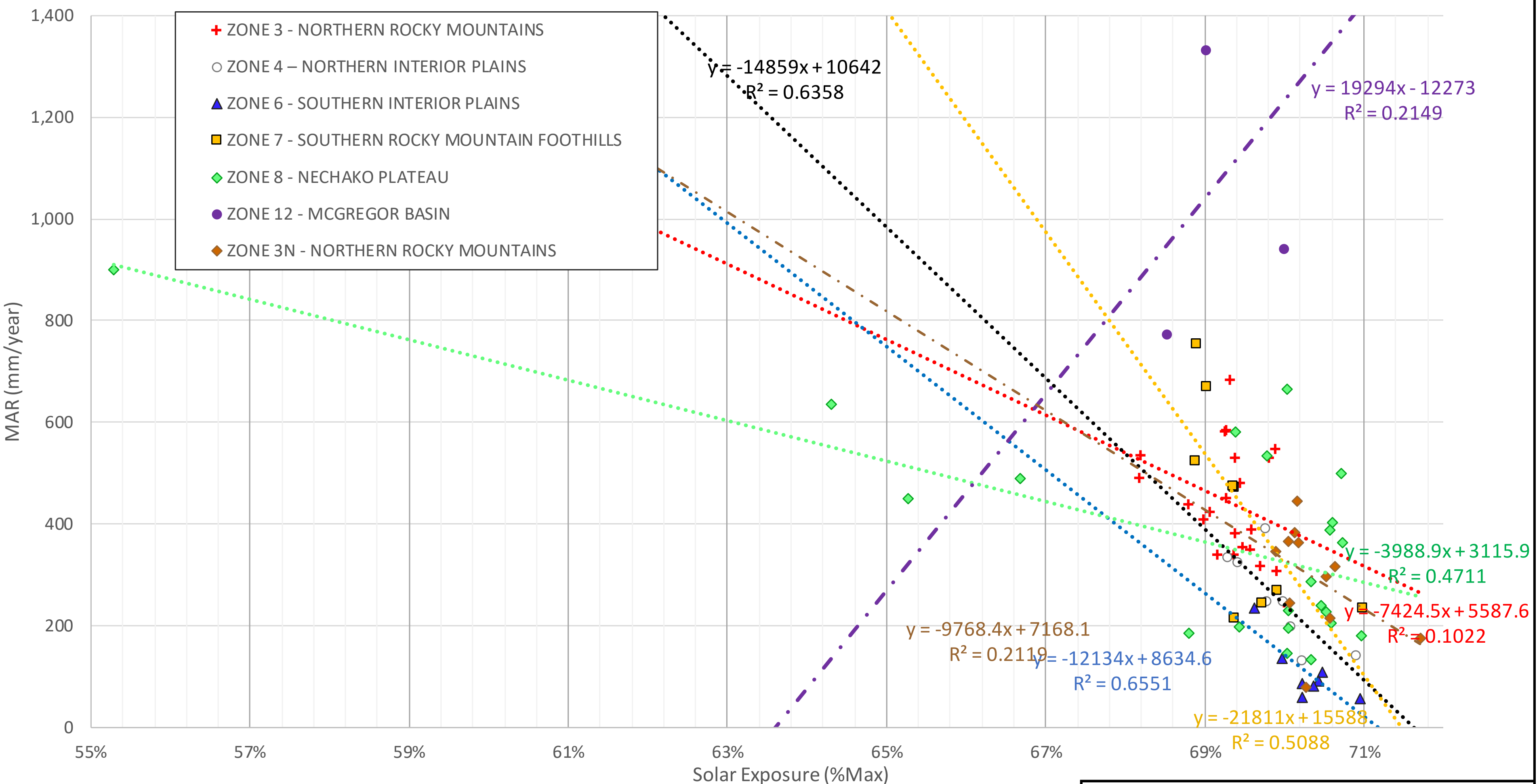
Figure 23: Comparison of MAR to PET



Notes:
1) This figure expresses the Mean Annual Runoff in mm/year for the 7 regions in Ahmed's "Inventory of Streamflow in the Omineca and Northeast Regions" as a function of Glaciation.
2) From this figure we can see there is a strong relationship between MAR and Glacier% in Zones which have glacier, except zone 12.

RSEA	
2019 HYDRO-STATS ANALYSIS FOR NE BC	
COMPARISON OF MAR TO GLACIATION	
Fathom Scientific Ltd. — Ver 0.6 — Jan 5, 2020	**FIGURE 24**

Figure 24: Comparison of MAR to Glaciation



Notes:

1) This figure expresses the Mean Annual Runoff in mm/year for the 7 regions in Ahmed's "Inventory of Streamflow in the Omineca and Northeast Regions" as a function of Solar Exposure.

2) From this figure we can see there is essentially no relationship between Solar Exposure and MAR, except perhaps in Zone 4 or Zone 3.

RSEA

2019 HYDRO-STATS ANALYSIS FOR NE BC

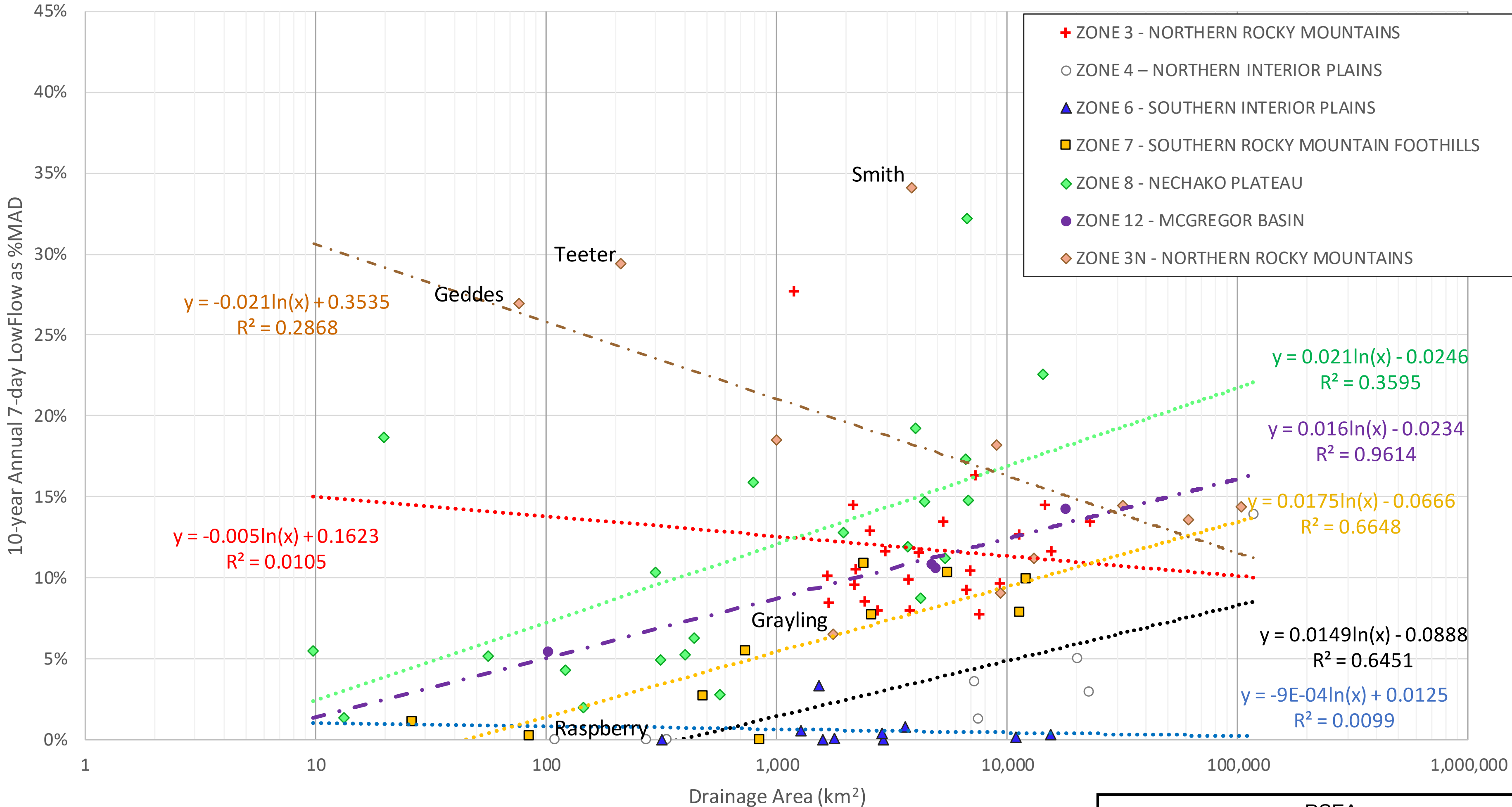
COMPARISON OF MAR TO HILLSHADE + SHADOWS

Fathom Scientific Ltd.

Ver 0.6 | Nov 12, 2019

FIGURE 25

Figure 25: Comparison of MAR to Hillshade + Shadows



Notes:
1) This figure expresses the 10-year Annual return low flow as %MAD for the 7 regions in Ahmed's "Inventory of Streamflow in the Omineca and Northeast Regions" as a function of Drainage Area.
2) From this figure we can see that there are significant relationships in Zone 12, Zone 7, and Zone 4.
3) Both the x-axis and the trend line are logarithmic.

RSEA

2019 HYDRO-STATS ANALYSIS FOR NE BC

ANNUAL 10-YEAR 7-DAY LOW FLOW AS %MAD COMPARED TO DRAINAGE AREA

Fathom Scientific Ltd.

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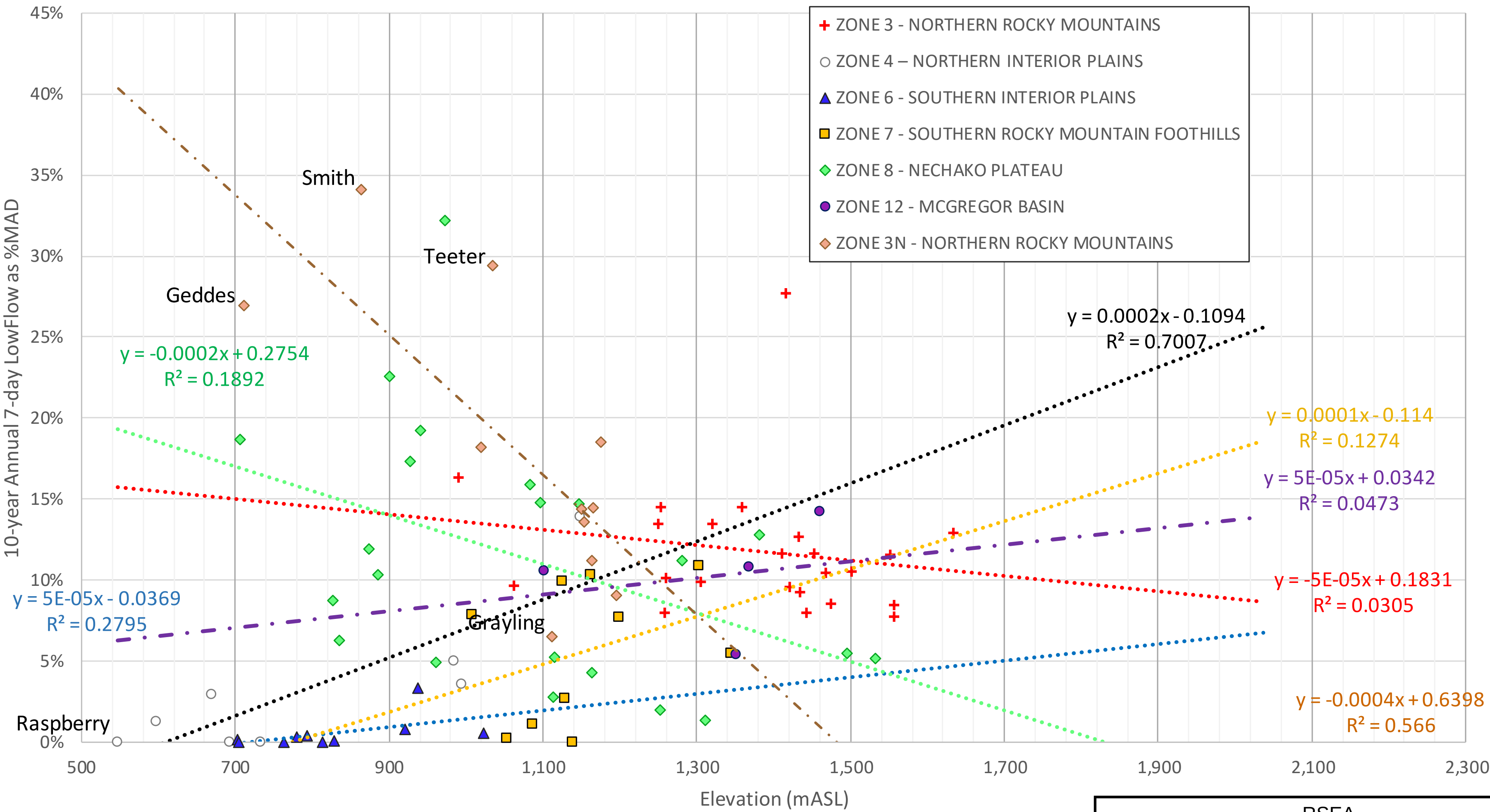
FIGURE 26

Figure 26: Annual 10-year 7-day Low Flow as %MAD Compared to Drainage Area



Notes:
1) This figure expresses the 10-year Annual return low flow as %MADfor the 7 regions in Ahmed's "Inventory of Streamflow in the Omineca and Northeast Regions" as a function of Elevation.
2) From this figure we can see that there is a relationship in Zone 4 and Zone 12.

RSEA

2019 HYDRO-STATS ANALYSIS FOR NE BC

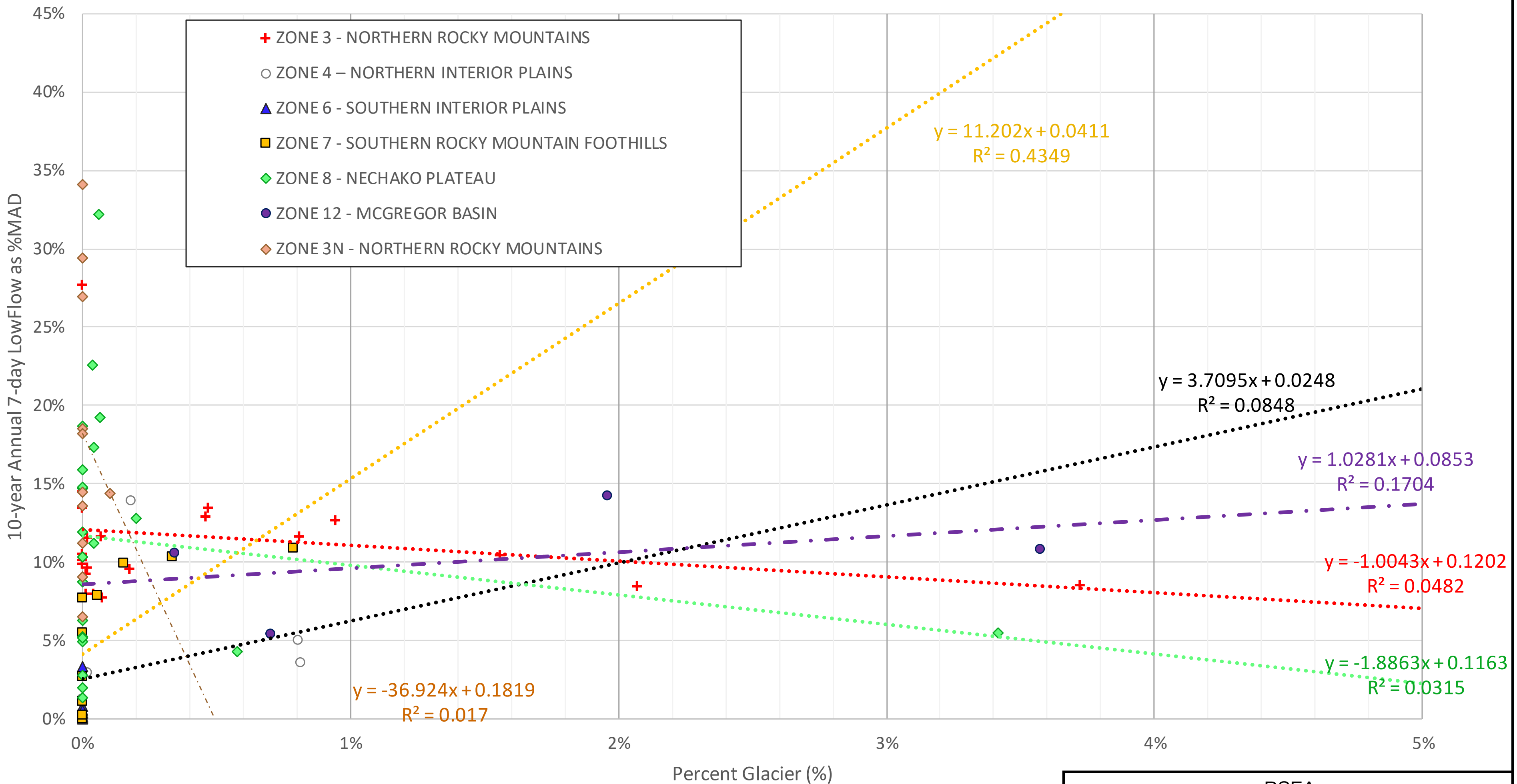
ANNUAL 10-YEAR 7-DAY LOW FLOW AS %MAD COMPARED TO MEDIAN ELEVATION

Fathom Scientific Ltd.

Ver 0.6 | Jan 6, 2020

FIGURE 27

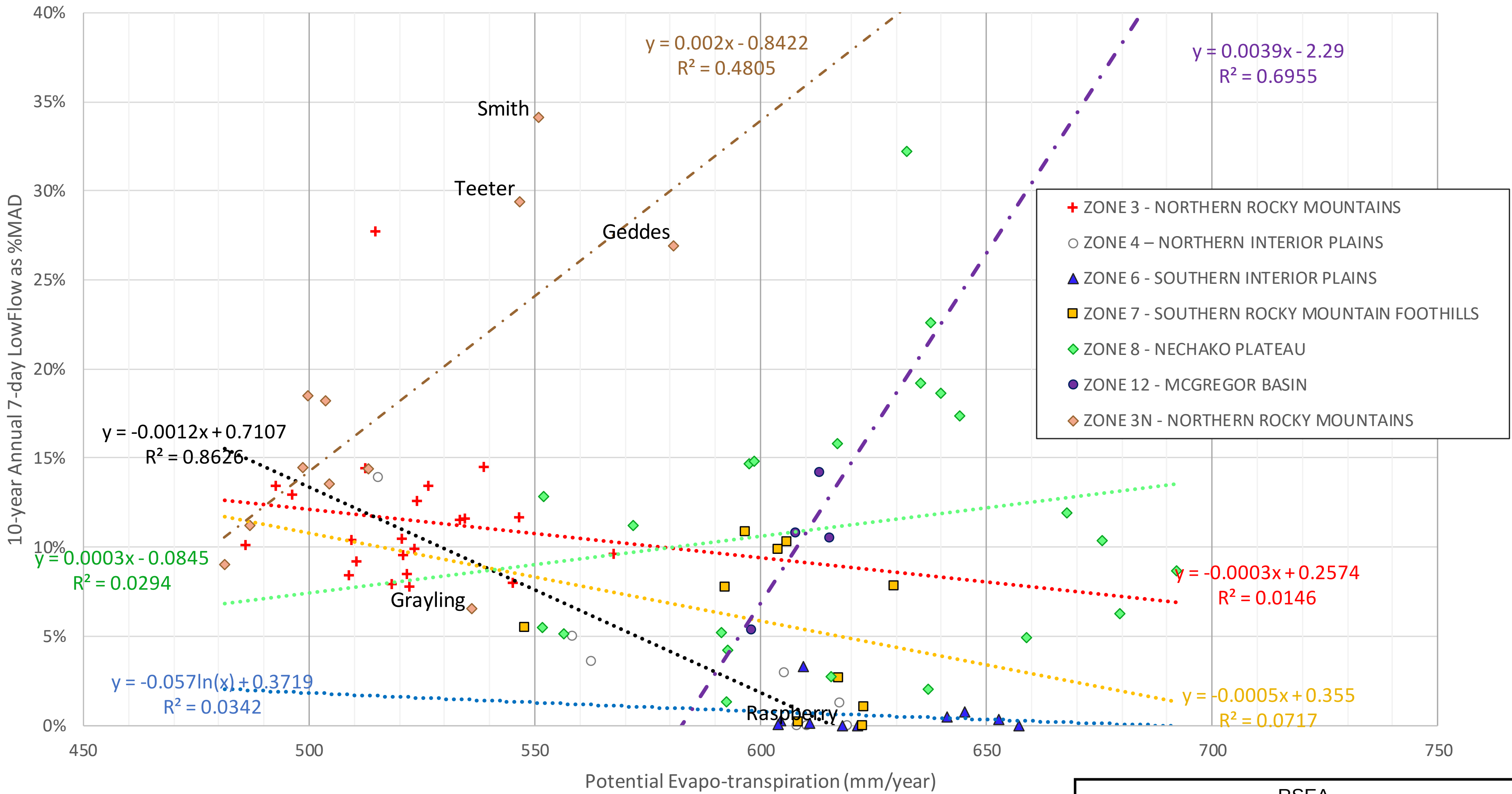
Figure 27: Annual 10-year 7-day Low Flow as %MAD Compared to Median Elevation



Notes:
1) This figure expresses the 10-year Annual return low flow as %MAD for the 7 regions in Ahmed's "Inventory of Streamflow in the Omineca and Northeast Regions" as a function of Glaciation.
2) From this figure we can see that there is a relationship in Zone 4, Zone 7, and Zone 12, although the training sets are not large.

RSEA	
2019 HYDRO-STATS ANALYSIS FOR NE BC	
ANNUAL 10-YEAR 7-DAY LOW FLOW AS %MAD COMPARED TO GLACIATION	
Fathom Scientific Ltd. Ver 0.6 Jan 5, 2020	**FIGURE 28**

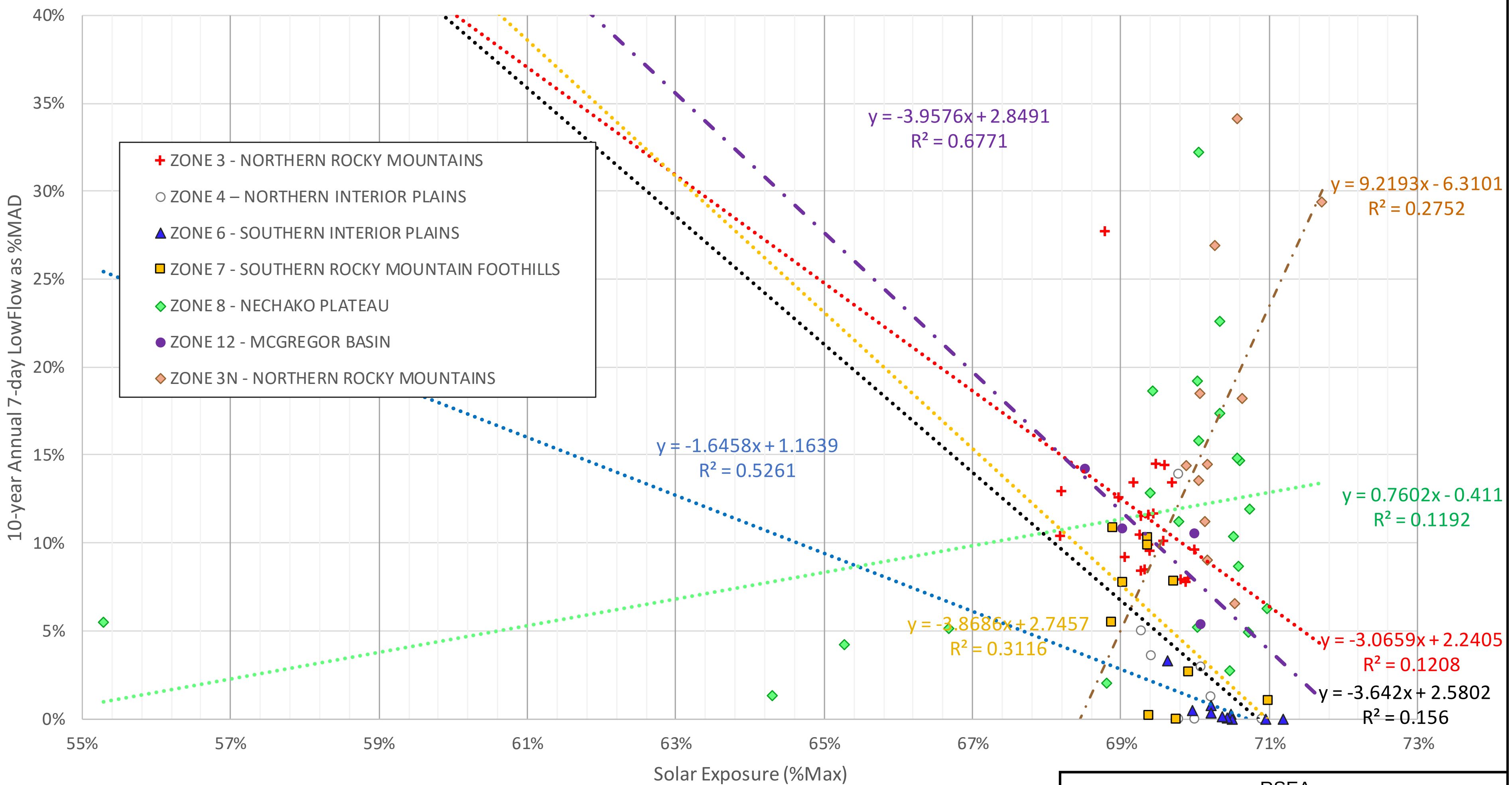
Figure 28: Annual 10-year 7-day Low Flow as %MAD Compared to Glaciation



Notes:
1)) This figure expresses the 10-year Annual return low flow as %MAD for the 7 regions in Ahmed's "Inventory of Streamflow in the Omineca and Northeast Regions" as a function of Potential Evapo-transpiration.
2) From this figure we can see that there is a relationship in Zone 3N and Zone 12.

RSEA	
2019 HYDRO-STATS ANALYSIS FOR NE BC	
ANNUAL 10-YEAR 7-DAY LOW FLOW AS %MAD COMPARED TO PET	
Fathom Scientific Ltd. Ver 0.6, Jan 6, 2020	**FIGURE 29**

Figure 29: Annual 10-year 7-day Low Flow as %MAD Compared to PET



Notes:

1) This figure expresses the 10-year Annual return low flow as %MAD for the 7 regions in Ahmed's "Inventory of Streamflow in the Omineca and Northeast Regions" as a function of hillshade with shadows. The azimuth in this hillshade analysis was set to 180o (due south) and the elevation at 45o from the horizon.

2) From this figure we cannot see any clear relationship.

3) Both the x-axis and the trend line are logarithmic.

RSEA

2019 HYDRO-STATS ANALYSIS FOR NE BC

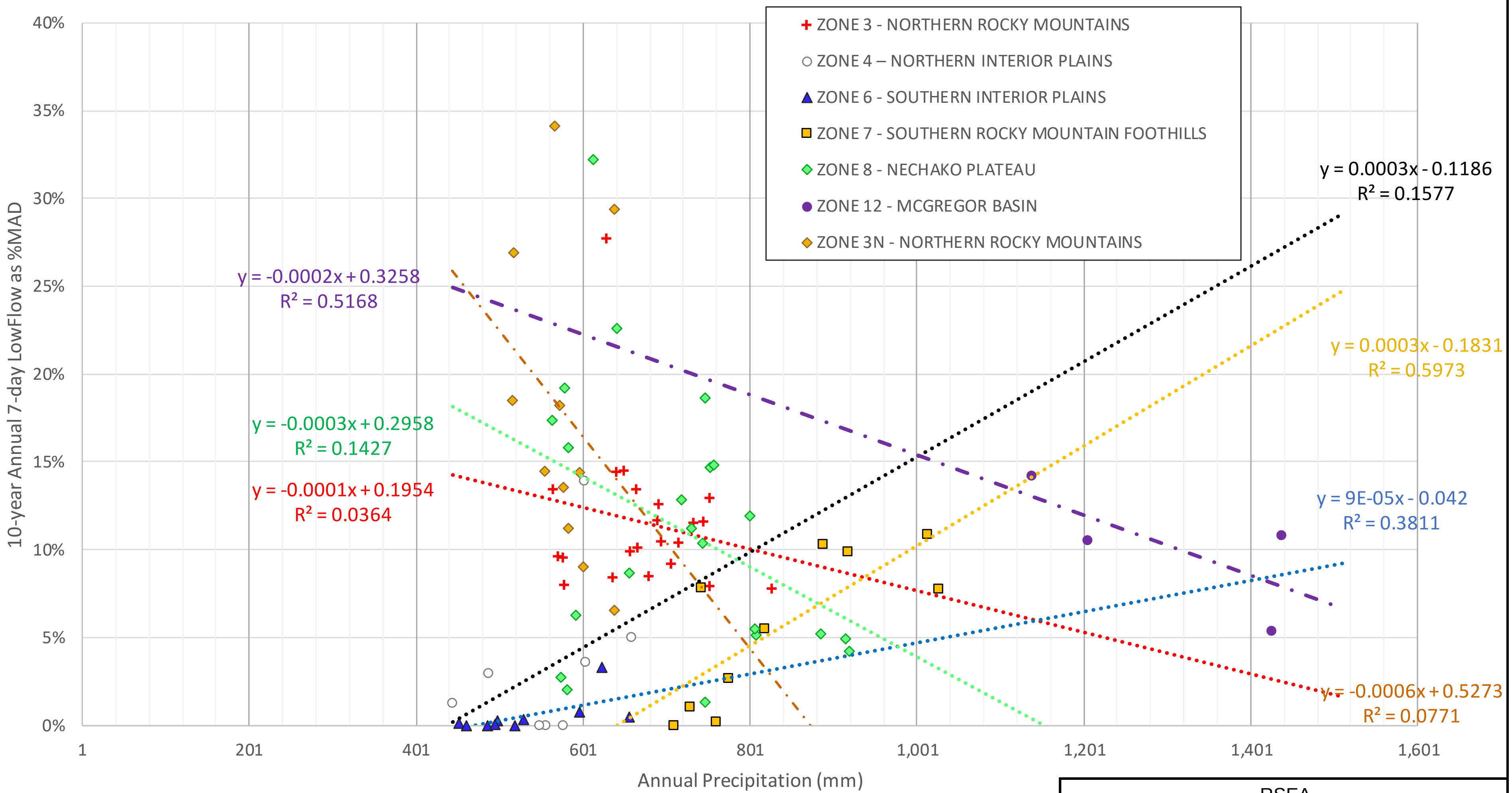
ANNUAL 10-YEAR 7-DAY LOW FLOW AS %MAD COMPARED TO HILLSHADE + SHADOWS

Fathom Scientific Ltd.

Ver 0.6	Nov 12, 2019

FIGURE 30

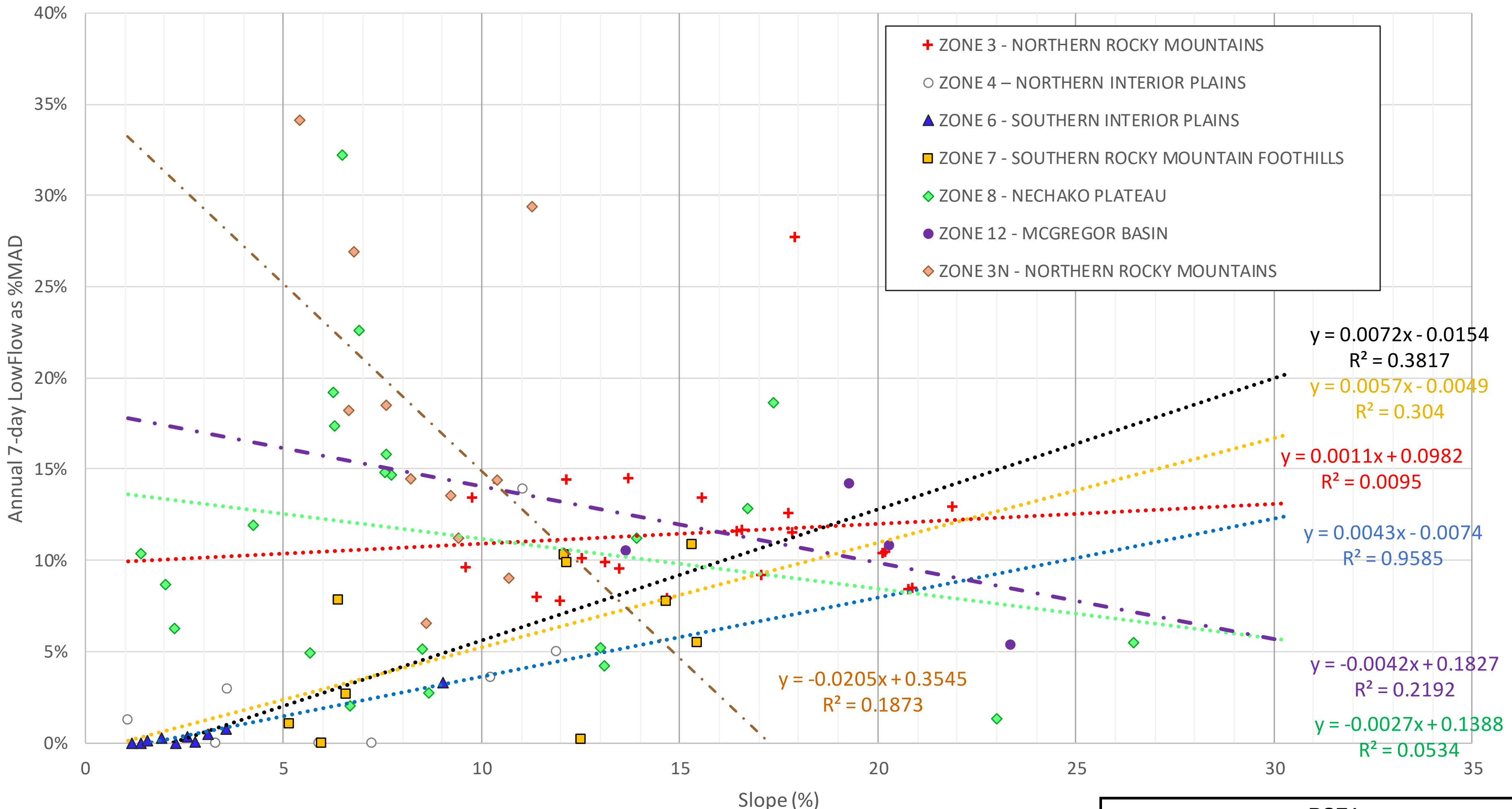
Figure 30: Annual 10-year 7-day Low Flow as %MAD Compared to Hillshade + Shadows



Notes:
1) This figure expresses the 10-year Annual return low flow as %MAD for the 7 regions in Ahmed's "Inventory of Streamflow in the Omineca and Northeast Regions" as a function of PRISM Precipitation.
2) From this figure we cannot see any clear relationship, except in Zone 7.
3) Both the x-axis and the trend line are logarithmic.

RSEA	
2019 HYDRO-STATS ANALYSIS FOR NE BC	
ANNUAL 10-YEAR 7-DAY LOW FLOW AS %MAD COMPARED TO PPT	
Fathom Scientific Ltd. — Ver 0.6 — Nov 12, 2019	**FIGURE 31**

Figure 31: Annual 10-year 7-day Low Flow as %MAD Compared to PPT



Notes:
1) This figure expresses the 10-year Annual return low flow as %MAD for the 7 regions in Ahmed's "Inventory of Streamflow in the Omineca and Northeast Regions" as a function of Slope.
2) From this figure we can see a clear positive relationship in Zone 6.

RSEA	
2019 HYDRO-STATS ANALYSIS FOR NE BC	
COMPARISON OF ANNUAL10-YEAR 7-DAY LOW FLOW AS %MAD COMPARED TO SLOPE	
Fathom Scientific Ltd. Ver 0.6 Nov 12, 2019	**FIGURE 32**

Figure 32: Annual 10-year 7-day Low Flow as %MAD Compared to Slope

Figure 33: Example of Model Robustness for Zone 7+12: S-7Q10/MAD

This figure shows an example of the model robustness test. In this case, 10 of the 15 samples are randomly chosen and the model is trained 30 times (iterations). The Adj.R2 value is using all 15/15 samples. The Avg_R2 is the average R2 of the 30 iterations using only 10 samples. The Min R2 is the minimum R2 from the 30 iterations. The SD_R2 is the standard deviation in the R2 of the 30 iterations. Higher R2 values are achievable when 3 variables are used. With 4+ variables, the model is at risk of being under-conditioned and prone to large error depending on the training set. In this case, Model 14 was chosen.

Zone 7+12

C:\gsentlin\FATHOM_SCI\CUSTOMERS\RSEA\Data\Regression\S-7Q10MAD\[Zone7+12_ARM_S-7Q10MAD_v0.4.xlsm]Regression 2019-10-21 8:39

Model#	#Variables	Intercept	DA	MedElev	Glc	Slope	SolExp	PPT	PET	R2	Adj.R2	Min_R2	Avg_R2	SD_R2	STEYX
1	1	0.11	1.92E-05							59%	56%	59%	59%	0%	9%
2	1	-0.49		5.78E-04						42%	38%	42%	42%	0%	11%
3	1	0.14			1.05E+01					60%	56%	60%	60%	0%	9%
4	1	0.01				1.43E-02				35%	30%	35%	35%	0%	11%
5	1	9.56					-1.35E+01			38%	33%	38%	38%	0%	11%
6	1	-0.10						3.18E-04		37%	32%	37%	37%	0%	11%
7	1	0.05							2.41E-04	0%	-8%	0%	0%	0%	14%
8	2	-0.40	1.63E-05	4.43E-04						82%	79%	78%	81%	1%	6%
9	2	0.09	1.42E-05		7.81E+00					88%	86%	76%	86%	3%	5%
10	2	-0.03	1.72E-05			1.14E-02				80%	77%	71%	79%	2%	6%
11	2	5.44	1.55E-05				-7.65E+00			69%	64%	63%	68%	1%	8%
12	2	-0.12	1.70E-05					2.52E-04		81%	78%	77%	80%	2%	6%
13	2	0.77	2.01E-05						-1.09E-03	61%	55%	38%	60%	5%	9%
14	3	-0.16	1.42E-05	2.22E-04	5.63E+00					92%	89%	85%	90%	2%	4%
15	3	-0.29	1.64E-05	2.91E-04		5.21E-03				84%	80%	74%	82%	2%	6%
16	3	1.28	1.55E-05	3.99E-04			-2.34E+00			83%	78%	75%	82%	2%	6%
17	3	-0.34	1.62E-05	2.80E-04				1.38E-04		86%	82%	78%	84%	2%	5%
18	3	-1.19	1.48E-05	5.22E-04					1.15E-03	84%	80%	77%	83%	2%	6%
19	4	-0.13	1.43E-05	1.71E-04	5.38E+00	2.07E-03				92%	89%	76%	89%	4%	4%
20	4	1.46	1.34E-05	1.80E-04	5.62E+00		-2.25E+00			92%	89%	76%	89%	4%	4%
21	4	-0.16	1.43E-05	1.98E-04	5.21E+00			3.41E-05		92%	89%	60%	88%	8%	4%
22	4	-0.15	1.42E-05	2.20E-04	5.65E+00				-1.86E-05	92%	88%	5%	85%	16%	4%
23	5	1.34	1.35E-05	1.48E-04	5.44E+00	1.46E-03	-2.06E+00			92%	88%	50%	89%	8%	4%
24	5	-0.13	1.43E-05	1.72E-04	5.30E+00	1.75E-03		9.48E-06		92%	88%	79%	88%	4%	4%
25	5	-0.26	1.42E-05	1.84E-04	5.16E+00	2.37E-03			1.86E-04	92%	88%	55%	83%	11%	4%
26	6	2.55	1.30E-05	1.42E-04	4.56E+00	-2.90E-03	-3.85E+00	1.13E-04		93%	88%	61%	87%	8%	4%
27	6	1.80	1.21E-05	1.94E-04	4.37E+00	2.58E-03	-3.65E+00		9.69E-04	93%	88%	29%	84%	14%	4%
28	7	2.63	1.20E-05	1.79E-04	3.92E+00	-9.97E-04	-4.69E+00	8.68E-05	7.65E-04	93%	87%	12%	79%	16%	4%

Notes

1) A limit of 3 variables is chosen for simplicity and to avoid overfitting the model

2) Solar Exposure is the average hillshade value for an azimuth of 180° (due South) and an elevation of 45° divided by the maximum possible value (usually 255).

Ver 0.4

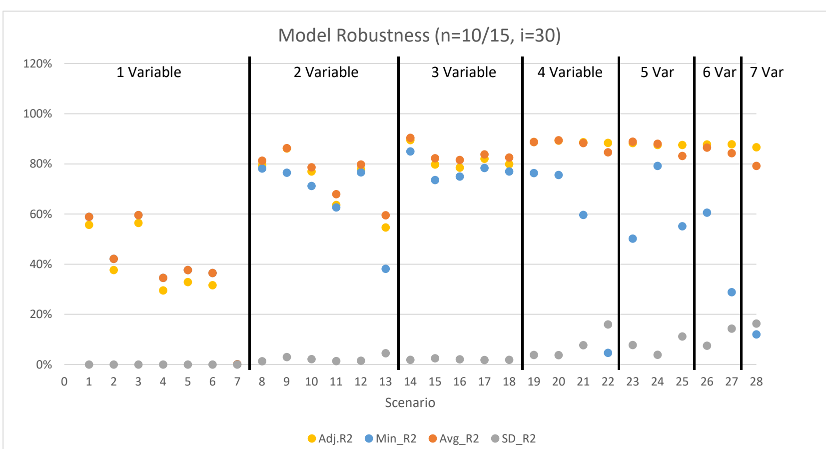


Figure 34: Example of Model Robustness for Zone 6: S-7Q10/MAD

This table shows just 1 of the 162 GMRm sensitivity analyses as an example. In this test, the 2-variable model 8 outperformed the 3+variable models due to its higher Min R^2 value.

C:\gsentlin\FATHOM_SCI\CUSTOMERS\RSEA\Data\Regression\S-7Q10MAD\[Zone7+12_ARM_S-7Q10MAD_v0.4.xlsm]Regression 2019-10-21 8:39

Model#	#Variables	Intercept	MedElev	PET	DA	PPT	Slope	SolExp	Ln(DA)	R2	Adj.R2	STEYX	Min_R2	Avg_R2	SD_R2
1	1	-0.39	5.24E-04							59%	55%	8%	59%	59%	0%
2	1	1.81		-2.82E-03						75%	73%	6%	75%	75%	0%
3	1	0.04			7.37E-06					10%	0%	11%	10%	10%	0%
4	1	-0.14				4.04E-04				5%	-5%	12%	5%	5%	0%
5	1	-0.03					2.59E-02			72%	69%	6%	72%	72%	0%
6	1	11.05						-1.56E+01		25%	16%	10%	25%	25%	0%
7	1	-0.28							4.48E-02	20%	11%	11%	20%	20%	0%
8	2	1.11	2.62E-04	-2.06E-03						85%	81%	5%	81%	84%	1%
9	2	-0.49	5.75E-04		1.06E-05					79%	74%	5%	59%	75%	6%
10	2	-0.06	8.13E-04			-1.08E-03				78%	72%	6%	66%	76%	3%
11	2	-0.12	1.14E-04				2.16E-02			73%	66%	6%	61%	69%	4%
12	2	-1.73	5.52E-04					1.87E+00		59%	49%	8%	55%	59%	1%
13	2	-0.70	5.08E-04						4.03E-02	75%	69%	6%	14%	71%	12%
14	3	0.66	3.58E-04	-1.52E-03	5.58E-06					89%	84%	4%	68%	84%	6%
15	3	0.93	3.99E-04	-1.67E-03		-3.27E-04				86%	79%	5%	75%	84%	2%
16	3	0.99	1.67E-04	-1.78E-03			6.90E-03			86%	80%	5%	72%	83%	5%
17	3	2.41	2.32E-04	-2.09E-03				-1.79E+00		85%	79%	5%	14%	78%	18%
18	3	0.65	3.02E-04	-1.68E-03					2.35E-02	89%	85%	4%	74%	86%	4%
19	4	0.39	5.42E-04	-9.74E-04	5.99E-06	-4.22E-04				90%	83%	4%	40%	84%	10%
20	4	0.46	2.43E-04	-1.09E-03	6.11E-06		9.07E-03			90%	84%	4%	24%	81%	13%
21	4	0.65	3.59E-04	-1.52E-03	5.59E-06			1.65E-02		89%	81%	4%	68%	84%	5%
22	4	0.65	3.05E-04	-1.67E-03	2.55E-07				2.26E-02	89%	82%	4%	71%	83%	5%
23	5	-0.38	5.32E-04	6.21E-04	7.63E-06	-9.62E-04	1.91E-02			95%	90%	3%	53%	88%	9%
24	5	4.46	5.67E-04	-7.36E-04	5.49E-06	-7.35E-04		-5.78E+00		91%	82%	4%	8%	82%	17%
25	5	0.41	4.77E-04	-1.16E-03	1.83E-06	-3.68E-04			1.74E-02	90%	81%	4%	4%	74%	22%
26	6	-3.85	5.10E-04	7.88E-04	8.40E-06	-8.30E-04	2.34E-02	4.69E+00		95%	88%	3%	60%	85%	9%
27	6	-0.54	6.03E-04	1.11E-03	1.25E-05	-1.12E-03	2.26E-02		-1.93E-02	95%	88%	3%	53%	82%	11%
28	7	-2.14	5.67E-04	1.02E-03	1.12E-05	-1.00E-03	2.34E-02	2.23E+00	-1.25E-02	95%	85%	3%	3%	66%	20%

Notes

1) A limit of 3 variables is chosen for simplicity and to avoid overfitting the model

2) Solar Exposure is the average hillshade value for an azimuth of 180° (due South) and an elevation of 45° divided by the maximum possible value (usually 255).

Ver 0.2

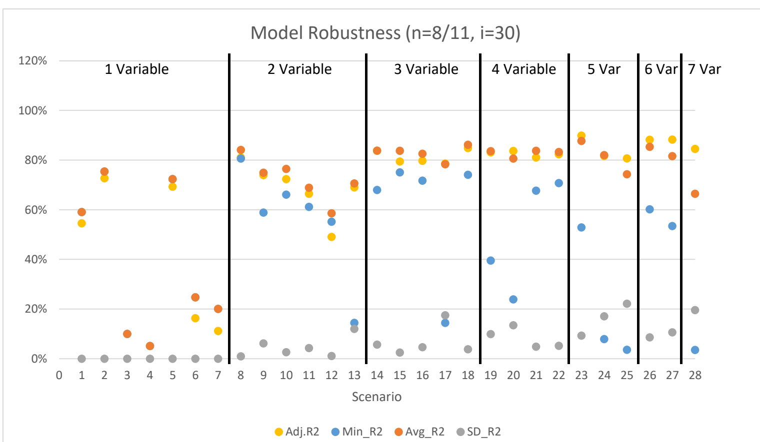


Figure 35: Diagram of Model Selection and Application for Zone 6: S-7Q10/MAD

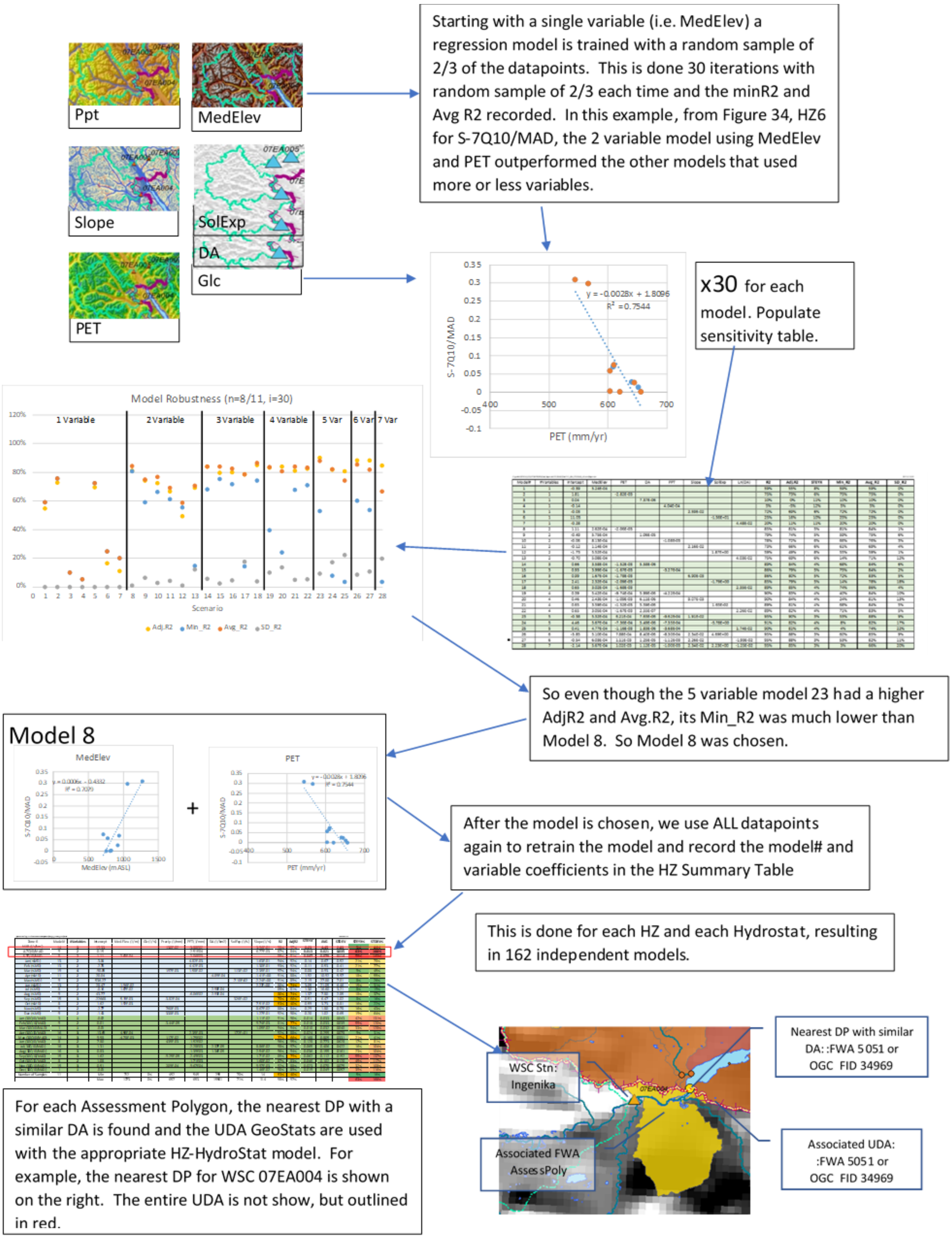
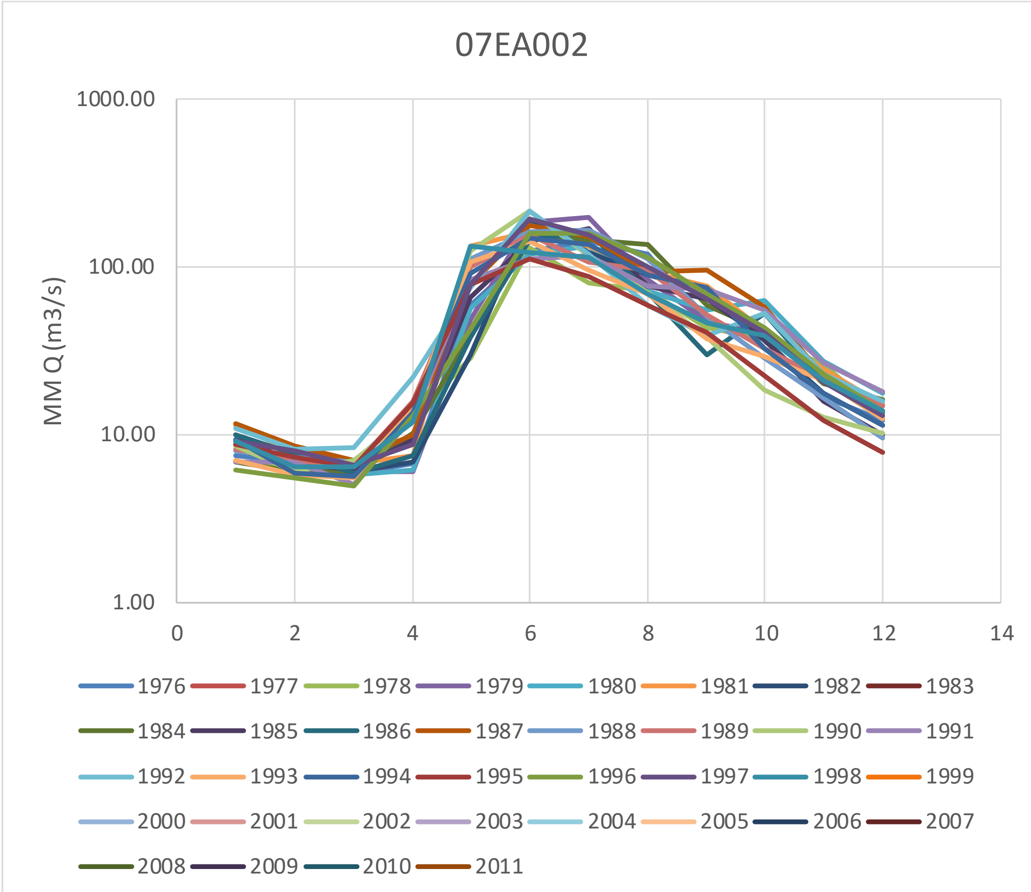


Figure 36: Comparison of KWADACHA RIVER NEAR WARE (07EA002) Mmm Q to Derived 10yr hydro-stats



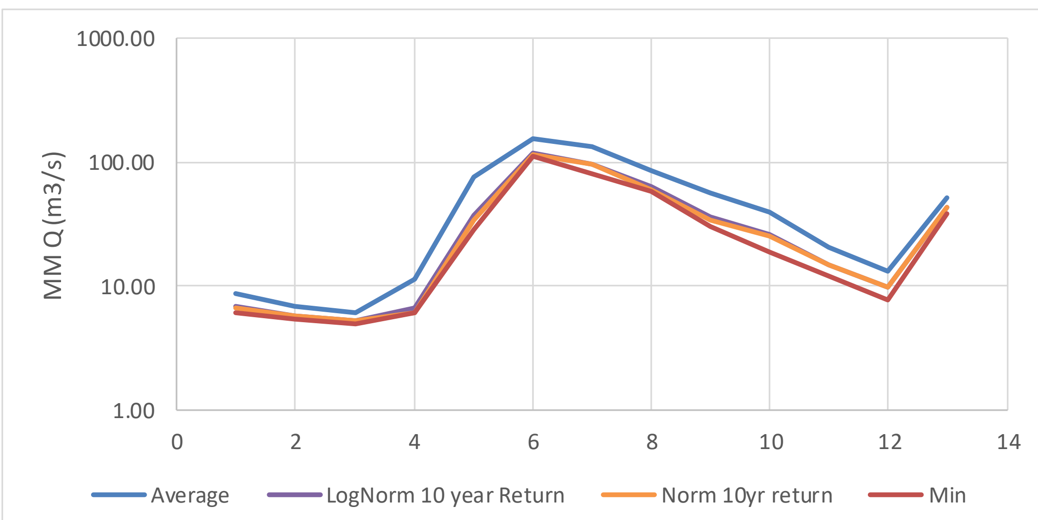
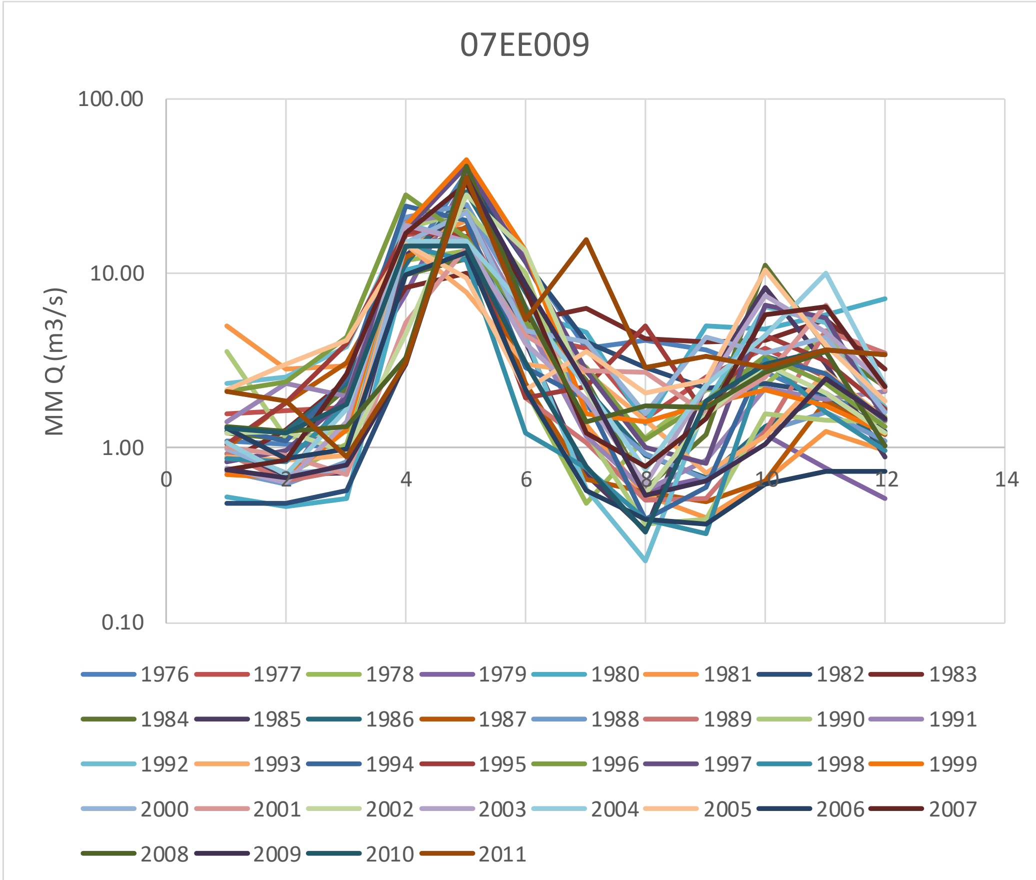


Figure 37: Comparison of CHUCHINKA CREEK NEAR THE MOUTH (07EE009) Mmm Q to Derived 10yr hydro-stats



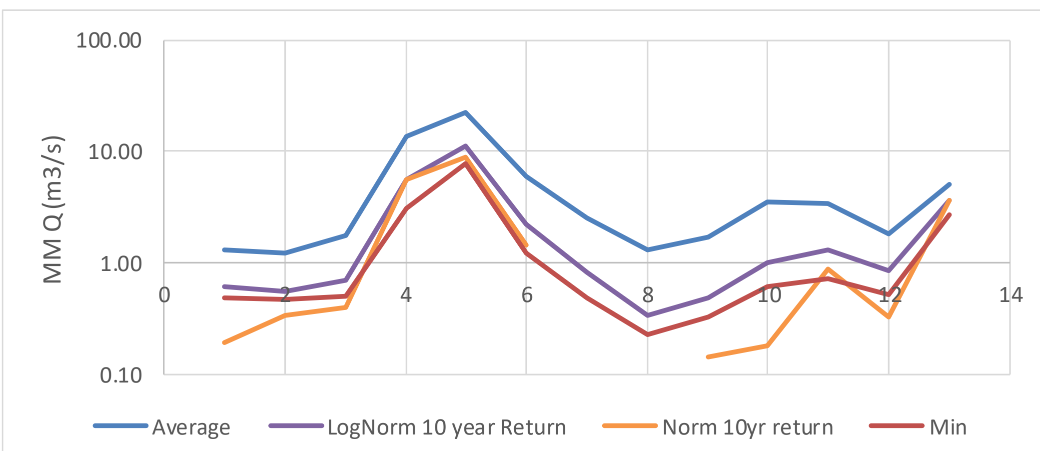
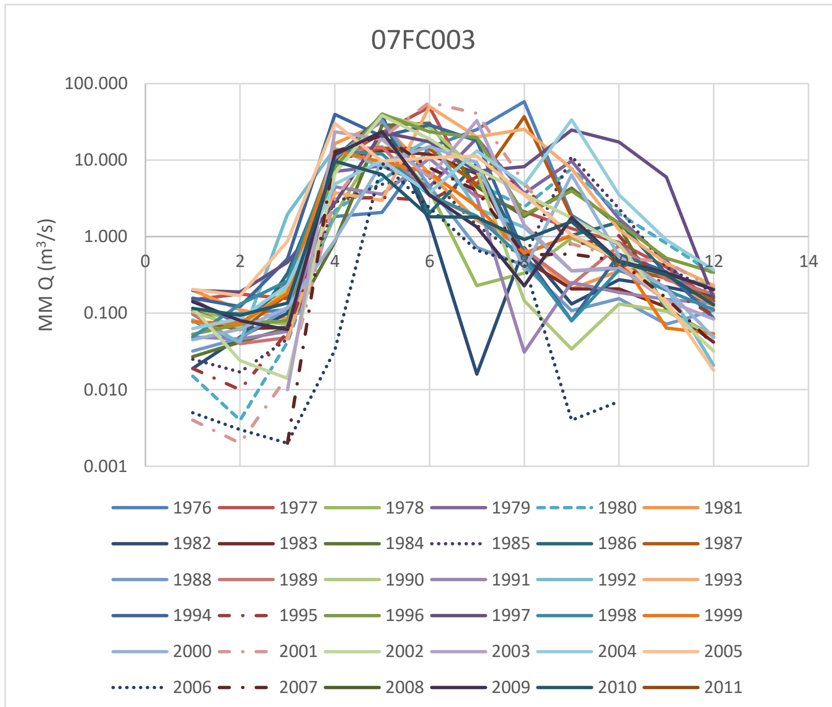


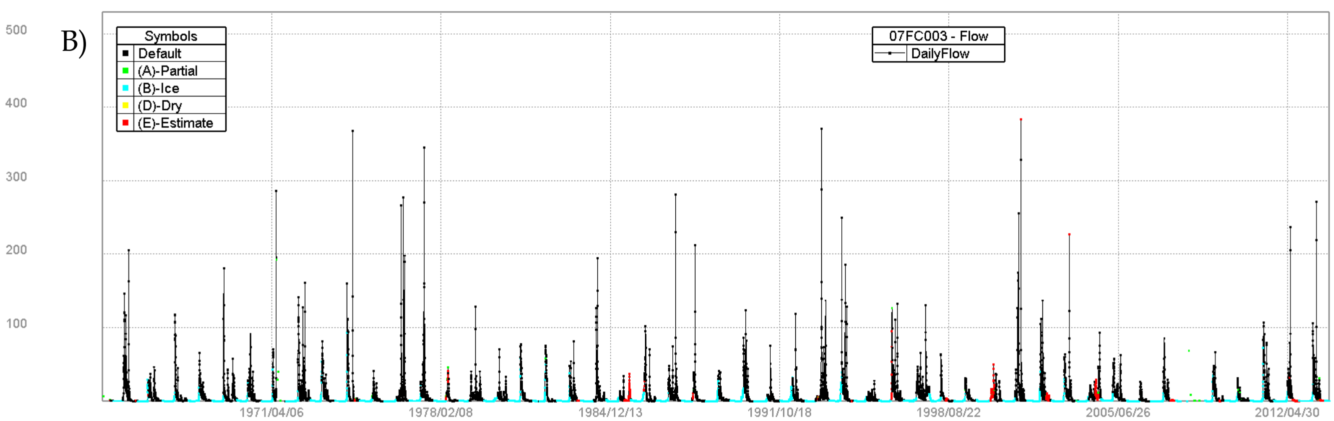
Figure 38: BLUEBERRY RIVER BELOW AITKEN CREEK (7FC003) Monthly and Daily Flows

While several years (1980, 1985, 1995, 2001, 2006, 2007) show very low monthly winter flows (A), there is nothing unusual in the daily flow series B) and C).

A)



B)



C)

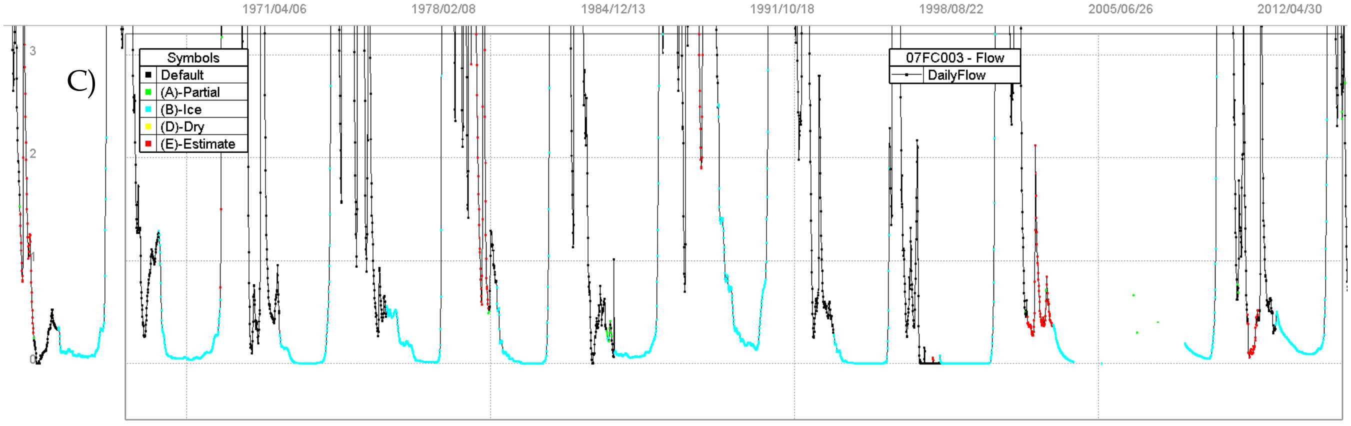


Figure 39: Diagram showing karst cross-section. Image by P. Griffiths

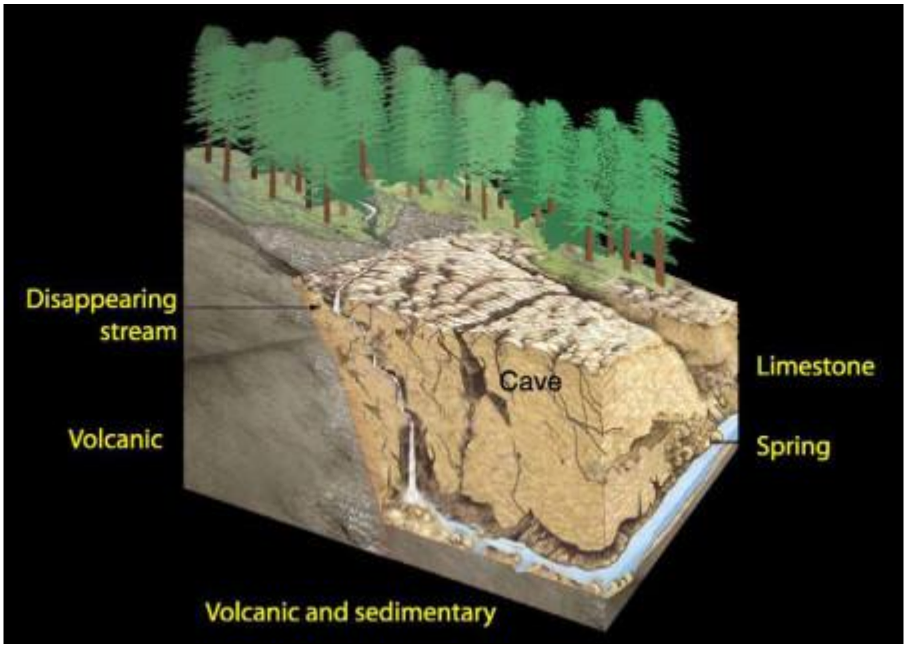
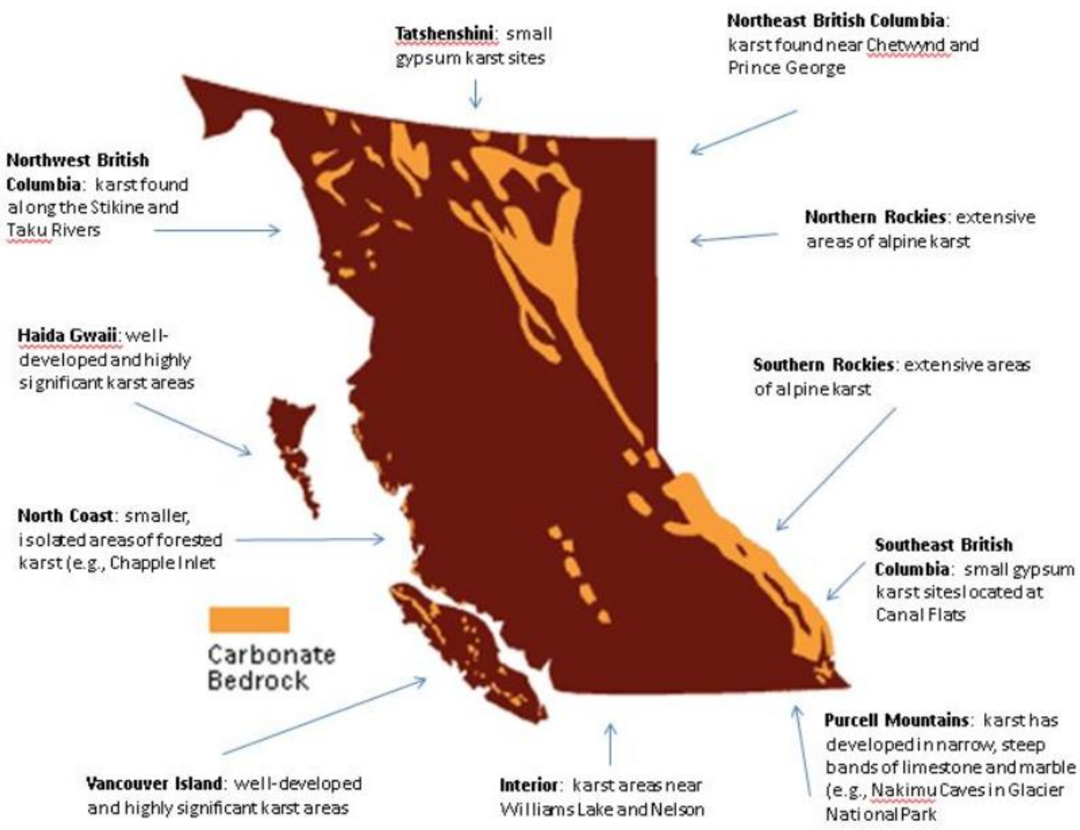


Figure 40 Location of Karst Geology in BC[24]



[24] From https://www2.gov.bc.ca/gov/content/industry/forestry/managing-our-forest-resources/managed-resource-features/best-practices-for-karst-management-training-module/understanding-karst-lesson-1-part-1

APPENDIX A: DATA TABLE AND MAPS