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Hydro-Economic Analysis of the Colorado River Basin: A Comprehensive Framework for Water Management

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Summary:

Water management concerns in the Colorado River Basin (CRB) require an integrated approach considering the interplay of physical, hydrological, and economic components affecting its performance. This paper presents a hydro-economic model of the basin that captures the spatial and temporal dynamics of the water system and incorporates basin decision-makers at various levels. The model encompasses agricultural production, urban water use, hydropower production, and environmental water use. The hydro-economic model reveals that agriculture consumes a significant amount of water in the basin, with 2.6 million acres of irrigated land across 40 irrigation districts in seven states. The agricultural sector diverts 8.9 million acre-feet of water, generating $1,773 million in net income. Furthermore, the hydro-economic model incorporates urban centers within and outside the basin that rely on the Colorado River for water supply. The model includes 379 cities with 33.4 million inhabitants, with an estimated 1.3 million acre-feet of water for domestic and non-domestic purposes. The economic benefits generated by urban water use totals $18,328 million. Irrigated cropland and urban water use of Tribal Nations are accounted for in the states where they are located. Mexico and environmental water use are included with a restriction of minimum water flow. In addition, the model includes the hydropower production capacity of the basin, which represents 95% of the installed capacity. The nine largest hydropower plants produce 10,225 gigawatt-hours annually, generating substantial economic benefits of $874 million. Notably, hydropower production reduces greenhouse gas emissions, with approximately 12,300 million pounds of carbon dioxide-equivalent emissions avoided. Finally, the hydro-economic model serves as a tool for evaluating potential policy changes in the CRB. By analyzing different policy interventions under various climate scenarios, decision-makers can gain insights into the likely economic effects of such changes. This information can aid in optimizing and contributing to sustainable decision-making in the CRB.

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Abstract
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Key Words: Agriculture, Climate change, Colorado River Basin, Hydro-economic model, Hydropower, Urban

JEL Codes: Q18, Q25, Q28, Q40, Q54, Q58

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1. Introduction

The Colorado River Basin (CRB) faces a supply crisis that makes the basin water system vulnerable to failure, economic losses, conflicts between regions and water users, and ecosystem degradation (Munia et al., 2016; Rushforth et al., 2022). The crisis results from water management that allows excessive water withdrawals, legal restrictions established on historical rights (e.g., the division of the basin), and over-allocation of decreased water supplies over time affected by climate change. The agricultural sector, urban centers, hydropower production, and aquatic ecosystems compete for the exhausted water resources in the basin. The shrinking and fluctuating water availability and growing demand for water will exacerbate the already existing problems. This array of natural and human forces combined alters the basin's future sustainability dramatically, urging policymakers and water managers to undertake immediate actions.

Designing water policies in response to the challenges facing the CRB requires information about the trade-offs that these policy interventions generate. This information helps reinforce the policy design by introducing compensation mechanisms that counteract unwanted sizeable effects. Identifying conflicts between water management objectives, which arise from interactions among elements of water systems, requires a comprehensive framework that captures the complex relationships of the water systems' elements. Hydro-economic analysis has been used as a water management tool, and it has shown the capacity to provide solutions to water problems in basins around the world.

This paper presents a novel hydro-economic model of the CRB (HEM-CRB) that analyzes the current and future conditions in the CRB. To the best of our knowledge, this is the first hydro-economic model of the CRB at a basin-wide level[1] that includes the water used for irrigation, urban centers, hydropower production, environmental flows, and Tribal water rights.[2] The HEM-CRB captures the temporal and spatial relationship between water availability and demand, and the various sectors' economic benefits resulting from water use. The level of detail in the HEM-CRB is of great usefulness. The number of irrigation districts in the model is 40, which include 39 different crops under three distinct irrigation systems with economic information on production cost, yields, and net revenues. The urban centers in

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[1] Note that in this paper we only focus on the United Sates portion of the CRB and do not include Mexico in the analysis.

[2] In this paper environmental flows, tribal water rights, and Mexico's share of the CRB enter to the model as constraints.

HEM-CRB comprises the main urban centers in the basin and the areas served by the Colorado River water outside the basin. The model's number of cities/towns is 379, with a population of 33.4 million. Irrigated cropland and urban water use of Tribal Nations are accounted for in the states where they are located. The hydropower production capacity of the nine plants included in the model is 4,200 MW with nearly 90% of the capacity installed in the basin. The model characterizes the river as having 251 nodes and 71 water inflows. The river's infrastructure includes the channels for the irrigation districts and the urban centers. Twenty-eight dams provide dynamic capacity to the HEM-CRB. Biophysical information on crop evapotranspiration and dam evaporation are included in the model. Environmental flows and Mexican water rights are included in the model as constraints of minimum quantities of water.

The HEM-CRB maximizes the private benefit and social welfare of water use, given the spatial and temporal availability of the water in the basin. Irrigated agriculture is observed at the irrigation district level. The irrigation district is assumed to be the decision-maker regarding irrigation water use. Agricultural activities maximize benefits from crop production subject to available land, water availability, and irrigation technological constraints. In the urban centers, benefits are calculated using the consumer surplus of households from water consumption and the producer surplus. The sum of both represents the social welfare of urban water use. Because of the natural monopoly characteristic of drinking water utilities, the state's Public Utilities Commission (PUC) regulates drinking water rates under the precepts of affordability and financial sustainability (Costello, 2014; GAO, 2021). The producer surplus of urban water use is expected to be zero, and the private benefit of urban water use equals the social welfare of urban water use. Hydropower electricity production benefits are calculated by multiplying electricity sold by the average price per kilowatt hour (kWh). Electricity produced depends on dam height and water flow through the facility's turbines.

Healthy ecosystems provide benefits to society via ecosystem services; however, they are complex and require biophysical information and valuation of the environmental benefits. This information is limited in the CRB, as well as in most of the other basins worldwide. Our hydro-economic model recognizes the importance of maintaining an ecologically healthy river and accounts for it by building in minimum flow requirements for these purposes. A baseline river flow is guaranteed, ensuring the river's ecosystem has enough water to support itself. This allows policymakers and stakeholder institutions to realize how each policy solution affects the river's ecological health and determines which solutions are the most effective at meeting the basin's challenges while preserving the environment. The economic value of ecosystem services arises from the shadow price of the water restriction for environmental purposes, which is a proxy in relative terms of economic activities. When the degradation of ecosystems is large, this approach underestimates the economic benefits of ecosystems. Sustainable water management involves recognizing the social benefits that ecosystems provide to society. Hydropower production also contributes to social welfare by avoiding emissions of carbon dioxide (CO_2) from alternate sources of electricity, like coal-fired power plants. Water management may incorporate the external benefits of hydropower into the decision-making process.

In an extension to this paper, the HEM-CRB will be used to assess the impact of policies, such as modifying the 1922 compact, leasing water rights allocated to the Native American tribes, and others. Water reductions due to climate change and increased water use because of population growth will also be examined to identify the performance of alternative water policies. This knowledge provides an understanding of the magnitude of growing socioeconomic and climate pressures in the basin. This is important because of the rising chorus of scientists, water managers, and policymakers who suspect the CRB is approaching a tipping point (Canon and Luscombe, 2022).

The initial phase of our model involved replicating the current conditions within the basin through a base run. The outcomes of this base run serve as the benchmark against which subsequent simulations, encompassing policy, and climate change scenarios will be evaluated. Our findings from the base run underscore a basin-wide benefit totaling $20,618 million, emanating from the agriculture, urban, and hydropower sectors.

Within the model, irrigated land spans 2.6 million acres, distributed across 40 irrigation districts spanning seven states. The model encompasses the cultivation of 39 diverse crops, classified under three distinct irrigation systems: flooding, sprinkler, and drip. Notably, the agricultural sector in the CRB emerges as a substantial water user, diverting 8.9 million acre-feet of water, leading to a net income of $1,773 million. On average, agricultural net income in the basin reaches $680 per acre, with state-specific variations ranging from $200 to $1,200 per acre. The analysis further highlights that 60% of cropland generates 90% of the net income, and 6% of high-value crops contribute to 40% of the total net income within the basin.

Furthermore, the base run showcases that a mere 10% of water usage yields 50% of the total net income, with a shadow price of $270 per acre-foot. Urban water use is estimated at 525,000 acre-feet for domestic purposes, resulting in an economic surplus of $18,328 million. Additionally, non-domestic urban water usage reaches 787,000 acre-feet, aggregating to a total urban utilization of 1.3 million acre-feet.

The hydropower segment of the model encompasses a production capacity of 4,223 megawatts (MW), representing nearly 90% of the installed capacity in the basin. The top nine hydropower plants produce 10,225 gigawatt hours (GWh) annually, yielding an annual benefit of $874 million. Remarkably, a substantial 84% of these benefits stem from the three major plants: Hoover Dam, Glen Canyon Dam, and Lake Mohave. Noteworthy is the role of hydropower in emissions reduction; the basin's hydropower production has avoided approximately 12,300 million pounds (lbs) of CO2e emissions.

The reminder sections of this paper are structured as follows: Section 2 delves into how hydro-economic modeling has been employed to address water challenges globally. In Section 3, we provide insight into the CRB's background, policies, and water management issues. Section 4 elaborates on the HEM-CRB and its constituent elements. Data assumptions and relationships are detailed in Section 5, while the calibration procedure for each model component is discussed in Section 6. Section 7 presents the outcomes of the base run across basin, state, and water use categories, alongside discrepancies with observed data. The paper concludes with policy implications and outlines forthcoming work.

2. Literature Review

The availability of water resources is highly variable, temporally and spatially. In addition, the existence of uncertainty associated with climatological variables hinders the management of water resources. However, both problems can be incorporated into hydro-economic models (HEMs). An extensive amount of literature has developed HEMs to analyze the allocation of water resources in basins worldwide.[3] Evaluation of water projects, assessment of risk from drought and climate change, and adaptation costs are addressed by HEMs (Ortiz-Partida et al., 2023). In addition, many studies have tried to analyze the impact of different economic policy measures on the management of water resources. Some studies have included simulations of crop-related elements, such as irrigation decisions by farmers or the

[3] For a complete list of these studies, see Bekchanov et al.(2017); Expósito et al. (2020); and Harou et al.(2009).

substitution of irrigation under different climatic situations (Kuhn et al., 2016; Torres et al., 2016). Other HEMs have been used to analyze the effectiveness and impact of various supply measures, such as the construction of reservoirs or canals (Bekchanov et al., 2017; Bhaduri et al., 2016). Other work has included groundwater use and the impact of aquifer extraction on basin resources (Graveline, 2016; Kahil et al., 2016; MacEwan et al., 2017; Soula et al., 2023). These models allow stakeholders to identify the strategy that optimizes the benefit of irrigation while maintaining aquifer recharge (MacEwan et al., 2017) and can even incorporate more complex management operations, such as electricity production and reservoir management in uncertain environments (Macian-Sorribes et al., 2017). On the other hand, adopting new irrigation technologies to increase crop production and reduce water use at the field level has also been addressed with HEMs (Bekchanov et al., 2016; Medellín-Azuara et al., 2012). Advanced models integrate HEMs into input-output models to identify the effects of water scarcity at regional levels (Almazán-Gómez et al., 2023).

HEMs emerge from the need for water system analysis in which social, hydrologic, and environmental processes interact, promoting the cohesion of multiple disciplines. Economic principles support decision-making in engineering, typically through optimization and simulation, providing water management with a perspective of water demand based on value and expanding the traditional perspective of water rights.

2.1. Introduction of Hydro-Economic Models

Mathematical models that reproduce the temporal and spatial interactions of water use are the basis for hydro-economic analysis. These models optimize and simulate water systems to identify trade-offs in water use by sector and location within the basin. Many water-related problems can be examined, such as economic growth, water supply, climate change adaptation and mitigation, flood control damage, and environmental flows (Ward, 2021). Enhancing water system resilience to reduce losses from water shortages involves expanding dam storage, water reuse, seawater desalination, water pricing, and water trading (Ward, 2022). Hydro-economic analysis incorporates multiple disciplines, such as biophysical processes, economic activities, or aquatic ecosystems in a framework capable of addressing the temporal and spatial dimensions of the water scarcity problem. In this regard, hydro-economic analysis can contribute to solving water scarcity problems and giving answers to water management concerns.

Hydro-economic mathematical models represent biophysical dynamics integrating social, technical, and economic constraints. Hydrological, engineering, environmental, and economic aspects are integrated into a coherent structure to represent a process at the basin level while capturing site-specific characteristics. HEMs represent the relationships between water, economic, and environmental resources. Through the hydrological component, water supply and demand interact. The representation of processes in the hydrological component includes water balance, such as flow rates, evaporation of water masses, groundwater recharge and withdrawal, and return flows (Harou et al., 2009). The economic component represents the economic activities of agricultural, urban, and industrial uses of water, as well as hydropower production.

HEMs capture the effects of interactions between the elements of the water systems, and the results show the optimal economic outcomes considering the sectoral spatial distribution of water and water use. Upstream and downstream sources and uses are connected by a hydrological network, making downstream recipients dependent on water availability and water allocation upstream. The location of water demand and supply nodes determines the impact of water allocation and water scarcity (Maneta et al., 2009).

The development of the hydrological component is complex and requires detailed hydrological and biophysical information and modeling experience. In the most straightforward way, the hydrology of a basin can be represented using historical data on water and the topology of the network (Cai et al., 2003). The basin is represented through a network of connected nodes by using simplified hydrological equations, such as water mass balance equations and regression equations (Labadie, 2004). This approach has been used in several studies, such as Booker and Young (1994), Cai et al. (2003), Connor et al. (2013) Dinar and Nigatu (2013), Gilmour et al. (2005), McKinney (1999), and Ward and Pulido-Velazquez (2008).

The economic benefits of water use in irrigation are jointly determined from positive mathematical programming models that examine the optimal behavior of irrigation demand and a set of constraints and resources. The economic benefit of urban use is estimated using econometric techniques that relate water use to price and other explanatory variables, such as income, climate, or household structure (Young and Loomis, 2014). The economic benefit of hydropower plants originates from electricity sales and depends on dam operations. Those operations are examined to fulfill multiple objectives, such as hydropower production, security of supply, and environmental flows (Hirsch et al., 2014; Rheinheimer et al., 2016).

Finally, the benefits of aquatic ecosystem services can be represented by models of ecosystem response to water allocation together with economic valuation studies of ecosystem services (Crespo et al., 2022; Keeler et al., 2012). When environmental assessment information and/or ecosystem status indicators are not available, environmental water use can be represented by minimum ecological flow constraints (Momblanch et al., 2016).

Water for irrigation, urban centers, and hydropower production has drawn the attention of hydro-economic modeling for decades. However, increasing concerns about environmental degradation have prompted the study of sustainability aspects. Currently, these models combine the hydrological, economic, and environmental features of basins to identify a wide range of interactions. HEMs simply represent the relationships between hydrological, economic, and ecological aspects of the water systems. Sources and demands of water and their connections are included in the hydrologic component. The economic component consists of the economic benefit of water use from agricultural, urban centers, and industrial sectors. Finally, the environmental component represents the services provided by aquatic ecosystems (Figure 1). HEMs consider the spatial distribution of water resources, capturing the interactions between hydrological and economic systems. The spatial location of demand nodes (irrigation districts, urban centers, or aquatic ecosystems) with respect to the availability of resources in rivers and dams determines the magnitude and impact of water distribution, especially in drought situations (Crespo et al., 2019; Maneta et al., 2009).

[INSERT FIGURE 1 HERE]

Figure 1. Modeling framework of the hydro-economic model

Representing hydrology is challenging because it requires accurate hydrological and biophysical information in combination with advanced modeling techniques. Lack of data availability and different temporal and spatial scales of the hydrological and economic model increases the complexity of modeling. The representation of the hydrology can be simulated as a network of connecting water nodes using historical data from water management institutions and data from existing models (Cai et al., 2003).

The economic component incorporates private decisions given resource restrictions. Agricultural water use maximizes the private benefit of water use, given water, land, and technical restrictions. Urban water use maximizes social welfare, and hydropower production maximizes the benefits of hydropower production and distribution.

Multiple disciplines, such as economics, biology, and engineering, participate in developing instruments to address scarcity problems. New sources of water, expansion, enhancements of infrastructure, and changes in technology are supply-side strategies analyzed by HEM.

Ecological processes and ecosystem structure and function are strongly related to flow and hydrological variations (Poff et al., 2010). Ecological responses to flow variations affect invertebrate populations, fish, and riparian vegetation, and are usually negative (Poff and Zimmerman, 2010). The functions and processes occurring in ecosystems generate services to society, and degradation of the ecological status deteriorates the provision of these services. Altering the hydrological regime sets off a chain of negative effects on the ecosystem status, which reduces its provision of services and benefits for society (Potschin-Young, 2017).

2.2. Previous Studies

HEMs have been used to analyze the sectoral allocation of water, considering water management objectives of efficiency, equity, and sustainability. The vulnerability to droughts of water systems and water scarcity are problems analyzed by HEMs (Crespo et al., 2022, 2019). HEMs usually analyze water management alternatives to provide information on water allocation trade-offs. The analysis of the water systems includes information on the suitability of the policy. Australia is an example of the effort to incorporate ecosystems and sustainability into water systems analysis, combining intuitional approach and biophysical models (Connor et al., 2013). Hydropower production and dam operations are conducted under uncertain conditions, as future water inflows are unknown. Stochastic optimization and HEMs can be combined to analyze water planning for multiple dams with multiple purposes (Goor et al., 2011).

The CRB has seen several models of water management. The United States Bureau of Reclamation (USBR) is the institution in charge of water management in the CRB. USBR developed two systems to support the decisions in the CRB: the Colorado River Mid-term Modeling System (CRMMS) and the Colorado River Simulation System (CRSS). CRMMS and CRSS are basin-wide models that combine water inflows and water demands in a distribution network. Scenarios of water inflows rely on climatic predictions and account for different levels of risk and uncertainty. These models support simulations for annual, mid-term, and long-term horizons, providing information for temporal and structural water planning. USBR uses the results to develop its planning in the basin, as in the Annual Operation Plan (USBR, 2022). Systems to support the decision have also been developed at the state level. For example, the Colorado Water Conservation Board has the state of Colorado's daily surface water allocation and accounting model [StateMod] (Colorado Water Conservation Board, 2012). This model analyzes the demand and supply, routing the water in a network, much like CRMSS and CRSS models. However, one distinction of StateMod is its ability to simulate scenarios on daily steps. Therefore, the output of StateMod had been used as input in an environmental model for ecological assessment (Poff et al., 2012).

Early hydro-economic analysis conducted in the CRB analyzes benefits from salinity abatement. The number of regions, water users, and complexity increased with time. For example, the first analysis of salinity was conducted by Gardner and Young (1985). That includes the agricultural and urban use of water and combining two hydrological regions to evaluate 25 projects of salinity reduction. A posterior study conducted by Lee et al. (1993) also analyzed salinity problems, adding stochasticity to the model. This model has a more complex hydrological network using CRSS outputs; the model also includes five regions. The economic value of alternative uses of water also has been studied in the CRB by hydro-economic modeling. Using a basin-wide model, Brown et al. (1990) analyzed the marginal value of increasing flow in the river for timber production. The model accounts for alternative uses of water in urban centers, irrigation, and hydropower production. Water markets and the economic impact of droughts have been examined in the CRB (Booker, 1995; Booker and Young, 1994). The analysis conducted by Booker and Young (1994) includes a network of 20 nodes, with the demand for water for agriculture, urban, thermal energy, and hydropower production. The model evaluates intrastate and interstate water markets.

The same model was used by Booker (1995) to assess the impact of drought in the basin under different alternative policies. Hydro-economic analyses of the CRB have addressed environmental concerns. Medellín-Azuara et al. (2007) developed an HEM of the CRB that includes Mexican agricultural and urban water uses and the Delta of the Colorado River. This HEM adapts the CALVIN model developed at the University of California, Davis (Jenkins et al., 2004) to the Mexican portion of the CRB. The contribution to the regional economy of water from CRB has been accounted with an input-output perspective, showing the sectoral impacts of water reduction from the CRB (James et al., 2014).

These previous analyses of the CRB are limited to a few sectors and need to address a basin-wide perspective, underrepresenting the interactions between regions and sectors. Long-term solutions require cooperation among regions and water users (E. R. A. Economics, 2022). Coalitions and mechanisms of compensation root cooperation between regions and sectors. HEM-CRB can analyze cooperation in a compressive way, since it is the first model that incorporates agricultural, urban, and hydropower production in a comprehensive way, which allows for the evaluation of responses to the basin's challenges. CRB is facing a number of challenges, including climate change, growing water demand, and conflict among multiple water users. These challenges are making it difficult to ensure that rural agriculture, native ecosystems, and ever-growing municipal and industrial water users can continue to coexist in the basin. Competing interests, diverse perspectives, and complicated stakeholder interactions make it challenging to develop informed and effective policy actions. This is especially true when different changes are happening in the same landscape. As a result, more reflective research modeling is required for evidence-based policies. The HEM-CRB can provide information about the concerns in the CRB.

3. Colorado River Basin Background

In the following subsections, we provide an overview of the available water resources in the basin, their present allocation rules, and the projections of water demand and water supply in the basin for 2050. This section demonstrates the important challenges the CRB faces.

3.1. The CRB Region and Water Resources

The CRB spans over 637,000 square kilometers in the United States and Mexico. It provides drinking water to 40 million people in Arizona, California, Nevada (Lower Basin), Colorado, New Mexico, Utah, Wyoming (Upper Basin), and in Mexico. Water withdrawals for agriculture irrigate nearly 5 million acres[4] and maintain livestock in the basin, which accounts for 15% of crop production and 13% of the livestock in the United States (CRS, 2023). The hydropower capacity in CRB is 4,600 MW, contributing cheap and low-emission energy to the grid. The aquatic ecosystems that depend on the CRB water provide recreational and environmental services to society. Figure 2 shows the main river stems and lakes of the CRB, the Upper and Lower Basins, the states in the basin, the main cities served by the Colorado water, the main hydropower facilities, and the irrigated area.

[4] Water withdrawal includes inter-basin transfers.

[INSERT FIGURE 2 HERE]

Figure 2. Colorado River Basin, water users, and administrative division

Between 1906 and 2007, natural flows in the CRB, estimated at Lees Ferry in Arizona, averaged 15 million acre-feet (maf) per year. Approximately 90% of water inflows in the system come from snowmelt and rainfall in three of the upper basin states: Colorado, Utah, and Wyoming (Jacobs et al., 2011). The Rocky Mountains region contributes around three-quarters of the total water, mainly from May through October (McCabe and Wolock, 2020). Groundwater plays an important role because around half of the total streamflow in the Upper Colorado River is provided from groundwater discharge to the streams (Rumsey et al., 2015).

The US Bureau of Reclamation (USBR) reports that the 21st-century average flow of the Colorado River (12.4 maf) is already about 18% lower than the 20th-century average (15.2 maf) [Figure 3]. The annual mean discharge has been decreasing by 9.3% per degree Celsius due to increased evaporation, mainly driven by snow loss. The snow water equivalent (SWE) in the CRB is peaking 2–3 weeks earlier than in the 1970s, and changes in snowfall and dust deposition during 1993–2014 have accelerated snowmelt timing by 7–18 days (Clow et al., 2016). Additionally, snowpack water losses due to sublimation are estimated at 2% to 30% of annual SWE, depending on geographic and atmospheric conditions (Sexstone et al., 2016, 2018). With climate change, reductions in rainfall and snowpack, and increments of evapotranspiration are the dominant drivers of streamflow reductions (Whitney et al., 2023). The sensitivity of flow to variations in precipitation, measured as the percentage variation of water flow when precipitation ranges between 2% and 3%, a variation of 1% (Udall and Overpeck, 2017).

[INSERT FIGURE 3 HERE]

Figure 3. Natural flow (1906–2021) in the Colorado River above All American Canal (USBR, 2023)

Aridification is spreading in the west, and more extreme and severe drought events are becoming the new normal conditions (Udall and Overpeck, 2017; Williams et al., 2022). Projections of climate change in the CRB indicate raising temperatures between 1 and 4 degrees Celsius (Lukas and Payton, 2020) that will result in streamflow reductions between 6% and 31% (Woodhouse et al., 2021). Climate change will increase the intensity and duration of droughts. In some locations of the basin, duration of droughts will persist at 5 to 20 times more than historical records (Bedri and Piechota, 2022).

3.2. The Law of the River

The Colorado River is governed by a complex series of compacts, laws, treaties, court decisions, and agreements (collectively known as the Law of the River) that regulate the use and management of the Colorado River among the seven basin states, Native American tribes, and Mexico. The Law of the River is lengthy and complex, and a complete discussion here would not be relevant. Instead, this subsection aims to highlight some of the most important elements of the Law of the River. For an exhaustive discussion of the topic, see Verburg (2011).

The cornerstone of the Law of the River is the Compact of 1922 (the Compact), which divided the CRB into the Upper and Lower sub-basins and equally allocated 7.5 maf per year to the Upper Basin and the Lower Basin states. However, this equal allocation provision must be taken in context with Article III(d) of the Compact, which states that the Upper Basin states shall "not cause the flow of the river at Lees Ferry to be depleted below an aggregate of 75 maf for any period of ten consecutive years" (USBR, 1922). Article III(d) effectively guarantees the Lower Basin states an average of 7.5 maf per year. But Article III(d) somewhat undercuts the Upper Basin's stated right to 7.5 maf per year. Since the Upper Basin is charged with not "causing to be depleted" a set amount of water, an ambiguous term that has thus far been largely interpreted to mean that the Upper Basin is required to deliver at least 7.5 maf of water on average each year to the Lower Basin, the Upper Basin has in practice only been allowed to use the water that remains after the Article III(d) delivery has been met (USBR, 2007a).

This allocation scheme effectively forces the Upper Basin to absorb the majority of the impacts of climate change, which some have said runs counter to the Compact's original goal of equally dividing the waters of the Colorado between the two sub-basins. Given this, there have been calls to develop a new interpretation of Article III(d). Yet, to date, no consensus has been reached on how Article III(d) should be interpreted to address climate change.

In addition, and as an incentive to join the Compact, Lower Basin states (Arizona, Nevada, and California) were given the right to increase their annual apportionment by one maf in case of surplus conditions.

When the Compact was negotiated and signed in 1922, the United States had yet to develop formal agreements with Mexico about how Colorado River water would be shared among the two nations. However, anticipating that some such agreement may arise in the future, the architects of the 1922 Compact included a provision [Article III(c)] which stated that Mexico's share should first be satisfied through excess flow, and that if no such excess existed then the deficiency burden would be equally divided between the Upper and Lower Basins (USBR, 1922). In 1944, this Compact provision was put to use when the United States and Mexico entered into a treaty to allocate Mexico 1.5 maf of water per year (USBR, 1945). It should be noted that Article III(c) is the source of some controversy, as Upper and Lower Basin states tend to disagree over what constitutes "surplus" (Getches, 1985) Therefore, it is not clear exactly how much water each basin is required to deliver in order to fulfill the 1944 treaty, although some theories have been put forward (Kuhn and Fleck, 2019).

By 1948, the Upper Basin states entered into the Upper Colorado River Basin Compact—an agreement assigning percentage shares to the Upper Basin states (51.75% Colorado, 23% Utah, 14% Wyoming, and 11.25% New Mexico) of the 7.5 maf apportionment to the Upper Basin, rather than fixed amounts to each state (Gelt, 1997). This approach addressed the uncertainty around the water available to the Upper Basin after complying with the Compact's Article III(d) requirement to deliver the Lower Basin 7.5 maf per year (meaning that Lower Basin allocation and Mexico have priority).

Lower Basin states, on the other hand, needed help reaching an agreement on how to divide their allocated 7.5 maf of water. After years of failed negotiations, the United States Congress stepped in to incentivize the Lower Basin states to reach an agreement. The Boulder Canyon Project Act of 1928 authorized and funded the construction of Hoover Dam and the All-American Canal contingent on the Lower Basin states, reaching an agreement on how to divide their share of the Colorado River's water (Enrolled Acts and Resolutions of Congress et al., 1928). Yet, disagreement over how to divide the water continued until the United States Supreme Court ruled in the 1963 case *Arizona v. California*, which finally allocated 4.4 maf to California, 2.8 maf to Arizona, and 0.3 maf to Nevada (United States Supreme Court, 1964).[5] The Supreme Court also ruled that the Lower Basin states have exclusive control over tributaries to the Colorado River in the Lower Basin (rivers like the Little Colorado, Virgin, and Gila) and that any water taken from these rivers did not count towards the state's allotment described above. This means that Lower Basin states are effectively entitled to use 7.5 maf of water each year from the Colorado River proper, plus

[5] *Arizona v. California* is used as shorthand to refer to a series of cases that have appeared before the Supreme Court between 1931 and 2000.

any water in the tributary rivers to the Colorado River. This is different from the Upper Basin states, whose tributary rivers are counted as part of their total 7.5 maf allotment.

Despite years of negotiation and litigation, the Lower Basin states have thus far failed to find an acceptable means of accounting for water lost to seepage and evaporation, which can exceed 1.5 maf per year (Earp and Moreo, 2021). In the Upper Basin, water lost to seepage and evaporation is automatically included in water use figures and “deducted” from the water available to any given Upper Basin state. The Lower Basin has no such scheme for dealing with system losses, creating a problem known as the “structural deficit.” The structural deficit has created numerous problems for the CRB, including contributing to rapid water level decline in Colorado River’s two main reservoirs—Lake Mead and Lake Powell.

Up until 1990, most of the states did not use their full allocations. Even so, hydrologic data indicates the implicit water scarcity built into the Compact due to overestimating the river’s annual average flow when the agreement was signed, which was rarely realized later (USBR, 2023a), and the fixed allocations.

This problem became even more apparent in the early 21st century when a climate change-fueled megadrought began gripping the basin. Rapidly declining water flows and reservoir levels have led the basin states and Mexico to adopt a number of short-term agreements designed to buoy reservoir levels.

The first of these short-term agreements was the 2007 Interim Guidelines, which were put in place following a series of particularly low water years in the early 2000s. The guidelines sought to create new operating plans for Lake Powell and Lake Mead to better manage the reservoirs in times of water scarcity. The 2007 Interim Guidelines set out many provisions, most consequential of which was a scheme that required the Lower Basin states to reduce their water use by set amounts whenever water levels in Lake Mead fell to certain thresholds (USBR, 2007b). The Guidelines were intended to last until December 31, 2025, when new operating decisions would be made.

However, by the late 2010s, it became clear that the 2007 Interim Guidelines needed to go farther to address the ever-worsening hydrologic conditions in the CRB. New measures were needed to ensure the CRB would make it to 2026 (when new guidelines would be created) without either Lake Powell or Lake Mead falling to catastrophically low levels. The result of the ensuing negotiation process was the Drought Contingency Plan (DCP), which was enacted in 2019 (USBR, 2019). The DCP mostly served to bolster the 2007 Interim

Guidelines' framework for water cuts at Lake Mead, adding additional water reduction volumes to each tier of cuts. However, the DCP also authorized additional actions, such as releasing emergency quantities of water from upstream reservoirs (namely Flaming Gorge), and reducing downstream deliveries from Lake Powell. These additional authorized actions were not used until 2021 and 2022, when the CRB once again faced a series of especially low runoff years.

Despite the DCP, the CRB once again found itself facing a water supply crisis. In June of 2022, the Commissioner of the Bureau of Reclamation told a Congressional committee that the Colorado River Basin states needed to cut between 0.2 maf and 0.4 maf of water to maintain stable reservoir levels until 2026, when the 2007 Interim Guidelines would expire and be replaced by new operating criteria (Touton, 2022). The testimony sparked a new round of negotiations among the basin states, with the original goal of producing a plan for the additional cuts by August of 2022. However, the basin states failed to reach an agreement by August, prompting the federal government to initiate a formal National Environmental Policy Act process to develop a supplement to the 2007 Interim Guidelines that would force unilateral cuts on the basin states. Facing this pressure, the basin states eventually came to a tentative agreement to cut 0.3 maf of water by 2026, although the specifics of who would cut how much water has not yet been determined (Colorado River Basin States Representatives of Arizona, California, Colorado, Nevada, New Mexico, Utah, and Wyoming, 2023). The Bureau of Reclamation is currently reworking the supplement to the 2007 Interim Guidelines to include the basin states' new proposal, and a final plan is anticipated by the end of 2023.

The Bureau of Reclamation also has begun the process of developing new guidelines that will replace the 2007 Interim Guidelines, which are set to expire in 2026 (USBR, 2023b). This process to develop new post-2026 guidelines is occurring simultaneously with the above-mentioned process to develop a supplement to the 2007 Interim Guidelines to ensure the CRB makes it to 2026 without reservoirs dropping to catastrophically low levels. Progress on the development of new, post-2026 guidelines is in the early stages and has thus far mostly involved gathering big-picture ideas from stakeholders.

The HEM-CRB can provide information on the impact of changing the Compact. Possible changes to the Compact could include reductions in the fixed allocation quantities, or converting the fixed allocations to relative allocations, depending on the water available in the river. The model can analyze alternative water management regimes that may contribute to reducing conflicts between regions, including Mexico, and improve water use efficiency.

The analysis of water markets among the regions/states and water users allows for identifying potential benefits of such institutions.

3.3. Tribal Nations' Water Rights and Environmental Flows

The negotiators of the Compact mainly overlooked environment and tribal water rights. In 1992, 10 federally recognized tribes with reserved water rights in the CRB formed The Colorado River Basin Tribes Partnership, also known as the Ten Tribes Partnership (Partnership), to advocate for and reserve the tribal water rights. The Partnership has reserved water rights to divert nearly two maf of water per year from the CRB and its tributaries with an additional 0.8 maf of unresolved claims. Additionally, 19 other tribes have CRB rights but are not part of the Partnership. Depletion rights[6] (also termed consumptive use) for each tribe are more restrictive than diversion rights (Table 1).

[INSERT TABLE 1 HERE]

Table 1. Federal Indian tribe reserved water rights, unresolved claims, and depletion

Managing environmental water flows to maintain rivers' health is an instrument that has been integrated into water management since environmental degradation is increasingly growing. The Colorado Stream Simulation model, developed by the Colorado Water Conservation Board, has determined environmental flows in the CRB. The environmental water requirements for the CRB are estimated a 27% of the long-term mean annual runoff (Smakhtin et al., 2004). The environmental water flows in the CRB are clearly insufficient, since water allocated to Mexico is around 10% of the natural resources. Water quality is a concern in the basin, and several projects have been implemented to reduce the concentration of salt in the water (Young and Loomis, 2014). For example, the model study of the US Geological Survey's "Enhanced and Updated Spatially Referenced Statistical Assessment of Dissolved-Solids Load Sources and Transport in Streams of the Upper Colorado River Basin" is a powerful tool to assess water quality problems (Miller et al., 2017).

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[6] Note that diversion is defined as "the removal of water from its natural course or location by means of ditches, headgates, reservoirs, pipeline, conduit, well, pump or other structure or device." Not all water is physically consumed when it is diverted. A depletion is defined as "the amount of water lost to a river system or aquifer when water is diverted from it." We will use "**Depletion**" and "**Consumptive Use.**" Consumptive use is the amount of water that does not return to its source after being diverted and put to beneficial use. Return flow, which is available for other downstream water users, is the unconsumed water that returns to a water supply through a municipal or industrial wastewater system or an irrigation system.

Alterations of the hydrological regime led to the degradation of aquatic ecosystems. The hydrological alterations are water withdrawals for irrigation, urban and industrial use, the construction of levees to control flooding, and the construction of dams and reservoirs (Poff and Zimmerman, 2010). Withdrawals reduce water available in basins, levees change the morphology of the river channel changing water speed and depth, and reservoir management causes flow changes over time, modifying the seasonality of the hydrological cycle and flooding intensity and frequency.

Several studies analyze ecosystem concerns in the CRB and shed light on the causes of ecological degradation in the basin (Sanderson et al., 2012; Sankey et al., 2015). Agricultural water withdrawal has an important impact on the degradation of the ecosystems in the basin (Richter et al., 2020)

3.4. Water Allocations

Total water use in the CRB includes withdrawals for public supply, domestic, commercial self-supply, industrial, mining, livestock, aquaculture, irrigation, thermoelectric power, and flows through hydroelectric powerplants and wastewater returns from publicly owned treatment plants and industrial facilities (Maupin et al., 2018). Per the U.S. Geological Survey (USGS) definition, water use includes the movement or disposition of water via withdrawals, deliveries, consumptive use, reclaimed wastewater, instream use (hydroelectric), and wastewater returns (Maupin et al., 2018).

Agriculture is currently the dominant water user in the Southwest, followed by municipal and industrial uses (Table 2). Despite the reduction in use per capita, population growth pushes the water demand in urban centers (Figure 4). The CRB water demand scenario by 2060 indicates an increase in water use in all sectors, except for agriculture. Water usage is expected to increase by 2060 from 1 maf to 3 maf in the extreme scenarios. Population growth is the main driver of water demand increase, with the current water consumption growing from 1 maf to 2.5 maf (USBR, 2012), which is around 82% of the 3 maf (in 2060). The urbanization and the development of large municipalities in the West have pressured decision-makers to divert water from farms to cities and industries. For instance, Southern California supplies more than 10% of its urban water use through long-term lease agreements with farmers (Hanak et al., 2018).

[INSERT TABLE 2 HERE]

Table 2. Total withdrawals for selected water-use—Colorado River Basin States, 2015

The gap between Colorado River flow and water use in the basin states has widened since the mid-1980s. Lake Powell, situated in the Upper Basin, and Lake Mead in the Lower Basin—the two major operational reservoirs on which water users and managers had relied to mitigate the basin's water supply-demand deficit in the past decades—are depleting (Stern and Sheikh, 2023). The water-sharing arrangements among states cause overallocation, since the legal water rights for consumptive use exceed the actual water flowing in the river during most of the period following the 1922 Compact. That gap is widening each year with prolonged incidents of severe climate change-induced droughts in the basin.

[INSERT FIGURE 4 HERE]

Figure 4. Water withdraws by sector between 1985 and 2015 (USGS 2018)

3.5. Policy and Water Management

In a 2012 study on water supply and demand projections in the CRB, the Bureau of Reclamation concluded that the foreseeable significant imbalances in the future could not be addressed without preparing for considerable conservation in agriculture, mining (not included in the HEM-CRB), and industrial sectors, energy water use efficiency, weather modification, water banking, and water importation from other basins (USBR, 2012).

However, the optimal adaptive policy (or combination of policies) for stakeholders depends not only on the total available water but also on the economic value and social cost of different water uses in the basin, as well as understanding policy barriers to embracing new Colorado River water delivery-management scenarios.

The second caveat to the current water-sharing framework in the CRB is the lack of efficient and comprehensive markets to trade water (sale or lease of water rights) between states and among stakeholders within each state. Except for occasional water rights transfer, a transparent mechanism that allows for regular water rights transactions is nonexistent, introducing inefficiency to present water use in the basin.

The issues discussed so far have significant long-term consequences on the CRB's future. The crucial issue is how to efficiently allocate extremely scarce (and growing in scarcity due to climate change) water to competing water needs (for instance, farming vs. urban and industrial) while satisfying all the CRB stakeholders and the environment. From an economic standpoint, efficient allocation would prioritize the activities that produce the highest value while maximizing stakeholders' collective benefits. The federal government manages all water delivery at Lake Powell and below Hoover Dam located on Lake Mead. These reservoirs' status is closely monitored as an indicator of basin storage conditions that have worsened in recent years. Climate change has reduced the river's average annual flow.

Recent empirical studies on other river basins with similar water scarcity issues (Baccour et al., 2021; Crespo et al., 2022, 2019) have developed a methodology to model interactions in a river basin by including a hydrological component, a regional economic optimization component, a political component, and an environmental component. When applied to arid and semiarid basins, hydro-economic models can analyze the effects of droughts on economic sectors and the environment and assess alternative adaptation policies.

3.5.1. Tradeoffs of water management alternatives

Water management in the basin relies on an evaluation of tradeoffs produced by water allocations, which is fundamental to designing policies that conciliate efficiency, sustainability, and equity objectives. Water market, changes in the law of the river, and adaption strategies are potential solutions that could alleviate pressure in the basin.

Water management accounts have been established with supply-side and demand-side policies to address water management objectives. Water storage, water treatment, new sources of water, improvements in water conveyance, and reuse and recycling are supply-side water policies aimed at increasing water supply. Water price, water conservation, water markets, and command and control measures are demand-side policies that promote the adjustment of water extraction. Nevertheless, water policies can have unintended consequences, generate winners and losers, and undermine alternative goals of water management.

Water law is the fundamental framework that capacitates water management to approach the gap between water availability and demand. However, good water law needs flexibility to respond to societal changes, such as technological and social preferences (Ward, 2007). In the CRB, the lack of flexibility and legal constraints intensify the exposition of climate-induced risks in the states of the Upper Basin (Grafton et al., 2019).

Laws have evolved to face water management challenges. One modification of the water law is to allow tribes to lease their senior water rights to other users, alleviating water scarcity. In fact, Colorado River Indian Tribes Water Resilience Act of 2022 authorizes to some tribes leasing, exchange agreements, storage agreements and agreements for water conservation, with the authorization of the Secretary (117th Congress Public Law 343, 2023). A potential modification is to increase environmental flows in the river to protect aquatic ecosystems. These changes act in opposite ways; one contributes to increased water use by economic activities, reducing water for the environment; the other contributes to the protection of ecosystems but reduces water availability for agriculture, urban, and industry.

Reservoirs balance water availability and demand in time but have an important environmental impact. In the CRB, reservoirs are necessary for irrigation since water demand exceeds natural resources in summer (Haddeland et al., 2006). However, the storage capacity in CRB appears to be sufficient since it is four times the average annual water inflow; moreover, the remaining water, after meeting demand, can barely fill the entire storage capacity. Water use from 1990 to 2022 has exceeded water inflows most of the year, depleting the storage in the reservoirs.

Water desalination plays an important role in securing water for crowded urban areas of Southern California served by CRB. Nevertheless, expanding water availability through desalination is costly, energy-intensive, damaging to the environment (Elsaid et al., 2020), and impracticable in some regions. For example, desalinated water from the Sea of Cortez to Arizona is estimated to be around 10 times more costly than water from the CRB (Minute 323 Desalination Work Group, 2020). Indicating that alternative sources of water, rather than desalination, may be more efficient. Additionally, higher water prices for desalinated water erode water affordability and deepen inequality in the urban centers.

Wastewater reuse or water recycling is a key instrument of adaptation in many places (Tortajada and van Rensburg, 2020). Water reuse provides independence of the hydrological cycle and contributes to mitigating water scarcity worldwide, including the CRB; contrarily, water reuse faces many social, economic, and technical barriers, such as negative public perception, high cost, and challenges of producing potable water (Lee and Jepson, 2020).

Water pricing seeks to increase the efficiency of water use, and its performance depends on the physical, institutional, and cultural characteristics of the water economy (Dinar, 2000). During the beginning of the century, water pricing and water conservation have contributed to reducing per-capita water urban use in most populated areas of the CRB, decupling the water use and growing population (Richter et al., 2020). Despite improvements in water use efficiency, it is expected that population growth will drive the expansion of water demand in the southern and western areas of the U.S (Warziniack et al., 2022).

In the western U.S., water markets have contributed to mitigating water scarcity, becoming an important mechanism for water allocation (Schwabe et al., 2020). However, water markets are accompanied by third-party effects and externalities that complicate their implementation (Hanak, 2003). In addition, high transaction costs are an obstacle to the expansion of water markets, and legal reforms could be tackled to reduce the transaction costs in some regions (Womble and Hanemann, 2020). Water markets can only function if there are existing water rights systems in which reallocations are allowed through separate ownership of land and water, relaxed enforcement of "*use it or lose it,*" a well-defined market, the ability to monitor and enforce water rights, and a clear definition of total extractions and transaction rules (Endo et al., 2018). Water laws and rules in the CRB limit water market implementation.

Water trade and markets between states and among sectors in each state are free-market solutions that could avoid low-value uses of water. However, there is room for speculative behavior of profit-maximizing investment firms that collect water rights in arid areas, which could exacerbate price spikes during extreme shortages. Water management could provide the "social planner" solution, in which the social is maximized. That implies that private benefits, given by the economic activities in the basin, and the public benefit provided by ecosystems are maximized.

Many efforts to transfer water rights take place to guarantee a steady supply of water to urban consumers. The target industry is often agriculture through demand management programs. Payments for agricultural water conservation and efficiency projects by downstream states to upstream states can contribute to guaranteeing water supply in the urban centers. Sub-basin agreements (mainly between Upper and Lower Basin states), by which Lower Basin states pay for efficiency improvement projects (usually in irrigated agriculture) in exchange for water saved, can contribute to mitigating water scarcity for irrigated agriculture of the Upper Basin and urban centers of the Lower Basin. These inter-basin arrangements have been contemplated in the past in different contexts in the Colorado River Basin and internationally.

Identifying tradeoffs and effects of water policy implementation in water systems requires a multidisciplinary approach. Water systems are networks of hydrological, environmental, and human processes that involve water resources. Water resources system analysis uses mathematical models to understand water systems and support water management decisions with information (Brown et al., 2015). The interdisciplinary nature of water resource analysis requires the use of models from different fields to identify the interaction between the components of the water systems.

Comprehensive identification and evaluation of the trade-offs from water management alternatives underpin the design of resilient and reliable water systems. This requires a framework that integrates water users, policymakers, water institutions, and physical infrastructure that captures the interactions among agents. This framework is missing in the CRB, and the existing models and studies of the CRB address water management and policy evaluation from different perspectives. Some models focus on hydrologic aspects, balancing water supply and water demand, while other models attend to economic and environmental aspects. In this respect, hydro-economic analysis is a valuable tool for water management since it recognizes the interactions and dependencies between water uses that emerge from water policy interventions (Ward, 2021). Hydro-economic modeling carries basin-scale analysis capable of assisting the design of sustainable water policies.

The water management alternatives discussed in this sub-section will be evaluated and compared, using the HEM-CRB, allowing the reader to rank them in terms of basin net benefits.

4. The Framework of the Hydro-Economic Model for the Colorado Basin (HEM-CRB)

This section describes and formulates the mathematical relationship that comprises the HEM-CRB, which are the economic, hydrological, and environmental components. The economic component includes the economic benefits of water use from irrigators, urban centers, and hydropower production. The environmental component is included by limiting deviation from natural conditions, and the hydrologic component is included as the network of water sources and demands. The first subsection contextualizes the HEM-CRB and relates some successful applications of HEMs in other basins around the world. The second, third, and fourth subsections describe the hydrological, economic, and environmental components of the HEM-CRB. The last subsection presents the optimization problem.

4.1. The Hydrologic Component of the HEM

The hydrologic component of the HEM-CRB characterizes the hydrology of the river, including seasonal water flows, water storage, and physical restrictions. The hydrologically reduced model is a node-link network that represents water flows in the river basin. The principles of flow continuity and mass balance are simple hydrologic concepts that underpin the hydrologic form. The water flows are routed through a network that connects nodes in which surface water, dams, and aquifers fulfill the principle of mass balance.

The model is initially constrained to replicate the current conditions of (a) water availability, (b) water operations, and (c) physical and institutional restrictions. Water availability is the total amount of water in the system, and includes water inflows and water in storage. Water inflows depend on climate conditions, and are defined by historical and climate change conditions. Water operations and physical restrictions are upper and lower bounds on water dam storage and water canal conveyance, with the objective of replicating the unknown operation rules and the known physical capacity of the water system in the basin. The institutional restrictions are rules of water allocations, such as water rights and minimum and maximum environmental water flows. Combining water inflows and water rules allocations allows investigators to set up a wide range of scenarios.

Two types of water variables comprise the hydrologic component: flow variables denoted by X_i, and stock variables denoted by Z_s. Set i includes all water flows in the river (i.e., water diversions and evaporation), and set s includes the water storage in reservoirs and aquifers. These variables and their relationships are explained in this section. The hydrologic component uses a monthly step, and the economic component combines monthly and annual time steps. For simplicity, the hydrologic component adopts the time index t, and the economic component combines the index m for months ($m = \{1,2,\dots,12\}$) and y for years.

4.1.1. Headwater inflows

Headwater inflow variables $X_{h,t}$ are the sources of surface water in the system (h is a subset of i), which are the main contributors to the water availability (equation 1). Total headwater inflows reflect the climatic conditions in the systems (i.e., drought, normal, or wet conditions). Headwater inflows are exogenous variables, and they are set up in the source of water (inputs of the model). The generation of climate conditions partially relies on this variable.

(1) $$X_{h,t} = source_{h,t}$$

4.1.2. Water flows at the river gauge

The water flow $X_{v,t}$ at river gauge, v (v subset of i) represents the flow in the river, and it results from the sum of any water flow located in upstream nodes, and is expressed as:

(2) $$X_{v,t} = \sum_i B_{i,v} X_{i,t}$$

where $B_{i,v}$ are coefficients that connect $X_{v,t}$ to $X_{i,t}$, and describe the edges of the river in the water network. The parameter $B_{i,v}$ in equation 2 takes the value -1 when water withdraws, 0 when there is a non-contributing node, and 1 when the flow of $X_{i,t}$ contributes to $X_{v,t}$. Water flow in the river $X_{v,t}$ is a non-negative variable, $X_{v,t} \geq 0$. Water flows that contribute to the river gauge are river tributaries from the river, returns flow from the canal and the irrigated parcel, and the activity that reduces flows are the water diversions. The meaning of these variables is explained in this section.

4.1.3. Water diversions, net divert, and return canal

Water diversions for agriculture are extractions from the river to satisfy the demands of irrigators through primary canals and are denoted as $X_{d,t}$ (d subset of i). A proportion of the water diverted through the canal returns to the river due to leaks, deep percolation, or unused water, for example. Then water extractions involve three flows: diverted water, the water returned by canals, and the water flow that it received by users. Return canal flows are denoted by $X_{rc,t}$ (rc subset of i), and the water flow that water users actually receive is the net diverted flow $X_{nd,t}$ (nd subset of i), and results in the difference between the diverted water and the water returned by canals. In other words, the sum of the return canal flows $X_{rc,t}$ and net diverted flows $X_{nd,t}$ equals to the diverted flows $X_{d,t}$ and:

(3) $$X_{d,t} = X_{rc,t} + X_{nd,t}.$$

The model assumes that the proportion of water that returns, $X_{rc,t}$, over the water diverted, $X_{d,t}$, is fixed. Therefore, the relationship between the return canal flows and the water diverted is:

(4) $$X_{rc,t} = \sum_d \mathrm{B}_{rc,d} X_{d,t}$$

where the parameter $B_{rc,d}$ has a value between zero and one[7] and links $X_{d,t}$ and $X_{rc,t}$. Also, the variable net diverted water $X_{nd,t}$ is a proportion of water diverted $X_{d,t}$. This proportion is fixed by the parameter $B_{nd,d}$ and is represented by the relationship:

(5) $$X_{nd,t} = \sum_d B_{nd,d} X_{d,t}$$

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[7] Water transport channels have losses that return to the river, evaporate, or are used by vegetation. The parameter $B_{rc,d}$ is the percentage of water diverted by canals that return to the river in form of percolation, leaks, or unused. This parameter is settled at 0.2, following the range of values of the model StateMod (Colorado Water Conservation Board, 2012), which range between 10% and 50%.

The value of the $B_{nd,d}$ ranges between zero and one, and the sum of $B_{rc,d}$ and $B_{nd,d}$ equals one ($B_{rc,d} + B_{nd,d} = 1$).

Under normal conditions, water availability is sufficient to satisfy the demand for water, but under drought conditions, water availability cannot meet the demand. Therefore, water diversions are constrained to the water availability in the tributaries minus water diversions from other water demand nodes. Equation (6) states water availability constraint:

(6) $$X_{d,t} \leq \sum_i B_{d,i} X_{i,t}$$

where the coefficients $B_{d,i}$ takes a value of -1 for water diversions upstream, 0 for noncontributing nodes, and 1 for contributing nodes. The nonnegativity of water diversions is ensured by the restriction $X_{d,t} \geq 0$.

4.1.4. Water applied, water use, and return flows

Water losses, like water evaporation, in primary and secondary canals are accounted for as a percentage of water net diverted $X_{nd,t}$. The flow of water that reaches the irrigation districts and urban centers is the applied water $X_{a,t}$ (a subset of i). The percentage of water applied over the net diverted water is the channel efficiency, and is characterized by the parameter[8] $B_{nd,a}$ and equation (7):

(7) $$X_{a,t} = \sum_{nd} B_{nd,a} X_{nd,t}$$

Water applied results from cropland acreage in the irrigation districts and by population in the urban centers. To distinguish both meanings, the superscripts ag and urb are added to $X_{a,t}$ for the agriculture and for urban water use.

The total water applied $X_{a,t}^{ag}$ in an irrigation district is obtained by adding the water applied to all crops. The water applied by crop corresponds with the net irrigation requirements, which are site-specific and depend on the irrigation technology. Water applied per one unit of cropland j, under the irrigation technology k, by water user u is accounted by the parameter $Ba_{u,j,k}$.

Depending on the efficiency of the irrigation technology, a given part of the water applied to crops returns to the river in the form of percolation, and the rest of the water is effectively

[8] This parameter is equal to 0.8 and implies 20% water evaporation. This parameter represents conveyance efficiency and takes the range of values used in the model StateMod (Colorado Water Conservation Board, 2012)

used by crops, producing evapotranspiration. The parameter $Bu_{u,j,k}$ describes the evapotranspiration by a unit of cropland j, under irrigation technology k, in irrigation district u. The amount of water used in the irrigation district (evapotranspiration) is $X_{u,t}^{ag}$ (u subset of i), and results from the sum of the water used by all crops. The water that returns to the river per unit of cropland is defined by the parameter $Brp_{u,j,k}$, and the total amount of water that returns to the river is $X_{rp,t}^{ag}$ (rp subset of i). The equations below (equations 8–10) show the relationship between the irrigated cropland and water applied, used, and returned.

The total water applied in the irrigation district is:

(8) $$X_{a,t}^{ag} = \sum_j \sum_k Ba_{u,j,k} L_{u,j,k,t}$$

where $L_{u,j,k,t}$ is the cropland of j under technology k. The total water used in an irrigation district is given by the expression:

(9) $$X_{u,t}^{ag} = \sum_j \sum_k Bu_{u,j,k} L_{u,j,k,t}$$

and the water returned to the basin is:

(10) $$X_{rp,t}^{ag} = \sum_j \sum_k Brp_{u,j,k} L_{u,j,k,t}$$

The water applied $X_{a,t}^{urb}$, water used $X_{u,t}^{urb}$ and water returned $X_{rp,t}^{urb}$ in the urban centers urb depends on the per capita water use and population. The model assumes that water applied in the urban center equals to water used. The water used in the urban center is the water supply in the optimization problem of the urban centers. The returns flow from urban centers are accounted for as a proportion of water used.

(11) $$X_{a,t}^{urb} = \sum_a B_{a,u} X_{u,t}^{urb}$$

(12) $$X_{rp,t}^{urb} = \sum_u B_{rp,u} X_{u,t}^{urb}$$

4.1.5. Reservoirs

Reservoirs store water and are used for hydropower generation. Water storage $Z_{res,t}$ at reservoir res (res subset of s) in month t depends on the water storage at the previous month, water inflows and outflows, and evaporation. It is included in the model via the expression in equation (13):

(13) $$Z_{res,t} = Z_{res,t-1} - X_{rel,t}^{res} - X_{evp,t}^{res}$$

where $X^{res}_{rel,t}$ (rel subset of i) are the net release (outflow minus inflow) from the reservoir, and X^{res}_{evp} (evp subset of i) is the water evaporation in the reservoir. Precipitation is implicitly included in the model in the parameters that account for evaporation.

Surface water area and climatic conditions determine evaporation from reservoir res. The model uses a linear function between evaporation and water surface via the following equation:

(14) $$X^{res}_{evp,t} = \alpha^{res}_{0,m} + \alpha^{res}_{1} A_{res,t}$$

where $A_{res,t}$ is the area of the reservoir, and $\alpha^{res}_{0,m}$ and α^{res}_{1} are coefficients. In equation (14), the coefficient $\alpha^{res}_{0,m}$ is different for each month m and can be interpreted a constant evaporation or precipitation. The parameter α^{res}_{1} accounts for evaporation variations by changing the surface water area, and it is greater than 0.

Surface water grows with water storage in the reservoir. Equation (15) states the relationship between water area and water storage. A power function links surface water area and water storage in the reservoir, and it takes the form:

(15) $$A_{res,t} = \beta^{res}_{0} Z^{\beta^{res}_{1}}_{res,t}$$

where β^{res}_{0} and β^{res}_{1} are positive parameters.

4.2. The Economic Component

The economic component includes benefits from irrigated agriculture, urban water use, and hydropower production. Each sector in the economic component maximizes the private benefits of its water use under technical, institutional, and resource constraints. The environmental component in the HEM-CRB is considered a restriction on water flow, because modeling environmental benefits is complex and required information. Modeling environmental benefits entails establishing the relationship between: (1) water flows and ecosystem functions, (2) ecosystem health and the environmental services, and (3) the services they provide and society's valuation of them.

4.2.1. Benefits from irrigation

Irrigated agriculture is observed at the irrigation district level. It is assumed that the irrigation district is the decision maker. Agricultural activities maximize benefits from crop production subject to land, water, and technological constraints. The assumptions for agricultural production are that (1) crop yield depends linearly on cropland acreage, following the diminishing returns of scale principle, (2) crop water requirements are fixed per crop and irrigation technology, and (3) the price of the inputs and the outputs are given.

Equation (16) states the optimization problem for irrigated agriculture, and is formulated as follows:

(16) $$Max(\Pi_{u,y}^{ag}) = \sum_{j,k} P_j Y_{u,j,k} L_{u,j,k,y} - \sum_{j,k}(PC_{u,j,k} + WC_{u,j,k}) L_{u,j,k,y}$$

where $\Pi_{u,y}^{ag}$ is benefit in irrigation district u and year y. The decision variable of the irrigation district is $L_{u,j,k,y}$, which is the acreage of crop j under irrigation technology k, in year y. This optimization model considers the main crops in each irrigation district/area, where flood, sprinkler, and drip are the relevant irrigation systems.

The revenue of crop production in irrigation district u is given by expression $P_j Y_{u,j,k} L_{u,j,k,y}$ in equation (16), where P_j is the price of crop j, and $Y_{u,j,k}$ is the yield of crop j under irrigation technology k. Water cost $WC_{u,j,k}$ per cropland acreage are distinguished from other production costs per cropland acreage $PC_{u,j,k}$, then the expression for the total production in equation (16) is $\sum_{j,k}(PC_{u,j,k} + WC_{u,j,k}) L_{u,j,k,y}$.

The decreasing yield functions for crops comply with the principle of Ricardian rent. The first production acreage has the highest yields, and yields decline when less-suitable lands enter into production. The crop production function relates total yields with acreage of crop j under irrigation technology k, and is defined by the following equation:

(17) $$\mathrm{Y}_{\mathrm{u,j,k,y}} = \beta 0_{\mathrm{u,j,k}} + \beta 1_{u,j,k} \mathrm{L}_{\mathrm{u,j,k,y}}$$

where $\beta_{0_{u.j,k}}$ and $\beta_{1_{u,j,k}}$ are the intercept and the slope of the production function. In equation (17), the intercept $\beta_{0_{u,j,k}}$ is a positive value and represents the yield per acreage of the first unit the slope $\beta_{1_{u,j,k}}$ is negative by reason of decreasing yield. Restrictions of the optimization problem are described below.

Land and irrigation technology restrictions:

(18) $$\sum_{j,k} L_{u,j,k,y} \leq \overline{L_u}$$

(19) $$\sum_{j} L_{u,j,k,y} \leq \overline{L_{u,k}}$$

(20) $$L_{u,per,k,y} \leq L_{u,per,k,y-1}$$

(21) $$L_{u,j,k,y} \geq 0$$

Equation (18) represents the land restriction and states that the total cropland acreage of u in production, $\sum_{j,k} L_{u,j,k,y}$, does not exceed the total land available $\overline{L_u}$, in irrigation district u. The irrigation technology restriction in irrigation district u is counted for by equation (19) . Where, $\overline{L_{u,k}}$ is the total land equipped with irrigation technology k, and constitutes an upper bound to the total irrigated cropland with irrigation technology k, $\sum_j L_{u,j,k,y}$. Equation (20) states that cropland acreage $L_{u,per,k,y}$ of perennial crop per (subset of j) in production during year y does not exceed the cropland in production in the previous year $y-1$, $L_{u,per,k,y-1}$. This constraint represents the future loss of capital investment in fruit trees if farmers decide not to irrigate perennial crops in the current period. Non-negativity restriction of cropland acreage is fixed in equation (21).

Water restrictions of the agricultural model:

Water for irrigation is limited by water availability and water allocation resulting from climatic and institutional scenarios. The water availability restriction is represented as:

(22) $$\sum_{j,k} Bw_{u,j,k,m} L_{u,j,k,y} \leq \overline{X_{u,m,y}}$$

In equation (22), the water available in month m of year y, for irrigation district u, is $\overline{X_{u,m,y}}$ and establishes a ceiling on the monthly water applied to the entire crop acreage in the irrigation district, $\sum_{j,k} Bw_{u,j,k,m} L_{u,j,k,y}$. The parameter $Bw_{u,j,k,m}$ is the monthly water requirements of crop j under irrigation technology k during month m. The water available $\overline{X_{u,m,y}}$ is the variable linking the optimization model of irrigation districts and the hydrological component. This variable equals the variable $X_{a,t}^{ag}$ in equation (8). Annual water allocation, $\overline{X_{u,y}}$ in equation (23) represents the total water rights of irrigation district u limiting the total water used by crops.

(23) $$\sum_{j,k,m} Bw_{u,j,k,m} L_{u,j,k,y} \leq \overline{X_{u,y}}$$

The variable $\overline{X_{u,y}}$ allows the simulation of water allocation alternatives.

4.2.2. Benefits from urban use

In the urban centers, water use maximizes the economic surplus, the sum of consumer and producer surpluses. The optimization problem for urban users are stated in following equations (24–26), and is represented by:

(24) $$Max \Pi_{u,y}^{URB} = \left(\beta_{0,du} X_{du,y} - ½\, \beta_{1,du} X_{du,y}^2 - \beta_{0,su} X_{su,y} + ½\, \beta_{1,su} X_{su,y}^2\right)$$

s.t.

(25) $X_{du,y} - X_{su,y} \leq 0$

(26) $X_{du,y};\ X_{su,y} \geq 0$

where $\Pi_{u,y}^{URB}$ is the consumer and producer surplus in urban center u and year y. The variables $X_{su,y}$ and $X_{du,y}$ are water supply and demand in u, respectively. The parameters $\beta_{0,du}$ and $\beta_{1,du}$ are the intercept and the slope of the inverse demand function. The parameters $\beta_{0,su}$ and $\beta_{1,su}$ are the intercept and slope of the inverse water supply function. Equation (25) states that the supply must be equal to or greater than the demand for water. The water supply $X_{su,y}$ links the urban water use with the hydrological component, and it is equal to $X_{u,t}^{urb}$.

Water demand depends on population growth and the per-capita demand for water. The HEM-CRB can account for changes in population and water demand, which are important to simulate future conditions in the basin. Equation (27) states water demand:

(27) $X_{du,y} = X_{pc} P_{urb}$

where X_{pc} is the per-capita demand and P_{urb} is the population in the urban center u.

4.2.3. Benefits from hydropower production

Benefits from energy production by hydropower water use are presented in equation (28), and take the following expression:

(28) $\Pi_{res,y}^{hpw} = P_e \sum_m E_{res,m,y} - C_{f_{res}} - C_{v_{res}} \sum_m E_{res,m,y}$

where $\Pi_{res,y}^{hpw}$ is the annual benefit from hydropower production in reservoir res during period y, P_e is electricity price, $E_{res,m,y}$ is the hydropower production in res during month m, and parameters $C_{f_{res}}$ and $C_{v_{res}}$ are the fixed and variable costs, respectively. Equation (29) states hydropower production that depends on the water flow through the turbines, the height of water in the reservoir, and the efficiency of the hydropower plant, and it takes the expression:

(29) $E_{res,m,y} = \delta \eta_{res} X_{res,m,y}^{hpw} H_{\ res,m,y}$

where η_{res} is the efficiency of the generation plan, $X_{res,m,y}^{hpw}$ is water used to produce hydropower, $H_{res,m,y}$ is the height of the reservoir, depending on water storage, and δ is a conversion constant that depends on the units of time and units of the flow, height, and energy production. The explanation of their calculation can be found in the calibration section (5.4). It is important to note the difference between the water release $X_{rel,t}^{res}$ [equation (13)] from reservoir res and the water used from res in hydropower production $X_{res,m,y}^{hpw}$. The water used for hydropower is constrained by the technical capacity of the hydropower plant. The parameter $\overline{X_{res}^{hpw}}$ is a technical restriction and represents the maximum water flow that the hydropower plant can run through its turbines. This relationship is assumed to be:

$$X_{res,m,y}^{hpw} = \min\{X_{rel,t}^{res}, \overline{X_{res}^{hpw}}\} \quad (30)$$

HEM-CRB approximates the height of the dam $H_{res,m,y}$ by the water storage variable $Z_{res,m,y}$ using an exponential relationship (Adeloye et al., 2019):

$$H_{res,m,y} = \eta_{res,0} Z_{res,m,y}^{\eta_{res,1}} \quad (31)$$

where $\eta_{res,0}$ and $\eta_{res,1}$ are the parameters of the function.

4.3. Environmental Component

4.3.1. Deviation from natural conditions and minimum environmental flow

Modeling the environmental component is a difficult task because biophysical information is not available, ecosystems are ruled by complex interactions, and lack of economic valuation of ecosystem services. Environmental flows seek to maintain functional ecosystems in good status by restricting water flows. Water ecosystem needs are connected to the hydrological cycle; then, the design of the environmental flows accounts for the variability of water inflows. The natural condition is the reference to establish the environmental flows. The method proposed for the HEM-CRB attends to the alteration of natural water flows by an index of the water pressure, defined as the ratio between observed flows and flows under natural conditions. Environmental flows maintain the index of water pressure in a safe range, preventing it from exceeding certain thresholds. Then, water allocation rules follow the following expression:

$$\beta_{min} < \frac{Flow_{current}}{Natural\ flow} < \beta_{max} \quad (32)$$

where β_{min} and β_{max} are the minimum and maximum alterations allowed by the policy.

4.3.2. Avoidance of CO2e emissions by hydropower production

Electricity generation via hydropower avoids emissions of CO_2e that result from electricity generation using fossil sources (coal, natural gas). The reduction in hydropower generation, assuming a constant demand for electricity, could increase the use of fossil sources that produce higher emissions. The environmental cost of reducing hydropower generation can be included in the HEM-CRB accounting for the social damage of climate change and water management.

4.4. Model Optimization

The net present value (NPV) of the benefits of all economic sectors is maximized over the planning horizon, where NPV is the sum of present benefits from agricultural irrigation, urban water use, and hydropower production. The model optimizes the objective function:

(33) $$Max\ NPV = \sum_{u,y} \frac{\Pi_{u,y}^{ag}}{(1+r)^{y}} + \sum_{u,y} \frac{\Pi_{u,y}^{URB}}{(1+r)^{y}} + \sum_{u,y} \frac{\Pi_{u,y}^{pwr}}{(1+r)^{y}}$$

subject to the basin's hydrological, land use, institutional, and environmental constraints stated in equations (1–32). r is the discount rate. Planning horizon for climate change scenarios will be 30 years, since base run scenario is calibrated with 30 years of historical water flows, projections of climate change include this horizon (Miller et al., 2021), and other HEMs includes this period (Esteve et al., 2015). However, this horizon could change in other simulations. The discount rate results from the 30 years treasury constant maturities adjusted to the inflation index, and it is settled at 2.3% (FED, 2023). Table 3 presents all the parameters and variables included in the HEM.

[INSERT TABLE 3 HERE]

Table 3. Summary and description of sets, variables, and parameters included in the HEM-CRB

5. Data and Assumptions in the CRB-HEM

This section presents the assumptions of the CRB-HEM and the data sources. The section is divided into three sections based on the economic, environmental, and hydrological components. Subsections 5.2–5.5 define water users, and their economic and water variables that connect water users with the hydrologic component. Subsection 5.6 is dedicated to ecosystems. Finally, subsection 5.7 presents data and variables of the hydrologic component and the variables that connect the hydrology and the water users.

5.1. Data Sources and Variable Construction for Water Users

Modeling water users in the HEM-CRB requires information on irrigation areas, urban centers, and the hydropower sector. Cropland and irrigation technology distribution, water requirements, and economic parameters are included in irrigation sector modeling. Parameters included in modeling urban water uses are observed water price, per capita water use, and population. Hydropower capacity, efficiency, and turbine water capacity are the parameters that characterize hydropower production. Ecosystems are represented by restrictions called environmental water flows and are affected by water management restrictions.

5.2. Agricultural Variables

5.2.1. Agricultural land use

HEM-CRB includes irrigated cropland by irrigation unit, crop type, and irrigation technology. Setting up the regional use of water for agriculture involves the identification of the irrigation units, crop acreage, and crop area equipped with certain types of irrigation system technologies. In this subsection, (1) we define irrigation units, (2) we identify the irrigation technology distribution, and (3) we assess the crop area equipped by irrigation system technology.

Irrigation units are regions where it is possible to identify water flows (water withdraws, water use, and returns flows) related to irrigation. The selection of irrigation units seeks to conciliate hydrological divisions with administrative and infrastructure units. Hydrological divisions are catchment areas in the basin that are related to gauge stations, and infrastructures that allow the identification of water inflows and water extractions in the system. Administrative and infrastructure divisions include associations or groups of irrigators with a common infrastructure and/or organization. Hydrological divisions are identified with data from the Watershed Boundary Dataset (WBD) (USGS, 2023). HU12 is the smallest basin division from the WBD[9], providing the highest resolution possible. Using HU12 boundaries ensures the reproducibility of the irrigation units. Irrigation units are assembling sets of hydrological units at level 12 (HU12). The area of an irrigated unit can overlap several states, notwithstanding it does not prevent water from applying interventions at state levels.

To identify the crop area equipped with an irrigation system technology involves three sources of data at different scales. First, we identify the irrigated area; second, the crop distribution; and third, the irrigation technology in the area. Irrigation units and crop pattern distribution have a resolution of 30 meters, and irrigation technology is available at the state level.

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[9] The HU14 and HU16 represent smaller basins, but they are not available for all of the U.S.

Irrigated land is identified using data from Xie and Lark (2021), and represents 2.97 million acres of irrigated area in the CRB. Cropland Data Layer dataset (CDL) from the United States Department of Agriculture (USDA) between 2008 and 2021 (USDA, 2023) overlapped with the irrigated land from Xie and Lark (2021) to identify cropland that is irrigated. Irrigated crops area amounts to 2.7 million acres, and the remaining 0.24 million acres are not covered by crops. In addition, around 0.27 million acres are fallow or idle cropland; the total cropland irrigated that is in production exceeds 2.2 million acres. Table A1 (appendix) shows the acreage of 94 crops in the CRB from 2008 to 2021 and the average acreage for the 8 more extended crops is displayed in Table 4.

[INSERT TABLE 4 HERE]

Table 4. Irrigated crop distribution in the Colorado River Basin. Mean value between 2008 and 2021

Distribution of crops by irrigation system technology is available at the state level from Irrigation and Water Management Survey (USDA, 2019), which is part of the Census of Agriculture. The survey provides irrigated crop area by technology system at the state level. We assume (strong assumption) that the percentage of crop area irrigated by irrigation systems at the state level can be imputed to the irrigation unit, maintaining the same distribution of irrigated crops by irrigation technology. Crop areas equipped with an irrigation technology at irrigation unit level are identified by weighting crop area equipped with an irrigation technology at the state level and the percentage of irrigation units within the states. For each irrigation unit, the results are the percentage of crop area equipped with a given irrigation technology (Table A2 and A3, appendix).

[INSERT TABLE 5 HERE]

Table 5. Irrigation system distribution by crop and state

Finally, cropland averaged between 2008 and 2021 is combined with the percentage of crop area irrigated by drip, flood, and sprinkler to obtain the distribution of cropland and irrigation technology for each irrigation unit. Figure 5 describes the process that is summarized as follows:

1) Point A describes the union of irrigated area and crop land coverage between 2008 and 2021 to obtain the irrigated crops area in the CRB.

2) Irrigation units/districts are selected using boundaries from HU12 (point B), which are combined with data from the distribution of crop area equipped with an irrigation technology

at the state level to obtain the irrigation technology distribution by crop and irrigation district (point C).

3) Cropping patterns by irrigation districts and year results from the zonal histogram of crops and irrigation units (point D).

4) Irrigation technology distribution by crop and irrigation district (point C) and crop acreage by irrigation unit (point D) gives crop acreage by irrigation technology and irrigation unit (point F).

[INSERT FIGURES 5 AND 6 HERE]

Figure 5. Crop and Irrigation data source and transformation process

Figure 6. Map of irrigation units of the HEM-CRB

5.2.2. Agricultural water use

Water is an important variable since it connects the economic component and the hydrologic component. In this subsection and subsequent sections, we explain the economic aspects related with water use, such as water requirements for crops, water use per capita in urban centers, and flows for hydropower production. In the subsection that explains the hydrologic component: water variable is related with water infrastructures that connect irrigation units and urban centers with rivers, dams and river flows, and additional flows that are part of the hydrological system.

Irrigation water requirements are the quantity of water needed to produce a crop yield, and it varies by crop type, irrigation system technology, location, and month. Annual requirements of water for irrigated crops are available from studies of the University of California, Davis, Department of Agricultural and Resource Economics (UC Davis, 2023), the New Mexico University (NM University, 2023), Colorado State University (CO State University, 2019), and Consumptive Use Program PLUS (CUP+) application developed by the California Department of Water Resources. California Department of Water Resources (2023) provides monthly data of irrigation requirements. Using data from CUP+, monthly water requirements are determined by applying a percentage over the annual water requirements. Irrigation efficiency is defined as the percentage of water applied that is used by the crop in the form of evapotranspiration. The water flow unused by the crop returns to the water system by percolation. The efficiencies assumed in the HEM-CRB are 0.6, 0.8, and 0.9 for flood, sprinkle, and drip, which are common assumptions in the studies (Brouwer et al., 1989; Wang, 2019). Table A4 shows the percentage of irrigation technology over the total acreage installed in the irrigation district. The monthly distribution of irrigation needs by crop are presented in in Table A5 as a percentage of the annual water requirements.

5.2.3. Economic parameters of agricultural activities

Yield, price, and production cost of crops determine the benefits of crop production and are selected from studies of the University of California, Davis, Department of Agricultural and Resource Economics (UC Davis, 2023), the New Mexico University (NM University, 2023), Colorado State University (CO State University, 2019), and Economic Research Service of USDA (USDA-ERS, 2023). Table 6 displays the price, yield, cost of water, and other costs, which are used to obtain the income, total cost, and net income of crop production. Net income is income minus total cost, excluding rents of land.

[INSERT TABLE 6 HERE]

Table 6. Price, yield, cost, water requirements, income, cost, and net income

5.3. Urban Variables

Residential, industrial, and municipal water users constitute urban water users of the HEM-CRB. Modeling urban water use needs information about sources of water and infrastructures to conform to the hydrological network, and economic information to specify water demand and benefits functions of the economic component. Data on number of inhabitants, water price, water use, and price elasticity of water demand have been collected and used to model domestic water use. HEM-CRB assumes that industrial and municipal water use is fixed for several reasons, explained below. Cities extracting water from the same source of water are brought together in the hydrologic component, making a group that denominates the urban node. However, the economic component handles each city as a single entity. Community Water Dataset (University of Arizona, 2020) is a geographic information system (GIS) layer that contains cities served by the CRB with more than 10,000 inhabitants in 2015. This data set provides information on the location and number of inhabitants in 2010 and 2015. Cities are identified by seven digits codification from U.S. Census Bureau. The GIS data layer of cities was updated with population data for 2020 from U.S. Census Bureau (2021).

5.3.1. The spatial location of urban centers and the location of water withdrawals

Figure 7 presents a map of the urban centers and urban nodes included in the model, and the density function of the inhabitants in 2020 by state, helping identify differences in population size distribution between states. Many cities served by CRB are located outside the boundaries of the basin, which indicates the importance of inter-basin water transfers to maintain population. The model includes around 33 million inhabitants, and 379 cities gathered in 20 urban nodes (Table 7). From Table 7, it can be noted that California has the largest number of inhabitants and cities, and along states, the population is highly concentrated in one single urban node, noting that some infrastructures carry a heavier load in certain parts of the basin.

[INSERT TABLE 7 AND FIGURE 7 HERE]

Figure 7. Urban centers in the Colorado River Basin and population density

Table 7. Population by state and water urban node and number of cities

5.3.2. Economic values of urban water

Data about water pricing, water use, and price elasticities of residential water demand was collected from the literature to characterize the demand and benefits function of domestic water use. Data availability varies along states and usually is available for the main cities of the state. To be able to use such data, HEM-CRB assumes that water price, water use, and water price elasticity are equal across state levels.

The estimation of water demand combines population and per capita water. Water use per capita was collected from several studies (Chini and Stillwell, 2018; Colby and Hansen, 2022). Also, water price at the state level was estimated from several sources (Luby et al., 2018; University of Arizona, 2014). Table 8 presents a summary of urban water use and water prices from those studies.

[INSERT TABE 8 HERE]

Table 8. Summary of water use and water price values of the main cities in the Colorado River Basin

Table 9 presents a summary of the studies used to assign the price elasticity of residential water demand and the values of the elasticities, water demand, and water price. California accounts for five, Arizona and Nevada for four, Colorado for three studies, and New Mexico and Utah for one study. The areas of study are the main cities and regions in the states, the range of years varies between 2 and 14, and the log-log model is the most common model specification. Elasticities range between -0.76 and -0.1 and are used to select the elasticities of the HEM-CRB.

[INSERT TABLE 9 HERE]

Table 9. Studies of water price elasticities, price, and water use

Table 10 displays water price and price elasticity of water demand that were selected for the CRB using the information in Tables 8 and 9. Water price for residential use ranges between 2.2 $ per 1,000 gallons in Utah and 12.8 $ per 1,000 gallons in New Mexico. Colorado accounts for the minimum water use with 109 gallons per capita per day (gpcd), and Wyoming has the highest at 181 gpcd. The water price elasticity ranges between -0.65 and -0.38 and are selected with average values of the studies.

[INSERT TABLE 10 HERE]

Table 10. Water price, water use, and price elasticity selected for the HEC-CRB

5.3.3. The assumption with other water uses in urban areas

Water is crucial for the industrial sector, and due to the high productivity of the sector, water shortages could lead to substantial losses. Despite the relevance of the sector, information in the CRB on the price elasticity of water demand for industries is scant. Similarly, commercial and municipal water use are important components of urban water use, maintaining economic activities, such as restaurants and offices, and providing a public supply of water. Domestic water use is the main component of urban water in the CRB and, across the state, it ranges between 55% and 81% of the total urban use (Dieter and Maupin, 2017). In the base run, HEC-CRB assumes that industrial, commercial, and municipal water use is 40% of the total urban water use, and the remaining 60% is for domestic use. Water use for industrial, municipal, and commercial purposes is assumed to be fixed, and water use in those sectors is maintained under any climate and policy scenarios.

5.3.4. Projections of water demand

Population growth between 2010 and 2020 is examined to design future scenarios of water demand. Figure 8 shows the number of inhabitants in 2020 and their percentage change with respect to the 2010 population of cities that is included in the HEM-CRB. A base-10 log scale for the population in 2020 is used to easily identify cities between 10,000 and 100,000 inhabitants, and 100,000 and 1,000,000 inhabitants and greater. Population growth in most cities is less than 10%. But in some populations between 10,000 and 100,000 inhabitants, growth rates of more than 20% were observed, reaching 40% in some cases. In some cities with between 100,000 and 1,000,000 inhabitants, growth rates between 10% and 30% were observed.

[INSERT FIGURE 8 HERE]

Figure 8. Population growth and population size of the cities included in the HEM

5.4. Hydropower Variables

Water for hydropower is considered a non-consumptive use that provides economic benefits through electricity generation and environmental benefits, since hydropower avoids intense CO_2 emissions from alternative sources of energy. Hydropower has a relatively small contribution to the total annual generation of electricity but plays an important role in maintaining regional grid reliability and resilience (Stern and Lawson, 2023). Hydropower plants are installed in dams or diversion structures and, by using elevation differences, they generate electricity (EERE, 2023). Modeling hydropower production requires identifying dams where plants are installed and the physical and technical characteristics of the hydropower plants and dams, such as the capacity of the facility to generate electricity and the height of the dam, among others. CRB accounts for 47 hydropower plants in dams, summing up 4,700 MW of installed capacity (HIFLD, 2023). In addition, USBR (2023b) identified additional hydropower production facilities located in tunnels, which extend by 126 MW the capacity listed by HIFLD, adding 70 additional hydropower plants.

The selection of modeling hydropower production requires modeling dams in the hydrological component, which requires information (explained in Section 5.6) that could not be available for some locations. Also, dams make the model harder to solve because dams confer dynamics to the system, connecting multiple time periods, increasing dramatically the number of dimensions of the model. A larger number of dams increase the computational efforts and the risk of failure of finding a feasible solution, because of dimensionality. In summary, the election of including a plant is based on data availability, the relative importance of the plant over the total plants, and tradeoffs between computational effort and the accuracy of the results. However, the nine plants included in HEM-CRB represent 90% of the total hydropower capacity installed in dams, modeling a wide coverage of the hydropower sector in the basin. Figure 9 shows the location of dams included in the HEM, nine of which have hydropower plants.

[INSERT FIGURE 9 HERE]

Figure 9. Hydropower production and dams of the CRB are included in the HEM

Electricity generation depends on the height of the dam, the amount of water flow that the hydropower plant can run through the turbine, and the time that it operates. Because the time frame of the HEM is monthly rather than continuous, and because hydropower plants have technical constraints on the flow of water to run through the turbines, the electricity generation and water flow for hydropower are constrained for preventing to exceed the observed production by adding an upper bound. Table 11 presents the characteristics of nine hydropower plants included in the HEM, which amounts to a capacity of 4,200 MW and is equivalent to 87% of the total (dams and tunnel) installed capacity in the basin (HIFLD, 2023). Also, Table 11 shows the mean annual hydropower production between 2012 and 2021 using data from WAPA (2023) and USBR (2023c). If a plant produces continuously every hour of the year, it will produce the maximum amount of electricity per year. This potential generation is hard to achieve and, in practice, it is usually much lower. The ratio of potential generation to actual generation in a year is the plant's capacity factor and indicates the percentage of time the plant is operating at full capacity. As indicated in Table 11, it ranges between 0.2 and 0.57 for the hydropower dams selected for the HEM-CRB.

[INSERT TABLE 11 HERE]

Table 11. Hydropower production parameters, installed power, potential hydropower production annually, efficiency, capacity factor, and head height

The efficiency of the Havasu Lake, Flaming Gorge, Marrow Point, Blue Mesa, Crystal, and Fontenelle is estimated with data from WAPA (2023). HEM-CRB assumes an efficiency of 0.85 for Lakes Powell, Mead, and Mohave because there is no data available for those plants. Tables 12 and 13 show the monthly average between 2012 and 2021 of water flow through the turbines, electricity generation, and height of the hydropower plants included in the HEM-CRB. Calibration of hydropower production involves identifying the efficiency of dams and the parameters of the storage-height relationship. Calibration details are presented in Section 6.

[INSERT TABLES 12 AND 13 HERE]

Table 12. Average water through turbines and hydropower generated data from USBR

Table 13. Average water through turbine, height, and hydropower generated data from Western Area Power Administration

5.4.1. Economic values

Benefits from hydropower production depend on electricity price and fixed and variable costs. Electricity prices from the "Monthly Energy Review," elaborated by U.S. Energy

Information Administration (EIA, 2022), and costs from "Hydropower Resource Assessment at Existing Reclamation Facilities" (USBR, 2023c), elaborated by USBR, are the parameters of the benefit function of hydropower production in HEM-CRB. Fixed costs include the investment cost of hydropower production and variable cost resulting from operation and maintenance costs. Table 17 presents electricity prices, and fixed and variable costs included in the hydropower production function of the HEM-CRB.

[INSERT TABLE 14 HERE]

Table14. Energy price, fixed cost of hydropower production, and variable cost of hydropower production

5.4.2. Additional information

The unprecedented drought conditions that occurred in the CRB from 2000 to 2023 have reduced electricity generation and boosted the depletion of water storage in dams. Figure 10 shows the hydropower production in Hover Dam between 1945 and 2023 that has been steadily declining through the last 20 years because of declining water inflows and losses in potential energy due to lower heights of dams. This tendency is expected to be consolidated by climate change, having lower water inflows and less water storage in dams, which is equivalent to lower-height dams.

[INSERT FIGURE 10 HERE]

Figure 10. Hydropower production in the Hoover Dam

Hydropower plants are connected by the water flows in the river, and those located in downstream locations are dependent upon those located upstream. This relationship is pointed out in Figure 12, that shows the correlation of hydropower generation in the three biggest plants, revealing the synchronization of hydropower generation. The tied behavior in hydropower generation suggests that hydropower system has no mechanics to reduce the impact of the hydrological cycle, balancing electricity generation over time and space. In terms of risk, the correlation between plants increases the variance of the total hydropower generation, strengthening the kurtosis, and making the distribution function fat-tailed. Then, coupled systems increase the risk of larger production losses, given the synchronization with the water cycle.

[INSERT FIGURE 11 HERE]

Figure 11. Hydropower production relationship for the Davis, Hoover, and Parker dams

5.5. Environmental Variables

The environmental component includes the alteration index and emissions avoidance presented in Section 4. The alteration index is computed with data from USBR and USGS (U. S. Geological Survey, 1994; USBR, 2023d), and the emission avoidance is from (EERE, 2023). Figure 12 shows the alteration index at Duchesne River in Utah between 1970 and 2019, showing the high pressure that supports the river, because more than half of the water is extracted. In addition, it is also possible to identify periods in which the index takes values greater than one, reaching 1.5 times the natural conditions. Usually, environmental flows limit water extractions but also limit operation rules in dams to maintain flooding under control.

[INSERT FIGURE 12 HERE]

Figure 12. The ratio between affected flow and natural flows at Duchesne River near Randlett, UT (USGS site: 09302000). Moving average in red

5.6. Hydrological Variables

Composed of nodes and edges, the CRB network is the core of the hydrological component and represents sources of water, demand of water, and water flows. The network distinguishes water flows from rivers, canals, dams, and other flows related to water use. Developing the network involves identifying nodes and edges of rivers, canals, water uses, and dams, and it is completed in two steps: the first one establishes the network of the river, which is the body in which infrastructures and uses of water are gathered; and in the second step, the network is completed by adding nodes and edges that represent infrastructures and uses of water.

5.6.1. Hydrological network

The set of nodes that describes the river is derived from data of the gauging stations and edges from spatial data (U. S. Geological Survey, 1994). CRB contains gauges in the river and dams to monitor variables related to water, such as stream flows, evaporation, temperature, and water quality, among others. USGS and USBR are the organizations that provide a comprehensive set of data, covering a wide number of gauging stations in the CRB, and over long periods of time. Data from both organizations is used to identify and measure the river nodes included in the network, making the correspondence between modeling and gauged water flows possible. The selection criterion of nodes and gauges respond to data availability and convenience (i.e., some gauging stations had been excluded because lack of data, and others were ignored in favor of network simplicity, by not counting on irrelevant nodes in terms of water demand and water supply). Data from gauging stations is available from USGS data for the nation (U. S. Geological Survey, 1994), and from RICE system from USBR (2023c). In addition to the nodes with data available, additional nodes are included to represent junctions of several water flows, such as tributaries, water inflows, and return flows.

Edges connect upstream nodes with downstream nodes, also named source nodes and sink nodes. Most nodes are source and sink simultaneously, with the exception of nodes that represent water inflows, which are only source nodes, and the node of the river mouth, which is only a sink node. Identification of the edges between nodes is accomplished using two geographic information systems from the National Hydrography Dataset. The first one is NHDPlus High-Resolution (U.S. Geological Survey, 2019) Dataset, which provides the location of streams of the river, and it is overlapped with the location of the gauge station to identify the connection between nodes. The second dataset provides subbasin divisions of drainage areas from the Watershed Boundary Dataset (WBD) (USGS, 2023) and allows to identify upstream nodes and water uses upstream. An example of water use is in agricultural use of water: an irrigation unit diverts water for irrigation from an upstream node, and water returns from canals and from crops contributing to downstream nodes.

The second part involves adding nodes and edges that represent infrastructure and water uses. Demand nodes and river nodes are connected by edges that represent diversions and returns flows of water. Spatial location of the irrigation units, urban centers, and channels serve as reference to identity water flows (edges) between the river (river nodes) and the users of water (demand nodes). Return flows from agricultural water use are identified by the drainage areas, using Watershed Boundary Dataset (USGS, 2023). Appendix B provides a scheme of the hydrological network. A description of the nodes, USGS code of the locations, and the names used to code in GAMS are included in the scheme to identify the river nodes. The scheme includes water diversions, return flows, dams, and water users. Two matrixes represent river and channels in the hydrological network. The matrix that represents the river includes three columns; the first column includes the source nodes, the second column the sink nodes, and the third column takes value one when the source nodes recharge, and minus one when there is water extraction. The network is available on the website of CRB. The second matrix represents the flows in channels. The channel flows included in the matrix are losses from canal and return flows, which are proportional to diverted water. This matrix has three columns: the first and second columns in the matrix are source and sink nodes, respectively, and the third column is a value between zero and one, which is the proportion of water applied and water returned by canals over diverted water.

5.6.2. Water inflows in the systems

Water inflows are an important element of HEM-CRB, since they establish water availability in the basin by replicating historical conditions or simulating future conditions of climate change. Water inflow inputs of the HEM-CRB are determined by observed water flows in the headwater, taking the monthly average of stream flows from 71 stations. Table A6 shows the USGS code for the gauging station and the name of the variable included in the model. Annex B includes a table for each station with the main statistics of the mean daily discharge, which are min, max, mean, median, and first and third quantiles of the observed water inflows. Also, in the same annex, two figures for each gauging station are included: a monthly boxplot, and a time series plot of the mean daily discharge. Table A7 shows the water inflows in the system under the base run scenario.

Simulation of climate conditions involves generating a series of water inflows that preserve the statistical properties of the observed conditions and successively perturbating those statistical properties; for example, by shifting the mean or the variance, to produce alternative water inflows. For this reason, four distribution functions of water inflows for each location and month were fitted and tested to determine their suitability for reproducing the historical conditions. Gamma, Generalized Extreme Value (GEV), log-normal, and Weibull are commonly used to characterize hydrological variables. Fitting and goodness of fit results are available in Annex B.

5.6.3. Dams

Dams have multiple functions, such as water storage, hydropower generation, and prevention of floods. Water storage is the main mechanism to accommodate water supply and demand, spreading water availability over time. It provides dynamics to the HEM-CRB, making it possible for water allocation decisions to take place over long periods of time. Technical restrictions, such as minimum and maximum storage capacity, and operation rules (e.g., risk reduction of flooding and limiting the functioning of dams are imposed). Consequently, the dam’s operations and water storage capacity constrain allocation decisions. Locations of the dams in the HEM-CRB are presented in Figure 9.

The technical restrictions on the water storage and operation rules are included in the HEM-CRB using the observed data from the USBR RICE system provided by USBR

(2023c). HEM-CRB assumes the first and ninth deciles of monthly water storage as the minimum and maximum capacity of the dam, respectively. This information is presented in two tables. Table 15 shows water storage for the first period of the simulation, and the maximum and minimum storage capacity. The first period of the simulation corresponds to the median water storage and provides initial conditions for the simulations. In Table 15, the minimum and maximum storage capacity are selected between monthly values and indicate the minimum and maximum overall monthly values. Table A8 shows the monthly storage capacity as a factor of the values from Table 15. Minimum storage is expressed in relative terms to the month with the lower minimum storage. Then the values are one for the minimum, and greater than one for larger storage capacity. In the same way, the maximum storage is presented as a percentage of the larger storage, and it takes one or lower. The values in Table 15 are then multiplied by the values in Table A8 to obtain the actual monthly storage capacity.

[INSERT TABLE 15 HERE]

Table 15. Water storage in reservoir the first period of simulation, and maximum and minimum storage capacity

Water surface area and season determines evaporation losses in dams. HEM-CRB assumes a linear relationship between evaporation and surface area, and it is estimated by OLS with data from Zhao et al. (2022) and USBR (2023c). Evaporation is explained by water storage in the dam, and a fixed effect by month that captures a monthly variability. A detailed explanation of the model and the results of the parameters is presented in Section 6.

6. Calibration

Calibration is one of the most critical processes of developing a HEM model and involves adjusting the parameters of the model so that the output replicates the observed data as closely as possible. The rationality and procedure of calibration of the economic and hydrological components are explained in this section.

6.1. Calibration of the Agricultural Component (PMP)

Crop yield calibration involves finding the intercept and slope of the crop production function for each irrigation district and irrigation system. The problem of identifying the yield function arises because the observed data is aggregated, and only the average crop yield at a regional level is available, which entails overlooking different levels of production specialization intrinsic to the irrigation units. To overcome those difficulties, the HEM-CRB uses Positive

Mathematical Programming (PMP) (Howitt, 1995) following the assumptions proposed by Dagnino and Ward (2012).

HEM-CRB assumes farmers maximize the private benefit of crop production and decrease crop yields in relation to cropland acreage. Private benefit optimization responds to the widespread principle of the rationality of the agents in economic theory. Decreasing yields are consistent with the Ricardian principle of decreasing rent, and have the advantage of overcoming overspecialization problems where constant yields originate. One important assumption is that the observed variables represent the optimal solution of the maximization problem. PMP calibrates the unknown parameters with the mathematical first-order conditions of the optimization problem and the observed variables. Calibration of the yield function, presented in Equation (15), involves finding the intercept and slope with data from Section 5. Since the yield function is linear, the intercept β_0 and slope β_1 are:

(34) $$\beta_0 = Yield - \beta_1 Cropland$$

and

(35) $$\beta_1 = -\frac{Net\ Revenue}{Price_{water} * Land}$$

Calibration produces 4,052 parameters because the combination of crops, irrigation technologies and irrigation districts. Because the large number of results, parameter estimations are available in up on request from the authors.

6.2. Calibration of the Urban Component (Elasticity Price)

6.3. Calibration of the Hydropower Production

Height of dam determines the potential generation of electricity by the hydropower plant. But energy losses due to lack of efficiency precludes achieving the potential generation. Efficiency of hydropower plants and height of dams are included in the hydropower component of the HEM-CRB needed for calibration.

Calibration of the hydropower plant's efficiency and storage-height relationship in dams is achieved by ordinary least squares (OLS) using data from USBR and WAPA (USBR, 2023d; WAPA, 2023). Hydropower production depends on the height of dam and the quantity of water run through the turbines of the plant, and it takes the expression:

(38) $$hpw = e\frac{h * q}{11,800}$$

where hpw is the observed hydropower, h is the height, q is turbined water, and e is the efficiency of the plant. The value $\frac{1}{11,800}$ is a conversion factor included because the units of h and q are feet and cubic feet per second (USBR, 2005). When the units are in the international metric system, height is expressed in meters and water flow in cubic meters per second. The expression of hydropower generation is:

(39) $$hpw = e * g * h * q$$

where g is the acceleration of gravity and equals 9.8 meters per second squared.

Efficiency takes values between zero and one and was estimated by OLS using a model without intercept. Figure 13 shows the observed and theoretical hydropower generation and the blue line that results from the estimations.

[INSERT FIGURE 13 HERE]

Figure 13. Observed and theoretical hydropower production and fitted relationship in blue

The second element of hydropower production that requires calibration is the relationship between water storage and the height of the dam. A power function establishes the relationship between height and storage and takes the form:

(40) $$h = a * Z^b$$

where h is the height of the dam, Z is the water storage volume. Height and water storage are normalized between zero and one, resulting in the expression:

(41) $$\frac{h-h_{min}}{h_{max}-h_{min}} = a' \left(\frac{Z-Z_{min}}{Z_{max}-Z_{min}}\right)^{b'}$$

Parameter estimation is done by the nonlinear least squares model, and the results are presented in Table 16.

[INSERT TABLE 16 HERE]

Table 16. Parameter estimation heigh-storage relationship for hydropower production

6.4. Calibration of the Hydrological Component

6.4.1. Dam evaporation

Water evaporation losses from dams depend on the area of the water surface and season, which increases with larger water surface areas and during summer. HEM-CRB assumes a linear relationship between evaporation and the area of the reservoir and varies by month. Evaporation is estimated by OLS with data from Zhao et al. (2022), and it assumes that evaporation is explained linearly by the area of the reservoir. Ideally, the interaction between month and surface area explains evaporation in dams having a distinguishable intercept and slope for each month. However, the estimation of this model suffers from the absence of results for some months in some locations due to singularities in the results. Then, to capture the monthly variability, the model includes an intercept for each month and a single slope for all months of the year and can be expressed as:

(42) $$evp_{month} = \beta_{month} + \beta_1 Surf$$

where evp_{month} is the evaporation, $Surf$ is the surface area, and β_{month} and β_1 are the intercept and the slope. The results of the estimation are presented in Table A9 in the appendix. Figure A1-A7 shows the relationship between evaporation and water storage in the main reservoirs of the basin.

7. Results

This section presents the results of the HEM-CRB and includes the economic benefit of water use from seven states, 40 irrigation units, 378 urban centers, and eight hydropower generation plants. The model assumes that Mexico has a fixed, un-negotiable quantity of water. Also, environmental is included with a fixed quantity of water. The results of the water use of the Tribal Nations are summed up with the states. This section is organized as follows: first, the results for agricultural, urban, and hydropower are analyzed individually to provide a sectoral and regional perspective of the current conditions in the basin; second, the interaction between sector and regions is highlighted to identify potential trade-offs and ties; finally, the calibration results are presented showing the discrepancy between observations and the simulated results.

7.1. Agriculture

Agricultural water use includes 40 irrigation districts from the seven states that maximize the benefits from the production of 39 crops using three irrigation system technologies. Table 17 presents crop acreage, water, revenue, cost, and net income of crop production by state. It is important to emphasize that crop production only includes the irrigation area inside the basin and the acreage irrigated by the All-American Canal. Consequently, irrigation area, water use, and benefits of water use from the CRB are greater than the results presented. This is the result of having a large proportion of Utah, Wyoming, New Mexico, and Nevada being outside the borders of the basin, and water use (from the CRB) in such regions is considered as inter-basin transfers. The results of benefits, cropland, and water use by irrigation district and state level are presented in Table A10-A11 and Figure A8-A10.

[INSERT TABLE 17 HERE]
Table 17. Cropland, water applied, income, cost, and net income

Crop production in California, Arizona, and Colorado produces 90% of the benefits from water use by using 85% of the water applied on 80% of the irrigated acreage. This shows that the benefit per acreage and benefit per unit of water used is greater in California, Arizona, and Colorado than in Utah, Wyoming, New Mexico, and Nevada. In particular, the economic value per cubic meter in California is more than double the value in other states, and benefits per acre display similar results. Arizona is the second state with the highest economic benefit per acre and per unit of water. Overall, the lower basin states produce greater benefits per input than the upper basin states.

Analyzing income and cost per unit of water used and land allows us to identify two states—Arizona and California—with the highest income and costs, and the second group is the rest of the states with the lowest income and costs. The cost of crop production in Arizona and California almost doubled and tripled the cost in the rest of the states but is offset by larger incomes.

Figure 14 shows the concentration curve of benefits by cropland acreage, and indicates the contribution of crops with the highest net income to the total benefit. The concentration curve is formed by ranking crop acreage by net income per acre, and accumulating the percentage of benefits and crop acreage over the total. The benefits that provide crops with higher net income per acre have a greater contribution and are accounted for.

[INSERT FIGURE 16 HERE]
Figure 14. Concentration curve of benefits by cropland acreage

The black line in Figure 14 provides the concentration of benefits at the basin level that can be easily highlighted, for example, 6% of cropland with the highest net income provides 40% of the total benefit. From another perspective, the figure can be interpreted in terms of cropland reduction, claiming, for example, that a reduction of 40% will produce a reduction in benefits of 10%. Both interpretations are not precise, since they assume that crop yields are constant instead of decreasing, underestimating the importance of the crops, or overestimating the impact of cropland reduction. In fact, less than 6% of the cropland acreage produces 40% of benefits, and the impact of a reduction of the 40% of cropland will be lower than 10%.

The diagonal line in Figure 14 represents the equal contribution of crop acreage to the total benefit; the curves closest to the diagonal show more equally distributed conditions. In the states with lower benefits, crop acreage contributes more equally to the regional benefit. By contrast, in Arizona and California, a relatively small percentage of cropland produces a relatively high percentage of the benefits. For instance, in Arizona, around 5% of cropland produces 30% of benefits, and in California, almost 20% of cropland produces 70% of the benefits. Cropping pattern, irrigation system technology, size of the irrigated area, and water use are examined at the irrigation unit level to determine the factors that characterize the benefits of water use.

Figure 15 shows crop acreage by irrigation unit and state. The number of irrigation units by state is heterogeneous, as well as the cropland. In the model, Colorado has the largest number of irrigation units, and Arizona and California have the biggest irrigation units, the Central Arizona Project (CAP) and Imperial Irrigation District (IID). Alfalfa and hay dominate the cropping pattern along the basin, and specialization is high for most irrigation units.

[INSERT FIGURE 15 HERE]
Figure 15. Cropland by irrigation unit and state

Figure 15 shows the percentage of cropland over the total irrigated area, coding the type of crop by color and the total irrigated area in descending order. Field crops are displayed in blue, turquoise is chosen for trees, and yellow for vegetables. Field crops cover the larger share of the area in almost all irrigation units, except for Coachella, and the Yuma and Gila Projects in Arizona, which combine large croplands of trees and vegetables.

Figure 16 compares the apparent productivity of land and water between irrigation units. The apparent productivity in Coachella, Yuma, and Gila is exceptionally higher compared with the rest of the irrigation units, especially for Coachella, where the productivity is almost an order of magnitude higher than in the irrigation units with lower productivity. The cropping pattern could explain the difference in the net revenue in Figure 17.

[INSERT FIGURES 16 AND 17 HERE]

Figure 16. Apparent productivity of land and water by irrigation unit

Figure 17. Crop pattern distribution as a percentage of the total acreage and total acre

Figure 18 presents the percentage of acreage that provides at least certain net income by irrigation district. Irrigation units are ordered from left to right and top to bottom by net income per acre in the irrigation unit. The irrigation unit with the higher net income per acre is Coachella, where 75% of the cropland area provides benefits greater than $2,000/acre. The Yuma Project provides around 30% benefits. In most of the irrigation units, the totality of the cropland area provides benefits lower than $1,000/acre. In Coachella cropping patterns provide a benefit greater than $5,000/acre. This suggests the existence of at least two groups of irrigation units—one group with production-oriented to high-value crops and another group with low-value crops.

[INSERT FIGURE 18 HERE]

Figure 18. Net income per acre and percentage of crop acreage over the total irrigated area by irrigation district

Several factors explain differences in net income, but crop pattern is a major contributor. Irrigation units that produce trees and vegetables have a higher benefit per unit of land and water. Another factor that could explain the differences of net income per unit of land and water between the irrigation units is the size, assuming the larger irrigation units have advantage over smaller ones. However, after analyzing the relationship between income per acre and total number of acres, and the relationship between income per cubic meter and total volume of water delivered, with a simple regression, there is no evidence of the contribution of size to net income.

Irrigation technology is a factor that characterizes irrigation units, and it is expected that drip irrigation is installed in vegetables crops and trees, and sprinkler is used for field crops. Flood irrigation has lowest irrigation efficiency and is employed for all types of crops. Figure 19 shows the percentage of irrigation technology in each irrigation unit. Irrigation units with a production oriented to vegetables and trees have a higher share of drip irrigation. Irrigation units that produce field crops combines flood and sprinkler, and they don't show a clear predominant pattern of irrigation system technology, and the degree of technification changes between irrigation units.

[INSERT FIGURE 19 HERE]

Figure 19. Percentage of irrigation technology availability over total cropland by irrigation districts

To identify the importance of the cropping pattern and irrigation technology in determining the net income, the irrigation units can be classified into clusters by a regression tree. The algorithm creates groups of irrigation units by splitting the sample with the criterion of minimizing the predicted error of an OLS of each group. The dependent variable is the net income per acre of the irrigation unit, and the independent variables are the percentage of field crops, vegetables, and trees over the total land acreage and the percentage of flood, sprinkler, and drip irrigation systems over the total. The minimum size of the cluster is five irrigation units. Results should be interpreted with caution as the size of the sample is small. The results contribute to the identification of the factors that distinguish between differences in irrigation units.

Figure 20 shows the clusters found with the regression tree algorithm. The percentage of field crops in the total irrigated area is the variable that divides the irrigation units into two big groups: irrigation units with more than 53% of field crops, and irrigation units with less. The group with around 47% of the cropland covered by vegetables and trees has an expected income of $2,780/acre, and the group highly specialized in field crops has an expected income ranging between $320/acre and $935/acre.

[INSERT FIGURE 20 HERE]

Figure 20. Groups of irrigation units in terms of crop type and irrigation unit

Those irrigation units highly specialized in field crops can reserve a percentage of vegetables and trees having a higher net income. If 10% of the irrigation unit is covered by trees and vegetables, the expected net income can reach $935/acre, but if it is covered by 5%, the income falls to $590/acre.

Irrigation technology also explains the differences between irrigation units specializing in field crops. Low technological irrigation units with 38% of sprinkler irrigation systems have around $200/acre (520–315), less than those that have installed sprinkler irrigation. In addition, irrigation units without irrigation system technology have lower net income per acre. In summary, crop type is the main factor that characterizes irrigation units, and between those oriented to field crop production, irrigation technology is a factor that contributes to higher net income.

7.2. Urban

The model includes 33 million inhabitants distributed in 379 urban centers across the seven states in the CRB. Table 18 shows the main variables included in the urban sector water use: number of cities, inhabitants, water use, and benefit from urban water use by state. The social welfare of urban water use exceeds $18 billion. More than half of the population and urban water users are in California and provide 73% of the total social welfare in the basin. It is important to emphasize the contribution of New Mexico, with 3% of water use providing 4% of the welfare. On the other hand, the value of urban water use in Utah is lowest in the basin. Water price is the main factor to explain the relative economic value of water use in urban centers.

[INSERT TABLE 18 HERE]

Table 18. Number of cities, population, urban water use, and benefits by state

7.3. Hydropower

The eight hydropower plants included in the HEM-CRB generate 10,200 GWh/year with a value of $874 million. Lakes Powell, Mead, and Mohave contribute 84% of the benefits of hydropower production because of the capacity size of the hydropower plants. Electricity generation by hydropower plants reduce the emissions of CO2 equivalent to 12,300 million pounds (Table 19).

[INSERT TABLE 19 HERE]

Table 19. Hydropower production, income, cost, and benefits and avoid emissions from hydropower

7.4. Summary the Results

Table 20 shows a summary by state and basin level of the results of crop production, urban water use, and hydropower production. Benefits from water use reached $20.6 billion, mainly from urban use, which provides 89% of the total benefits. Total water use is 11,000 $Hm^{3,}$ and agriculture is the largest user of water at 85%. California contributes 67% of the total benefits. The largest population and higher price of water for urban water use led to greater benefits of urban water use in California.

[INSERT TABLE 20 HERE]

Table 20. Summary of cropland, water use, and benefits of urban, agricultural, and hydropower sectors by state and basin

Nearly 7% of the benefits in the basin are provided by agricultural water use. Water use is different between the Upper and Lower Basin: The Lower Basin is characterized by a pattern of high-value crops, such as trees and vegetables; the Upper Basin produces field crops with a low economic value. Coachella ID provides a greater benefit per acre than the rest of irrigation units in the basin because of the crop distribution, which is characterized by trees and vegetable crops. The presence of high-value crops in the irrigation districts boosts the contribution of California to the total basin benefits.

Electricity generation provides around 4% of total benefits in the basin. Lakes Mead and Mohave are at the border between Arizona and Nevada, and Lake Havasu is at the border between Arizona and California. The attribution of the hydropower production in those cases is equally distributed between states. Since Lakes Mead and Mohave have the largest hydropower production plants, Arizona contributes 61% of the benefits provided by the hydropower production.

7.5. Results from River Calibration

Calibration of the river of the hydrological network is carried out with data from the gauging stations, and with slack variables that consider the unmeasured water inflows and water uses. The model is constrained to replicate the flows in the observed gauges, which allows it to find the unmeasured water inflows and water uses. Once the unmeasured variables are found, they are fixed, and the nodes with observations are released from the restriction. A good performance of river calibration requires that the simulated variables replicate the observed variables. The absolute value of the deviation, as difference and percentage, between the observed and simulated variables is analyzed to evaluate the performance of the calibration. HEC-CRB uses monthly average water inflows from 105 stations to calibrate the river of the hydrological network. The average difference in absolute values is 3,000 acre-feet per month, and in percentage, there is an 18% error between observed and simulated.

Nevertheless, in around 90% of the months, the error is minor at 5%, but in some locations for some months the performance of the calibration is compromised. One of the main factors of the error arises from the limitations of the model to incorporate the operation rules in dams, which are included by upper and lower bounds. The second factor is the HEM-CRB maximizes the hydropower production without attending to alternative objectives. The water flows observed in the river used for river calibration are presented in Table A12.

8. Concluding Remarks and Future Work

The HEM-CRB stands as a versatile tool poised to address the various concerns within the CRB, offering insights into the intricacies of water policies and evaluating the concomitant trade-offs. Of paramount significance is the pressing issue arising from the interplay between population growth and the looming occurrence of climate change, which jointly amplify existing water scarcity challenges, thereby imperiling the CRB's sustainability. In this context, effective water management mandates the identification of mechanisms that not only foster the water system's sustainability but also mitigate unintended repercussions stemming from the interplay between beneficiaries and those impacted adversely.

Under the prevailing climatic conditions, the HEC-CRB model assumes a pivotal role in assessing both the present and alternative water allocation regulations. This encompasses pivotal aspects like inter-sectoral and inter-regional water trading, potential alterations to the Law of the River, leasing of water rights granted to tribes, allocations dedicated to environmental preservation, and the resolution of social-planner policies. Through these simulations, we aim to unravel the intricate web of trade-offs and ripple effects inherent in water allocations—barriers that often thwart the attainment of water management objectives encompassing efficiency, equity, and sustainability.

Embarking on the next stage, we extend our policy simulations to encompass the dynamic of altered climatic conditions. By infusing climate change projections and population growth dynamics, we intend to gauge the ramifications of diminishing water supply alongside expanding water demand, all within the context of diverse policy scenarios. This robust spectrum of scenarios serves as a vantage point for assessing the potential vulnerabilities stemming from climate change.

Acknowledging the role of institutions in mitigating inter-regional and inter-sectoral water conflicts, we delve into decision-making that integrates divergent interests. This cooperative endeavor necessitates a foundation of collaboration to underscore the efficacy of agreements. As part of this exploration, scenarios spanning cooperation and non-cooperation among regions and sectors will be crafted, thereby gauging the efficacy of negotiation strategies. The subsequent identification of potential coalitions holds the potential to furnish insight into the bedrock of successful negotiations.

Furthermore, recognizing the transformative potential of technological shifts within the agricultural sector, we explore their capacity to alleviate water scarcity within urban hubs.

The HEC-CRB model assumes the mantle of assessing compensation mechanisms that bridge the divide between urban and agricultural water users, thereby facilitating efficiency enhancements. However, the intricate interplay between technological changes and unintended consequences mandates careful consideration. While technological advancements can spur increased water use, inadvertently jeopardizing water availability for alternative applications, such as environmental preservation, our model strives to ascertain configurations that concurrently empower urban water use expansion, safeguard ecosystems, and stave off agricultural water scarcity risks.

In summary, the HEM-CRB model emerges as a dynamic and indispensable instrument for understanding, navigating, and mitigating the complex challenges intertwined with water management in the CRB. Its holistic approach spans diverse scenarios, encapsulating policy, climate change, cooperation dynamics, and technological transformations—laying the groundwork for informed decision-making and sustainable resource allocation.

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10. Figures and Tables

Figure 1. Modeling framework of the hydro-economic model

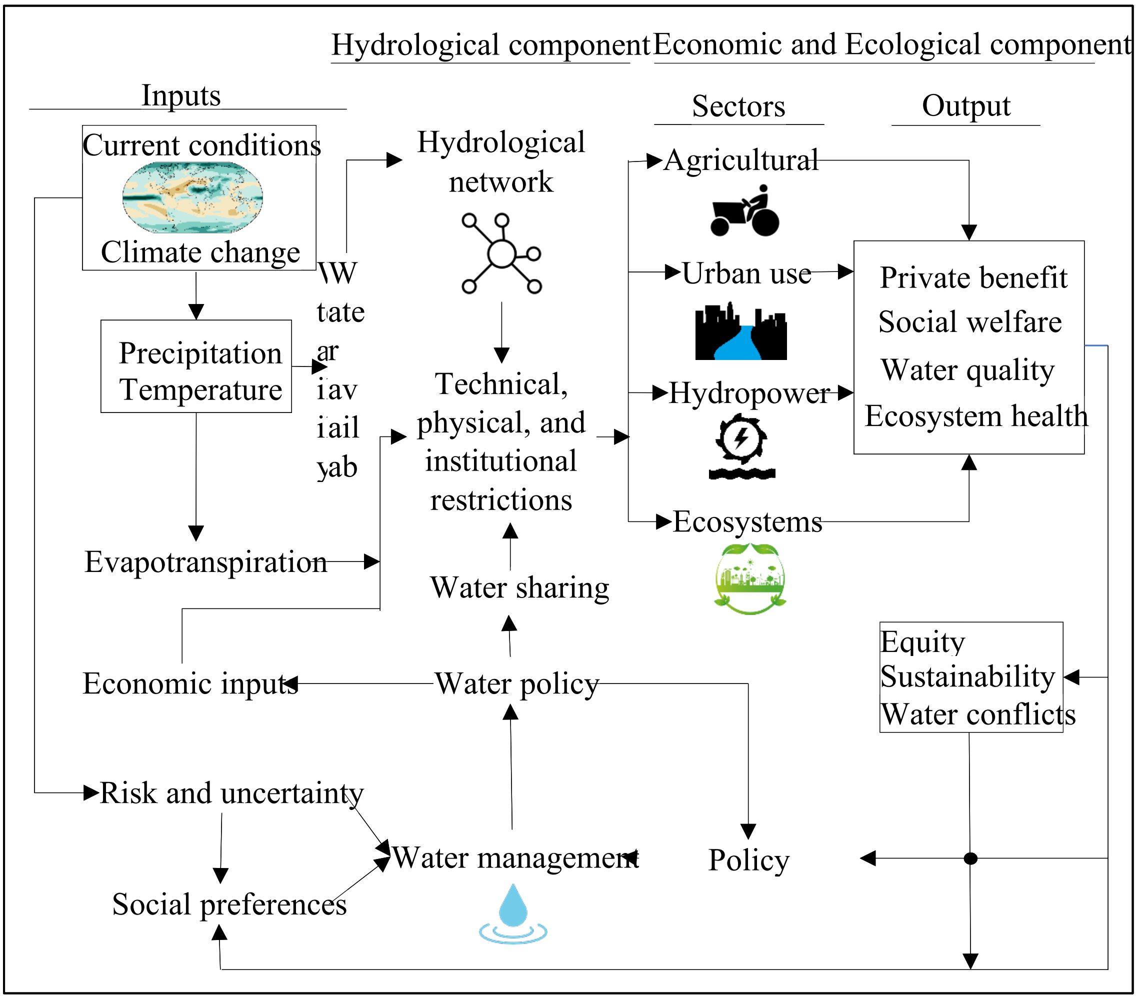


Figure 2. Colorado River Basin, water users and administrative division

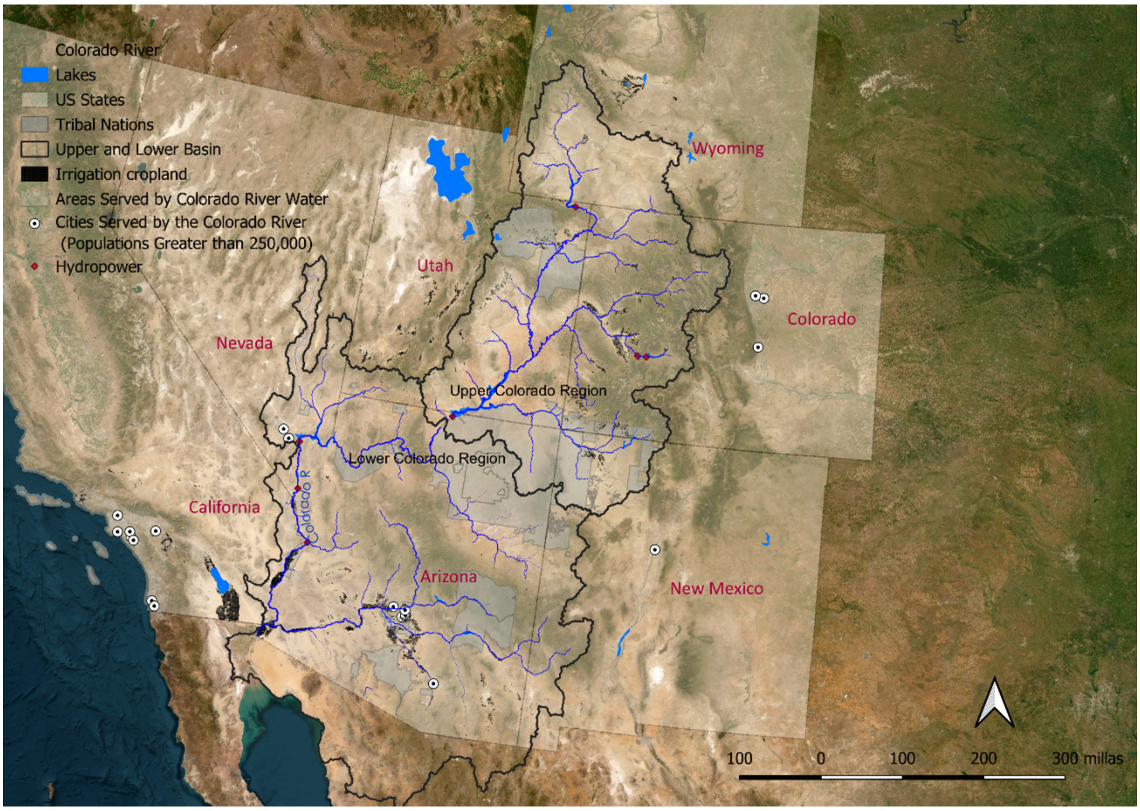


Figure 3. Natural flow (1906-2021) in the Colorado River above All American Canal (USBR, 2023a)

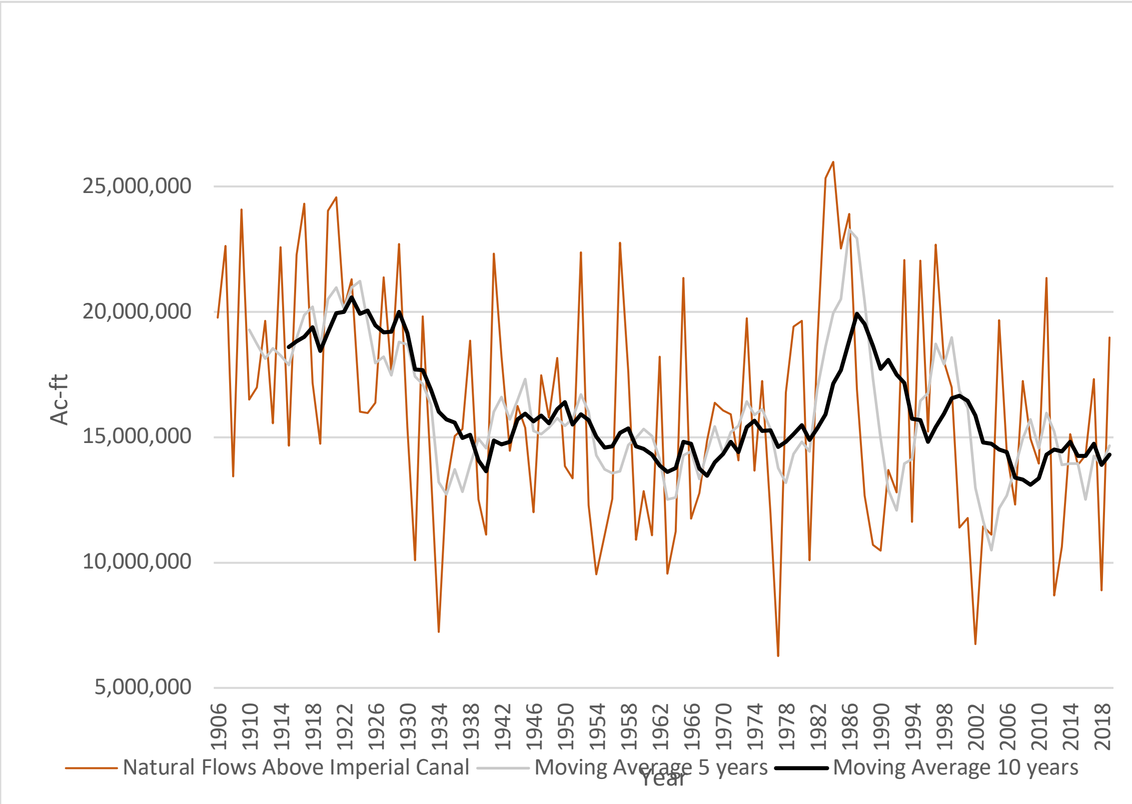
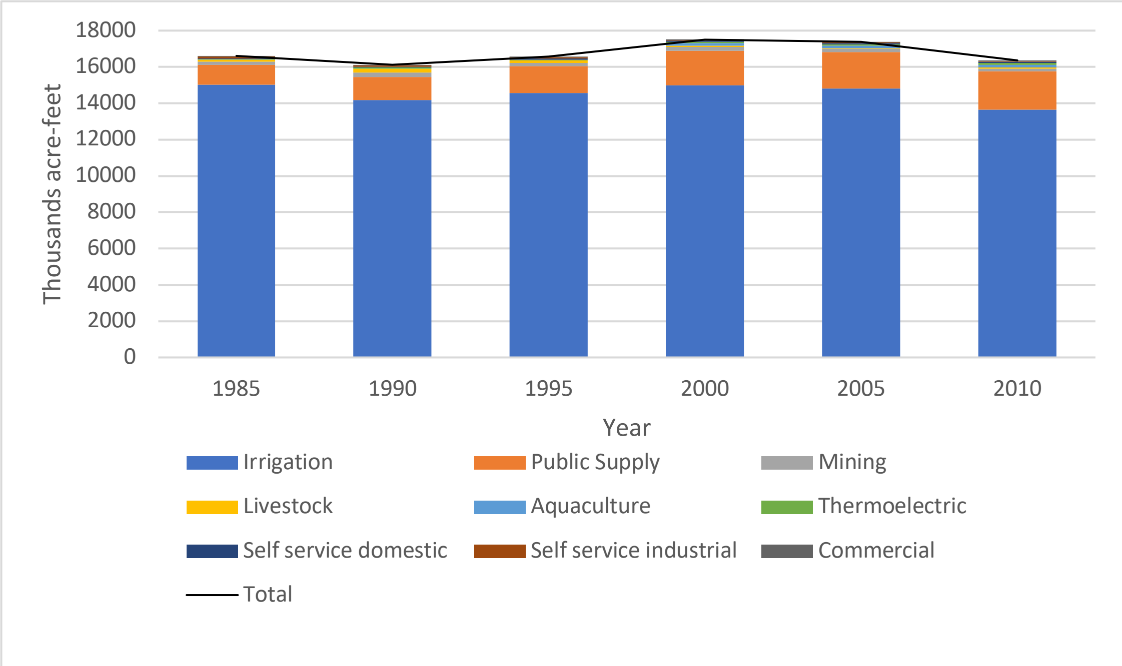


Figure 4. Water withdraws by sector between 1985 and 2015 (USGS 2018)



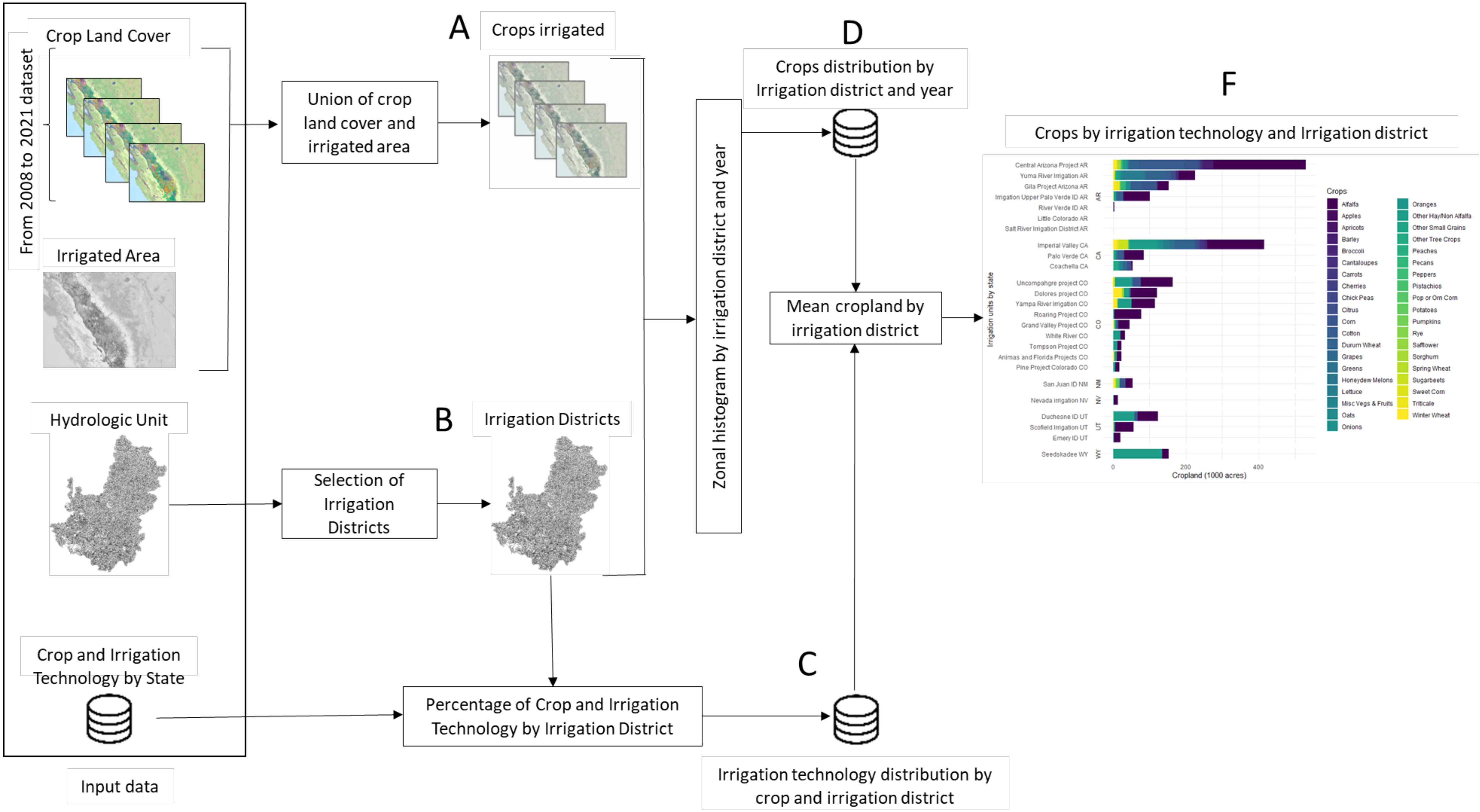


Figure 5. Crop and Irrigation data source and transformation process

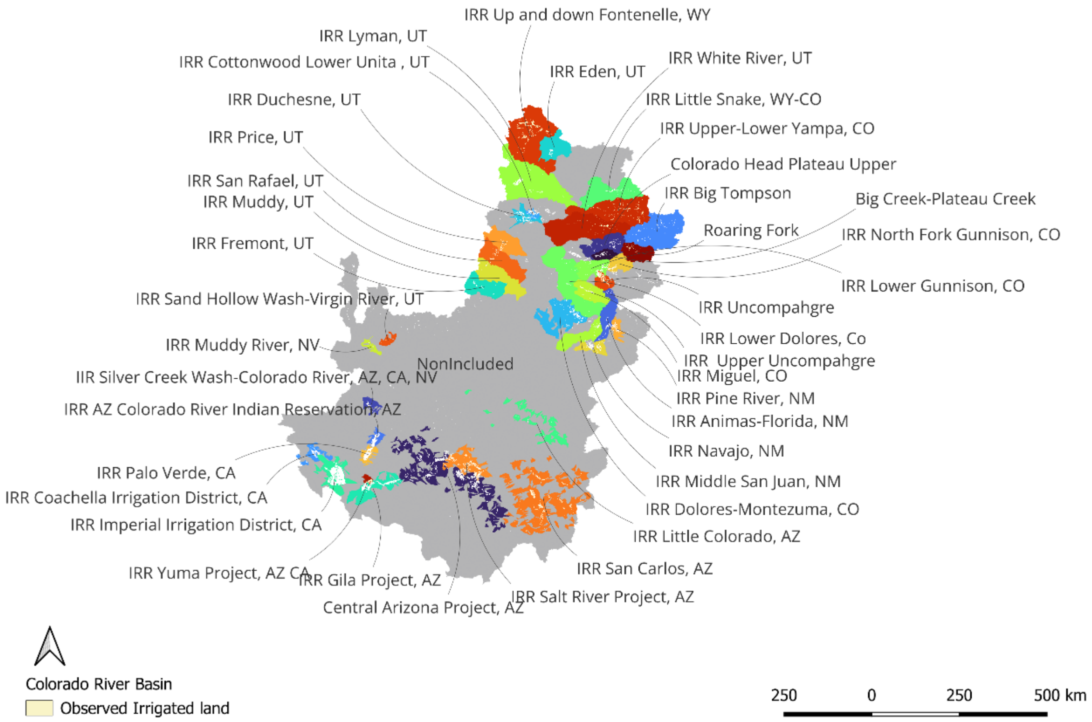


Figure 6. Map of irrigation units of the HEM-CRB

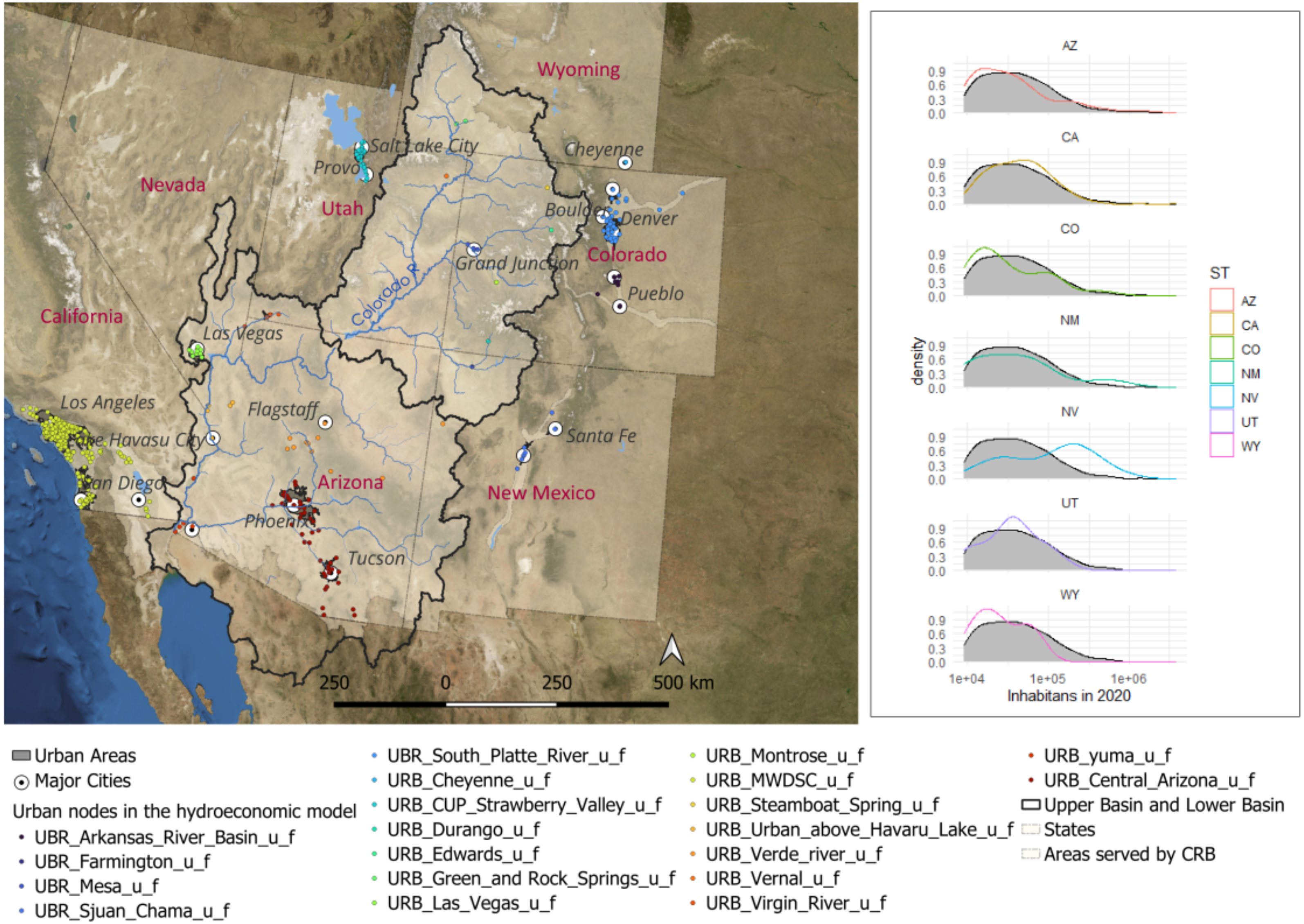


Figure 7. Urban centers in the Colorado River Basin and population density

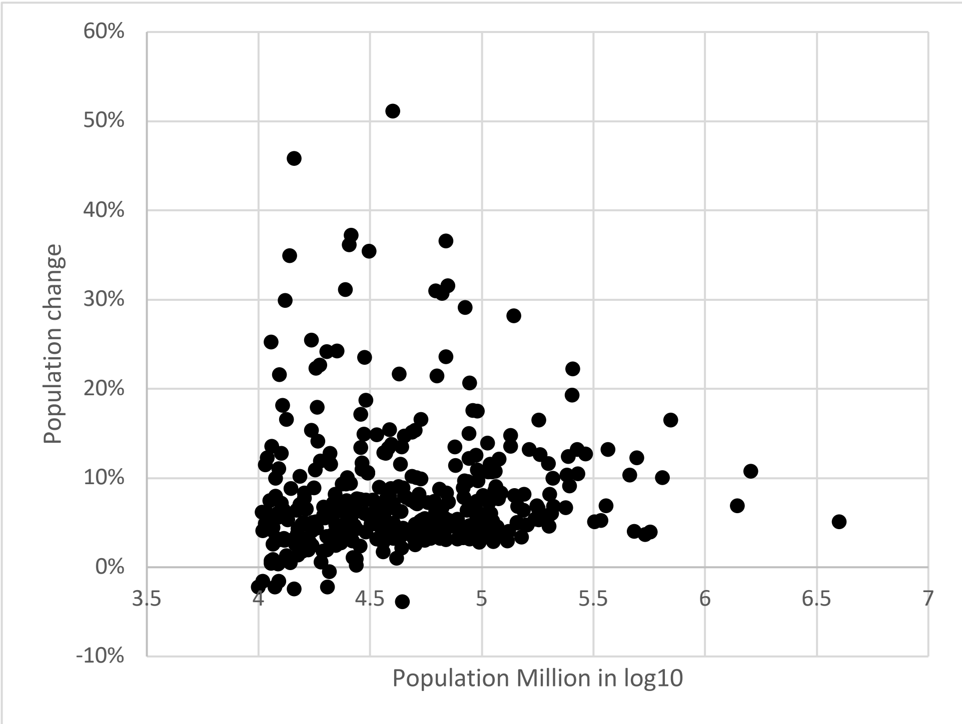


Figure 8. Population growth and population size of the cities included in the HEM

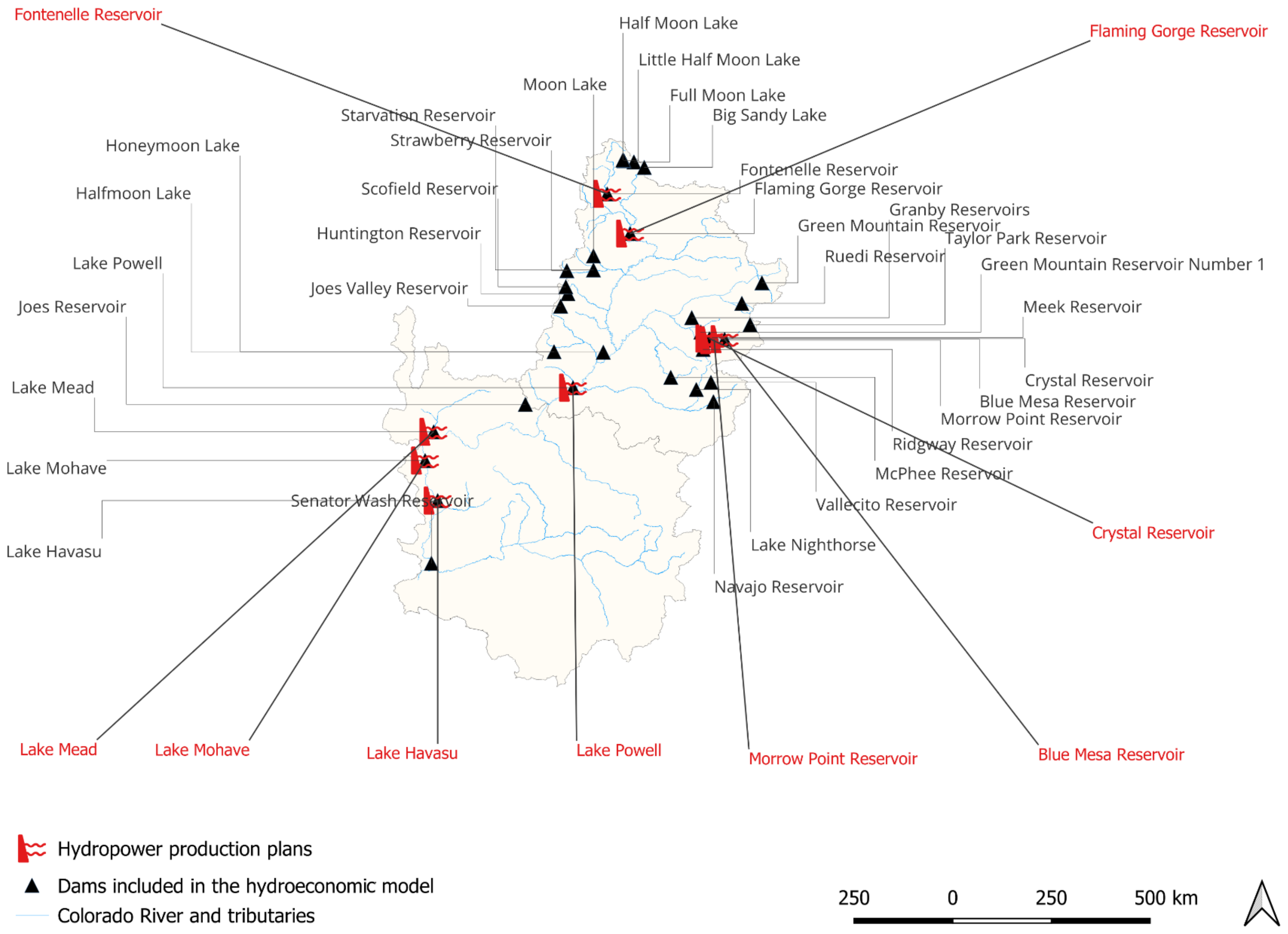


Figure 9. Hydropower production and dams of the CRB included in the HEM

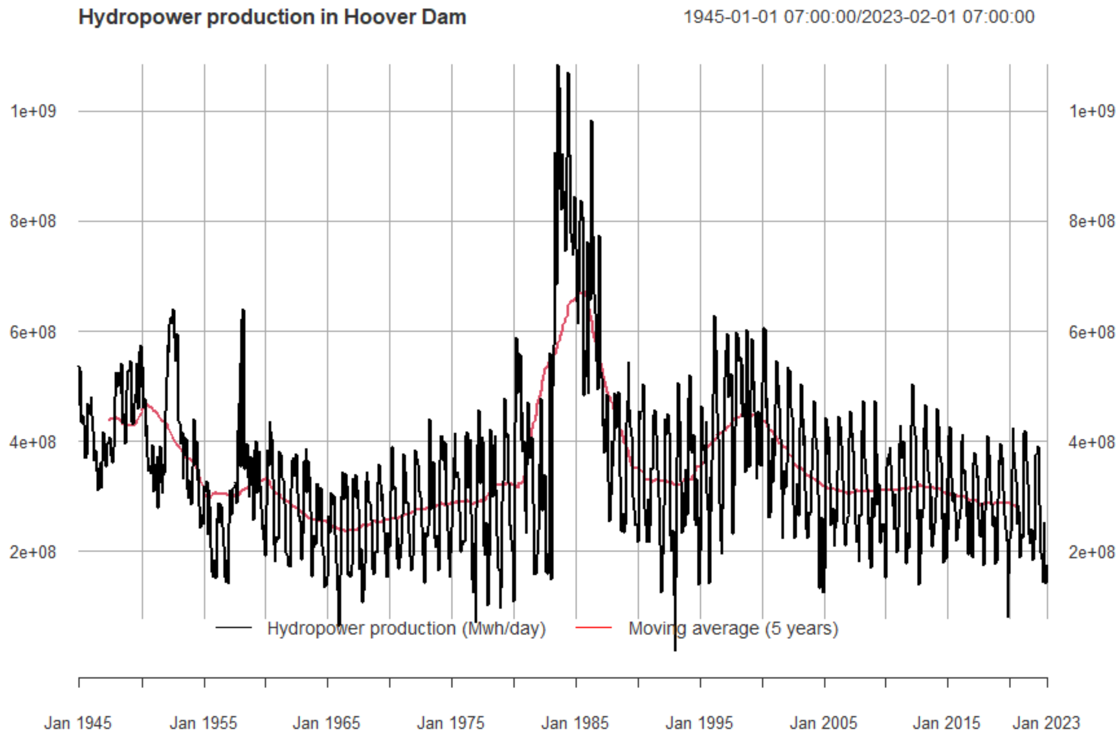
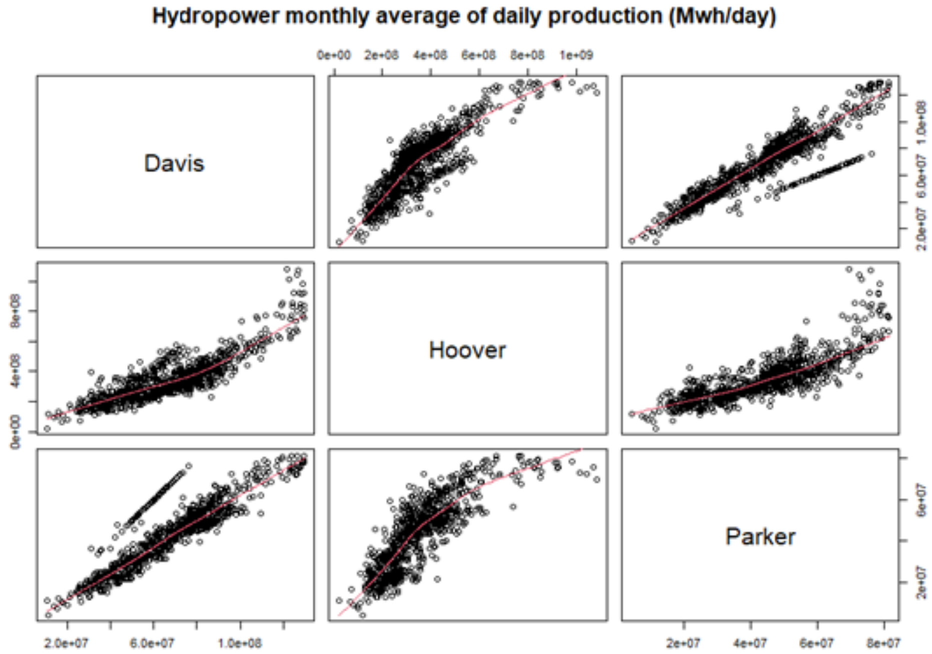


Figure 10. Hydropower production in the Hoover Dam

Figure 11. Hydropower production relationship for the Davis, Hoover, and Parker dams



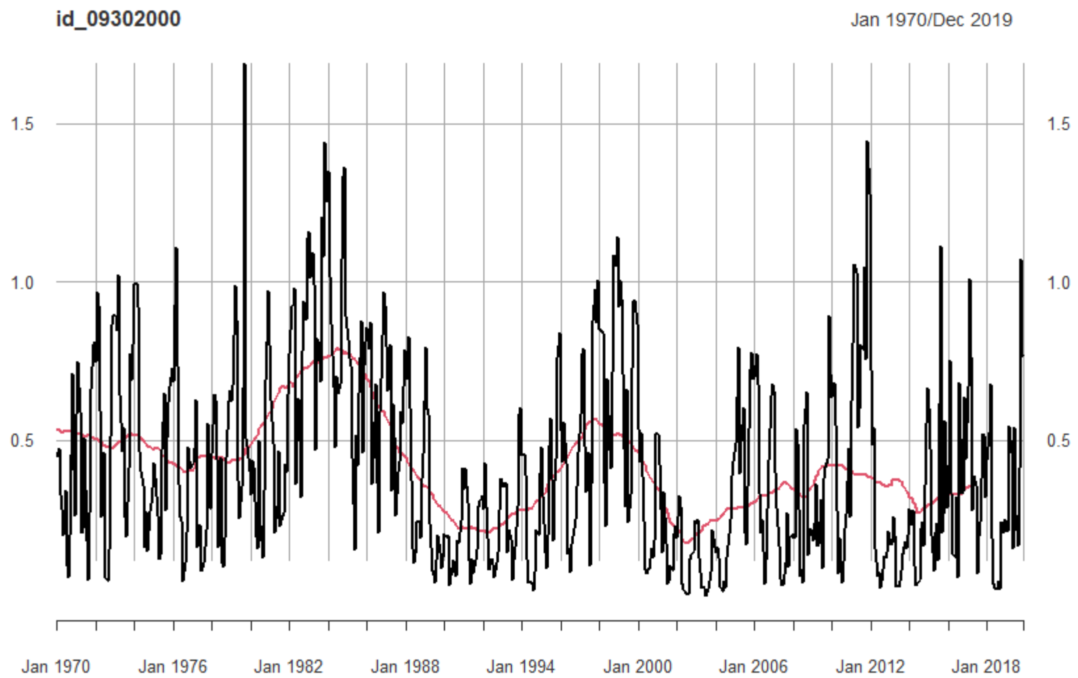


Figure 12. Ratio between affected flow and natural flows at Duchesne River near Randlett, UT (USGS site: 09302000). Moving average in red.

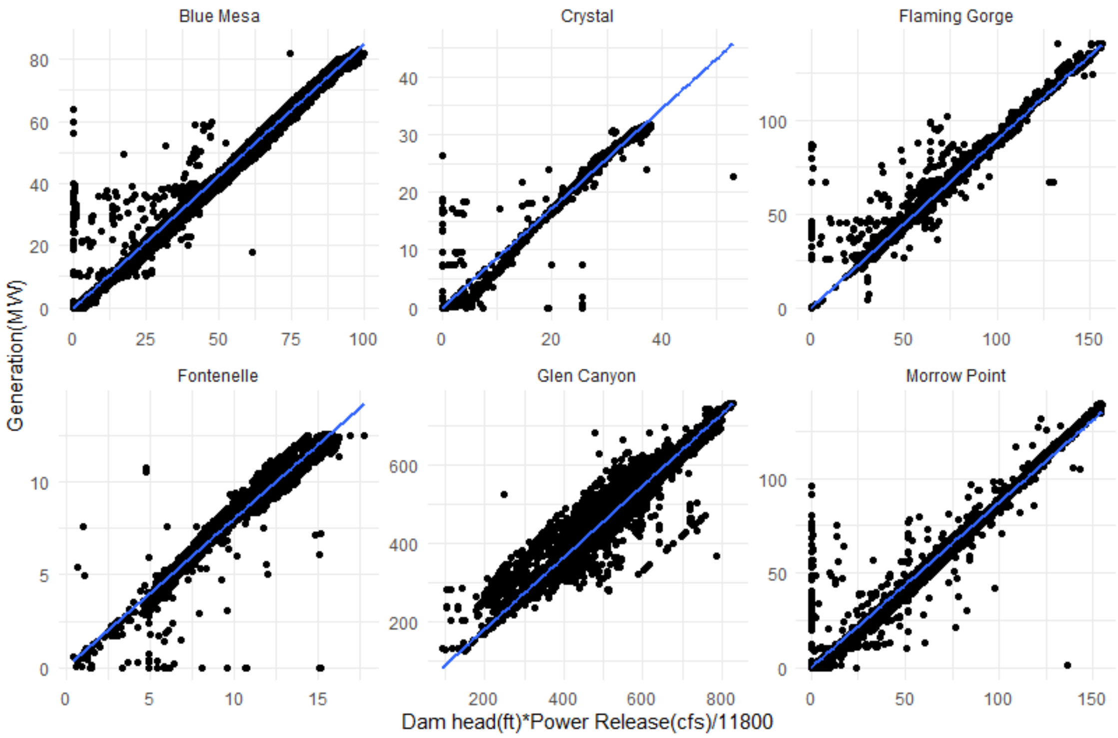


Figure 13. Observed and theoretical hydropower production and fitted relationship (in blue)

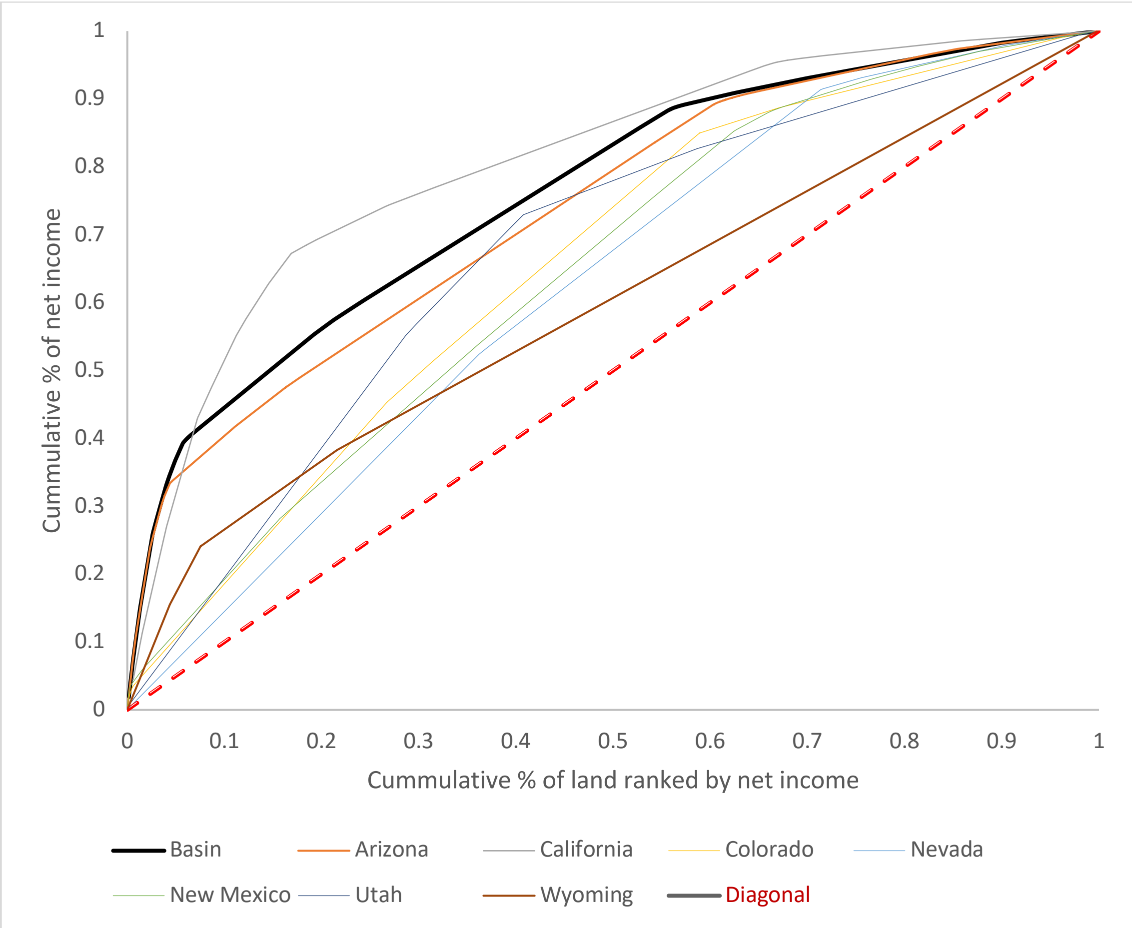


Figure 14. Concentration curve of benefits by cropland acreage

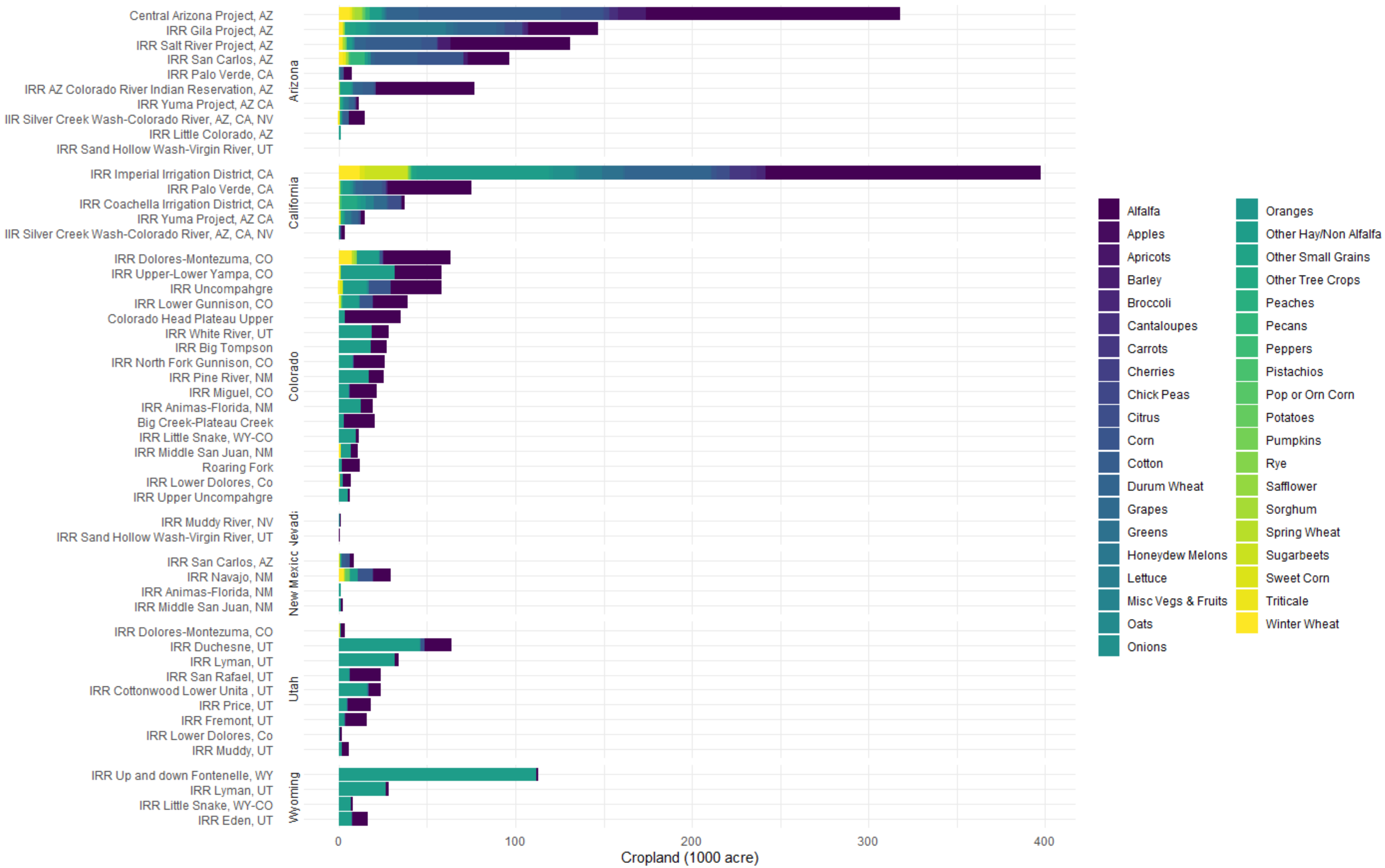


Figure 15. Cropland by irrigation unit and state

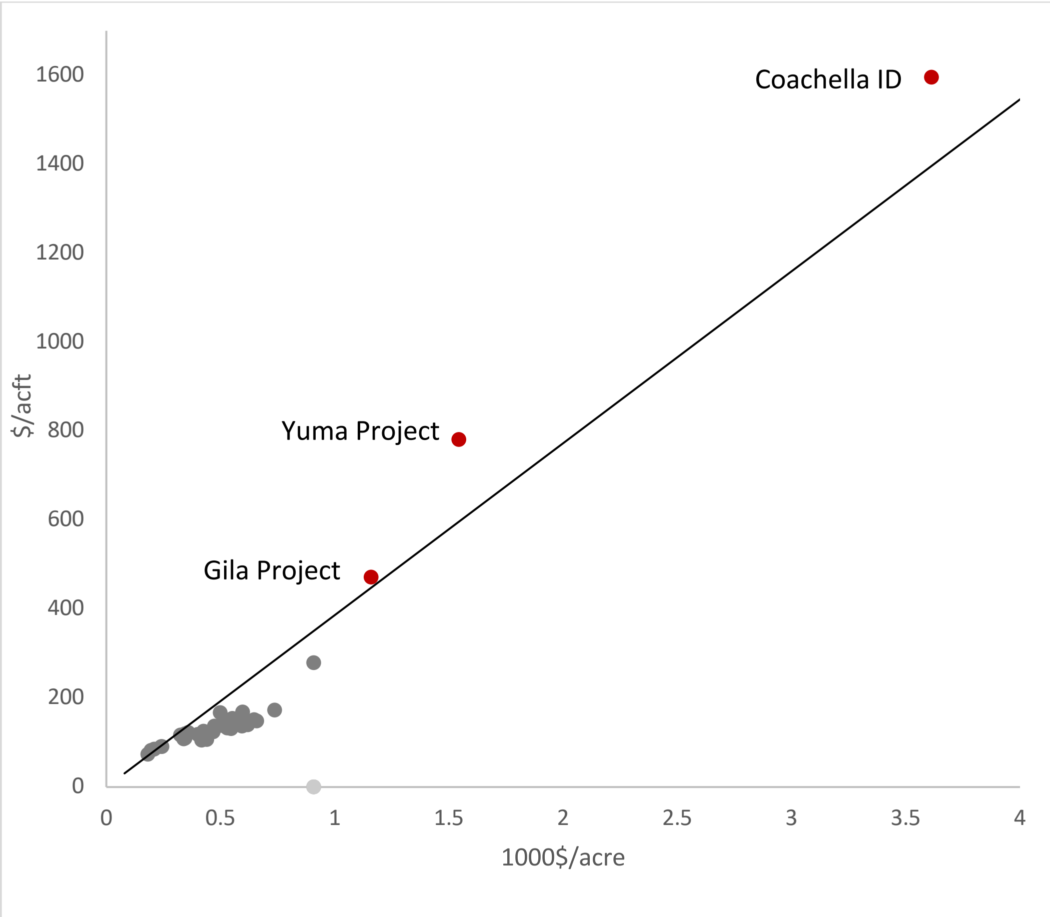


Figure 16 Apparent productivity of land and water by irrigation unit

Figure 17. Cropping pattern distribution as percentage of the total acreage and total acre

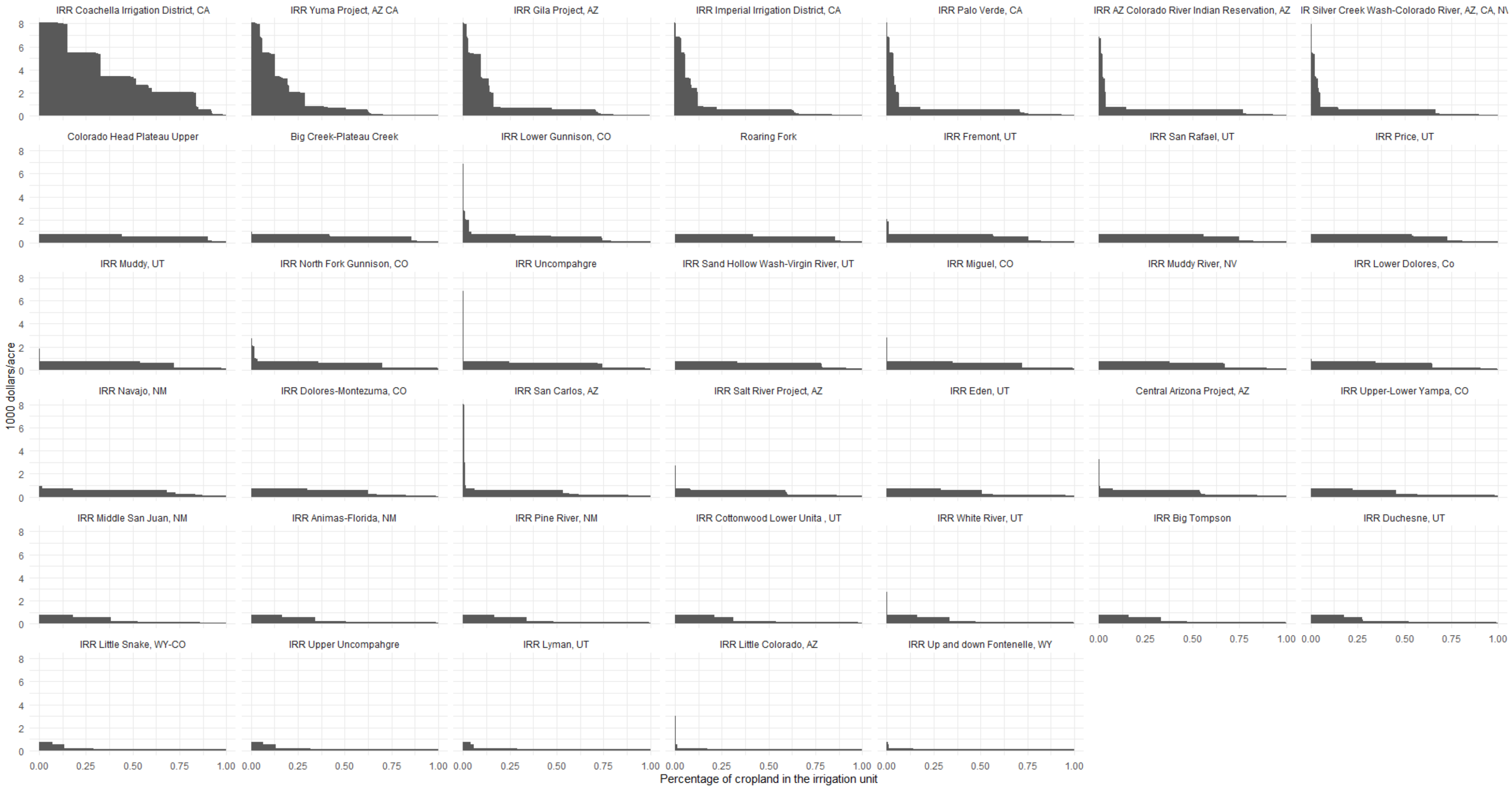


Figure 18. Net income per acre and percentage of crop acreage over the total irrigated area by irrigation district

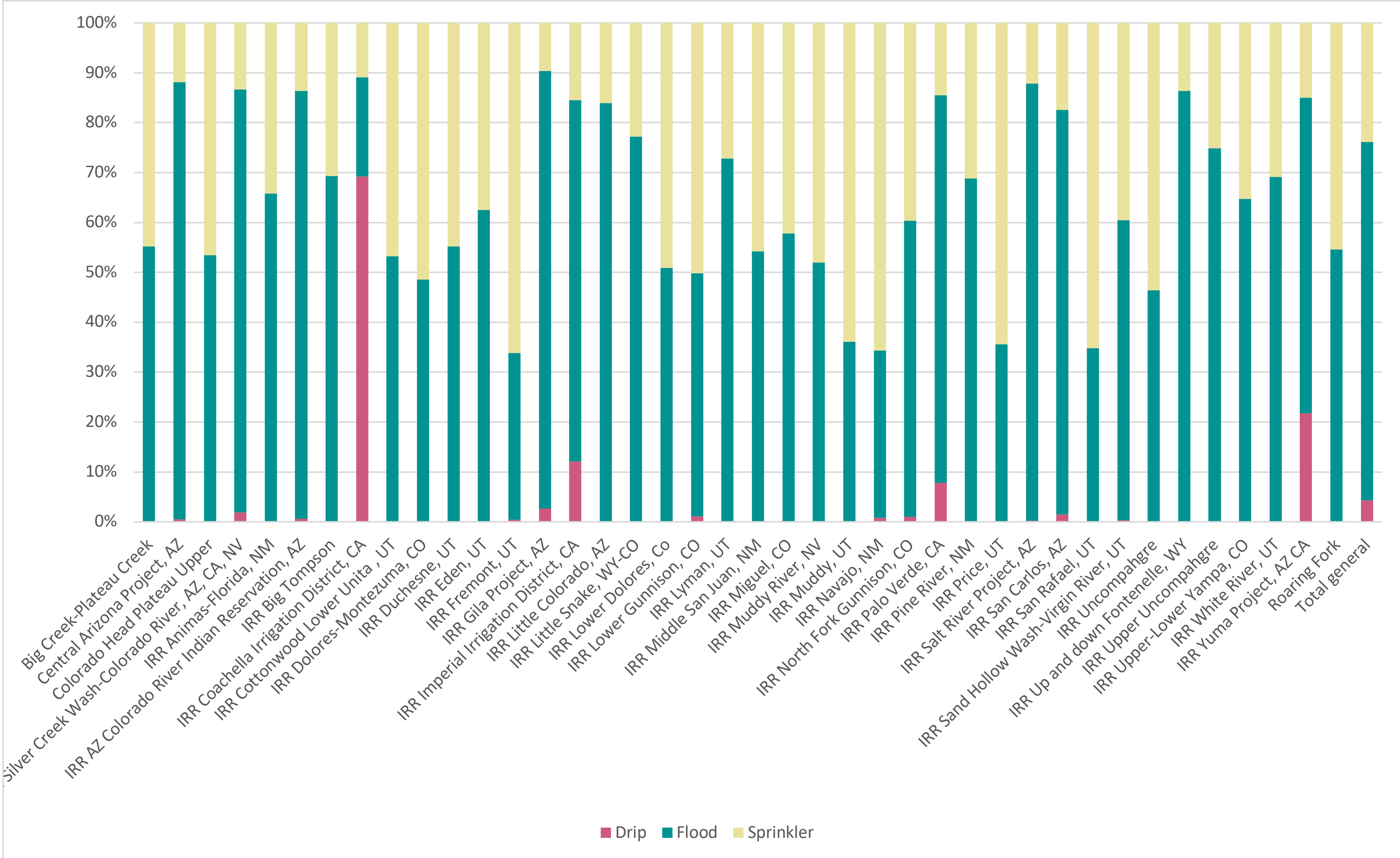


Figure 19. Percentage of irrigation technology availability over total cropland by irrigation districts

Figure 20. Groups of irrigation units in terms of crop type and irrigation unit

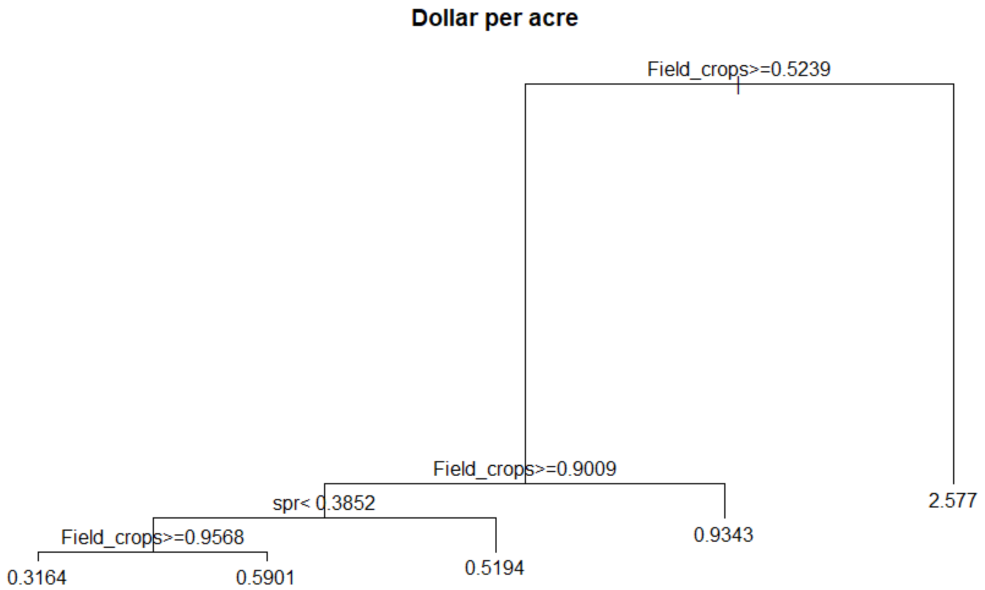


Table 1. Federal Indian tribe reserves' water rights, unresolved claims, and depletion (maf)

State	Partnership Tribe	Reserved Diversion Right	Unresolved Diversion Claim	Current Depletion
Arizona	Navajo Nation, Fort Mojave Indian Tribe, Colorado River Indian Tribes, Quechan Indian Tribe, and Cocopah Indian Tribe	0.78	0.10	0.45
California	Fort Mojave Indian Tribe, Colorado River Indian Tribes, Quechan Indian Tribe, and Chemehuevi Indian Tribe	0.16	-	0.05
Colorado	Ute Mountain Ute Tribe and Southern Ute Indian Tribe	0.23	-	0.04
New Mexico	Jicarilla Apache Nation and Navajo Nation	0.65	-	0.22
Nevada	Fort Mojave Indian Tribe	0.013	-	0.003
Utah	Ute Indian Tribe and Navajo Nation	0.18	0.69	0.14
Total		2.013	0.79	0.9

Notes: The authors calculated the total of reserved rights, claims, and depletion for each state using the data obtained from (USBR, 2018).

Table 2. Total withdrawals for selected water-use – Colorado River Basin states, 2015

	Arizona	California	Colorado	New Mexico	Nevada	Utah	Wyoming
Population (mm)	6.83	39.2	5.5	2.1	2.9	3	0.6
Sectoral withdrawals from all sources (maf)[a]							
Municipal	2.44	9.52	1.7	0.48	1	1.27	0.22
Agricultural	5.16	22.28	10.41	2.72	2.36	3.5	8.77
Industrial	0.18	4.02	0.17	0.21	0.33	0.52	0.23
Total	7.78	35.82	12.28	3.41	3.69	5.29	9.22
Total withdrawals from Colorado River Basin, (maf)[b]							
Diversion	3.43	5.16	N/A	N/A	0.45	N/A	N/A
Depletion	2.63	4.62	1.64	0.39	0.22	0.76	0.35

Notes: Calculated by authors. Note that we did not include environmental water use in this table. For California, environmental water use in 2015 was about 38.3 maf. Depletion refers to consumptive use in this table. [a] See (Dieter et al., 2018) for more details. [b] Data for Upper Basin states is obtained from USBR, 2019 and for Lower Basin states from USBR, 2022. Note that we were not able to find reliable information on diversion amounts for Upper Basin states.

Table 3. Table 3. Summary and description of sets, variables and parameters included in the HEM-CRB

Set			
i	Set of all water flows included in the river		
Subset of i			
	h	Set of head flows	
	v	Set of the river gauge	
	d	Set of water flows diverted	
	rc	Set of water flows that return by channels	
	rp	Set of the water flows that return from parcel level	
	nd	Set of water flows that are net diverted	
	a	Set for applied water	
	rel	Release of water	
	evp	Water evaporation	
u	Set of all water users		
Subset of u			
	ag	Agricultural users	
	urb	Urban users	
	hpw	Hydropower production users	
j	Set of crops		
Subset of j			
	per	Set of perineal crops	
k	Set of irrigation technologies		
t	Time (months): {1,2,…,360}		
m	Month:{1,2,..,12}		
y	Year:{1,2,…,30}		
s	Set of all water storage		
Subset of s			
	res	Reservoir	
Variable	**Description**	**Units**	**Bounds**
X_i	Water flows in the system	Thousands of acre-feet per month	Real
Z_s	Water storage in dams	Thousands of acre-feet per month	No negative
$X_{h,t}$	Headwater inflow	Thousands of acre-feet per month	No negative

$X_{v,t}$	Water flow at river gauge, v	Thousands of acre-feet per month	No negative
$X_{d,t}$	Water diversions	Thousands of acre-feet per month	No negative
$X_{rc,t}$	Return canal flows	Thousands of acre-feet per month	No negative
$X_{rp,t}$	Returns flows from irrigation districts and urban centers to the river	Thousands of acre-feet per month	No negative
$X_{nd,t}$	Water net diverted $X_{nd,t}$	Thousands of acre-feet per month	No negative
$X_{a,t}$	Water flow that reaches the irrigation districts and urban centers and accounts losses by evaporation in channels	Thousands of acre-feet per month	No negative
$X_{a,t}^{ag}$	Water applied $X_{a,t}^{ag}$ in an irrigation district	Thousands of acre-feet per month	No negative
$X_{u,t}^{ag}$	Water used in the irrigation district (total evapotranspiration)	Thousands of acre-feet per month	No negative
$X_{rp,t}^{ag}$	Total amount of water that returns to the river from irrigation districts	Thousands of acre-feet per month	No negative

$L_{u,j,k,t}$	Cropland of j under the technology k	Thousands of acres per year	No negative
$X_{a,t}^{urb}$	Water applied in urban centers	Thousands of acres per year	No negative
$X_{u,t}^{urb}$	Water use in urban center	Thousands of acres per year	No negative
$X_{rp,t}^{urb}$	Return flows from urban center to the river	Thousands of acres per year	No negative
$Z_{res,t}$	Water storage in reservoirs	Thousands of acres	No negative
$X_{rel,t}^{res}$	Water release from reservoirs	Thousands Acre-feet per month	Real
$X_{evp,t}^{res}$	Water evaporated from reservoir	Thousands of acre-feet per month	No negative
$A_{res,t}$	Reservoir area	Thousands of acres per month	No negative
$\Pi_{u,y}^{ag}$	Benefits from crop production by the water user u in year y	Millions of dollars per year	Positive
$Y_{u,j,k,y}$	Yield production of the crop j in the irrigation district u under the irrigation technology	Ton per acre per year	No negative
$L_{u,j,k,y}$	Cropland of j in the irrigation district u under the irrigation technology k and year y	Thousands of acres per year	No negative
$\Pi_{u,y}^{URB}$	Benefits of urban water use	Millions of	Positive

		dollars per year			
$X_{du,y}$	Water demand by urban centers	Thousands of acre-feet per year	No negative		
$X_{su,y}$	Water supply in urban centers	Thousands of acre-feet per year	No negative		
X_{pc}	Water use per-capita	Thousands of acre-feet per year	No negative		
$\Pi_{res,y}^{hpw}$	Benefits from hydropower production in the reservoir res	Millions of dollars per year	Positive		
$E_{res,m,y}$	Electricity production	Megawatt hour per month	Positive		
$H_{res,m,y}$	Height of the dam	Feet	Positive		
$X_{res,m,y}^{hpw}$	Water used by hydropower production	Thousands of acre-feet per month	No negative		
NPV	Net present value	Millions of dollars per year	Positive		
Parameters	**Description**	**Value**	**Units**	**Comments**	**Values**
$source_{h,t}$	Source of the surface water in the system	No negative	Acre-feet month		Table A6
$B_{i,v}$	Matrix that connects $X_{v,t}$ to $X_{i,t}$ in the river	{-1,0,1}	Dimensionless	Minus one indicates water extraction, zero no relationship between two nodes and one means that the node upstream contributes	Repository on Website

				with a water flow	
$B_{rc,d}$	Proportion of water that returns over the water diverted	[0,1)	Dimensionless		0.2 by default
$B_{nd,d}$	Proportion of water that is net diverted over the water that is diverted	(0,1]	Dimensionless		0.8 by default
$B_{d,i}$	Matrix that determines water availability for diversion	{0,1}	Dimensionless		Website repository
$Ba_{u,j,k}$	Water applied to the crop j in the irrigation district u and the irrigation technology k	Positive	Acre-feet per acre	Represent the irrigation requirements of crops. Irrigation efficiency {flood: 0.6; sprinkle: 0.8; drip:0.9}	Table 6, table A5
$Bu_{u,j,k}$	Water used by the crop j in the irrigation district u under the irrigation technology k	Positive	Acre-feet per acre	This parameter represents crop evapotranspiration. Irrigation efficiency {flood: 0.6; sprinkle: 0.8; drip:0.9}	Table 6, table A5
$Brp_{u,j,k}$	Returns flows by the crop j in the irrigation district u under the irrigation technology k	Positive	Acre-feet per acre	This parameter represents the water that returns to river in form of percolation after of irrigation. Irrigation efficiency {flood: 0.6; sprinkle: 0.8; drip:0.9}	Table 6, table A5

P_j	Price of the crop j	Positive	Millions of dollars per thousand of acre		Table 6
$PC_{u,j,k}$	Cost of crop production excluding water costs	Positive	Millions of dollars per thousand of acre		Table 6
$WC_{u,j,k}$	Cost of water	Positive	Million of dollars per thousand of acre-feet		Table 6
$\overline{L_u}$	Restriction of the total land availability in the irrigation district	No negative	Thousands of acres	The restriction of total cropland can change according to the policy	Table A11
$\overline{X_{u,m,y}}$	Restriction of total water availability during the month m in the water user u	No negative	Thousands of acres	This restriction can change according to the policy	Scenario depending (no settled in base run scenario)
$\overline{X_{u,y}}$	Annual water availability in the water user u	No negative	Thousands of acres	This restriction can change according to the policy	Scenario depending (no settled in base run scenario)
$B_{a,u}$	Indicator matrix that connects water apply and water use in urban centers	{0,1}	Dimensionless		Repository on Website
$B_{rp,u}$	Indicator matrix for urban water users	{0,1}	Dimensionless		Repository on Website
$\alpha_{0,m}^{res}$	Intercept of the evaporation equation	Real	Thousand of acre-feet	The parameter considers the monthly evaporation in dams	Table A9
α_1^{res}	Slope of the evaporation equation	No negative	Thousands of acre-feet per acre		Table A9
β_0^{res}	Coefficient of the function that relates reservoir	Positive	Acre per acre-feet		Repository on Website

	surface and water storage in the dam				
β_1^{res}	Coefficient of the function that relates surface of water table in the reservoir and water storage	[0,1]	Dimensionless		Repository on Website
$\beta_{0_{u,j,k}}$	Intercept of yield equation of crops	Positive	Tons per acre		Repository on Website
$\beta_{1_{u,j,k}}$	Slope of the yield equation of crops	Negative	Tons per acres squared		Repository on Website
$Bw_{u,j,k,m}$	Percentage of monthly water use by crop over the annual water use	[0,1]	Dimensionless	The sum of the months equals one	Table A5
$\beta_{0,du}$	Intercept of the inverse demand function of urban water	Positive	Dollar per acre-feet		Repository on Website
$\beta_{1,du}$	Slope of the inverse demand function of urban water	Negative	Dollar per acre food squared		Repository on Website
$\beta_{0,su}$	Intercept of the supply function of water	Negative	Dollar per acre-feet		Repository on Website
$\beta_{1,su}$	Slope of the supply function of water	Positive	Dollar per acre food squared		Repository on Website
P_{urb}	Price of urban water	Positive	Dollar per acre-feet		Table 10
P_e	Price of electricity	Positive	Dollar per gigawatt hour		Table 14
$C_{f_{res}}$	Fix cost of hydropower production	Positive	Dollar per megawatt installed in the hydropower plant		Table 14
$C_{v_{res}}$	Variable cost of hydropower production	Positive	Dollar per gigawatt hour		Table 14
δ	Conversion factor from international units to imperial units			Heigh and water flow are measured in	1/11,800

				feet and cubic feet per second. The units in the international system are meter and cubic meter per second	
η_{res}	Efficiency of the hydropower production plant	(0,1)	Dimensionless		Table 11
$\eta_{res,0}$	Multiplicative parameter of the height-storage function	Positive	Acre per acre feet		Table 16
$\eta_{res,1}$	Exponential parameter of the height-storage function	(0,1]	Dimensionless		Table 16
$\overline{X_{res}^{hpw}}$	Technical restriction for the water used by hydropower	Positive	Acre-feet per moths		Table 11
$\overline{L_{u,k}}$	Restriction of irrigation technology installed in the irrigation district u	Positive	Thousands of acres		
r	Annual interest rate	Positive	Dimensionless		0.23

Table 4. Irrigated crop distribution in the Colorado River Basin. Mean value between 2008 and 2021

Crops	Thousands of acres
Alfalfa	1,005
Other Hay/Non Alfalfa	346
Grass/Pasture	315
Fallow/Idle Cropland	285
Cotton	167
Durum Wheat	108
Corn	104
Other crops (87 types)	412
Total	**2,742**

Table 5. Irrigation system distribution by crop and state

State and crop	Irrigation system		
	Drip	Flood	Sprinkle
Arizona			
Alfalfa and alfalfa mixtures (dry hay, greenchop, and silage)		85%	15%
All other hay (dry hay, greenchop, and silage)		84%	16%
Corn for grain or seed		84%	16%
Cotton		95%	5%
Irrigated pastureland, all types		79%	21%
Land in orchards, vineyards, and nut trees	15%	57%	28%
Land in vegetables	14%	72%	14%
Lettuce and romaine		100%	
Other small grains (barley, oats, rye, etc.)		84%	16%
Potatoes, excluding sweet potatoes			100%
Sorghum for grain or seed		78%	22%
Wheat for grain or seed		100%	
California			
Alfalfa and alfalfa mixtures (dry hay, greenchop, and silage)		82%	18%
All other hay (dry hay, greenchop, and silage)		92%	8%
Corn for grain or seed		97%	3%
Cotton	8%	92%	
Irrigated pastureland, all types		98%	2%
Land in orchards, vineyards, and nut trees	85%	6%	8%
Land in vegetables	67%	12%	21%
Lettuce and romaine	55%	7%	38%
Other small grains (barley, oats, rye, etc.)		93%	7%
Potatoes, excluding sweet potatoes	20%	41%	39%
Sorghum for grain or seed		0%	100%
Wheat for grain or seed		82%	18%
Colorado			
Alfalfa and alfalfa mixtures (dry hay, greenchop, and silage)		51%	49%
All other hay (dry hay, greenchop, and silage)		79%	21%
Corn for grain or seed		11%	89%
Irrigated pastureland, all types		86%	14%
Land in orchards, vineyards, and nut trees	27%	68%	5%
Land in vegetables	1%	3%	97%
Lettuce and romaine	36%	18%	45%
Other small grains (barley, oats, rye, etc.)		11%	89%
Potatoes, excluding sweet potatoes	0%	0%	100%
Sorghum for grain or seed		40%	60%
Wheat for grain or seed		13%	87%
Nevada			
Alfalfa and alfalfa mixtures (dry hay, greenchop, and silage)		43%	57%
All other hay (dry hay, greenchop, and silage)		79%	21%
Corn for grain or seed		78%	22%
Irrigated pastureland, all types		100%	0%

State and crop	Irrigation system		
Land in orchards, vineyards, and nut trees	35%	36%	29%
Land in vegetables	65%	12%	24%
Lettuce and romaine	0%	100%	0%
Other small grains (barley, oats, rye, etc.)		40%	60%
Potatoes, excluding sweet potatoes	81%	0%	19%
Sorghum for grain or seed		100%	
Wheat for grain or seed		82%	18%
Cotton		100%	
New Mexico			
Alfalfa and alfalfa mixtures (dry hay, greenchop, and silage)		52%	48%
All other hay (dry hay, greenchop, and silage)		26%	74%
Corn for grain or seed		17%	83%
Cotton		50%	50%
Irrigated pastureland, all types		75%	25%
Land in orchards, vineyards, and nut trees	19%	80%	0%
Land in vegetables	44%	13%	44%
Lettuce and romaine	1%	99%	0%
Other small grains (barley, oats, rye, etc.)		0%	100%
Potatoes, excluding sweet potatoes	0%	94%	6%
Sorghum for grain or seed		2%	98%
Wheat for grain or seed		19%	81%
Utah			
Alfalfa and alfalfa mixtures (dry hay, greenchop, and silage)		25%	75%
All other hay (dry hay, greenchop, and silage)		66%	34%
Corn for grain or seed		46%	54%
Irrigated pastureland, all types		75%	25%
Land in orchards, vineyards, and nut trees	35%	7%	58%
Land in vegetables	12%	65%	23%
Lettuce and romaine	0%	100%	0%
Other small grains (barley, oats, rye, etc.)		34%	66%
Potatoes, excluding sweet potatoes	40%	59%	2%
Sorghum for grain or seed		100%	
Wheat for grain or seed		69%	31%
Wyoming			
Alfalfa and alfalfa mixtures (dry hay, greenchop, and silage)		43%	57%
All other hay (dry hay, greenchop, and silage)		87%	13%
Corn for grain or seed		50%	50%
Irrigated pastureland, all types		89%	11%
Land in orchards, vineyards, and nut trees	0%	77%	23%
Land in vegetables	2%	6%	92%
Other small grains (barley, oats, rye, etc.)		44%	56%
Potatoes, excluding sweet potatoes	100%	0%	0%
Sorghum for grain or seed		0%	100%
Wheat for grain or seed		44%	56%

Table 6. Price, yield, cost, water requirements, income, cost, and net income

Crop	Crop cod	Price*	Yield*	Cost (no water)	Water cost	Irrigation	Income	Cost	Net income
		1000$/ton	ton/ac	1000$/ac	1000$/acft	Acft/acre	1000$/ac	1000$/ac	1000$/ac
Alfalfa	alf	0.21	12.00	1.18	132.0	5.33	2.46	1.88	0.57
Apples	apl	0.28	22.00	4.98	235.6	0.50	6.05	5.10	0.95
Apricots	apc	0.90	7.00	4.20	104.8	3.00	6.30	4.52	1.78
Barley	brl	0.27	3.10	0.68	90.0	0.50	0.83	0.72	0.11
Broccoli	brc	1.10	7.10	7.11	215.9	1.50	7.81	7.43	0.38
Cantaloupes	ctp	0.40	9.48	3.41	23.4	4.00	3.76	3.50	0.26
Carrots	crr	0.15	27.00	1.57	360.2	0.21	4.05	1.65	2.40
Cherries	chr	5.38	3.67	16.86	60.4	2.50	19.75	17.01	2.74
Chick Peas	chp	1.02	1.32	1.02	115.9	1.05	1.35	1.14	0.21
Citrus	ctr	1.04	13.50	8.40	113.5	2.75	14.08	8.71	5.37
Corn	crn	0.05	30.00	0.78	43.2	3.67	1.50	0.94	0.56
Cotton	ctn	1.80	0.65	0.95	7.4	4.60	1.17	0.98	0.19
Durum Wheat	wht	0.27	3.10	0.68	90.0	0.50	0.83	0.72	0.11
Grapes	grp	1.98	15.50	26.90	144.3	3.67	30.69	27.43	3.26
Greens	grn	1.48	6.20	5.78	215.9	0.73	9.16	5.94	3.22
Honeydew Melons	hdm	0.40	9.48	3.41	23.4	4.00	3.76	3.50	0.26
Lettuce	ltc	0.68	17.20	10.48	492.2	1.17	11.73	11.06	0.68
Misc Vegs & Fruits	ms	0.97	20.40	11.50	170.2	2.00	19.79	11.84	7.95
Oats	oat	0.27	3.10	0.68	90.0	0.50	0.83	0.72	0.11
Onions	ons	0.30	31.30	2.14	144.3	2.87	9.26	2.55	6.71
Oranges	org	1.05	9.60	7.20	113.5	2.50	10.08	7.49	2.59
Other Hay/Non Alfalfa	hay	0.24	5.00	0.82	75.2	2.50	1.17	1.01	0.17
Other Small Grains	osg	0.27	3.10	0.68	90.0	0.50	0.83	0.72	0.11
Other Tree Crops	otc	0.49	20.00	7.57	60.4	3.50	9.80	7.78	2.02
Peaches	pch	0.49	20.00	7.57	60.4	3.50	9.80	7.78	2.02
Pecans	pcn	2.65	0.91	1.93	48.1	4.67	2.40	2.15	0.25
Peppers	ppp	0.97	20.40	11.50	170.2	2.00	19.79	11.84	7.95
Pistachios	ptc	5.69	1.27	3.58	175.2	3.75	7.22	4.24	2.99
Pop or Orn Corn	pcr	0.05	30.00	0.78	43.2	3.67	1.50	0.94	0.56
Potatoes	ptt	0.14	22.00	2.53	144.3	1.71	3.14	2.78	0.37
Pumpkins	pkn	0.59	13.97	7.23	58.0	2.50	8.26	7.37	0.88
Rye	rye	0.27	3.10	0.68	90.0	0.50	0.83	0.72	0.11
Safflower	sfw	0.24	1.95	0.30	65.4	2.00	0.47	0.43	0.04
Sorghum	sgh	0.27	3.10	0.68	90.0	0.50	0.83	0.72	0.11
Spring Wheat	swt	0.27	3.10	0.68	90.0	0.50	0.83	0.72	0.11
Sugarbeets	sgb	0.04	44.00	1.12	18.5	7.33	1.85	1.25	0.59

Crop	Crop cod	Price*	Yield*	Cost (no water)	Water cost	Irrigation	Income	Cost	Net income
		1000$/ton	ton/ac	1000$/ac	1000$/acft	Acft/acre	1000$/ac	1000$/ac	1000$/ac
Sweet Corn	scr	0.05	30.00	0.78	43.2	3.67	1.50	0.94	0.56
Triticale	trt	0.27	3.10	0.68	90.0	0.50	0.83	0.72	0.11
Winter Wheat	wwh	0.27	3.10	0.68	90.0	0.50	0.83	0.72	0.11

Table 7. Population by state and water urban node and number of cities

State/ Water user	Inhabitants 2010	Inhabitants 2020	Number of urban centers
Arizona	5,361,591	5,936,247	65
URB_Central_Arizona_u_f	4,830,750	5,373,205	46
URB_Urban_above_Havaru_Lake_u_f	146,633	152,958	5
URB_Verde_river_u_f	225,087	240,792	10
URB_yuma_u_f	159,121	169,292	4
California	17,733,427	18,784,769	205
URB_MWDSC_u_f	17,712,610	18,764,050	204
URB_yuma_u_f	20,817	20,719	1
Colorado	3,457,689	3,877,959	54
UBR_Arkansas_River_Basin_u_f	628,124	686,583	7
UBR_Mesa_u_f	91,101	95,849	3
UBR_South_Platte_River_u_f	2,680,091	3,033,362	40
URB_Durango_u_f	16,887	18,909	1
URB_Edwards_u_f	10,266	10,895	1
URB_Montrose_u_f	19,132	19,488	1
URB_Steamboat_Spring_u_f	12,088	12,873	1
New Mexico	846,243	880,416	9
UBR_Farmington_u_f	45,877	44,126	1
UBR_Sjuan_Chama_u_f	778,688	814,077	7
URB_Verde_river_u_f	21,678	22,213	1
Nevada	1,863,785	2,085,335	11
URB_Las_Vegas_u_f	1,848,509	2,066,597	10
URB_Virgin_River_u_f	15,276	18,738	1
UT	1,543,963	1,725,568	32
URB_CUP_Strawberry_Valley_u_f	1,429,468	1,583,413	28
URB_Vernal_u_f	9,089	11,384	1
URB_Virgin_River_u_f	105,406	130,771	3
Wyoming	95,017	101,048	3
URB_Cheyenne_u_f	59,466	64,676	1
URB_Green_and Rock_Springs_u_f	35,551	36,372	2
Basin	30,901,715	33,391,342	379

Table 8. Summary of water use and water price values of the main cities in the Colorado River

Source			a	a	b	c	d	d	d	d
State	**City**	**Population in 2021**	**Population**	**G/hab/d**	**G/hab/day**	**$/gallon (2015)**	**$/gallon (2013)**	**$/gallon (2012)**	**$/gallon (2011)**	**$/gallon (2010)**
CA	Los Angeles	3,979,576		123		0.0115	0.0055	0.0049	0.0054	0.0049
CA	San Diego	1,423,851		137		0.0120				
AZ	Phoenix	1,680,992		170	155	0.0051	0.0032	0.0030	0.0030	0.0029
AZ	Tucson	548,073		133	119		0.0039	0.0033	0.0030	0.0028
AZ	Yuma	98,285								
AZ	Flagstaff	75,038								
AZ	Lake Havasu City	55,865								
CO	Colorado Springs	478,221		177						
CO	Fort Collins	170,243		167						
CO	Pueblo	112,361								
CO	Boulder	105,673								
CO	Grand Junction	63,597								
CO	Denver	727,211		172	144	0.0073	0.0033	0.0033	0.0031	0.0028
UT	Provo	116,618								
UT	Salt Lake City	200,567		250	206		0.0022	0.0021	0.0020	0.0019
NM	Santa Fe	84,683		105	93		0.0128	0.0118	0.0109	0.0101
NM	Albuquerque	560,513			121					
WY	Cheyenne	64,235			134					
NV	Las Vegas	651,319	3,441,583	188		0.0055	0.0034	0.0034	0.0030	0.0027
Total	-	**11,196,921**								

a: Chini and Stillwell (2018), b: Colby and Hansen (2022), c: Luby et al. (2018), d: University of Arizona, (2014).

Table 9. Studies of water price elasticities, price, and water use

Study	Area studied	State	Data base year	Model	Elasticity	Quantity	Average Price
Clarke et al.(2017)	Tucson, Arizona	AR	2001-2011	Stone–Geary	-0.2,-0.12	12.22 ccf/billing cicle (30.39 days) 9023 G/m (Household)	6.6/ccf 8.8$/1000g
(Yoo et al., 2014)	Phoenix Metropolitan Area	AR	2000, 2002, …, 2008	Linear (differences)	2000-2002: -0.661 2000-2008: -1.155 Median: -1.697	13.97ccf/m;10450g/m (Household)	7.23$/1000g
(Klaiber et al., 2014)	Phoenix Municipal water system	AR	2000-2003	Linear	-1.53 winter (median) -0.68 summer (median)	Median value: 15.02ccf/m, 11234g/m (Household)	From 0.927$/g (1.24$/ccf) to 1.41$/g (1.89$ccf)
(Ouyang et al., 2014)	Phoenix MA	AR			-0.03		
(Baerenklau and Pérez-Urdiales, 2019)	Eastern Municipal Water District (EMWD)	CA	2003-2012	log-level	-0.38	15.73ccf/m 11766g/m (Household)	1.48$/1000g (1.98$/ccf)
(Baerenklau et al., 2014)	Eastern Municipal Water District (EMWD)	CA	2003-2011	log-log	-0.76	15.73ccf/m 11766g/m (Household)	1.48$/1000g (1.98$/ccf)
(Buck et al., 2021)	Metropolitan Water Disctrict of Southern California	CA	2004-2008	lo-log	-0.56,-0.36,-0.1	22.8cccf/m 17054g/m (Household)	4.67$/1000g (1524$acre-feet)
(Rightnar and Dinar, 2020)	Coachella Valley Water District (CVWD), Metropolitan Water District (MWD), San Diego County Water Authority (SDCWA)	CA		log-log	-0.39		

Study	Area studied	State	Data base year	Model	Elasticity	Quantity	Average Price
(Pérez-Urdiales and Baerenklau, 2020)	Several Water districts in Califronia (District E and H are Los Angeles)	CA	2014-2015	log-log	(-0.482,-0.136)	[5414;10438]g/m (Household)	(5.85$/g and 9.2$/g)
(Maas et al., 2020)	Colorado	CO	Nine years (2006–2014)	log-log	-0.594, -0.785	8646G/m (Household)	6.2$/1000g (nominal price)
(Puri and Maas, 2020)	Fort Collins, Colorado	CO	Nine years (2006–2014)	log-log	-0.71	9,039.83G/m (Household)	2.27$/1,000G
(Kenney et al., 2008)	Aurora (Colorado, Denver suburb)	CO	From 2000 to 2005	log-log	-0.6	10.25G/m (Household)	2.22$/1000G (Base year 1999)
(Price et al., 2014)	Albuquerque Bernalillo County Water Utility Authority	NM	January 1994 and June 2008	log-log	(-0.48;-0.28)	9990g/m	3$/1000G
(Garcia and Islam, 2018)	Las Vegas Valley Water District (LVVWD)	NV	from 1990 to 2014	Linear (differences)	-0.24	985 lpcpd	
(Bowman, n.d.)	Las Vegas Valley	NV			-0.51		
(Tchigriaeva et al., 2014)	Las Vegas	NV	2007-2011	log-level	-0.34	12000g/m (Household)	2.31$/1000g
(Lott et al., 2014)	Reno metropolitan area	NV	from February 2003 to December 2011		-0.2	12318g/m (Household)	2.9$/1000g (aprox)
(Coleman, 2009)	Salt Lake City	UT	February 1999 to October 2002	log-level	Long run −0.485 Short run −0.391 Summer −1.445 Winter −0.378	25.029 ccf/m 18721g/m	0.329$/ccf 0.246$/1000g Marginal

Study	Area studied	State	Data base year	Model	Elasticity	Quantity	Average Price
					Residential −0.413 Non-residential −0.665		
Central Utah Water Conservancy District (1995)	Utah	UT			-0.592		

Table 10. Water price, water use and price elasticity selected for the HEC-CRB

State	Water price ($/1000 gallons)	Water use (gallons per capita and day)	Water price elasticity
Arizona	5.1	166	-0.39
California	12.0	127	-0.39
Colorado	7.3	109	-0.65
New Mexico	12.8	137	-0.38
Nevada	5.5	127	-0.355
Utah	2.2	129	-0.49
Wyoming	7.5	181	-0.44

Table 11. Hydropower production parameters, installed power, potential hydropower production annually, capacity factor, head height

Hydropower plan	Power installed (MW)	Hydropower production (MWh per year)	Capacity factor	Eficiency	Rated Head ft (tecnical)	Rate Head (max of the mean value by mounth)	Max. Turbined water (cfs)	Max water turbined by month (1000 acre-feet)	Max. production (GW) per month
Powell Lake	1320.0	3772010	0.33	0.91	510	477	14253	848	358
Mead Lake	2079.1	3757690	0.21	0.85	576	NA	NA	667	420
Mohave Lake	254.8	1122303	0.50	0.85	136	NA	NA	632	83
Havasu Lake	120.0	443354	0.42	0.85	136	NA	NA	521	56
Flaming Gorge	151.8	420581	0.32	0.90	400	425	1837	109	41
Marrow Point	173.2	296977	0.20	0.87	396	399	1578	94	33
Blue Mesa	86.4	224560	0.30	0.85	332	332	1774	106	31
Crystal	28.0	138706	0.57	0.86	207	218	1759	105	20
Fontenelle	10.0	49817	0.57	0.80	94	103	1431	85	8

Table 12. Average water turbinated and hydropower generated data from USBR

	January	February	March	April	May	June	July	August	September	October	November	December
Davis												
1000 acre-feet	268	350	537	628	590	593	632	550	458	378	288	267
Gwh	46	51	72	79	78	80	83	73	62	52	43	42
Hoover												
1000 acre-feet	349	367	565	660	667	579	608	560	431	364	367	350
Gwh	281	276	392	419	420	373	378	361	294	256	261	262
Parker												
1000 acre-feet	206	289	447	513	479	484	521	451	371	304	228	202
Gwh	30	33	49	52	51	52	56	50	42	35	28	26

Table 13. Average water flow via turbines, height and hydropower generated data from Western Area Power Administration

Average between 2012 and 2021	January	February	March	April	May	June	July	August	September	October	November	December
Blue Mesa												
Water release (cfs)	626	548	550	940	1,471	1,774	1,732	1,598	1,275	1,074	468	638
Height (ft)	317	316	316	314	320	328	332	327	319	313	314	312
Production (Mw)	14	12	12	21	33	41	41	38	29	24	11	15
Crystal												
Water release (cfs)	640	405	529	1,080	1,564	1,534	1,759	1,720	1,522	1,018	476	767
Height (ft)	216	216	218	216	216	216	214	213	212	214	217	216
Production (Mw)	9	5	7	17	25	25	28	27	24	16	6	10
Flaming Gorge												
Water release (cfs)	1,829	1,837	1,416	1,246	1,316	1,663	1,584	1,732	1,724	1,357	1,371	1,673
Height (ft)	421	421	421	421	422	422	425	424	423	423	423	421
Production (Mw)	59	59	45	40	42	54	52	56	56	44	44	54
Fontenelle												
Water release (cfs)	1,049	1,048	1,027	1,174	1,332	1,431	1,269	1,173	934	1,040	1,020	1,010
Height (ft)	88	82	78	78	84	97	103	103	98	98	96	93
Production (Mw)	6	6	5	6	8	9	9	8	6	7	7	6
Glen Canyon												
Water release (cfs)	13,438	11,868	11,022	10,471	10,440	12,349	14,253	13,806	10,682	9,585	9,439	12,651
Height (ft)	464	461	459	458	461	470	477	475	473	472	469	464
Production (Mw)	484	423	390	371	373	449	528	509	391	349	340	455
Morrow Point												
Water release (cfs)	613	580	537	987	1,480	1,466	1,578	1,415	1,395	1,013	405	591
Height (ft)	398	398	396	396	398	399	399	399	399	396	398	398
Production (Mw)	17	16	14	28	43	42	46	41	41	29	11	16

Table14. Energy price, fix cost of hydropower production and variable cost of hydropower production.

Energy Price ($/MWh)	Fix cost per MW installed ($/MW year)	Variable Cost for hydropower production ($/MWh)
105	0.04378	1.46

Table 15. Water storage in reservoir the first period of simulation, and maximum and minimum storage capacity

Reservoir	Source of data	Storage (1000 acre-feet)		
		Initial storage	Maximum	Minimum
Big Sandy Reservoir and Dam	USBR	15	39	2
Blue Mesa Reservoir Dam and Powerplant	USBR	584	819	271
Crystal Reservoir Dam and Powerplant	USBR	16	18	13
Flaming Gorge Reservoir Dam and Powerplant	USBR	3,041	3,621	1,970
Fontenelle Reservoir Dam and Powerplant	USBR	215	349	36
Lake Granby and Dam	USBR	399	536	143
Green Mountain Reservoir Dam and Powerplant	USBR	95	153	47
Huntington North Reservoir and Dam	USBR	2	4	1
Joes Valley Reservoir and Dam	USBR	40	63	27
Morrow Point Reservoir Dam and Powerplant	USBR	112	116	106
Mcphee Reservoir and Dam	USBR	268	382	161
Meeks Cabin Reservoir and Dam	USBR	8	31	2
Moon Lake Reservoir and Dam	USBR	18	38	4
Navajo Reservoir and Dam	USBR	1,245	1,617	698
Lake Powell Glen Canyon Dam and Powerplant	USBR	14,454	23,799	6,522
Ridgway Reservoir and Dam	USBR	66	82	51
Ruedi Reservoir and Dam	USBR	79	102	53
Scofield Reservoir and Dam	USBR	24	70	8
Starvation Reservoir and Dam	USBR	134	167	87
Strawberry Reservoir and Soldier Creek Dam	USBR	834	1,027	472
Taylor Park Reservoir and Dam	USBR	68	108	41
Vallecito Reservoir and Dam	USBR	54	123	24
WOLFORD MTN RESERVOIR NR KREMMLING	USGS	51	33	67
Basin		**21,822**	**33,298**	**10,809**

Table 16. Parameter estimation heigh-storage relationship for hydropower production

Parameter	Estimate	Std. Error	t value	Pr(>|t|)
Blue Mesa Reservoir Dam and Powerplant				
α_0	1.0098	9.78E-05	10,326	0
α_1	0.8164	1.84E-04	4438	0
Crystal Reservoir Dam and Powerplant				
α_0	1.0103	5.66E-05	17,846	0
α_1	0.8545	1.45E-04	5,909	0
Flaming Gorge Reservoir Dam and Powerplant				
α_0	1.0159	1.28E-04	7,923	0
α_1	0.8254	2.87E-04	2,874	0
Fontenelle Reservoir Dam and Powerplant				
α_0	1.0173	2.37E-04	4,289	0
α_1	0.6263	4.03E-04	1,556	0
Lake Havasu Parker Dam and Powerplant				
α_0	1.9569	1.14E-02	172	0
α_1	2.7930	1.40E-02	200	0
Lake Mead Hoover Dam and Powerplant				
α_0	1.0660	8.91E-04	1,196	0
α_1	0.7311	1.32E-03	552	0
Lake Mohave Davis Dam and Powerplant				
α_0	1.0074	1.18E-04	8,530	0
α_1	1.1442	8.98E-04	1,274	0
Morrow Point Reservoir Dam and Powerplant				
α_0	1.0043	2.48E-05	40,469	0
α_1	0.9628	5.08E-05	18,959	0
Lake Powell Glen Canyon Dam and Powerplant				
α_0	1.0245	1.75E-04	5,854	0
α_1	0.6884	2.87E-04	2,396	0

Table 17. Cropland, water applied, income, cost, and net income

	1000 ac	Water Apply 1000 acft	Income M$	Costs M$	Water Costs M$	Net Income M$	1000 Ha (%)	Water Apply Mm3 (%)	Net Income M$ (%)
California	528.8	1743.0	2125	1358	190	576	24.0	23.1	40.7
Arizona	803.1	2996.4	2342	1558	296	489	36.5	39.7	34.5
Colorado	469.5	1655.5	900	492	188	220	21.3	22.0	15.6
Utah	190.3	582.9	319	182	62	75	8.6	7.7	5.3
Wyoming	165.6	423.2	211	140	35	35	7.5	5.6	2.5
New Mexico	42.0	130.5	77	45	12	20	1.9	1.7	1.4
Nevada	2.5	6.5	4	2	1	1	0.1	0.1	0.1
Basin	2,199.4	7,539.2	5,976.72	3,778.08	783.31	1,415.33			

Table 18. Number of cities, population, urban water use and benefits by state

State	Number of cities	Population (Thousand)	Population (%)	Water urban use (hm^3)	Water use (%)	Benefits (Million of dollar)	Benefits (%)
CA	205	18,781	0.563	350	0.540	13,384	0.730
AZ	65	5,936	0.178	145	0.223	2,358	0.129
CO	54	3,878	0.116	62	0.095	861	0.047
NV	11	2,085	0.062	39	0.060	747	0.041
UT	32	1,726	0.052	33	0.050	180	0.010
NM	9	880	0.026	18	0.027	742	0.041
WY	3	101	0.003	3	0.004	57	0.003
CRB	379	33,391	1	648	1	18,328	1

Table 19. Hydropower production, income, cost, and benefits and avoid emissions from hydropower

	MW	Estimated Energy (GWh year)	Income (Million $)	Fix Cost (Million $)	Variable cost (Million $)	Benefits (Million $)	Avoid Emmsions (Million Lb)
Powell Lake	1320.0	3772.0	396.06	57.79	5.51	332.8	4543.4
Marrow Point	173.2	297.0	31.18	7.58	0.43	23.2	357.7
Flaming Gorge	151.8	420.6	44.16	6.65	0.61	36.9	506.6
Blue Mesa	86.4	224.6	23.58	3.78	0.33	19.5	270.5
Crystal	28.0	138.7	14.56	1.23	0.20	13.1	167.1
Fontenelle	10.0	49.8	5.23	0.44	0.07	4.7	60.0
Mead Lake	2079.1	3757.7	394.56	91.02	5.49	298.0	4526.2
Mohave Lake	254.8	1122.3	117.84	11.16	1.64	105.0	1351.8
Havasu Lake	120.0	443.4	46.55	5.25	0.65	40.7	534.0
Basin	4223.3	10226.0				873.9	12317.3

Table 20. Summary of cropland, water use, and benefits of urban, agricultural and hydropower sectors by state and basin

State	Arizona	California	Colorado	Nevada	New Mexico	Utah	Wyoming	**Basin**
Urban sector								
Benefits (Million of dollar)	2,358	13,384	861	747	742	180	57	18,328
Domestic water use (maf)	117.6	283.7	50.3	31.6	14.6	26.8	2.4	525.3
Industrial water use (maf)	196.2	472.6	83.5	52.7	24.3	44.6	4.1	875.6
Total urban use (maf)	313.7	756.4	133.8	84.3	38.9	71.3	6.5	1400.9
Agricultural sector								
Net Income (Million of dollar)	489	576	220	1	20	75	35	1,416
Crop acreage (1000 acre)	803.1	528.8	469.5	2.5	42.0	190.3	165.6	2199.2
Water use (maf)	2996.4	1743.0	1655.5	6.5	130.5	582.9	423.2	7539.6
Hydropower								
Benefits (Million of dollar)	534	20	56	202	0	37	5	874
All sectors								
Benefits (Million of dollar)	3,381	13,980	1,137	950	762	292	97	20,618
Water use (maf)	3310.1	2499.4	1789.2	90.8	169.4	654.2	429.7	8940.6

Hydropower production at Mead Lake and Mohave Lake is shared equally between Arizona and Nevada.

Hydropower production at Havasu Lake is shared equally between Arizona and California.

Industrial water use is fix at 40 percent of total use.

Net income = Revenue – Cost (excluding land rent).

11. Appendix A

Table A1. Cropland distribution between 2008 and 2021

Crop	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	**Mean**
Alfalfa	807.52	814.33	925.69	909.92	918.43	944.40	1070.48	1078.20	1113.05	1113.05	1043.07	1088.42	1142.24	1098.02	**1004.8**
Almonds	0.25	0.02		0.75	0.98	0.85	0.63	0.45	0.50	0.50	0.17				**0.5**
Apples	0.42	0.32	1.57	0.72	5.68	0.93	3.03	1.14	0.99	0.99	1.75	0.67	0.66	0.73	**1.4**
Apricots				0.08	0.07	0.01	0.01		0.18	0.18		0.01		0.00	**0.1**
Asparagus	0.02	0.03		0.04	0.04	0.01					0.02	0.02	0.05		**0.0**
Avocados											0.06	0.04	0.09	0.07	**0.1**
Barley	35.10	42.60	43.10	60.23	45.55	65.28	28.51	12.51	13.64	13.64	10.14	12.97	9.04	15.30	**29.1**
Broccoli	2.47	3.54		1.83	3.10	5.19	7.85	4.01	9.22	9.22	18.04	20.39	10.73	12.61	**8.3**
Cabbage	1.23	1.37		1.14	1.79	1.96	3.32	0.89	3.38	3.38	3.01	2.84	4.34	4.92	**2.6**
Caneberries									0.01	0.01					**0.0**
Canola	0.06	0.96	0.01		0.11	0.35	0.06		0.03	0.03	0.00	0.22			**0.2**
Cantaloupes	12.01	12.71	11.66	10.18	7.10	9.67	9.84	11.59	10.71	10.71	5.24	7.66	8.29	7.43	**9.6**
Carrots	4.82	9.49	1.14	10.13	13.33	9.36	15.64	12.71	15.30	15.30	31.80	19.39	13.07	15.12	**13.3**
Cauliflower	0.42	1.11	0.26	1.35	1.40	0.86	0.81	0.55	2.68	2.68	1.84	3.17	2.34	3.80	**1.7**
Celery	0.02	0.04		0.06	1.72	0.10	0.19	0.34	0.16	0.16	1.28	0.33	0.38	0.64	**0.4**
Cherries	0.07	0.05	0.58	0.23	0.63	0.57	0.76	0.13	0.38	0.38	0.26	0.36	0.43	0.55	**0.4**
Chick Peas												6.14	1.17	3.20	**3.5**
Christmas Trees									0.00	0.00					**0.0**
Citrus	1.34	28.05	1.17	32.35	31.20	60.24	31.61	28.29	25.31	25.31	25.45	28.29	44.58	50.06	**29.5**
Clover/Wildflowers	0.06	0.07		0.08					0.19	0.19	0.47		0.00		**0.2**
Corn	71.40	94.74	80.98	112.43	128.56	112.51	110.06	109.68	104.35	104.35	120.82	101.90	104.47	103.39	**104.3**
Cotton	130.64	147.90	203.29	265.50	209.45	174.19	167.67	115.61	161.83	161.83	175.31	172.42	128.60	127.13	**167.2**
Cucumbers					0.09										**0.1**
Dbl Crop Barley/Corn	1.76	0.33		0.24	0.07	1.34		0.03	0.32	0.32	0.51	0.88	0.38	1.14	**0.6**
Dbl Crop Barley/Sorghum		2.48	4.28	5.24	4.81	8.29	4.82								**5.0**

Crop	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	**Mean**
Dbl Crop Durum Wht/Sorghum	0.18	3.64	0.75	0.22	4.03	0.46	2.35								**1.7**
Dbl Crop Lettuce/Barley		0.20		0.09		0.20	0.12		0.22	0.22	0.88	0.62	0.18	0.48	**0.3**
Dbl Crop Lettuce/Cantaloupe	5.90	5.59	1.95	2.72	3.56	0.31	3.52		3.92	3.92	4.46	1.72	2.72	5.87	**3.6**
Dbl Crop Lettuce/Cotton	9.27	9.08	14.27	11.40	7.70	4.64	9.16		9.36	9.36	7.42	10.01	6.64	9.96	**9.1**
Dbl Crop Lettuce/Durum Wht	0.12	0.07	36.57	29.92	39.59	27.87	28.25								**23.2**
Dbl Crop Oats/Corn	2.47	0.27	4.17	5.42	3.48	11.77	12.24	9.07	7.15	7.15	13.46	9.33	10.61	17.16	**8.1**
Dbl Crop Triticale/Corn												9.73	1.64	12.88	**8.1**
Dbl Crop WinWht/Corn						0.16	1.22		1.14	1.14	1.23	5.02	5.70	10.79	**3.3**
Dbl Crop WinWht/Cotton				0.61	0.10	0.51	0.69	0.00	9.91	9.91	6.20	4.72	2.42	0.99	**3.3**
Dbl Crop WinWht/Sorghum		0.27		0.07	1.36	0.91	0.90	0.90	2.37	2.37	2.38	2.39	3.44	1.12	**1.5**
Dry Beans	17.86	13.89	24.88	28.38	32.72	21.02	27.58	30.49	29.40	29.40	20.57	12.74	20.57	13.26	**23.1**
Durum Wheat	265.84	210.92	112.32	94.33	159.82	100.50	73.82	221.57	31.19	31.19	24.70	59.74	64.80	56.83	**107.7**
Eggplants		0.13		0.07	0.06	0.01	0.04	0.04	0.00	0.00		0.02			**0.0**
Fallow/Idle Cropland	280.31	288.44	334.87	283.86	245.31	269.20	291.81	329.96	383.68	383.68	305.70	174.81	216.54	200.78	**284.9**
Flaxseed			0.37		0.45	0.20								0.00	**0.3**
Garlic	0.28			0.36		0.21	0.77	1.02	0.80	0.80	0.14	0.24	0.88	0.61	**0.6**
Gourds	0.02			0.02	0.00	0.02			0.01	0.01	0.00	0.02	0.01	0.02	**0.0**

Crop	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	**Mean**
Grapes	8.67	8.06	0.23	9.44	8.65	8.05	9.56	9.63	10.93	10.93	6.78	9.68	20.68	18.16	**10.0**
Grass/Pasture	571.37	582.55	191.59	356.97	362.96	288.74	284.65	348.83	253.56	253.56	222.72	238.03	218.16	237.63	**315.1**
Greens	1.72	7.98	0.37	7.00	9.83	5.22	10.67	17.58	23.39	23.39	42.37	23.65	27.66	26.42	**16.2**
Herbs	1.09	1.93		1.83	0.46	1.20	1.88	2.11	1.59	1.59	1.43	1.54	1.08	1.95	**1.5**
Honeydew Melons	2.05	1.63		1.24	2.48	2.09	1.24	2.92	1.48	1.48	2.02	2.08	0.95	1.12	**1.8**
Hops				0.27			0.07		0.03	0.03	0.03			0.08	**0.1**
Lentils														0.04	**0.0**
Lettuce	7.78	21.16	54.48	9.77	16.76	27.67	33.04	30.54	43.14	43.14	50.22	77.65	33.64	44.86	**35.3**
Millet	0.13	0.04	0.14	0.53	0.03	0.16	0.62	0.62	1.66	1.66	0.40	0.00	0.23	0.60	**0.5**
Mint													0.02	0.09	**0.1**
Misc Vegs & Fruits	0.55	0.12	0.22	25.68	26.65	30.98	24.89	28.66	0.88	0.88	1.65	0.16	0.32	0.91	**10.2**
Mustard	0.00						0.01		0.01	0.01	0.25				**0.1**
Nectarines	0.00														**0.0**
Oats	11.25	21.23	20.81	14.54	19.07	15.80	10.54	10.97	7.38	7.38	11.07	12.31	10.83	8.48	**13.0**
Olives	0.90	0.89	0.70	0.63	0.52	0.43	0.48	0.47	1.86	1.86	0.98	1.72	2.13	0.66	**1.0**
Onions	12.58	14.60	1.73	9.91	10.94	8.72	15.63	15.82	24.34	24.34	25.73	15.51	15.32	22.30	**15.5**
Oranges	28.68	0.30	6.94	0.28	0.12	0.25	0.40	0.35	0.31	0.31	0.35	0.31	0.33	0.03	**2.8**
Other Crops	3.82	2.26	0.61	2.07	1.33	4.14	1.60	1.10	0.87	0.87	2.40	10.92	11.91	3.26	**3.4**
Other Hay/Non Alfalfa	310.20	309.31	445.51	237.82	231.29	328.97	394.01	278.89	339.17	339.17	425.54	387.87	408.52	409.16	**346.1**
Other Small Grains	18.20			0.04	0.31	0.63	0.13	0.01							**3.2**
Other Tree Crops	16.16	21.20	0.71	2.75	3.98	3.29	3.78	3.36	12.74	12.74	53.58	28.16	19.60	41.40	**16.0**
Peaches	0.68	0.76	4.36	3.76	7.21	2.75	2.02	3.43	2.84	2.84	2.08	2.01	2.27	2.93	**2.9**
Peanuts														0.00	**0.0**
Pears	0.03	0.00			1.77	0.21	0.40	0.62	0.43	0.43	0.48	0.30	0.19	0.13	**0.4**
Peas		0.10	0.00	0.04	0.63	0.23					0.07	0.05	0.07	0.34	**0.2**
Pecans	4.85	5.95	3.24	6.31	8.99	9.72	11.14	9.92	12.98	12.98	12.15	15.26	20.48	21.74	**11.1**
Peppers	3.35	3.19	1.64	2.54	1.16	1.06	1.98	2.33	1.71	1.71	0.87	1.95	0.41	0.07	**1.7**
Pistachios	0.72	0.41	1.90	0.52	0.52	0.78	0.44	0.00	2.03	2.03	0.78	0.70	0.84	0.60	**0.9**

Crop	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	**Mean**
Pomegranates		0.01	0.15				0.00								**0.1**
Pop or Orn Corn			0.87	3.98	4.27	3.99	4.10	2.72	3.21	3.21	2.41	4.11	3.47	4.92	**3.4**
Potatoes	0.94	4.51	5.49	9.25	8.90	8.39	6.79	7.56	4.64	4.64	7.39	5.32	9.68	7.32	**6.5**
Pumpkins	0.04	0.00	0.16	0.86	1.16	0.98	1.06	0.93	0.92	0.92	0.91	0.96	0.87	1.19	**0.8**
Radishes	0.07	0.16		0.17	0.07	0.38	0.36	0.32	0.73	0.73	0.28	0.01	0.01	0.00	**0.3**
Rye	0.53	0.46	1.38	0.93	2.49	0.66	0.68	0.40	0.55	0.55	2.48	7.09	1.97	1.84	**1.6**
Safflower	0.66	1.34	2.08	1.27	1.19	1.32	0.27	1.13	0.25	0.25	1.19	0.60	2.73	3.79	**1.3**
Sod/Grass Seed	8.47	6.51	5.28	2.97	3.57	2.54	3.16	2.85	15.92	15.92	18.97	14.45	13.44	9.97	**8.9**
Sorghum	16.74	10.35	6.57	4.45	7.94	8.67	8.12	6.32	6.24	6.24	8.48	6.18	9.69	6.89	**8.1**
Soybeans	0.12	0.03	0.14	0.07	0.09			0.30	0.14	0.14	0.14	0.02	0.03	0.01	**0.1**
Speltz	0.02	0.06	0.67	0.11	0.36	0.09	0.25	0.47			0.53	0.76	0.80		**0.4**
Spring Wheat	12.54	3.80	4.75	4.61	1.32	1.29	1.33	1.28	1.81	1.81	1.44	0.80	1.62	2.45	**2.9**
Squash	0.01	0.07	0.00	0.01	0.10	0.04		0.04			0.19	0.00	0.34	0.04	**0.1**
Strawberries	0.09	0.24						0.34				0.03			**0.2**
Sugarbeets	8.26	9.65	0.00	30.07	33.64	23.29	28.34	25.77	10.10	10.10	41.15	32.17	31.37	35.49	**22.8**
Sugarcane	0.03	0.17					0.22				0.31	0.31	0.32	0.07	**0.2**
Sunflower	1.74	1.78	0.44	1.27	0.23	0.39	0.46	0.10	0.57	0.57	1.94	2.01	0.68	0.13	**0.9**
Sweet Corn	4.88	7.39	3.01	7.56	3.57	5.52	6.50	5.28				8.74	7.79	7.16	**6.1**
Tomatoes	0.12	0.36	0.02	0.25	0.13		0.32	0.17			0.00	0.04	0.03		**0.1**
Triticale	2.56	1.38	3.26	1.03	1.19	1.43	2.51	2.60	2.87	2.87	3.23	3.17	22.67	9.16	**4.3**
Turnips		0.10	0.01												**0.1**
Vetch			0.00	0.06											**0.0**
Watermelons	3.09	3.51	0.63	3.40	2.83	5.82	1.93	4.18	2.80	2.80	2.74	4.26	2.02	3.87	**3.1**
Winter Wheat	16.34	17.08	20.49	59.00	22.17	27.66	23.57	26.78	89.12	89.12	61.18	23.60	25.77	24.27	**37.6**
Annual	**2733.9**	**2765.3**	**2594.5**	**2695.2**	**2683.2**	**2667.6**	**2806.9**	**2826.9**	**2824.6**	**2824.6**	**2845.3**	**2701.7**	**2738.0**	**2736.4**	**2780.1**

Table A2. Percentage of irrigation unit within each state

State and irrigation unit	% of the irrigation unit [or area?] within state
Arizona	
Central Arizona Project, AZ	1
IIR Silver Creek Wash-Colorado River, AZ, CA, NV	0.8
IRR AZ Colorado River Indian Reservation, AZ	1
IRR Gila Project, AZ	1
IRR Little Colorado, AZ	1
IRR Palo Verde, CA	0.09
IRR Salt River Project, AZ	1
IRR San Carlos, AZ	0.92
IRR Sand Hollow Wash-Virgin River, UT	0.31
IRR Yuma Project, AZ CA	0.44
California	
IIR Silver Creek Wash-Colorado River, AZ, CA, NV	0.2
IRR Coachella Irrigation District, CA	1
IRR Imperial Irrigation District, CA	1
IRR Palo Verde, CA	0.91
IRR Yuma Project, AZ CA	0.56
Colorado	
Big Creek-Plateau Creek	1
Colorado Head Plateau Upper	1
IRR Animas-Florida, NM	0.93
IRR Big Tompson	1
IRR Dolores-Montezuma, CO	0.95
IRR Little Snake, WY-CO	0.59
IRR Lower Dolores, Co	0.79
IRR Lower Gunnison, CO	1
IRR Middle San Juan, NM	0.84
IRR Miguel, CO	1
IRR North Fork Gunnison, CO	1
IRR Pine River, NM	1
IRR Uncompahgre	1
IRR Upper Uncompahgre	1
IRR Upper-Lower Yampa, CO	1
IRR White River, UT	1
Roaring Fork	1
Nevada	
IRR Muddy River, NV	1
IRR Sand Hollow Wash-Virgin River, UT	0.69
New Mexico	
IRR Animas-Florida, NM	0.07
IRR Middle San Juan, NM	0.16
IRR Navajo, NM	1
IRR San Carlos, AZ	0.08
Utah	

State and irrigation unit	% of the irrigation unit [or area?] within state
IRR Cottonwood Lower Unita , UT	1
IRR Dolores-Montezuma, CO	0.05
IRR Duchesne, UT	1
IRR Fremont, UT	1
IRR Lower Dolores, Co	0.21
IRR Lyman, UT	0.54
IRR Muddy, UT	1
IRR Price, UT	1
IRR San Rafael, UT	1
Wyoming	
IRR Eden, UT	1
IRR Little Snake, WY-CO	0.41
IRR Lyman, UT	0.45
IRR Up and down Fontenelle, WY	1

Table A3. Crop name, crop code and crop name used in irrigation

Crop	Crop Cod	Crop irrigation
Alfalfa	alf	Alfalfa and alfalfa mixtures (dry hay, greenchop, and silage)
Apples	apl	Land in orchards, vineyards, and nut trees
Apricots	apc	Land in orchards, vineyards, and nut trees
Barley	brl	Other small grains (barley, oats, rye, etc.)
Broccoli	brc	Land in vegetables
Cantaloupes	ctp	Land in vegetables
Carrots	crr	Land in vegetables
Cherries	chr	Land in orchards, vineyards, and nut trees
Chick Peas	chp	Land in vegetables
Citrus	ctr	Land in orchards, vineyards, and nut trees
Corn	crn	Corn for grain or seed
Cotton	ctn	Cotton
Durum Wheat	wht	Wheat for grain or seed
Grapes	grp	Land in orchards, vineyards, and nut trees
Greens	grn	Land in vegetables
Honeydew Melons	hdm	Land in vegetables
Lettuce	ltc	Lettuce and romaine
Misc Vegs & Fruits	ms	Land in vegetables
Oats	oat	Other small grains (barley, oats, rye, etc.)
Onions	ons	Land in vegetables
Oranges	org	Land in orchards, vineyards, and nut trees
Other Hay/Non Alfalfa	hay	All other hay (dry hay, greenchop, and silage)
Other Small Grains	osg	Other small grains (barley, oats, rye, etc.)
Other Tree Crops	otc	Land in orchards, vineyards, and nut trees
Peaches	pch	Land in orchards, vineyards, and nut trees
Pecans	pcn	Land in orchards, vineyards, and nut trees
Peppers	ppp	Land in vegetables
Pistachios	ptc	Land in orchards, vineyards, and nut trees
Pop or Orn Corn	pcr	Corn for grain or seed
Potatoes	ptt	Potatoes, excluding sweet potatoes
Pumpkins	pkn	Land in vegetables
Rye	rye	Other small grains (barley, oats, rye, etc.)
Safflower	sfw	Other small grains (barley, oats, rye, etc.)
Sorghum	sgh	Sorghum for grain or seed
Spring Wheat	swt	Wheat for grain or seed
Sugarbeets	sgb	Irrigated pastureland, all types
Sweet Corn	scr	Corn for grain or seed
Triticale	trt	Other small grains (barley, oats, rye, etc.)
Winter Wheat	wwh	Wheat for grain or seed

Table A4. Percentage of irrigation technology by irrigation district

Irrigation District	Drip	Flood	Sprinkler
Big Creek-Plateau Creek	0.00	0.55	0.45
Central Arizona Project, AZ	0.01	0.88	0.12
Colorado Head Plateau Upper	0.00	0.53	0.47
IIR Silver Creek Wash-Colorado River, AZ, CA, NV	0.02	0.85	0.13
IRR Animas-Florida, NM	0.00	0.66	0.34
IRR AZ Colorado River Indian Reservation, AZ	0.01	0.86	0.14
IRR Big Tompson	0.00	0.69	0.31
IRR Coachella Irrigation District, CA	0.69	0.20	0.11
IRR Cottonwood Lower Unita , UT	0.00	0.53	0.47
IRR Dolores-Montezuma, CO	0.00	0.49	0.51
IRR Duchesne, UT	0.00	0.55	0.45
IRR Eden, UT	0.00	0.62	0.38
IRR Fremont, UT	0.00	0.33	0.66
IRR Gila Project, AZ	0.03	0.88	0.10
IRR Imperial Irrigation District, CA	0.12	0.73	0.15
IRR Little Colorado, AZ	0.00	0.84	0.16
IRR Little Snake, WY-CO	0.00	0.77	0.23
IRR Lower Dolores, Co	0.00	0.51	0.49
IRR Lower Gunnison, CO	0.01	0.49	0.50
IRR Lyman, UT	0.00	0.73	0.27
IRR Middle San Juan, NM	0.00	0.54	0.46
IRR Miguel, CO	0.00	0.58	0.42
IRR Muddy River, NV	0.00	0.52	0.48
IRR Muddy, UT	0.00	0.36	0.64
IRR Navajo, NM	0.01	0.34	0.66
IRR North Fork Gunnison, CO	0.01	0.59	0.40
IRR Palo Verde, CA	0.08	0.78	0.14
IRR Pine River, NM	0.00	0.69	0.31
IRR Price, UT	0.00	0.36	0.64
IRR Salt River Project, AZ	0.00	0.88	0.12
IRR San Carlos, AZ	0.01	0.81	0.17
IRR San Rafael, UT	0.00	0.35	0.65
IRR Sand Hollow Wash-Virgin River, UT	0.00	0.60	0.40
IRR Uncompahgre	0.00	0.46	0.54
IRR Up and down Fontenelle, WY	0.00	0.86	0.14
IRR Upper Uncompahgre	0.00	0.75	0.25
IRR Upper-Lower Yampa, CO	0.00	0.65	0.35
IRR White River, UT	0.00	0.69	0.31
IRR Yuma Project, AZ CA	0.22	0.63	0.15
Roaring Fork	0.00	0.55	0.45
Colorado River Basin	0.04	0.72	0.24

Table A5. Monthly distribution of irrigation needed. Percentage over the annual irrigation requirements.

Crop	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
alf	0.02	0.03	0.06	0.09	0.11	0.14	0.15	0.14	0.11	0.08	0.05	0.03
apc	0.06	0.12	0.21	0.28	0.15	0.00	0.00	0.00	0.00	0.00	0.11	0.08
apl	0.00	0.00	0.00	0.07	0.10	0.16	0.20	0.19	0.15	0.10	0.03	0.00
brc	0.05	0.14	0.25	0.38	0.19	0.00	0.00	0.00	0.00	0.00	0.00	0.00
brl	0.00	0.00	0.06	0.16	0.35	0.42	0.01	0.00	0.00	0.00	0.00	0.00
chp	0.02	0.03	0.06	0.09	0.11	0.14	0.15	0.14	0.11	0.08	0.04	0.03
chr	0.06	0.12	0.22	0.28	0.15	0.00	0.00	0.00	0.00	0.00	0.09	0.08
crn	0.00	0.00	0.00	0.09	0.12	0.16	0.19	0.18	0.14	0.10	0.03	0.00
crr	0.00	0.00	0.00	0.00	0.04	0.18	0.27	0.25	0.20	0.06	0.00	0.00
ctn	0.06	0.12	0.22	0.28	0.15	0.00	0.00	0.00	0.00	0.00	0.09	0.08
ctp	0.02	0.03	0.06	0.09	0.11	0.14	0.15	0.14	0.11	0.08	0.05	0.03
ctr	0.00	0.00	0.00	0.04	0.06	0.16	0.24	0.22	0.17	0.10	0.02	0.00
grn	0.02	0.03	0.06	0.09	0.11	0.14	0.15	0.14	0.11	0.08	0.05	0.03
grp	0.00	0.00	0.05	0.11	0.15	0.20	0.22	0.18	0.10	0.00	0.00	0.00
hay	0.02	0.03	0.06	0.09	0.11	0.14	0.15	0.14	0.11	0.08	0.05	0.03
hdm	0.00	0.00	0.00	0.00	0.05	0.16	0.32	0.29	0.18	0.00	0.00	0.00
ltc	0.00	0.00	0.00	0.07	0.11	0.18	0.22	0.21	0.16	0.05	0.00	0.00
ms	0.02	0.03	0.06	0.09	0.11	0.14	0.15	0.14	0.11	0.08	0.05	0.03
oat	0.00	0.00	0.17	0.36	0.47	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ons	0.00	0.00	0.00	0.04	0.26	0.38	0.32	0.00	0.00	0.00	0.00	0.00
org	0.00	0.00	0.08	0.20	0.24	0.31	0.17	0.00	0.00	0.00	0.00	0.00
osg	0.00	0.00	0.05	0.08	0.12	0.18	0.20	0.18	0.14	0.04	0.00	0.00
otc	0.06	0.12	0.21	0.28	0.15	0.00	0.00	0.00	0.00	0.00	0.11	0.08
pch	0.06	0.12	0.21	0.28	0.15	0.00	0.00	0.00	0.00	0.00	0.11	0.08
pcn	0.06	0.12	0.21	0.28	0.15	0.00	0.00	0.00	0.00	0.00	0.11	0.08
pcr	0.00	0.00	0.00	0.09	0.12	0.16	0.19	0.18	0.14	0.10	0.03	0.00
pkn	0.02	0.03	0.06	0.09	0.11	0.14	0.15	0.14	0.11	0.08	0.05	0.03
ppp	0.00	0.00	0.03	0.04	0.11	0.21	0.24	0.22	0.16	0.00	0.00	0.00
ptc	0.06	0.12	0.21	0.28	0.15	0.00	0.00	0.00	0.00	0.00	0.11	0.08
ptt	0.00	0.00	0.00	0.00	0.06	0.23	0.37	0.30	0.04	0.00	0.00	0.00
rye	0.00	0.00	0.05	0.08	0.12	0.18	0.20	0.18	0.14	0.04	0.00	0.00
scr	0.00	0.00	0.00	0.09	0.12	0.16	0.19	0.18	0.14	0.10	0.03	0.00
sfw	0.00	0.00	0.00	0.07	0.14	0.19	0.21	0.19	0.14	0.06	0.00	0.00
sgb	0.00	0.00	0.00	0.05	0.10	0.28	0.33	0.24	0.00	0.00	0.00	0.00
sgh	0.00	0.00	0.05	0.08	0.12	0.18	0.20	0.18	0.14	0.04	0.00	0.00
swt	0.06	0.12	0.22	0.28	0.15	0.00	0.00	0.00	0.00	0.00	0.09	0.08
trt	0.06	0.12	0.22	0.28	0.15	0.00	0.00	0.00	0.00	0.00	0.09	0.08
wht	0.06	0.12	0.22	0.28	0.15	0.00	0.00	0.00	0.00	0.00	0.09	0.08
wwh	0.06	0.12	0.22	0.28	0.15	0.00	0.00	0.00	0.00	0.00	0.09	0.08

Table A5. USGS station code and water inflow variable of the HEM-CRB

Water inflow node	USGS CODE
RF_Lime_Creek_h_f	9079450
RF_Marron_Creek_h_f	9076300
CR_blw_Shadow_Mont_Rer_h_f	9015000
CR_Troblesome_h_f	9040500
MC_AntelopeCreek_h_f	9041090
BR_blw_Dillon_h_f	9050700
CR_Canyon_Creek_nr_new_Castle_h_f	9085500
CR_Elk_Creek_nr_new_Castle_h_f	9087500
CR_Parachute_nr_at_Parachute_h_f	9093500
CR_Roan_Creek_nr_de_Beque_h_f	391953108130201
CR_Plateau_Creek_nr_Cameo_h_f	9105000
CR_Big_Salt_wash_at_Fruital_h_f	9153270
CR_Salt_Creek_nr_Mouth_nr_Mack_h_f	9163492
GR_North_Fork_Gunnison_blw_Paonia_h_f	9134100
GR_Leroux_Creek_abv_Mouth_nr_hotchkiss_h_f	9135920
GR_Fruit_Growers_res_near_orchard_h_f	9143600
GR_Taylor_River_at_Taylor_Park_h_f	9107000
GR_Texa_Creek_at_Taylor_Park_h_f	9107500
GR_Willow_Creek_abv_Taylor_Park_Res_h_f	9108250
GR_Ohio_Creek_abv_Mouth_nr_Gunnison_h_f	9113980
GR_East_River_at_Almont_h_f	9112500
GR_Tomichi_Creek_at_Gunnison_h_f	9119000
GR_Cimarron_River_blw_Squaw_Creek_h_f	9127000
GR_Uncompahgre_River_nr_ouray_h_f	9146020
GR_Dallas_Creek_nr_Ridgway_h_f	9147000
GR_Loutsenhizer_Arroyo_nr_Olathe_h_f	383926107593001
DR_SanMiguel_nr_placerville_h_f	9172500
DR_Dolores_at_Dolores_h_f	9166500
SJR_Piedra_River_nr_Arboles_h_f	9349800
SJR_San_Carracas_h_f	9346400
SJR_Los_Pinos_Avb_Vallecito_NR_Bayfield_h_f	9352800
SJR_Vallecito_creek_nr_Bayfield_h_f	9352900
SJR_AnimasRiver_Bl_Silverton_h_f	9359020
SJR_La_Plata_River_nr_Farmington_h_f	9367500
GNR_BlacksFork_Robertson_h_f	9217900
GNR_Muddy_Creek_nr_Hampton_h_f	9222400
GNR_HamsFk_blw_Pole_Creek_h_f	9223000
GNR_Green_nr_Daniel_h_f	9188500
GNR_New_Fork_R_nr_Big_Piney_h_f	9205000
GNR_Big_Sandy_Riv_nr_Farson_h_f	9213500
GNR_Straberry_Res_inflow_h_f	USBR
GNR_Duchesne_nr_Tabiona_h_f	9277500
GNR_Lake_blw_Moon_Lake_h_f	9289500
GRN_Yellowstone_River_nr_Altonah_h_f	9292500
GRN_Uinta_R_blw_PowerPlant_Diversion_nr_Neola_h_f	9296800
GRN_WhiteRocks_River_nr_WhiteRocks_h_f	9299500
YR_MuddyCk_blw_Young_h_f	9258980

Water inflow node	USGS CODE
YR_Little_Snake_R_Slater_h_f	9253000
GNR_Slater_fork_nr_Slater_h_f	9255000
YR_Yampa_abv_Stagecoach_Res_h_f	9237500
GNR_Elkhead_creek_nr_Milner_h_f	9242500
GNR_Elkhead_creek_nr_Craig_h_f	9246500
GNR_White_River_Above_Coal_Creek_nr_Meeker_h_f	9304200
GNR_Piceance_Creek_At_River_h_f	9306222
GNR_FishCk_nr_Scofield_h_f	9310500
GNR_Mud_Ck_Scofield_h_f	9310700
GNR_White_blw_Rk_Summit_h_f	9312600
Joes_Valley_Res_tail_h_f	USBR
GNR_Ferron_Creek_nr_Ferron_h_f	9326500
DDR_Muddy_creek_nr_emery_h_f	9330500
GNR_Escalante_nr_Escalante_h_f	9337500
LCR_Little_Colorado_Grenn_h_f	9383400
GR_Virgin_River_ab_creek_la_verkin_h_f	9406100
GR_ASH_springs_blw_Div_h_f	9415645
BWR_BillW_River_nr_Parker_h_f	9426620
GR_GILA_at_Head_Safford_nr_Solomon_h_f	9448500
GR_SanPedro_at_REDINGTON_h_f	9472050
GR_Verde_River_abv_Horseshoe_Dam_h_f	9508500
GR_Salt_River_Stewart_Mont_Dam_h_f	9502000
GR_Hassayampa_River_Morristown_h_f	9516500

Table A6. Water inflow by month

Water inflow node	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
GR_Salt_River_Stewart_Mont_Dam_h_f	1.91	5.46	30.23	52.11	60.12	74.02	80.55	72.68	67.30	24.34	1.53	3.15	473.41
GNR_New_Fork_R_nr_Big_Piney_h_f	12.18	11.10	15.45	23.50	66.96	161.64	77.63	29.11	19.62	20.79	18.57	14.60	471.15
GNR_Elkhead_creek_nr_Milner_h_f	5.04	4.78	9.63	44.81	130.85	135.19	28.86	7.86	5.69	7.32	5.95	5.53	391.52
GNR_White_River_Above_Coal_Creek_nr_Meeker_h_f	17.85	15.72	18.46	30.37	89.10	95.15	25.43	15.62	12.61	20.19	19.15	18.46	378.10
SJR_San_Carracas_h_f	8.63	10.11	29.23	48.07	97.70	78.55	20.83	16.56	13.88	12.47	10.48	8.95	355.44
GNR_Green_nr_Daniel_h_f	6.46	5.91	7.60	15.76	60.98	99.97	69.94	29.75	16.24	11.07	8.47	7.17	339.30
DR_Dolores_at_Dolores_h_f	2.82	2.79	6.41	37.74	96.69	69.05	18.99	13.24	8.38	5.69	3.87	3.01	268.68
SJR_Piedra_River_nr_Arboles_h_f	4.25	4.20	16.08	43.71	67.39	50.42	10.55	10.53	8.00	7.69	5.77	4.84	233.45
GR_North_Fork_Gunnison_blw_Paonia_h_f	6.27	5.31	12.32	54.34	97.30	31.84	1.87	1.44	1.46	3.57	5.43	4.25	225.40
GR_East_River_at_Almont_h_f	3.83	3.25	3.89	14.00	56.82	73.70	27.78	12.64	6.94	6.24	5.30	4.39	218.79
GR_Verde_River_abv_Horseshoe_Dam_h_f	25.69	24.61	39.93	11.25	8.26	4.87	8.73	15.76	9.58	10.75	12.14	17.11	188.68
SJR_AnimasRiver_Bl_Silverton_h_f	3.84	3.18	4.13	10.72	40.23	57.89	22.82	12.05	8.08	7.60	4.96	4.14	179.64
GR_GILA_at_Head_Safford_nr_Solomon_h_f	13.18	14.97	27.53	16.86	8.58	4.13	10.20	19.18	14.93	9.38	10.23	12.26	161.43
DR_SanMiguel_nr_placerville_h_f	3.69	3.43	4.45	13.06	32.27	45.63	21.83	11.62	7.36	6.19	4.61	3.90	158.06
YR_Little_Snake_R_Slater_h_f	1.88	1.77	2.88	15.71	64.25	50.47	6.99	2.03	1.52	2.15	2.00	1.83	153.48
RF_Marron_Creek_h_f	4.78	4.16	4.58	8.11	20.43	53.01	17.90	9.89	7.27	7.59	6.12	5.34	149.18
BR_blw_Dillon_h_f	4.56	4.01	4.54	5.99	16.08	36.13	17.24	11.62	7.15	6.43	5.57	4.77	124.10
GNR_Duchesne_nr_Tabiona_h_f	5.68	4.91	5.81	7.71	24.97	31.22	7.87	5.29	5.13	6.59	6.63	6.21	118.02
CR_Plateau_Creek_nr_Cameo_h_f	4.77	4.56	6.50	12.67	31.31	18.10	5.08	4.42	4.99	6.31	6.02	5.42	110.16
GR_Tomichi_Creek_at_Gunnison_h_f	3.90	3.77	6.44	12.12	19.53	21.44	9.17	9.18	4.64	5.34	5.61	4.42	105.56
GNR_BlacksFork_Robertson_h_f	1.50	1.22	1.45	2.91	24.61	43.00	12.94	4.91	3.27	3.06	2.32	1.80	102.99
SJR_Vallecito_creek_nr_Bayfield_h_f	1.33	1.10	2.03	7.30	23.45	26.66	10.93	6.81	5.29	4.40	2.25	1.57	93.11
GRN_Yellowstone_River_nr_Altonah_h_f	3.12	2.61	2.94	3.42	14.36	26.10	10.92	7.98	6.31	5.36	4.17	3.48	90.76
CR_blw_Shadow_Mont_Rer_h_f	1.48	1.31	1.40	1.56	17.90	47.45	4.02	3.13	2.48	2.13	2.53	1.78	87.19
GRN_Uinta_R_blw_PowerPlant_Diversion_nr_Neola_h_f	1.89	1.64	2.01	2.81	14.66	22.97	11.79	8.17	6.09	4.45	2.76	2.19	81.44
SJR_Los_Pinos_Avb_Vallecito_NR_Bayfield_h_f	1.53	1.42	2.59	12.81	26.13	16.19	6.10	5.07	2.15	3.19	2.15	1.69	81.01
GR_Uncompahgre_River_nr_ouray_h_f	1.60	1.33	2.18	5.68	20.95	23.86	8.87	5.80	3.54	2.93	2.09	1.81	80.65
GNR_Elkhead_creek_nr_Craig_h_f	0.31	0.33	2.69	21.63	37.80	7.15	0.64	0.69	2.10	0.58	0.30	0.30	74.52

GRN_WhiteRocks_River_nr_WhiteRocks_h_f	1.78	1.44	1.65	2.46	15.90	18.60	9.82	7.53	4.92	3.61	2.40	1.99	72.10
GR_Cimarron_River_blw_Squaw_Creek_h_f	1.93	1.82	2.64	5.87	12.69	29.69	5.86	2.58	1.59	2.43	2.42	2.20	71.72
CR_Salt_Creek_nr_Mouth_nr_Mack_h_f	1.54	1.33	0.61	4.25	9.07	7.49	8.36	10.58	10.71	9.86	6.79	1.06	71.65
GNR_Lake_blw_Moon_Lake_h_f	1.59	1.32	1.49	2.43	15.71	25.99	8.09	4.54	3.36	2.81	2.24	1.90	71.46
GNR_Straberry_Res_inflow_h_f	3.04	2.39	5.33	8.28	22.77	14.59	6.20	1.93	2.16	0.98	1.09	1.82	70.58
GR_Taylor_River_at_Taylor_Park_h_f	2.13	1.88	2.17	4.46	14.77	20.67	7.18	4.70	3.45	3.38	2.63	2.35	69.76
GNR_HamsFk_blw_Pole_Creek_h_f	0.84	0.83	1.25	5.37	23.27	19.30	4.32	1.62	1.11	1.31	1.15	0.97	61.35
CR_Elk_Creek_nr_new_Castle_h_f	1.24	0.95	1.35	2.38	25.16	24.88	1.00	0.20	0.29	1.25	1.28	1.30	61.29
GNR_Big_Sandy_Riv_nr_Farson_h_f	0.68	0.67	1.23	3.27	14.21	23.20	8.21	2.35	1.39	1.68	1.19	0.86	58.94
Joes_Valley_Res_tail_h_f	1.63	1.42	1.85	3.45	18.19	15.61	4.63	2.83	2.40	2.10	1.80	1.67	57.59
GNR_Slater_fork_nr_Slater_h_f	1.01	0.99	1.59	7.35	23.06	12.23	1.16	0.43	0.57	1.08	1.11	1.03	51.62
YR_Yampa_abv_Stagecoach_Res_h_f	3.19	2.97	3.86	3.97	4.97	5.48	4.87	4.58	3.53	3.08	3.10	2.95	46.54
CR_Big_Salt_wash_at_Fruital_h_f	0.60	0.48	0.87	3.96	5.53	5.28	5.58	5.85	6.96	6.83	1.49	0.86	44.30
GR_Virgin_River_ab_creek_la_verkin_h_f	3.35	2.74	3.47	5.62	4.81	2.30	3.51	4.35	3.92	3.48	3.05	3.31	43.91
GNR_Ferron_Creek_nr_Ferron_h_f	0.53	0.50	0.79	2.15	12.44	14.76	4.57	2.13	1.24	0.93	0.74	0.61	41.40
GR_Ohio_Creek_abv_Mouth_nr_Gunnison_h_f	1.12	0.93	1.58	5.08	9.32	9.30	4.96	2.94	1.60	1.20	1.10	1.22	40.36
CR_Canyon_Creek_nr_new_Castle_h_f	1.14	0.93	1.10	1.91	11.69	16.54	1.36	0.17	0.27	0.94	1.16	1.23	38.44
MC_AntelopeCreek_h_f	0.46	0.44	0.81	5.73	20.08	6.71	0.77	0.45	0.32	0.42	0.51	0.51	37.22
CR_Troblesome_h_f	1.22	1.08	1.55	4.89	14.46	5.60	1.14	1.55	1.06	1.11	1.49	1.37	36.51
GR_Loutsenhizer_Arroyo_nr_Olathe_h_f	0.61	0.54	0.64	2.96	3.82	4.20	4.59	5.61	5.40	5.07	1.38	0.85	35.68
GNR_FishCk_nr_Scofield_h_f	0.49	0.44	0.66	3.13	14.36	5.58	1.54	0.84	0.59	0.62	0.60	0.53	29.38
GR_Texa_Creek_at_Taylor_Park_h_f	0.44	0.38	0.56	1.08	5.85	7.40	3.23	1.80	1.23	0.85	0.65	0.56	24.01
DDR_Muddy_creek_nr_emery_h_f	0.47	0.45	0.70	1.55	4.89	6.46	3.45	2.39	1.34	0.87	0.61	0.55	23.74
GR_Dallas_Creek_nr_Ridgway_h_f	1.04	0.98	1.43	2.74	1.46	2.92	3.50	2.63	1.74	1.60	1.38	1.15	22.58
RF_Lime_Creek_h_f	0.00	0.00	0.00	1.20	4.22	8.28	2.34	1.16	0.65	0.00	0.00	0.00	17.85
CR_Parachute_nr_at_Parachute_h_f	0.67	0.70	1.04	3.17	6.90	1.43	0.45	0.37	0.34	0.52	0.71	0.74	17.05
GNR_Muddy_Creek_nr_Hampton_h_f	0.51	0.52	1.98	3.42	6.87	1.61	0.12	0.14	0.09	0.24	0.36	0.48	16.34
GNR_White_blw_Rk_Summit_h_f	0.21	0.22	0.61	2.61	5.94	2.01	0.74	0.30	0.22	0.27	0.27	0.24	13.62
GNR_Piceance_Creek_At_River_h_f	1.32	1.36	1.94	1.39	0.67	0.29	0.37	1.05	0.73	1.14	1.50	1.38	13.13
GR_ASH_springs_blw_Div_h_f	0.97	0.93	1.07	1.04	1.03	1.01	1.04	1.04	1.00	1.08	1.05	1.05	12.30

GNR_Mud_Ck_Scofield_h_f	0.53	0.49	0.63	1.08	2.55	1.68	0.84	0.63	0.63	0.64	0.57	0.55	10.81
GR_Willow_Creek_abv_Taylor_Park_Res_h_f	0.00	0.00	0.00	1.18	2.45	2.23	1.30	1.08	0.88	1.20	0.00	0.00	10.31
Huntingtion_North_Res_tail_h_f	0.69	0.68	0.37	0.19	0.87	1.32	1.55	0.99	0.41	0.25	0.65	0.65	8.62
LCR_Little_Colorado_Grenn_h_f	0.30	0.32	0.51	1.80	1.51	0.70	0.59	0.73	0.45	0.19	0.17	0.22	7.48
SJR_La_Plata_River_nr_Farmington_h_f	0.73	0.94	0.83	0.71	0.30	0.24	0.14	0.22	0.17	0.22	0.22	0.45	5.18
YR_MuddyCk_blw_Young_h_f	0.02	0.09	1.46	1.57	1.46	0.30	0.06	0.05	0.03	0.03	0.02	0.02	5.12
BWR_BillW_River_nr_Parker_h_f	0.65	0.68	0.76	0.62	0.39	0.17	0.09	0.11	0.19	0.27	0.50	0.57	5.00
GNR_Escalante_nr_Escalante_h_f	0.33	0.44	0.57	0.36	0.39	0.18	0.31	0.38	0.25	0.29	0.33	0.27	4.10
GR_SanPedro_at_REDINGTON_h_f	0.02	0.00	0.00	0.00	0.00	0.00	0.74	1.96	0.27	0.03	0.00	0.00	3.01
GR_Hassayampa_River_Morristown_h_f	0.06	0.11	0.13	0.01	0.00	0.00	0.00	0.22	0.01	0.00	0.00	0.02	0.56
GR_Leroux_Creek_abv_Mouth_nr_hotchkiss_h_f	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GR_Fruit_Growers_res_near_orchard_h_f	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CR_Roan_Creek_nr_de_Beque_h_f	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total Basin	193	184	324	651	1613	1732	675	438	329	277	214	193	6827

Table A7. Monthly dam operation restrictions

Reservoir	January	February	March	April	May	June	July	August	September	October	November	December
Big Sandy Reservoir and Dam												
Percentage of Maximum storage	0.65	0.66	0.71	0.77	0.96	1.00	0.98	0.80	0.60	0.59	0.62	0.63
Percentage of Minimum storage	3.13	3.61	4.23	5.55	7.68	11.63	8.22	2.23	1.00	1.43	2.25	2.71
Blue Mesa Reservoir Dam and Powerplant												
Percentage of Maximum storage	0.72	0.70	0.69	0.69	0.77	0.97	1.00	0.99	0.94	0.89	0.85	0.79
Percentage of Minimum storage	1.21	1.15	1.09	1.00	1.17	1.58	1.56	1.41	1.25	1.20	1.20	1.20
Crystal Reservoir Dam and Powerplant												
Percentage of Maximum storage	0.91	0.91	0.92	0.93	0.95	1.00	0.93	0.92	0.92	0.92	0.91	0.91
Percentage of Minimum storage	1.04	1.00	1.03	1.10	1.13	1.09	1.05	1.05	1.01	1.04	1.04	1.04
Flaming Gorge Reservoir Dam and Powerplant												
Percentage of Maximum storage	0.91	0.90	0.89	0.89	0.90	0.95	0.99	1.00	0.99	0.98	0.96	0.94
Percentage of Minimum storage	1.01	1.01	1.00	1.01	1.01	1.16	1.16	1.11	1.10	1.19	1.17	1.01
Fontenelle Reservoir Dam and Powerplant												
Percentage of Maximum storage	0.74	0.64	0.58	0.55	0.63	0.92	1.00	0.99	0.94	0.92	0.88	0.82
Percentage of Minimum storage	1.34	1.52	1.98	2.47	1.08	3.11	4.18	1.02	1.03	1.00	1.04	1.10
Green Mountain Reservoir Dam and Powerplant												
Percentage of Maximum storage	0.71	0.61	0.53	0.47	0.60	0.97	1.00	1.00	0.97	0.94	0.88	0.83

Reservoir	January	February	March	April	May	June	July	August	September	October	November	December
Percentage of Minimum storage	1.35	1.31	1.18	1.00	1.00	1.65	2.55	2.40	1.90	1.57	1.43	1.41
HORSESHOE RESERVOIR AT HORSESHOE DAM												
Percentage of Maximum storage	0.59	0.98	1.00	1.00	0.98	0.74	0.37	0.29	0.28	0.17	0.25	0.40
Percentage of Minimum storage	8.16	82.64	182.33	133.75	19.04	1.70	1.33	1.00	2.60	2.77	2.81	5.32
Huntington North Reservoir and Dam												
Percentage of Maximum storage	0.95	0.97	0.99	0.99	1.00	0.99	0.94	0.87	0.79	0.72	0.76	0.86
Percentage of Minimum storage	2.71	3.76	4.73	5.68	4.98	3.86	2.60	1.38	1.08	1.00	1.21	1.99
Joes Valley Reservoir and Dam												
Percentage of Maximum storage	0.74	0.74	0.75	0.77	0.88	1.00	0.98	0.89	0.79	0.73	0.72	0.73
Percentage of Minimum storage	1.09	1.10	1.11	1.03	1.13	1.43	1.39	1.21	1.09	1.00	1.04	1.06
Lake Granby and Dam												
Percentage of Maximum storage	0.89	0.85	0.82	0.79	0.83	0.98	1.00	0.99	0.98	0.96	0.94	0.92
Percentage of Minimum storage	1.43	1.23	1.04	1.00	1.12	1.74	2.10	2.09	1.96	1.94	1.80	1.62
Lake Havasu Parker Dam and Powerplant												
Percentage of Maximum storage	0.89	0.90	0.91	0.96	1.00	1.00	1.00	0.97	0.93	0.93	0.91	0.90
Percentage of Minimum storage	1.01	1.00	1.00	1.03	1.07	1.07	1.07	1.05	1.03	1.02	1.02	1.01
Lake Mead Hoover Dam and Powerplant												

Reservoir	January	February	March	April	May	June	July	August	September	October	November	December
Percentage of Maximum storage	0.96	0.95	0.95	0.95	0.95	0.98	0.99	0.99	1.00	0.98	0.98	0.97
Percentage of Minimum storage	1.05	1.08	1.09	1.09	1.08	1.04	1.02	1.01	1.00	1.00	1.00	1.02
Lake Mohave Davis Dam and Powerplant												
Percentage of Maximum storage	0.97	0.98	0.98	0.98	1.00	0.99	0.97	0.97	0.95	0.90	0.90	0.93
Percentage of Minimum storage	1.15	1.19	1.20	1.16	1.17	1.18	1.07	1.01	1.00	1.00	1.02	1.08
Lake Powell Glen Canyon Dam and Powerplant												
Percentage of Maximum storage	0.90	0.88	0.88	0.88	0.92	0.98	1.00	0.98	0.96	0.94	0.93	0.92
Percentage of Minimum storage	1.01	1.00	1.02	1.05	1.10	1.12	1.12	1.12	1.10	1.08	1.07	1.03
Mcphee Reservoir and Dam												
Percentage of Maximum storage	0.84	0.84	0.85	0.93	0.98	1.00	0.98	0.92	0.87	0.85	0.84	0.84
Percentage of Minimum storage	1.04	1.04	1.05	1.13	1.28	1.20	1.10	1.05	1.00	1.00	1.01	1.02
Meeks Cabin Reservoir and Dam												
Percentage of Maximum storage	0.55	0.57	0.65	0.73	0.99	1.00	0.96	0.81	0.66	0.56	0.53	0.53
Percentage of Minimum storage	1.72	2.04	2.63	3.36	5.22	7.04	3.60	2.04	1.26	1.00	1.14	1.43
Moon Lake Reservoir and Dam												
Percentage of Maximum storage	0.81	0.83	0.87	0.91	0.88	1.00	0.96	0.86	0.67	0.64	0.69	0.76
Percentage of Minimum storage	2.26	2.49	2.77	3.06	2.51	3.34	1.76	1.24	1.00	1.18	1.49	1.94

Reservoir	January	February	March	April	May	June	July	August	September	October	November	December
Morrow Point Reservoir Dam and Powerplant												
Percentage of Maximum 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
Percentage of Minimum storage	1.00	1.00	1.00	1.00	1.02	1.03	1.04	1.04	1.03	1.01	1.01	1.01
Navajo Reservoir and Dam												
Percentage of Maximum storage	0.94	0.92	0.91	0.93	0.96	0.99	1.00	0.99	0.98	0.97	0.96	0.95
Percentage of Minimum storage	1.01	1.01	1.00	1.10	1.16	1.28	1.19	1.14	1.06	1.03	1.02	1.02
Ridgway Reservoir and Dam												
Percentage of Maximum storage	0.92	0.93	0.93	0.91	0.92	1.00	1.00	0.97	0.89	0.89	0.90	0.91
Percentage of Minimum storage	1.03	1.04	1.06	1.06	1.02	1.19	1.23	1.11	1.01	1.00	1.01	1.03
Ruedi Reservoir and Dam												
Percentage of Maximum storage	0.81	0.76	0.71	0.68	0.79	0.98	1.00	0.99	0.98	0.96	0.92	0.86
Percentage of Minimum storage	1.23	1.18	1.07	1.00	1.01	1.40	1.73	1.62	1.46	1.27	1.22	1.21
SAN CARLOS RESERVOIR AT COOLIDGE DAM												
Percentage of Maximum storage	0.61	0.93	1.00	0.76	0.79	0.70	0.56	0.48	0.39	0.38	0.47	0.56
Percentage of Minimum storage	32.42	64.95	67.41	30.26	6.01	1.00	1.36	4.49	13.01	17.22	16.46	23.59
Scofield Reservoir and Dam												
Percentage of Maximum storage	0.70	0.72	0.74	0.76	0.84	1.00	0.94	0.84	0.72	0.67	0.66	0.68

Reservoir	January	February	March	April	May	June	July	August	September	October	November	December
Percentage of Minimum storage	1.17	1.34	1.57	1.79	2.48	2.98	2.23	1.58	1.14	1.03	1.00	1.08
Starvation Reservoir and Dam												
Percentage of Maximum storage	0.91	0.95	0.98	0.99	0.98	1.00	1.00	0.99	0.93	0.91	0.91	0.91
Percentage of Minimum storage	1.26	1.34	1.42	1.45	1.44	1.48	1.31	1.12	1.00	1.02	1.11	1.16
Strawberry Reservoir and Soldier Creek Dam												
Percentage of Maximum storage	0.95	0.95	0.95	0.95	0.97	1.00	1.00	0.99	0.96	0.95	0.95	0.95
Percentage of Minimum storage	1.01	1.00	1.01	1.03	1.03	1.10	1.06	1.03	1.01	1.02	1.02	1.01
Taylor Park Reservoir and Dam												
Percentage of Maximum storage	0.71	0.72	0.72	0.73	0.79	0.97	1.00	0.98	0.89	0.78	0.74	0.72
Percentage of Minimum storage	1.02	1.02	1.06	1.02	1.06	1.64	1.87	1.64	1.36	1.13	1.02	1.00
Vallecito Reservoir and Dam												
Percentage of Maximum storage	0.62	0.62	0.63	0.71	0.90	1.00	0.99	0.89	0.74	0.65	0.62	0.62
Percentage of Minimum storage	1.29	1.37	1.33	1.37	1.84	2.96	2.50	1.77	1.17	1.00	1.14	1.23
WOLFORD MTN RESERVOIR NR KREMMLING												
Percentage of Maximum storage	0.81	0.81	0.81	0.89	0.99	1.00	0.98	0.97	0.88	0.85	0.83	0.82
Percentage of Minimum storage	1.03	1.01	1.00	1.00	1.39	1.58	1.61	1.45	1.18	1.09	1.07	1.05

Table A9. Evaporation parameters (acre-foot and acres)

Reservoir	Intercept	January	February	March	April	May	June	July	August	September	October	November	December
Big Sandy	0.377	-0.025	-0.001	-0.023	-0.056	0.003	0.122	0.139	0.120	0.062	-0.031	-0.139	-0.145
Blue Mesa	0.255	-0.062	0.000	0.000	-0.075	0.208	1.235	1.596	1.755	1.482	0.762	-0.211	-0.653
Crystal	0.078	-0.016	-0.013	-0.006	0.004	0.015	0.025	0.025	0.015	0.009	-0.004	-0.013	-0.016
Flaming Gorge	0.158	-0.366	-0.010	-0.107	-0.181	2.074	6.112	9.241	10.906	9.671	7.047	2.973	0.394
Fontenelle	0.309	0.000	0.000	-0.004	-0.062	0.050	0.344	0.505	0.435	0.197	0.028	-0.146	-0.051
Granby Dam	0.272	-0.003	0.000	0.000	-0.033	-0.045	0.552	1.025	1.251	0.979	0.420	-0.374	-0.431
Green Mont	0.246	0.000	0.000	0.000	-0.004	0.053	0.313	0.456	0.462	0.320	0.118	-0.092	-0.106
Havasu Lake	1.896	-26.861	-27.374	-25.357	-22.625	-20.171	-18.635	-18.425	-18.064	-18.881	-20.150	-23.033	-25.126
Joes Valley	0.267	-0.002	0.000	-0.006	-0.016	0.083	0.245	0.289	0.261	0.161	0.052	-0.064	-0.076
Marrow Point	0.224	-0.003	0.000	0.000	0.006	0.080	0.150	0.156	0.152	0.121	0.055	-0.019	-0.062
McPhee	0.267	-0.110	-0.062	-0.161	0.009	0.508	1.018	1.026	0.956	0.768	0.433	-0.021	-0.276
Mead Lake	0.417	-19.199	-25.891	-18.798	-7.464	4.989	14.595	18.298	25.653	25.228	18.553	3.478	-8.531
Meek Cabin	0.321	-0.001	0.000	0.000	-0.002	0.004	0.065	0.087	0.065	0.023	-0.009	-0.041	-0.029
Mohave Lake	1.778	-39.705	-40.623	-37.958	-34.022	-30.269	-27.732	-27.064	-26.079	-27.453	-27.955	-32.759	-35.893
Moon Lake	0.320	0.000	0.000	0.000	-0.005	0.001	0.086	0.126	0.108	0.045	-0.016	-0.070	-0.018
Navajo	0.221	-0.578	-0.335	-0.509	0.392	1.991	3.701	3.842	3.814	3.434	2.618	1.004	-0.242
Powell Lake	0.348	-5.293	-6.324	-4.670	-1.511	2.269	5.940	6.971	7.573	6.992	4.454	-0.118	-3.555
Ruedi	0.271	-0.061	0.000	0.000	-0.001	0.025	0.154	0.194	0.199	0.130	0.029	-0.088	-0.189
Scofield	0.301	0.000	0.000	-0.005	-0.077	0.041	0.376	0.505	0.469	0.292	0.076	-0.163	-0.039
Starvation	0.203	-0.027	-0.002	-0.036	0.063	0.451	0.867	1.002	0.959	0.689	0.393	0.047	-0.157
Strawberry	0.268	-0.084	0.000	-0.025	-0.446	-0.178	1.599	2.756	3.340	2.552	1.272	-0.417	-1.018
Taylor Park	0.283	0.000	0.000	0.000	0.000	0.006	0.212	0.298	0.288	0.190	0.043	-0.151	-0.044
Vallecito Lake	0.260	-0.003	0.000	-0.005	-0.028	0.162	0.495	0.534	0.488	0.366	0.186	-0.071	-0.103
Huntingtion North	**0.286**	**-1.360**	**-1.718**	**-1.282**	**-0.523**	**0.291**	**0.921**	**1.133**	**1.195**	**0.990**	**0.573**	**-0.060**	**-0.828**
Horseshoes	**0.286**	**-1.360**	**-1.718**	**-1.282**	**-0.523**	**0.291**	**0.921**	**1.133**	**1.195**	**0.990**	**0.573**	**-0.060**	**-0.828**
Ridgway	**0.286**	**-1.360**	**-1.718**	**-1.282**	**-0.523**	**0.291**	**0.921**	**1.133**	**1.195**	**0.990**	**0.573**	**-0.060**	**-0.828**
SanCarlos	**0.286**	**-1.360**	**-1.718**	**-1.282**	**-0.523**	**0.291**	**0.921**	**1.133**	**1.195**	**0.990**	**0.573**	**-0.060**	**-0.828**
Wolford	**0.286**	**-1.360**	**-1.718**	**-1.282**	**-0.523**	**0.291**	**0.921**	**1.133**	**1.195**	**0.990**	**0.573**	**-0.060**	**-0.828**

Table A10. Cropland, Water applied, Income, No water cost, water cost, net income.

State/Irrigation Unit	Crop acreage 1000 acres	Water applied 1000 acft	Income (M$)	Costs (M$)	Water Costs (M$)	Net Income (M$)
Arizona	803.81	2996.56	2341.90	1557.59	295.79	488.52
Central Arizona Project, AZ	317.75	1266.59	587.71	346.11	109.25	132.35
IRR Gila Project, AZ	146.68	360.27	965.83	736.57	59.12	170.14
IRR Salt River Project, AZ	131.11	542.42	250.69	143.09	50.16	57.44
IRR San Carlos, AZ	96.45	363.32	175.63	107.36	23.30	44.96
IRR AZ Colorado River Indian Reservation, AZ	76.87	342.85	209.39	118.32	40.49	50.58
IIR Silver Creek Wash-Colorado River, AZ, CA, NV	14.75	63.06	42.02	25.99	6.50	9.52
IRR Yuma Project, AZ CA	11.47	22.66	88.00	67.11	3.19	17.69
IRR Palo Verde, CA	7.44	31.80	20.79	11.86	3.44	5.48
IRR Little Colorado, AZ	0.99	2.39	1.22	0.85	0.18	0.20
IRR Sand Hollow Wash-Virgin River, UT	0.30	1.21	0.63	0.32	0.15	0.16
California	528.36	1743.38	2124.51	1358.27	190.43	575.81
IRR Imperial Irrigation District, CA	397.34	1292.63	1242.83	741.67	140.82	360.35
IRR Palo Verde, CA	75.29	321.48	210.20	119.95	34.83	55.42
IRR Coachella Irrigation District, CA	37.41	84.66	548.97	404.73	9.09	135.14
IRR Yuma Project, AZ CA	14.60	28.85	112.00	85.42	4.06	22.52
IIR Silver Creek Wash-Colorado River, AZ, CA, NV	3.68	15.76	10.50	6.50	1.63	2.38
Colorado	468.31	1655.74	900.49	492.21	187.98	220.30
IRR Dolores-Montezuma, CO	63.16	216.60	119.75	63.79	26.23	29.73
IRR Upper-Lower Yampa, CO	58.47	197.89	102.65	57.40	21.97	23.28
IRR Uncompahgre	58.27	208.13	112.78	58.76	21.99	32.03
IRR Lower Gunnison, CO	38.80	137.06	88.53	50.81	14.58	23.14

State/Irrigation Unit	Crop acreage 1000 acres	Water applied 1000 acft	Income (M$)	Costs (M$)	Water Costs (M$)	Net Income (M$)
Colorado Head Plateau Upper	35.11	155.55	82.48	40.75	20.05	21.68
IRR White River, UT	28.19	88.15	45.31	26.62	9.11	9.59
IRR Big Tompson	26.98	84.23	43.15	25.33	8.69	9.14
IRR North Fork Gunnison, CO	25.80	99.73	59.98	33.68	12.01	14.29
IRR Pine River, NM	25.55	80.25	41.20	24.10	8.34	8.76
IRR Miguel, CO	21.42	85.72	45.03	23.22	10.49	11.33
Big Creek-Plateau Creek	20.24	87.65	46.64	23.39	11.16	12.09
IRR Animas-Florida, NM	19.05	59.30	30.67	17.94	6.17	6.56
Roaring Fork	12.08	52.20	27.46	13.65	6.66	7.15
IRR Little Snake, WY-CO	11.47	30.76	15.51	10.01	2.71	2.79
IRR Middle San Juan, NM	11.05	32.35	17.90	10.46	3.50	3.95
IRR Lower Dolores, Co	6.72	24.16	13.36	7.09	2.91	3.35
IRR Upper Uncompahgre	6.03	16.02	8.07	5.22	1.41	1.45
Utah	189.83	582.76	318.68	182.44	61.54	74.70
IRR Duchesne, UT	63.70	177.54	95.21	57.76	16.82	20.63
IRR Lyman, UT	33.80	83.37	42.27	28.44	6.75	7.08
IRR San Rafael, UT	24.02	90.44	51.07	26.09	11.18	13.80
IRR Cottonwood Lower Unita , UT	23.80	67.76	36.63	21.84	6.65	8.14
IRR Price, UT	18.26	67.48	38.19	19.62	8.28	10.29
IRR Fremont, UT	15.59	57.92	33.86	17.47	7.19	9.19
IRR Muddy, UT	5.54	20.43	11.60	5.98	2.50	3.11
IRR Dolores-Montezuma, CO	3.34	11.40	6.30	3.36	1.38	1.56
IRR Lower Dolores, Co	1.78	6.42	3.55	1.89	0.77	0.89

State/Irrigation Unit	Crop acreage 1000 acres	Water applied 1000 acft	Income (M$)	Costs (M$)	Water Costs (M$)	Net Income (M$)
Wyoming	165.81	423.53	210.56	140.36	35.00	35.20
IRR Up and down Fontenelle, WY	113.05	276.03	134.51	93.16	21.05	20.30
IRR Lyman, UT	28.17	69.48	35.23	23.70	5.63	5.90
IRR Eden, UT	16.61	56.64	30.04	16.54	6.44	7.07
IRR Little Snake, WY-CO	7.96	21.37	10.78	6.96	1.88	1.94
New Mexico	41.54	130.67	77.03	45.37	11.76	19.89
IRR Navajo, NM	29.60	88.45	56.04	32.70	8.61	14.73
IRR San Carlos, AZ	8.38	31.59	15.27	9.34	2.03	3.91
IRR Middle San Juan, NM	2.10	6.16	3.41	1.99	0.67	0.75
IRR Animas-Florida, NM	1.43	4.47	2.31	1.35	0.46	0.49
Nevada	1.73	6.61	3.55	1.85	0.81	0.90
IRR Muddy River, NV	1.09	3.92	2.15	1.12	0.48	0.54
IRR Sand Hollow Wash-Virgin River, UT	0.64	2.68	1.40	0.72	0.33	0.35
Basin	2199.36	7539.24	5976.72	3778.08	783.31	1415.33

Table A11. Cropland, Water applied, Income, No water cost, water cost, net income at irrigation district level.

Irrigation Unit	Cropland (1000 acre)	Water Apply (1000 acft)	Net Income (M$)	Cropland	Water Apply	Net Income
IRR Imperial Irrigation District, CA	397.34	1292.63	360.35	18.07%	17.15%	25.46%
IRR Gila Project, AZ	146.68	360.27	170.14	6.67%	4.78%	12.02%
IRR Coachella Irrigation District, CA	37.41	84.66	135.14	1.70%	1.12%	9.55%
Central Arizona Project, AZ	317.75	1266.59	132.35	14.45%	16.80%	9.35%
IRR Palo Verde, CA	82.73	353.28	60.90	3.76%	4.69%	4.30%
IRR Salt River Project, AZ	131.11	542.42	57.44	5.96%	7.19%	4.06%
IRR AZ Colorado River Indian Reservation, AZ	76.87	342.85	50.58	3.50%	4.55%	3.57%
IRR San Carlos, AZ	104.82	394.92	48.87	4.77%	5.24%	3.45%
IRR Yuma Project, AZ CA	26.07	51.50	40.21	1.19%	0.68%	2.84%
IRR Uncompahgre	58.27	208.13	32.03	2.65%	2.76%	2.26%
IRR Dolores-Montezuma, CO	66.47	228.00	31.30	3.02%	3.02%	2.21%
IRR Upper-Lower Yampa, CO	58.47	197.89	23.28	2.66%	2.62%	1.65%
IRR Lower Gunnison, CO	38.80	137.06	23.14	1.76%	1.82%	1.63%
Colorado Head Plateau Upper	35.11	155.55	21.68	1.60%	2.06%	1.53%
IRR Duchesne, UT	63.70	177.54	20.63	2.90%	2.35%	1.46%
IRR Up and down Fontenelle, WY	113.05	276.03	20.30	5.14%	3.66%	1.43%
IRR Navajo, NM	29.60	88.45	14.73	1.35%	1.17%	1.04%
IRR North Fork Gunnison, CO	25.80	99.73	14.29	1.17%	1.32%	1.01%
IRR San Rafael, UT	24.02	90.44	13.80	1.09%	1.20%	0.98%
IRR Lyman, UT	62.00	152.86	12.98	2.82%	2.03%	0.92%
Big Creek-Plateau Creek	20.24	87.65	12.09	0.92%	1.16%	0.85%
IIR Silver Creek Wash-Colorado River, AZ, CA, NV	18.43	78.82	11.91	0.84%	1.05%	0.84%
IRR Miguel, CO	21.42	85.72	11.33	0.97%	1.14%	0.80%

Irrigation Unit	Cropland (1000 acre)	Water Apply (1000 acft)	Net Income (M$)	Cropland	Water Apply	Net Income
IRR Price, UT	18.26	67.48	10.29	0.83%	0.90%	0.73%
IRR White River, UT	28.19	88.15	9.59	1.28%	1.17%	0.68%
IRR Fremont, UT	15.59	57.92	9.19	0.71%	0.77%	0.65%
IRR Big Tompson	26.98	84.23	9.14	1.23%	1.12%	0.65%
IRR Pine River, NM	25.55	80.25	8.76	1.16%	1.06%	0.62%
IRR Cottonwood Lower Unita , UT	23.80	67.76	8.14	1.08%	0.90%	0.58%
Roaring Fork	12.08	52.20	7.15	0.55%	0.69%	0.51%
IRR Eden, UT	16.61	56.64	7.07	0.76%	0.75%	0.50%
IRR Animas-Florida, NM	20.49	63.77	7.06	0.93%	0.85%	0.50%
IRR Little Snake, WY-CO	19.42	52.13	4.72	0.88%	0.69%	0.33%
IRR Middle San Juan, NM	13.15	38.51	4.70	0.60%	0.51%	0.33%
IRR Lower Dolores, Co	8.50	30.58	4.24	0.39%	0.41%	0.30%
IRR Muddy, UT	5.54	20.43	3.11	0.25%	0.27%	0.22%
IRR Upper Uncompahgre	6.03	16.02	1.45	0.27%	0.21%	0.10%
IRR Muddy River, NV	1.09	3.92	0.54	0.05%	0.05%	0.04%
IRR Sand Hollow Wash-Virgin River, UT	0.94	3.89	0.51	0.04%	0.05%	0.04%
IRR Little Colorado, AZ	0.99	2.39	0.20	0.05%	0.03%	0.01%
Basin	**2199.36**	**7539.24**	**1415.33**			

Table A12. Observed flow in the river used as calibration gauge (acre-foot).

Gauge	January	February	March	April	May	June	July	August	September	October	November	December
CR_Colorado_blw_Rk_Springs_v_f	885.42	733.09	750.15	696.20	713.26	821.16	953.06	983.80	714.05	670.22	660.50	836.23
CR_Colorado_Hoover_Dam_v_f	621.03	627.57	925.39	993.72	1014.55	904.46	922.32	860.83	702.15	614.88	612.89	598.28
CR_Colorado_Mohave_Davis Dam_v_f	527.56	599.80	928.46	1017.52	971.51	963.97	1002.25	891.57	761.65	639.47	531.37	497.44
CR_Colorado_nr_Grand_Canyon_v_f	621.03	545.38	651.77	731.90	1014.55	1068.10	946.91	873.13	636.70	566.30	537.92	589.05
CR_Colorado_at_Lee_Ferry_v_f	595.82	518.72	601.35	696.20	983.80	1041.32	916.17	830.08	592.66	526.95	511.14	564.46
CR_Colorado_Parket_Dam_v_f	378.76	478.45	725.56	785.46	737.85	785.46	854.68	750.15	612.89	507.89	387.67	357.55
CR_Colorado_blw_Palo_Verde_Dam_v_f	284.07	358.22	560.77	624.79	563.23	571.84	621.03	521.42	452.23	394.14	301.69	249.95
CR_nr_Cisco_v_f	170.94	161.06	202.91	361.79	934.61	1106.78	377.53	218.28	202.91	227.50	209.46	186.92
CR_nr_ColoradoUtah_state_line_v_f	183.85	166.06	204.75	260.03	694.81	880.66	299.14	211.21	210.35	237.34	216.00	201.68
GNR_Green_at_Green_River_v_f	122.98	129.96	220.74	345.72	811.64	963.97	332.03	180.16	143.41	166.02	155.90	125.43
CR_at_Potash_v_f	183.23	158.56	187.54	218.98	598.58	755.70	263.17	220.43	212.43	245.95	202.91	189.38
GNR_Green_at_Mineral_v_f	186.31	186.05	207.83	257.36	639.47	734.88	193.69	134.66	132.10	163.56	157.39	178.93
GRN_nr_Jensen_v_f	111.60	108.30	151.26	273.72	627.17	624.79	196.76	129.74	110.68	118.67	111.87	114.98
GNR_Green_River_Ouray_v_f	142.04	141.62	136.81	245.75	561.08	577.19	156.18	123.28	120.20	127.59	120.79	140.81
CR_nr_Cameo_v_f	92.85	83.86	103.30	149.65	461.77	678.35	261.94	153.72	129.72	129.74	110.68	99.61
CR_ColoradoR_blw_Grand_Vall_div_nr_Palisade_v_f	95.92	85.53	106.99	91.64	345.56	481.39	126.66	63.95	64.26	74.40	109.49	97.77
GR_Gunnison_nr_G_Junction_v_f	58.41	55.54	71.33	135.07	355.09	309.12	104.53	74.40	75.57	84.85	75.57	65.18
CR_nr_Dotsero_v_f	52.88	47.76	58.29	89.26	242.26	343.04	137.43	93.46	78.55	74.40	60.69	55.34
YR_Yampa_at_Deerlodge_v_f	22.47	22.21	61.03	163.64	438.72	350.18	46.42	15.68	13.21	25.21	27.97	22.07
SJR_SJuan_nr_Bluff_v_f	49.53	51.87	73.79	108.89	228.73	244.56	83.01	62.72	53.46	59.21	53.02	49.84
GR_Green_River_nr_Greelndales_v_f	83.01	75.53	67.64	87.47	116.83	123.77	106.99	101.76	93.12	84.24	77.95	86.08
SJR_Sjuan_at_Farmington_v_f	43.84	44.26	62.10	99.37	221.97	229.69	76.24	53.83	49.63	52.14	44.84	44.03
GR_Gunninson_Delta_v_f	62.10	54.70	65.79	100.86	199.22	145.49	66.41	63.33	58.31	60.63	57.63	66.41
SJR_SJuan_4Corners_v_f	53.19	50.54	63.95	86.28	180.77	222.25	67.64	52.57	51.59	55.95	53.58	55.22
GNR_Green_River_nr_GrennRiver_v_f	49.19	46.85	59.03	79.14	103.91	228.20	116.21	81.78	56.53	55.68	51.77	48.58
GNR_Green_blw_FontanelleReser_v_f	56.02	49.87	57.74	74.98	102.07	214.81	106.99	84.24	60.69	57.80	55.34	55.34
YR_Yampa_at_Maybell_v_f	15.99	16.38	32.59	124.96	352.32	299.01	51.90	17.52	11.07	17.65	18.57	16.36
GNR_Green_nr_Barge_v_f	27.05	25.55	39.44	71.41	144.50	273.72	150.03	64.56	41.56	43.56	41.59	30.74

RF_Glenwood_Spr_v_f	25.82	21.66	25.95	41.65	135.58	254.68	115.60	53.19	41.65	39.97	33.56	29.21
GNR_Yampa_River_blw_Craig_v_f	12.67	12.83	29.36	114.25	283.77	225.52	35.20	11.99	10.35	15.43	16.33	12.73
GNR_Yampa_abv_Elkhead_creek_nr_Hayden_v_f	12.42	12.02	20.41	98.48	248.41	229.09	31.54	12.42	8.81	17.16	17.32	12.79
CR_Colorado_Yuma_Main_Canal_v_f	60.69	45.21	52.11	54.42	70.10	56.35	51.10	65.18	69.62	47.71	59.09	63.33
CR_nr_Kremmling_v_f	27.61	25.16	32.04	50.43	99.00	137.75	78.09	65.18	51.77	46.18	33.62	28.41
GR_Gunninson_blw_GTunnel_v_f	28.90	27.21	37.08	42.84	121.13	151.14	53.37	36.46	26.66	26.44	34.75	30.74
SJR_Sjuan_nr_Fruitland_v_f	34.19	29.27	31.91	36.03	106.68	85.98	49.13	43.38	38.62	40.31	35.61	35.14
SJR_AnimasRiver_nr_Cedar_v_f	14.27	13.00	20.72	51.08	132.20	144.60	52.26	30.62	23.59	21.89	17.26	15.34
SJR_AnimasRiver_nr_Farmington_v_f	15.56	14.83	21.83	46.71	120.52	139.54	42.37	20.78	16.10	19.55	18.24	16.66
GR_Salt_River_Stewart_Mont_Dam_v_f	0.61	0.62	27.18	48.56	63.95	77.95	84.85	76.24	67.24	27.42	0.58	0.65
SJR_San_Juan_Archuleta_v_f	30.50	28.10	31.91	34.33	67.02	60.10	40.49	42.76	39.27	36.34	29.63	30.44
GNR_White_River_nr_Watson_v_f	20.91	21.10	29.27	34.36	86.08	99.97	32.47	23.27	21.66	25.82	23.98	21.52
GNR_White_River_Below_Boise_Creek_nr_Rangely_v_f	22.75	20.27	25.82	36.30	83.32	95.21	33.20	21.52	20.80	27.67	25.26	23.98
GNR_New_Fork_R_nr_Big_Piney_v_f	12.30	11.27	15.37	21.36	49.01	151.14	67.02	26.99	19.58	20.66	18.68	14.45
GNR_White_River_blw_Meeker_v_f	20.29	18.33	22.14	30.59	83.62	102.35	33.45	22.44	21.48	25.82	23.21	21.52
GNR_White_River_nr_Meeker_v_f	19.06	16.88	20.29	28.26	85.47	105.92	31.67	21.58	19.64	23.06	21.06	19.98
RF_nr_Enma_v_f	15.31	13.05	15.19	22.05	49.68	96.69	43.90	32.77	26.75	22.07	18.27	16.54
DR_Dolores_nr_Bedrock_v_f	11.73	12.64	19.68	52.36	149.54	42.13	16.23	15.00	11.66	11.14	10.07	10.35
GNR_White_River_Above_Coal_Creek_nr_Meeker_v_f	17.71	15.61	18.02	26.90	79.32	92.83	24.47	15.37	13.27	20.41	19.34	18.45
GNR_Elkhead_creek_nr_Milner_v_f	5.23	4.72	9.10	38.26	121.13	124.96	24.04	7.50	5.04	7.13	5.95	5.53
SJR_San_Carracas_v_f	8.30	8.50	22.07	47.40	91.62	79.74	20.66	14.57	11.45	11.62	10.12	8.61
DR_Dolores_nr_Cisco_v_f	9.22	9.75	13.53	53.49	106.07	69.62	19.74	11.74	7.68	9.90	9.40	8.79
GR_Salt_Roosevelt_v_f	17.49	28.05	71.33	69.02	35.29	13.09	12.91	22.38	16.07	12.91	13.57	15.13
YR_Little_Snake_R_Lily_v_f	5.16	5.28	15.56	46.65	135.89	89.26	7.56	1.23	1.01	5.04	6.37	5.53
CR_Colorado_Laguna_Dam_v_f	24.96	22.16	28.96	29.28	30.62	27.58	27.67	29.64	29.34	24.23	23.09	23.86
GNR_Green_nr_Daniel_v_f	6.46	5.89	7.38	14.28	52.05	97.88	67.02	27.18	15.35	11.07	8.27	7.38
SJR_SJuan_at_Boloak_v_f	23.40	22.55	24.99	24.55	18.08	21.84	35.60	34.31	39.01	29.02	20.59	22.44
SJR_AnimasRiver_Timber_v_f	5.84	5.34	6.89	21.90	71.33	101.16	34.86	19.03	11.90	11.68	7.85	6.09
BR_GreenMontain_Res_v_f	15.37	13.22	14.70	17.79	21.03	40.46	36.71	34.99	29.69	22.75	15.89	16.11
CR_Colorado_Imperial_Dam_v_f	22.32	18.27	22.20	24.87	24.04	22.31	22.69	24.53	24.49	17.62	17.05	18.94

GR_Uncompahgre_BI_Rigway_v_f	6.06	5.55	7.13	24.28	36.40	47.60	46.24	41.57	17.73	9.44	6.03	6.39
UR_Uncompahgre_blw_Rigway_v_f	6.06	5.55	7.13	24.28	36.40	47.60	46.24	41.57	17.73	9.44	6.03	6.39
GR_North_Gunnison_abv_mouth_nr_lazear_v_f	8.55	7.00	11.07	28.98	84.85	61.29	7.01	7.35	8.09	10.88	10.00	8.52
DR_Dolores_at_Dolores_v_f	2.83	2.78	5.53	32.61	91.62	63.67	17.09	11.99	7.56	5.43	3.87	3.07
GR_GILA_at_KELVIN_v_f	7.93	11.00	22.75	24.22	23.12	23.80	35.11	36.43	17.82	7.69	3.45	10.21
GNR_Duchesne_nr_Randlett_v_f	20.29	21.10	24.66	15.29	22.01	52.66	6.58	5.41	6.19	10.51	16.96	20.29
GR_North_Fork_Gunnison_blw_Paonia_v_f	5.77	4.93	10.11	39.99	107.60	35.76	1.48	1.13	1.07	3.82	5.28	4.33
GNR_Duchesne_River_at_Myton_v_f	16.60	15.77	19.31	16.48	33.73	60.69	6.52	4.08	3.63	7.62	13.98	17.22
GR_Verde_River_Bartlett_Dam_v_f	17.22	21.10	38.80	24.40	12.54	10.68	13.53	15.43	11.13	13.96	16.90	18.51
SJR_Piedra_River_nr_Arboles_v_f	4.20	4.17	12.60	39.27	66.41	43.62	10.18	9.28	6.90	7.13	5.54	4.61
UR_Uncompahgre_nr_Rigwat_v_f	5.41	4.89	6.64	11.78	35.11	63.43	31.79	15.99	10.95	9.84	7.71	6.21
GR_Uncompahgre_nr_Rigwat_v_f	5.41	4.89	6.64	11.78	35.11	63.43	31.79	15.99	10.95	9.84	7.71	6.21
GR_East_River_at_Almont_v_f	3.81	3.28	3.75	10.77	55.86	72.60	24.60	11.93	6.78	6.21	5.36	4.30
GR_Taylor_River_at_Almont_v_f	7.07	6.11	7.38	10.77	27.70	42.66	29.45	22.44	18.21	11.62	8.33	7.38
GR_Verde_River_SCOTTSDALE_v_f	14.27	18.16	28.78	16.48	10.88	18.06	17.83	10.08	5.89	15.19	22.20	20.41
DR_SanMiguel_at_Uravan_v_f	4.92	5.16	7.50	30.64	50.97	46.12	16.17	7.44	4.53	7.04	5.88	4.98
GR_Uncompahgre_nrncompahgre_v_f	9.04	7.72	9.53	13.69	22.69	26.12	13.77	13.83	21.66	25.33	15.65	11.13
GR_GILA_blw_Coolodge_Dam_v_f	4.12	7.55	18.32	23.24	23.18	24.52	28.56	23.80	13.69	6.09	1.55	7.50
LCR_Little_River_v_f	13.90	13.00	26.29	14.73	13.47	12.97	13.83	18.63	14.22	14.02	13.27	13.77
DR_Dolores_nr_Gateway_v_f	6.33	7.94	11.74	20.74	36.28	40.58	15.93	10.61	4.89	8.36	7.68	6.33
GR_Verde_River_abv_Horseshoe_Dam_v_f	18.94	17.83	27.98	13.60	9.47	6.37	7.87	12.97	10.12	11.68	13.75	16.72
GR_Uncompahgre_river_at_Colona_v_f	4.55	4.17	5.53	12.14	29.91	44.48	23.49	14.20	6.84	6.64	5.65	4.92
SJR_AnimasRiver_Bl_Silverton_v_f	3.87	3.11	3.94	8.90	32.71	55.37	20.11	10.51	7.74	7.01	4.94	4.09
RF_Marron_Creek_v_f	4.79	4.24	4.76	6.90	24.75	53.79	17.59	10.02	7.32	7.99	6.28	5.32
DR_SanMiguel_nr_placerville_v_f	3.69	3.39	4.30	10.47	29.64	43.32	20.66	10.70	6.84	6.02	4.64	3.94
YR_Little_Snake_R_Slater_v_f	1.84	1.72	2.64	10.89	60.26	45.88	5.37	1.89	1.39	1.97	1.96	1.84
GR_GILA_at_Head_Safford_nr_Solomon_v_f	12.91	13.72	22.50	15.71	7.75	3.75	6.58	15.00	10.00	7.81	9.52	11.93
GNR_Blacks_blw_Fk_America_v_f	2.71	4.19	12.30	16.90	36.68	35.32	8.42	2.77	2.14	3.44	3.81	2.89
BR_blw_Dillon_v_f	4.55	4.00	4.67	5.91	12.11	35.43	17.65	10.33	6.55	6.39	5.57	4.74
RF_FryingpanRiver_v_f	5.66	5.27	6.76	7.62	12.05	15.98	11.99	11.81	10.35	7.01	5.55	5.76

GNR_Duchesne_nr_Tabiona_v_f	5.53	4.89	5.66	7.08	18.20	25.62	7.50	5.29	5.16	6.46	6.66	6.15
GR_Tomichi_Creek_at_Gunnison_v_f	3.94	3.72	5.78	11.07	17.83	20.83	8.36	8.61	4.76	5.29	5.61	4.37
CR_Plateau_Creek_nr_Cameo_v_f	4.67	4.38	6.03	10.65	28.28	13.30	4.24	4.24	4.76	6.33	5.89	5.29
YR_Yampa_blw_Stagecoach_Res_v_f	5.71	5.26	6.76	10.12	12.67	10.95	9.84	9.22	7.14	6.52	6.43	5.78
YR_Yampa_abv_Stagecoach_Res_v_f	5.71	5.26	6.76	10.12	12.67	10.95	9.84	9.22	7.14	6.52	6.43	5.78
GNR_BlacksFork_Robertson_v_f	1.54	1.24	1.48	2.38	20.60	37.64	12.30	4.69	3.15	2.99	2.34	1.84
SJR_Los_Pinos_River_at_Boca_v_f	3.69	3.94	8.12	9.85	9.78	11.01	9.65	9.72	8.96	7.38	3.99	3.81
SJR_Vallecito_creek_nr_Bayfield_v_f	1.28	1.06	1.72	6.01	21.77	25.38	10.27	6.03	4.44	3.87	2.20	1.54
VR_Virgin_River_nr_Overton_v_f	12.11	10.91	10.70	9.10	6.46	2.34	2.06	2.52	2.95	7.50	6.90	10.82
GRN_Yellowstone_River_nr_Altonah_v_f	3.07	2.61	2.89	3.33	11.50	23.36	10.33	7.69	6.01	5.29	4.05	3.44
CR_blw_Shadow_Mont_Rer_v_f	1.44	1.28	1.41	1.43	17.74	42.87	3.27	3.07	2.32	2.20	2.46	1.78
GR_Virgin_River_nr_Bloomington_v_f	8.98	8.11	11.62	12.59	7.32	2.38	2.35	3.14	3.39	5.12	6.84	7.50
GNR_Lake_avb_Moon_Lake_v_f	0.00	0.00	0.00	0.30	17.95	18.45	20.05	15.56	6.07	0.31	0.00	0.00
GR_Uncompahgre_River_nr_ouray_v_f	1.58	1.32	2.00	5.11	16.60	25.94	8.49	4.70	3.38	2.88	2.15	1.80
GRN_Uinta_R_blw_PowerPlant_Diversion_nr_Neola_v_f	1.91	1.65	2.03	2.59	12.48	19.67	11.44	7.50	5.98	4.44	2.68	2.15
GNR_StrawberryR_nr_ Duchesne_v_f	4.24	4.33	5.41	6.90	14.14	8.93	5.84	5.29	5.16	5.04	4.64	4.43
SJR_Los_Pinos_Avb_Vallecito_NR_Bayfield_v_f	1.57	1.44	2.59	7.38	25.33	11.16	5.02	4.06	2.15	2.77	2.15	1.70
GR_Taylor_River_at_Taylor_Park_v_f	2.15	1.87	2.15	4.28	12.60	20.11	7.38	4.30	3.34	3.32	2.67	2.40
GRN_WhiteRocks_River_nr_WhiteRocks_v_f	1.72	1.44	1.66	2.20	12.36	16.60	9.59	7.01	4.88	3.63	2.44	1.97
GR_GILA_at_Calva_v_f	11.84	10.77	10.70	6.07	2.18	0.57	0.61	3.81	2.74	2.49	5.30	7.62
GNR_Lake_blw_Moon_Lake_v_f	1.60	1.33	1.48	2.08	11.38	22.88	8.12	4.36	3.09	2.77	2.16	1.84
GR_Cimarron_River_blw_Squaw_Creek_v_f	1.91	1.74	2.46	4.91	11.53	25.08	3.88	2.52	1.61	2.32	2.40	2.12
CR_Salt_Creek_nr_Mouth_nr_Mack_v_f	1.83	0.58	0.58	1.87	8.55	7.29	8.49	10.21	10.20	8.64	1.41	1.21
CR_Elk_Creek_nr_new_Castle_v_f	1.29	1.06	1.47	2.00	23.12	24.75	0.92	0.18	0.16	1.23	1.31	1.35
GNR_Elkhead_creek_nr_Craig_v_f	0.32	0.33	2.28	16.66	31.36	4.95	0.42	0.25	1.25	0.36	0.27	0.31
GNR_Duchesne_at_Randlet_v_f	7.75	7.83	9.22	5.71	3.46	3.43	2.25	2.41	2.12	3.22	4.54	5.08
DDR_Fremont_River_nr_Bicknell_v_f	5.23	5.11	5.84	5.00	4.37	3.57	3.69	4.02	4.28	4.67	5.00	5.10
GNR_HamsFk_blw_Pole_Creek_v_f	0.86	0.78	1.11	4.17	19.92	18.15	3.87	1.48	1.12	1.25	1.13	0.98
GNR_Big_Sandy_Riv_nr_Farson_v_f	0.68	0.67	1.23	2.89	10.88	21.36	7.07	2.15	1.37	1.60	1.19	0.80
DRR_Dirty_Devil_Poison_v_f	5.95	6.83	7.38	4.55	2.66	0.98	0.46	1.35	1.77	3.63	5.47	5.66

GNR_Slater_fork_nr_Slater_v_f	1.00	1.00	1.48	5.12	20.35	11.48	0.93	0.42	0.52	1.03	1.07	1.05
CR_Big_Salt_wash_at_Fruital_v_f	0.64	0.47	0.61	4.20	5.59	5.47	5.41	5.84	6.69	6.79	1.28	0.82
GNR_SRafael_nr_grn_river_v_f	1.91	2.50	3.32	2.20	4.24	12.50	2.83	1.91	1.79	2.60	2.50	2.03
CR_nr_Lk_Granby_v_f	2.28	2.00	2.46	4.46	4.80	4.58	4.69	2.58	1.42	4.06	3.33	2.71
MC_blw_Wolford_v_f	1.29	1.16	1.32	2.98	6.01	6.93	4.07	5.35	4.94	1.59	1.26	1.29
DR_Dolores_nr_SlickRock_v_f	1.78	1.80	2.92	5.89	5.75	4.17	3.87	4.04	2.10	2.40	1.76	1.62
GNR_Ferron_Creek_nr_Ferron_v_f	0.52	0.50	0.74	1.84	11.25	13.75	4.12	1.91	1.13	0.89	0.71	0.61
GR_Ohio_Creek_abv_Mouth_nr_Gunnison_v_f	1.09	0.94	1.35	4.04	8.49	9.34	4.61	2.47	1.49	1.14	1.08	1.23
GR_Virgin_River_ab_creek_la_verkin_v_f	2.79	2.47	3.41	4.55	3.12	2.47	2.79	3.25	2.85	3.41	2.64	2.74
GNR_Price_Woodside_v_f	1.72	2.22	4.18	4.34	4.55	3.21	2.34	2.64	2.56	2.77	2.38	1.91
CR_Canyon_Creek_nr_new_Castle_v_f	1.17	0.94	0.98	1.67	9.53	15.14	1.23	0.16	0.12	0.86	1.19	1.23
MC_AntelopeCreek_v_f	0.46	0.45	0.74	4.45	19.55	4.64	0.68	0.44	0.30	0.40	0.48	0.49
CR_blw_Lk_Granby_v_f	1.24	1.14	1.24	1.20	4.58	5.32	5.80	4.51	4.10	1.38	1.25	1.24
CR_Troblesome_v_f	1.20	1.11	1.48	4.28	11.74	4.64	1.23	1.54	1.01	1.17	1.49	1.35
GNR_StrawberryR_nr_ Pinnacles_v_f	1.91	1.78	2.01	2.50	3.04	2.98	2.94	2.77	2.65	2.10	1.96	1.92
GR_Muddy_Glendale_v_f	2.71	2.44	2.64	2.38	2.28	1.99	1.97	1.97	2.05	2.28	2.38	2.67
GR_Escalte_creek_nr_Delta_v_f	0.68	0.72	1.23	6.19	14.70	1.25	0.21	0.22	0.26	0.55	0.77	0.68
SJR_McElmo_creek_nr_Bluff_v_f	1.91	2.39	2.77	1.00	1.91	3.27	3.07	2.44	2.38	2.52	1.79	1.54
GRN_Uinta_River-at_Randlett_v_f	1.68	2.50	3.71	1.49	2.82	3.81	1.55	1.38	1.62	1.72	1.54	1.60
GNR_FishCk_nr_Scofield_v_f	0.49	0.44	0.61	2.23	12.30	4.16	1.41	0.74	0.56	0.60	0.60	0.52
GR_Hassayampa_River_Alington_v_f	2.99	2.11	2.09	1.79	1.79	1.40	1.76	1.67	1.96	2.46	0.89	3.25
GR_Texa_Creek_at_Taylor_Park_v_f	0.46	0.41	0.61	1.01	5.24	7.41	3.14	1.72	1.19	0.85	0.65	0.56
DDR_Muddy_creek_nr_emery_v_f	0.46	0.44	0.61	1.31	4.60	6.37	3.26	2.21	1.25	0.86	0.60	0.55
SJR_Los_Pinos_River_nr_Ignacio_v_f	2.07	1.94	4.34	5.46	1.66	1.12	0.26	0.20	0.27	0.90	1.55	1.78
GR_Dallas_Creek_nr_Ridgway_v_f	1.05	0.95	1.27	2.14	1.23	2.38	3.14	2.46	1.73	1.60	1.41	1.16
CR_Parachute_nr_at_Parachute_v_f	0.68	0.67	0.98	1.96	6.27	1.61	0.37	0.31	0.32	0.57	0.71	0.74
GNR_Piceance_Creek_At_River_v_f	1.29	1.33	1.89	1.41	0.55	0.29	0.42	0.94	0.71	1.19	1.44	1.41
GNR_Muddy_Creek_nr_Hampton_v_f	0.34	0.50	1.30	2.69	5.60	1.02	0.12	0.10	0.10	0.20	0.33	0.40
GR_ASH_springs_blw_Div_v_f	1.01	0.94	1.09	1.05	1.02	1.01	1.05	1.05	1.01	1.08	1.07	1.05
GNR_White_blw_Rk_Summit_v_f	0.21	0.22	0.49	2.25	5.35	1.67	0.59	0.29	0.21	0.26	0.26	0.22

GNR_SRafael_at_Mouth_nr_GR_v_f	0.86	1.28	1.59	1.20	1.78	0.46	0.35	0.57	0.43	1.27	1.24	0.85
GNR_BlacksFork_Lyman_v_f	0.40	0.42	1.23	0.85	0.56	3.30	1.34	0.20	0.27	0.70	0.65	0.54
GNR_Mud_Ck_Scofield_v_f	0.54	0.49	0.65	0.95	2.20	1.48	0.80	0.62	0.62	0.65	0.57	0.55
DDR_Seven_Mile_Creek_nr_Fish_Lake_v_f	0.41	0.36	0.41	0.65	2.34	1.26	0.68	0.58	0.51	0.52	0.50	0.44
GR_Gila_Painted_Rock_Dam_v_f	1.98	0.99	0.88	0.25	0.07	0.02	0.01	0.01	0.02	0.22	0.50	2.64
CLR_LittleCR_at_Holbrook_v_f	0.61	0.56	0.48	0.23	0.17	0.08	0.33	3.07	0.65	0.39	0.36	0.52
LCR_Little_Colorado_Grenn_v_f	0.30	0.28	0.49	1.26	1.35	0.71	0.57	0.68	0.43	0.16	0.14	0.20
BWR_BillW_River_nr_Parker_v_f	0.63	0.67	0.74	0.59	0.39	0.19	0.03	0.00	0.10	0.27	0.50	0.58
YR_MuddyCk_blw_Young_v_f	0.02	0.02	0.61	1.36	1.44	0.20	0.04	0.03	0.02	0.02	0.02	0.02
SJR_La_Plata_River_nr_Farmington_v_f	0.61	0.83	0.79	0.23	0.15	0.08	0.02	0.03	0.04	0.07	0.16	0.39
GNR_Escalante_nr_Escalante_v_f	0.31	0.39	0.53	0.28	0.32	0.12	0.11	0.15	0.13	0.21	0.27	0.28
GR_Gila_at_Estrella_Parkway_Goodyear_v_f	0.22	0.40	0.80	0.15	0.00	0.00	0.00	0.00	0.00	0.00	0.74	0.04
GR_Gila_Dome_v_f	0.16	0.21	0.33	0.29	0.18	0.11	0.10	0.12	0.17	0.16	0.15	0.18
SJR_Chinle_creek_at_mouth_nr_Bluff_v_f	0.08	0.09	0.24	0.01	0.00	0.00	0.05	0.64	0.09	0.13	0.01	0.03
GNR_Yellow_Creek_nr_River_v_f	0.09	0.12	0.14	0.12	0.11	0.08	0.06	0.06	0.07	0.09	0.09	0.09

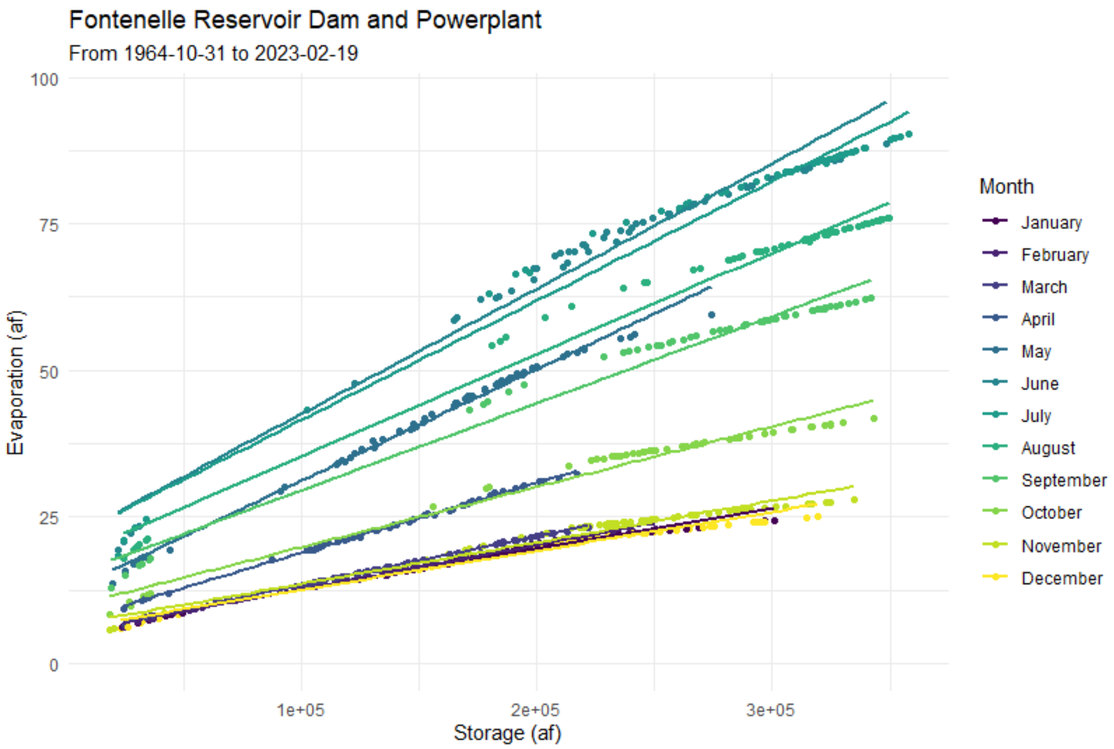


Figure A1. Monthly evaporation and water storage relationship at Fontanelle

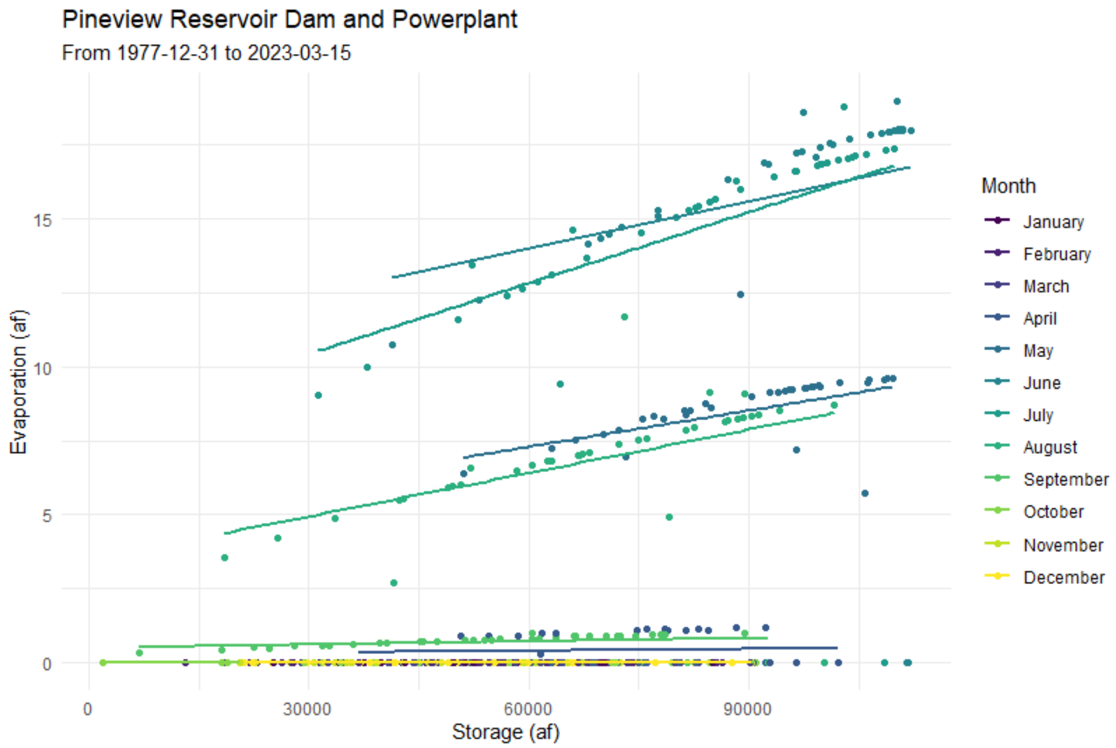


Figure A2. Monthly evaporation and water storage relationship at Pineview

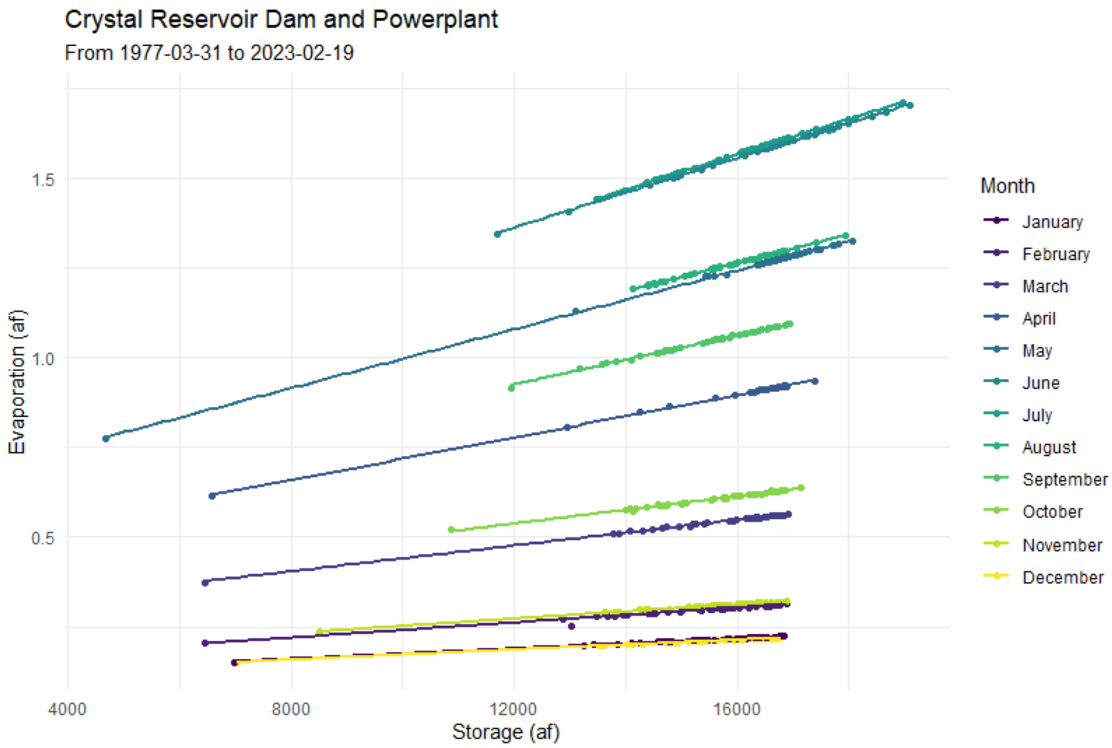


Figure A3. Monthly evaporation and water storage relationship at Crystal

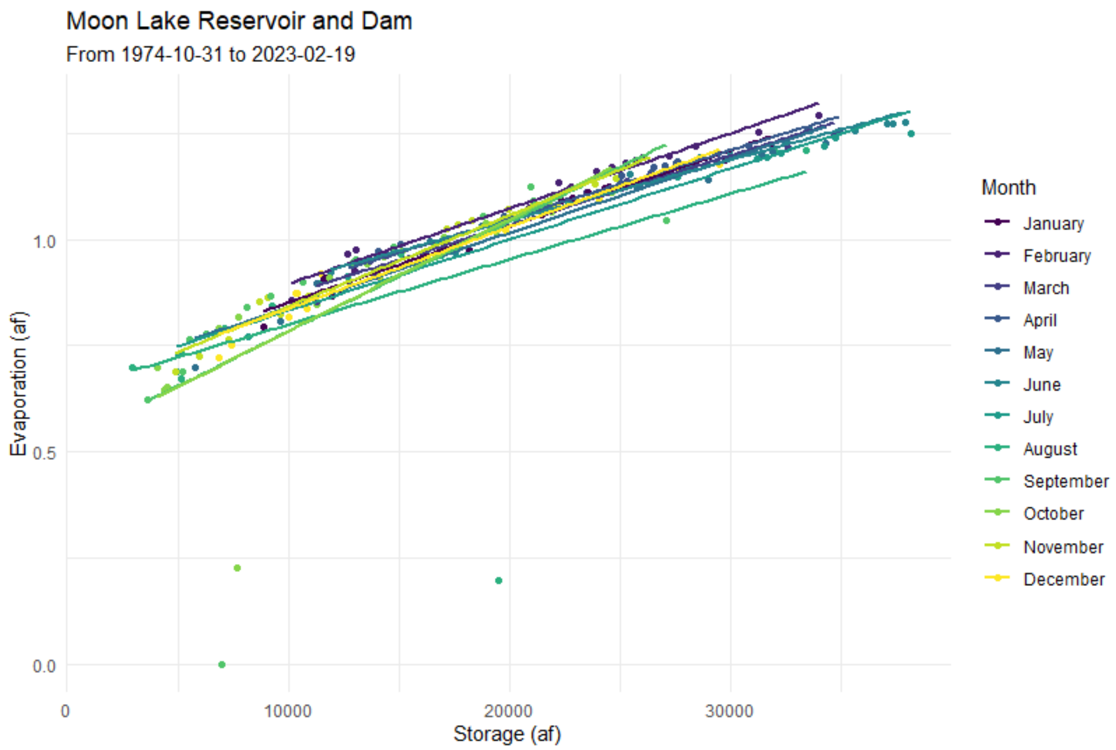


Figure A4. Monthly evaporation and water storage relationship at Moon Lake

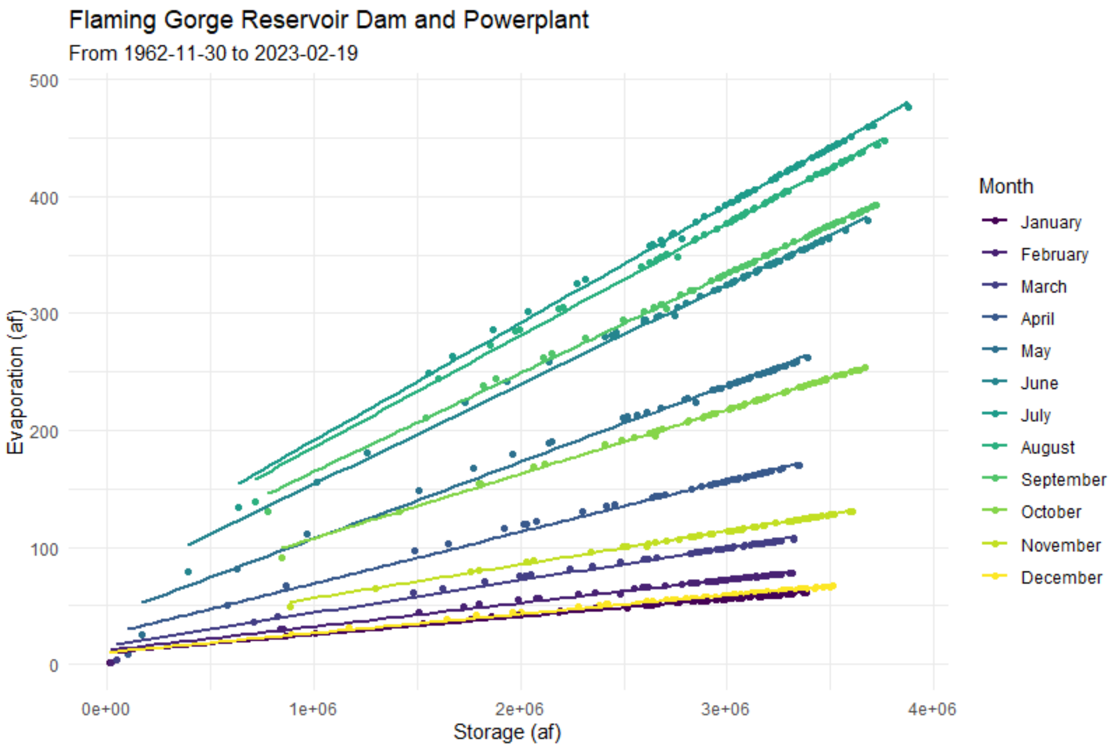


Figure A5. Monthly evaporation and water storage relationship at Flaming Gorge

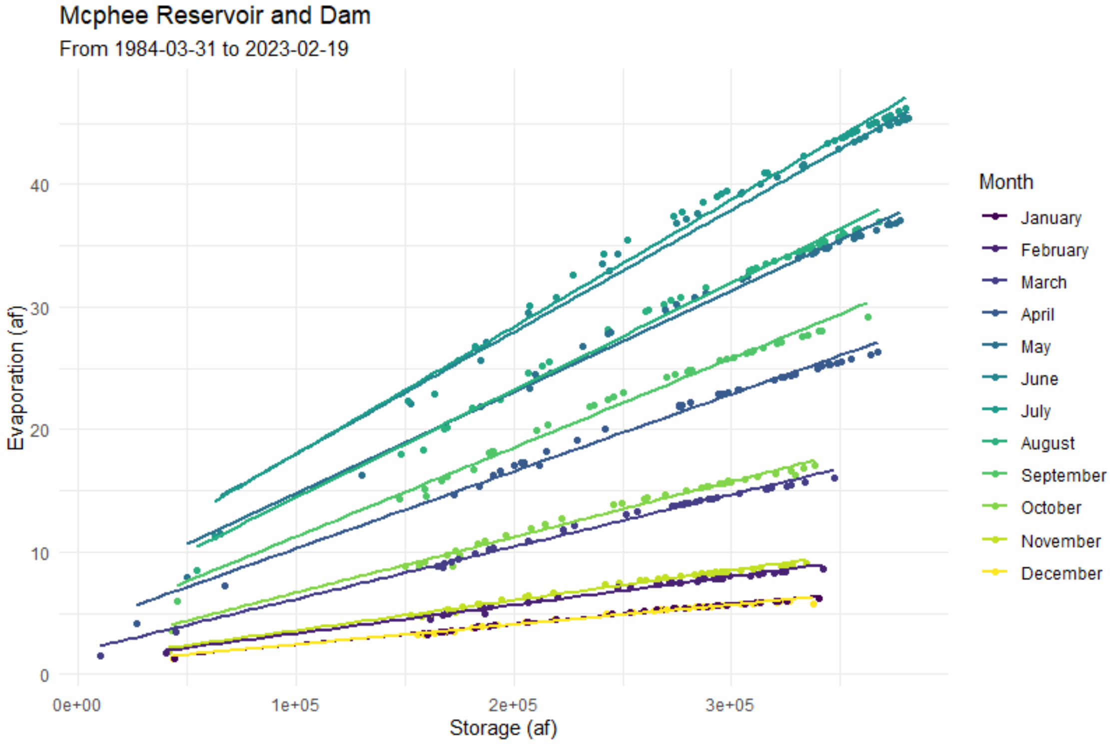


Figure A6. Monthly evaporation and water storage relationship at Mcphee

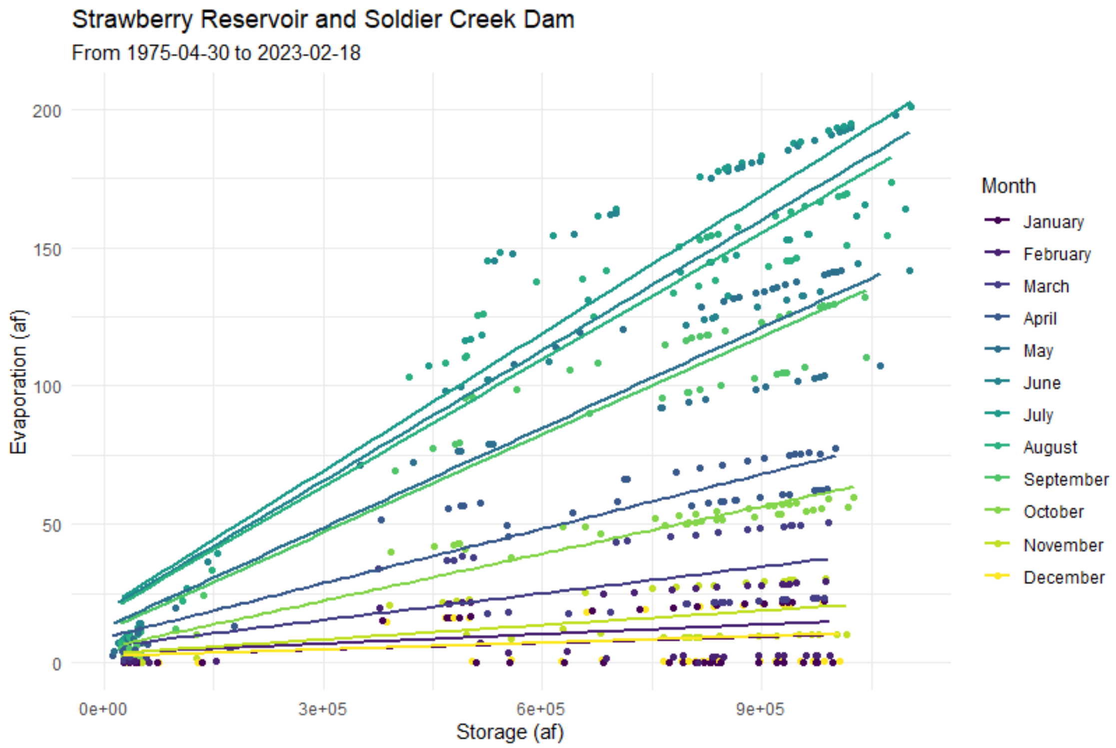


Figure A7. Monthly evaporation and water storage relationship at Strawberry Reservoir

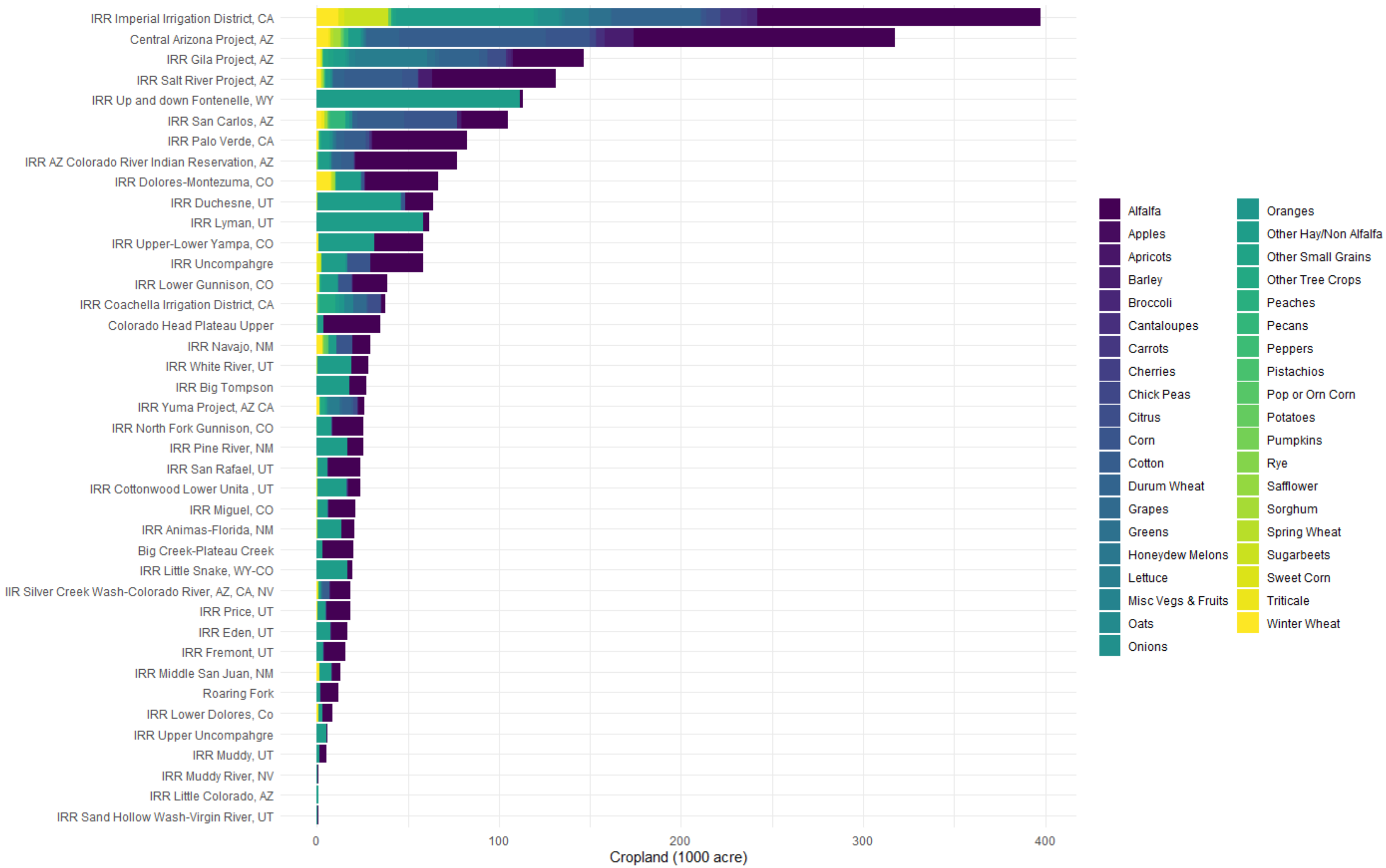


Figure A8. Cropland by irrigation unit

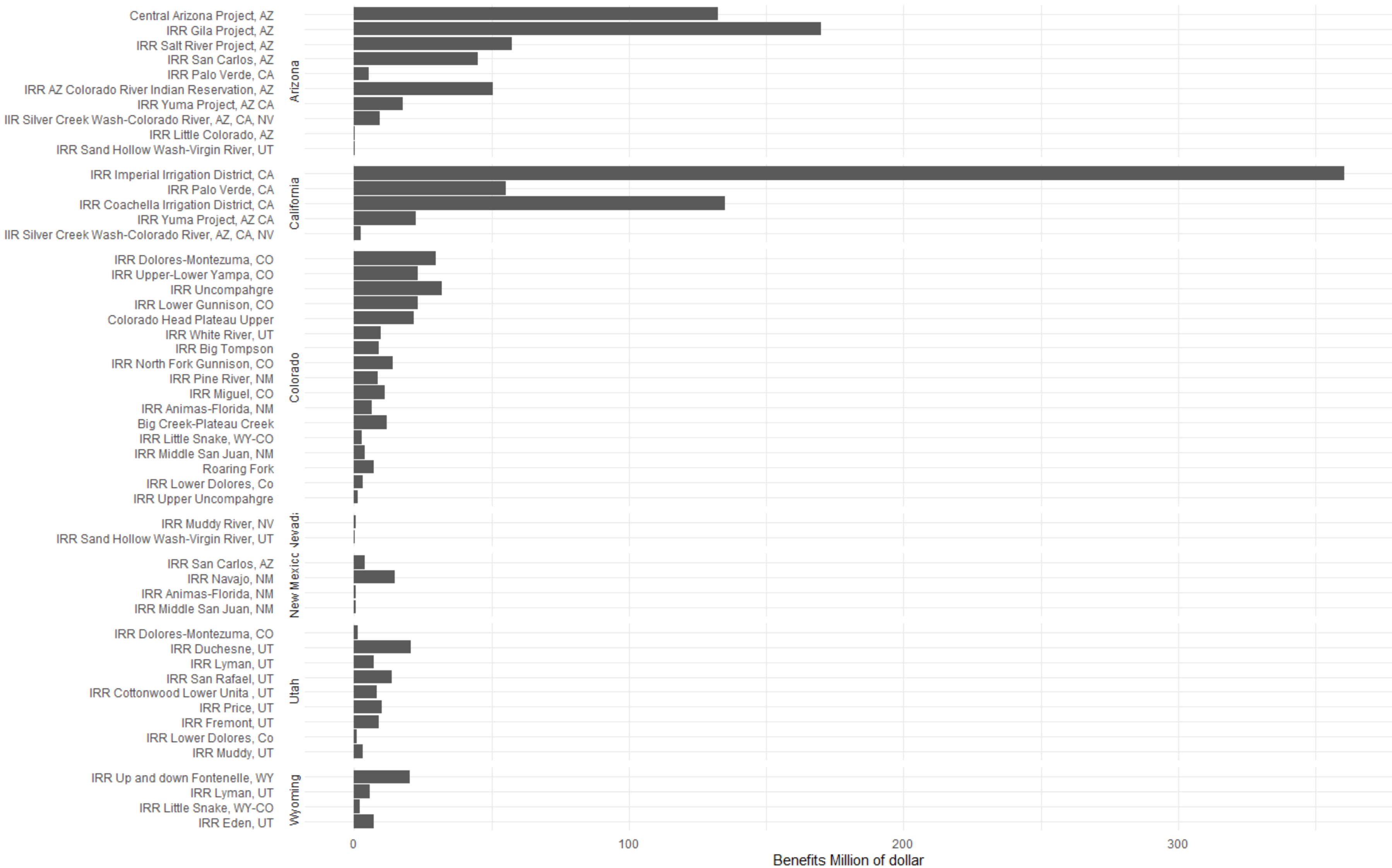


Figure A9. Benefits by State and Irrigation unit

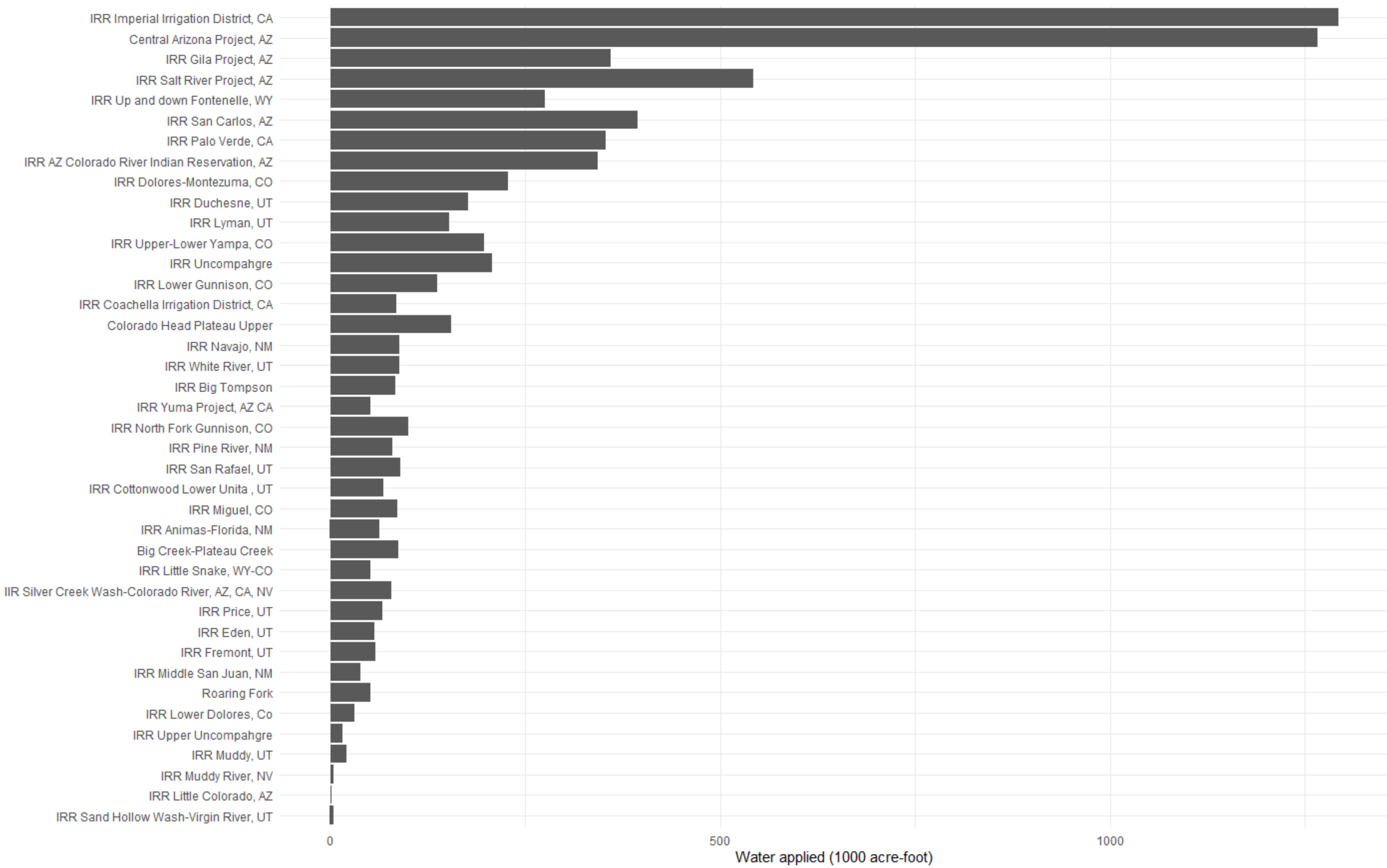


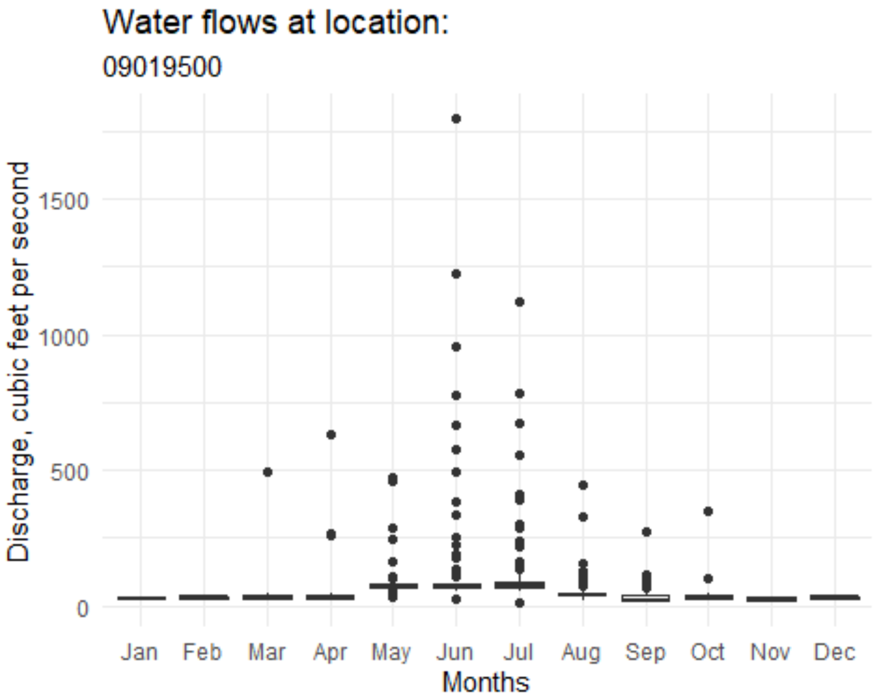
Figure A10 Water applied by irrigation unit.

12. Appendix B

12.1. Observed Water flows

Table B1. Main statistics of water discharge (cf/s) at USGS 09019500

	January	February	March	April	May	June	July	August	September	October	November	December
Min.	20.1	20.4	21.7	20.8	32.6	23.1	14.6	19.2	11.1	16.0	17.2	21.7
1st Qu.	24.9	27.6	28.2	26.0	69.6	67.1	64.8	36.3	19.4	22.8	20.8	26.8
Median	28.2	30.3	31.0	30.5	75.4	75.4	75.6	40.6	21.0	29.4	25.1	30.0
Mean	27.0	30.4	108.7	73.3	99.3	179.8	141.1	59.7	36.4	47.8	25.2	28.3
3rd Qu.	30.3	33.1	41.0	42.0	80.8	80.9	88.6	47.9	39.2	36.2	30.2	31.4
Max.	31.6	40.6	496.6	628.6	476.4	1794.0	1122.0	447.8	272.8	347.9	32.7	31.6



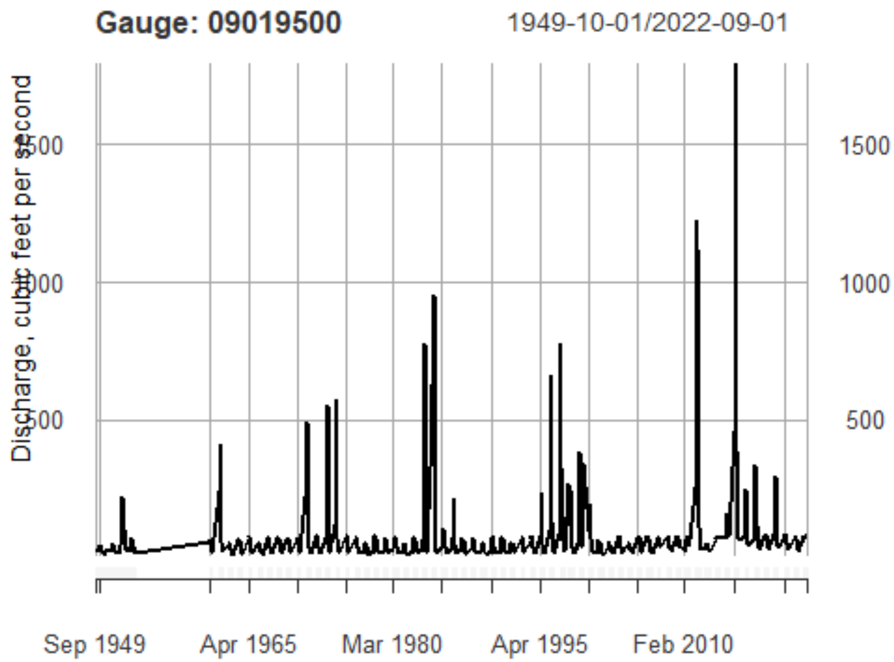


Figure B1. Monthly discharge (cf/s) at location USGS 09019500 Figure B2. Discharge (cf/s) at location USGS 09019500

Table B2. Main statistics of water discharge (cf/s) at USGS 09040500

	January	February	March	April	May	June	July	August	September	October	November	December
Min.	10.0	10.0	13.2	35.1	13.0	2.7	5.7	11.6	4.4	7.5	15.0	12.0
1st Qu.	15.8	16.6	20.5	56.2	127.0	47.6	11.7	19.9	14.3	13.8	22.1	20.0
Median	19.9	19.5	25.2	82.1	235.1	94.1	18.6	25.2	17.9	18.0	25.0	22.2
Mean	18.7	18.9	25.6	85.3	212.7	112.8	22.8	26.1	17.1	19.1	26.2	23.3
3rd Qu.	22.0	21.0	29.4	109.4	270.2	159.5	37.3	32.7	20.4	23.2	29.6	26.6
Max.	23.7	25.0	41.7	165.8	436.0	296.4	52.1	40.1	29.8	37.1	42.5	33.7

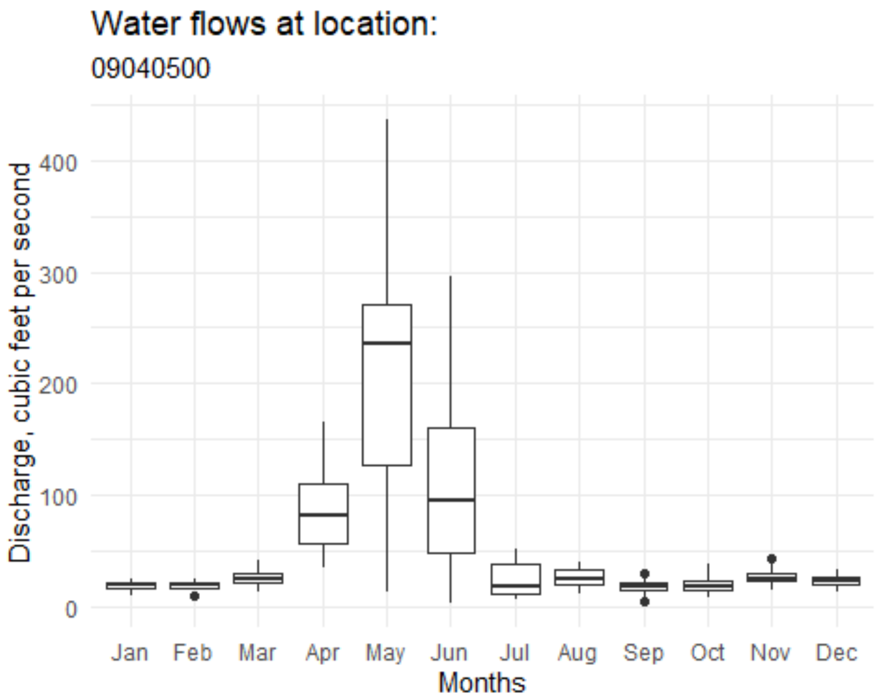


Figure B3. Monthly discharge (cf/s) at location USGS 09040500

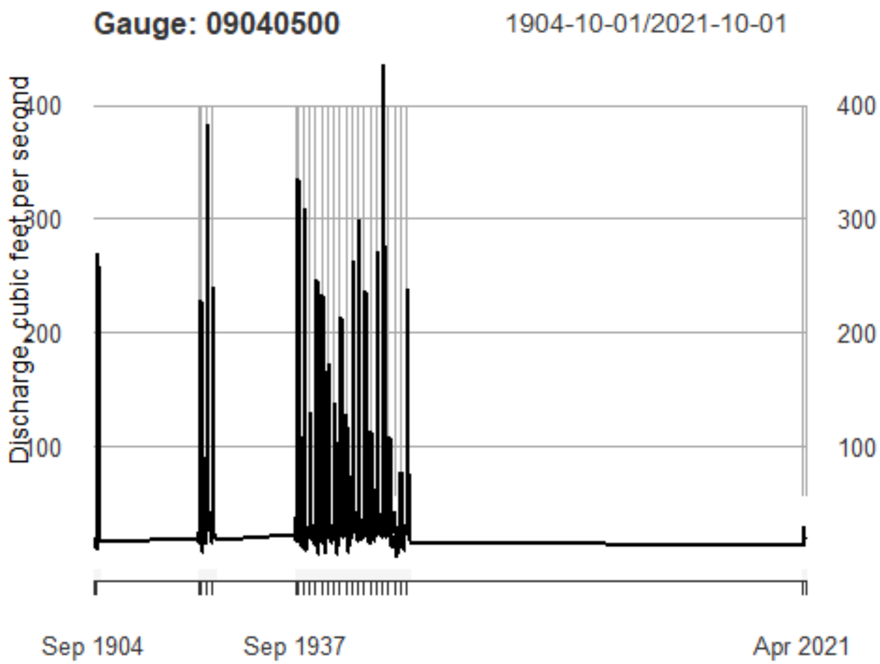
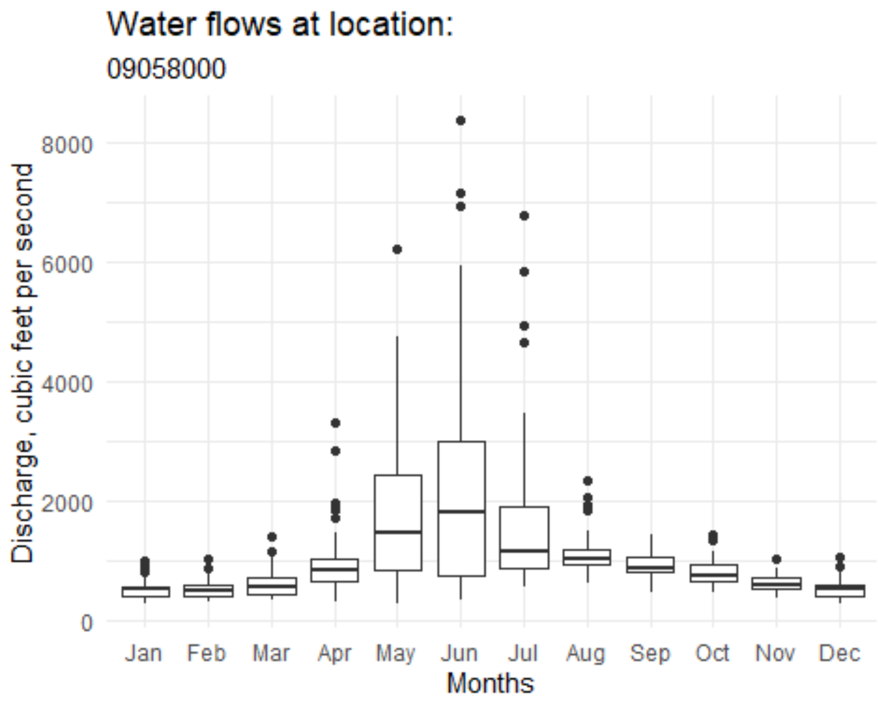


Figure B4. Discharge (cf/s) at location USGS 09040500

Table B3. Main statistics of water discharge (cf/s) at USGS 09058000

	January	February	March	April	May	June	July	August	September	October	November	December
Min.	277.7	294.1	330.9	287.6	270.2	327.8	538.9	630.4	460.8	450.0	352.4	277.3
1st Qu.	410.0	402.1	440.7	638.4	845.1	734.2	850.6	934.7	801.9	654.1	509.8	409.1
Median	507.5	505.6	554.0	841.2	1456.5	1817.0	1147.0	1030.0	861.9	747.4	584.3	510.7
Mean	516.3	512.6	608.0	951.5	1787.5	2232.5	1604.0	1110.5	937.7	797.6	605.4	530.2
3rd Qu.	562.0	579.2	720.5	1011.5	2435.5	2992.2	1901.8	1191.2	1064.2	914.9	701.3	597.1
Max.	1000.0	1025.0	1394.0	3297.0	6200.0	8361.0	6788.0	2321.0	1434.0	1413.0	1030.0	1067.0



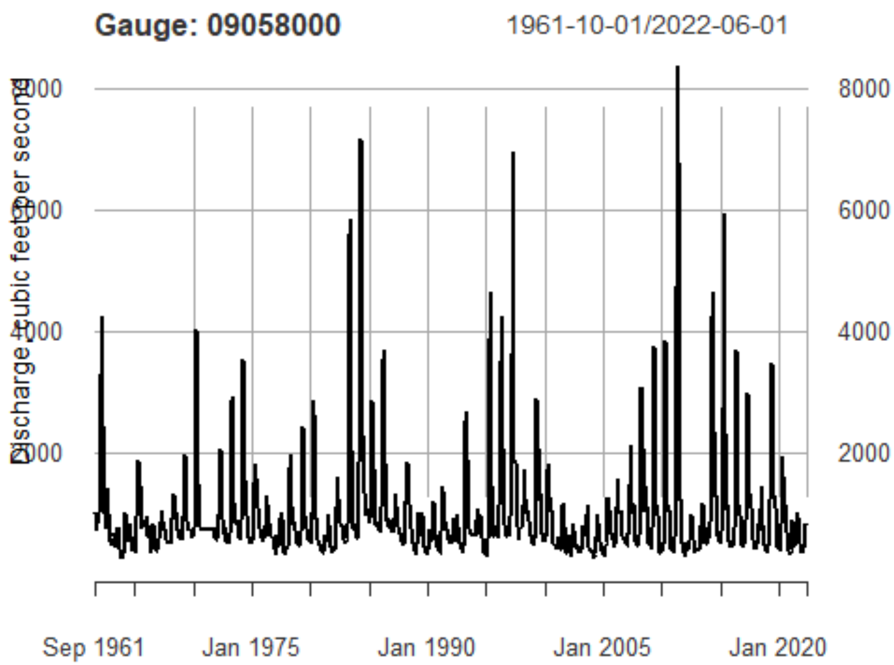


Figure B5. Monthly discharge (cf/s) at location USGS 09058000 Figure B6. Discharge (cf/s) at location USGS 09058000

Table B4. Main statistics of water discharge (cf/s) at USGS 09050700

	January	February	March	April	May	June	July	August	September	October	November	December
Min.	31.0	47.6	48.6	39.3	24.0	32.3	51.5	51.7	18.6	0.0	23.2	44.6
1st Qu.	60.9	60.1	64.8	74.1	93.7	276.8	150.7	104.8	100.8	79.6	69.7	66.0
Median	74.2	72.2	73.8	100.7	261.6	607.2	280.5	188.9	120.2	104.6	93.6	77.7
Mean	78.1	81.0	87.9	129.1	322.0	674.9	403.9	218.0	141.9	112.9	99.2	84.1
3rd Qu.	93.6	98.2	100.2	133.3	426.3	1092.0	615.8	263.0	175.4	130.7	106.6	103.7
Max.	158.1	197.0	324.9	741.6	1101.0	1813.0	1476.0	998.7	347.9	304.6	268.3	192.8

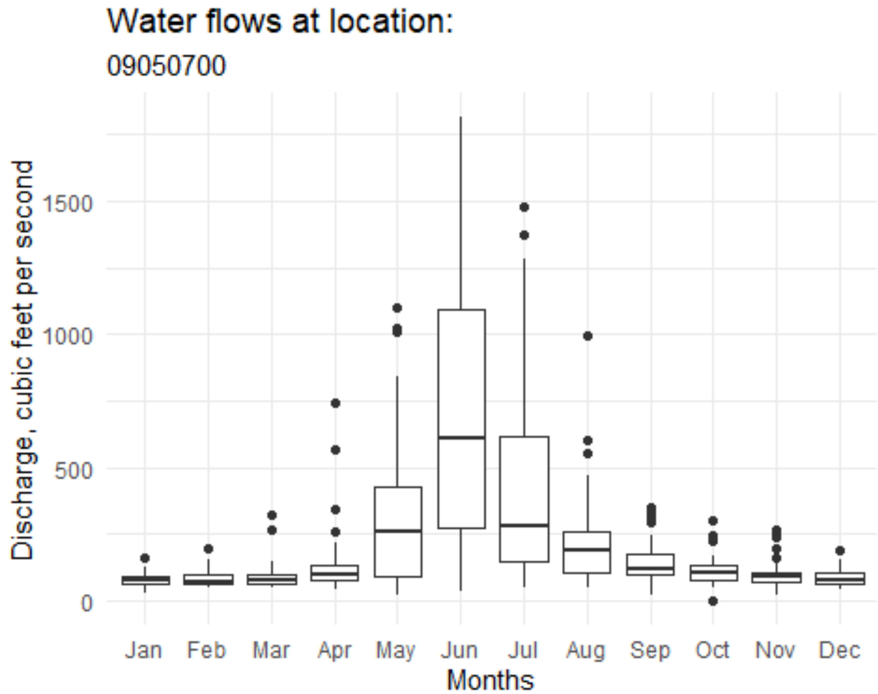


Figure B7. Monthly discharge (cf/s) at location USGS 09050700

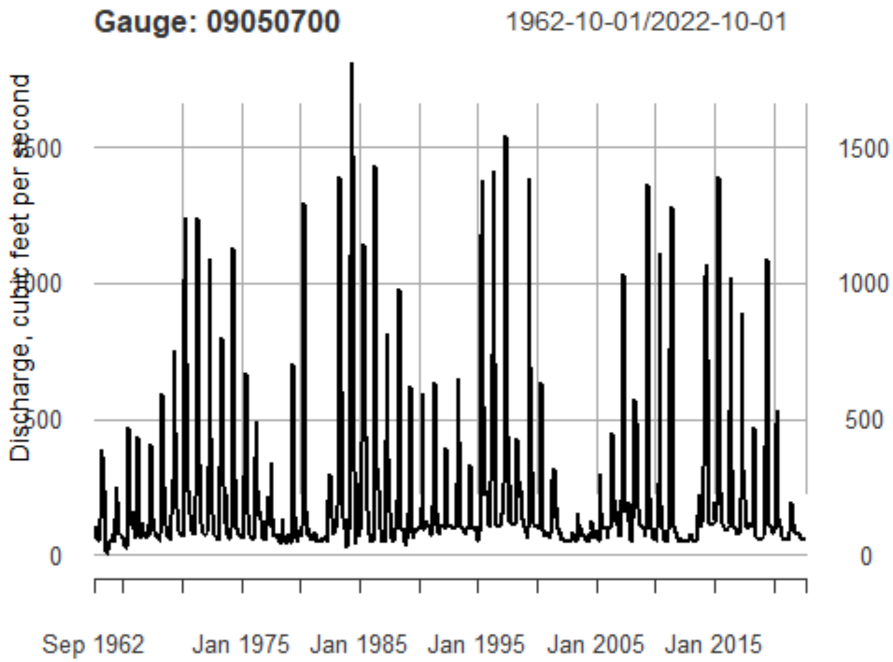


Figure B8. Discharge (cf/s) at location USGS 09050700

Table B5. Main statistics of water discharge (cf/s) at USGS 09057500

	January	February	March	April	May	June	July	August	September	October	November	December
Min.	0.5	0.2	0.6	47.2	53.6	54.4	131.4	269.9	69.9	108.3	82.5	0.7
1st Qu.	197.1	186.1	179.8	212.2	111.1	178.0	415.0	507.0	419.4	305.4	219.8	201.7
Median	259.6	266.7	265.0	318.6	359.0	596.5	592.8	569.8	505.9	371.5	280.9	280.5
Mean	281.1	272.1	294.7	355.0	471.2	718.0	777.7	612.2	526.4	416.6	280.6	284.3
3rd Qu.	352.6	355.6	387.5	475.4	729.2	1153.2	1018.2	680.9	639.5	479.7	323.7	351.7
Max.	565.8	559.2	863.9	1286.0	1557.0	2134.0	2536.0	1547.0	968.7	1258.0	799.9	580.0

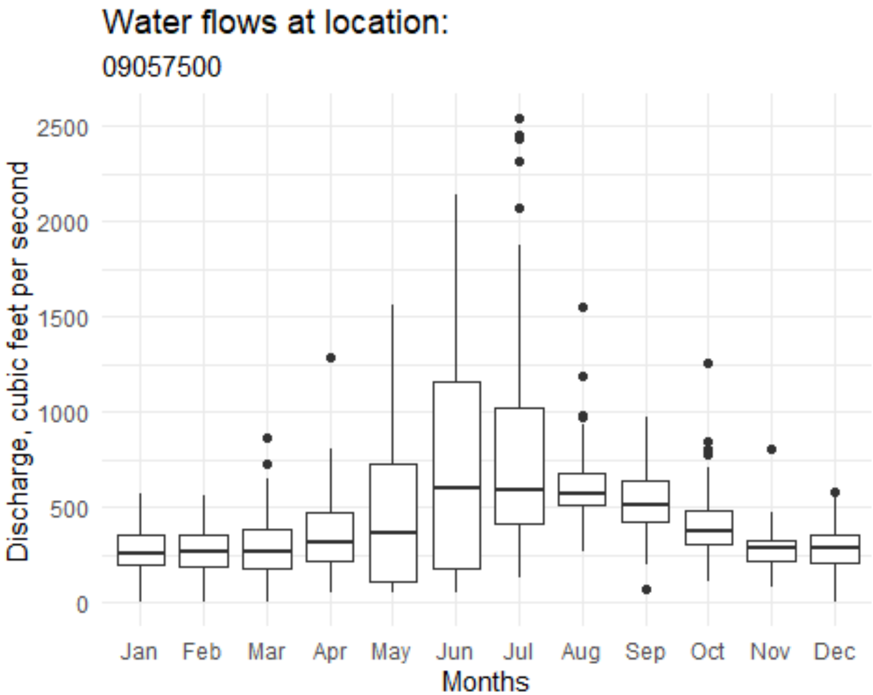


Figure B9. Monthly discharge (cf/s) at location USGS 09057500

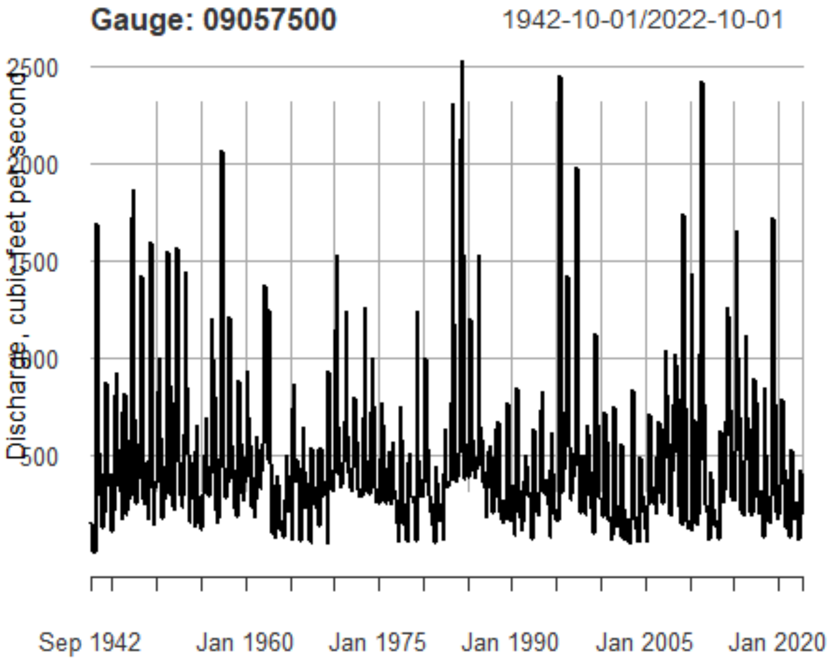
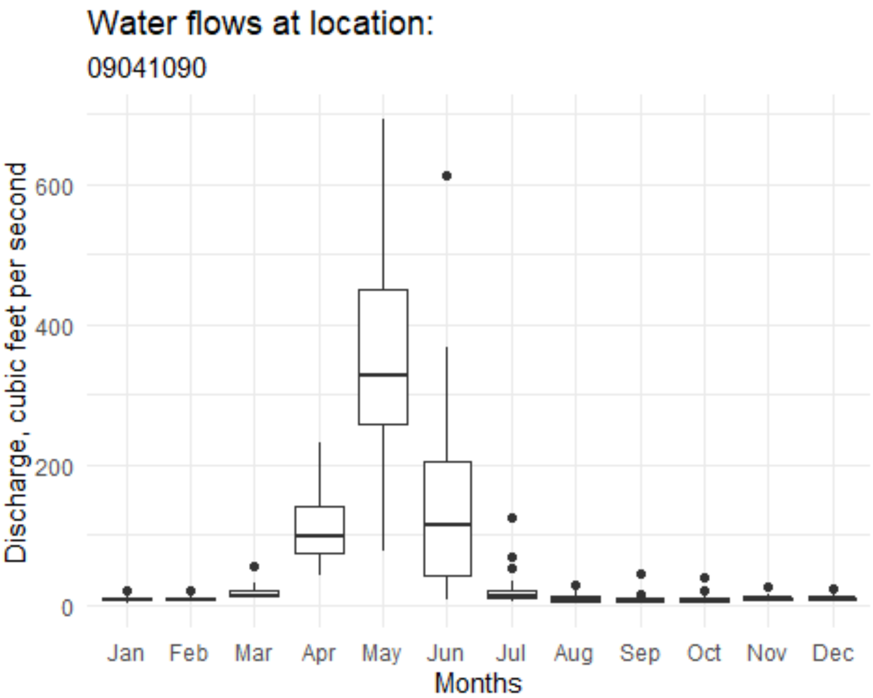


Figure B10. Discharge (cf/s) at location USGS 09057500

Table B6. Main statistics of water discharge (cf/s) at USGS 09041090

	January	February	March	April	May	June	July	August	September	October	November	December
Min.	2.0	3.0	8.7	40.8	76.9	6.0	2.7	2.1	1.3	1.4	4.4	2.8
1st Qu.	5.6	6.5	11.3	72.5	258.6	40.6	8.0	4.1	3.4	5.2	6.5	6.0
Median	7.4	8.0	13.2	96.3	326.6	112.8	12.4	7.3	5.3	6.9	8.7	8.4
Mean	7.9	8.2	17.4	105.5	358.1	152.2	19.5	9.1	6.9	8.6	9.1	8.3
3rd Qu.	9.8	10.1	20.1	138.8	449.0	202.9	21.0	13.1	8.2	10.5	10.4	9.5
Max.	20.3	18.7	53.4	231.3	691.5	611.2	123.5	27.5	45.2	38.2	26.4	21.8



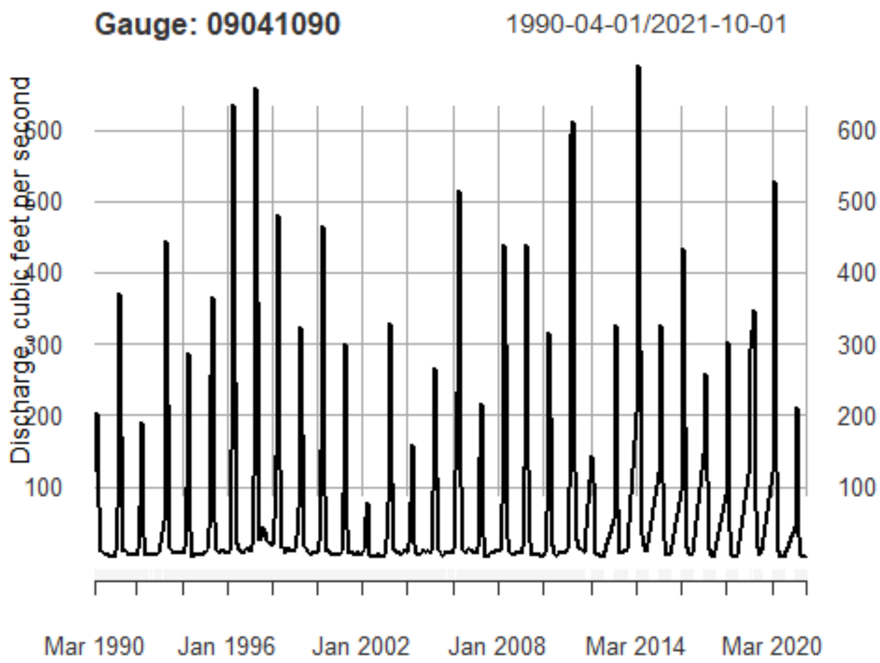


Figure B11. Monthly discharge (cf/s) at location USGS 09041090 Figure B12. Discharge (cf/s) at location USGS 09041090

Table B7. Main statistics of water discharge (cf/s) at USGS 09041400

	January	February	March	April	May	June	July	August	September	October	November	December
Min.	14.8	13.8	15.1	15.9	21.7	28.9	22.5	23.5	19.5	18.7	14.2	7.1
1st Qu.	18.6	18.0	20.4	34.3	66.8	69.3	49.4	67.1	50.6	22.6	20.5	19.8
Median	20.8	21.0	23.0	52.5	153.4	172.6	74.7	101.2	94.2	28.8	21.5	21.0
Mean	21.0	21.1	29.3	64.8	229.5	214.8	84.1	100.8	102.8	49.0	23.0	20.8
3rd Qu.	22.1	22.6	31.8	76.3	375.5	288.6	92.4	120.5	130.7	50.9	23.9	22.4
Max.	32.3	34.4	75.8	249.2	557.7	879.0	240.0	277.8	277.2	172.5	46.5	32.7

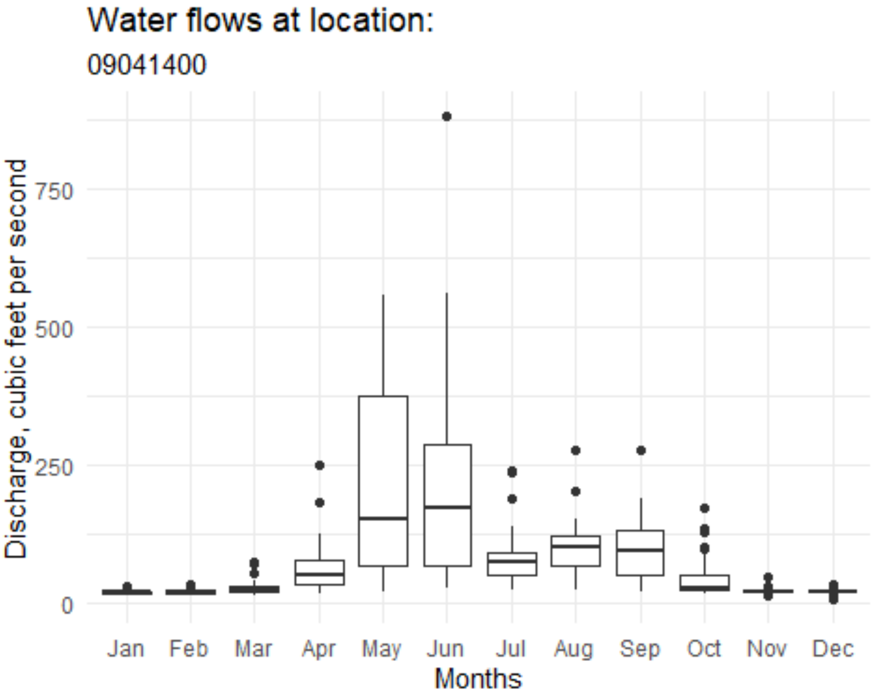


Figure B13. Monthly discharge (cf/s) at location USGS 09041400

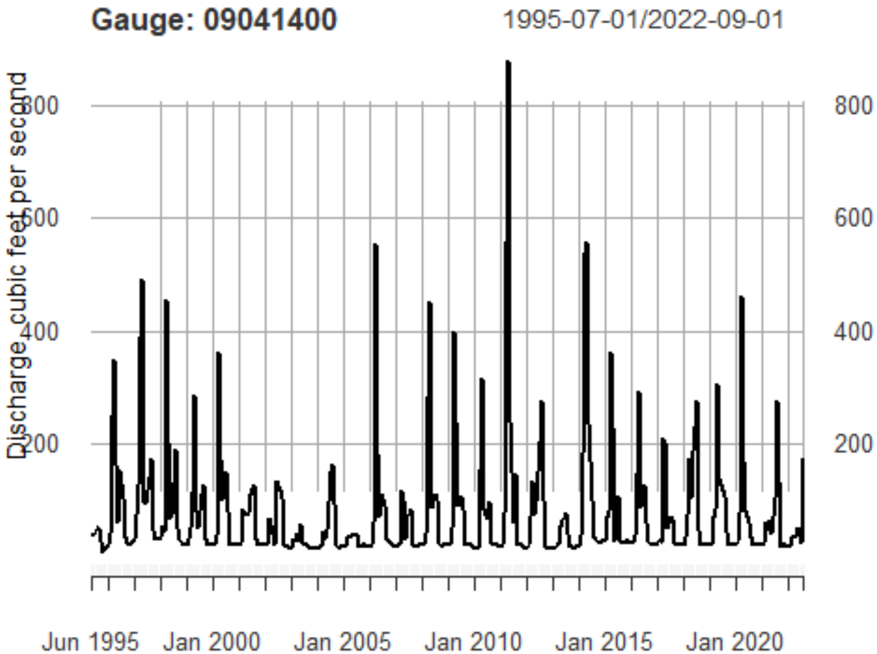
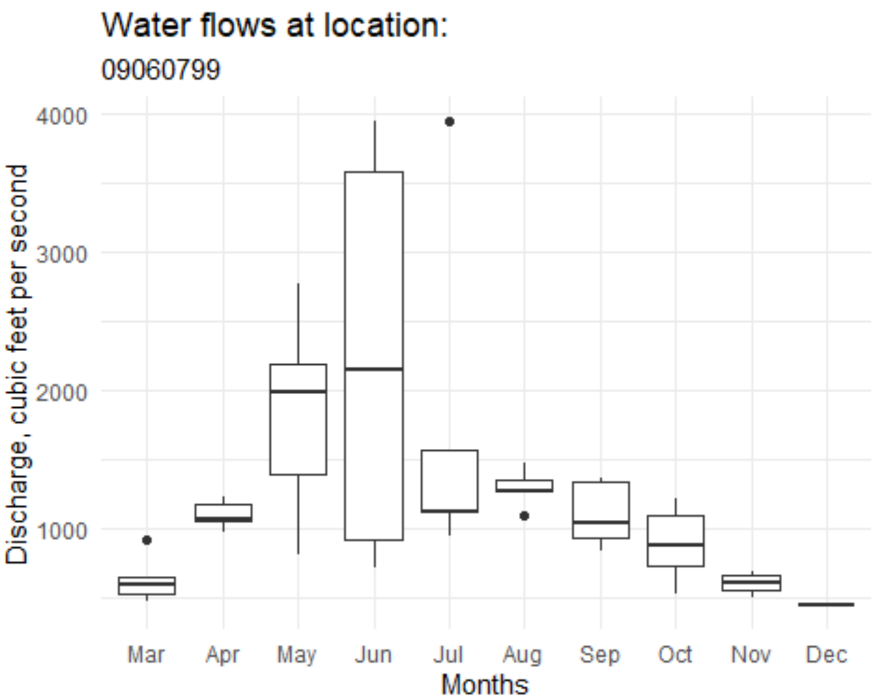


Figure B14. Discharge (cf/s) at location USGS 09041400

Table B8. Main statistics of water discharge (cf/s) at USGS 09060799

	March	April	May	June	July	August	September	October	November	December
Min.	480.8	980.4	809.2	714.1	950.7	1091.0	836.2	532.0	503.7	446.8
1st Qu.	531.4	1058.0	1391.0	920.0	1119.0	1271.0	927.8	729.6	553.4	446.8
Median	596.0	1071.0	1985.0	2154.0	1124.0	1272.0	1037.0	880.9	603.5	446.8
Mean	626.8	1103.7	1829.6	2261.4	1742.3	1293.2	1100.4	893.5	602.9	446.8
3rd Qu.	646.5	1172.0	2194.0	3577.0	1575.0	1354.0	1337.0	1095.8	660.4	446.8
Max.	914.8	1237.0	2769.0	3942.0	3943.0	1478.0	1364.0	1221.0	690.5	446.8



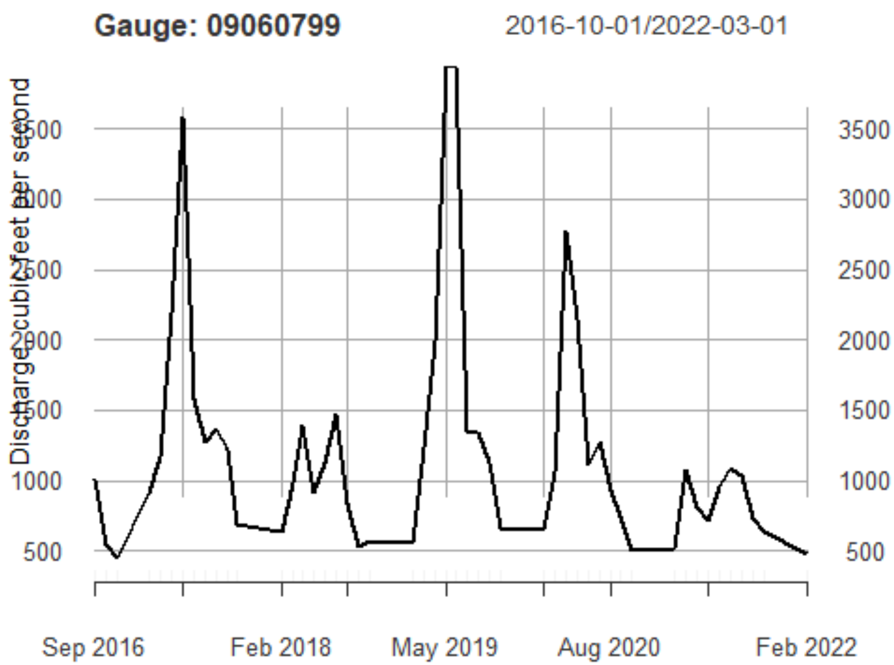


Figure B15. Monthly discharge (cf/s) at location USGS 09060799 Figure B16. Discharge (cf/s) at location USGS 09060799

Table B9. Main statistics of water discharge (cf/s) at USGS 09070500

	January	February	March	April	May	June	July	August	September	October	November	December
Min.	503.5	528.9	609.5	877.4	1254.0	1220.0	1021.0	911.7	661.1	706.6	677.4	520.9
1st Qu.	742.8	742.1	814.9	1308.5	3128.8	3475.0	1604.5	1356.0	1162.0	1020.5	881.4	773.2
Median	862.2	889.3	966.8	1576.5	4092.5	6342.0	2437.5	1521.5	1336.0	1204.0	1014.0	901.0
Mean	878.8	889.4	1024.2	1808.3	4617.5	6154.6	3064.2	1699.5	1343.3	1242.2	1050.7	915.3
3rd Qu.	1011.8	1015.8	1161.2	2003.2	5666.0	8037.8	3779.8	1848.2	1516.0	1398.8	1155.0	1046.0
Max.	1473.0	1603.0	1961.0	5601.0	10770.0	15380.0	10760.0	4055.0	2616.0	2038.0	1664.0	1503.0

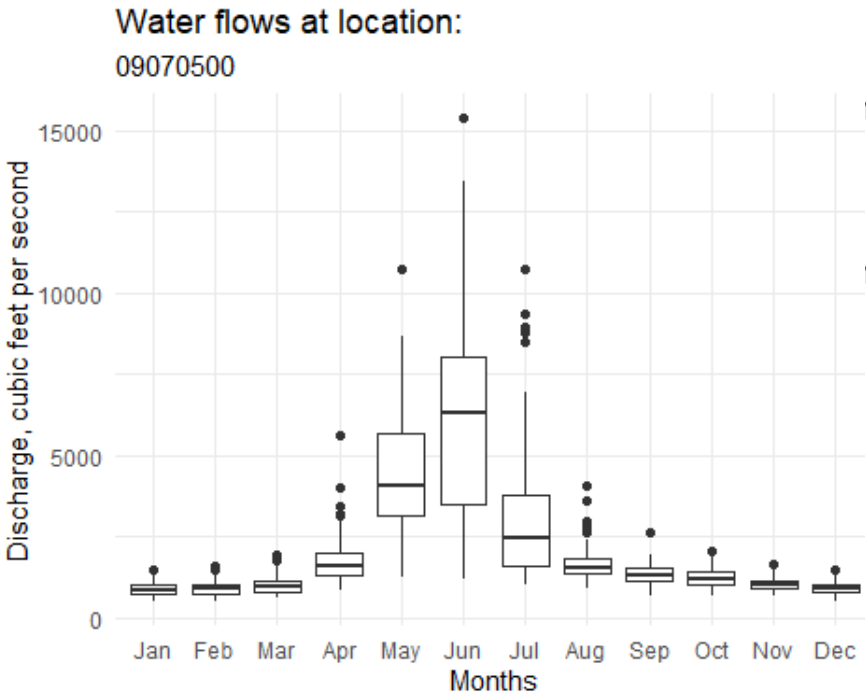


Figure B17. Monthly discharge (cf/s) at location USGS 09070500

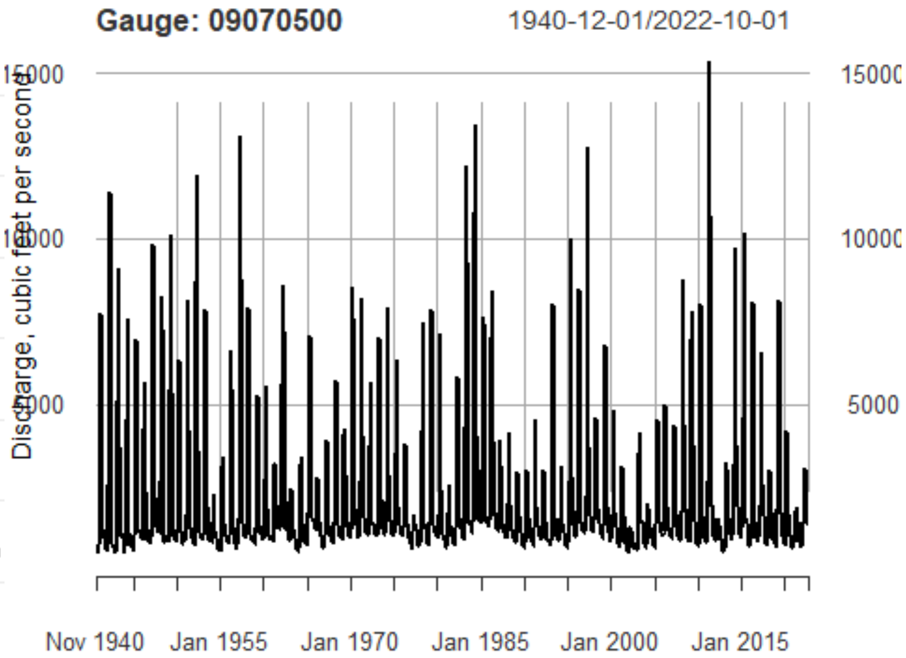
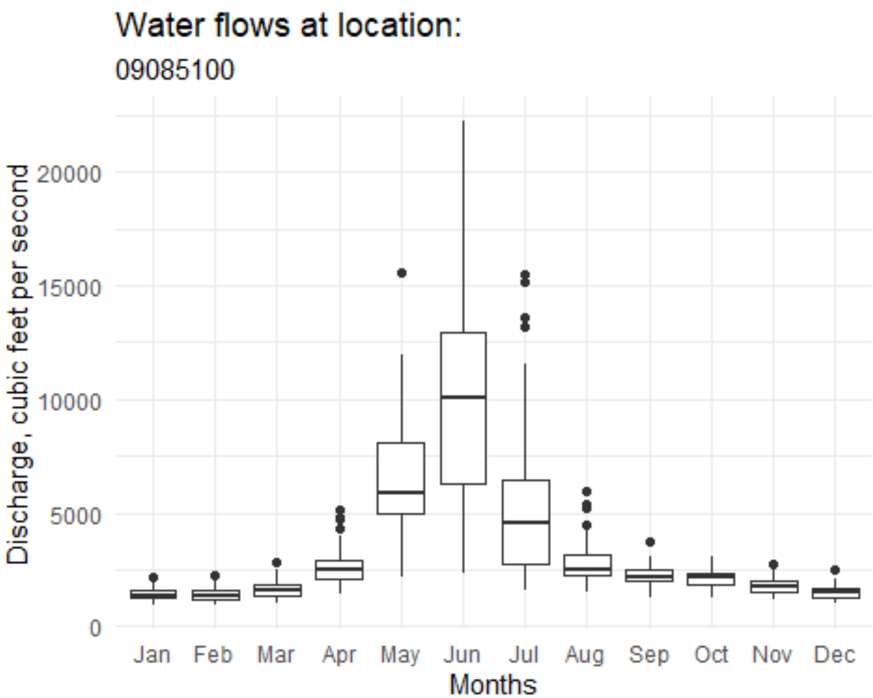


Figure B18. Discharge (cf/s) at location USGS 09070500

Table B10. Main statistics of water discharge (cf/s) at USGS 09085100

	January	February	March	April	May	June	July	August	September	October	November	December
Min.	925.5	940.1	1018.0	1421.0	2146.0	2364.0	1594.0	1464.0	1255.0	1257.0	1186.0	975.6
1st Qu.	1224.8	1207.5	1346.5	2045.0	4973.8	6316.8	2751.8	2239.8	1970.0	1828.0	1539.2	1283.5
Median	1372.0	1364.5	1562.5	2515.5	5859.5	10085.0	4538.5	2534.0	2201.0	2127.0	1721.5	1476.5
Mean	1422.3	1412.2	1637.7	2647.5	6702.8	9927.3	5251.7	2783.8	2278.5	2115.4	1790.8	1501.0
3rd Qu.	1568.5	1581.2	1808.8	2944.0	8118.5	12987.5	6409.2	3113.0	2489.0	2338.0	2003.2	1656.0
Max.	2192.0	2209.0	2814.0	5113.0	15570.0	22230.0	15540.0	5975.0	3716.0	3082.0	2703.0	2487.0



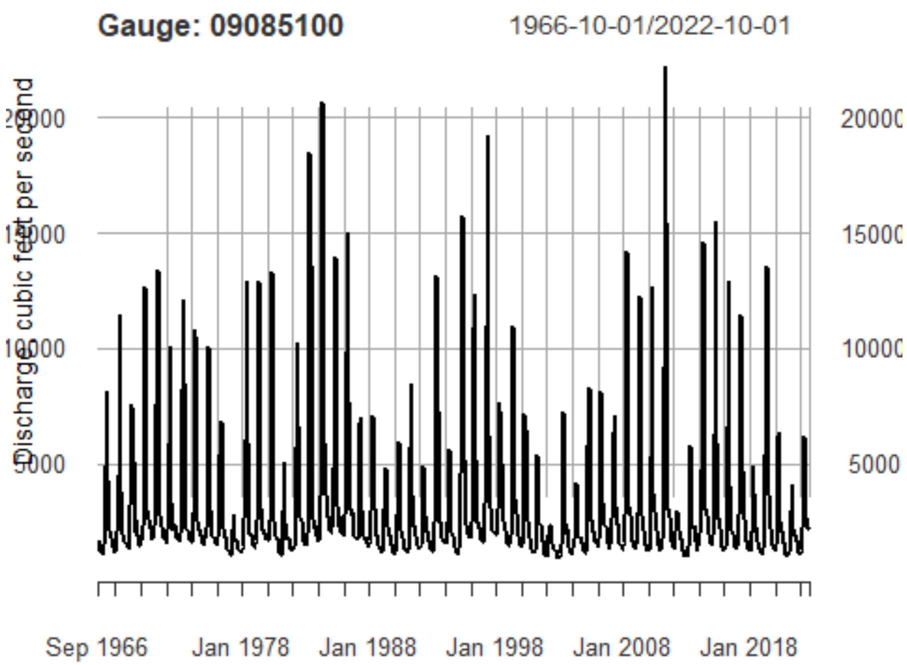


Figure B19. Monthly discharge (cf/s) at location USGS 09085100 Figure B20. Discharge (cf/s) at location USGS 09085100

Table B11. Main statistics of water discharge (cf/s) at USGS 09085000

	January	February	March	April	May	June	July	August	September	October	November	December
Min.	285.1	266.0	292.7	352.2	592.7	1100.0	422.2	316.5	362.8	383.9	411.3	334.6
1st Qu.	405.0	381.1	421.1	611.8	1641.8	2661.0	1027.5	647.1	616.7	583.9	550.8	473.5
Median	462.6	435.9	515.9	785.0	1892.0	3864.0	1620.0	862.8	714.8	685.7	623.5	521.3
Mean	472.9	448.0	507.8	817.3	2122.6	3838.2	2121.5	939.8	738.8	712.7	628.7	531.8
3rd Qu.	524.7	504.4	571.2	963.0	2638.8	5019.5	2739.2	1129.2	850.8	810.1	689.0	586.2
Max.	677.3	688.5	860.7	1602.0	4663.0	7383.0	7483.0	2676.0	1160.0	1159.0	968.7	789.8

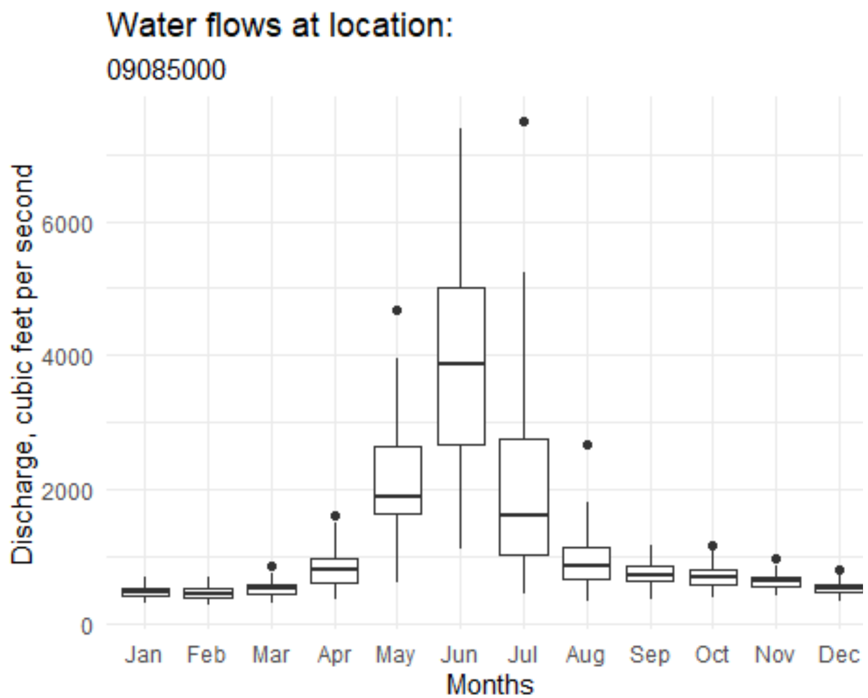


Figure B21. Monthly discharge (cf/s) at location USGS 09085000

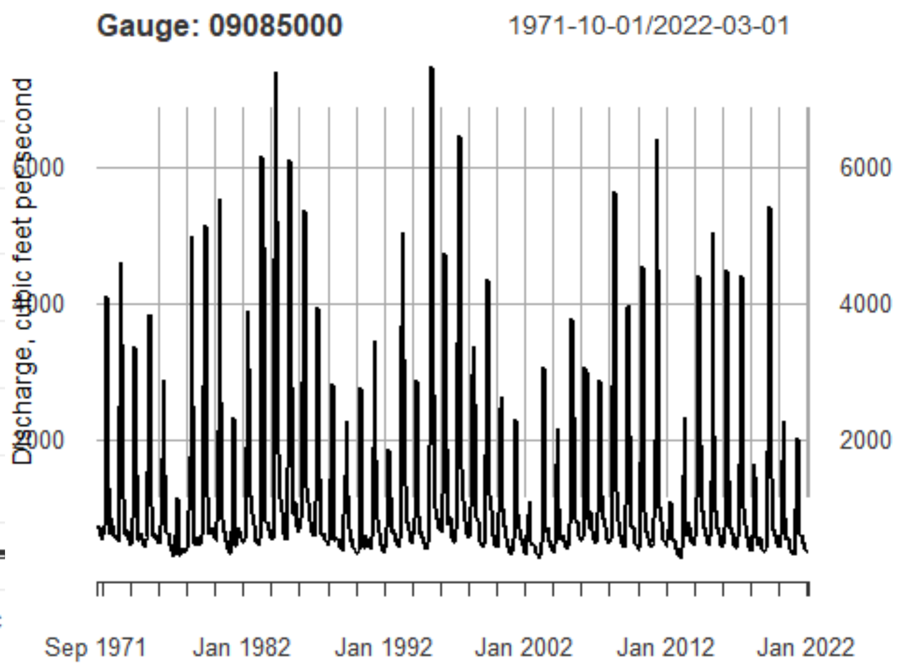


Figure B22. Discharge (cf/s) at location USGS 09085000

Table B12. Main statistics of water discharge (cf/s) at USGS 09081000

	January	February	March	April	May	June	July	August	September	October	November	December
Min.	172.1	158.7	172.1	210.9	398.9	518.6	306.9	298.1	291.7	218.5	218.3	185.3
1st Qu.	226.2	217.3	218.0	290.8	760.0	1204.5	516.7	402.6	385.9	323.7	265.9	240.0
Median	255.8	236.4	249.4	402.9	839.6	1546.0	750.0	545.8	450.5	372.6	318.6	268.9
Mean	249.4	242.6	274.1	404.5	918.2	1812.0	1001.4	542.1	454.1	374.2	307.7	266.9
3rd Qu.	270.3	266.7	313.7	479.0	1109.5	2476.2	1225.5	646.0	514.0	437.4	346.0	299.6
Max.	334.8	349.0	483.0	702.8	1869.0	3667.0	2933.0	874.5	612.0	554.8	399.7	339.6

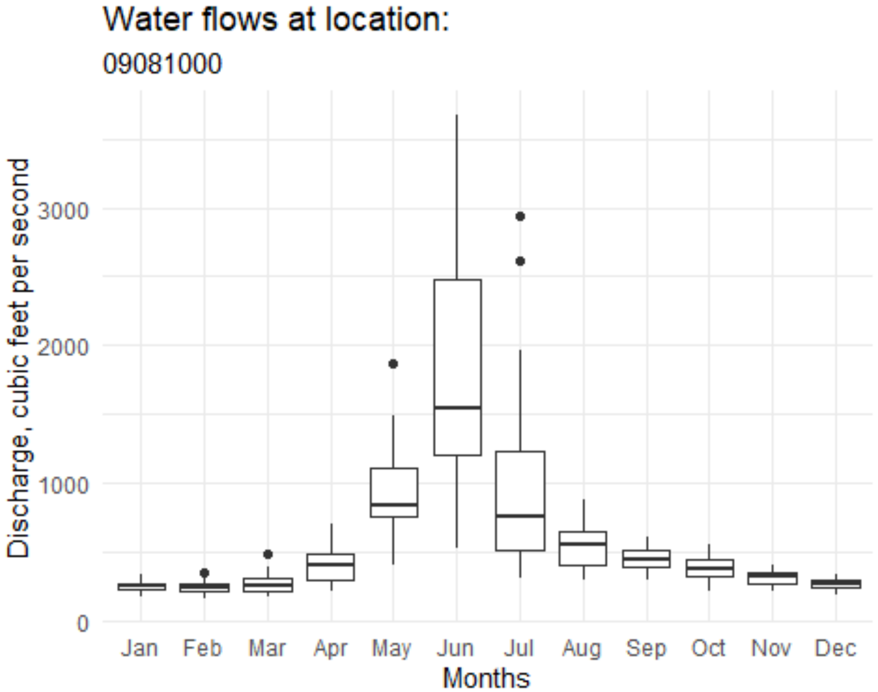


Figure B23. Monthly discharge (cf/s) at location USGS 09081000

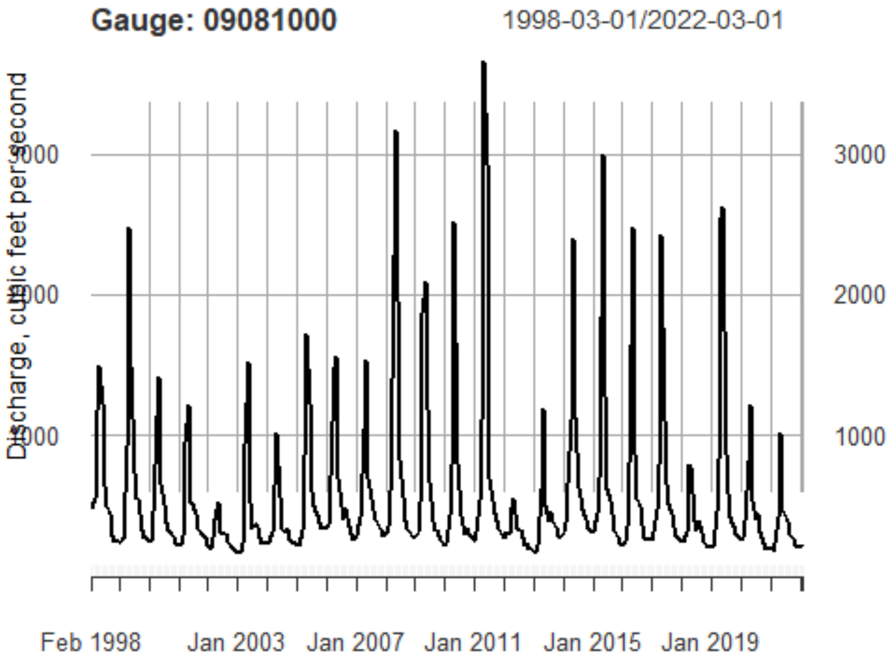
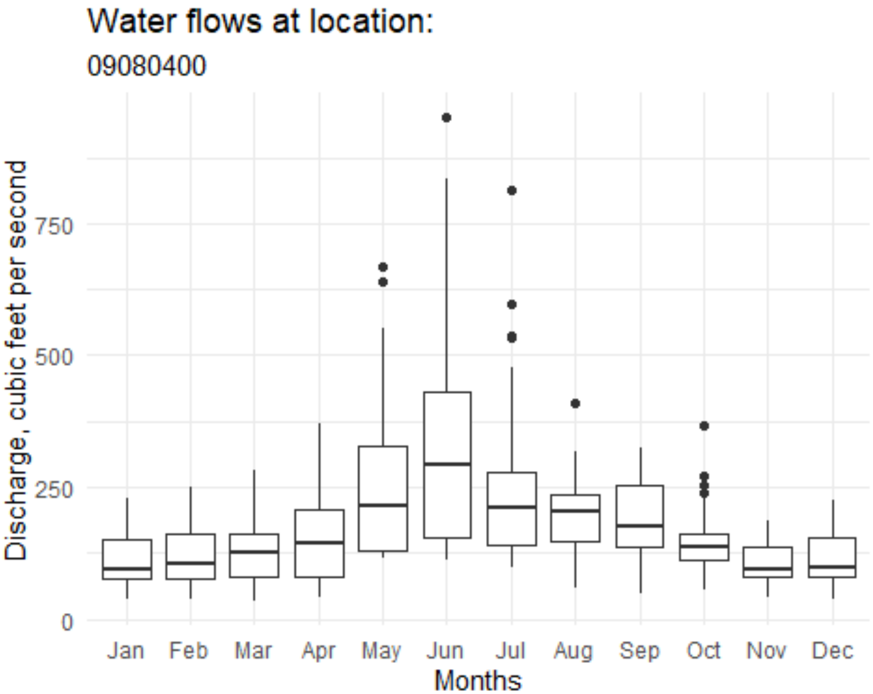


Figure B24. Discharge (cf/s) at location USGS 09081000

Table B13. Main statistics of water discharge (cf/s) at USGS 09080400

	January	February	March	April	May	June	July	August	September	October	November	December
Min.	36.8	36.3	33.6	39.1	113.5	111.1	95.9	57.1	49.1	54.8	42.2	38.2
1st Qu.	76.0	74.8	78.2	80.6	128.3	153.1	141.6	147.4	138.2	110.6	78.3	79.9
Median	94.4	103.4	124.5	141.8	213.4	292.0	212.4	204.9	173.9	138.1	94.6	96.0
Mean	110.7	116.5	124.5	147.8	240.7	325.9	249.4	198.3	189.7	144.7	105.6	111.0
3rd Qu.	150.9	160.1	160.4	208.9	328.4	429.9	276.8	237.3	253.7	161.1	136.4	155.1
Max.	227.6	250.3	280.0	369.8	669.2	950.1	811.9	410.8	324.3	366.2	184.7	223.7



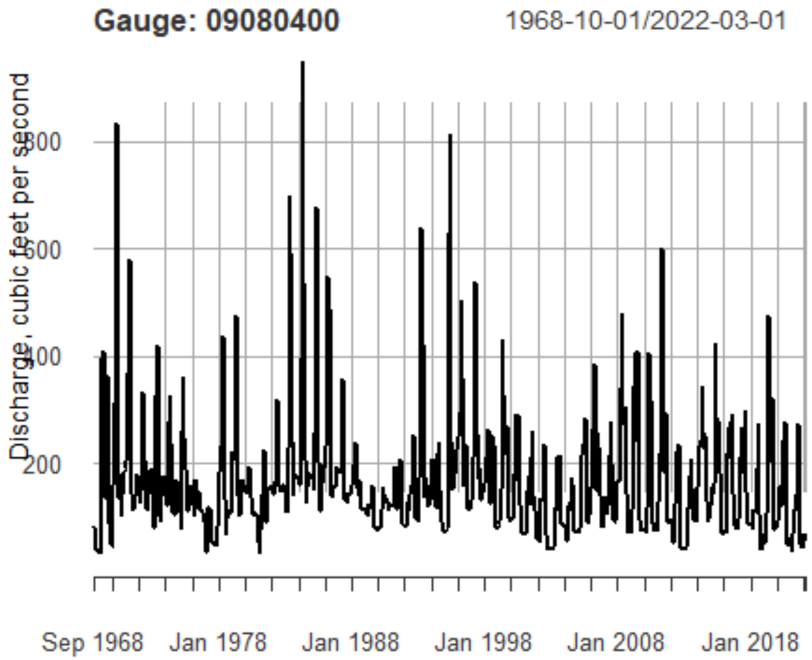


Figure B25. Monthly discharge (cf/s) at location USGS 09080400 Figure B26. Discharge (cf/s) at location USGS 09080400

Table B14. Main statistics of water discharge (cf/s) at USGS 09076300

	January	February	March	April	May	June	July	August	September	October	November	December
Min.	72.6	71.2	74.4	107.9	308.7	757.2	191.4	105.6	88.2	120.3	94.1	80.2
1st Qu.	75.2	73.1	74.4	122.1	320.5	824.0	241.1	136.0	101.5	122.5	100.1	82.1
Median	77.8	74.9	74.5	136.3	332.3	890.8	291.0	160.8	122.2	123.4	102.8	86.8
Mean	86.2	81.7	83.3	132.5	406.7	1024.7	601.6	240.6	132.6	134.6	111.1	94.0
3rd Qu.	92.9	87.0	87.8	144.8	455.7	1158.4	651.6	265.4	153.4	135.6	113.8	98.7
Max.	108.1	99.1	101.1	153.3	579.1	1426.0	1633.0	535.3	197.8	171.1	144.7	122.2

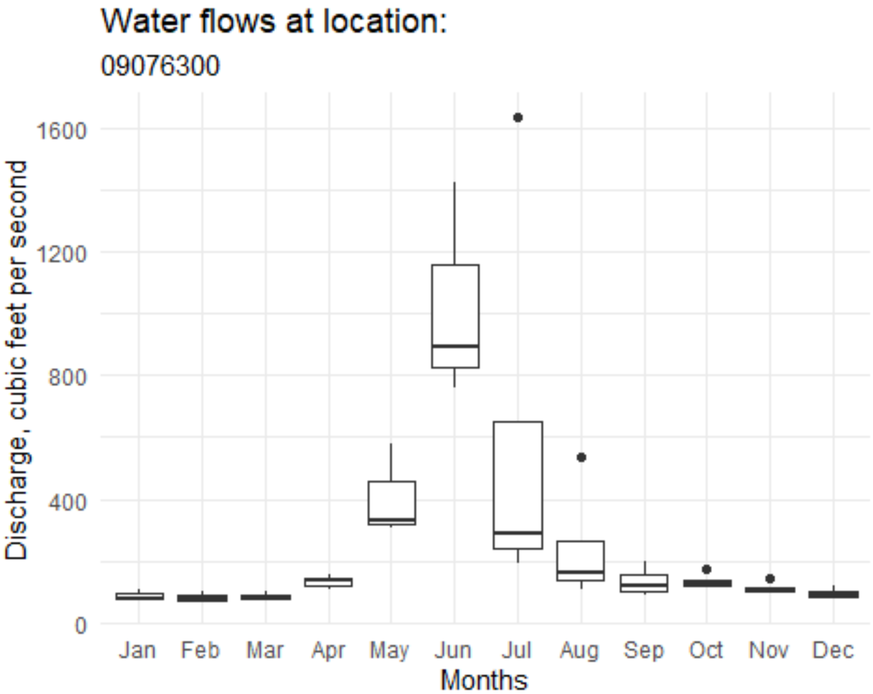


Figure B27. Monthly discharge (cf/s) at location USGS 09076300

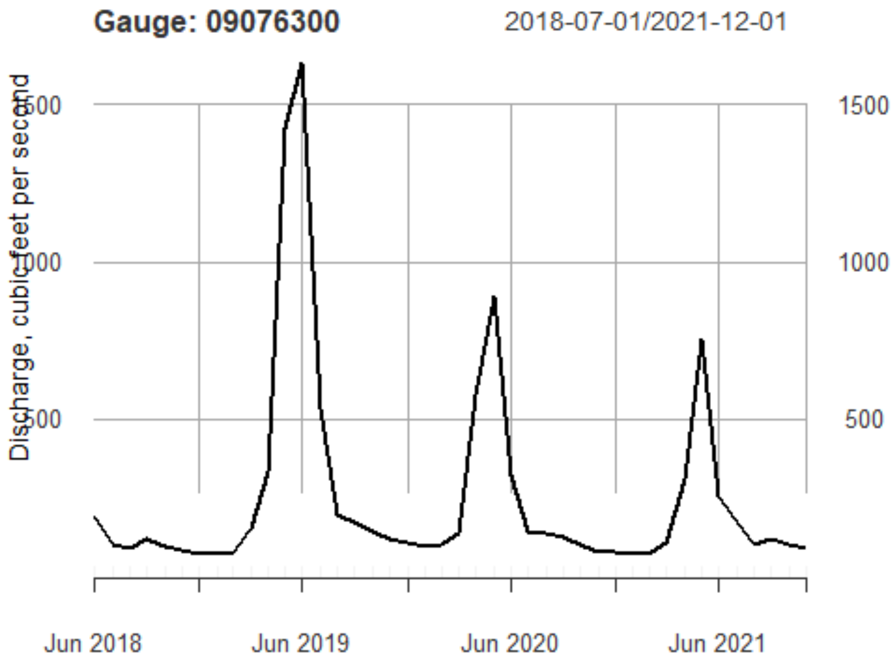


Figure B28. Discharge (cf/s) at location USGS 09076300

Table B15. Main statistics of water discharge (cf/s) at USGS 09095500

	January	February	March	April	May	June	July	August	September	October	November	December
Min.	940.3	941.0	1020.0	1428.0	2536.0	2606.0	1515.0	1332.0	1243.0	1084.0	1038.0	1004.0
1st Qu.	1346.8	1329.0	1479.8	2236.0	6071.0	7559.8	2978.2	2158.0	1866.0	1764.0	1634.0	1414.2
Median	1530.5	1528.5	1722.5	2864.5	7700.0	12240.0	4752.0	2538.0	2146.5	2058.0	1860.0	1626.5
Mean	1566.2	1582.7	1801.6	3112.3	8707.2	12062.9	5671.6	2825.5	2259.6	2191.4	1923.6	1667.4
3rd Qu.	1737.2	1762.2	2022.8	3501.8	11162.5	15117.5	7216.2	3292.8	2588.5	2503.0	2167.0	1892.5
Max.	2621.0	2775.0	3365.0	8615.0	20290.0	25830.0	17430.0	6571.0	4271.0	3732.0	3253.0	3002.0

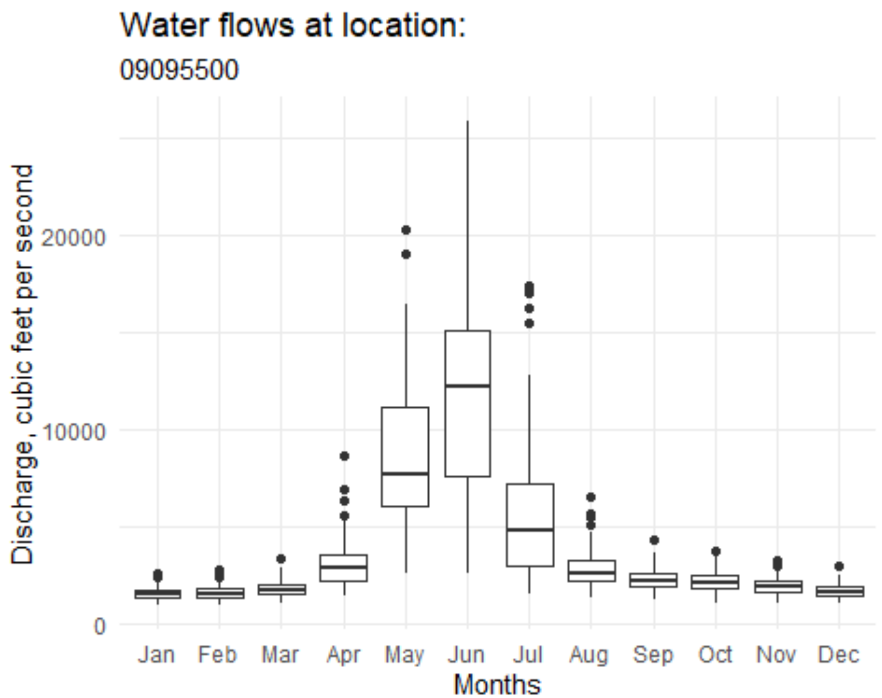


Figure B29. Monthly discharge (cf/s) at location USGS 09095500

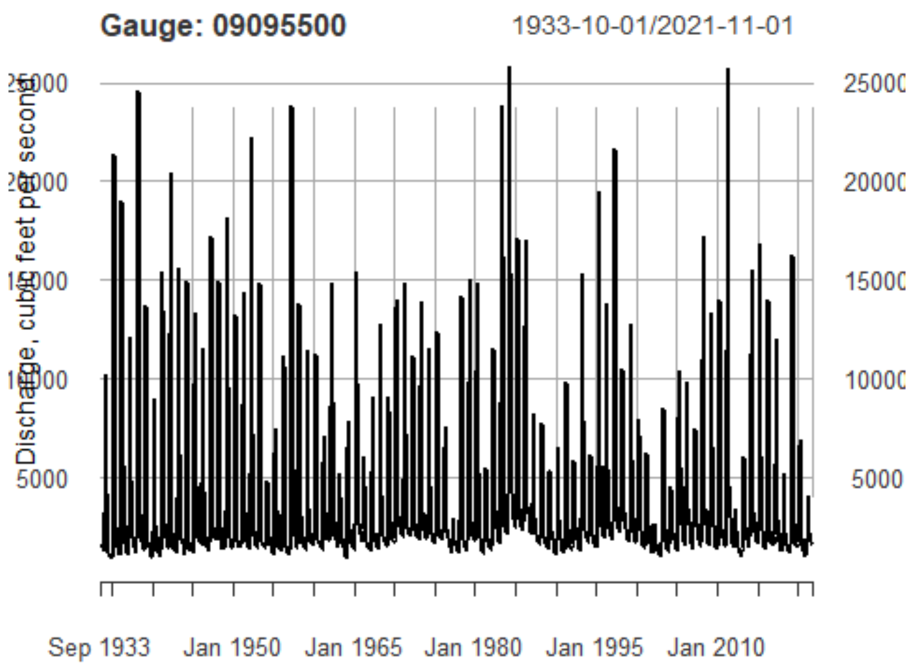


Figure B30. Discharge (cf/s) at location USGS 09095500

Table B16. Main statistics of water discharge (cf/s) at USGS 09163500

	January	February	March	April	May	June	July	August	September	October	November	December
Min.	1871.0	1815.0	1984.0	1631.0	2283.0	2431	1662.0	1350.0	1361.0	1916.0	2363.0	1980.0
1st Qu.	2496.0	2472.5	2805.5	3379.5	8869.0	8756	3100.5	2552.0	2833.5	3182.5	3043.5	2619.5
Median	3057.0	3050.0	3453.0	5048.0	11570.0	15300	5023.0	3577.0	3614.0	3945.0	3724.0	3286.0
Mean	3224.3	3267.4	3695.1	5601.0	13368.1	16415	7441.7	3896.4	3736.2	4023.3	3855.5	3433.7
3rd Qu.	3836.5	3827.0	4189.0	7363.0	17625.0	22525	8974.0	4643.0	4433.5	4656.0	4392.0	4181.0
Max.	6129.0	5996.0	7486.0	15600.0	37960.0	43830	29650.0	10190.0	7174.0	7672.0	6925.0	5993.0

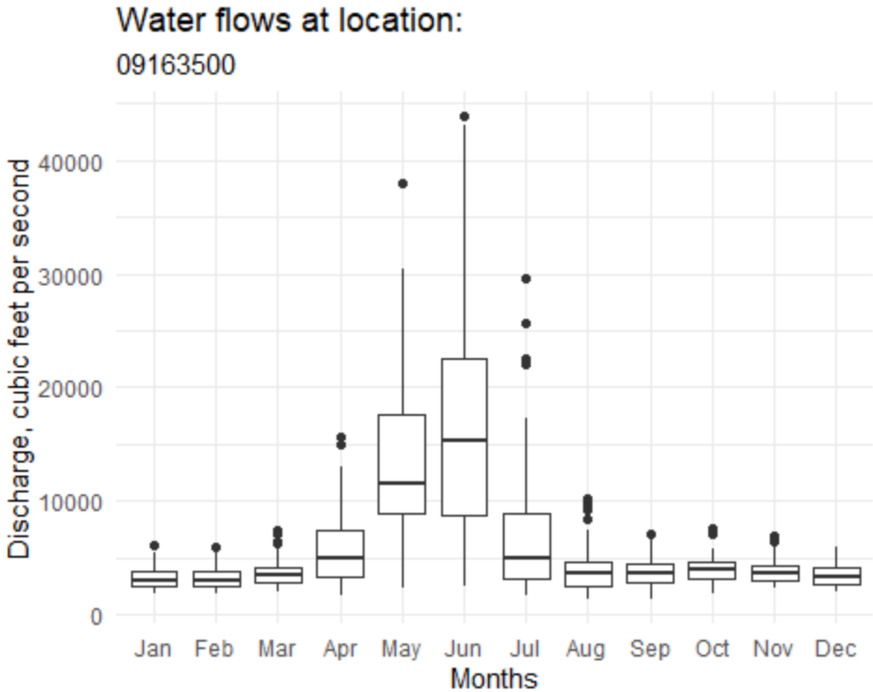


Figure B31. Monthly discharge (cf/s) at location USGS 09163500

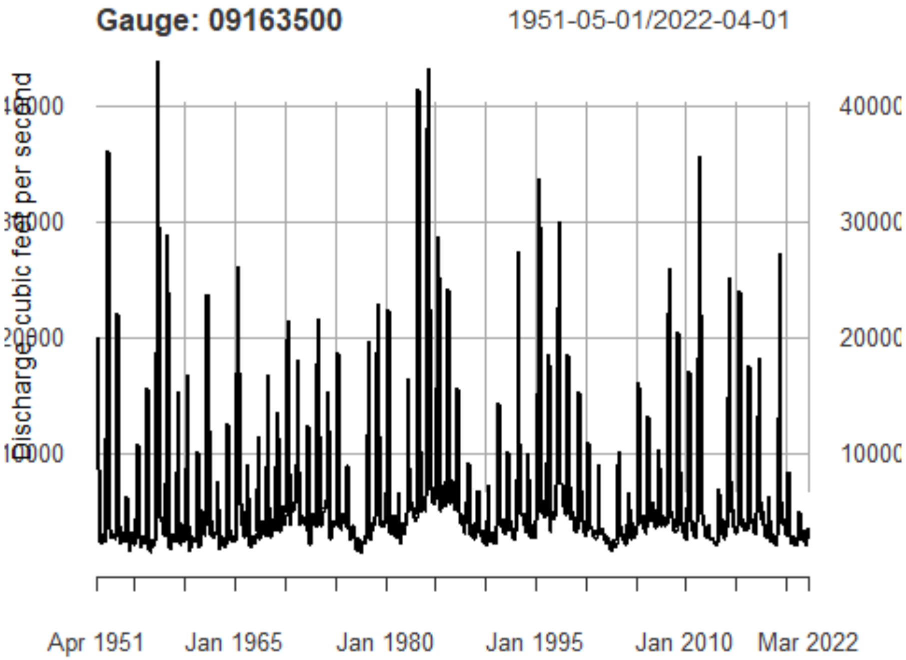


Figure B32. Discharge (cf/s) at location USGS 09163500

Table B17. Main statistics of water discharge (cf/s) at USGS 09152500

	January	February	March	April	May	June	July	August	September	October	November	December
Min.	500.0	500.0	500.0	580.1	698.4	577.2	164.6	152.8	266.8	268.3	496.7	500.0
1st Qu.	800.8	822.3	912.5	1639.0	3598.0	2820.0	1063.0	842.3	859.4	1031.2	1038.5	896.3
Median	948.4	1033.0	1200.0	2593.5	6089.0	5393.0	1914.0	1291.0	1285.0	1375.0	1264.5	1045.0
Mean	1259.1	1252.8	1440.2	2975.4	6834.2	6463.4	2422.6	1432.7	1441.7	1532.1	1437.2	1347.6
3rd Qu.	1582.8	1359.8	1531.2	3854.2	9447.0	9308.0	3083.0	1888.0	1863.0	1923.8	1745.0	1809.5
Max.	3515.0	3844.0	4114.0	9184.0	18870.0	19630.0	11950.0	3639.0	4959.0	3479.0	3303.0	3225.0

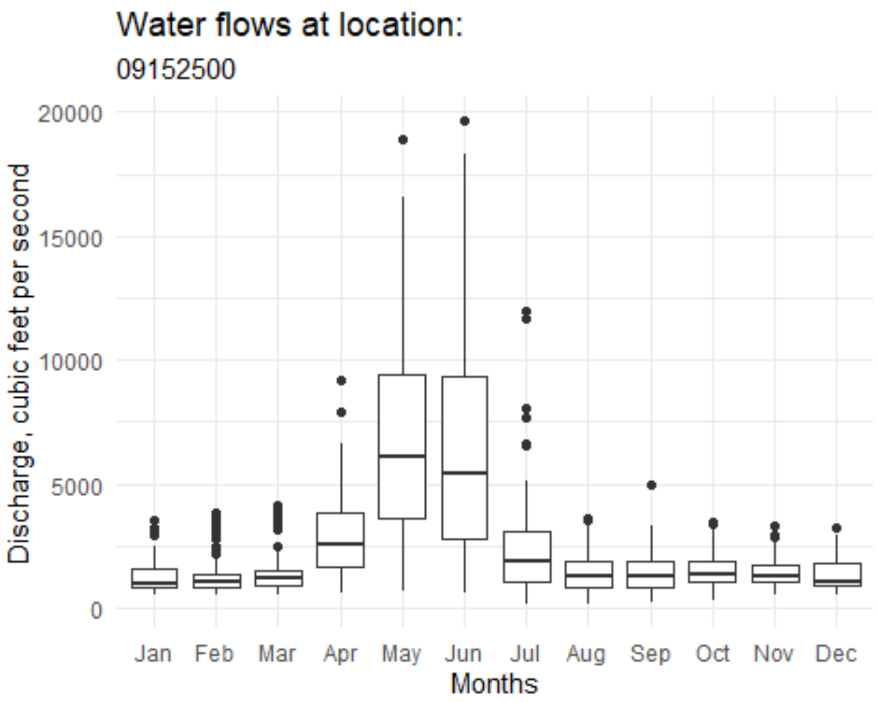


Figure B33. Monthly discharge (cf/s) at location USGS 09152500

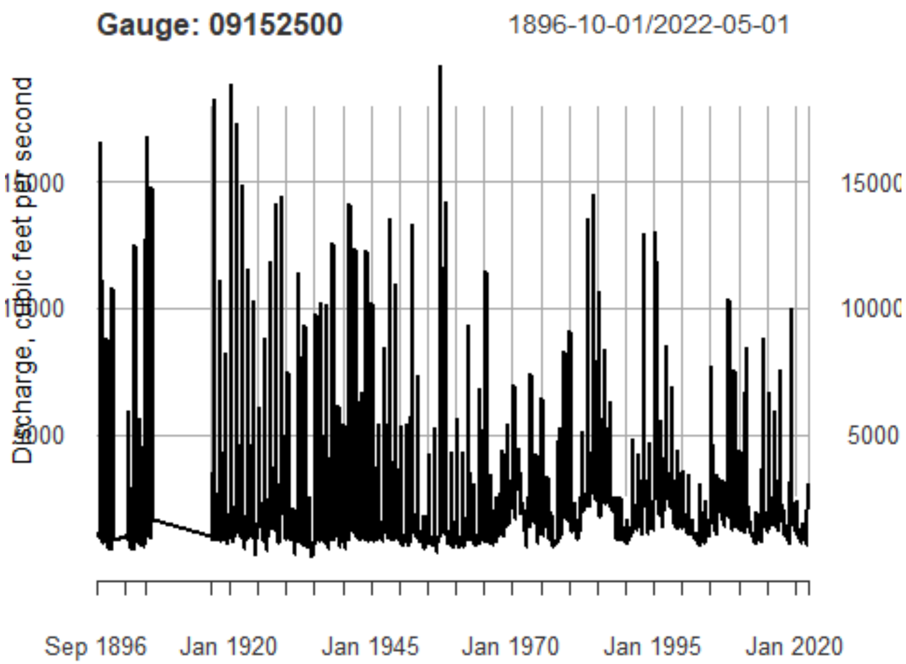
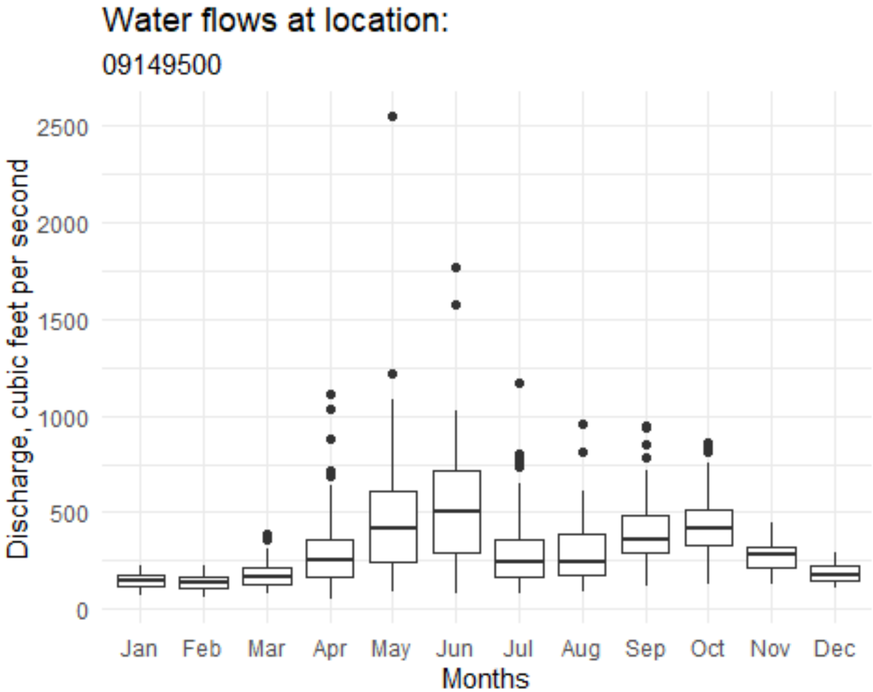


Figure B34. Discharge (cf/s) at location USGS 09152500

Table B18. Main statistics of water discharge (cf/s) at USGS 09149500

	January	February	March	April	May	June	July	August	September	October	November	December
Min.	70.9	66.5	80.7	51.8	92.2	82.3	82.2	93.7	123.2	130.7	125.0	111.1
1st Qu.	123.7	112.5	132.2	164.0	242.3	290.9	165.5	179.1	294.9	331.2	218.9	146.9
Median	146.1	136.9	168.1	251.0	413.8	501.6	240.8	249.3	364.6	414.8	281.6	177.1
Mean	150.1	143.5	178.6	295.6	468.1	527.6	314.3	300.9	403.0	443.9	271.8	183.7
3rd Qu.	177.1	168.6	213.0	363.0	612.0	717.0	361.6	387.6	486.9	515.7	324.8	220.8
Max.	227.4	230.1	392.2	1107.0	2542.0	1763.0	1170.0	959.5	943.7	862.4	442.1	294.4



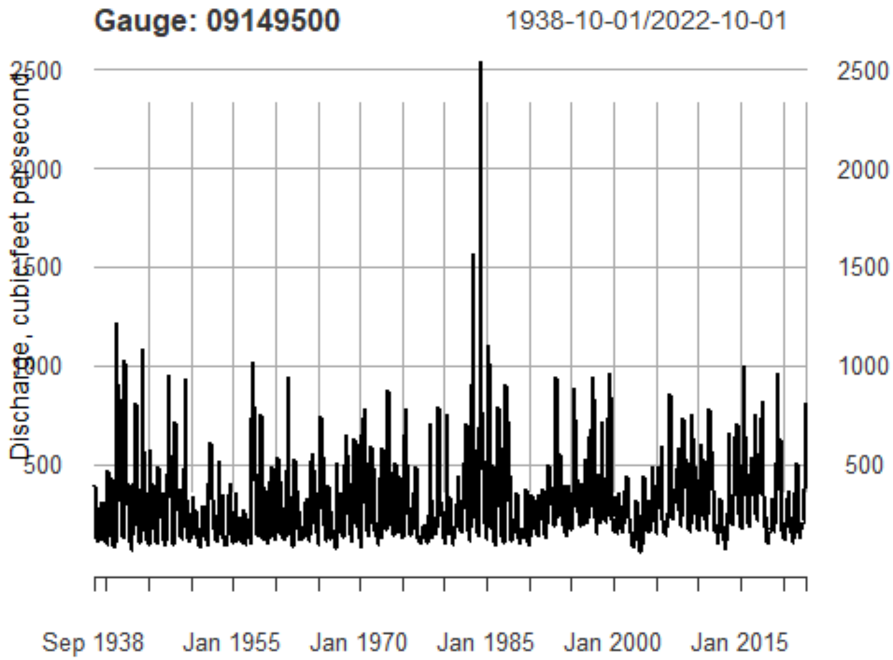
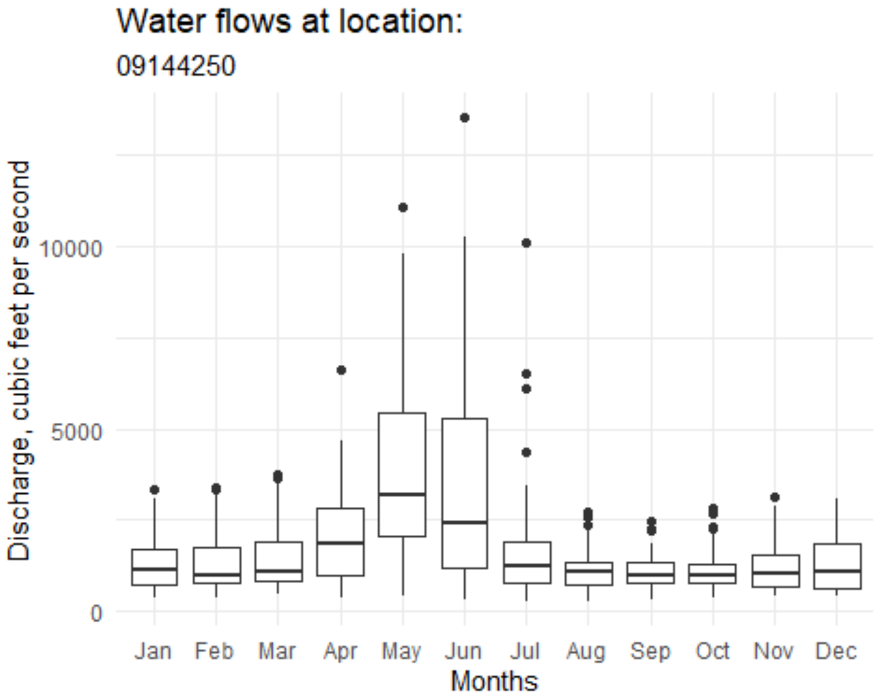


Figure B36. Monthly discharge (cf/s) at location USGS 09149500 Figure B37. Discharge (cf/s) at location USGS 09149500

Table B19. Main statistics of water discharge (cf/s) at USGS 09144250

	January	February	March	April	May	June	July	August	September	October	November	December
Min.	386.2	383.5	450.5	366.1	411.0	331.1	274.7	268.8	335.1	398.3	421.8	402.3
1st Qu.	753.5	768.7	816.9	984.3	2055.2	1196.0	774.9	714.6	767.2	779.6	662.2	610.8
Median	1119.5	972.0	1090.0	1841.0	3201.0	2418.0	1224.0	1065.0	998.7	1007.0	1024.7	1107.0
Mean	1291.9	1298.7	1488.3	2112.1	3962.2	3604.3	1775.7	1115.5	1104.6	1178.8	1220.4	1314.0
3rd Qu.	1682.5	1752.8	1928.0	2810.5	5454.8	5304.5	1923.5	1322.5	1356.5	1314.5	1559.0	1867.8
Max.	3349.0	3381.0	3744.0	6641.0	11090.0	13520.0	10110.0	2752.0	2496.0	2833.0	3156.0	3103.0



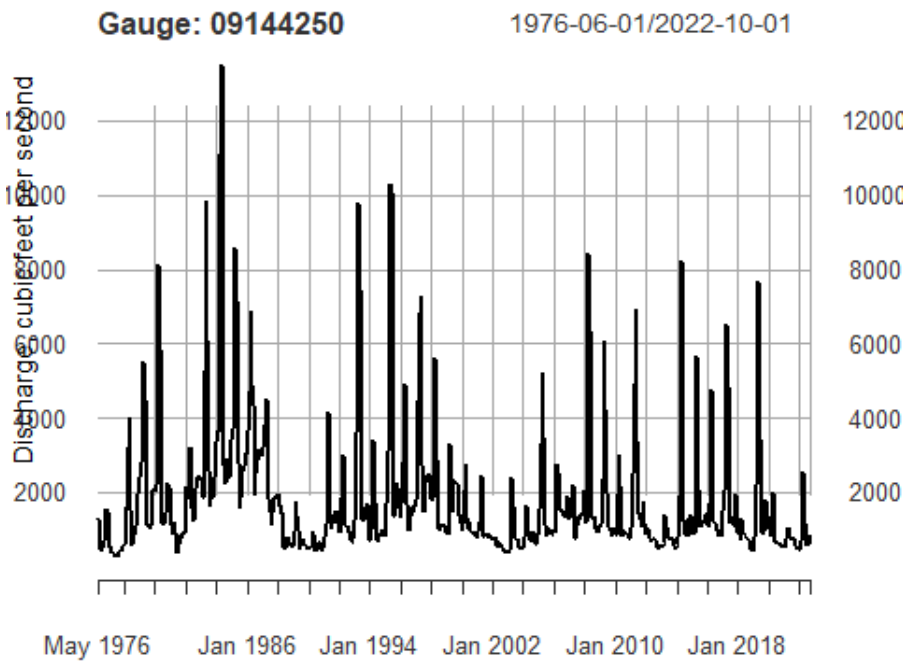


Figure B38. Monthly discharge (cf/s) at location USGS 09144250 Figure B39. Discharge (cf/s) at location USGS 09144250

Table B20. Main statistics of water discharge (cf/s) at USGS 09180500

	January	February	March	April	May	June	July	August	September	October	November	December
Min.	1876.0	1843.0	2009.0	1638.0	2322.0	2504.0	1057.0	1017.0	1078.0	1353.0	1730.0	2023.0
1st Qu.	2349.8	2534.0	2862.5	4321.8	10815.0	11447.5	3495.8	2574.8	2605.2	2994.0	3033.5	2523.8
Median	2807.0	2917.0	3455.5	7117.5	16125.0	18660.0	7191.5	3653.0	3463.5	3669.0	3536.0	2962.0
Mean	3059.1	3193.8	3755.2	7758.8	17809.2	20518.5	8498.5	4233.0	3749.5	4050.6	3771.5	3257.7
3rd Qu.	3411.8	3592.0	4182.0	9847.2	24825.0	27370.0	11157.5	5186.5	4483.2	4816.0	4313.0	3849.0
Max.	6371.0	6326.0	8412.0	22590.0	42090.0	55530.0	31750.0	11400.0	11330.0	9416.0	7601.0	6588.0

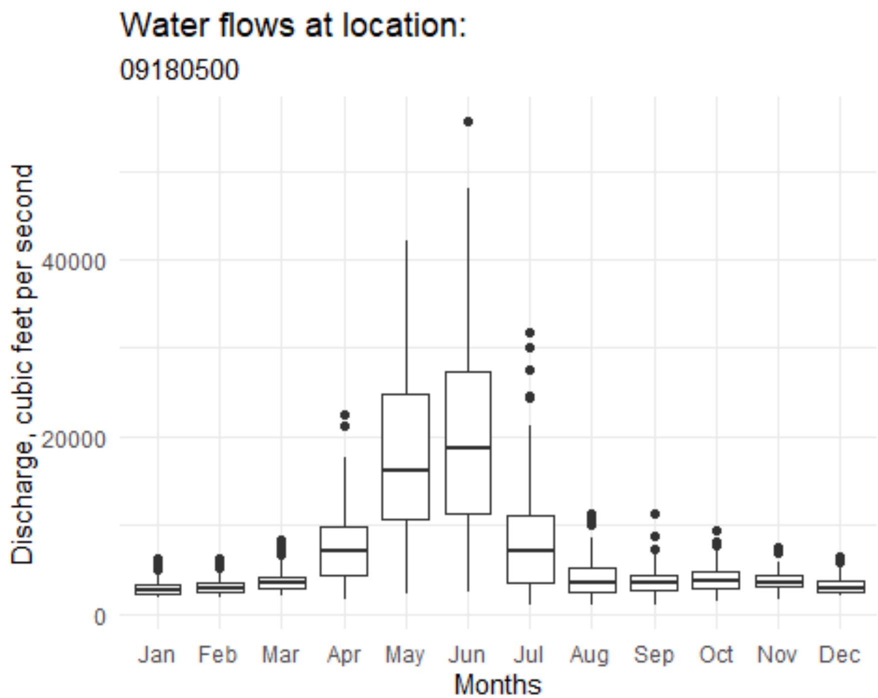


Figure B40. Monthly discharge (cf/s) at location USGS 09180500

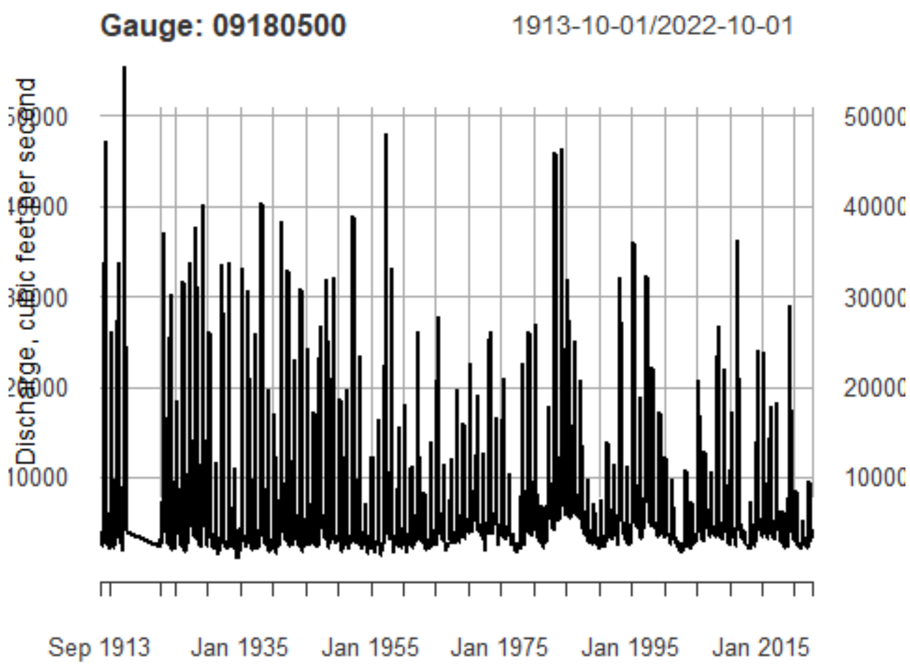


Figure B41. Discharge (cf/s) at location USGS 09180500

Table B22. Main statistics of water discharge (cf/s) at USGS 09180000

	January	February	March	April	May	June	July	August	September	October	November	December
Min.	76.3	77.5	95.5	123.9	113.2	76.4	5.4	9.6	22.8	47.9	93.5	59.9
1st Qu.	109.9	149.8	178.8	577.8	618.4	481.0	192.2	112.8	112.0	135.8	144.7	114.2
Median	141.5	170.1	250.7	829.0	1256.0	935.8	294.7	248.4	164.0	198.1	171.9	145.4
Mean	148.2	185.9	366.8	1262.7	1864.4	1268.9	437.6	258.2	203.2	221.9	194.6	160.7
3rd Qu.	175.8	202.4	457.9	1736.0	2439.5	1719.0	602.4	307.8	267.5	250.3	194.2	172.0
Max.	370.4	518.3	1037.0	5338.0	8803.0	3895.0	1827.0	916.6	779.0	782.8	894.1	605.8

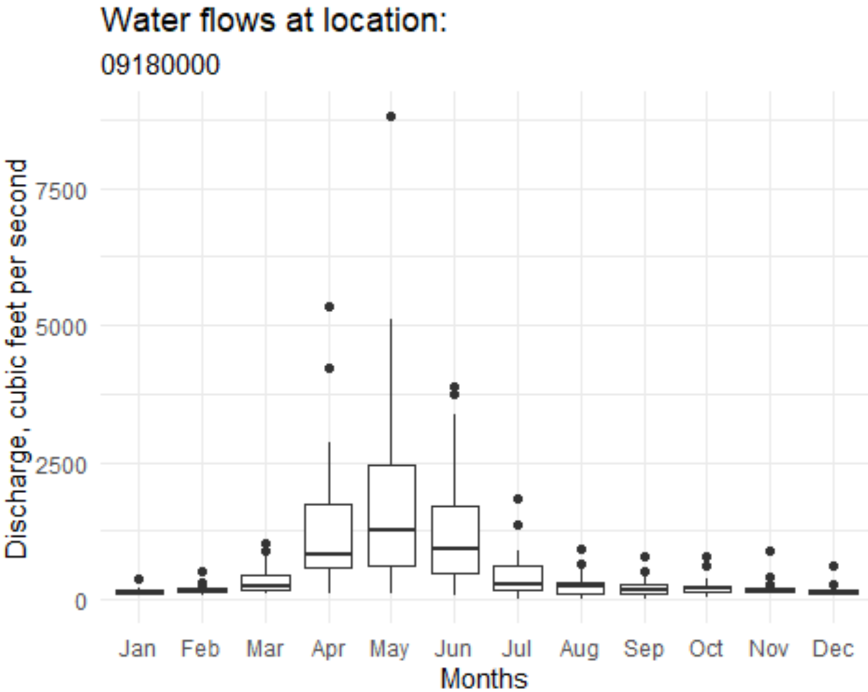


Figure B42. Monthly discharge (cf/s) at location USGS 09180000

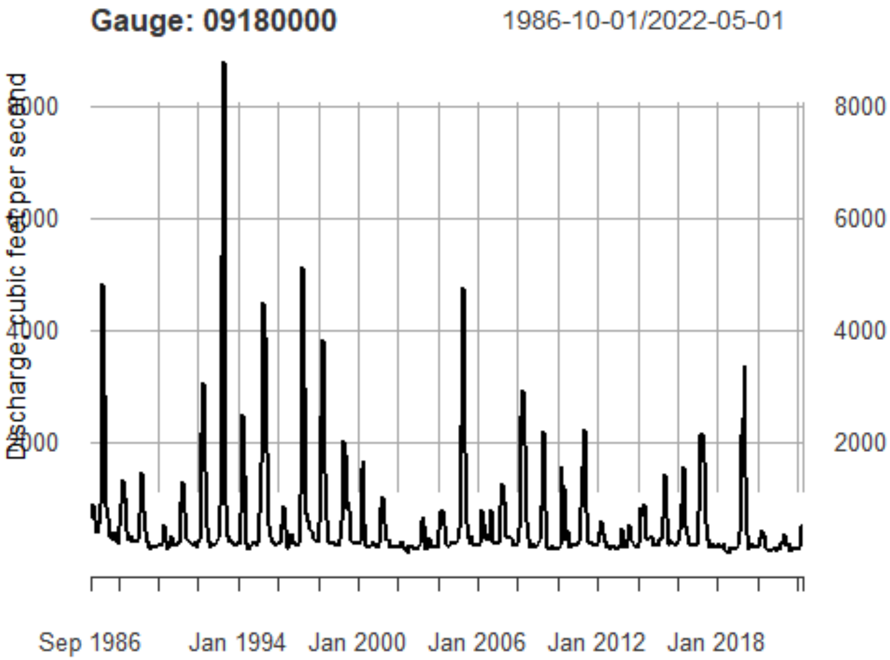


Figure B43. Discharge (cf/s) at location USGS 09180000

Table B23. Main statistics of water discharge (cf/s) at USGS 09179450

	January	February	March	April	May	June	July	August	September	October	November	December
Min.	66.7	112.2	101.2	119.0	193.0	87.9	25.8	37.4	23.8	49.9	89.2	73.0
1st Qu.	79.7	141.3	167.8	221.9	328.5	394.3	139.5	133.0	47.8	111.2	103.7	81.4
Median	109.7	165.8	252.4	250.8	653.0	1409.0	442.6	231.2	99.1	131.1	133.8	107.7
Mean	113.1	162.4	326.9	830.2	977.0	1266.5	470.5	210.7	88.4	127.3	131.9	109.2
3rd Qu.	139.1	189.9	407.3	1396.3	1584.5	1596.0	562.0	295.2	119.1	142.4	145.0	133.9
Max.	174.9	196.4	784.4	2205.0	2167.0	3388.0	1422.0	349.5	162.2	203.1	202.2	153.8

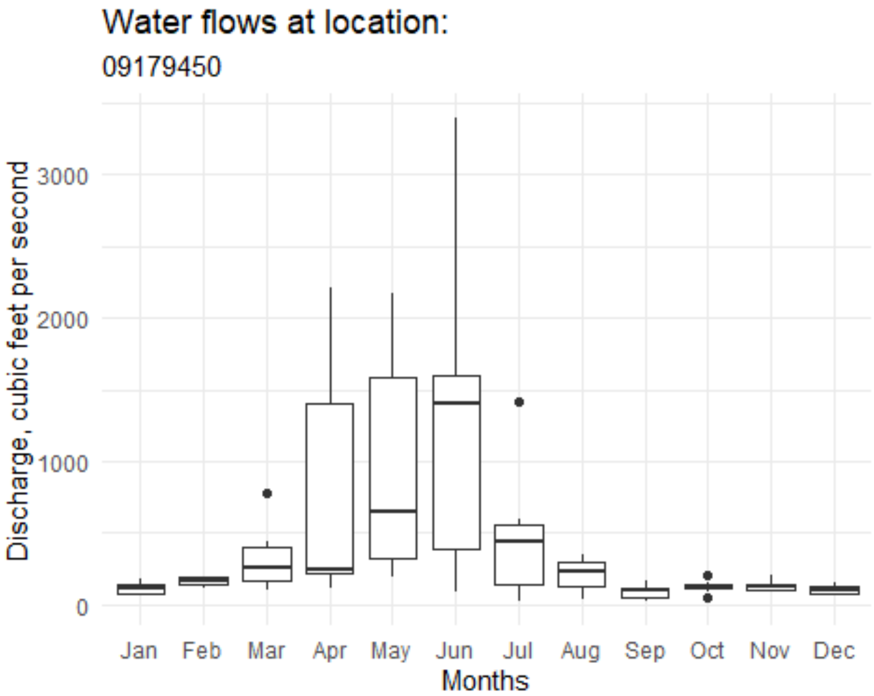


Figure B44. Monthly discharge (cf/s) at location USGS 09179450

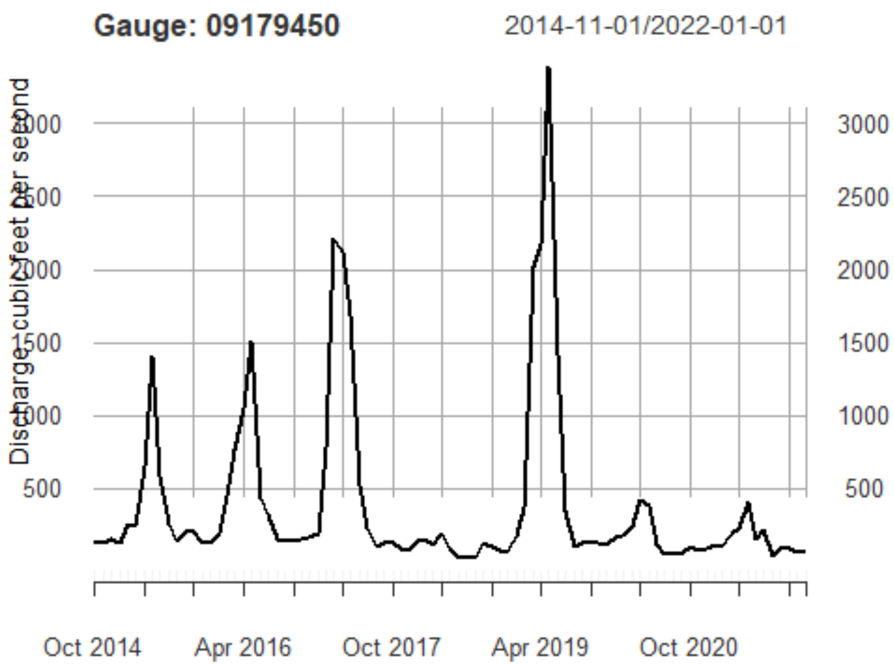


Figure B45. Discharge (cf/s) at location USGS 09179450

+Table B24. Main statistics of water discharge (cf/s) at USGS 09177000

	January	February	March	April	May	June	July	August	September	October	November	December
Min.	42.4	54.1	50.3	59.6	86.6	79.2	9.2	9.0	14.2	30.6	57.7	42.4
1st Qu.	67.3	78.7	99.3	437.1	595.2	496.6	146.8	75.7	50.3	86.2	82.2	64.4
Median	78.7	96.2	145.5	636.4	832.3	753.4	277.6	142.4	95.0	113.8	97.3	80.8
Mean	84.9	102.9	194.0	741.2	1007.2	886.5	368.2	169.7	119.7	138.7	111.2	89.8
3rd Qu.	103.8	120.9	235.8	971.9	1396.2	1239.5	525.9	203.2	148.8	175.7	130.5	107.8
Max.	139.4	225.5	611.8	2154.0	3420.0	2361.0	1306.0	646.3	416.3	496.5	384.8	187.6

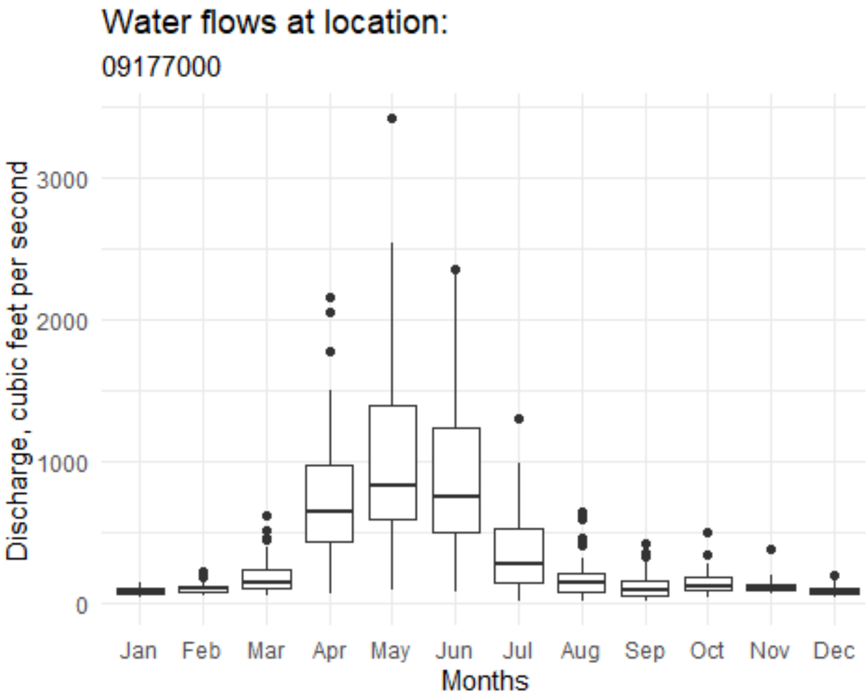


Figure B46. Monthly discharge (cf/s) at location USGS 09177000

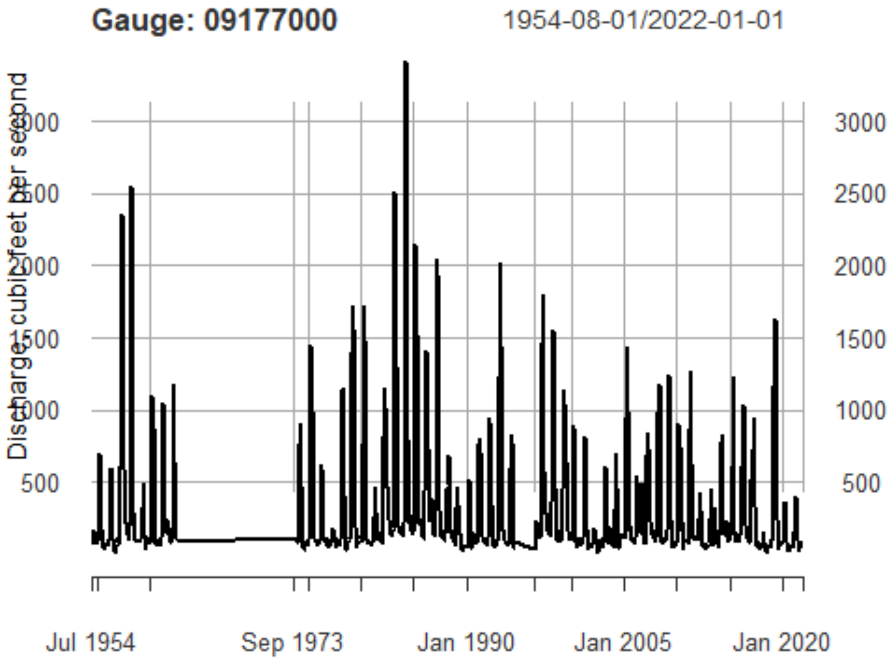


Figure B47. Discharge (cf/s) at location USGS 09177000

Table B25. Main statistics of water discharge (cf/s) at USGS 09171100

	January	February	March	April	May	June	July	August	September	October	November	December
Min.	21.4	28.7	31.9	21.1	12.2	2.6	1.9	1.7	8.9	6.0	7.2	20.9
1st Qu.	36.0	48.1	57.7	104.1	61.0	50.3	56.8	62.7	47.2	39.8	38.1	35.5
Median	47.2	53.6	85.6	210.2	383.4	244.9	77.2	77.2	61.9	62.1	46.2	45.4
Mean	57.9	68.4	174.1	592.1	830.8	484.1	115.1	90.3	84.0	71.7	63.0	55.0
3rd Qu.	67.7	78.6	218.3	776.2	1366.0	725.5	117.9	106.9	89.8	81.7	62.5	58.3
Max.	208.2	207.0	811.3	2552.0	3219.0	1766.0	677.4	273.9	379.4	268.9	430.2	261.7

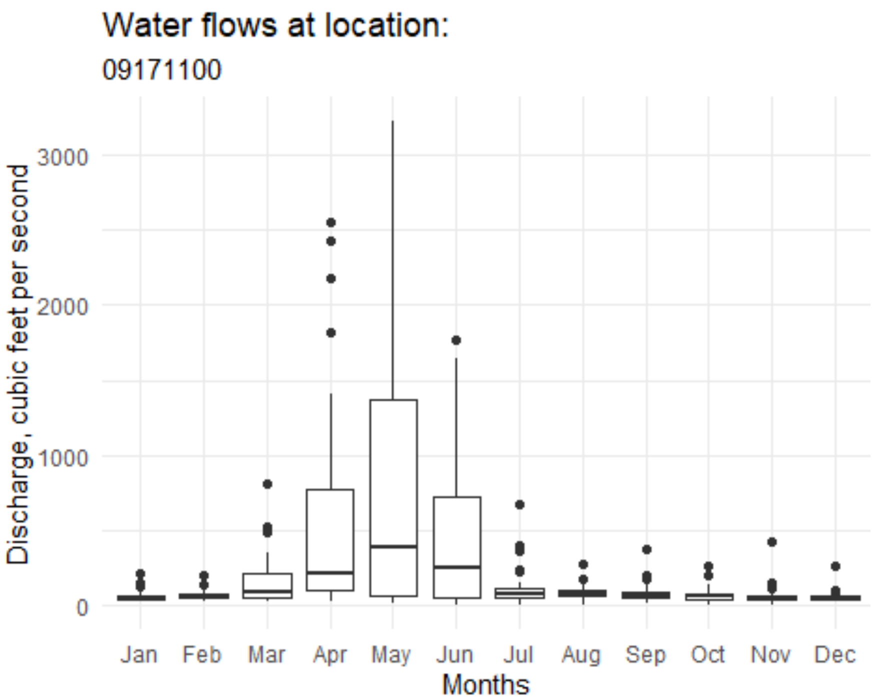


Figure B48. Monthly discharge (cf/s) at location USGS 09171100

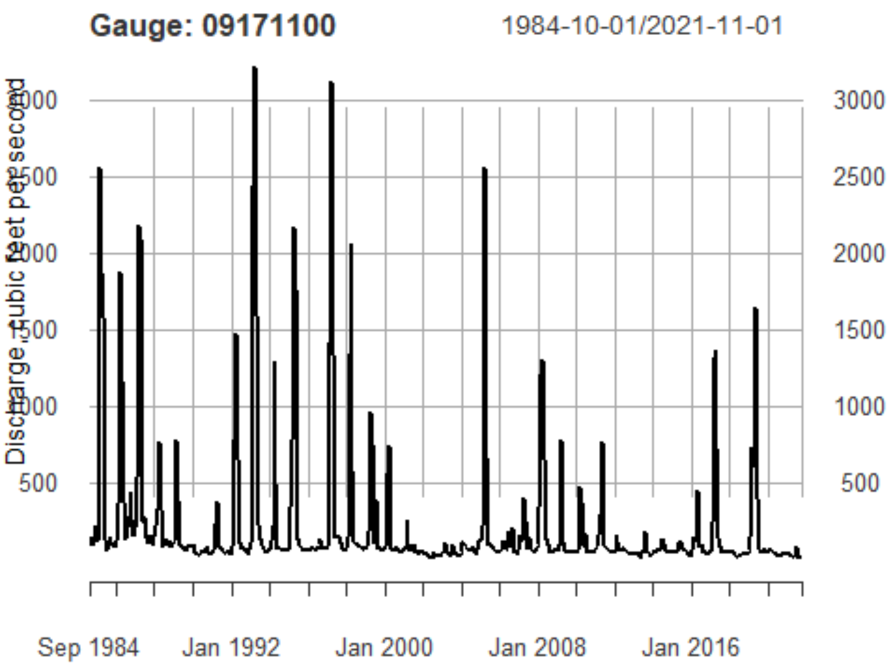


Figure B49. Discharge (cf/s) at location USGS 09171100

Table B26. Main statistics of water discharge (cf/s) at USGS 09019000

	January	February	March	April	May	June	July	August	September	October	November	December
Min.	19.7	20.0	19.2	19.6	67.4	81.0	89.9	70.1	54.5	18.4	20.2	19.4
1st Qu.	20.1	20.0	19.7	19.8	72.7	84.5	94.3	73.0	58.8	21.0	20.4	19.8
Median	20.2	20.1	19.9	20.1	74.8	86.1	95.8	77.6	66.8	24.1	20.7	20.0
Mean	20.2	20.2	19.9	20.1	75.0	87.4	145.5	76.8	66.9	23.4	21.0	20.0
3rd Qu.	20.4	20.4	20.1	20.4	77.2	89.0	147.0	81.3	74.9	26.5	21.4	20.2
Max.	20.8	20.7	20.4	20.6	83.1	96.4	300.3	82.1	79.5	27.0	22.0	20.4

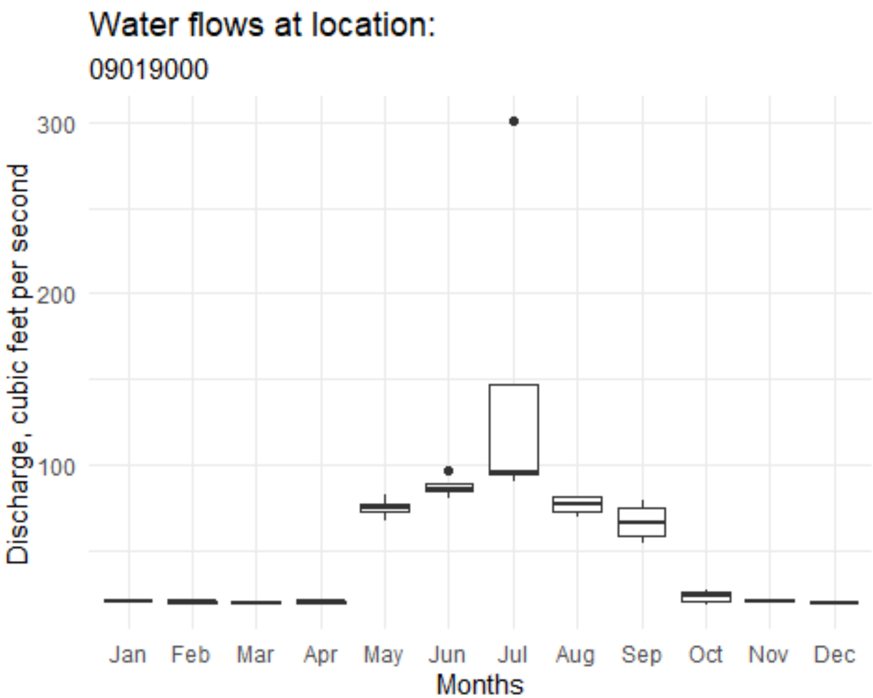


Figure B50. Monthly discharge (cf/s) at location USGS 09019000

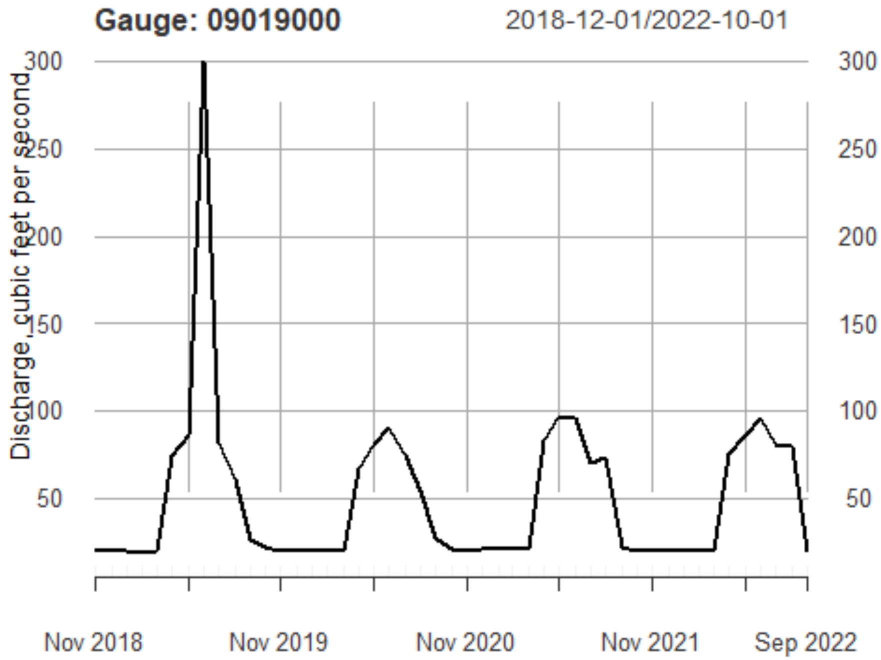


Figure B51. Discharge (cf/s) at location USGS 09019000

Table B27. Main statistics of water discharge (cf/s) at USGS 09015000

	January	February	March	April	May	June	July	August	September	October	November	December
Min.	20.0	20.5	19.2	21.1	30.1	60.7	42.4	24.6	23.4	19.1	19.3	18.8
1st Qu.	22.6	22.0	21.9	23.7	236.6	494.1	54.5	46.0	39.2	24.1	25.4	24.3
Median	24.1	23.6	22.9	26.3	291.1	797.4	65.3	50.9	41.7	34.7	42.5	29.0
Mean	24.7	24.2	25.4	53.5	354.3	798.1	202.6	62.1	45.5	47.9	44.1	33.3
3rd Qu.	26.3	24.7	26.2	86.0	476.2	1048.5	266.0	66.6	51.0	38.8	47.9	45.4
Max.	34.4	36.1	44.8	160.5	899.9	1523.0	1134.0	171.2	68.7	260.3	143.4	49.3

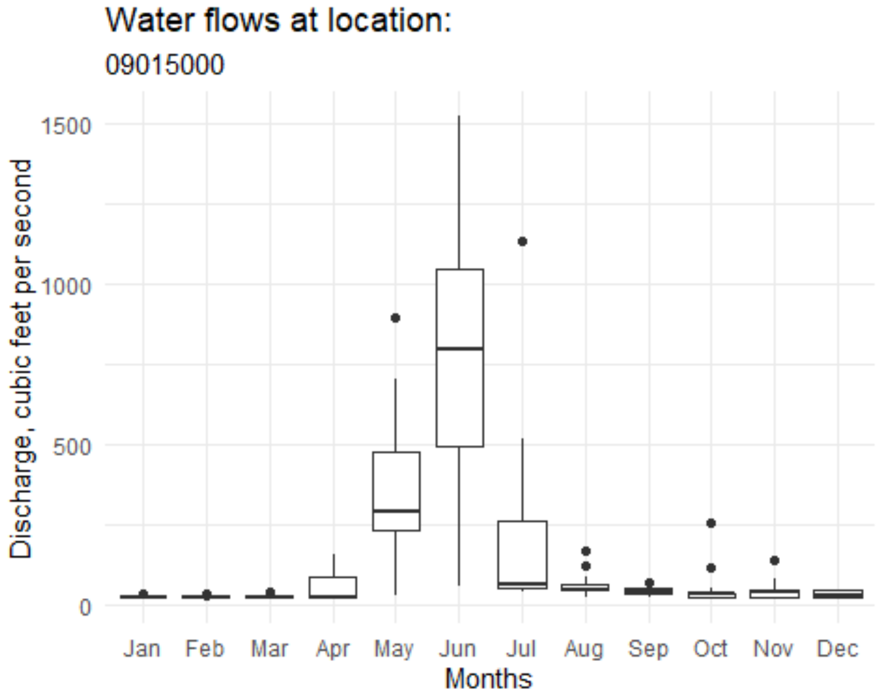


Figure B52. Monthly discharge (cf/s) at location USGS 09015000

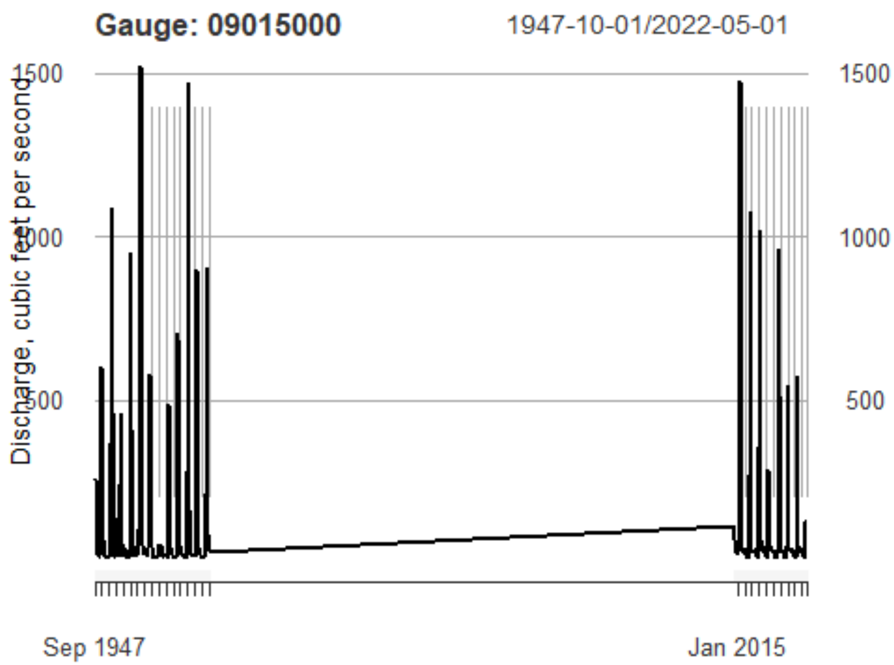


Figure B53. Discharge (cf/s) at location USGS 09015000

Table B28. Main statistics of water discharge (cf/s) at USGS 09128000

	January	February	March	April	May	June	July	August	September	October	November	December
Min.	143.2	154.6	248.4	177.0	215.6	123.2	61.1	34.4	8.4	17.0	115.5	141.3
1st Qu.	380.0	400.0	472.7	454.0	876.0	846.4	530.8	309.7	200.8	252.7	411.5	410.3
Median	472.5	500.0	607.2	827.3	2147.0	3026.5	968.0	586.5	475.0	434.5	573.9	497.3
Mean	775.5	763.5	827.9	1173.9	2804.4	3529.8	1424.3	709.0	540.1	563.3	731.5	795.0
3rd Qu.	1046.8	824.1	882.5	1672.5	4442.0	5688.5	1762.0	1026.0	765.0	757.8	890.5	1293.8
Max.	2732.0	3153.0	3278.0	3282.0	8617.0	11670.0	8468.0	2237.0	2447.0	2114.0	1888.0	2165.0

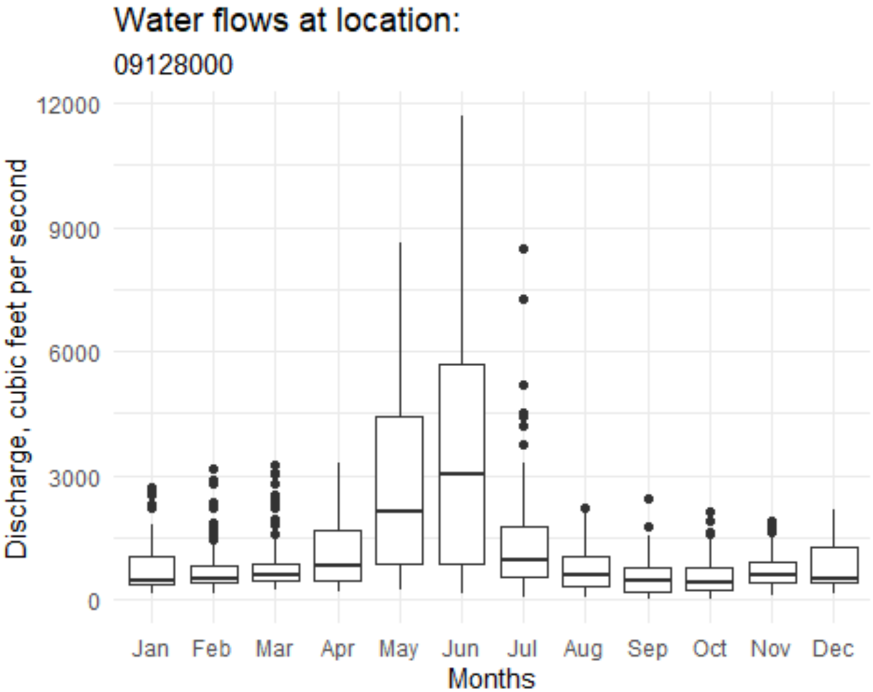


Figure B54. Monthly discharge (cf/s) at location USGS 09128000

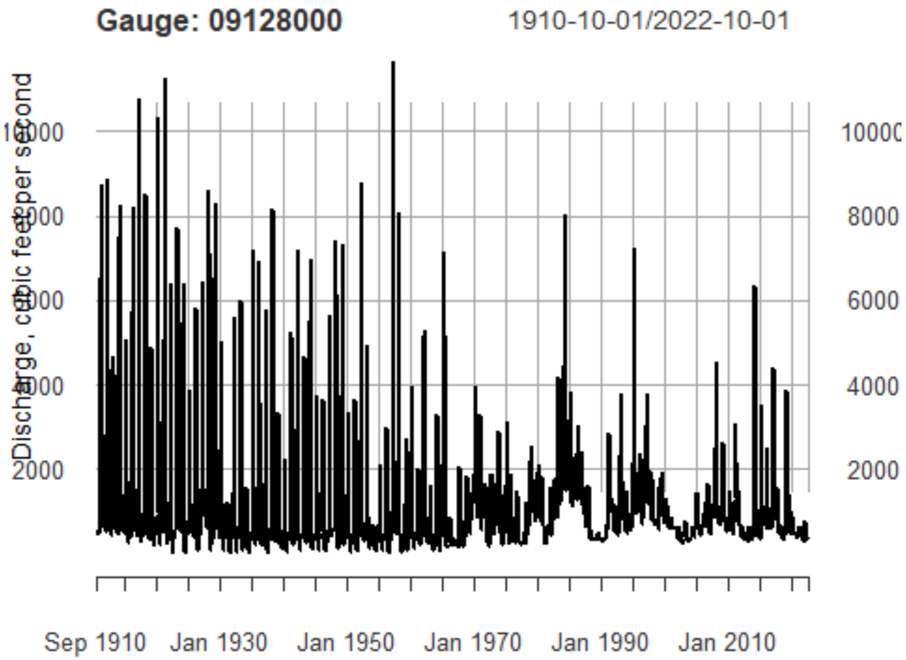
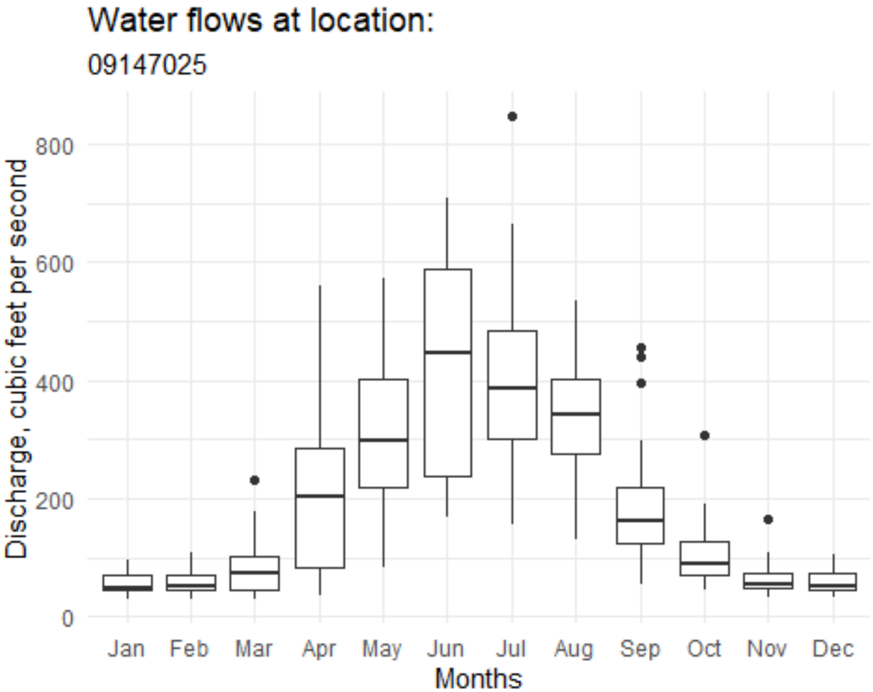


Figure B55. Discharge (cf/s) at location USGS 09128000

Table B29. Main statistics of water discharge (cf/s) at USGS 09147025

	January	February	March	April	May	June	July	August	September	October	November	December
Min.	29.7	29.7	29.0	36.8	81.3	168.1	154.3	130.9	54.2	46.0	30.7	30.7
1st Qu.	46.0	44.2	46.2	83.7	218.9	238.8	300.3	275.1	122.5	69.0	46.6	44.5
Median	49.4	50.0	72.9	204.4	296.7	445.0	387.1	340.5	163.3	89.2	54.3	52.5
Mean	54.6	57.3	81.6	202.2	313.7	435.0	403.8	338.1	185.3	107.2	64.0	59.9
3rd Qu.	70.5	70.9	100.2	283.6	402.9	589.2	483.5	402.7	220.0	128.3	74.1	72.8
Max.	94.7	106.7	229.7	559.9	571.2	709.6	846.1	534.8	455.5	307.5	165.4	105.5



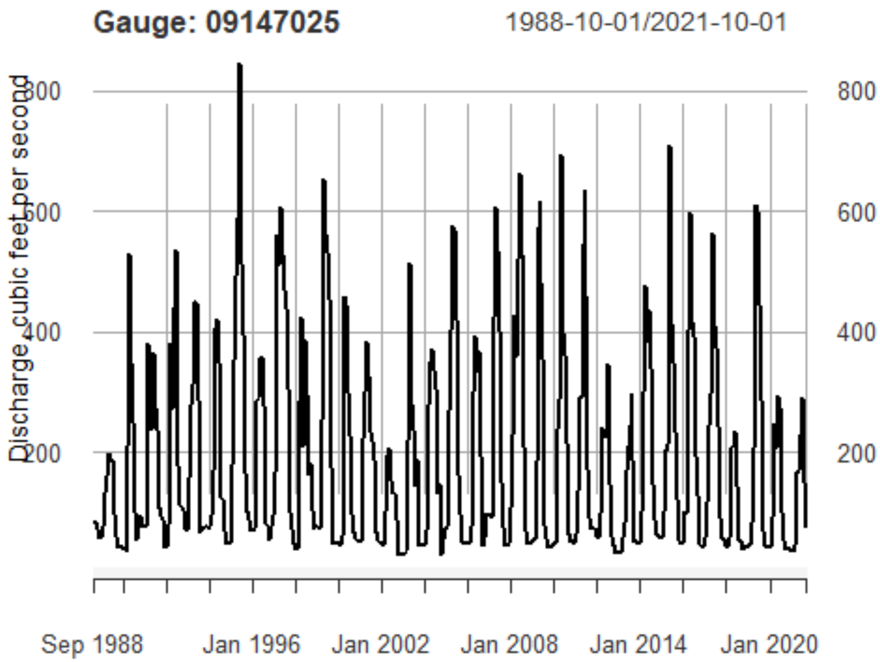


Figure B56. Monthly discharge (cf/s) at location USGS 09147025 Figure B57. Discharge (cf/s) at location USGS 09147025

Table B30. Main statistics of water discharge (cf/s) at USGS 09146200

	January	February	March	April	May	June	July	August	September	October	November	December
Min.	32.3	32.0	40.5	67.5	122.1	148.9	57.2	47.6	50.9	44.2	46.7	35.8
1st Qu.	40.5	40.3	51.2	89.2	256.7	426.1	189.8	106.0	76.3	65.2	57.9	46.8
Median	44.2	44.3	57.0	108.8	317.9	596.3	269.2	143.5	94.0	79.9	65.2	51.0
Mean	44.7	45.3	60.7	114.7	330.5	571.4	310.6	152.2	105.2	88.1	67.0	51.8
3rd Qu.	48.9	50.7	67.9	135.9	396.8	725.8	390.7	181.3	128.2	105.2	73.7	54.8
Max.	61.5	61.5	105.5	195.3	765.3	914.0	848.4	313.4	250.2	177.8	94.4	67.3

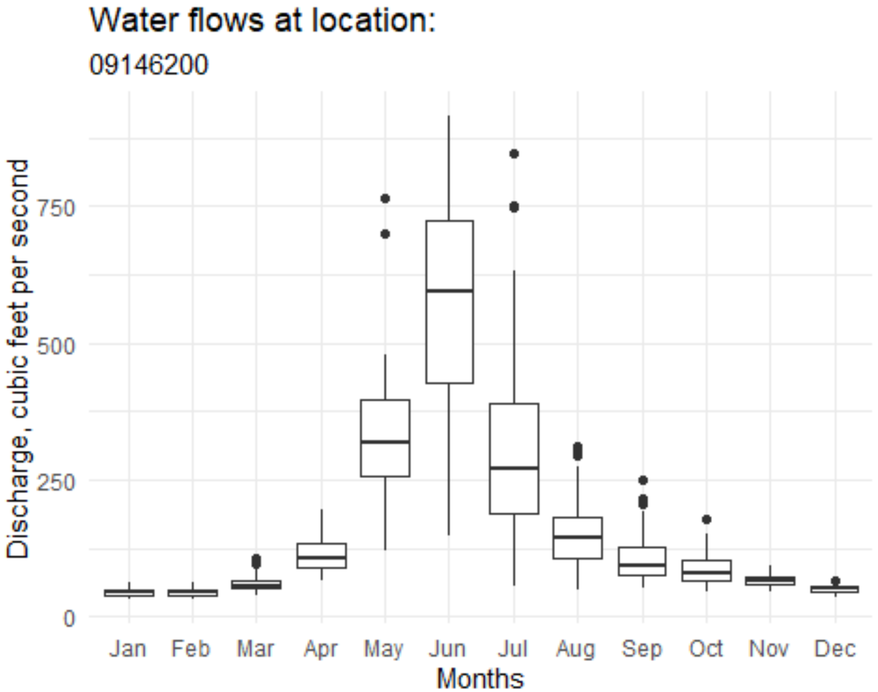


Figure B58. Monthly discharge (cf/s) at location USGS 09146200

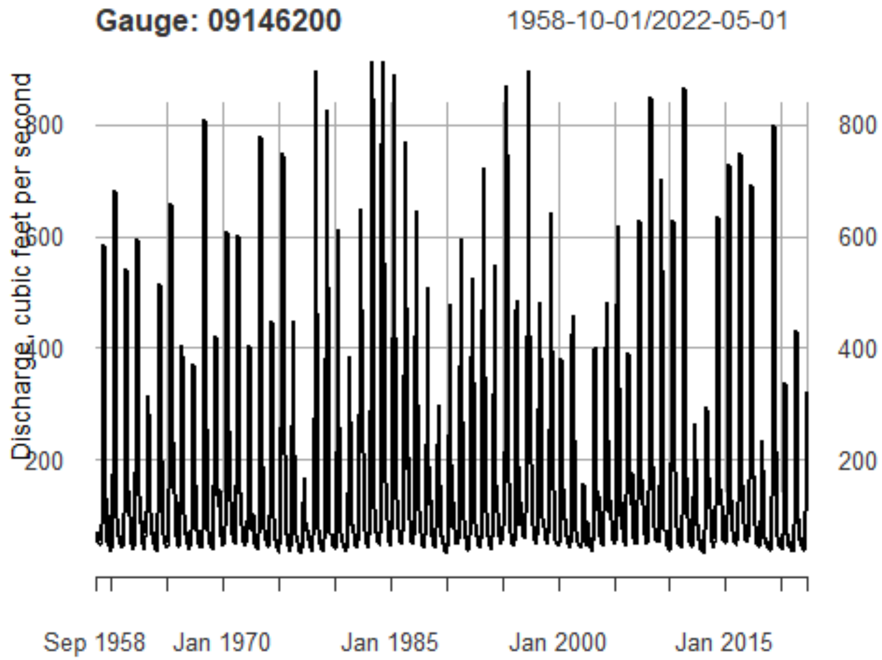
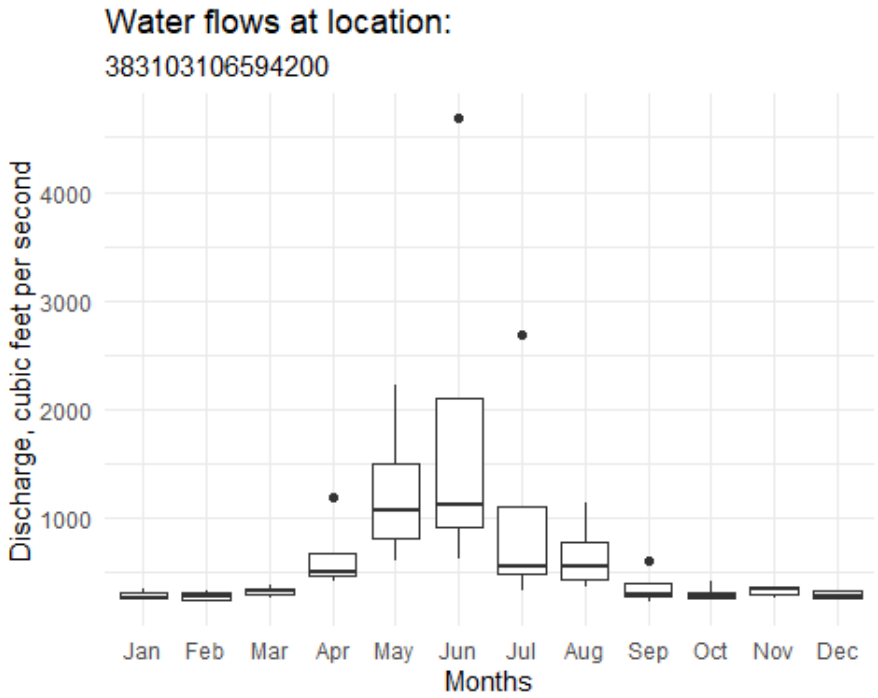


Figure B59. Discharge (cf/s) at location USGS 09146200

Table B31. Main statistics of water discharge (cf/s) at USGS 383103106594200

	January	February	March	April	May	June	July	August	September	October	November	December
Min.	240.1	238.2	265.7	419.7	598.6	619.8	330.0	368.2	225.6	252.8	258.4	240.9
1st Qu.	253.6	247.9	297.3	466.7	804.1	908.7	477.1	428.4	270.1	256.0	300.1	264.0
Median	258.6	284.0	325.0	496.3	1061.3	1123.0	548.0	556.2	302.7	272.8	347.1	273.8
Mean	282.9	283.6	325.4	651.6	1236.3	1885.0	1029.0	655.4	359.4	303.0	326.9	288.0
3rd Qu.	317.4	319.8	353.0	681.1	1493.5	2099.2	1099.8	783.2	392.0	319.7	363.4	327.1
Max.	344.7	328.3	385.8	1194.0	2224.0	4674.0	2690.0	1141.0	606.7	413.6	365.5	334.2



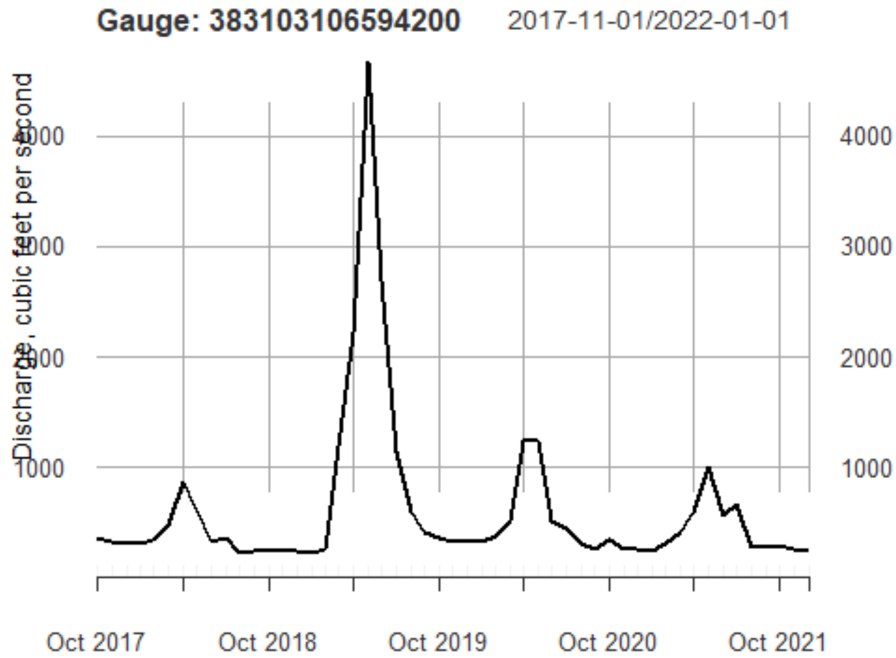


Figure B60. Monthly discharge (cf/s) at location USGS 383103106594200 Figure B61. Discharge (cf/s) at location USGS 383103106594200

Table B32. Main statistics of water discharge (cf/s) at USGS 09168730

	January	February	March	April	May	June	July	August	September	October	November	December
Min.	11.7	21.1	19.7	17.0	9.7	1.0	7.8	15.6	4.7	25.0	22.7	14.8
1st Qu.	27.0	28.9	39.1	41.3	38.1	21.4	39.9	40.8	34.1	33.9	28.4	23.1
Median	30.8	34.1	53.9	124.0	99.4	76.8	75.9	73.6	45.3	45.6	29.7	26.1
Mean	31.2	35.1	73.2	335.9	551.5	354.0	84.7	69.4	43.9	45.7	32.1	27.4
3rd Qu.	32.0	40.5	80.6	436.0	821.3	611.2	106.1	95.0	50.1	56.1	31.8	30.4
Max.	52.4	51.3	288.9	1455.0	3062.0	1673.0	342.9	125.5	91.1	71.1	57.8	47.5

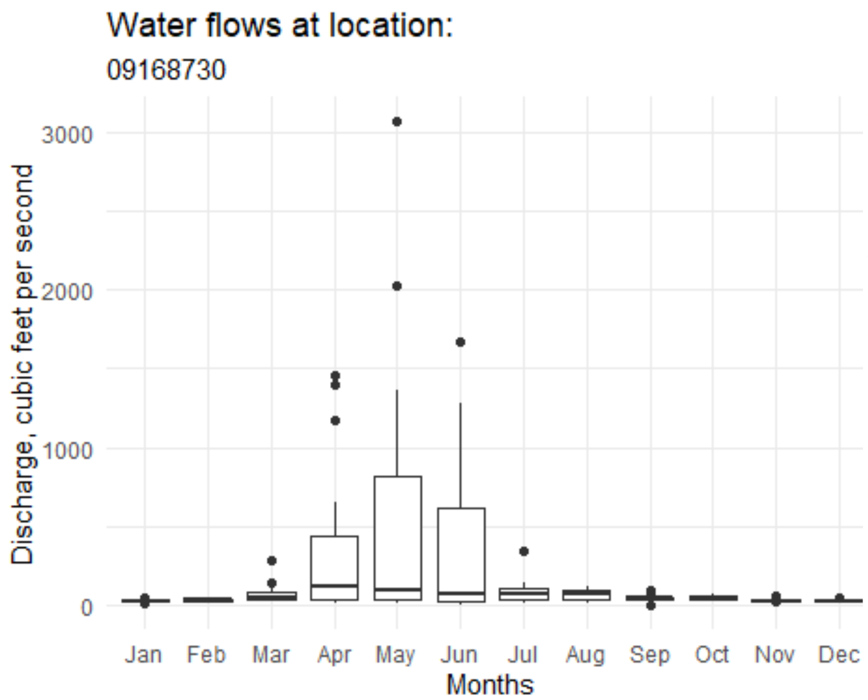


Figure B62. Monthly discharge (cf/s) at location USGS 09168730

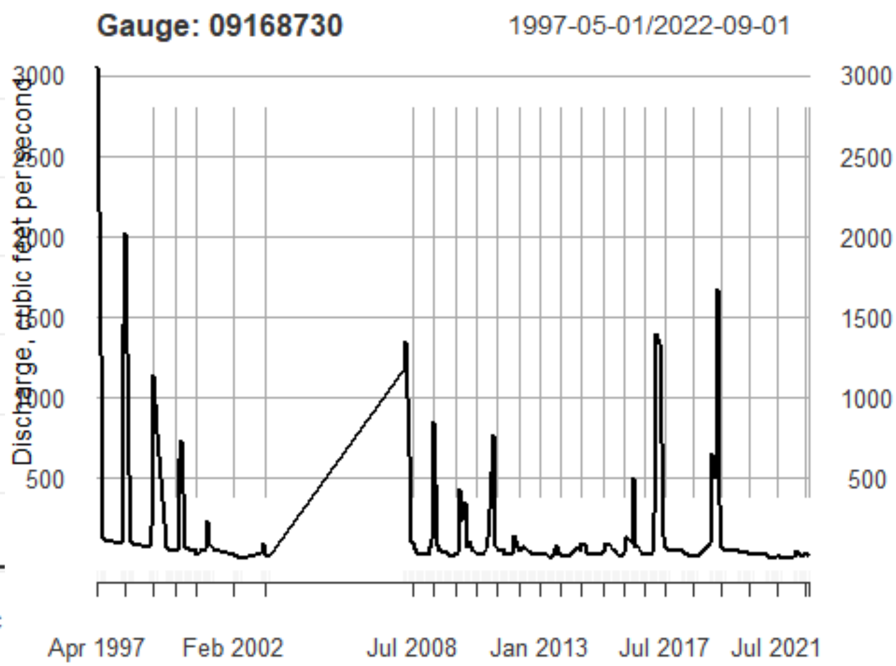


Figure B63. Discharge (cf/s) at location USGS 09168730

Table B33. Main statistics of water discharge (cf/s) at USGS 09166500

	January	February	March	April	May	June	July	August	September	October	November	December
Min.	19.3	20.0	25.0	157.9	234.6	67.3	55.4	29.0	33.5	26.0	20.0	19.8
1st Qu.	36.5	40.6	76.8	471.9	1127.2	639.1	188.0	139.7	105.1	67.7	49.5	40.0
Median	45.9	50.2	104.3	634.2	1572.5	1160.5	308.9	215.2	140.8	92.6	65.0	49.0
Mean	50.6	55.8	135.9	724.9	1669.6	1282.8	382.7	228.3	178.5	131.7	80.9	56.8
3rd Qu.	60.1	67.8	169.0	961.1	2195.5	1719.8	473.9	272.4	195.7	150.8	90.6	69.3
Max.	151.0	139.6	523.0	1955.0	3625.0	3470.0	1490.0	649.9	1354.0	1247.0	453.4	198.6

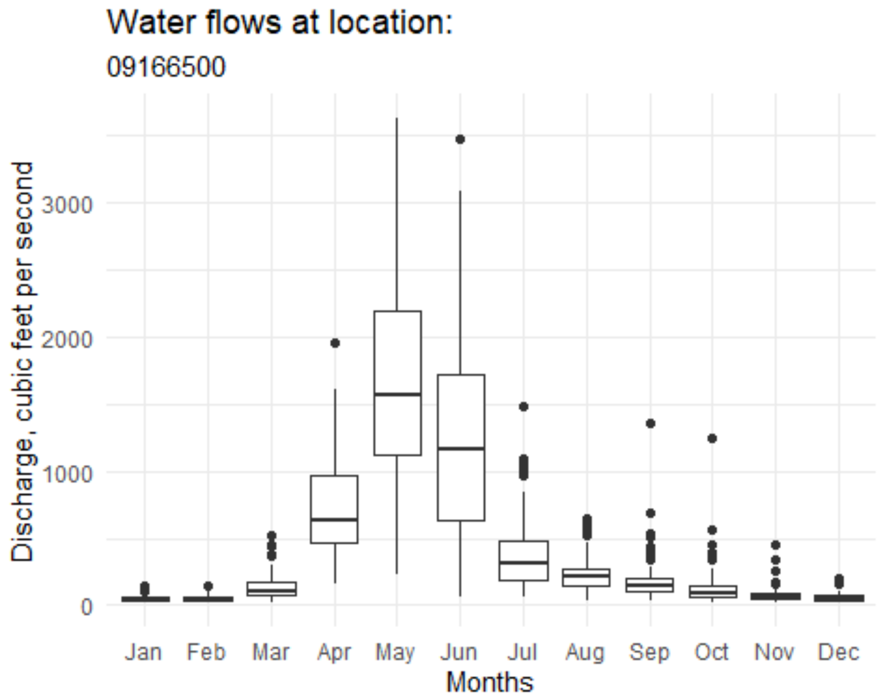


Figure B64. Monthly discharge (cf/s) at location USGS 09166500

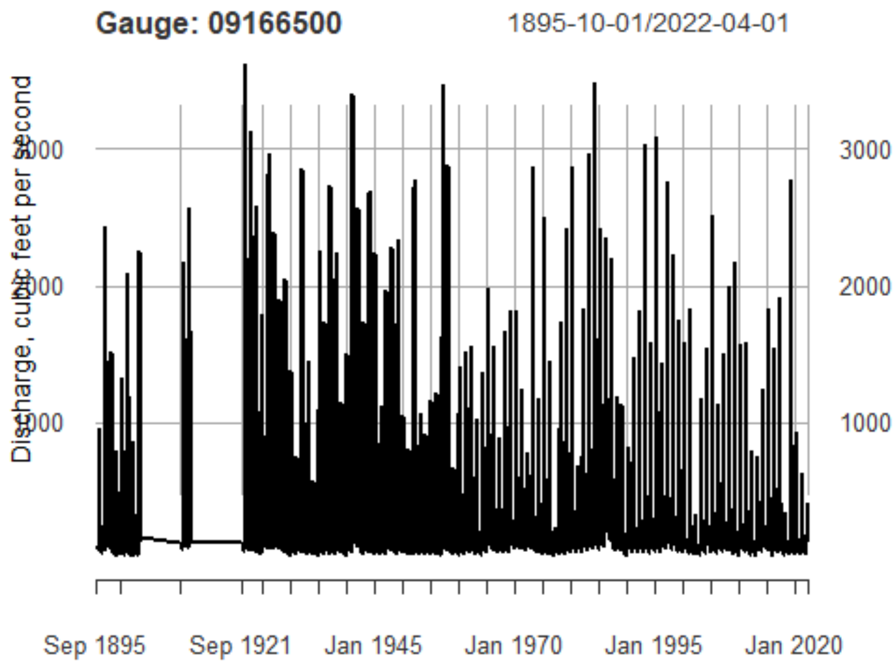


Figure B65. Discharge (cf/s) at location USGS 09166500

Table B34. Main statistics of water discharge (cf/s) at USGS 09185600

	January	February	March	April	May	June	July	August	September	October	November	December
Min.	2129.0	2128.0	2192.0	2410.0	3809.0	4404.0	2163.0	2115.0	2218.0	2494.0	2649.0	2065.0
1st Qu.	2249.5	2327.5	2682.5	2849.0	7136.5	6634.0	2812.5	2763.2	2675.5	3305.5	2785.0	2357.0
Median	3120.0	2857.0	3036.0	4442.0	9597.0	8230.0	4712.0	3717.0	3339.5	4120.0	3450.0	3066.0
Mean	2828.7	2879.6	3307.6	4834.6	10201.3	13068.9	6196.1	3820.0	3277.2	3831.9	3410.6	2961.9
3rd Qu.	3322.5	3306.5	3686.5	6766.5	14435.0	18645.0	6461.5	4503.5	3946.5	4420.0	3901.0	3500.5
Max.	3408.0	3904.0	5187.0	7759.0	14860.0	28290.0	17950.0	6160.0	4163.0	4758.0	4403.0	3887.0

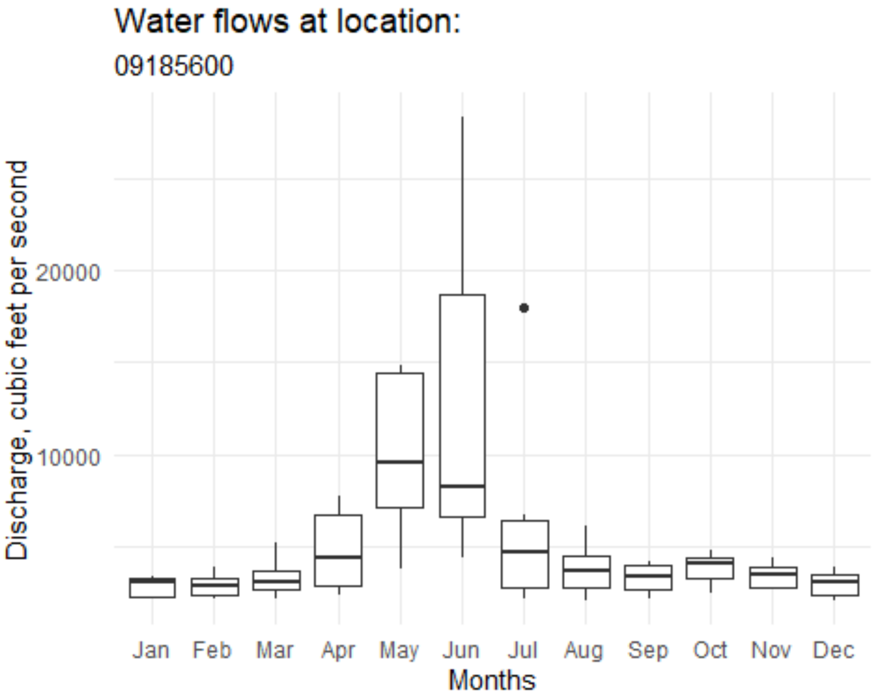


Figure B67. Monthly discharge (cf/s) at location USGS 09185600

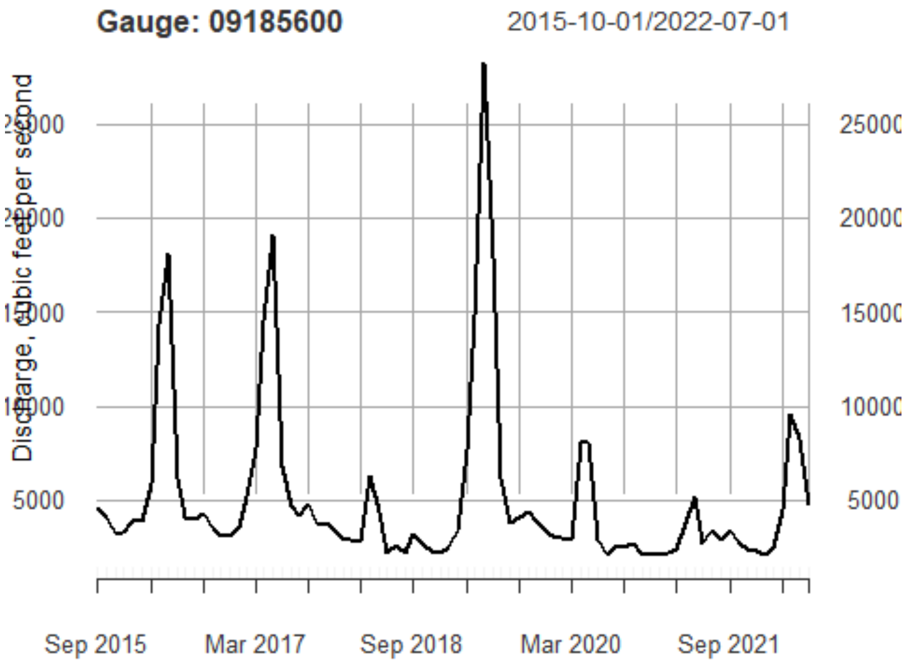
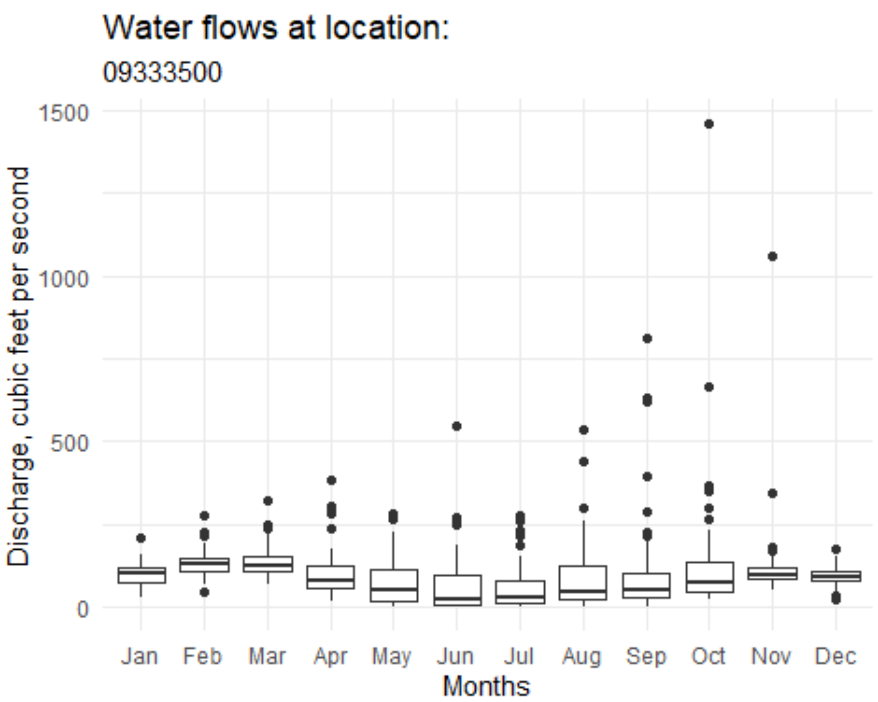


Figure B68. Discharge (cf/s) at location USGS 09185600

Table B35. Main statistics of water discharge (cf/s) at USGS 09333500

	January	February	March	April	May	June	July	August	September	October	November	December
Min.	29.6	43.5	68.9	15.8	1.3	0.0	0.0	0.2	0.2	20.9	52.5	22.8
1st Qu.	76.2	110.1	105.2	55.3	17.2	3.1	13.2	21.0	25.8	47.0	83.8	79.7
Median	102.6	131.3	125.6	77.7	52.8	24.7	29.3	44.0	53.0	74.9	96.8	92.1
Mean	99.3	131.4	134.4	99.4	75.6	66.0	53.6	88.0	98.9	124.1	119.2	92.8
3rd Qu.	118.6	145.2	153.7	123.7	110.8	95.3	76.4	124.3	100.1	133.3	116.7	109.6
Max.	207.5	277.2	320.5	383.5	279.9	549.4	276.9	538.0	811.7	1459.0	1059.0	173.9



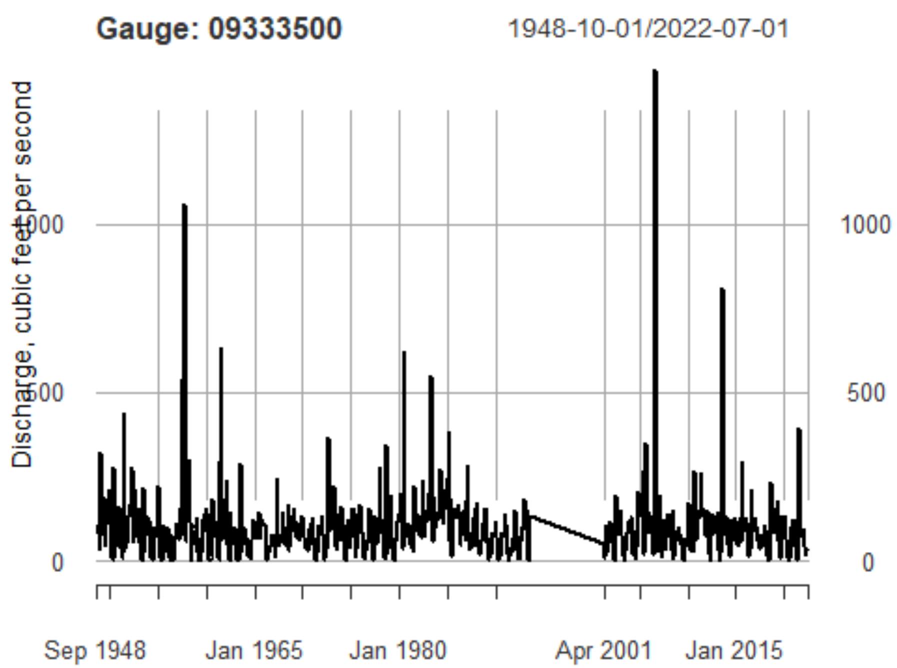


Figure B69. Monthly discharge (cf/s) at location USGS 09333500 Figure 70. Discharge (cf/s) at location USGS 09333500

Table B36. Main statistics of water discharge (cf/s) at USGS 09379500

	January	February	March	April	May	June	July	August	September	October	November	December
Min.	335.5	515.7	463.4	398.8	339.3	478.8	236.0	80.4	64.5	205.4	344.7	408.5
1st Qu.	601.1	754.2	896.0	1066.0	2104.5	2212.8	851.0	727.9	713.0	794.8	745.8	650.7
Median	811.6	942.6	1279.0	1895.0	4337.0	4276.0	1560.0	1208.0	1076.5	1075.0	923.8	796.7
Mean	1046.6	1315.5	1712.2	2955.9	4672.6	5144.5	2246.6	1638.9	1541.3	1442.7	1146.2	1027.7
3rd Qu.	1265.0	1552.0	2233.0	4408.0	6170.0	7059.8	2763.0	1947.2	1875.5	1630.5	1210.0	1166.0
Max.	3374.0	3683.0	6209.0	10120.0	21520.0	15380.0	9212.0	9335.0	11870.0	10650.0	4435.0	3821.0

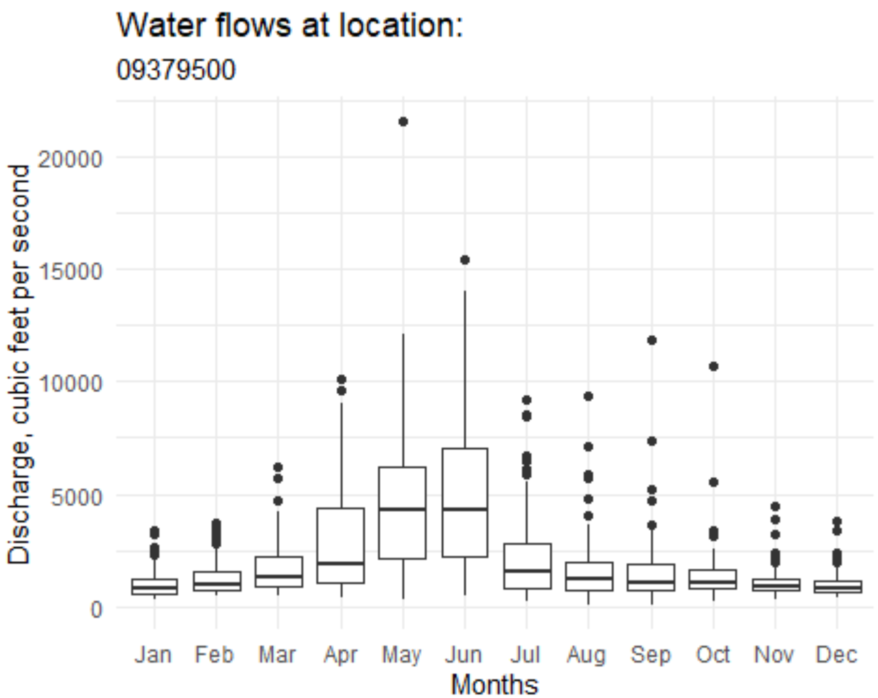


Figure B71. Monthly discharge (cf/s) at location USGS 09379500

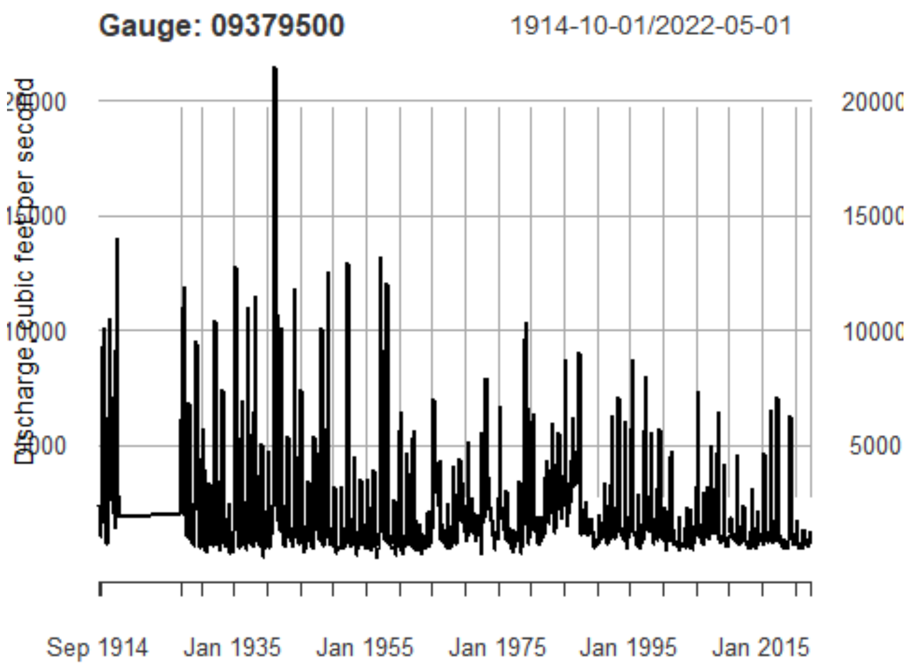


Figure B72. Discharge (cf/s) at location USGS 09379500

Table B37. Main statistics of water discharge (cf/s) at USGS 09328920

	January	February	March	April	May	June	July	August	September	October	November	December
Min.	1691.0	1684.0	2230.0	2103	4066.0	4163.0	1347.0	1845.0	1810.0	1705.0	1843.0	1585.0
1st Qu.	2630.8	2715.8	2594.0	4311	9203.0	9211.0	2534.0	1986.0	1975.0	2589.0	2494.0	2475.0
Median	3079.0	3701.5	3425.0	4530	10270.0	11190.0	3891.0	2189.0	2385.0	2807.0	2639.0	2991.5
Mean	2893.0	3379.1	3640.2	5351	10426.7	12851.1	4258.1	2457.9	2483.4	2797.3	2693.6	2813.4
3rd Qu.	3313.5	3964.8	3715.0	5086	11870.0	18330.0	5041.0	3095.0	2776.0	3205.0	3012.0	3285.5
Max.	3922.0	5006.0	7260.0	13940	17040.0	22240.0	9952.0	3439.0	3640.0	3669.0	3604.0	3965.0

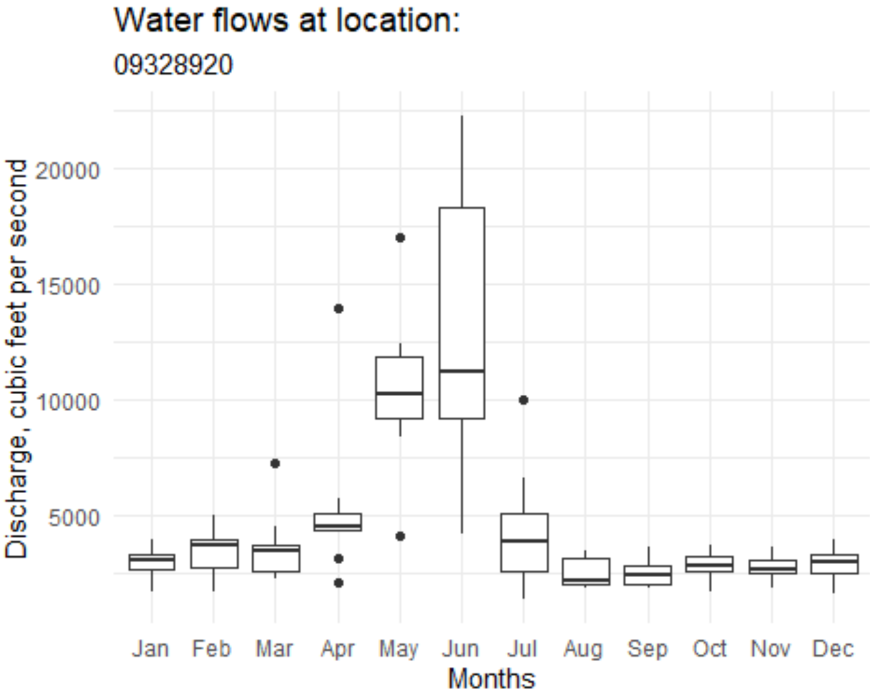


Figure B73. Monthly discharge (cf/s) at location USGS 09328920

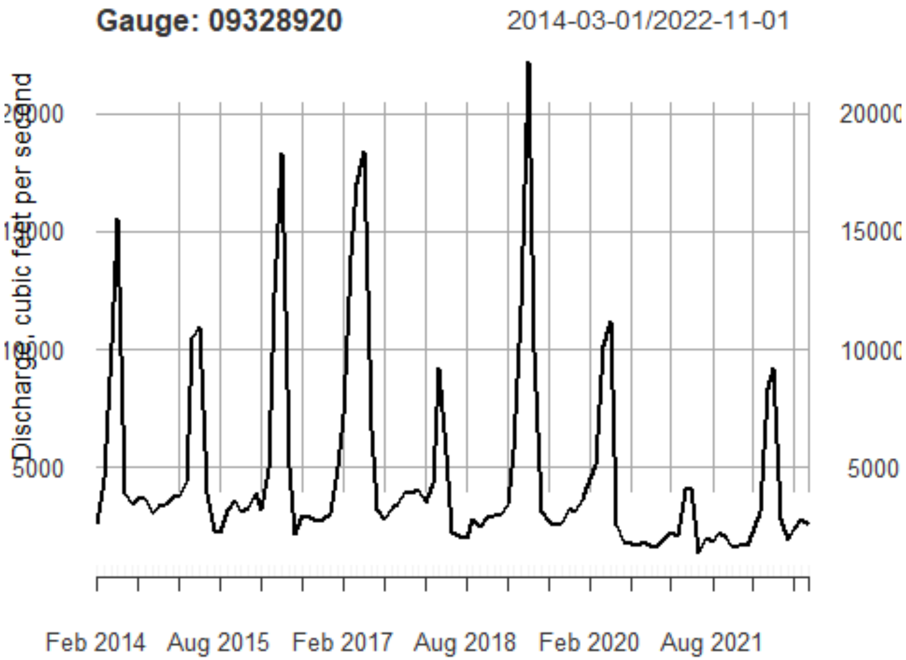


Figure B74. Discharge (cf/s) at location USGS 09328920

Table B38. Main statistics of water discharge (cf/s) at USGS 09371010

	January	February	March	April	May	June	July	August	September	October	November	December
Min.	491.0	544.9	521.5	540.2	712.6	500.8	329.7	258.9	466.9	602.0	500.7	515.9
1st Qu.	753.6	728.6	887.2	814.3	1715.2	2155.8	848.9	680.1	727.9	750.6	791.3	756.0
Median	860.4	1003.1	1129.0	1660.0	3228.5	4369.0	1272.0	1017.0	1027.4	919.4	909.8	931.2
Mean	1106.4	1225.3	1594.9	2164.9	3790.5	4366.0	1808.3	1265.9	1233.7	1114.2	1092.1	1092.2
3rd Qu.	1180.2	1296.0	1886.5	2853.2	5611.5	6382.2	2202.2	1459.0	1434.2	1351.0	1174.2	1090.0
Max.	3300.0	3365.0	5454.0	7893.0	10220.0	10370.0	6846.0	6135.0	4852.0	2959.0	3732.0	3466.0

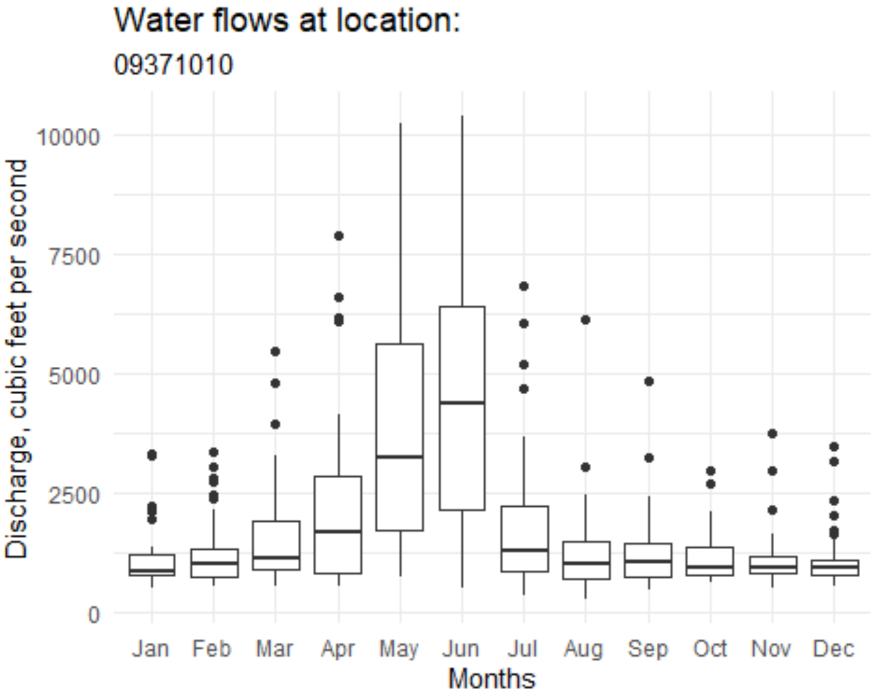


Figure B75. Monthly discharge (cf/s) at location USGS 09371010

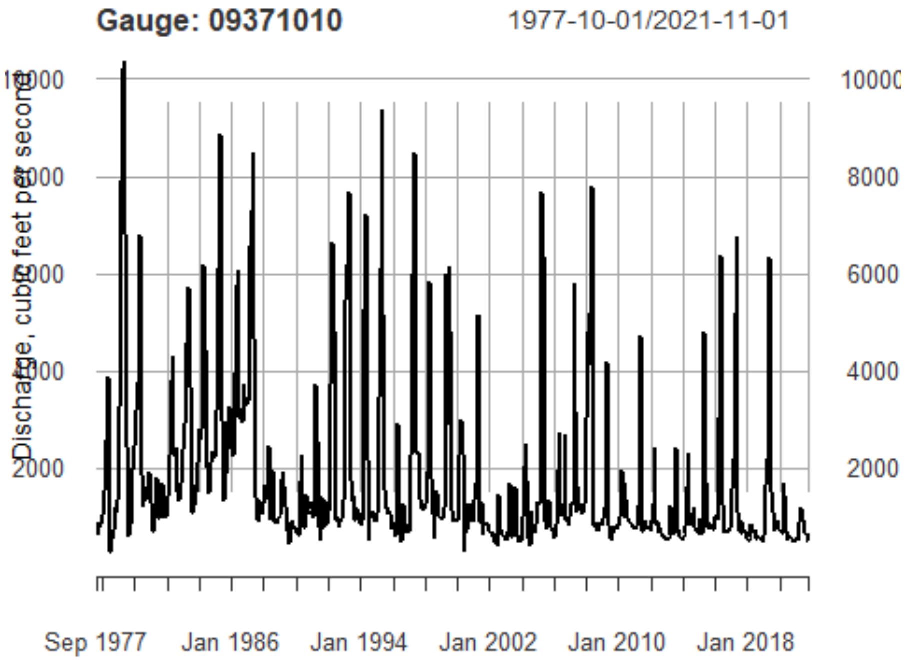
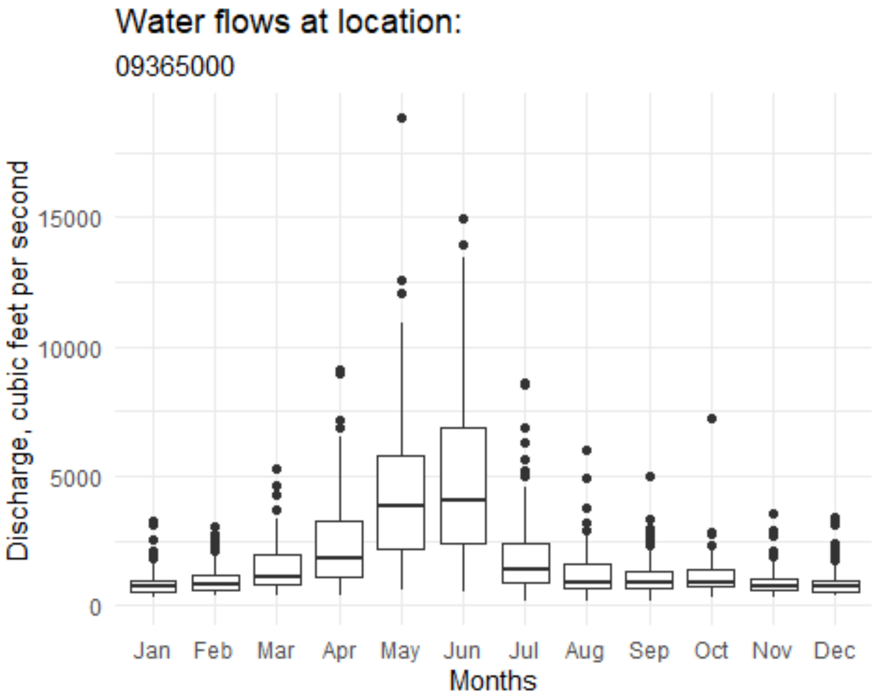


Figure B76. Discharge (cf/s) at location USGS 09371010

Table B39. Main statistics of water discharge (cf/s) at USGS 09365000

	January	February	March	April	May	June	July	August	September	October	November	December
Min.	329.4	374.4	349.0	391.0	575.7	517.2	192.1	165.7	170.3	286.4	314.8	361.7
1st Qu.	539.8	634.4	818.7	1083.2	2206.2	2403.2	872.3	694.5	698.9	734.5	569.6	537.6
Median	733.4	841.9	1130.5	1829.0	3850.0	4065.0	1368.0	911.7	896.0	884.6	765.8	760.7
Mean	946.5	1073.5	1456.8	2623.9	4561.7	5016.6	2019.1	1246.4	1141.9	1144.1	958.1	935.1
3rd Qu.	991.8	1206.0	1938.5	3264.8	5812.5	6909.0	2397.8	1575.5	1313.0	1370.5	1063.2	996.7
Max.	3271.0	3032.0	5304.0	9133.0	18830.0	14990.0	8639.0	6044.0	4978.0	7271.0	3549.0	3381.0



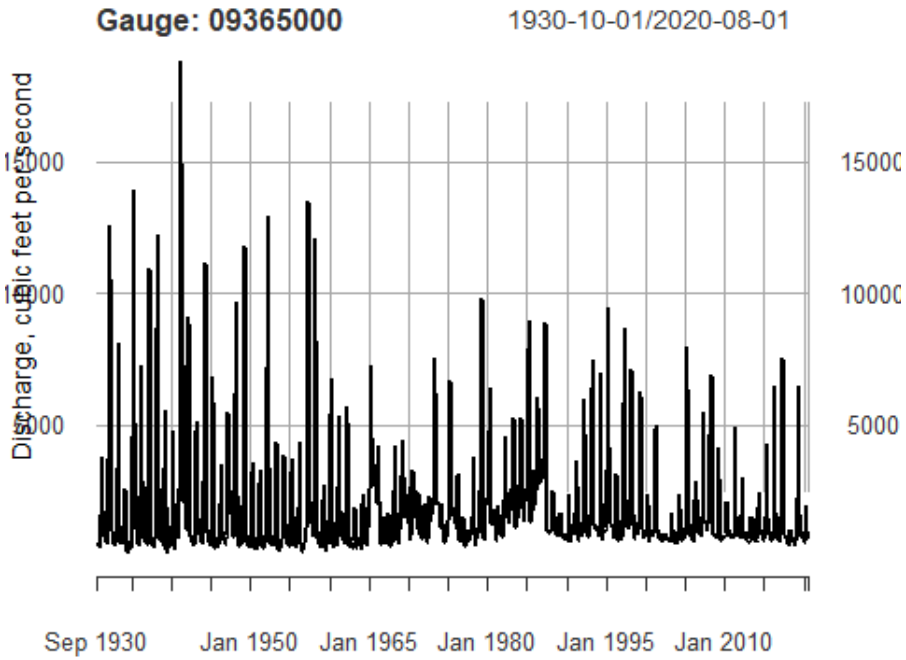
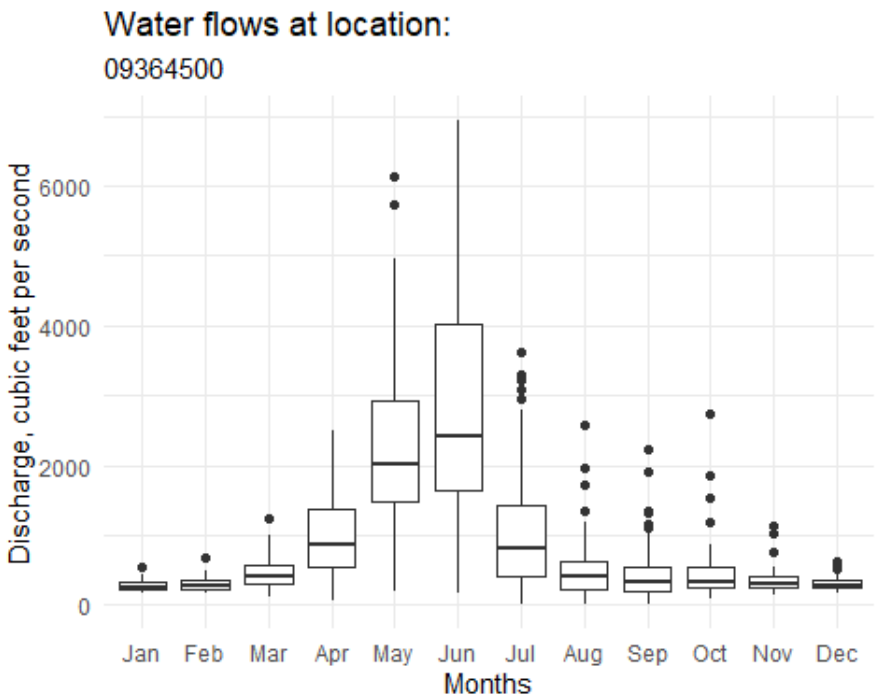


Figure B77. Monthly discharge (cf/s) at location USGS 09365000 Figure B78. Discharge (cf/s) at location USGS 09365000

Table B40. Main statistics of water discharge (cf/s) at USGS 09364500

	January	February	March	April	May	June	July	August	September	October	November	December
Min.	162.7	162.1	112.5	54.1	194.5	170.5	14.2	4.7	10.6	87.0	151.6	174.0
1st Qu.	227.2	229.8	299.1	545.5	1476.0	1628.5	414.5	218.2	197.5	242.9	255.3	233.3
Median	256.0	275.3	408.0	849.3	2026.5	2412.0	797.0	396.4	330.4	327.5	313.2	273.9
Mean	274.7	296.5	454.6	956.0	2300.5	2815.1	1048.1	484.1	431.5	435.4	352.6	296.2
3rd Qu.	316.0	347.3	580.0	1383.5	2928.2	4019.0	1417.2	631.0	552.6	552.8	413.1	341.7
Max.	554.3	676.1	1242.0	2489.0	6126.0	6930.0	3609.0	2581.0	2226.0	2726.0	1140.0	608.6



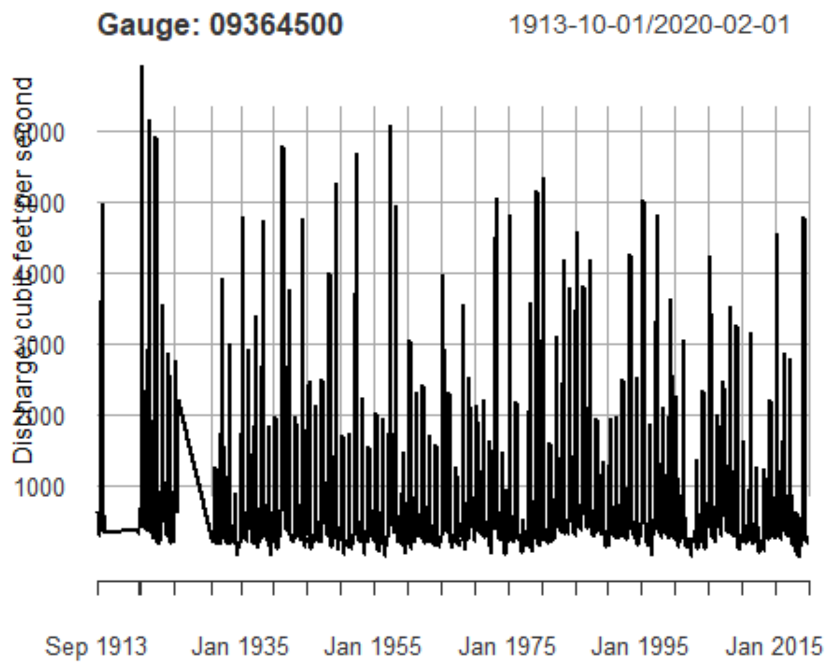
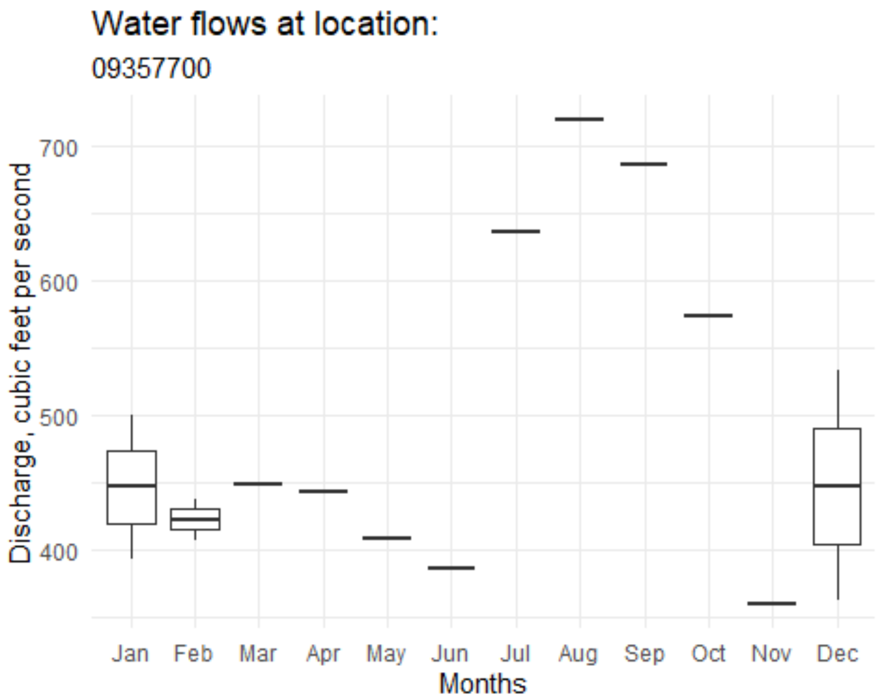


Figure B79. Monthly discharge (cf/s) at location USGS 09364500 Figure B70. Discharge (cf/s) at location USGS 09364500

Table B41. Main statistics of water discharge (cf/s) at USGS 09357700

	January	February	March	April	May	June	July	August	September	October	November	December
Min.	393.4	407.5	448.7	443.8	408.5	386.5	635.5	718.6	685.9	574.3	360.2	362.4
1st Qu.	420.1	415.1	448.7	443.8	408.5	386.5	635.5	718.6	685.9	574.3	360.2	405.0
Median	446.9	422.8	448.7	443.8	408.5	386.5	635.5	718.6	685.9	574.3	360.2	447.6
Mean	446.9	422.8	448.7	443.8	408.5	386.5	635.5	718.6	685.9	574.3	360.2	447.6
3rd Qu.	473.6	430.5	448.7	443.8	408.5	386.5	635.5	718.6	685.9	574.3	360.2	490.2
Max.	500.3	438.1	448.7	443.8	408.5	386.5	635.5	718.6	685.9	574.3	360.2	532.8



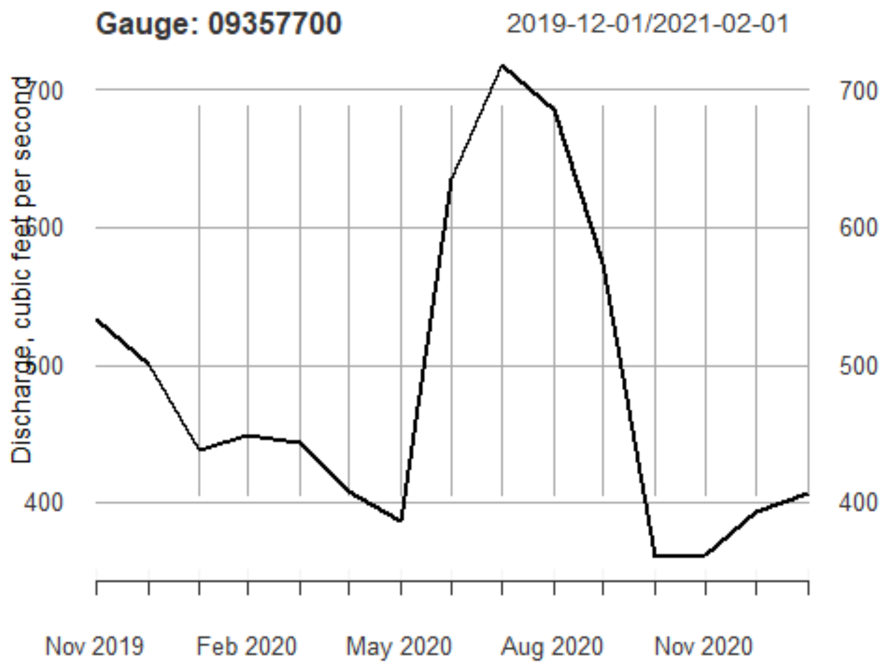


Figure B71. Monthly discharge (cf/s) at location USGS 09357700 Figure B72. Discharge (cf/s) at location USGS 09357700

Table B42. Main statistics of water discharge (cf/s) at USGS 09363500

	January	February	March	April	May	June	July	August	September	October	November	December
Min.	147.9	150.6	141.4	273.1	449.2	367.5	146.3	114.4	131.0	168.6	157.6	158.2
1st Qu.	206.4	209.8	282.4	705.2	1740.0	1713.5	598.8	408.6	324.0	295.8	255.8	219.2
Median	231.6	241.7	403.7	896.1	2226.0	2382.0	888.7	545.4	439.7	360.8	297.4	251.9
Mean	246.3	261.3	434.3	1057.0	2436.0	2842.6	1182.4	610.7	523.9	470.0	337.6	268.5
3rd Qu.	277.0	290.3	553.0	1480.5	2847.0	3979.0	1567.5	703.2	624.9	552.2	384.9	297.6
Max.	469.7	612.7	1043.0	2334.0	5686.0	6145.0	3710.0	2372.0	1922.0	2479.0	1068.0	554.6

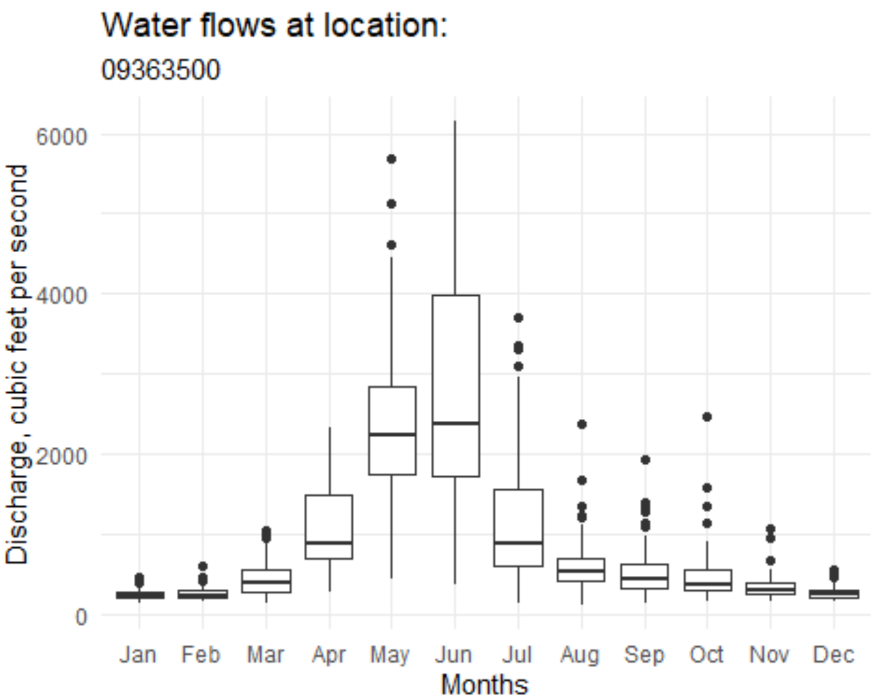


Figure B73. Monthly discharge (cf/s) at location USGS 09363500

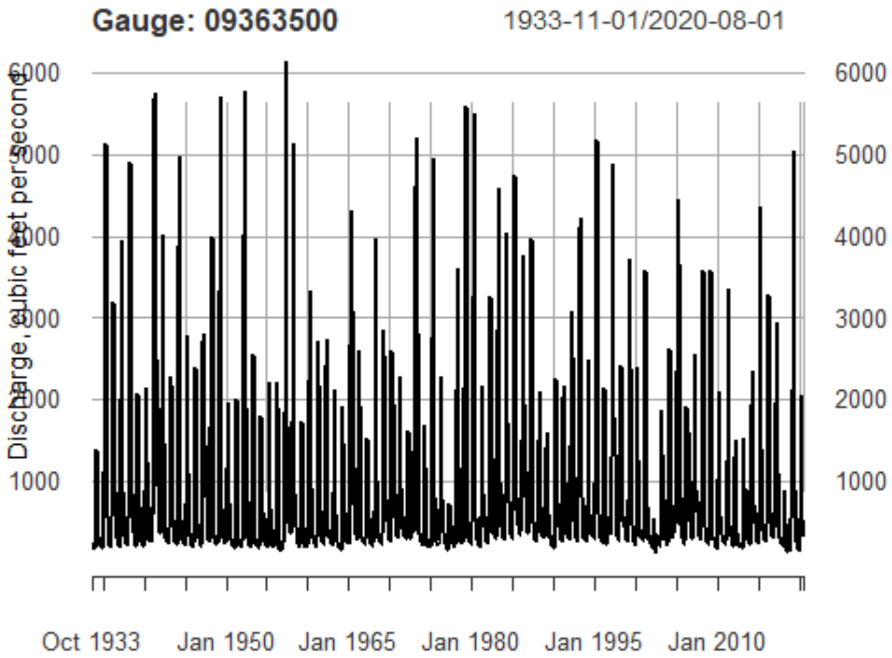


Figure B74. Discharge (cf/s) at location USGS 09363500

Table B43. Main statistics of water discharge (cf/s) at USGS 09359500

	January	February	March	April	May	June	July	August	September	October	November	December
Min.	49.3	52.7	79.5	228.5	821.7	463.8	200.6	131.0	103.6	88.8	73.5	50.4
1st Qu.	81.9	85.2	98.2	310.3	1041.0	1402.5	447.8	277.0	166.5	149.2	110.8	87.4
Median	97.7	100.3	120.3	466.4	1280.5	1847.5	605.1	355.4	207.1	186.3	130.5	97.9
Mean	98.9	100.8	148.1	453.8	1336.0	2002.5	763.7	360.7	262.0	255.7	145.4	109.4
3rd Qu.	111.3	108.2	151.7	564.3	1489.0	2436.0	1034.3	412.3	294.0	282.3	185.9	134.8
Max.	157.2	172.7	384.2	728.2	2471.0	3902.0	2230.0	690.0	754.1	1062.0	246.4	172.5

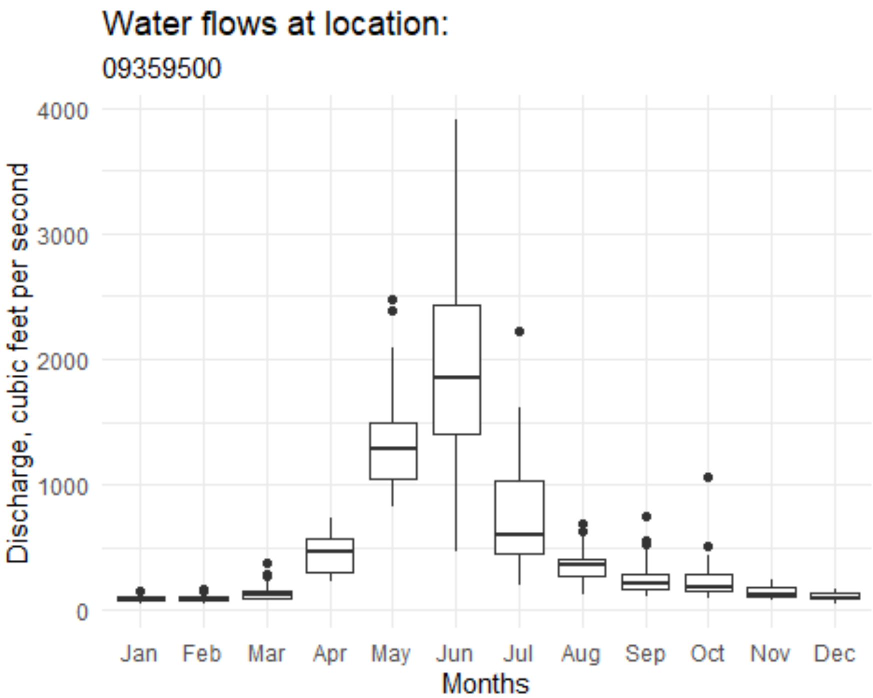


Figure B75. Monthly discharge (cf/s) at location USGS 09359500

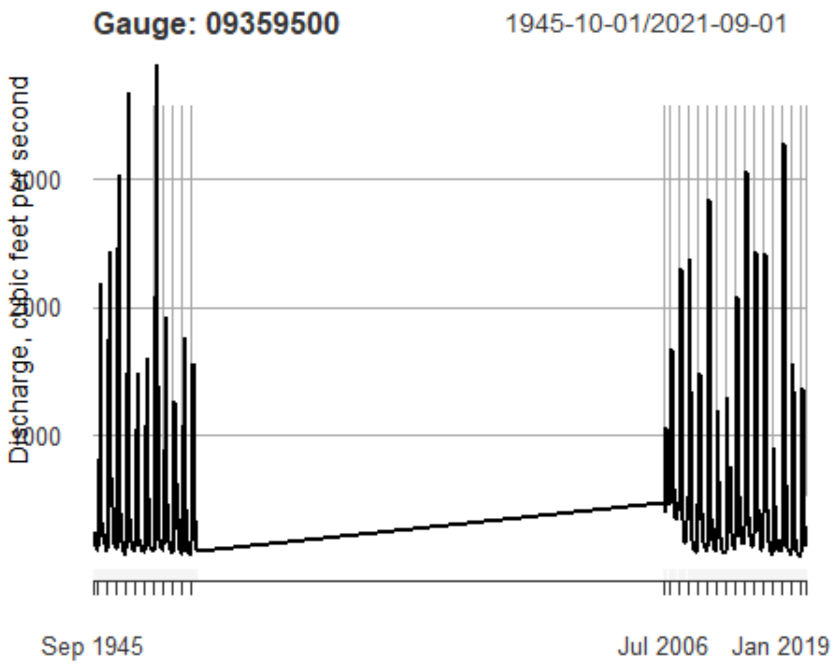


Figure B76. Discharge (cf/s) at location USGS 09359500

Table B44. Main statistics of water discharge (cf/s) at USGS 09359020

	January	February	March	April	May	June	July	August	September	October	November	December
Min.	40.2	40.9	46.0	117.4	301.4	231.7	83.0	70.5	69.2	59.1	46.9	46.2
1st Qu.	54.8	46.8	57.2	138.5	498.6	738.8	221.5	122.6	122.5	94.6	74.1	58.7
Median	62.4	57.3	67.2	180.1	654.2	972.8	371.1	196.0	135.8	123.7	83.4	67.4
Mean	61.9	57.9	75.3	177.7	660.1	1002.2	443.9	212.5	163.3	139.7	85.6	67.1
3rd Qu.	71.3	64.2	94.2	196.4	782.1	1328.5	584.8	230.8	199.6	163.0	98.7	75.1
Max.	79.8	85.6	116.0	298.3	1185.0	1647.0	1393.0	519.6	335.9	424.2	135.5	92.9

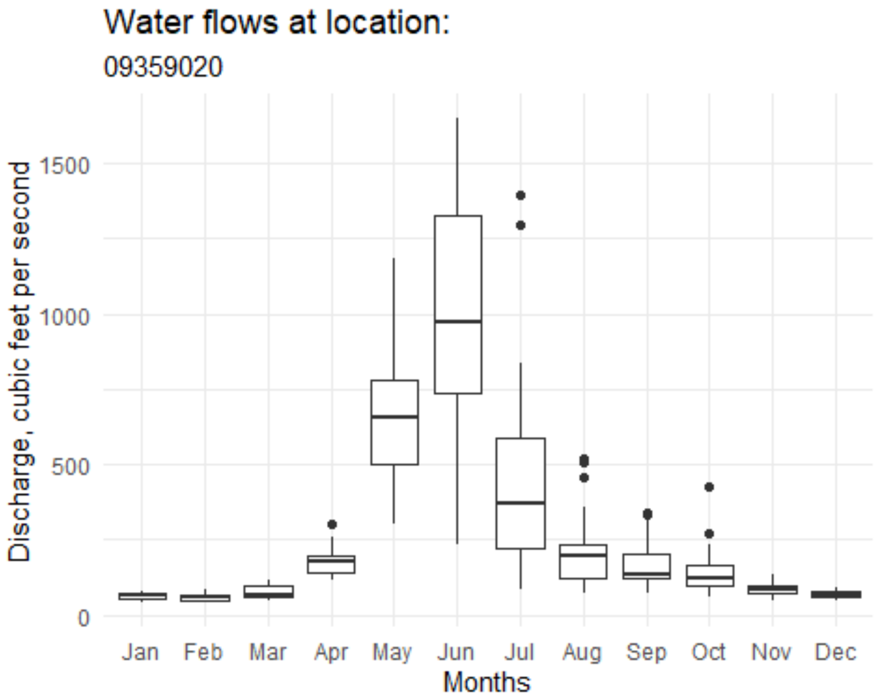


Figure B77. Monthly discharge (cf/s) at location USGS 09359020

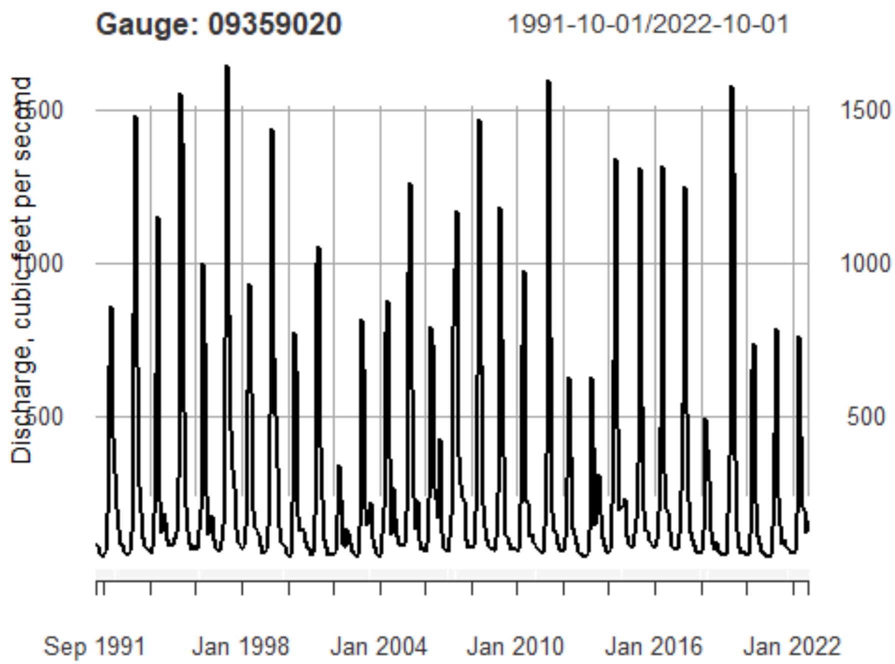


Figure B78. Discharge (cf/s) at location USGS 09359020

Table B45. Main statistics of water discharge (cf/s) at USGS 09355500

	January	February	March	April	May	June	July	August	September	October	November	December
Min.	114.6	148.8	207.4	244.2	276.5	300.2	319.7	352.6	337.5	266.7	239.7	161.9
1st Qu.	380.2	415.7	413.4	494.6	517.2	546.7	539.5	615.8	605.2	493.4	369.1	395.3
Median	516.0	516.2	521.5	590.1	966.0	1293.0	731.5	690.2	701.7	602.6	507.9	520.1
Mean	812.9	841.5	921.1	1097.4	1584.6	1778.2	1048.8	907.6	865.1	739.5	707.6	778.3
3rd Qu.	928.9	1140.2	1108.5	1378.5	2231.5	2673.5	1045.6	861.5	938.5	764.2	653.7	827.8
Max.	2768.0	2382.0	4216.0	4768.0	4962.0	5169.0	5126.0	3508.0	3241.0	2131.0	3018.0	2886.0

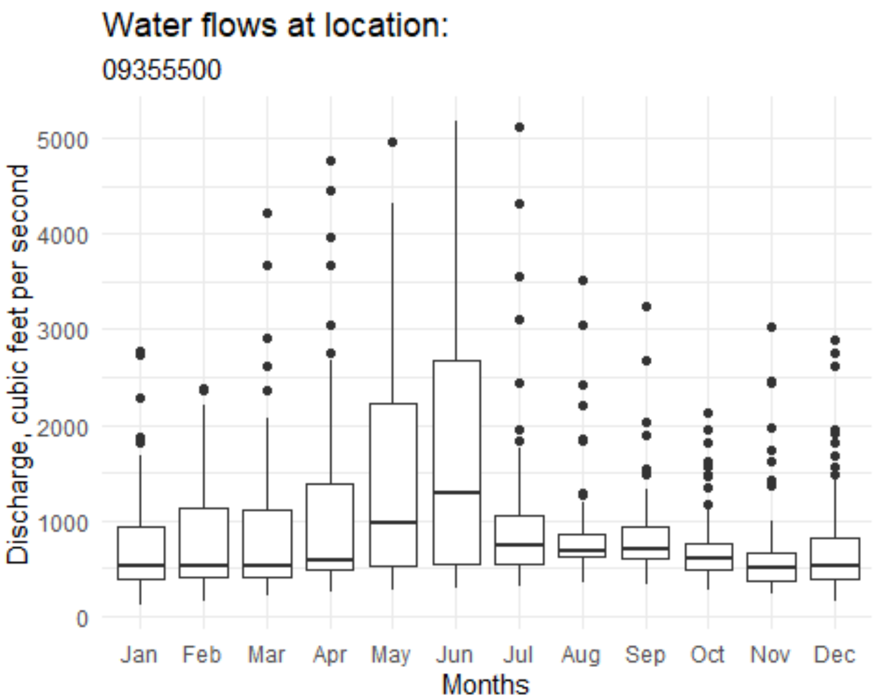


Figure B79. Monthly discharge (cf/s) at location USGS 09355500

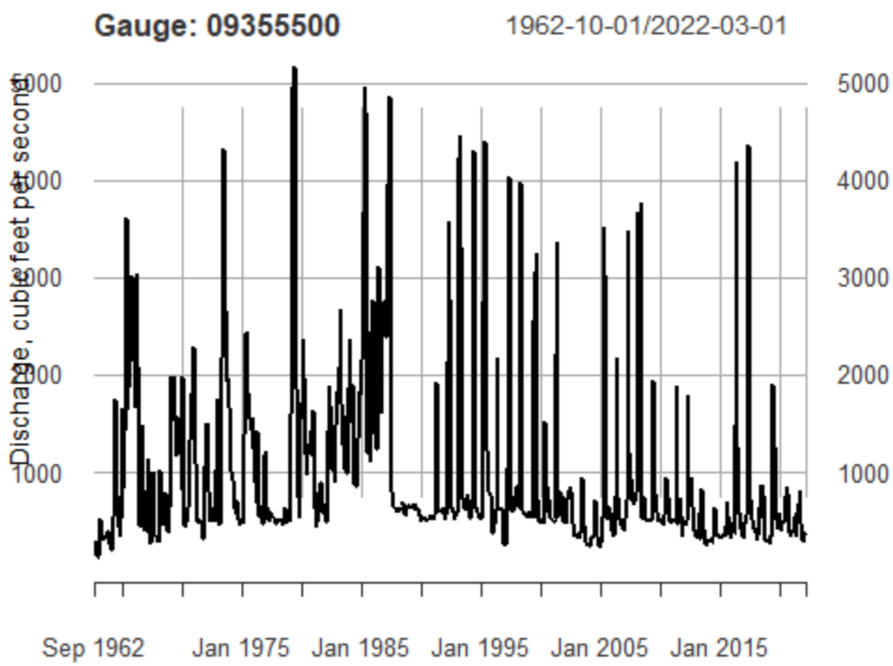


Figure B80. Discharge (cf/s) at location USGS 09355500

Table B46. Main statistics of water discharge (cf/s) at USGS 09346400

	January	February	March	April	May	June	July	August	September	October	November	December
Min.	71.7	85.0	129.7	232.8	269.0	72.1	22.6	18.8	36.5	64.5	92.1	72.9
1st Qu.	113.6	119.5	304.9	600.6	1127.0	747.8	224.1	155.7	141.8	157.3	136.9	116.0
Median	140.3	182.0	475.4	807.9	1589.0	1320.0	338.7	269.3	233.2	202.8	176.1	145.5
Mean	156.6	192.3	553.7	974.3	1611.4	1521.5	508.0	291.6	266.0	286.1	218.5	169.6
3rd Qu.	192.8	225.8	726.5	1354.0	1994.0	2153.0	618.9	397.6	314.6	330.3	250.4	187.5
Max.	315.0	490.5	1369.0	2524.0	3195.0	4039.0	2427.0	1004.0	879.9	932.1	982.9	508.8

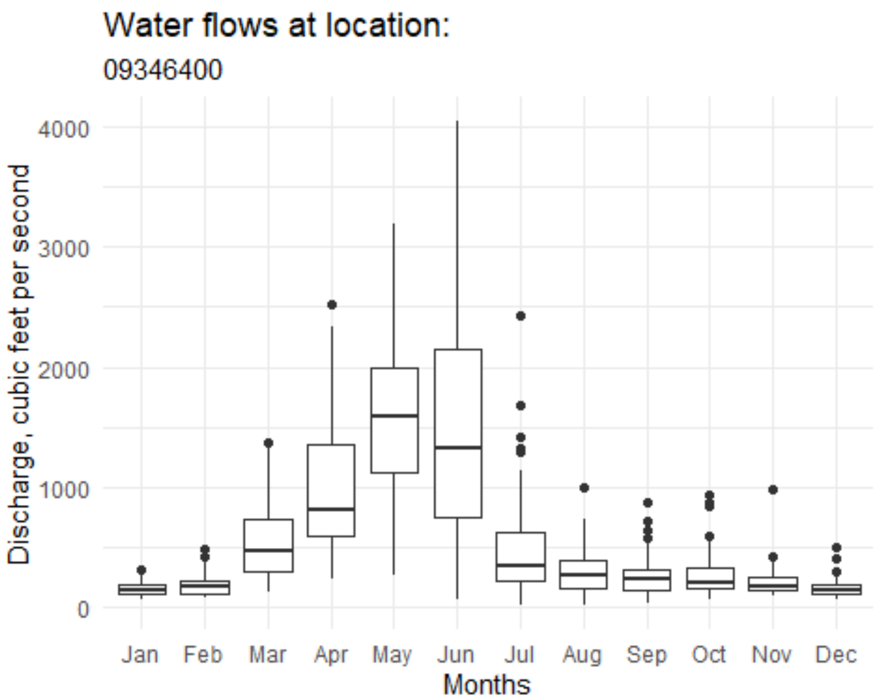


Figure B81. Monthly discharge (cf/s) at location USGS 09346400

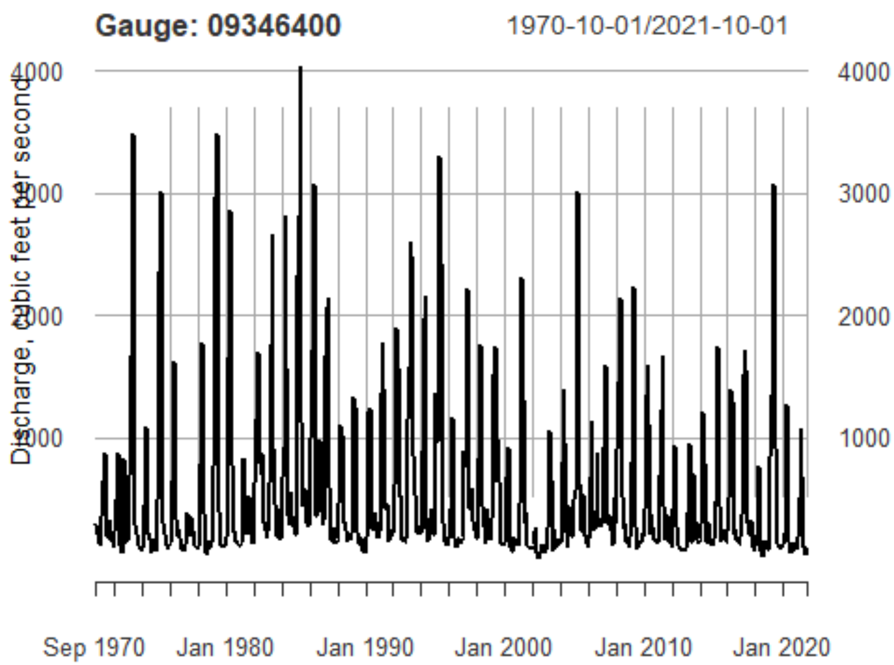


Figure B82. Discharge (cf/s) at location USGS 09346400

Table B47. Main statistics of water discharge (cf/s) at USGS 09188500

	January	February	March	April	May	June	July	August	September	October	November	December
Min.	50.0	60.0	70.0	129.0	232.5	610.0	399.5	198.3	149.6	102.1	67.7	70.0
1st Qu.	95.0	95.9	108.8	221.4	751.4	1408.2	785.7	372.4	226.2	156.5	116.1	105.2
Median	105.0	106.3	123.6	264.9	991.7	1680.0	1137.5	483.8	272.9	180.0	142.3	116.6
Mean	108.4	108.3	126.6	291.3	1005.5	1787.1	1211.4	501.9	287.6	198.5	145.9	122.0
3rd Qu.	120.0	119.3	141.0	349.1	1189.0	2108.8	1605.2	622.4	335.2	228.6	166.1	137.9
Max.	175.5	166.4	240.0	599.7	2063.0	3855.0	2549.0	997.4	592.0	433.2	257.2	214.8

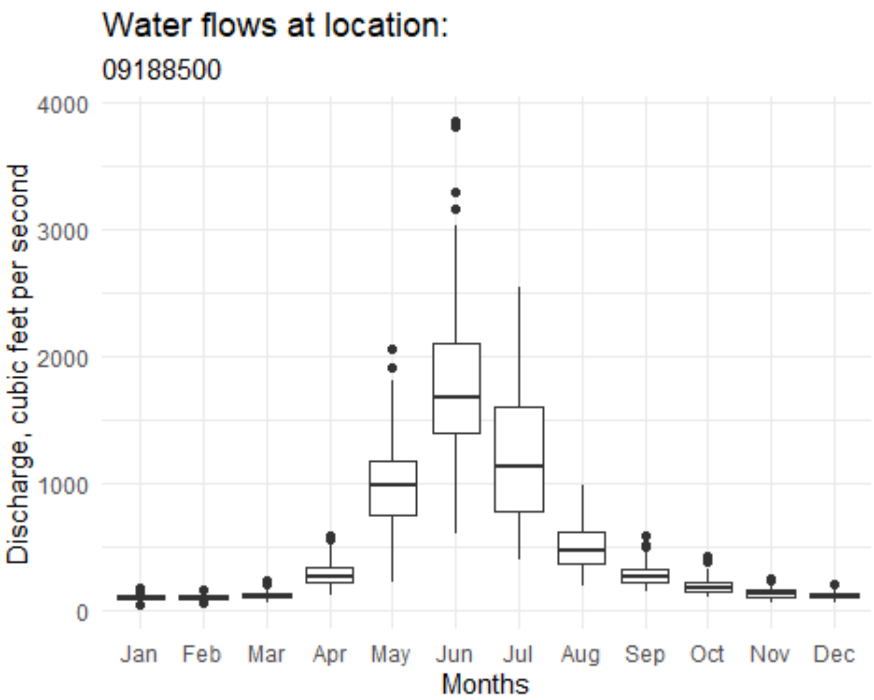


Figure B83. Monthly discharge (cf/s) at location USGS 09188500

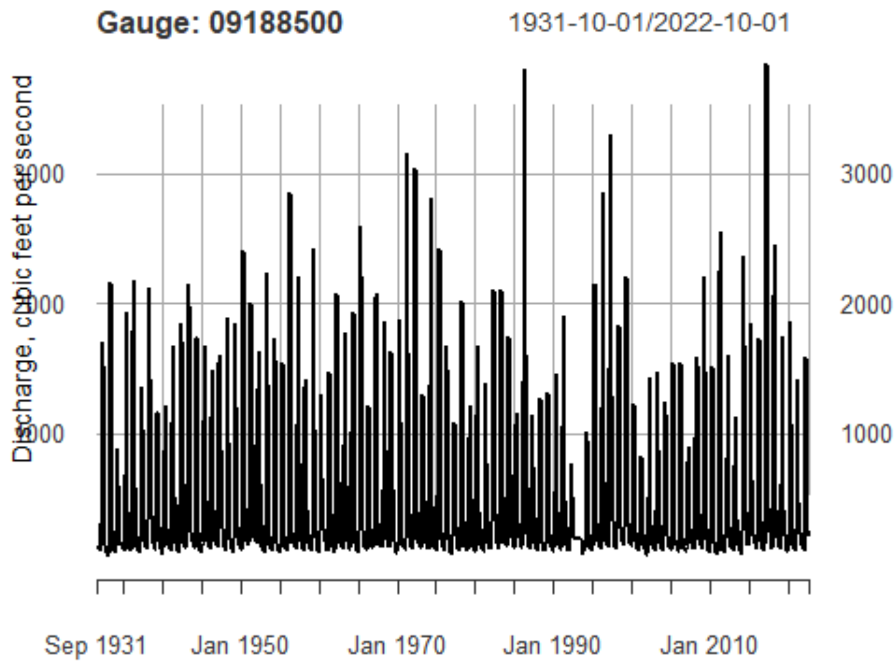


Figure B84. Discharge (cf/s) at location USGS 09188500

Table B48. Main statistics of water discharge (cf/s) at USGS 09205000

	January	February	March	April	May	June	July	August	September	October	November	December
Min.	107.7	122.3	160.6	180.5	253.7	699.1	405.1	225.1	164.5	170.9	187.8	138.5
1st Qu.	180.0	179.8	219.6	280.4	718.3	1876.2	787.1	356.5	267.1	287.0	265.0	201.0
Median	198.2	199.9	251.2	394.9	1089.0	2716.5	1262.5	473.4	329.8	338.1	312.1	237.4
Mean	204.4	215.2	290.0	424.5	1146.0	2901.0	1532.0	533.2	358.8	368.7	322.2	240.2
3rd Qu.	221.0	240.2	303.7	492.2	1431.5	3774.8	1989.0	614.2	427.0	398.6	359.9	271.0
Max.	348.6	610.4	1336.0	1114.0	2539.0	7065.0	4290.0	1279.0	766.2	988.8	608.1	397.1

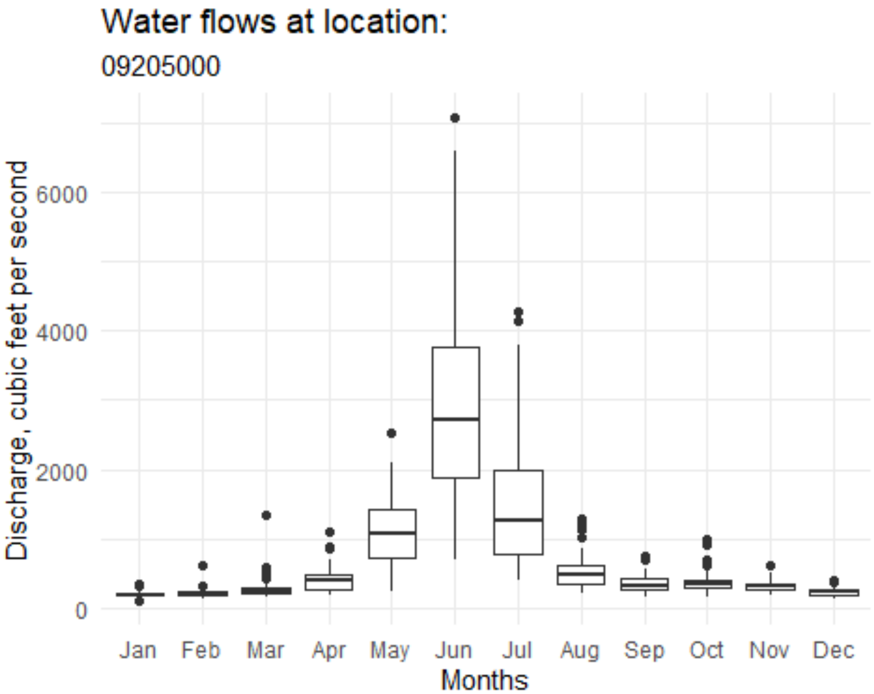


Figure B85. Monthly discharge (cf/s) at location USGS 09205000

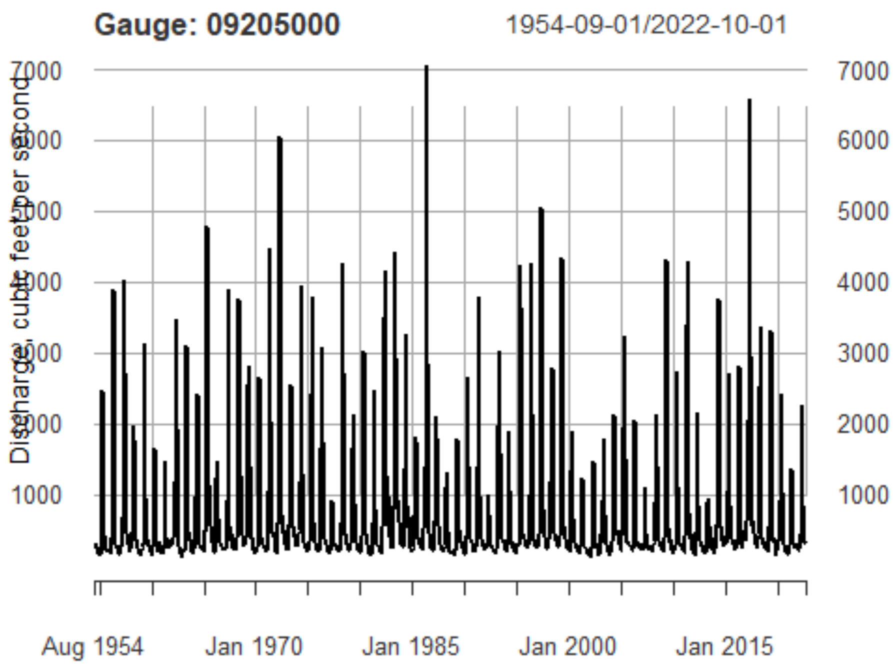
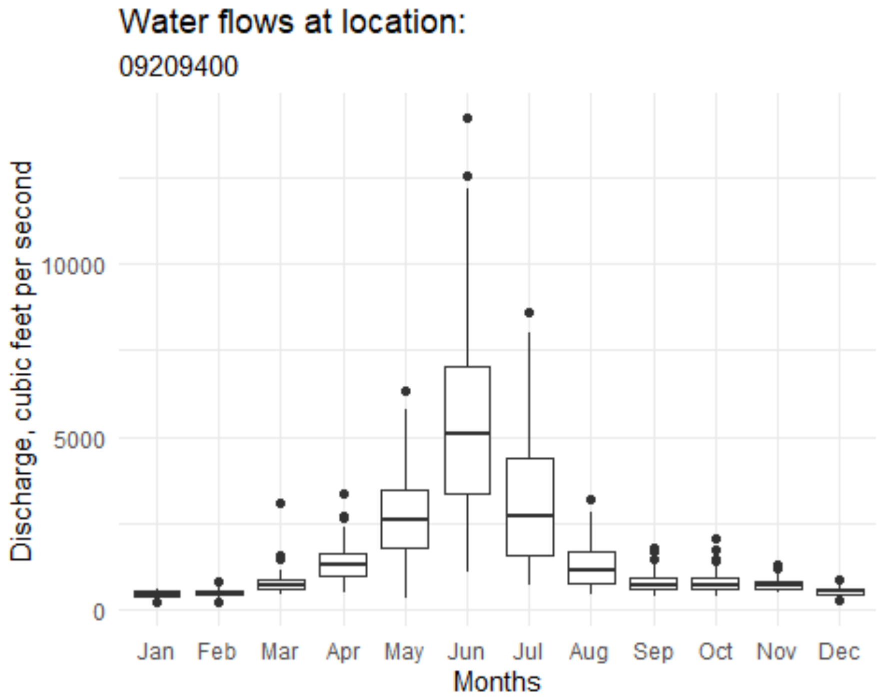


Figure B86. Discharge (cf/s) at location USGS 09205000

Table B49. Main statistics of water discharge (cf/s) at USGS 09209400

	January	February	March	April	May	June	July	August	September	October	November	December
Min.	202.5	213.2	403.1	469.3	305.4	1080.0	710.2	448.1	350.3	352.6	468.7	268.7
1st Qu.	389.2	418.2	574.0	978.5	1752.0	3369.0	1580.0	740.7	560.4	594.9	592.6	447.1
Median	437.2	475.6	680.3	1313.0	2610.0	5083.0	2722.0	1119.0	715.4	681.8	698.6	506.7
Mean	447.0	479.1	762.6	1369.3	2751.8	5431.1	3166.1	1270.7	791.7	791.5	724.4	517.1
3rd Qu.	505.4	526.8	843.5	1618.0	3479.0	7022.5	4386.5	1687.5	912.2	886.8	827.5	565.8
Max.	608.1	806.3	3057.0	3333.0	6339.0	14230.0	8609.0	3185.0	1768.0	2049.0	1306.0	866.1



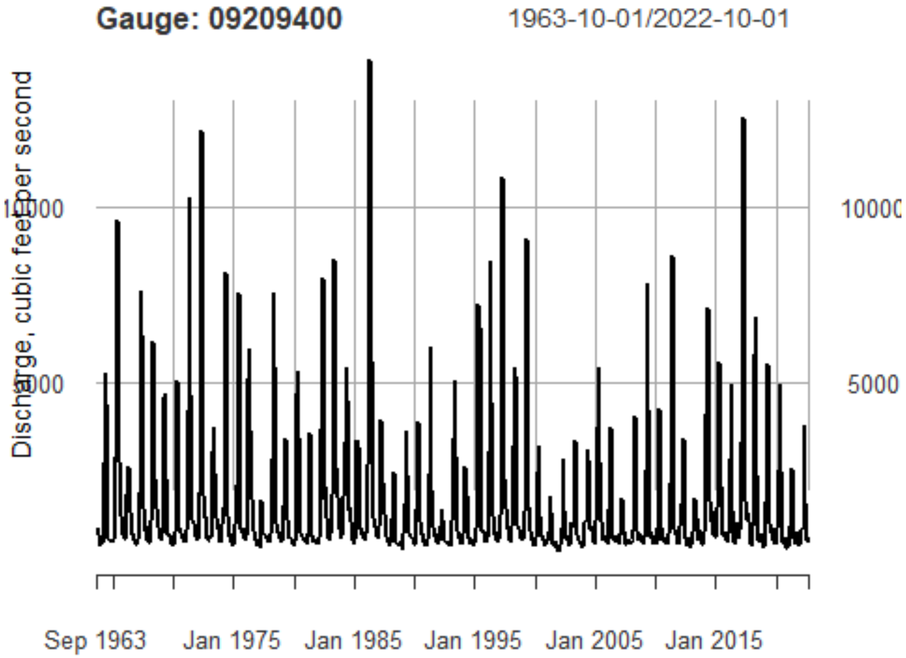


Figure B87. Monthly discharge (cf/s) at location USGS 09209400 Figure B88. Discharge (cf/s) at location USGS 09209400

Table B50. Main statistics of water discharge (cf/s) at USGS 09211200

	January	February	March	April	May	June	July	August	September	October	November	December
Min.	272.6	262.1	365.0	370.0	462.8	464.9	364.2	366.7	285.3	290.7	308.2	272.0
1st Qu.	671.8	684.4	754.8	988.4	1084.0	1512.0	1268.0	1095.0	832.5	755.4	769.9	693.3
Median	928.3	885.8	959.4	1303.0	1817.0	3570.0	2000.0	1398.0	1018.0	939.0	905.4	869.9
Mean	874.7	905.5	974.5	1409.0	2222.7	4123.3	2811.9	1483.7	1141.7	987.9	902.7	864.9
3rd Qu.	1082.0	1079.5	1125.0	1563.0	2795.0	6161.0	3989.0	1835.5	1208.0	1125.0	1081.0	1079.0
Max.	1312.0	1818.0	2647.0	5361.0	7025.0	11240.0	8868.0	3466.0	7893.0	3138.0	1522.0	1308.0

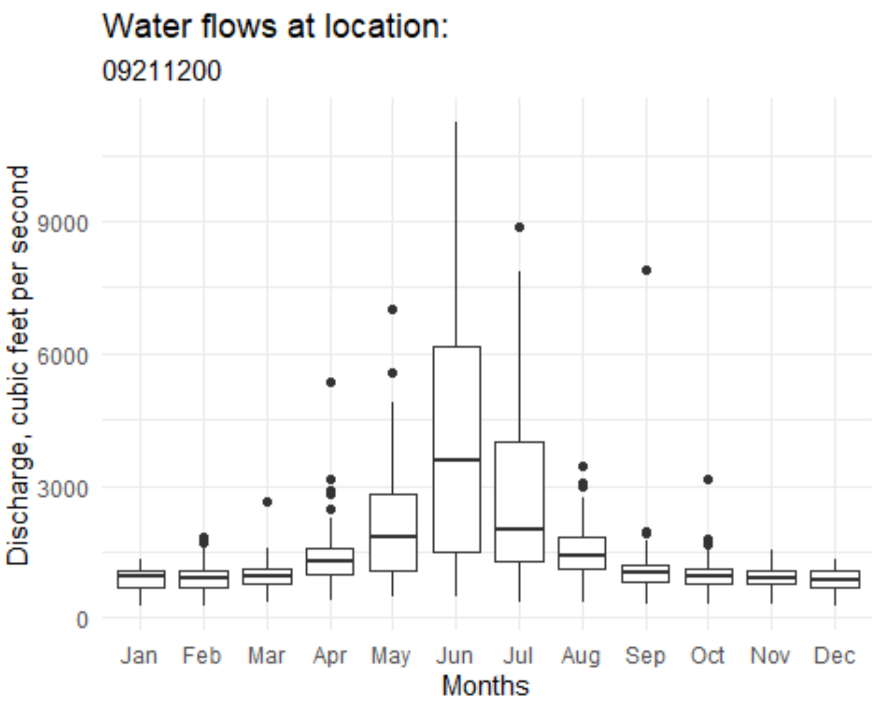


Figure B89. Monthly discharge (cf/s) at location USGS 09211200

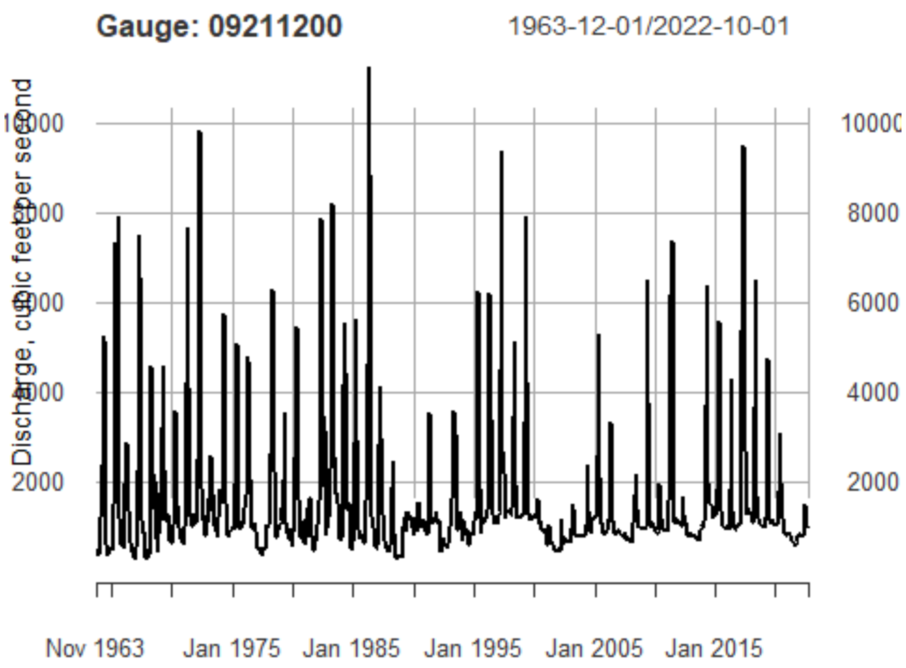


Figure B90. Discharge (cf/s) at location USGS 09211200

Table B51. Main statistics of water discharge (cf/s) at USGS 09213500

	January	February	March	April	May	June	July	August	September	October	November	December
Min.	0.3	0.1	3.0	14.3	78.1	55.5	14.3	8.5	2.1	8.9	9.2	3.0
1st Qu.	8.0	10.0	17.0	43.8	168.5	262.3	78.2	26.2	17.1	17.0	15.3	8.9
Median	11.0	12.0	20.0	55.0	231.1	389.9	133.5	38.3	23.3	27.4	20.0	14.0
Mean	11.1	12.1	24.7	59.7	230.0	399.3	163.9	45.2	29.0	31.1	24.4	13.2
3rd Qu.	15.0	15.0	30.0	69.6	294.4	535.3	201.7	58.5	38.0	43.4	28.8	17.0
Max.	22.9	26.0	61.5	148.5	453.8	905.2	522.5	155.3	83.9	75.6	127.0	21.7

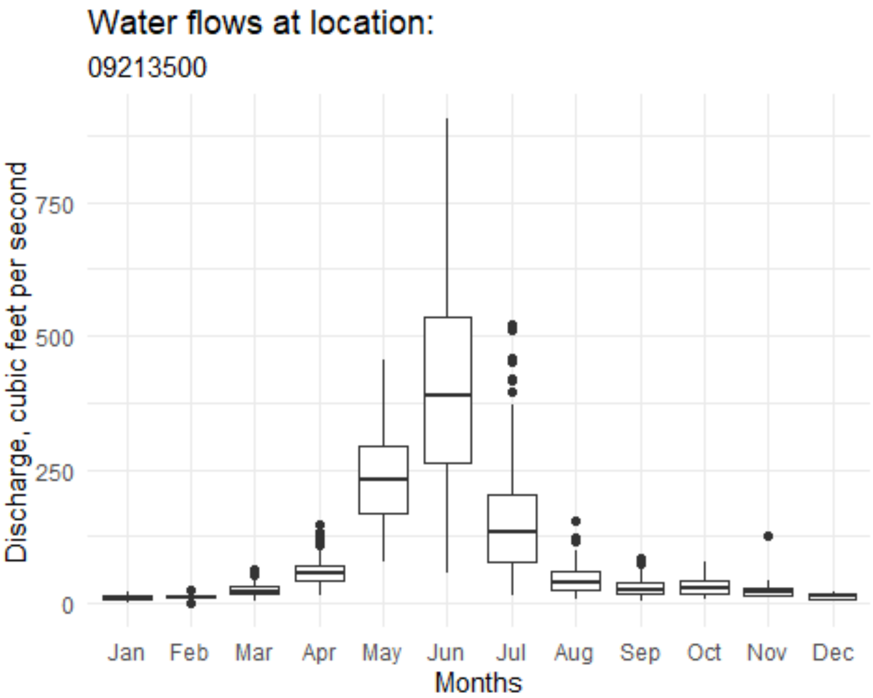


Figure B91. Monthly discharge (cf/s) at location USGS 09213500

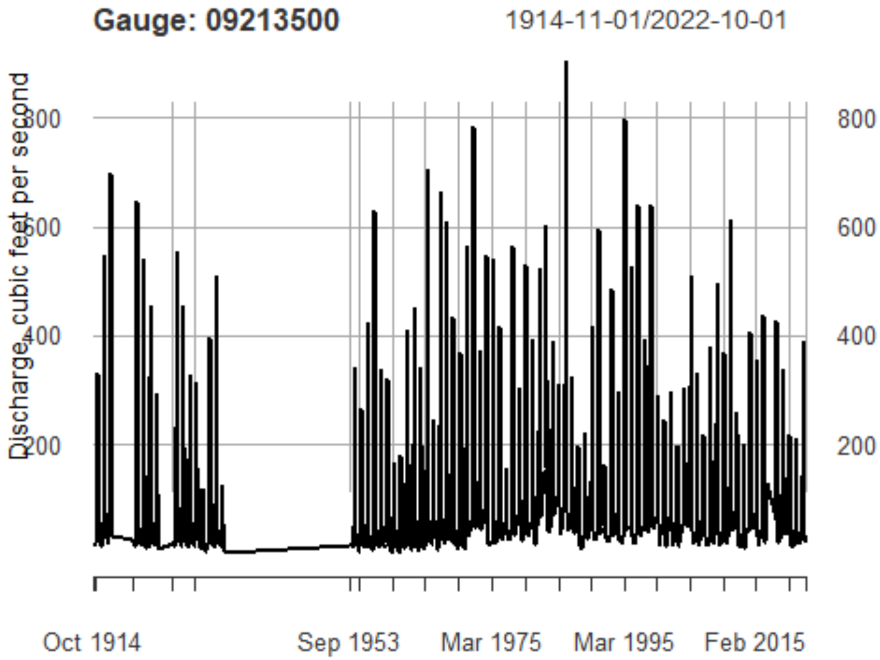


Figure B92. Discharge (cf/s) at location USGS 09213500

Table B52. Main statistics of water discharge (cf/s) at USGS 09217000

	January	February	March	April	May	June	July	August	September	October	November	December
Min.	265.8	266.8	350.3	516.1	434.3	413.6	368.2	372.1	251.1	278.8	281.0	271.9
1st Qu.	521.3	621.4	785.3	1009.2	1117.2	2565.0	1216.8	991.5	696.7	671.1	659.2	490.0
Median	778.1	852.8	968.2	1367.0	1956.5	4318.0	2113.0	1397.0	989.6	929.0	867.5	773.6
Mean	804.8	857.3	1052.4	1542.3	2374.9	4436.4	2909.0	1453.2	1075.6	951.7	871.5	786.7
3rd Qu.	1029.5	1047.5	1257.0	1744.8	3363.5	6153.5	4065.8	1787.8	1210.2	1114.0	1029.5	1025.5
Max.	1442.0	1980.0	2628.0	5350.0	6677.0	11700.0	9415.0	3577.0	7746.0	3109.0	1844.0	1419.0

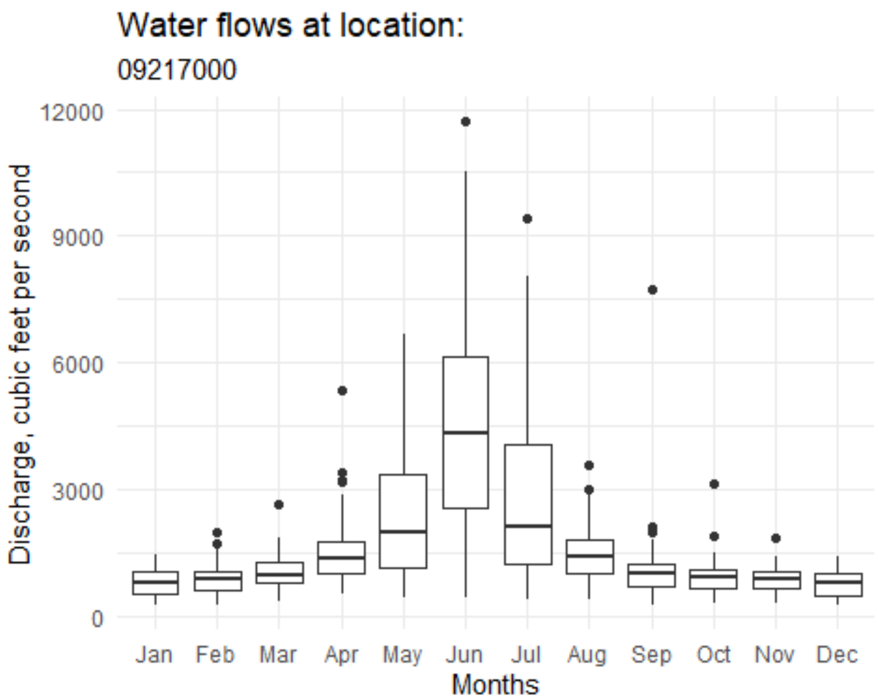


Figure B93. Monthly discharge (cf/s) at location USGS 09217000

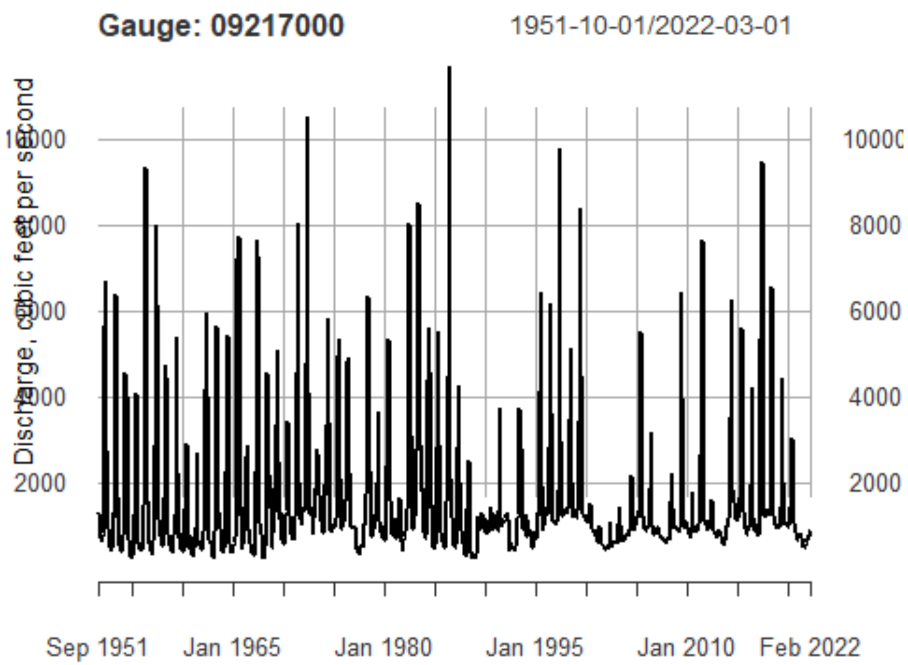


Figure B94. Discharge (cf/s) at location USGS 09217000

Table B53. Main statistics of water discharge (cf/s) at USGS 09224700

	January	February	March	April	May	June	July	August	September	October	November	December
Min.	1.8	5.9	33.9	23.3	21.1	14.0	2.9	0.0	0.0	7.0	13.0	5.4
1st Qu.	25.0	53.9	152.7	180.0	231.4	220.3	73.7	21.9	14.9	30.4	36.0	29.0
Median	45.6	90.1	272.8	288.6	720.0	759.5	174.7	56.7	41.4	62.0	68.5	47.8
Mean	67.5	117.6	337.4	444.8	841.7	946.2	291.7	90.3	79.1	89.5	96.1	67.4
3rd Qu.	92.2	139.8	462.6	675.7	1218.0	1347.2	305.3	114.1	92.2	110.8	123.4	97.2
Max.	370.7	941.1	2298.0	1433.0	2918.0	4573.0	2211.0	541.7	576.0	376.3	336.1	229.7

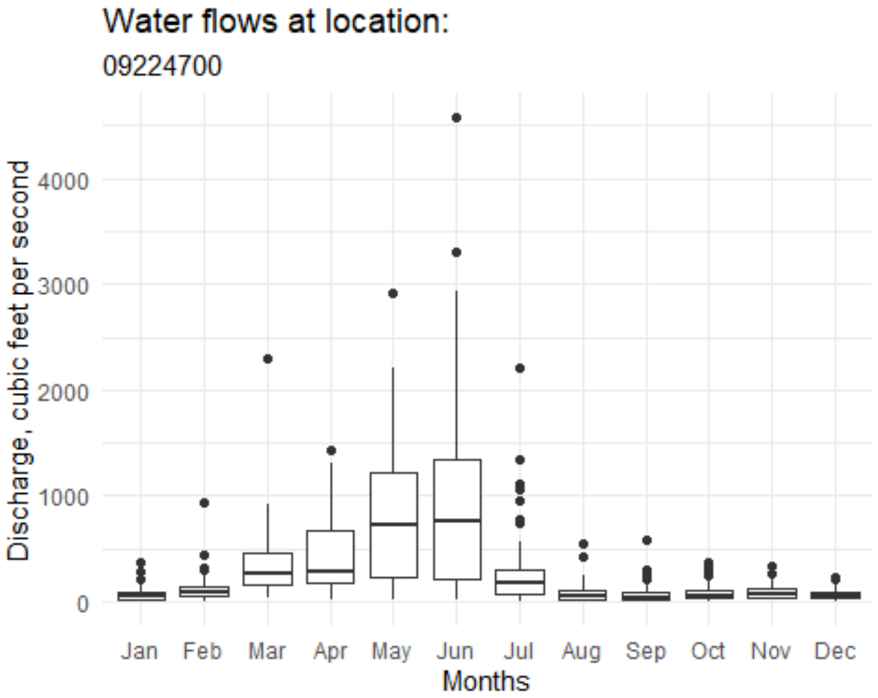


Figure B95. Monthly discharge (cf/s) at location USGS 09224700

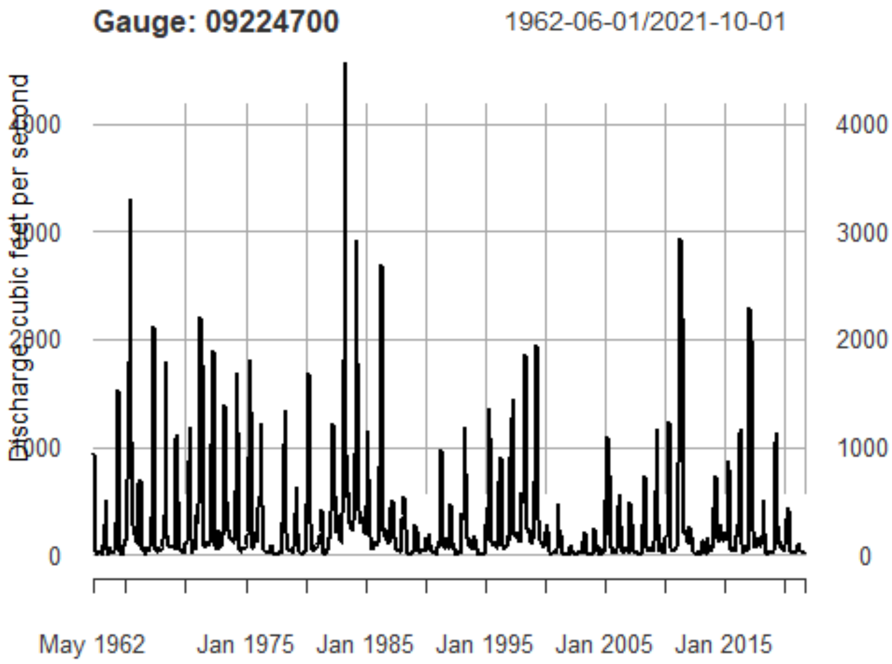


Figure B96. Discharge (cf/s) at location USGS 09224700

Table B54. Main statistics of water discharge (cf/s) at USGS 09222400

	January	February	March	April	May	June	July	August	September	October	November	December
Min.	0.0	6.0	9.0	17.7	8.1	0.3	0.0	0.0	0.0	1.9	1.6	1.9
1st Qu.	5.0	6.2	15.3	34.9	66.2	11.8	1.4	0.5	1.2	2.8	4.9	4.1
Median	8.3	9.3	32.2	57.5	111.8	27.0	2.0	2.3	1.5	3.8	6.1	7.8
Mean	7.8	14.0	51.4	102.5	106.0	55.5	10.6	4.0	3.5	7.6	9.8	9.0
3rd Qu.	11.2	15.6	92.3	95.8	139.5	121.0	13.8	6.2	4.4	10.1	11.5	9.9
Max.	15.1	31.8	130.5	354.1	277.5	130.0	56.7	14.2	12.8	21.0	23.3	21.4

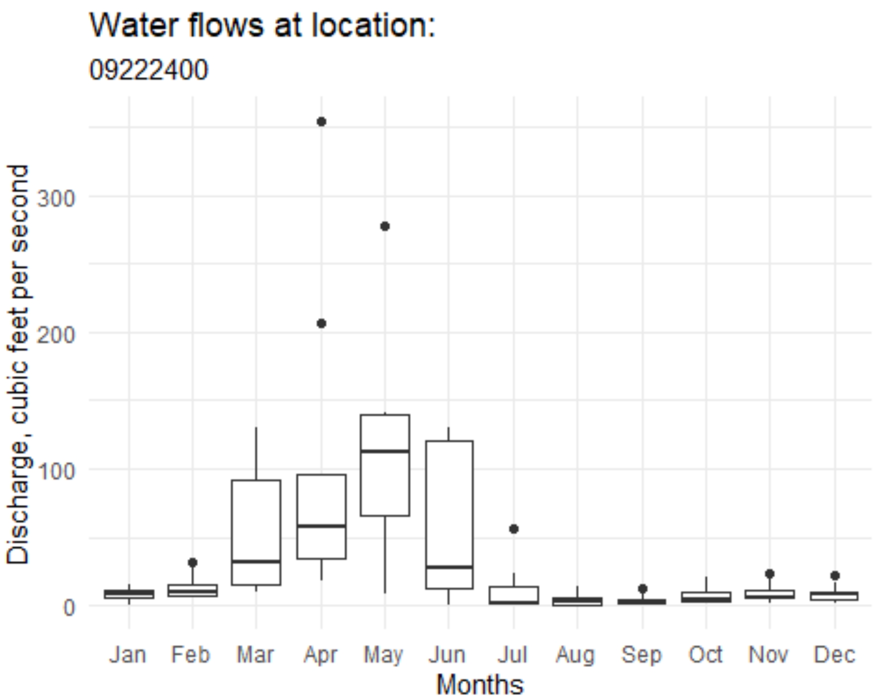


Figure B97. Monthly discharge (cf/s) at location USGS 09222400

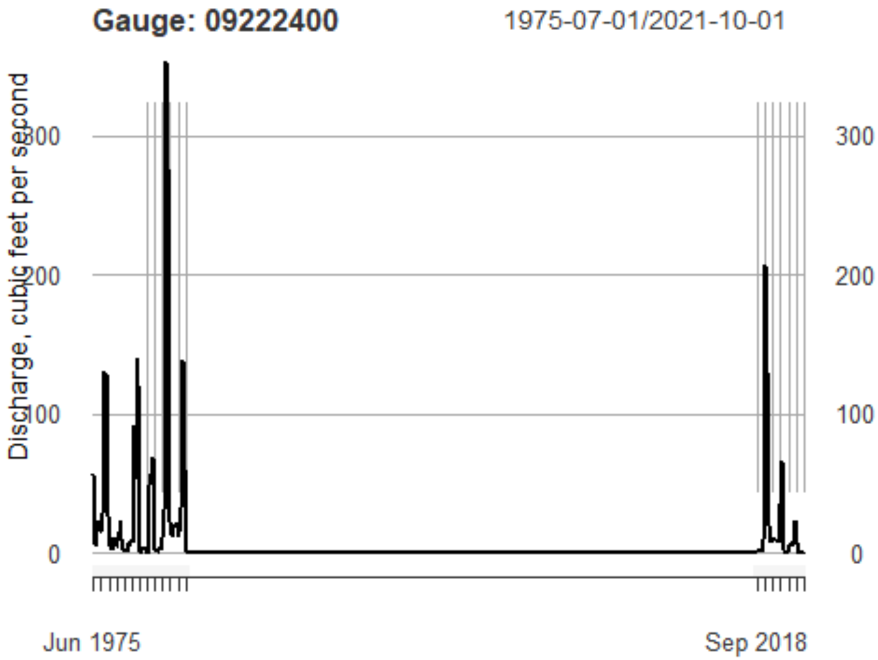


Figure B98. Discharge (cf/s) at location USGS 09222400

Table B55. Main statistics of water discharge (cf/s) at USGS 09219200

	January	February	March	April	May	June	July	August	September	October	November	December
Min.	6.5	6.8	25.7	15.3	2.2	9.4	9.8	0.1	1.0	4.8	5.8	7.3
1st Qu.	9.6	6.8	29.7	17.5	16.3	26.1	10.0	1.3	2.4	5.8	9.6	10.4
Median	12.8	6.8	33.7	23.2	24.5	99.1	20.1	3.3	5.3	8.2	13.4	13.6
Mean	15.0	14.0	41.3	78.2	41.2	145.9	38.2	11.6	9.6	14.6	23.6	21.6
3rd Qu.	19.3	17.7	49.1	83.9	49.4	218.9	48.4	13.6	12.6	17.0	32.5	28.7
Max.	25.8	28.5	64.6	251.0	113.6	375.9	102.9	39.7	26.8	37.3	51.5	43.8

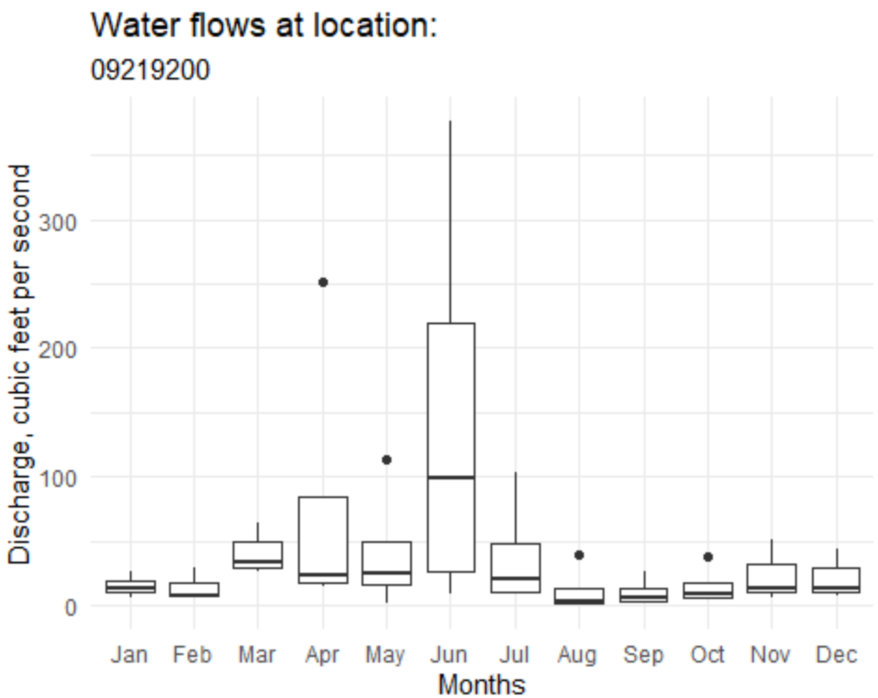


Figure B99. Monthly discharge (cf/s) at location USGS 09219200

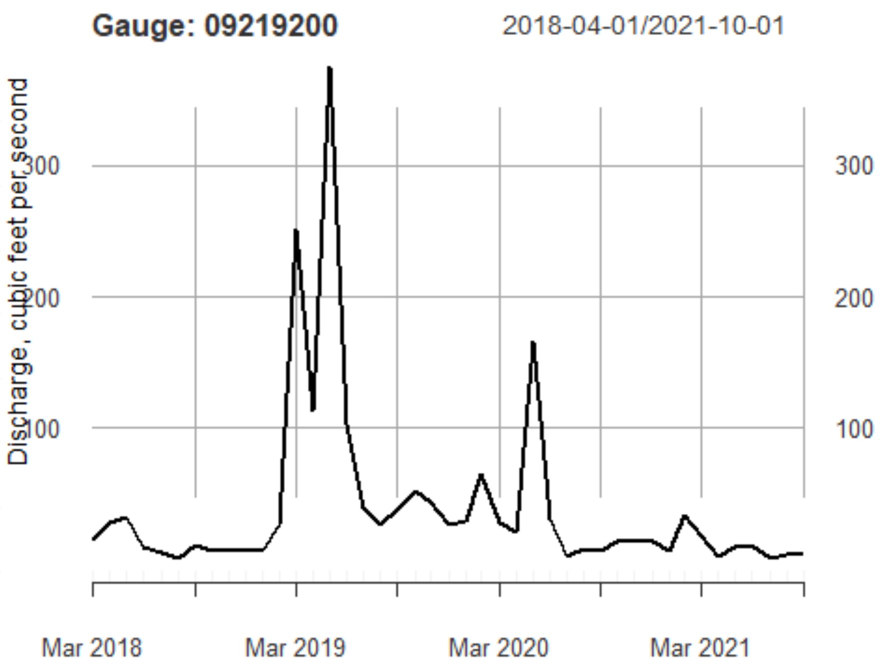
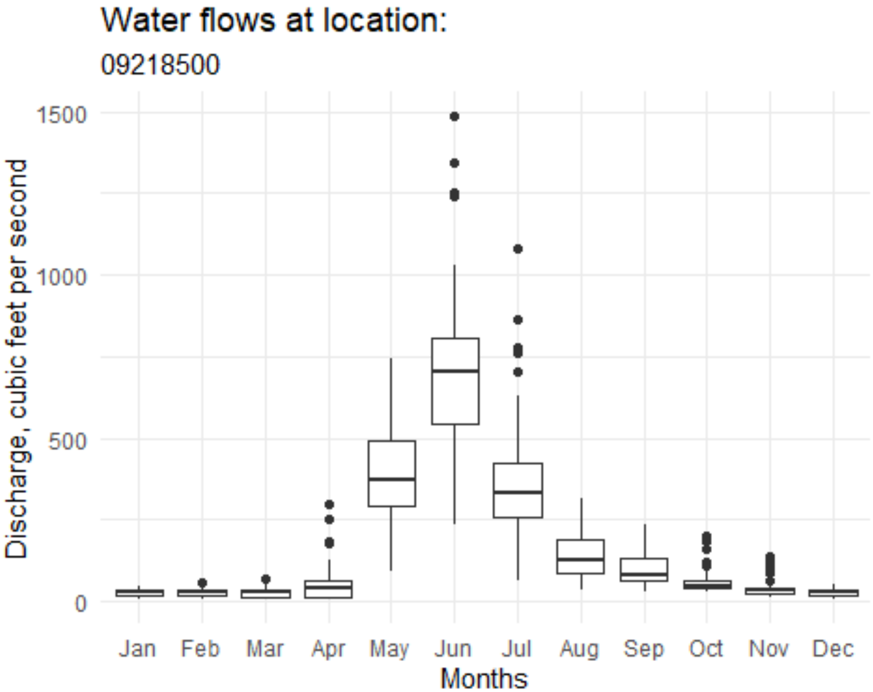


Figure B100. Discharge (cf/s) at location USGS 09219200

Table B56. Main statistics of water discharge (cf/s) at USGS 09218500

	January	February	March	April	May	June	July	August	September	October	November	December
Min.	7.9	6.1	6.5	7.4	91.6	237.1	65.9	34.1	31.5	28.9	11.6	8.5
1st Qu.	18.0	17.6	12.8	13.2	291.4	545.0	257.1	85.7	61.5	38.2	26.0	20.0
Median	28.0	26.9	28.6	37.9	374.4	704.2	330.6	128.2	80.6	45.9	34.3	30.0
Mean	26.4	25.3	27.5	51.8	397.0	705.9	354.3	140.0	101.7	60.2	39.5	29.1
3rd Qu.	34.9	32.7	35.0	63.6	491.9	808.0	422.0	190.6	133.8	66.1	40.8	37.0
Max.	47.8	57.2	71.7	297.5	743.0	1484.0	1081.0	317.1	232.6	199.3	137.3	52.8



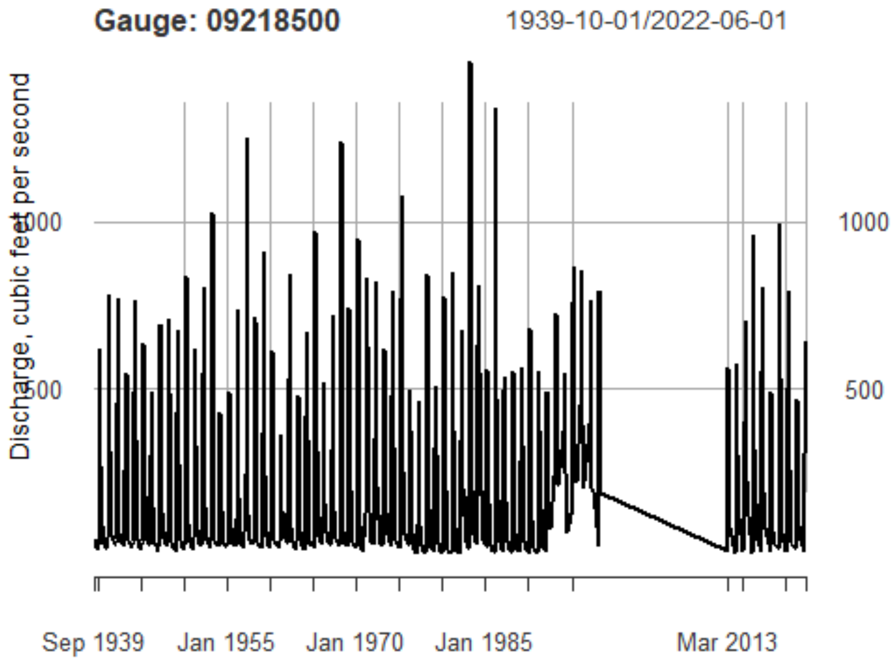


Figure B101. Monthly discharge (cf/s) at location USGS 09218500 Figure B102. Discharge (cf/s) at location USGS 09218500

Table B57. Main statistics of water discharge (cf/s) at USGS 09217900

	January	February	March	April	May	June	July	August	September	October	November	December
Min.	6.7	9.2	7.4	16.4	134.2	182.4	56.6	28.8	25.2	22.9	18.5	11.1
1st Qu.	21.7	18.2	19.6	35.6	324.9	443.8	147.9	62.0	47.1	36.5	31.3	24.2
Median	24.4	22.0	23.6	48.9	400.2	722.7	210.4	79.8	54.9	49.7	39.0	29.2
Mean	26.4	22.5	24.4	67.0	419.3	713.1	289.6	96.4	63.8	54.3	40.0	30.8
3rd Qu.	31.7	26.2	28.7	77.2	501.1	921.9	351.5	133.6	72.7	58.8	48.1	37.5
Max.	55.7	36.9	58.7	223.3	788.7	1340.0	1158.0	231.9	156.9	139.6	68.5	50.0

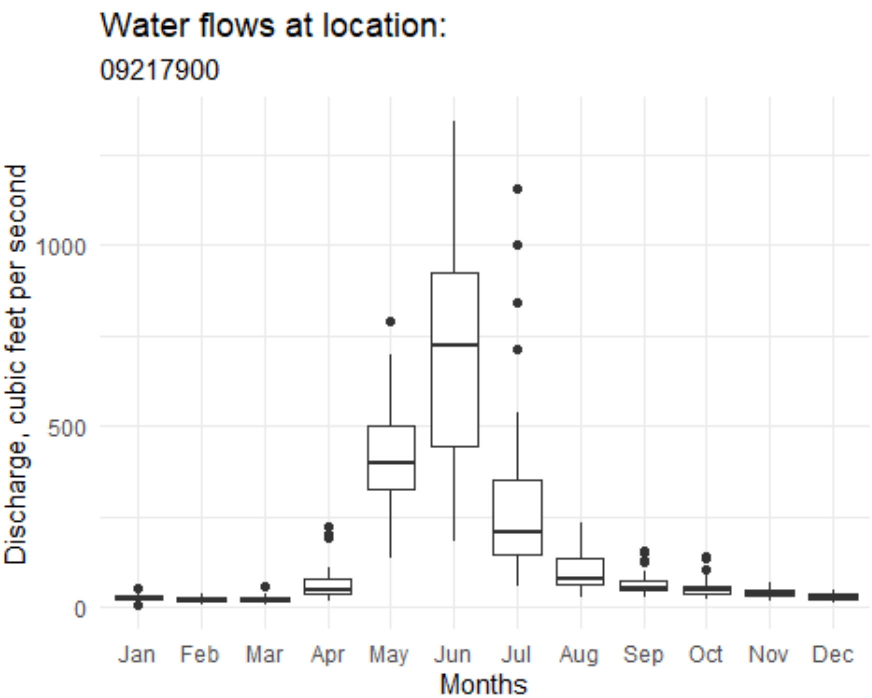


Figure B103. Monthly discharge (cf/s) at location USGS 09217900

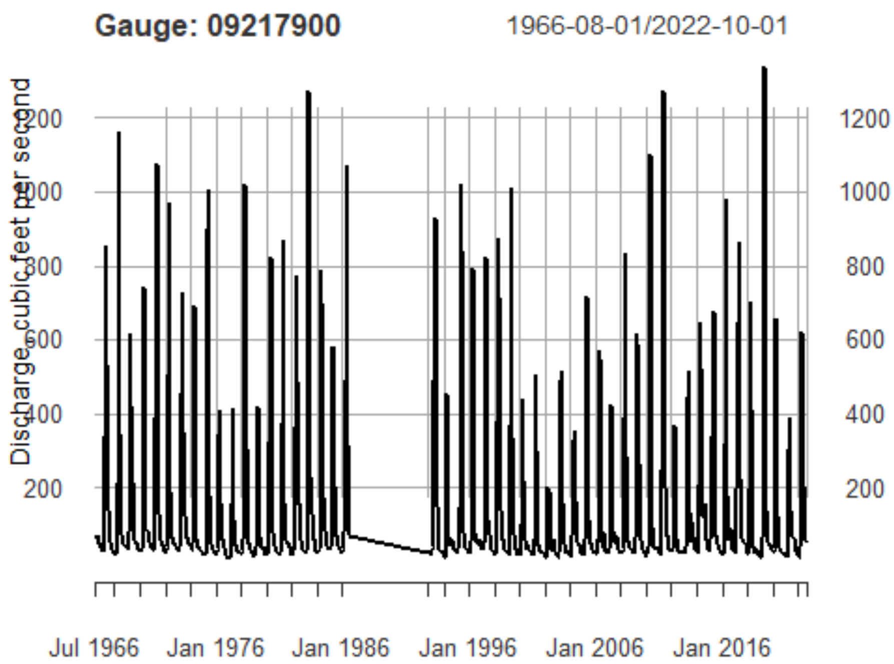


Figure B104. Discharge (cf/s) at location USGS 09217900

Table B58. Main statistics of water discharge (cf/s) at USGS 09223000

	January	February	March	April	May	June	July	August	September	October	November	December
Min.	6.2	5.6	5.4	19.8	40.5	24.0	9.3	4.6	5.6	8.4	9.4	7.7
1st Qu.	11.8	11.7	15.0	58.5	238.1	156.8	42.7	16.9	14.7	16.9	15.7	13.2
Median	13.7	14.9	20.4	90.3	378.5	324.4	70.2	26.4	18.7	21.3	19.4	15.7
Mean	14.4	14.7	22.8	105.2	398.6	369.1	91.0	27.4	20.8	22.8	19.9	16.6
3rd Qu.	17.1	18.0	26.6	134.0	506.4	475.1	112.9	37.2	25.4	25.1	23.9	19.4
Max.	26.7	29.1	117.8	397.7	969.9	1039.0	369.1	64.0	51.8	54.2	36.5	39.6

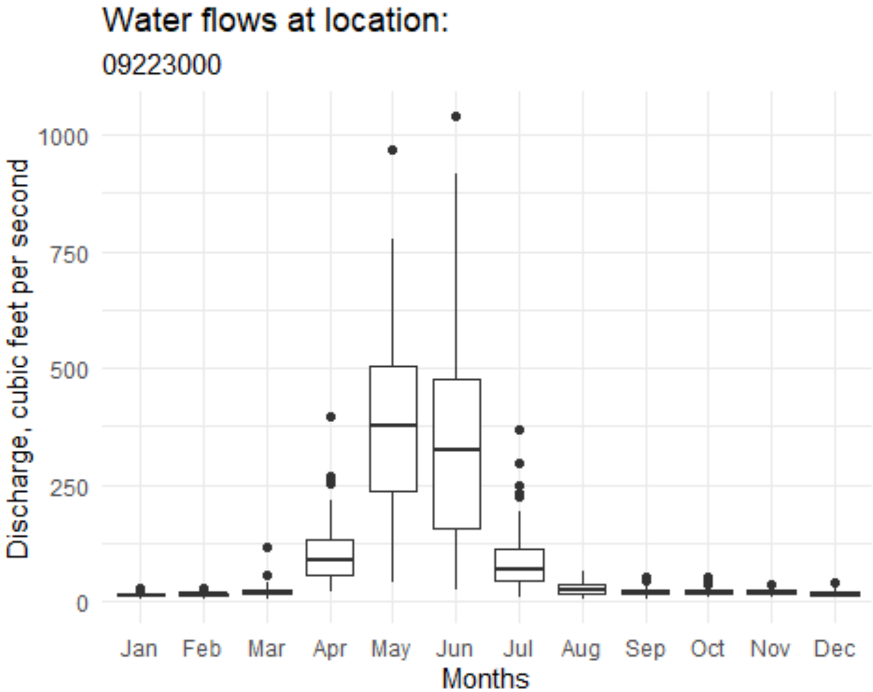


Figure B105. Monthly discharge (cf/s) at location USGS 09223000

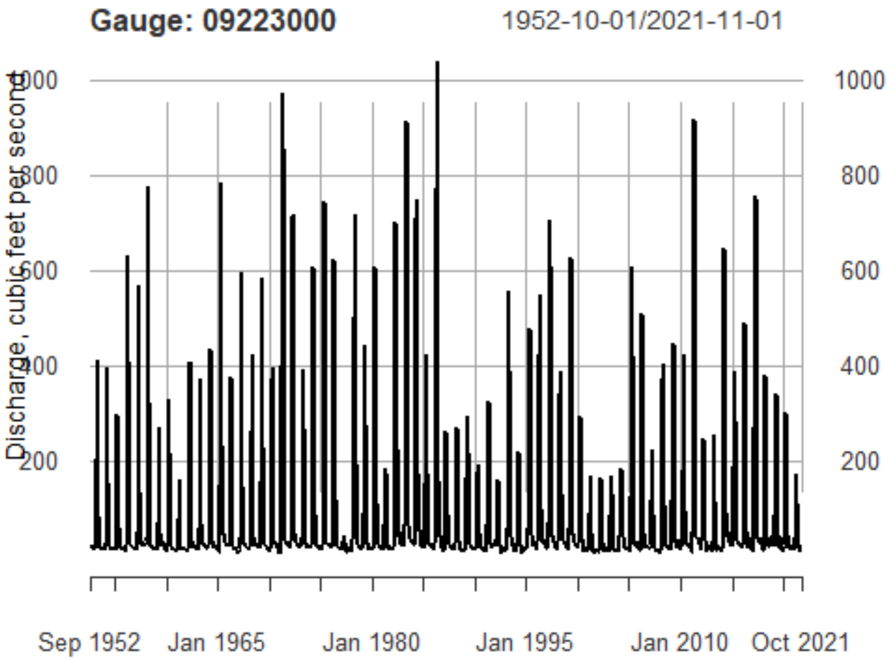


Figure B106. Discharge (cf/s) at location USGS 09223000

Table B59. Main statistics of water discharge (cf/s) at USGS 09261000

	January	February	March	April	May	June	July	August	September	October	November	December
Min.	598.1	721.4	946.2	1890.0	4220.0	2505.0	503.9	453.2	502.6	343.6	589.9	527.1
1st Qu.	1252.8	1318.0	2060.2	3737.8	8196.2	6793.0	2138.0	1638.2	1399.2	1543.0	1427.2	1278.2
Median	1854.5	1913.5	2621.5	5030.5	10590.0	10950.0	3720.5	2174.0	1911.5	1936.0	1865.5	1820.5
Mean	2089.9	2302.9	2974.6	5463.2	11027.3	11034.8	4340.5	2327.0	1936.5	2097.6	2136.2	2120.6
3rd Qu.	2739.0	3124.8	3626.2	6767.2	13760.0	14242.5	5248.8	2785.0	2330.5	2517.0	2786.0	2869.0
Max.	4844.0	4839.0	6643.0	15350.0	24110.0	26460.0	16110.0	6460.0	4159.0	5020.0	4833.0	4414.0

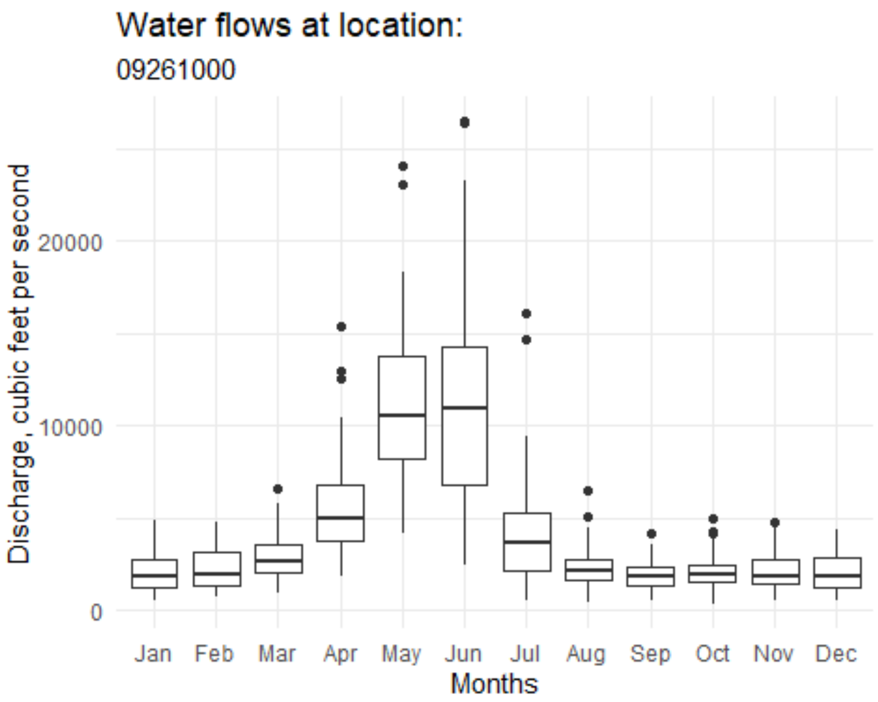


Figure B107. Monthly discharge (cf/s) at location USGS 09261000

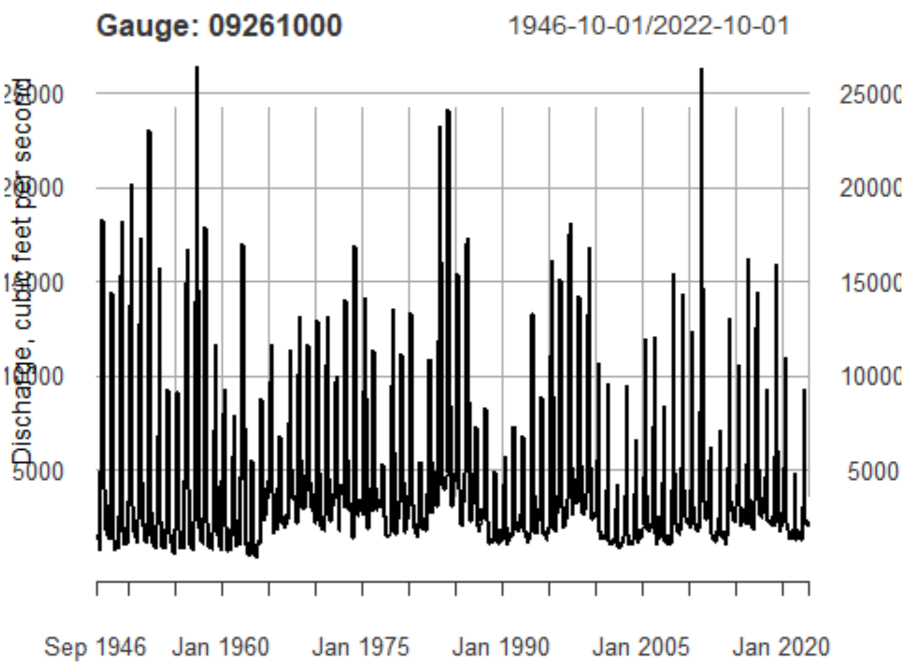


Figure B108. Discharge (cf/s) at location USGS 09261000

Table B60. Main statistics of water discharge (cf/s) at USGS 09260050

	January	February	March	April	May	June	July	August	September	October	November	December
Min.	178.9	204.3	388.6	901.9	2442.0	757.2	34.4	21.6	45.6	133.1	189.3	183.0
1st Qu.	308.5	306.4	826.7	2645.0	5938.0	2814.0	422.5	145.2	148.5	267.5	383.0	292.8
Median	369.0	421.7	1220.0	3335.0	7738.0	6457.0	837.9	266.2	247.6	404.4	466.4	376.6
Mean	400.4	481.5	1265.2	3569.4	8066.5	6774.5	1535.2	397.7	314.6	510.4	539.6	401.3
3rd Qu.	487.2	624.1	1544.0	4186.0	10380.0	8689.0	1829.0	532.5	358.8	690.9	671.0	496.7
Max.	742.0	1811.0	3200.0	8211.0	18330.0	19640.0	8703.0	1537.0	1594.0	1412.0	1127.0	831.9

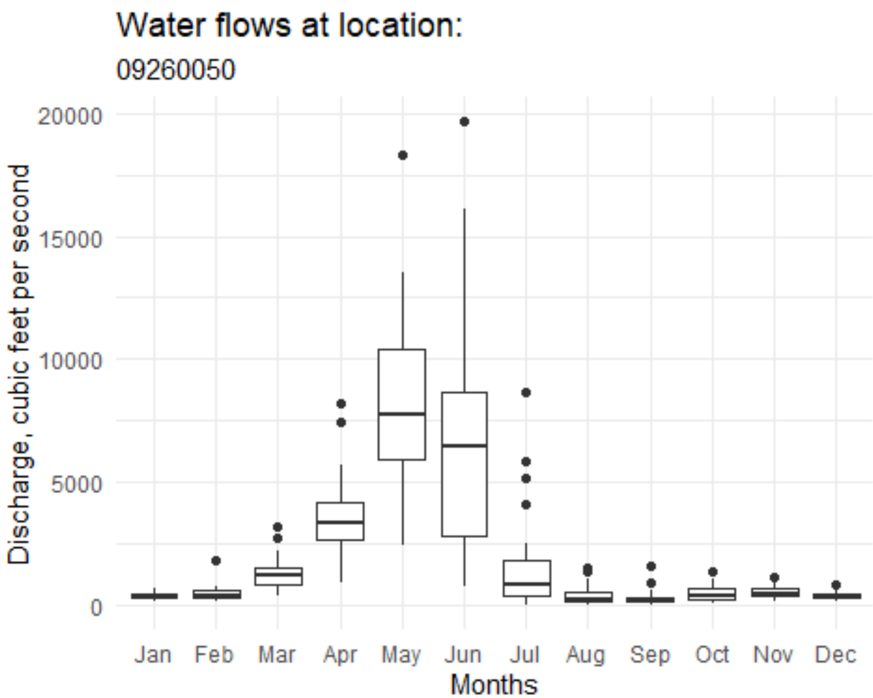


Figure B109. Monthly discharge (cf/s) at location USGS 09260050

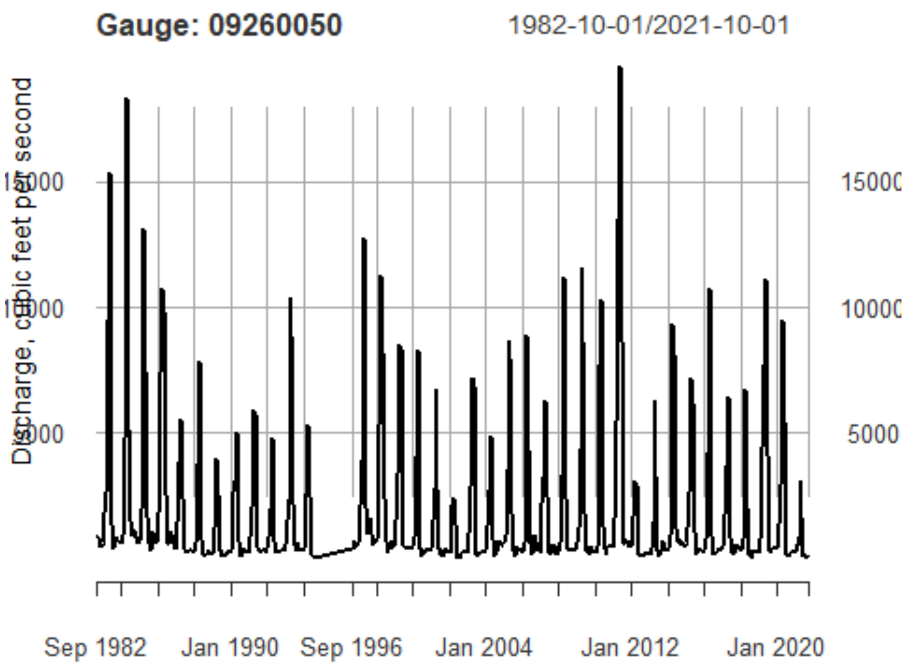


Figure B110. Discharge (cf/s) at location USGS 09260050

Table B61. Main statistics of water discharge (cf/s) at USGS 09260000

	January	February	March	April	May	June	July	August	September	October	November	December
Min.	16.0	18.0	80.5	264.5	477.0	36.7	0.3	0.0	0.0	0.0	0.0	25.0
1st Qu.	65.9	77.4	216.3	637.8	1550.2	994.8	68.2	9.1	5.3	45.3	68.9	69.4
Median	85.7	95.0	297.9	909.8	2442.0	1675.5	182.2	34.1	29.4	96.6	112.8	90.0
Mean	94.5	124.3	374.5	1028.5	2481.9	1827.2	296.8	64.7	55.1	112.7	122.0	98.6
3rd Qu.	115.6	145.3	433.5	1233.8	3220.8	2529.5	424.2	84.0	77.1	173.9	153.5	120.6
Max.	227.9	595.1	1260.0	3259.0	5967.0	6310.0	2064.0	534.2	313.8	384.9	363.0	244.0

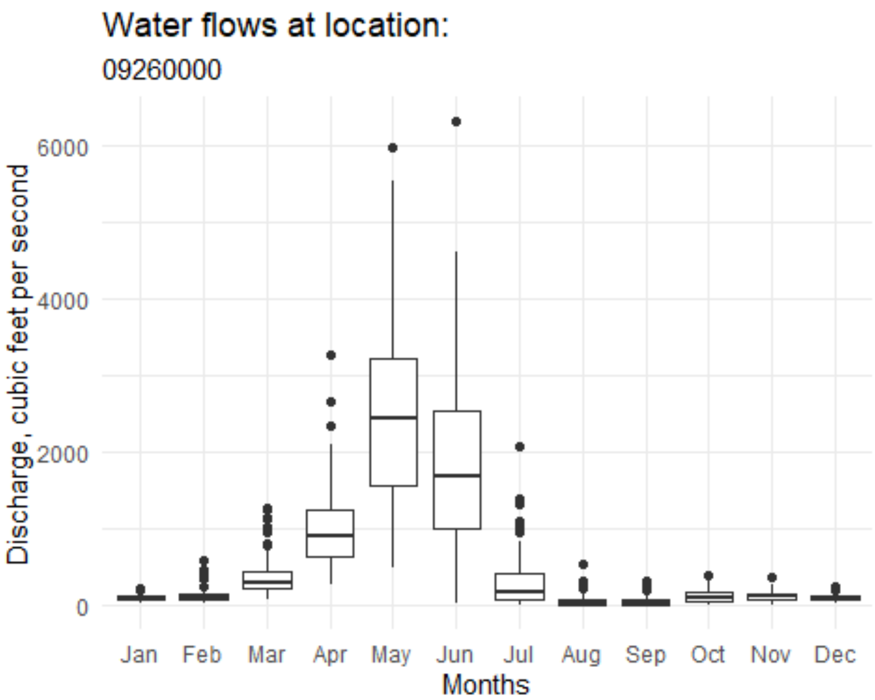


Figure B111. Monthly discharge (cf/s) at location USGS 09260000

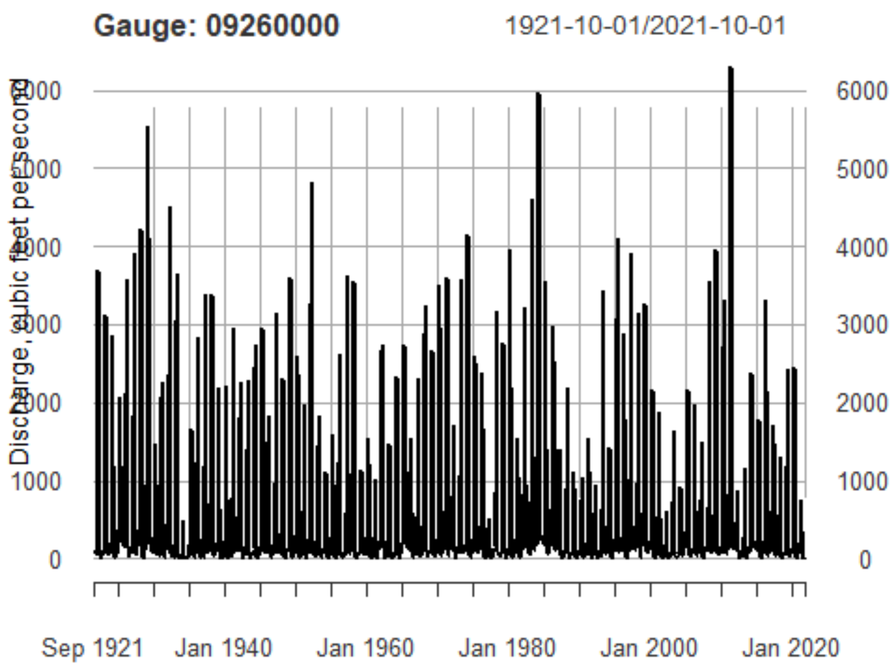


Figure B112. Discharge (cf/s) at location USGS 09260000

Table B62. Main statistics of water discharge (cf/s) at USGS 09253000

	January	February	March	April	May	June	July	August	September	October	November	December
Min.	16.3	20.4	23.8	77.6	379.3	118.8	26.9	12.9	11.0	16.2	18.4	14.8
1st Qu.	25.7	26.4	34.4	153.6	802.2	518.2	66.5	25.6	19.7	25.2	26.2	24.5
Median	30.6	31.8	46.9	264.0	1045.0	848.2	113.7	33.0	25.5	34.9	33.5	29.8
Mean	32.1	32.9	54.8	278.0	1078.2	905.8	154.0	37.7	28.6	39.0	36.6	32.6
3rd Qu.	36.9	36.6	58.9	351.4	1345.5	1247.5	188.2	46.5	35.0	48.9	43.9	40.1
Max.	74.5	59.5	174.4	842.2	2122.0	3124.0	868.2	97.3	80.5	91.8	77.8	59.4

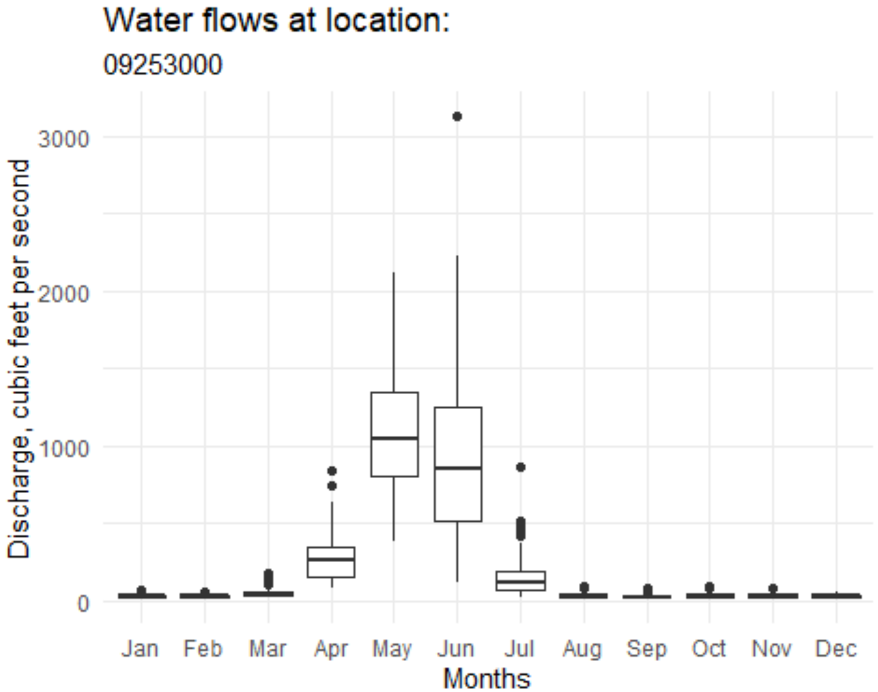


Figure B113. Monthly discharge (cf/s) at location USGS 09253000

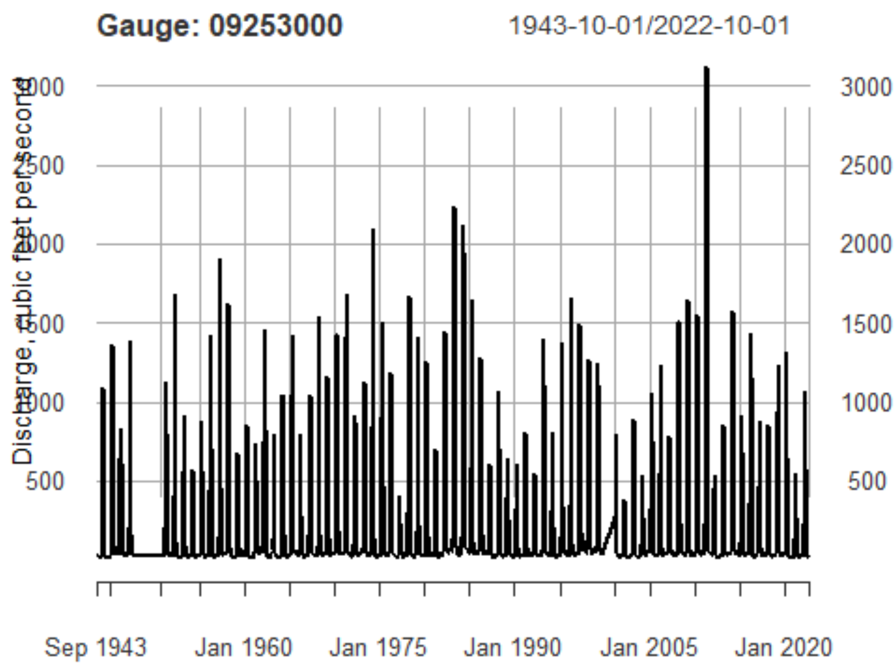


Figure B114. Discharge (cf/s) at location USGS 09253000

Table B63. Main statistics of water discharge (cf/s) at USGS 09258980

	January	February	March	April	May	June	July	August	September	October	November	December
Min.	0.2	0.2	0.4	0.4	3.9	0.5	0.2	0.1	0.1	0.2	0.2	0.2
1st Qu.	0.2	0.3	4.8	12.2	12.9	2.3	0.5	0.3	0.3	0.3	0.3	0.2
Median	0.3	1.7	23.7	26.4	23.8	5.0	1.0	0.8	0.5	0.5	0.4	0.3
Mean	4.2	5.8	32.8	47.1	52.9	20.0	4.0	1.4	1.0	1.3	1.5	0.9
3rd Qu.	0.3	5.7	30.9	58.0	82.1	21.8	4.2	1.2	1.1	1.4	0.8	0.3
Max.	62.2	34.5	143.0	260.2	200.6	115.4	38.4	6.2	4.3	7.5	9.2	5.4

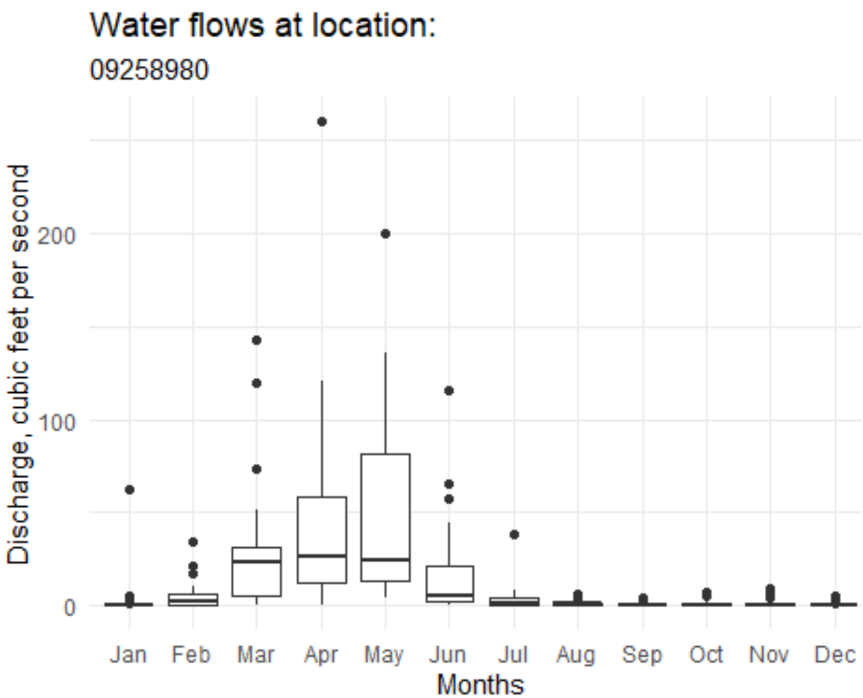


Figure B115. Monthly discharge (cf/s) at location USGS 09258980

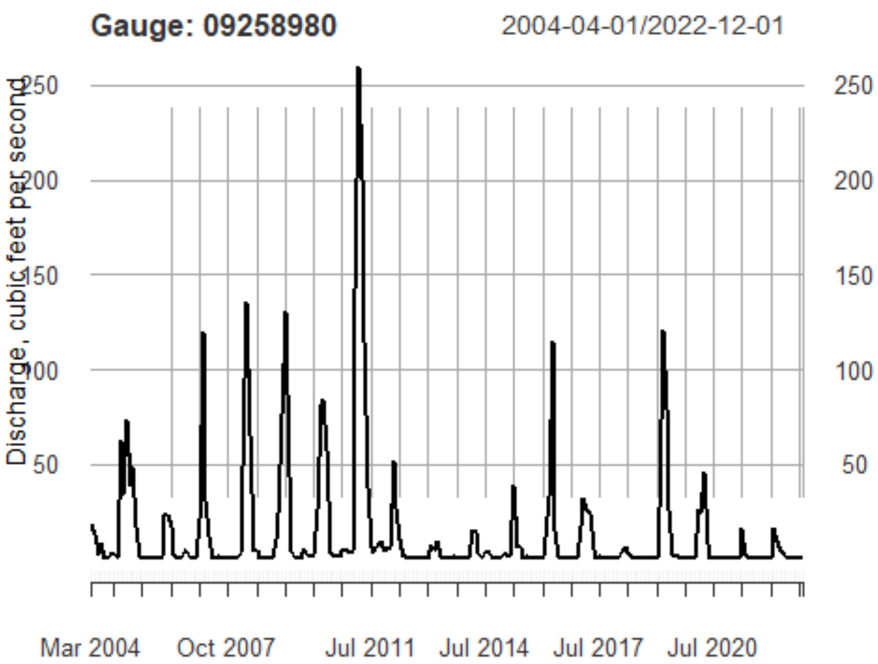


Figure B116. Discharge (cf/s) at location USGS 09258980

Table B64. Main statistics of water discharge (cf/s) at USGS 09251000

	January	February	March	April	May	June	July	August	September	October	November	December
Min.	115.0	160.3	220.6	656.5	1850.0	548.1	20.4	12.7	27.8	117.3	183.7	137.4
1st Qu.	220.3	249.3	458.5	1673.0	4577.5	3697.0	546.7	176.1	137.0	207.3	248.1	209.7
Median	253.7	297.9	639.1	2487.0	6106.0	5346.5	1107.0	312.5	196.0	293.0	313.6	272.6
Mean	276.6	324.4	724.6	2609.8	6169.6	5404.2	1339.4	358.0	237.5	347.7	352.6	292.9
3rd Qu.	321.6	376.8	889.4	3277.0	7456.8	6787.5	1896.0	504.7	278.4	419.7	427.4	355.1
Max.	609.7	1071.0	2063.0	6496.0	14000.0	14310.0	6199.0	1052.0	1366.0	1174.0	768.2	623.9

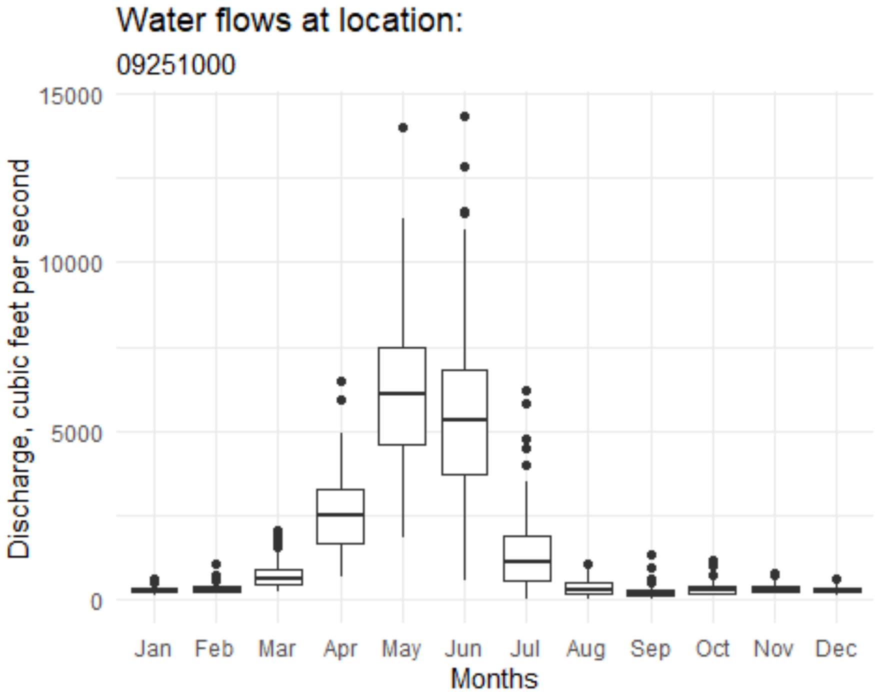


Figure B117. Monthly discharge (cf/s) at location USGS 09251000

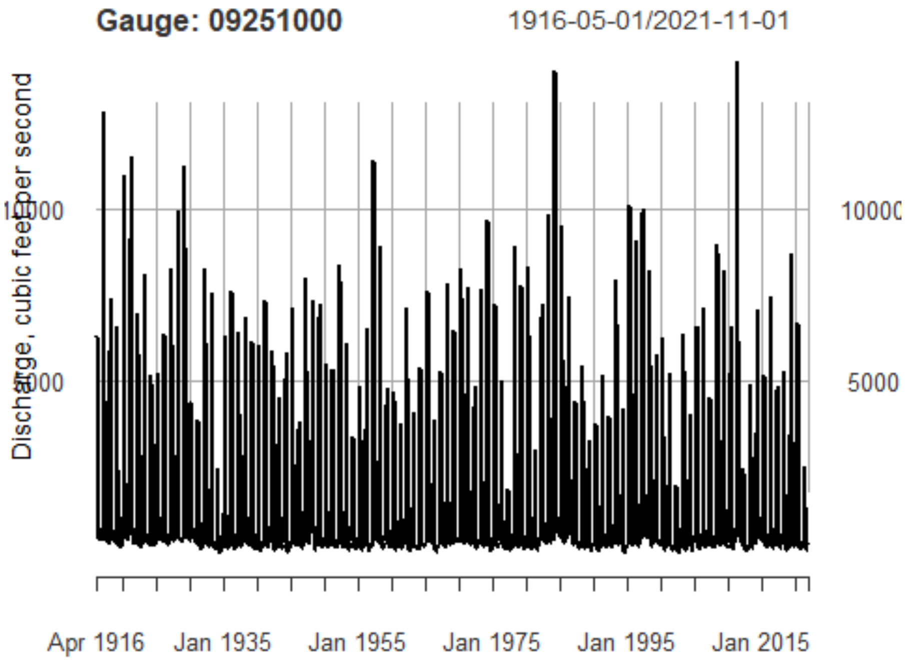


Figure B118 . Discharge (cf/s) at location USGS 09251000

Table B65. Main statistics of water discharge (cf/s) at USGS 09237500

	January	February	March	April	May	June	July	August	September	October	November	December
Min.	28.4	27.6	18.0	32.3	12.4	12.8	22.3	34.4	31.8	25.8	29.3	27.0
1st Qu.	42.9	44.9	44.7	46.4	46.3	43.0	57.9	67.5	49.2	41.2	44.3	40.2
Median	51.8	53.4	62.8	66.7	80.8	92.1	79.2	74.6	59.4	50.1	52.0	48.0
Mean	53.2	55.0	60.2	75.0	103.9	100.7	92.2	82.6	66.2	54.5	54.8	52.0
3rd Qu.	60.6	69.1	78.7	83.5	128.6	124.8	119.4	94.7	80.6	59.8	66.1	61.8
Max.	89.8	84.8	90.3	166.2	303.1	377.5	353.5	226.1	135.0	110.4	94.7	93.3

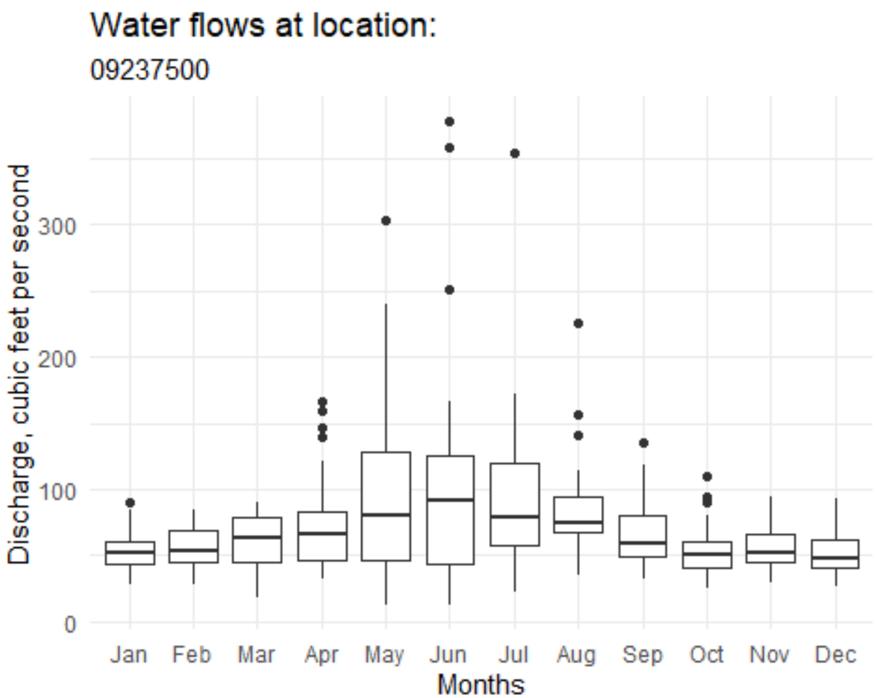


Figure B119. Monthly discharge (cf/s) at location USGS 09237500

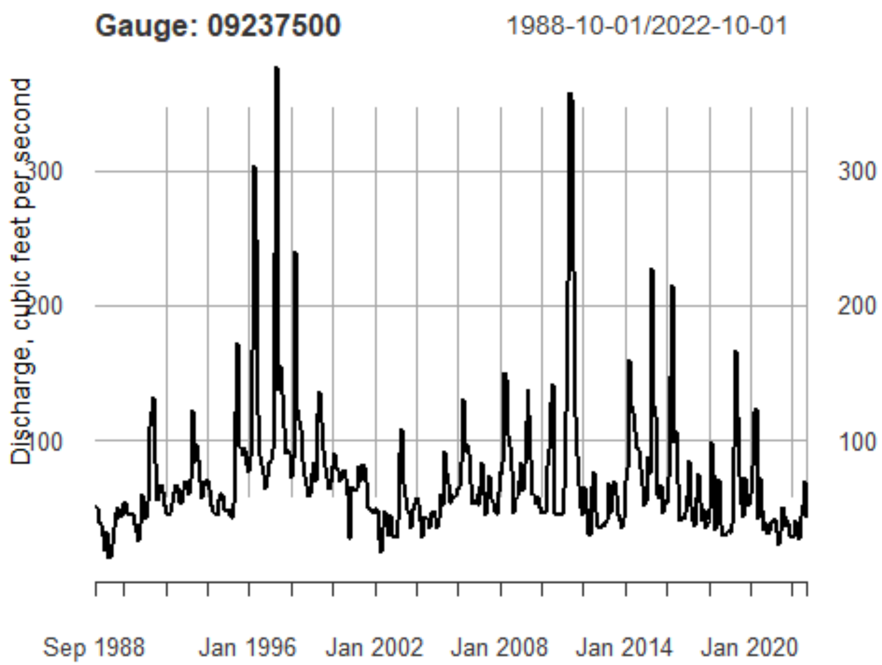


Figure B120. Discharge (cf/s) at location USGS 09237500

Table B66. Main statistics of water discharge (cf/s) at USGS 09272400

	January	February	March	April	May	June	July	August	September	October	November	December
Min.	1243.0	1251.0	1594.0	1764.0	4323.0	2695.0	1167.0	1237	1309.0	1159	1304.0	1131.0
1st Qu.	1373.0	1764.0	1861.0	3711.0	8563.0	6265.0	2015.0	1837	1716.0	1762	1685.0	1373.0
Median	2496.0	2604.0	2142.0	4699.0	9162.5	10860.0	3316.0	2007	2069.0	1953	1999.0	2249.0
Mean	2224.6	2417.3	2826.2	4932.2	9955.6	11085.8	4159.1	2159	2122.2	2057	2046.6	2144.9
3rd Qu.	2723.0	2909.0	3292.0	5223.0	10947.5	14650.0	4144.0	2355	2271.0	2526	2335.0	2550.0
Max.	3449.0	3692.0	6582.0	12190.0	17050.0	25590.0	16360.0	3706	3309.0	2963	2989.0	3337.0

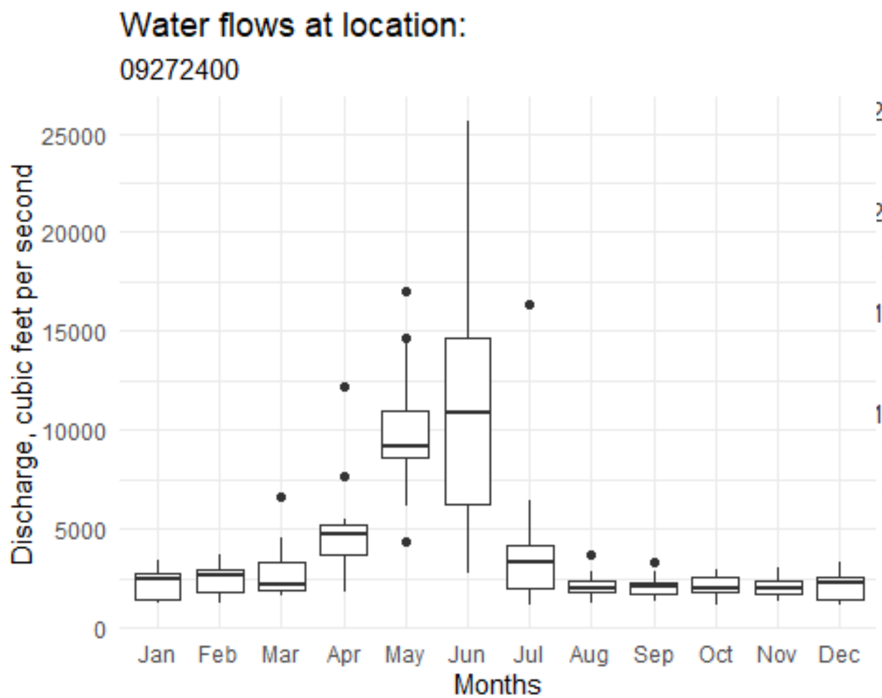


Figure B121. Monthly discharge (cf/s) at location USGS 09272400

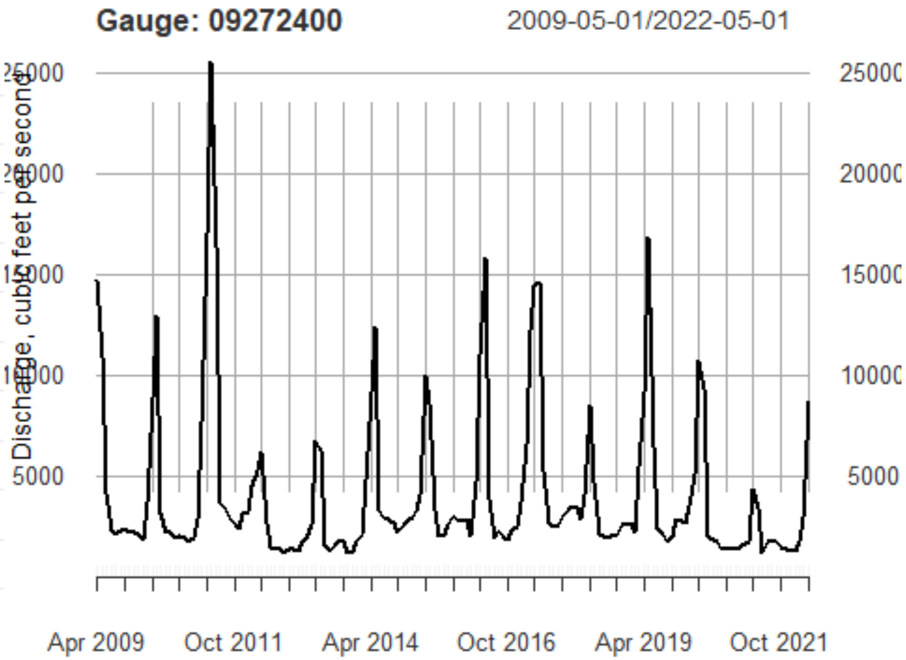


Figure B122. Discharge (cf/s) at location USGS 09272400

Table B67. Main statistics of water discharge (cf/s) at USGS 09302000

	January	February	March	April	May	June	July	August	September	October	November	December
Min.	39.4	52.6	66.1	23.5	27.4	23.0	7.1	5.9	18.9	30.1	42.6	39.6
1st Qu.	180.1	208.8	178.9	107.5	137.8	285.2	59.2	51.6	69.0	93.7	152.2	130.8
Median	342.9	388.3	389.4	249.4	593.6	953.2	120.3	95.9	104.9	194.8	282.9	344.6
Mean	343.1	386.4	440.2	360.2	832.1	1636.3	469.2	191.1	212.5	275.1	339.7	351.5
3rd Qu.	446.5	507.7	645.1	531.2	1187.5	2459.8	486.9	216.2	233.9	319.6	435.5	476.6
Max.	1246.0	1033.0	1202.0	1865.0	4938.0	7988.0	4727.0	977.6	1264.0	1529.0	1443.0	1353.0

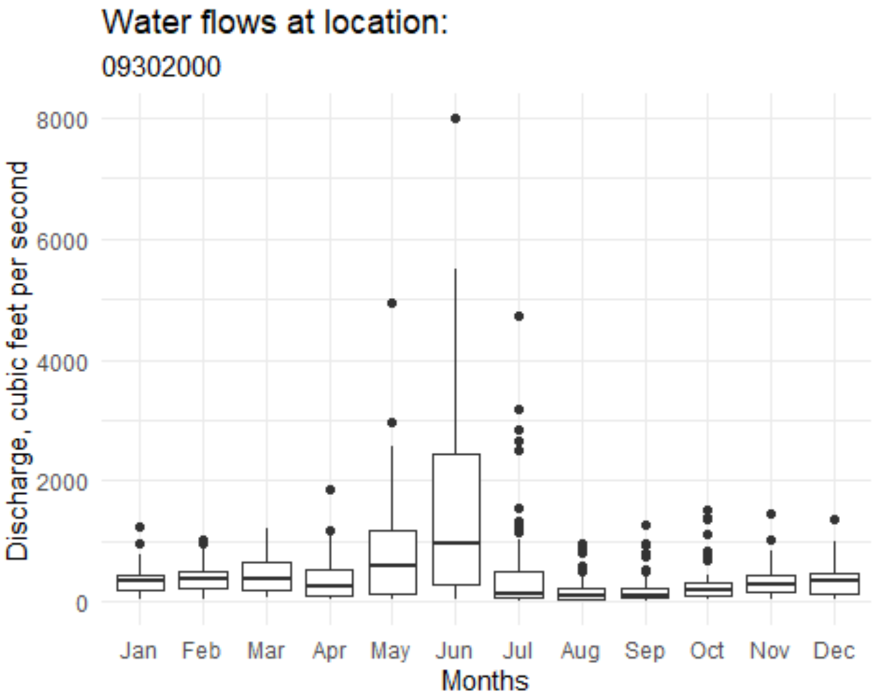


Figure B123. Monthly discharge (cf/s) at location USGS 09302000

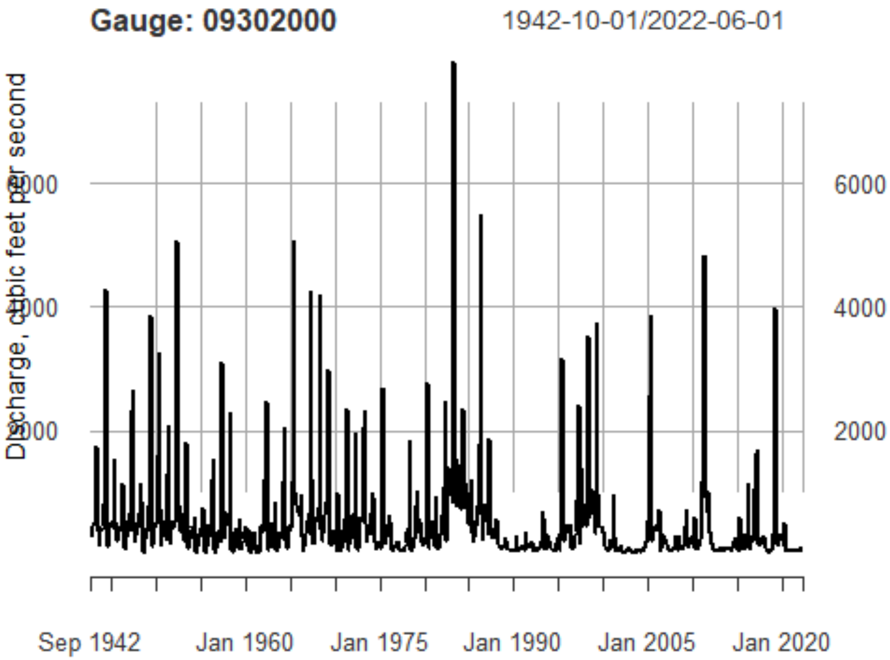


Figure B124. Discharge (cf/s) at location USGS 09302000

Table B68. Main statistics of water discharge (cf/s) at USGS 09295100

	January	February	March	April	May	June	July	August	September	October	November	December
Min.	34.7	48.3	52.1	8.3	12.8	14.1	9.3	6.7	7.6	15.8	30.4	30.2
1st Qu.	52.8	55.7	91.4	55.7	34.8	43.0	27.3	29.7	30.0	35.7	54.0	50.8
Median	126.9	146.3	144.6	120.3	63.8	126.1	35.7	38.4	35.3	71.6	124.9	84.2
Mean	149.8	180.4	220.8	186.1	272.3	602.0	236.8	88.6	107.7	127.3	182.1	159.7
3rd Qu.	203.4	213.8	268.6	230.3	307.5	535.8	54.0	66.9	92.1	152.7	221.3	200.3
Max.	483.6	709.3	742.5	1090.0	1449.0	3182.0	3754.0	804.8	790.9	575.2	847.1	654.5

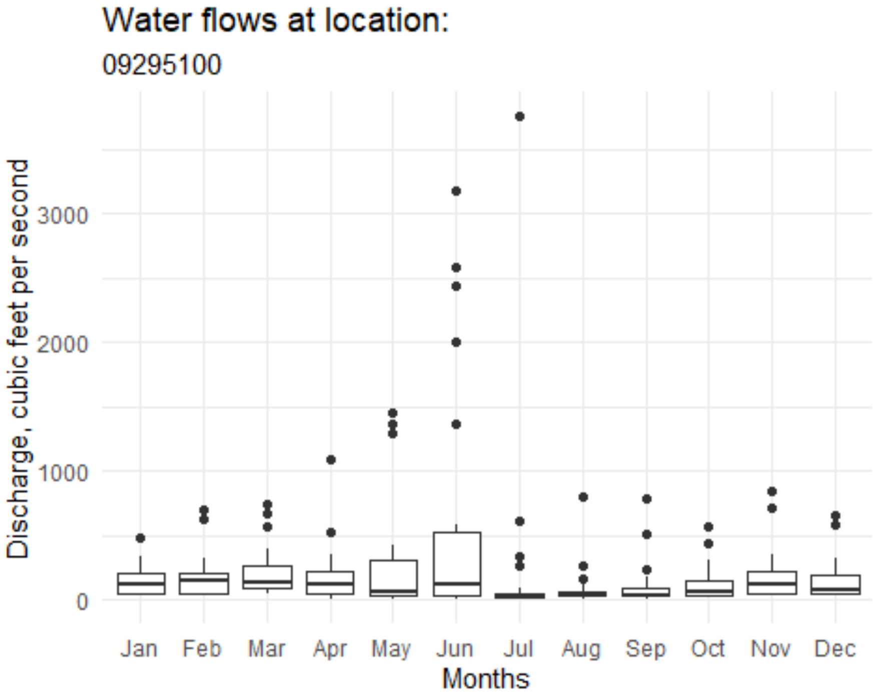


Figure B125. Monthly discharge (cf/s) at location USGS 09295100

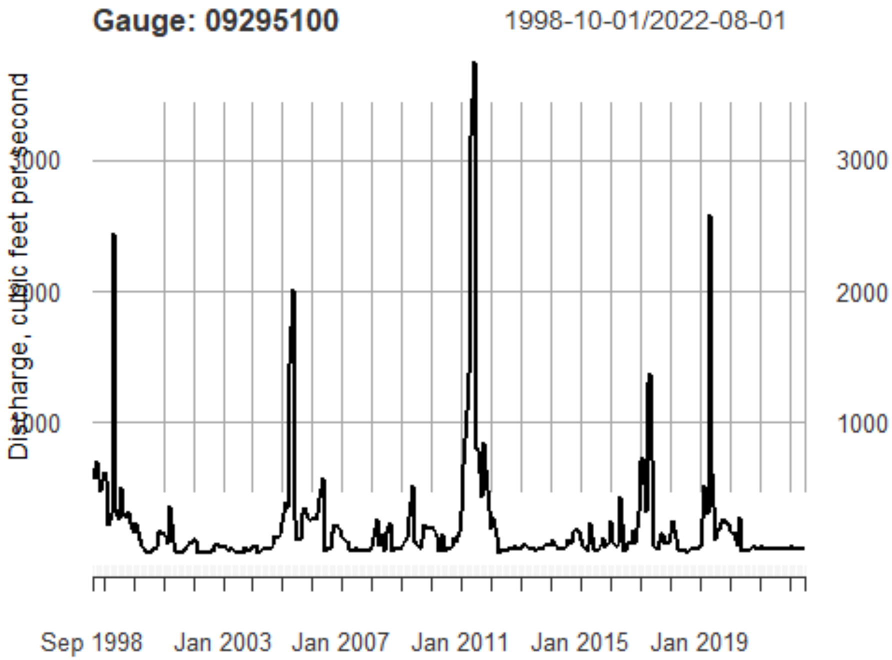
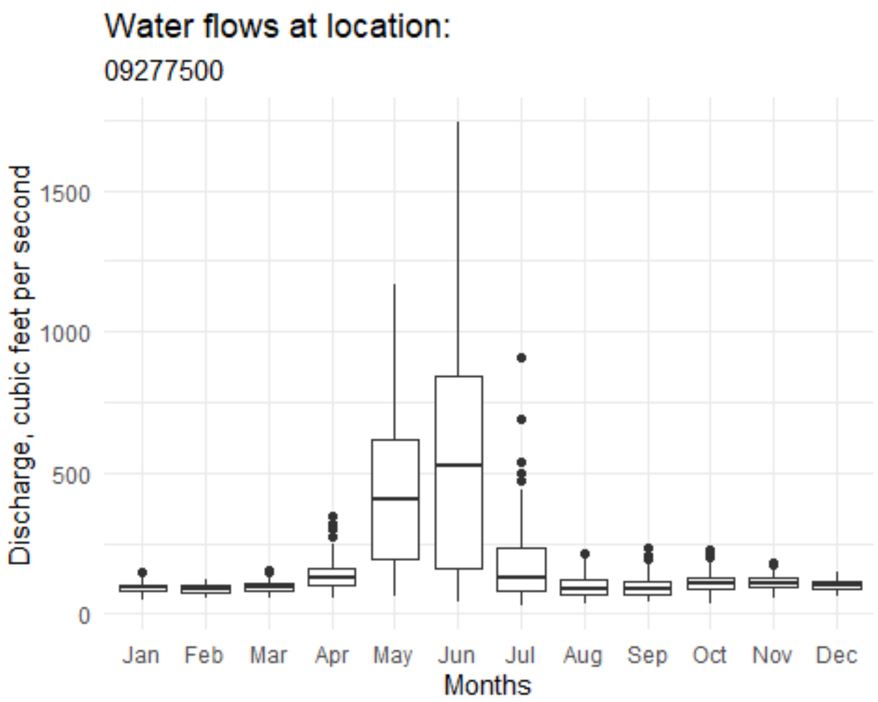


Figure B126. Discharge (cf/s) at location USGS 09295100

Table B69. Main statistics of water discharge (cf/s) at USGS 09277500

	January	February	March	April	May	June	July	August	September	October	November	December
Min.	51.7	53.2	53.8	53.9	63.9	40.1	29.1	37.5	40.4	37.5	57.6	64.2
1st Qu.	79.7	77.5	83.5	103.8	191.4	163.2	83.1	65.7	71.0	90.9	98.4	87.3
Median	92.3	88.4	94.6	129.6	406.1	524.8	127.9	86.0	86.2	107.2	111.4	101.0
Mean	90.9	88.5	95.6	145.0	436.0	556.5	181.3	97.8	97.7	112.9	114.3	101.8
3rd Qu.	100.0	100.0	107.1	164.5	617.4	839.4	237.2	124.9	116.8	130.8	128.2	114.8
Max.	147.2	123.9	153.4	348.1	1165.0	1739.0	906.9	216.0	232.6	230.1	179.6	151.4



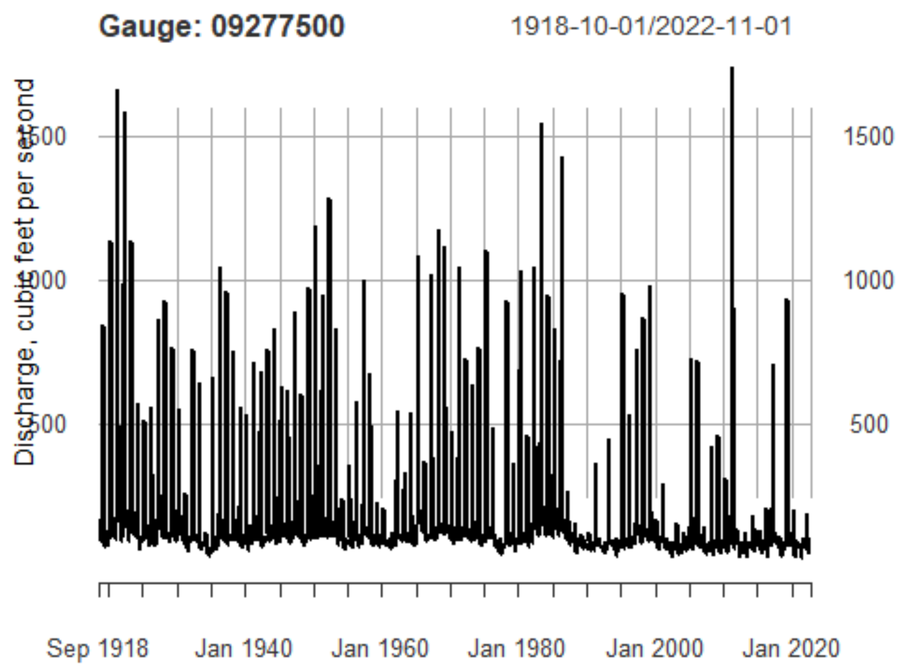


Figure B127. Monthly discharge (cf/s) at location USGS 09277500 Figure 128. Discharge (cf/s) at location USGS 09277500

Table 70. Main statistics of water discharge (cf/s) at USGS 09288180

	January	February	March	April	May	June	July	August	September	October	November	December
Min.	33.1	34.1	59.6	57.5	44.2	32.9	36.9	29.9	33.8	37.1	57.0	47.9
1st Qu.	62.8	68.0	79.8	97.8	127.1	96.1	77.8	71.0	77.3	73.2	71.1	64.8
Median	69.3	77.3	89.3	119.3	283.6	149.3	95.7	89.6	86.5	82.1	78.4	73.2
Mean	83.5	87.8	106.9	162.8	345.8	244.1	132.6	112.0	111.6	103.0	93.7	90.3
3rd Qu.	79.6	86.8	111.0	207.6	496.9	305.6	141.5	110.4	103.8	99.6	91.6	85.4
Max.	362.2	335.6	293.5	534.4	1047.0	1181.0	624.6	406.0	384.0	379.5	346.7	371.8

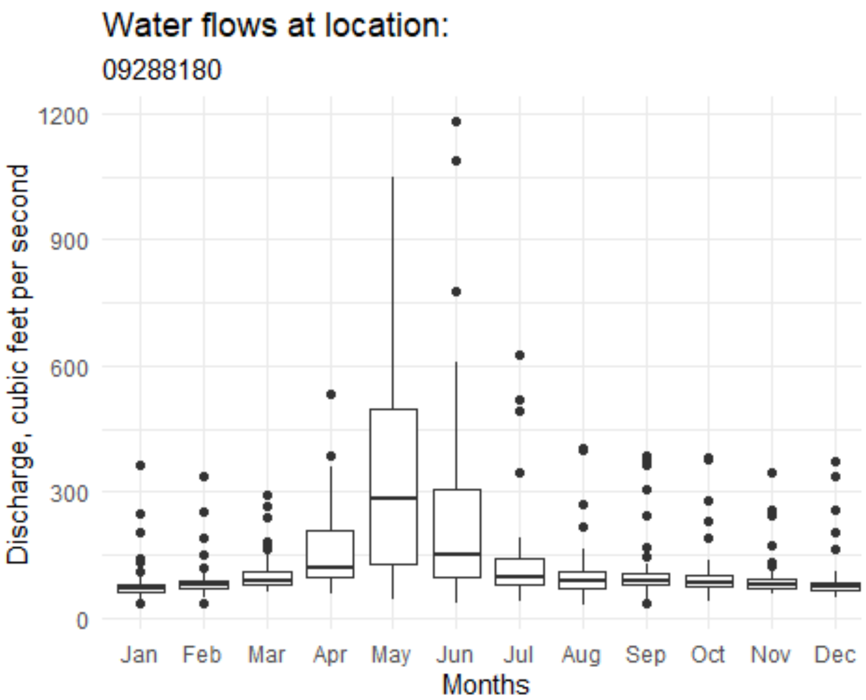


Figure B129. Monthly discharge (cf/s) at location USGS 09288180

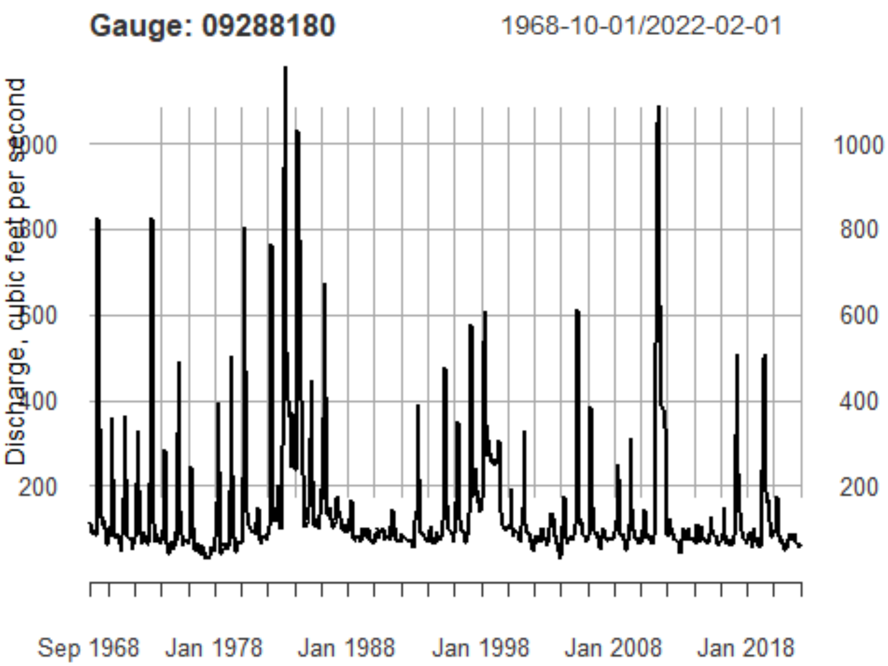


Figure B130. Discharge (cf/s) at location USGS 09288180

Table 71. Main statistics of water discharge (cf/s) at USGS 09285900

	January	February	March	April	May	June	July	August	September	October	November	December
Min.	23.5	24.9	26.8	34.1	39.4	34.9	37.6	38.0	36.1	27.3	23.1	24.9
1st Qu.	28.4	30.0	31.3	39.3	46.2	43.7	43.8	43.4	42.3	31.1	30.4	28.8
Median	31.5	32.8	32.8	42.7	48.5	49.8	47.8	46.2	44.5	35.0	33.0	30.4
Mean	37.4	33.0	36.0	56.6	96.2	83.6	64.8	61.7	59.3	48.4	43.3	42.5
3rd Qu.	35.5	35.4	34.4	46.1	148.6	85.8	61.0	53.1	48.9	40.8	36.4	36.2
Max.	162.4	48.4	108.8	279.9	361.0	381.5	309.8	322.3	297.5	295.3	267.3	277.1

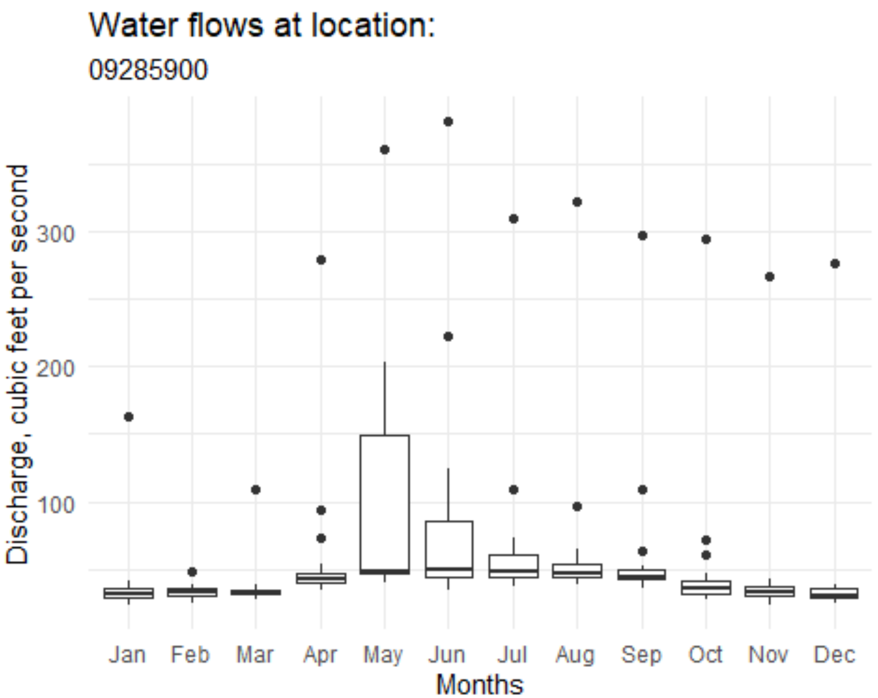


Figure B131. Monthly discharge (cf/s) at location USGS 09285900

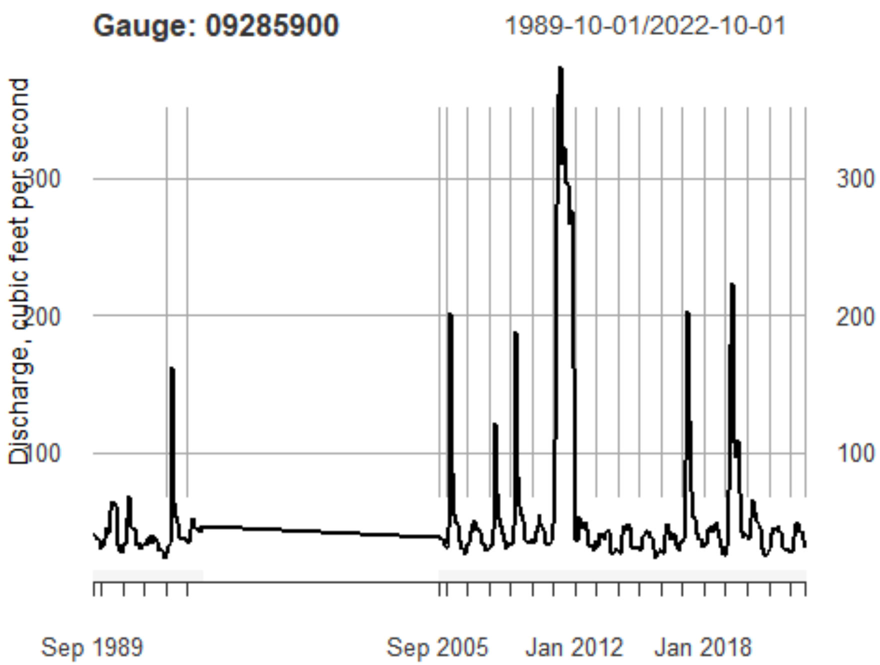


Figure B132. Discharge (cf/s) at location USGS 09285900

Table 72. Main statistics of water discharge (cf/s) at USGS 09291000

	January	February	March	April	May	June	July	August	September	October	November	December
Min.	0.0	0.0	0.0	0.0	129.6	144.0	59.3	35.6	0.0	0.0	0.0	0.0
1st Qu.	0.0	0.0	0.0	14.3	240.5	266.4	299.6	180.5	56.2	11.7	0.0	0.0
Median	0.0	0.0	0.0	41.0	278.9	353.0	334.9	252.8	120.8	28.0	0.7	0.0
Mean	2.0	2.6	3.6	49.3	293.7	376.7	338.2	235.6	127.4	39.7	8.1	1.6
3rd Qu.	1.6	2.4	3.7	74.2	329.5	419.8	377.5	301.8	182.8	51.9	6.4	1.3
Max.	28.2	44.4	72.3	202.0	555.5	919.7	770.5	410.1	325.6	201.6	134.6	17.3

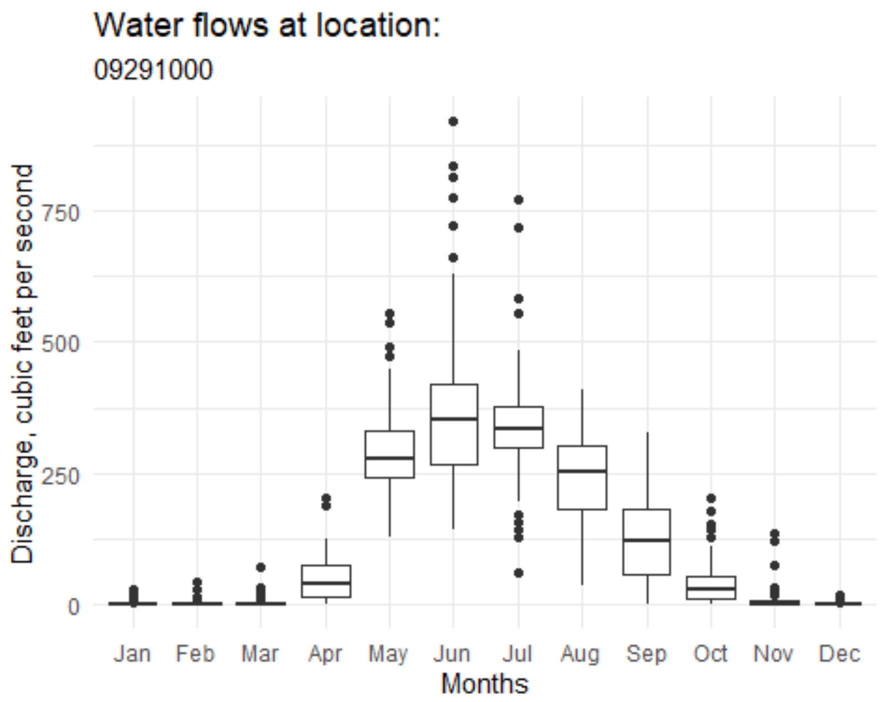


Figure B133. Monthly discharge (cf/s) at location USGS 09291000

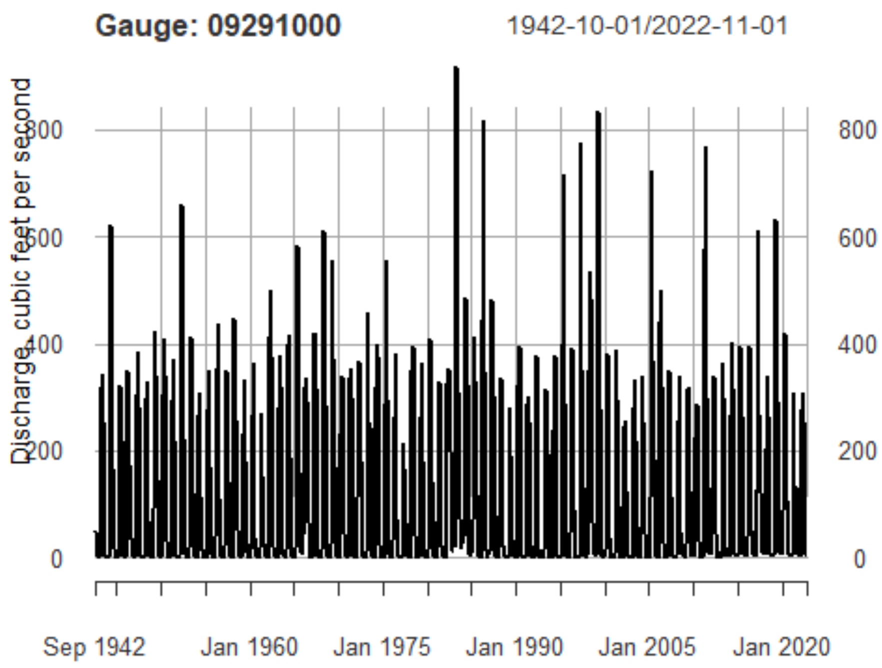


Figure B134. Discharge (cf/s) at location USGS 09291000

Table 73. Main statistics of water discharge (cf/s) at USGS 09289500

	January	February	March	April	May	June	July	August	September	October	November	December
Min.	14.8	13.6	15.0	18.6	65.9	90.0	40.0	29.8	32.1	26.3	21.1	15.0
1st Qu.	22.7	20.5	21.8	29.0	167.3	300.0	97.5	55.2	47.3	40.6	31.6	25.4
Median	25.8	23.8	24.2	40.8	255.4	436.9	131.6	73.8	56.4	45.7	37.7	30.9
Mean	26.5	24.5	26.0	42.3	261.2	495.1	198.8	86.9	66.5	53.9	39.1	30.4
3rd Qu.	30.6	28.0	29.2	53.3	332.5	679.7	254.9	114.8	76.2	59.8	44.5	34.1
Max.	40.1	39.5	55.1	96.9	578.2	946.1	825.7	212.4	174.2	142.3	80.1	61.3

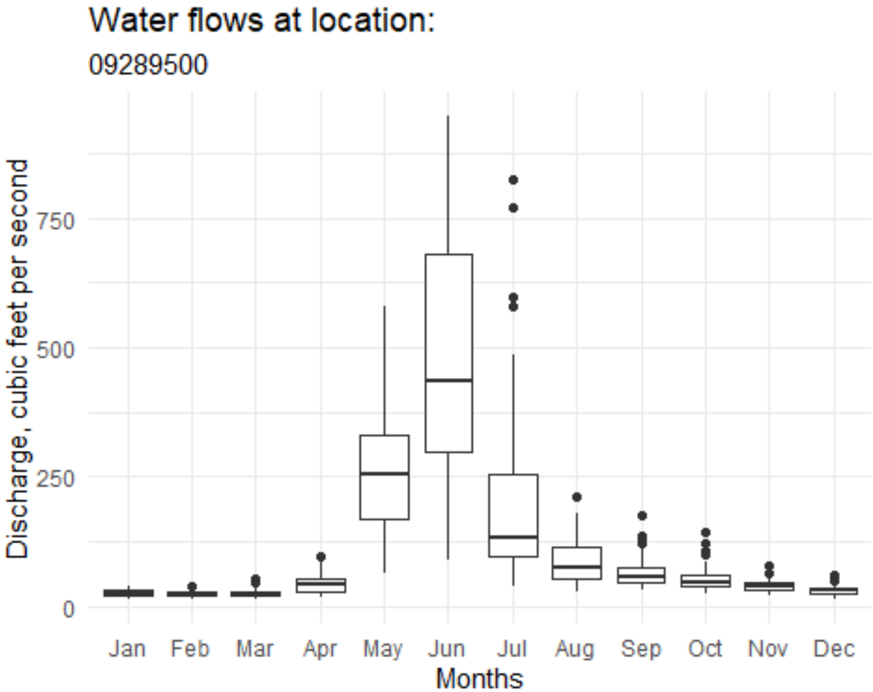


Figure B135. Monthly discharge (cf/s) at location USGS 09289500

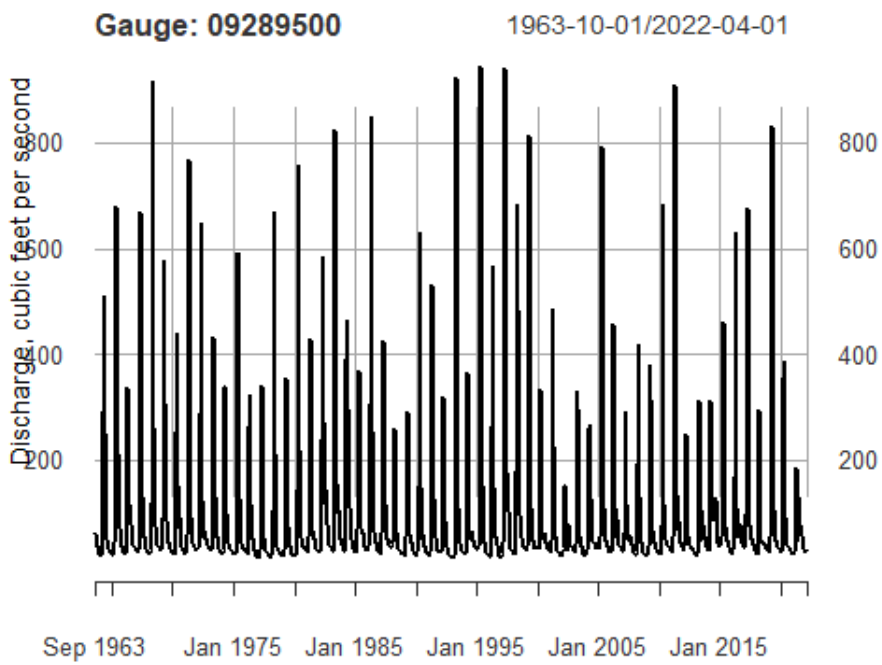


Figure B136. Discharge (cf/s) at location USGS 09289500

Table 74. Main statistics of water discharge (cf/s) at USGS 09310500

	January	February	March	April	May	June	July	August	September	October	November	December
Min.	3.3	3.1	5.0	11.5	23.5	7.9	3.3	3.1	0.4	5.3	2.8	2.9
1st Qu.	6.5	6.6	8.8	32.5	147.0	41.2	14.8	8.5	7.4	8.2	7.9	6.6
Median	8.0	8.0	10.8	52.5	233.5	93.7	25.0	13.6	9.9	10.1	10.1	8.6
Mean	8.4	8.8	12.9	59.4	249.9	128.6	27.7	13.7	10.3	11.0	10.6	9.0
3rd Qu.	9.5	10.0	15.3	74.4	324.4	150.0	35.0	17.7	12.7	12.4	12.2	10.0
Max.	20.3	21.2	42.7	167.2	680.6	731.4	99.6	37.5	27.0	26.7	28.8	19.3

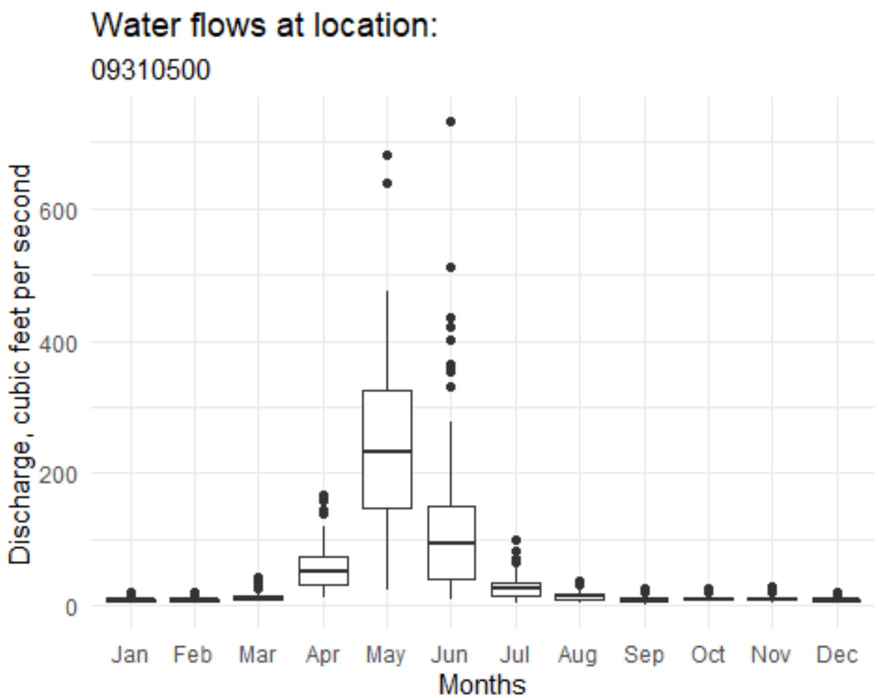


Figure B137. Monthly discharge (cf/s) at location USGS 09310500

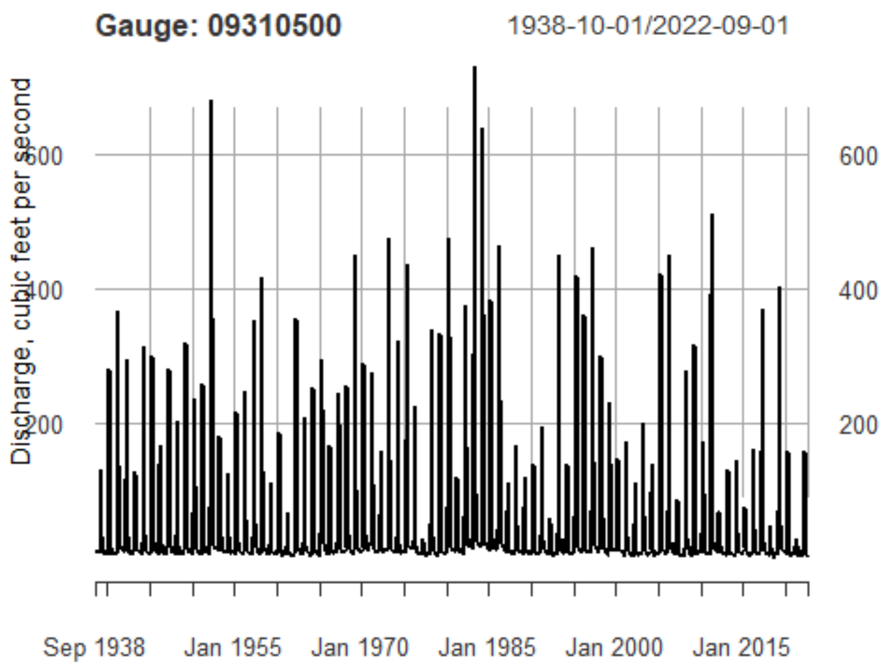


Figure B138. Discharge (cf/s) at location USGS 09310500

Table 75. Main statistics of water discharge (cf/s) at USGS 09310700

	January	February	March	April	May	June	July	August	September	October	November	December
Min.	2.0	3.0	4.3	9.0	9.2	6.3	3.4	2.9	2.0	2.7	3.4	2.8
1st Qu.	5.9	5.9	8.1	13.3	26.2	16.6	9.6	6.8	7.6	7.3	6.7	5.6
Median	8.6	8.8	10.3	18.1	41.4	28.3	13.6	10.3	10.6	10.3	9.6	8.9
Mean	9.2	9.5	11.4	18.7	53.3	41.3	13.9	10.1	10.3	10.5	10.3	9.6
3rd Qu.	12.5	13.1	14.5	21.4	74.8	51.5	19.0	13.0	12.6	12.9	12.9	12.6
Max.	21.1	22.6	26.7	40.7	141.5	134.3	30.8	20.9	22.9	21.0	22.9	22.2

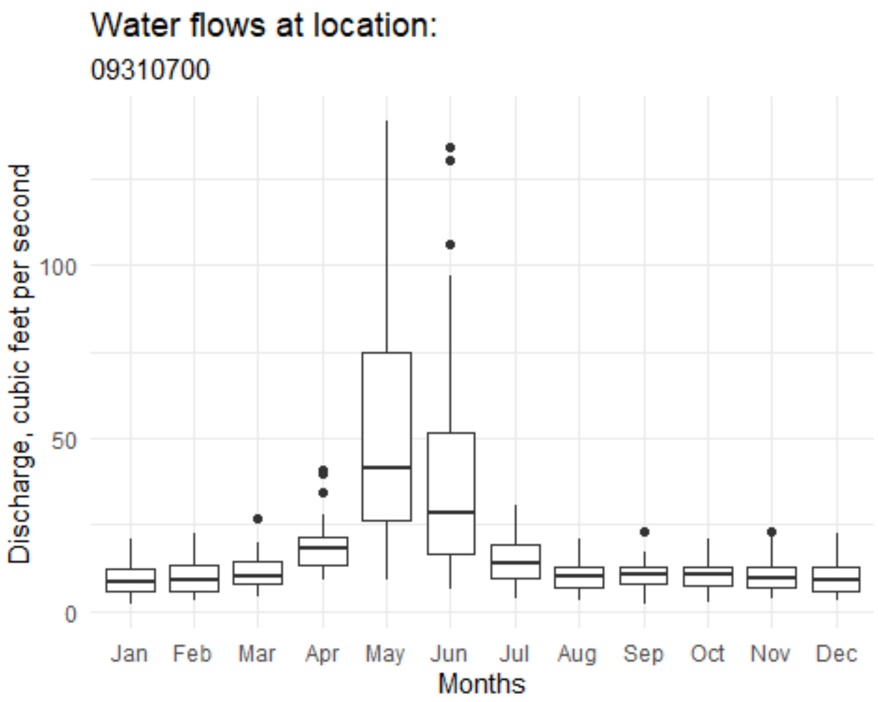


Figure B139. Monthly discharge (cf/s) at location USGS 09310700

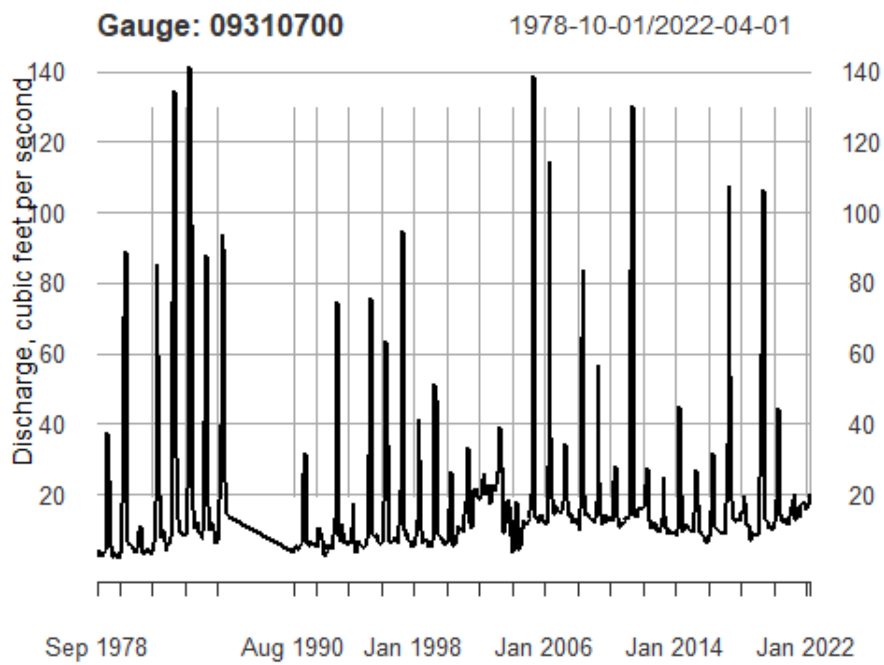


Figure B140. Discharge (cf/s) at location USGS 09310700

Table 76. Main statistics of water discharge (cf/s) at USGS 09312600

	January	February	March	April	May	June	July	August	September	October	November	December
Min.	0.2	0.5	2.6	4.6	3.5	0.7	0.0	0.0	0.0	0.8	0.8	1.1
1st Qu.	2.3	3.2	6.7	25.2	32.5	12.2	3.8	1.7	2.2	3.0	3.0	2.6
Median	3.4	3.9	9.8	43.9	96.6	33.7	12.0	4.8	3.6	4.3	4.6	3.9
Mean	3.6	4.4	12.7	56.8	130.9	43.8	12.3	5.6	4.1	4.9	4.6	3.9
3rd Qu.	4.9	5.2	13.6	81.2	206.4	61.0	17.0	7.8	5.4	6.7	5.9	5.1
Max.	7.7	20.3	55.0	168.9	415.7	209.1	41.1	22.8	11.7	11.9	9.9	8.2

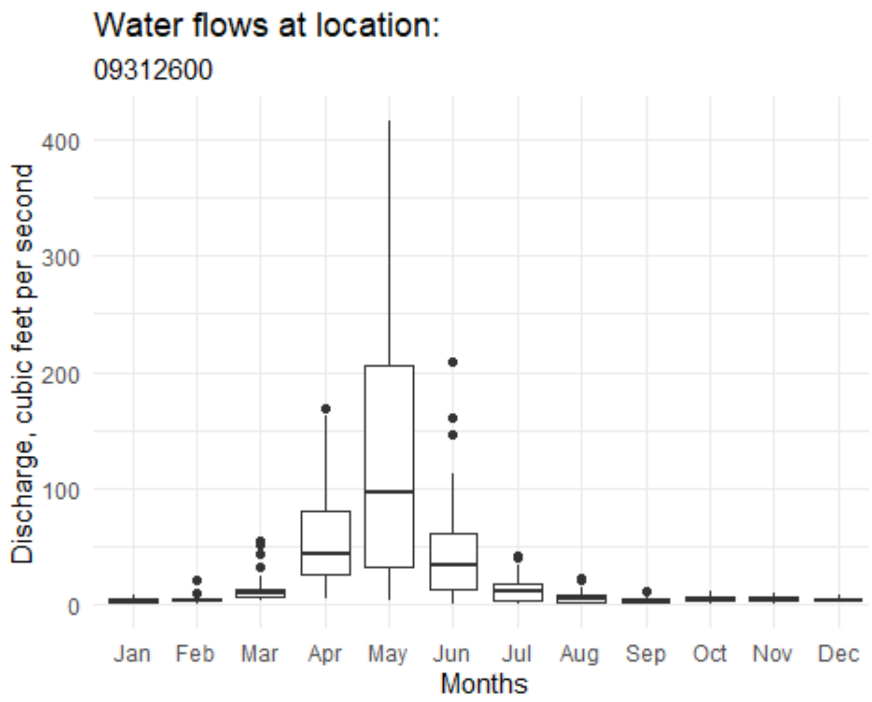


Figure B141. Monthly discharge (cf/s) at location USGS 09312600

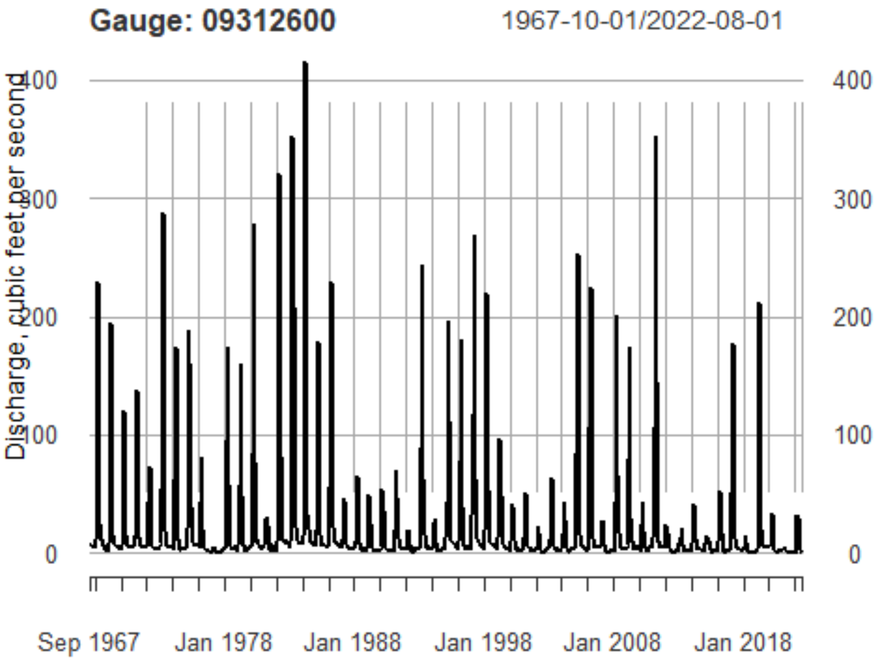
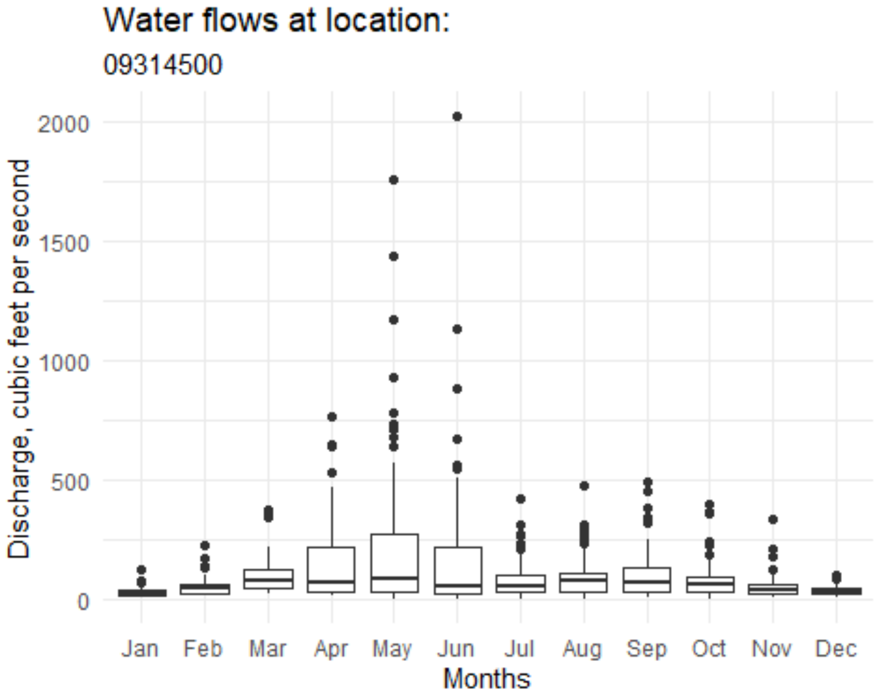


Figure B142. Discharge (cf/s) at location USGS 09312600

Table 77. Main statistics of water discharge (cf/s) at USGS 09314500

	January	February	March	April	May	June	July	August	September	October	November	December
Min.	10.3	16.8	22.3	13.6	5.3	1.5	4.2	3.9	5.7	2.4	12.3	9.3
1st Qu.	19.9	28.9	45.2	34.6	36.8	25.3	32.1	35.0	32.7	33.9	28.1	23.8
Median	28.8	46.3	77.2	72.7	90.0	58.0	53.0	77.9	69.4	65.3	43.5	33.4
Mean	32.7	54.3	99.3	159.5	245.0	183.1	83.0	97.4	104.8	87.0	56.2	36.8
3rd Qu.	38.9	62.0	124.6	223.1	277.4	222.7	104.1	113.0	133.9	95.8	64.2	46.1
Max.	128.8	226.9	375.0	768.3	1762.0	2023.0	426.5	477.7	494.1	399.1	337.0	100.7



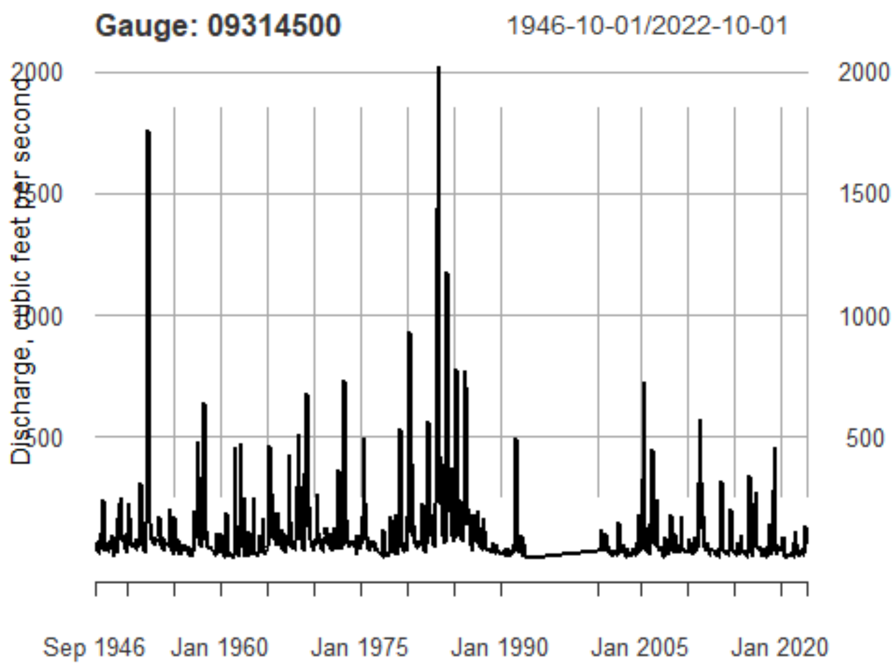


Figure B143. Monthly discharge (cf/s) at location USGS 09314500 Figure B144. Discharge (cf/s) at location USGS 09314500

Table 78. Main statistics of water discharge (cf/s) at USGS 09315000

	January	February	March	April	May	June	July	August	September	October	November	December
Min.	960.8	1050.0	1617	2122.0	4212.0	2128.0	645.0	711.8	603.1	717.7	934.8	801.5
1st Qu.	1555.0	1937.8	3178	4639.0	10365.0	11005.0	3271.5	2072.5	1765.5	2034.0	2052.2	1535.0
Median	2013.0	2354.5	3982	6287.0	13770.0	17120.0	6126.0	2978.0	2537.0	2853.0	2674.5	2065.5
Mean	2331.5	2812.6	4371	6974.9	14918.6	17886.2	7383.6	3453.3	2751.7	2976.3	2842.6	2358.8
3rd Qu.	2965.5	3381.8	5228	8791.5	19025.0	22625.0	9623.5	4340.0	3202.5	3712.5	3352.0	2821.8
Max.	5739.0	7258.0	11430	18370.0	40990.0	46650.0	31630.0	11220.0	9960.0	7701.0	6490.0	5894.0

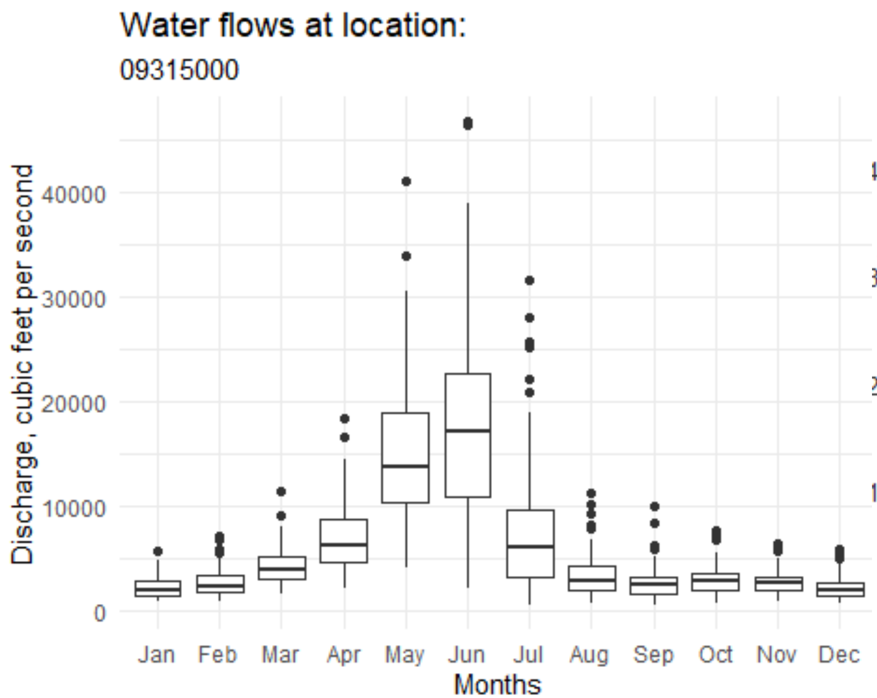


Figure B145. Monthly discharge (cf/s) at location USGS 09315000

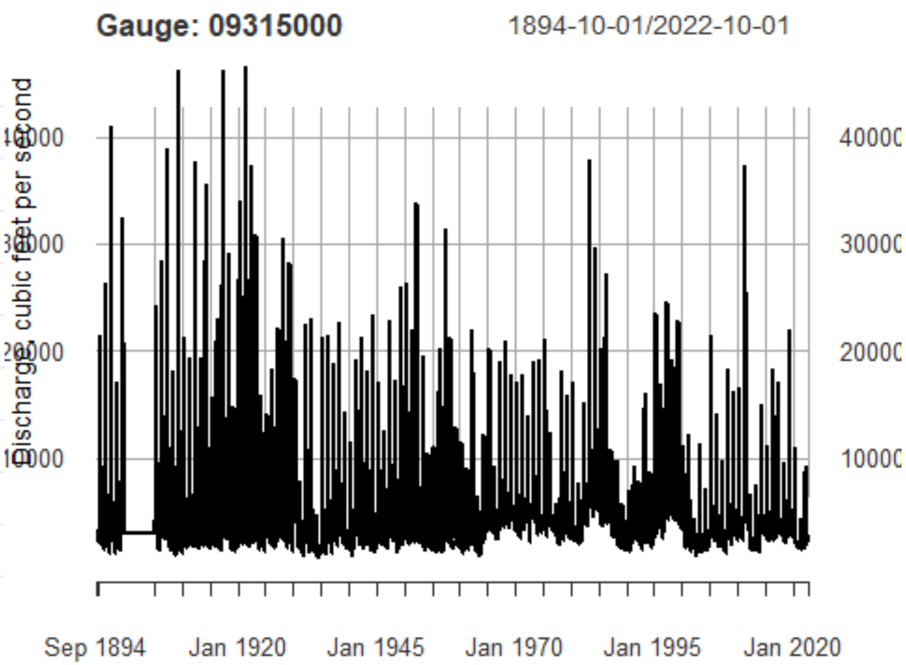


Figure B146. Discharge (cf/s) at location USGS 09315000

Table 79. Main statistics of water discharge (cf/s) at USGS 09328910

	January	February	March	April	May	June	July	August	September	October	November	December
Min.	7.6	13.4	22.0	8.2	2.3	0.0	0.8	0.4	0.0	0.0	1.5	4.2
1st Qu.	11.8	19.9	23.0	16.8	16.8	2.8	3.8	4.3	1.7	13.9	13.5	11.0
Median	13.9	25.1	24.3	33.5	68.3	53.8	19.3	23.0	20.2	27.1	24.9	14.9
Mean	18.1	33.3	43.9	67.0	147.7	212.1	71.4	26.9	31.0	57.5	21.0	17.8
3rd Qu.	21.0	49.2	49.6	106.7	289.7	408.7	79.8	35.5	34.8	98.4	29.3	16.2
Max.	39.7	56.2	116.0	184.7	384.4	651.9	312.9	84.8	124.0	150.3	35.1	50.6

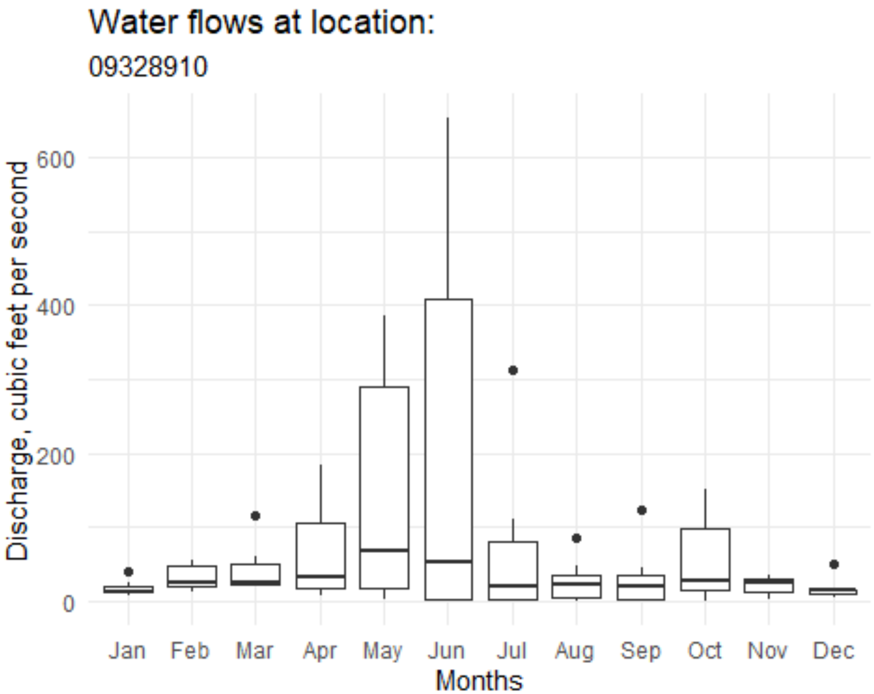


Figure B147. Monthly discharge (cf/s) at location USGS 09328910

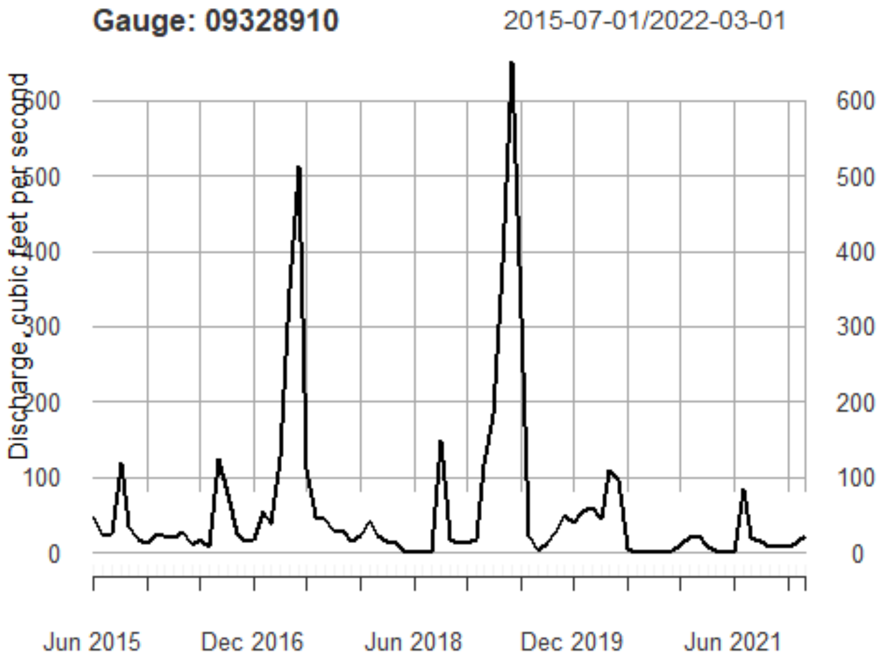


Figure B148. Discharge (cf/s) at location USGS 09328910

Table 80. Main statistics of water discharge (cf/s) at USGS 09337500

	January	February	March	April	May	June	July	August	September	October	November	December
Min.	1.0	1.2	0.7	0.7	0.2	0.3	0.3	0.3	0.4	0.4	0.8	0.8
1st Qu.	3.1	3.7	5.0	2.5	1.8	1.0	2.0	2.5	1.7	2.6	3.2	2.7
Median	5.3	8.0	9.3	6.0	6.4	3.0	5.0	6.2	4.1	4.8	5.6	4.4
Mean	7.4	9.3	11.3	11.2	19.5	17.3	6.4	8.5	7.6	7.6	6.4	6.4
3rd Qu.	11.1	13.8	16.8	18.2	28.5	14.0	7.5	12.2	7.6	9.3	8.1	9.5
Max.	26.4	23.8	39.7	54.8	124.4	175.3	31.1	30.8	75.6	38.4	27.3	18.1

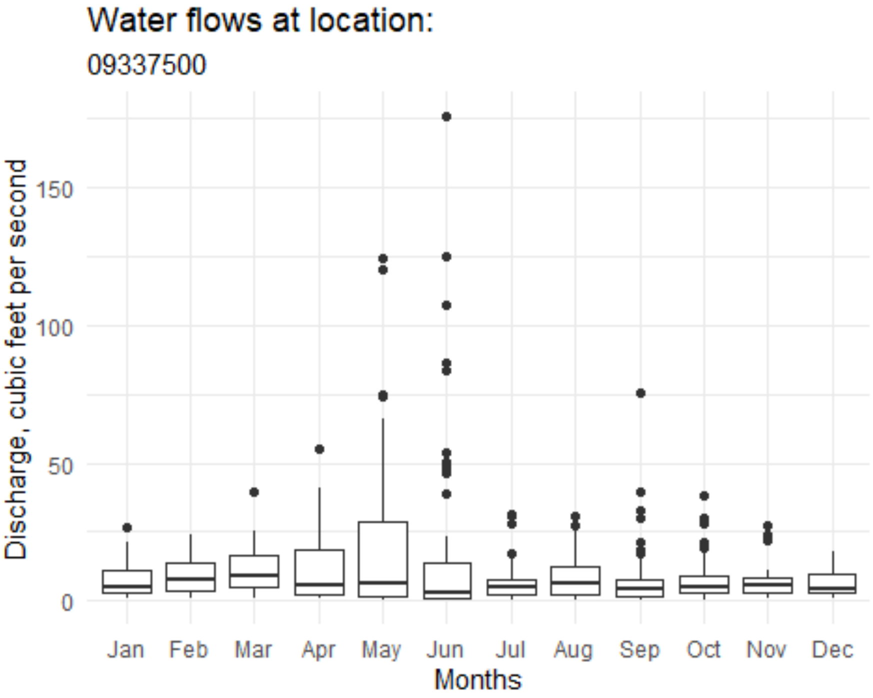


Figure B149. Monthly discharge (cf/s) at location USGS 09337500

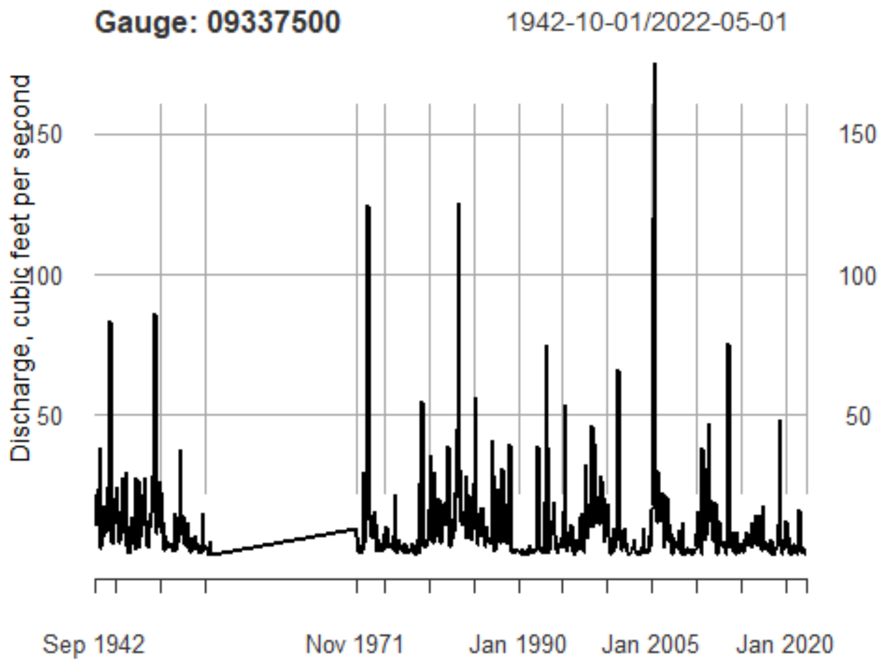
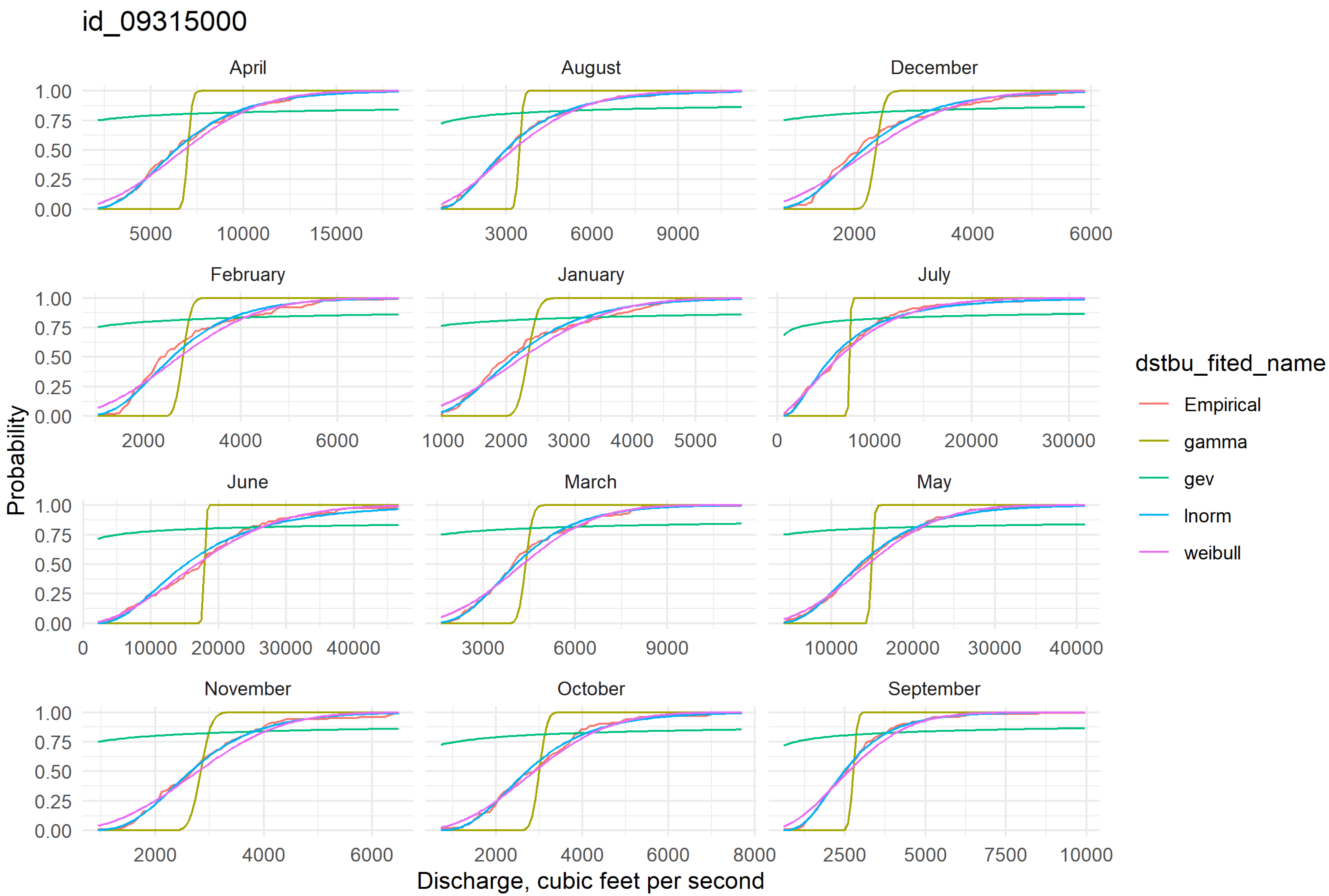


Figure B150. Discharge (cf/s) at location USGS 09337500

12.2. Distribution functions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August
December
February
January
July
June
March
May
November
October
September
Probability
Discharge, cubic feet per second
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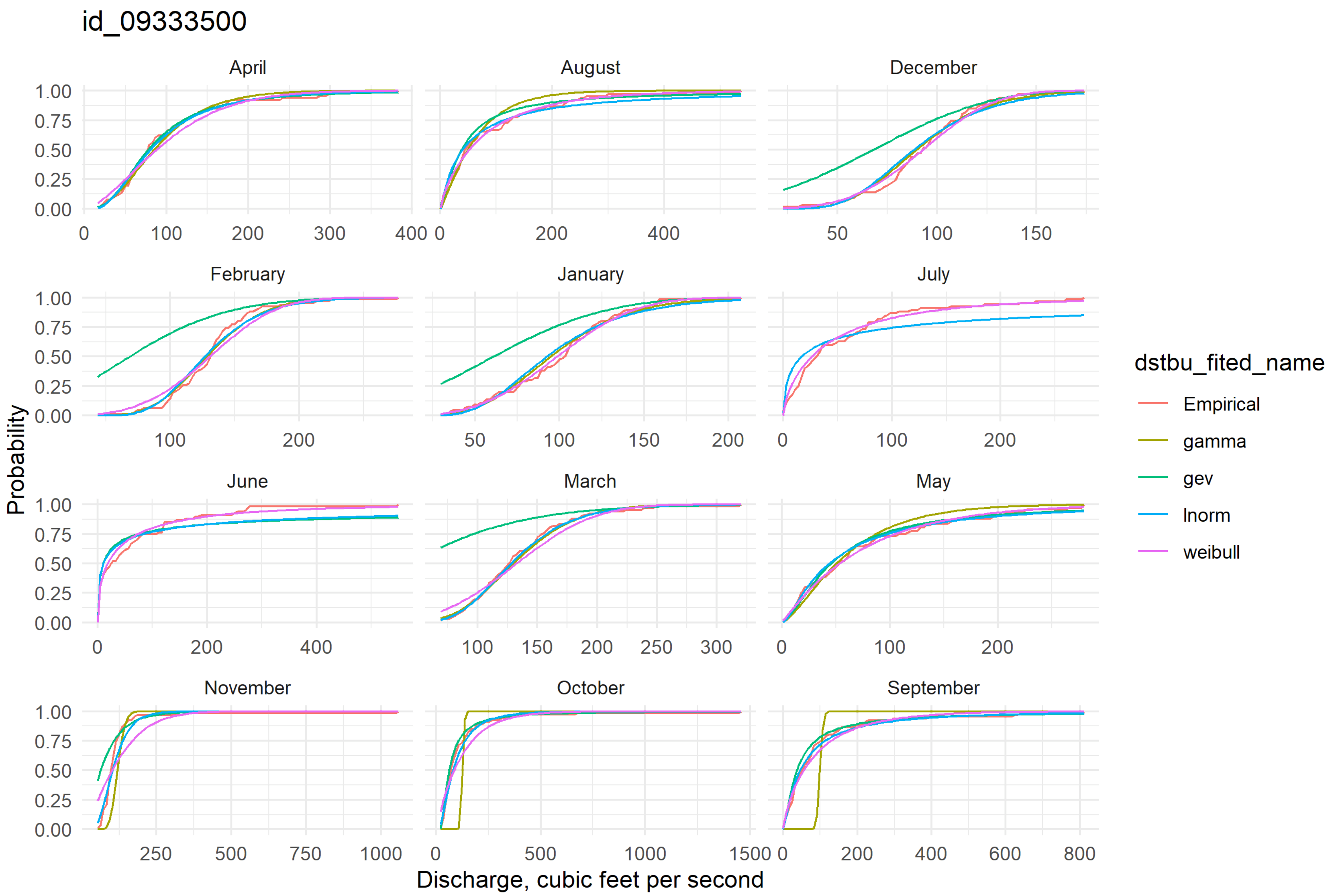
gamma
gev
lnorm
weibull



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April
August
December
February
January
July
June
March
May
November
October
September
Probability
Discharge, cubic feet per second
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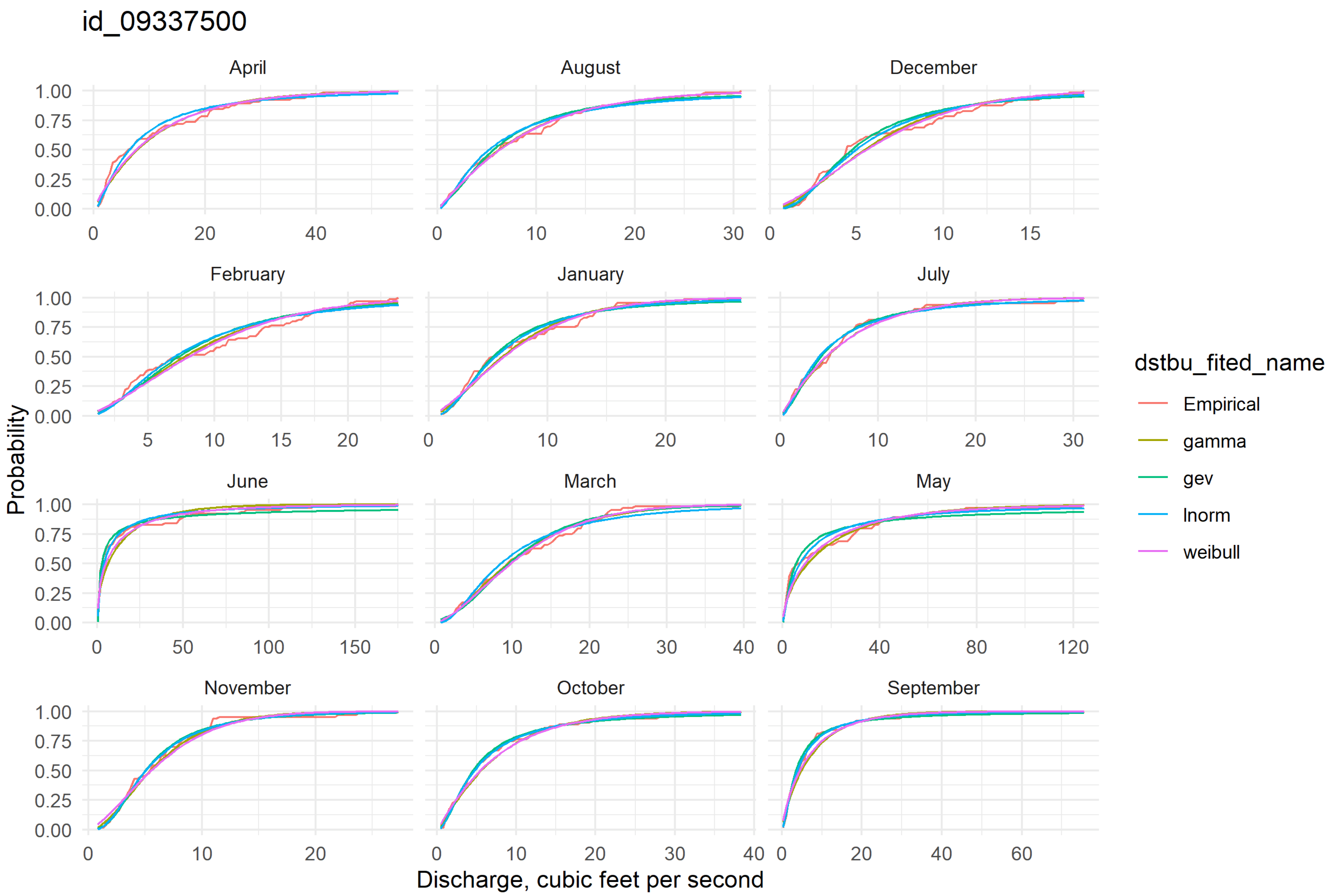
gamma
gev
lnorm
weibull



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April
August
December
February
January
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June
March
May
November
October
September
Probability
Discharge, cubic feet per second
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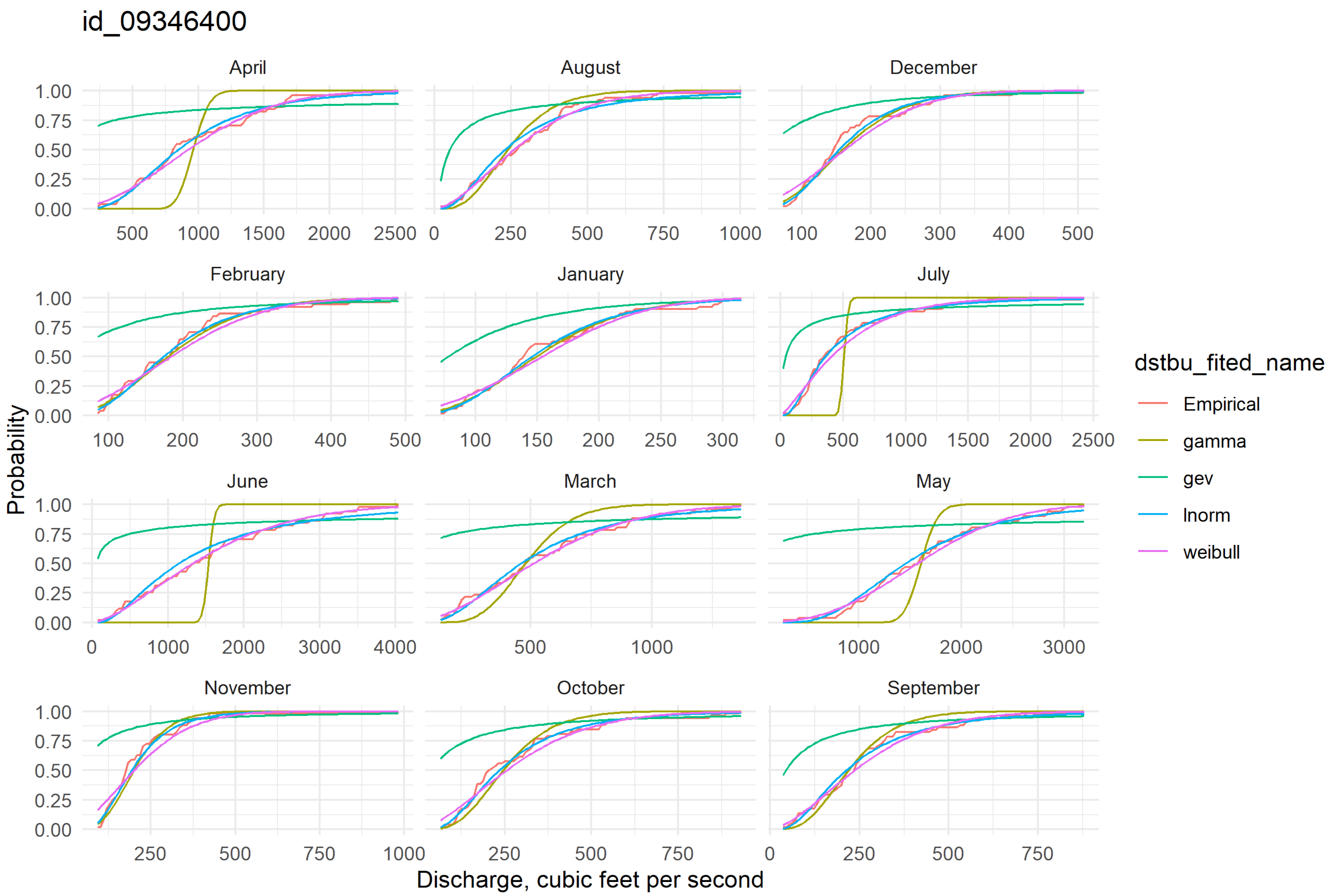
gamma
gev
lnorm
weibull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October
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Probability
Discharge, cubic feet per second
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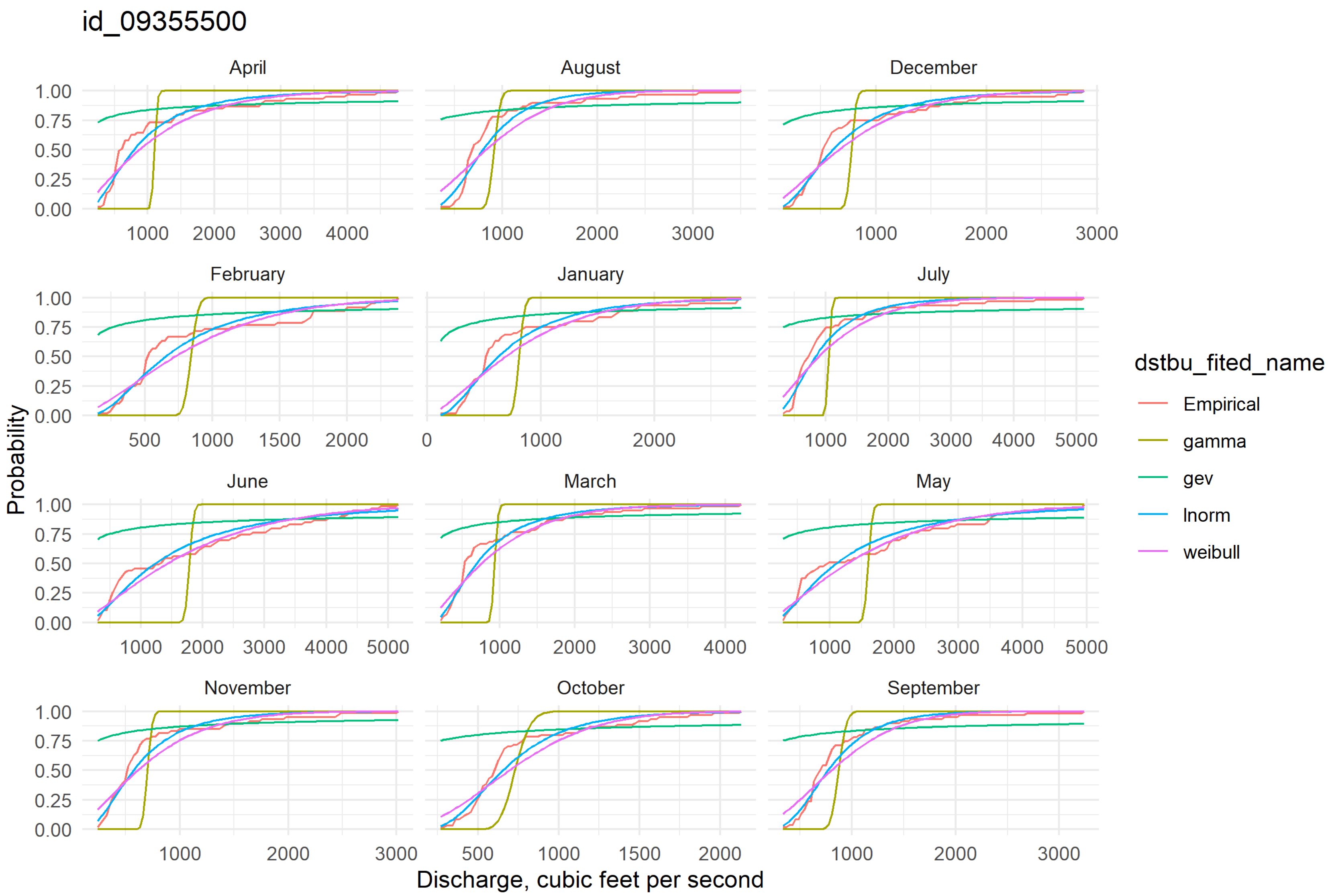
gamma
gev
lnorm
weibull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Probability
Discharge, cubic feet per second
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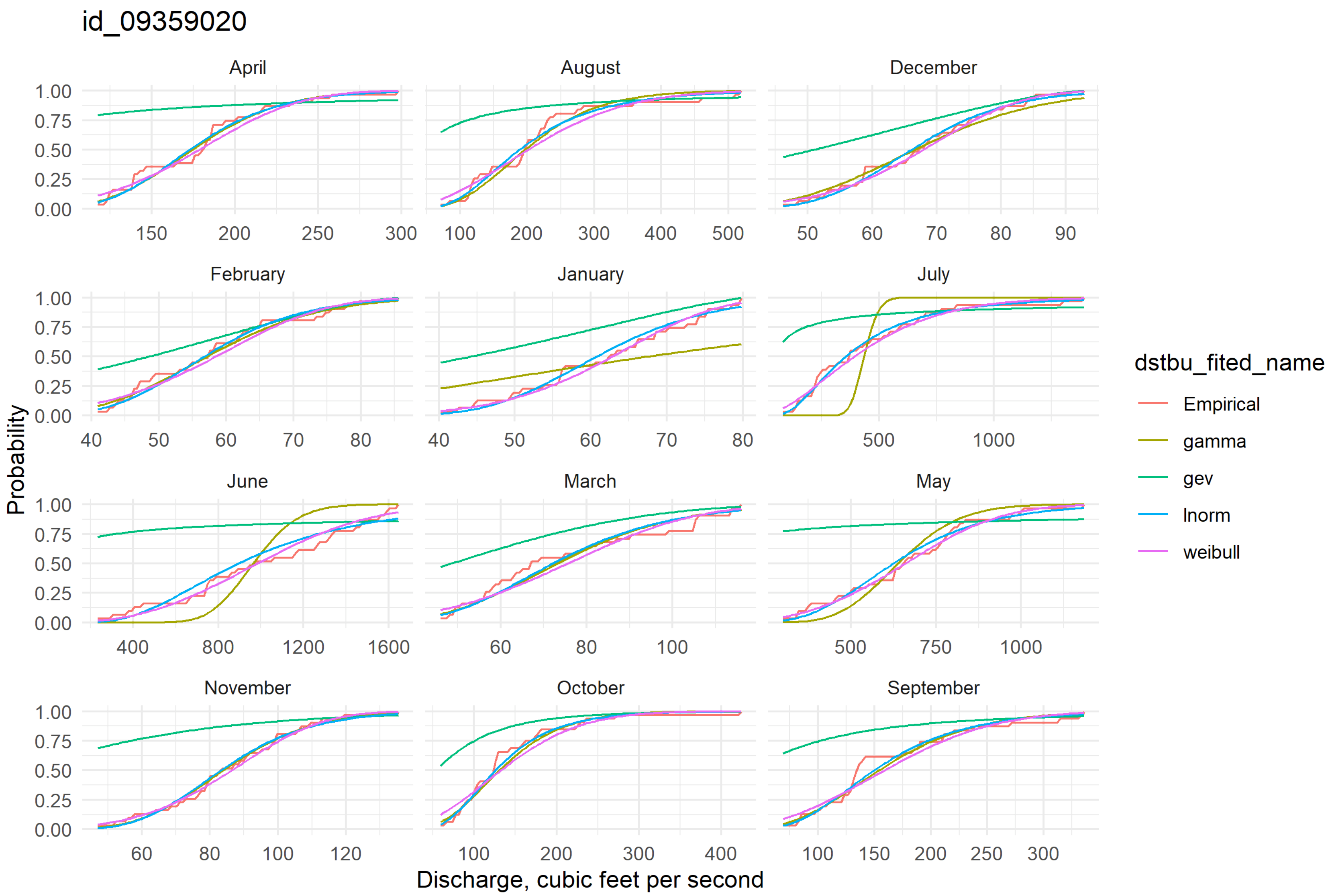
lnorm
weibull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Probability
Discharge, cubic feet per second
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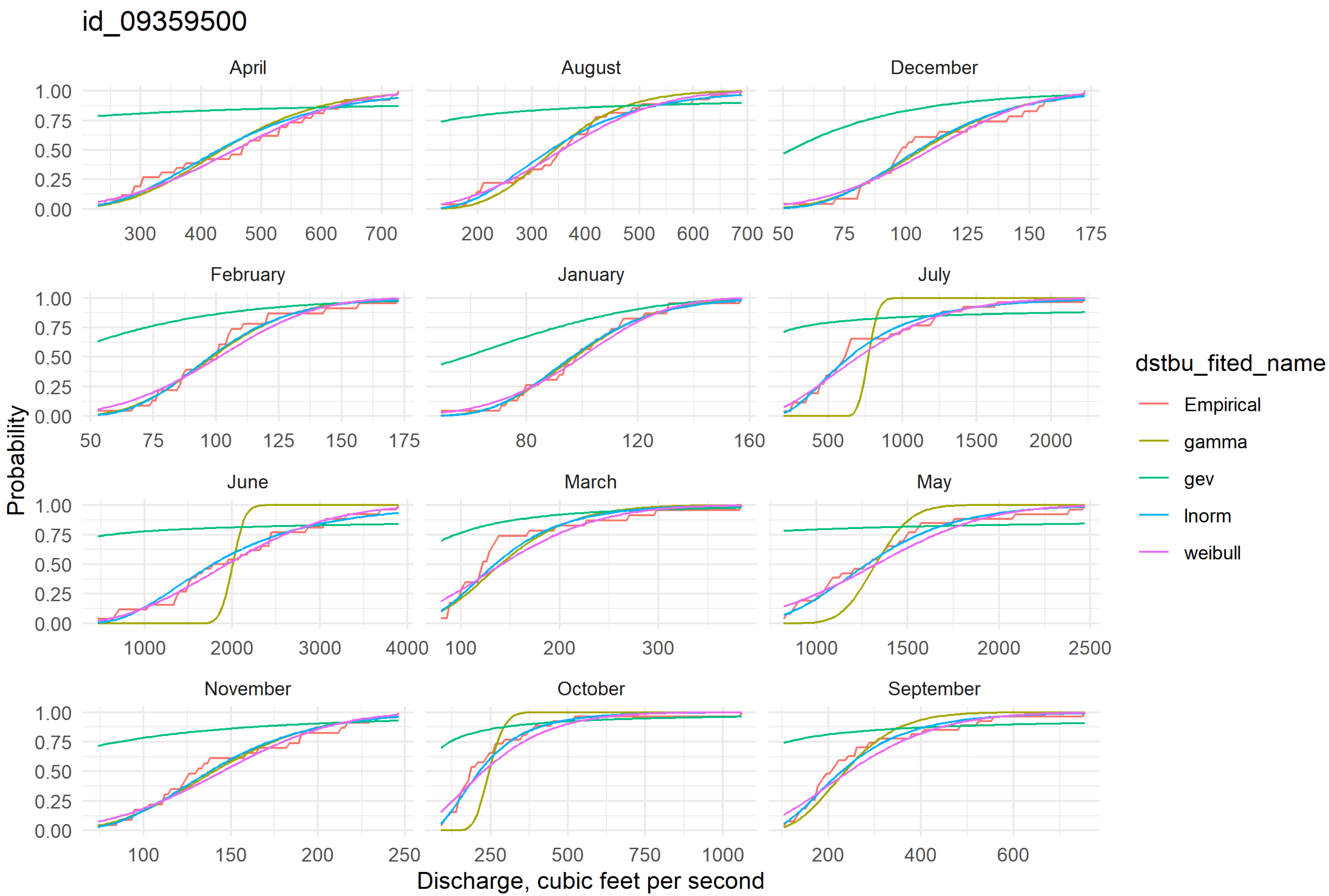
lnorm
weibull



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October
September
Probability
Discharge, cubic feet per second
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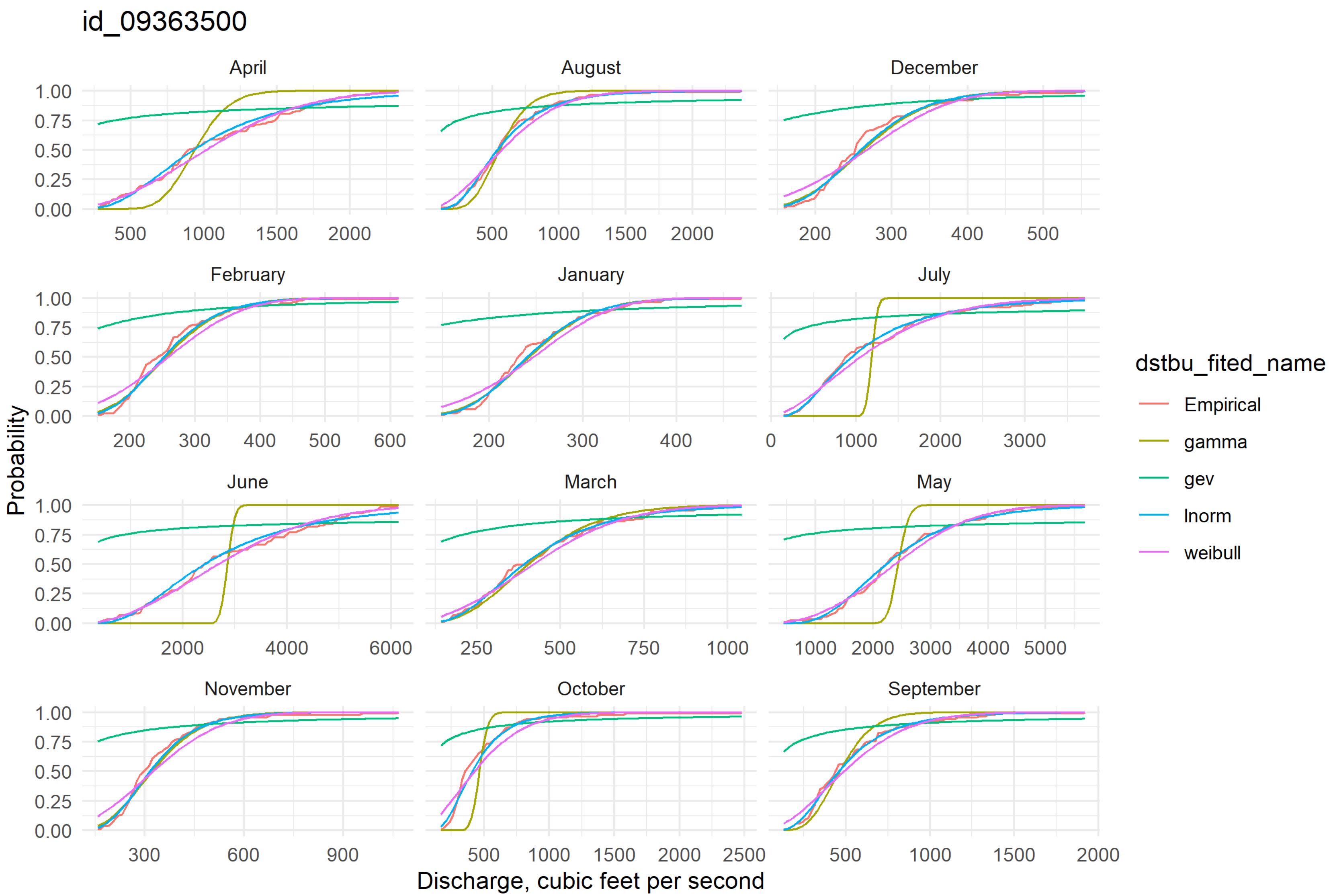
gamma
gev
lnorm
weibull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Probability
Discharge, cubic feet per second
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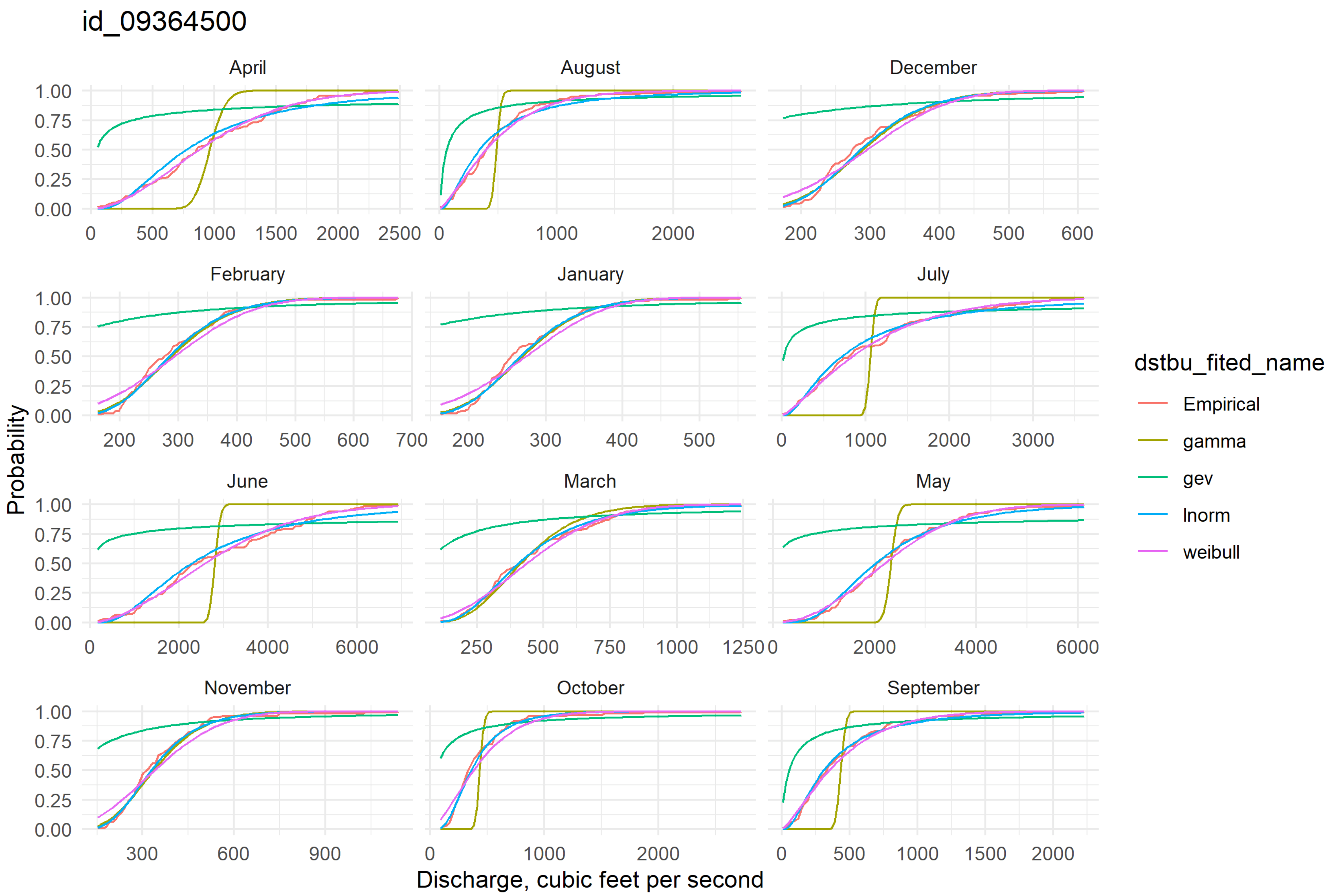
gamma
gev
lnorm
weibull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Probability
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lnorm
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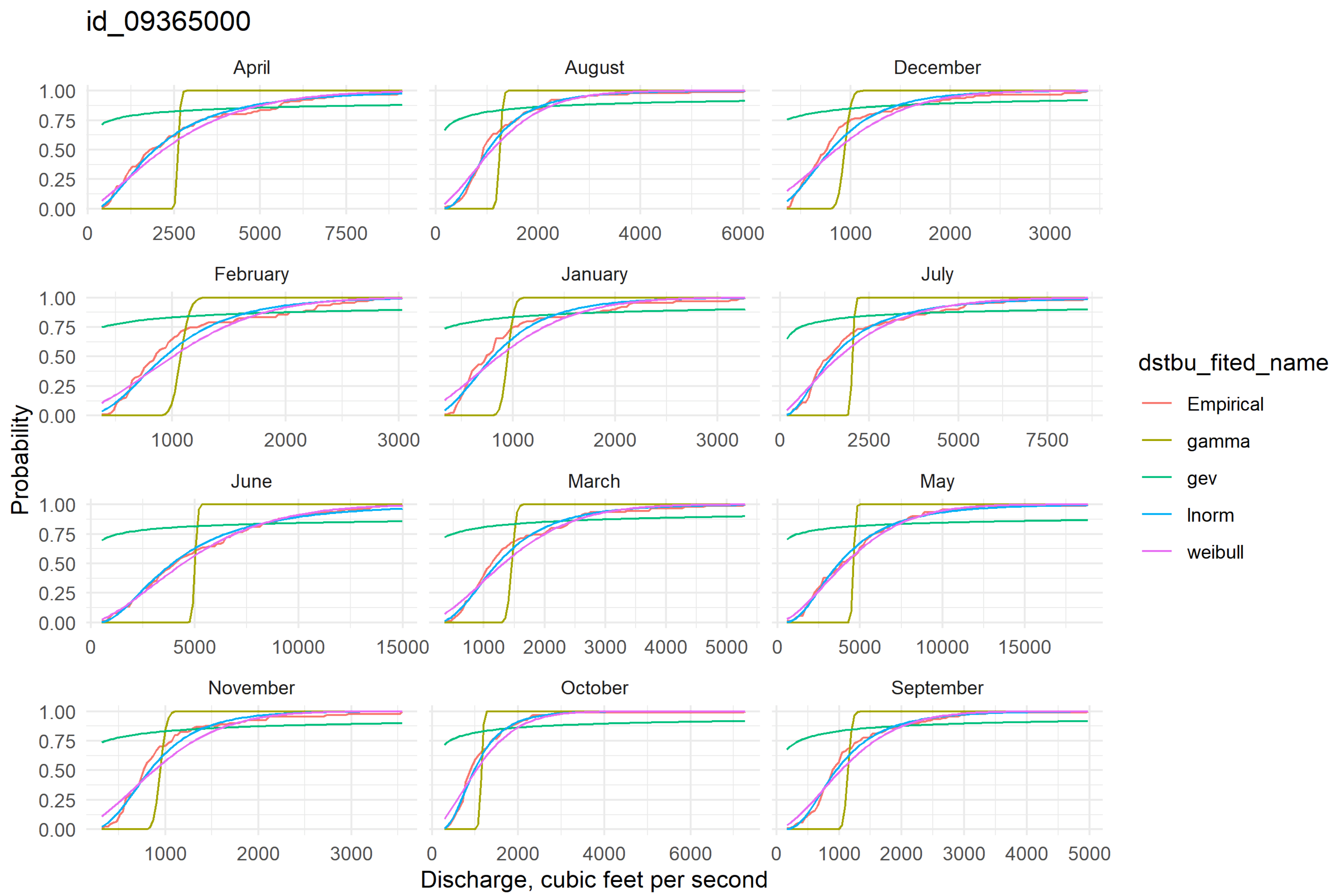
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Probability
Discharge, cubic feet per second
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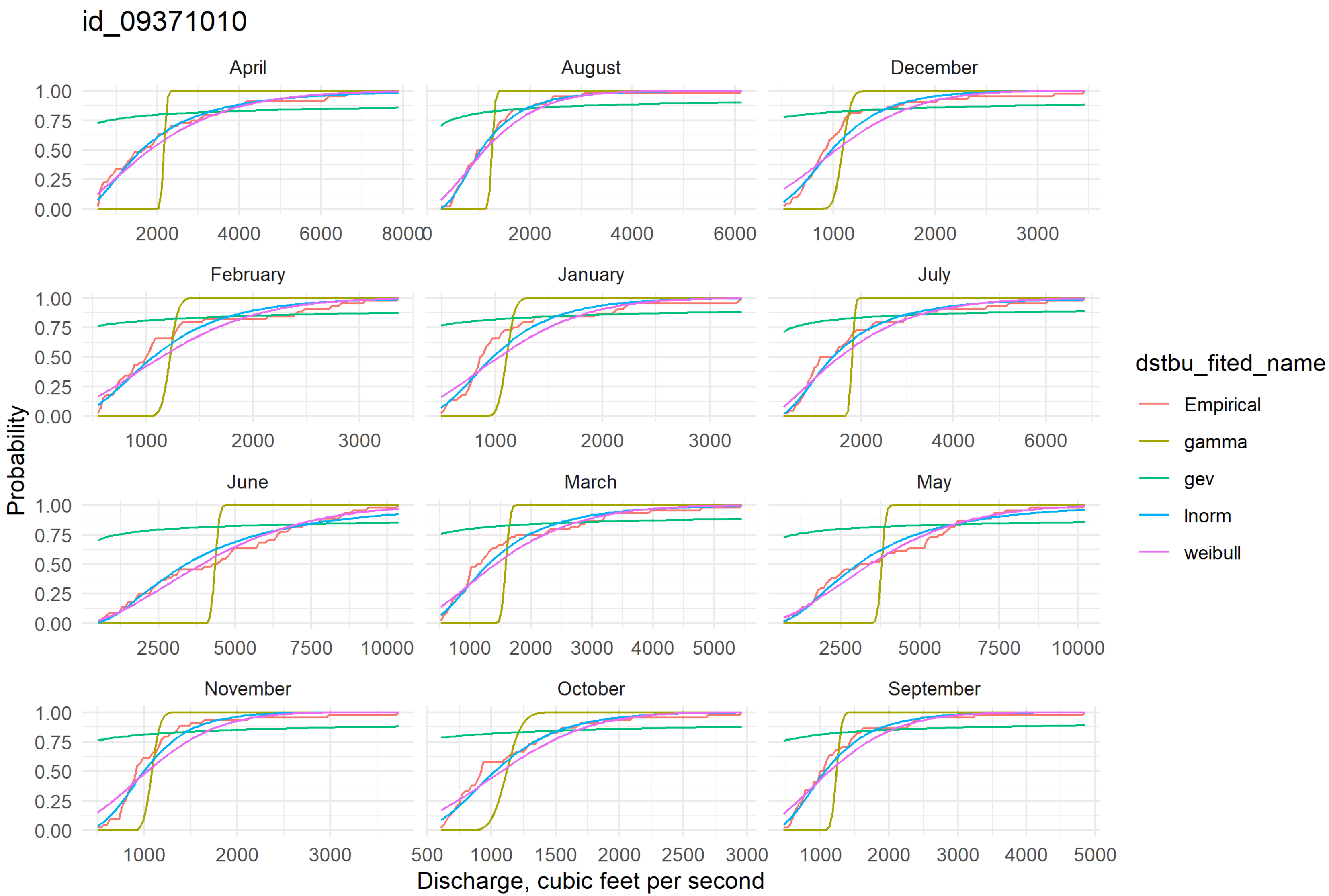
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lnorm
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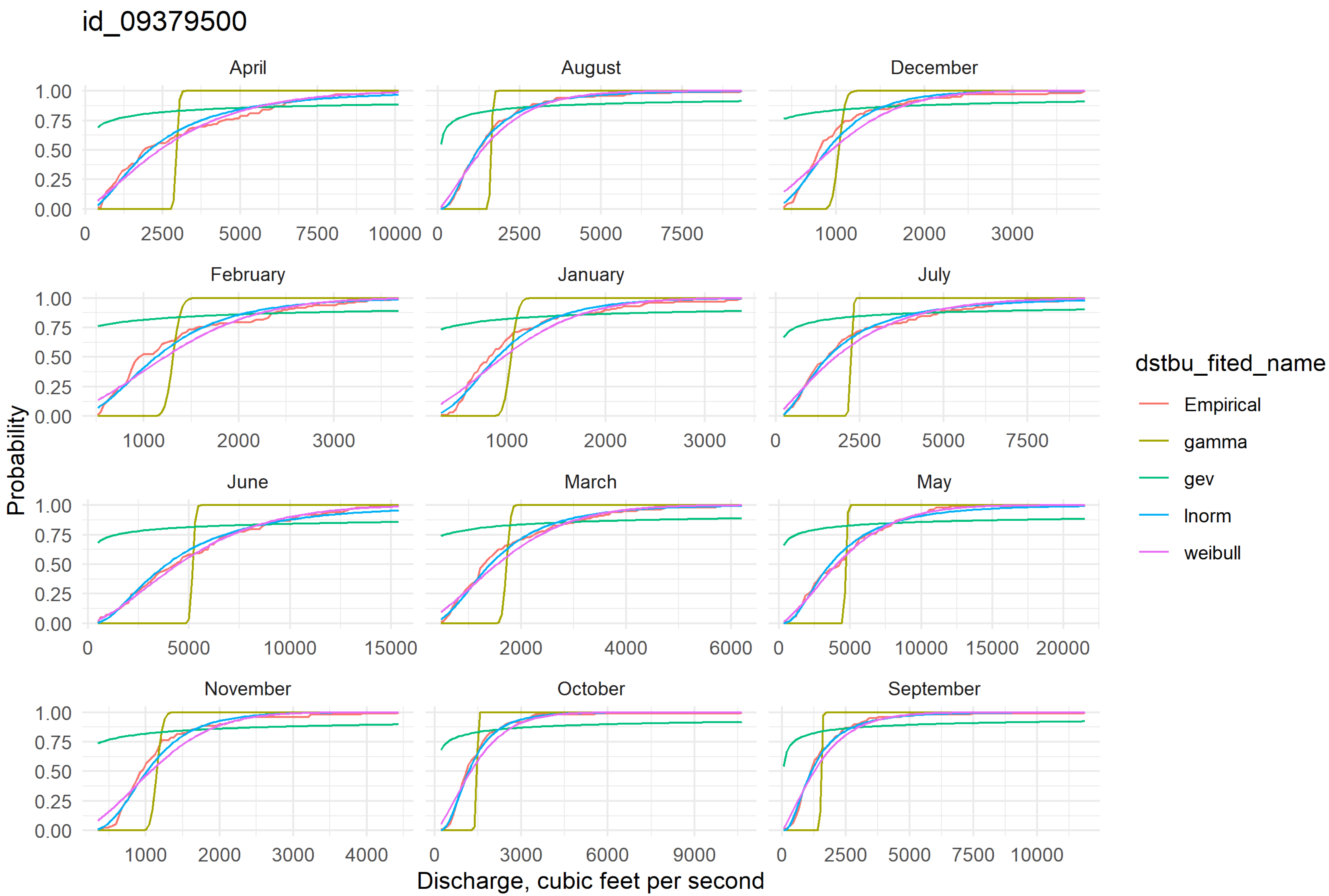

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Probability
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gev
lnorm
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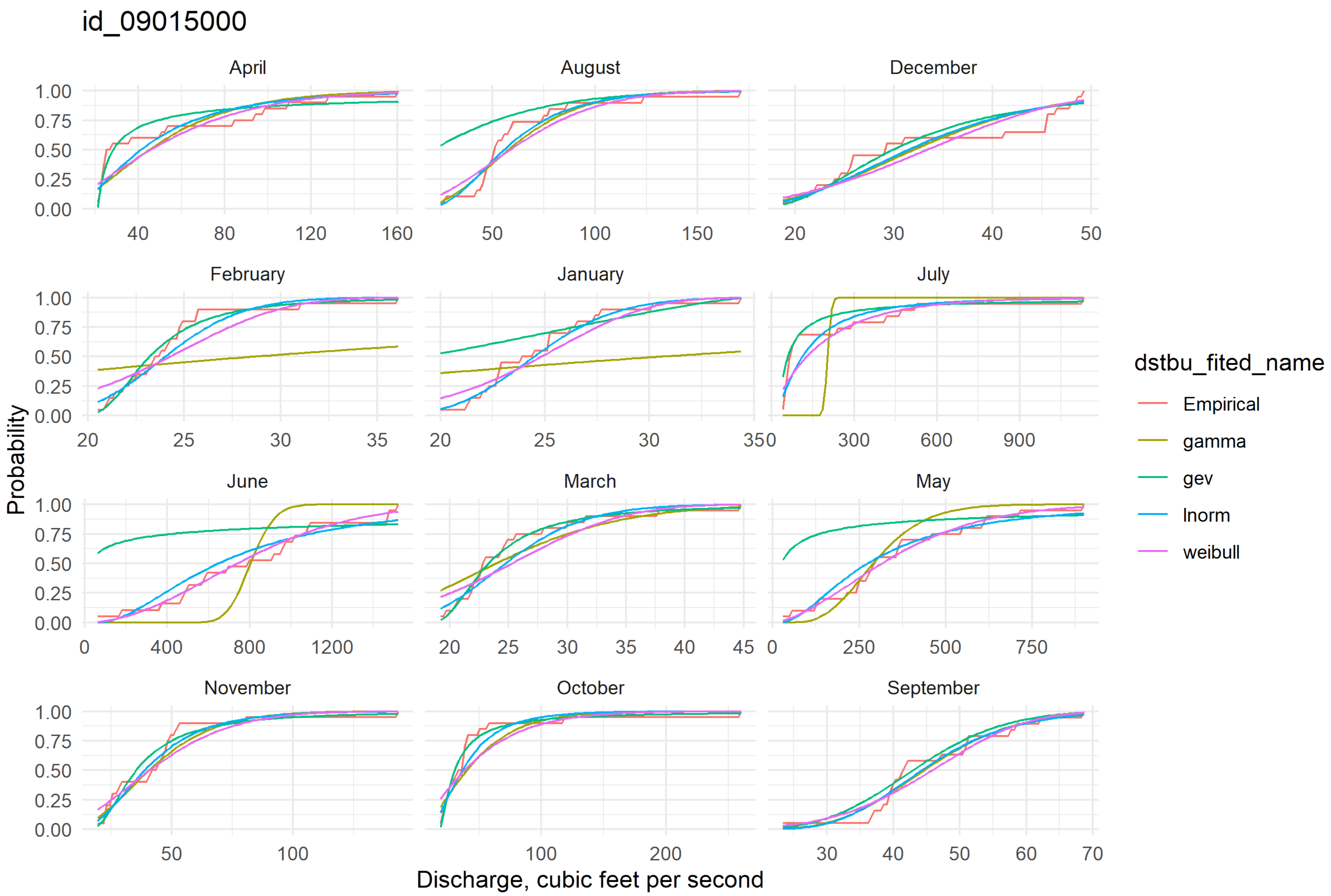
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Probability
Discharge, cubic feet per second
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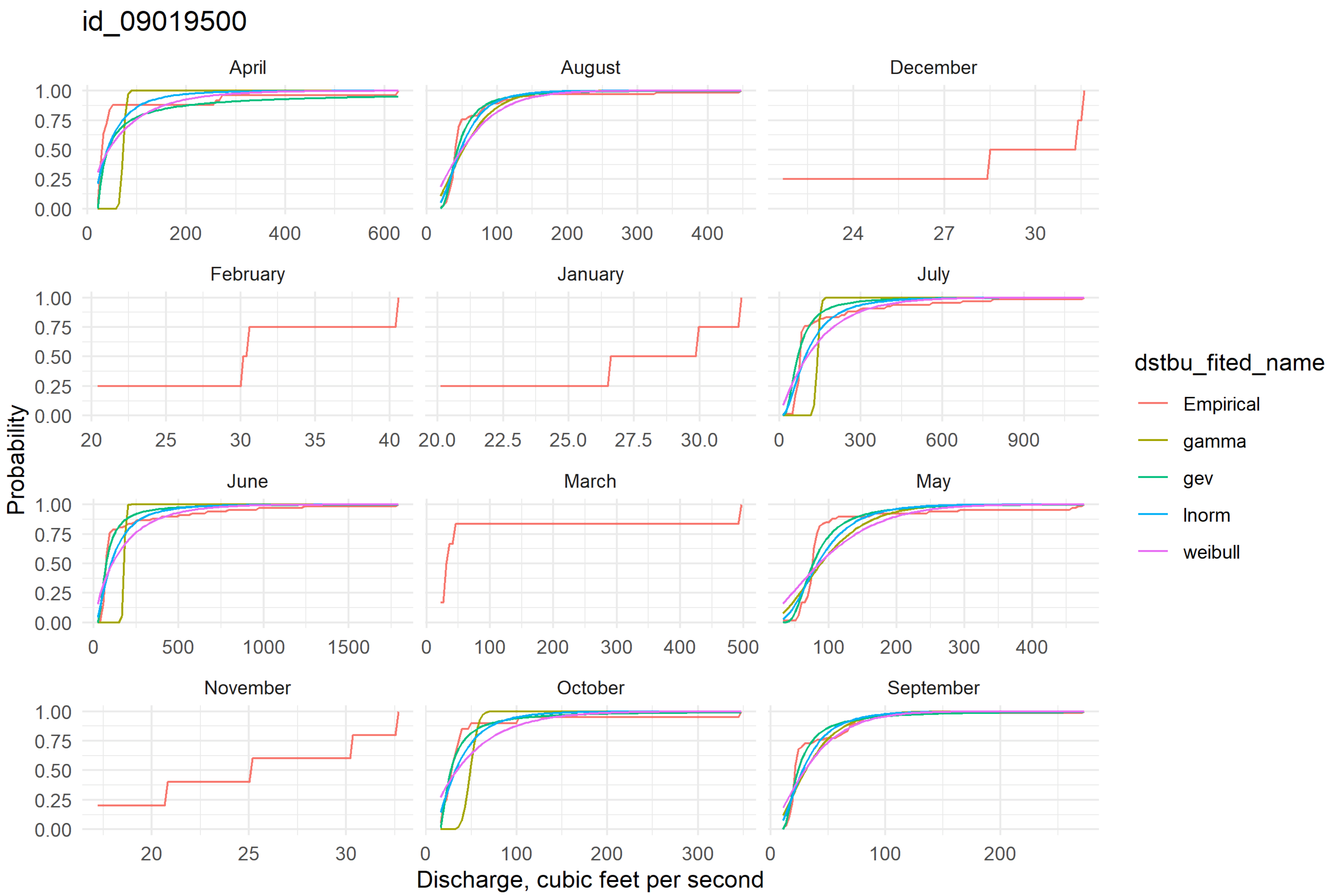
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Probability
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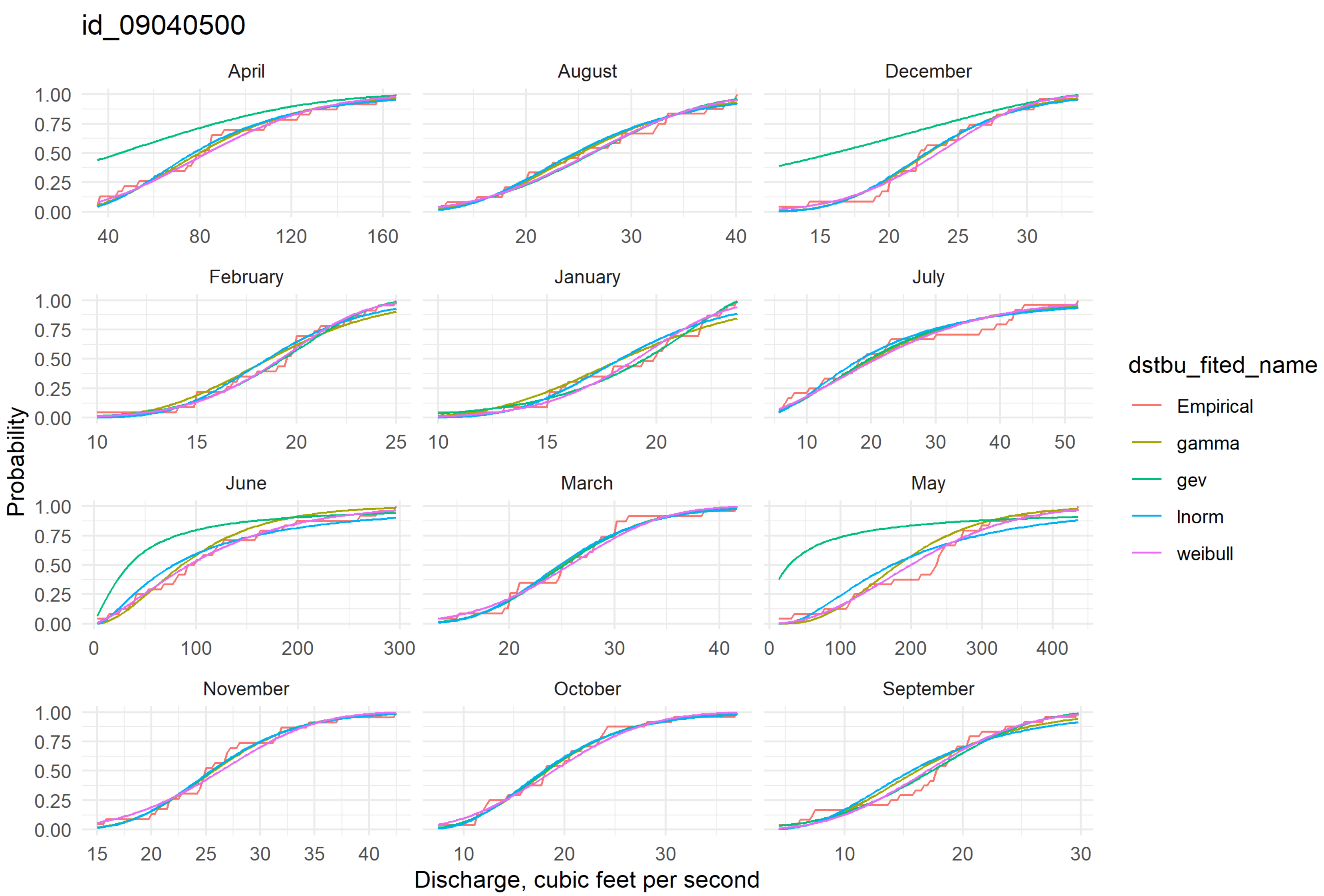
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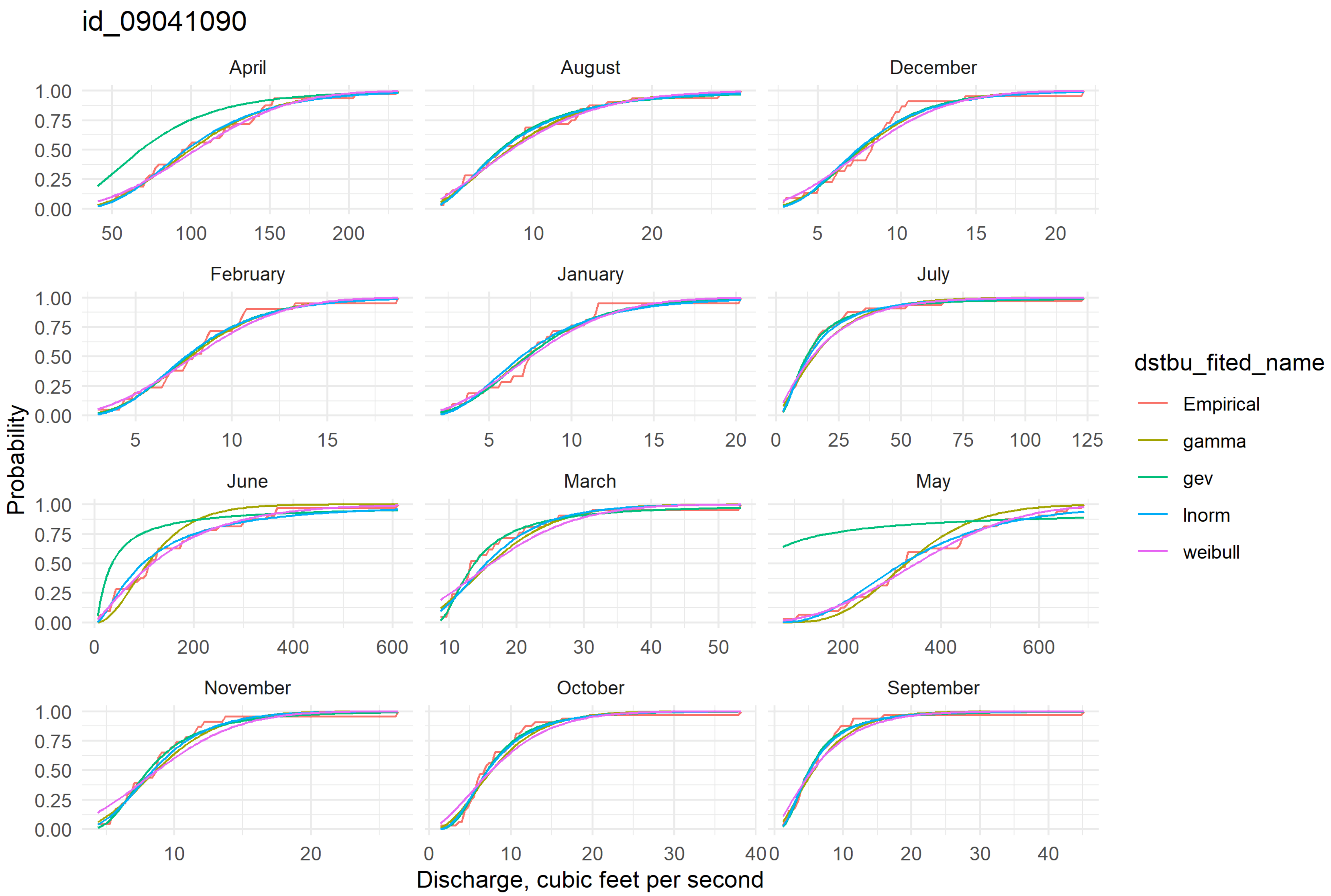
lnorm
weibull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November
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Probability
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gamma
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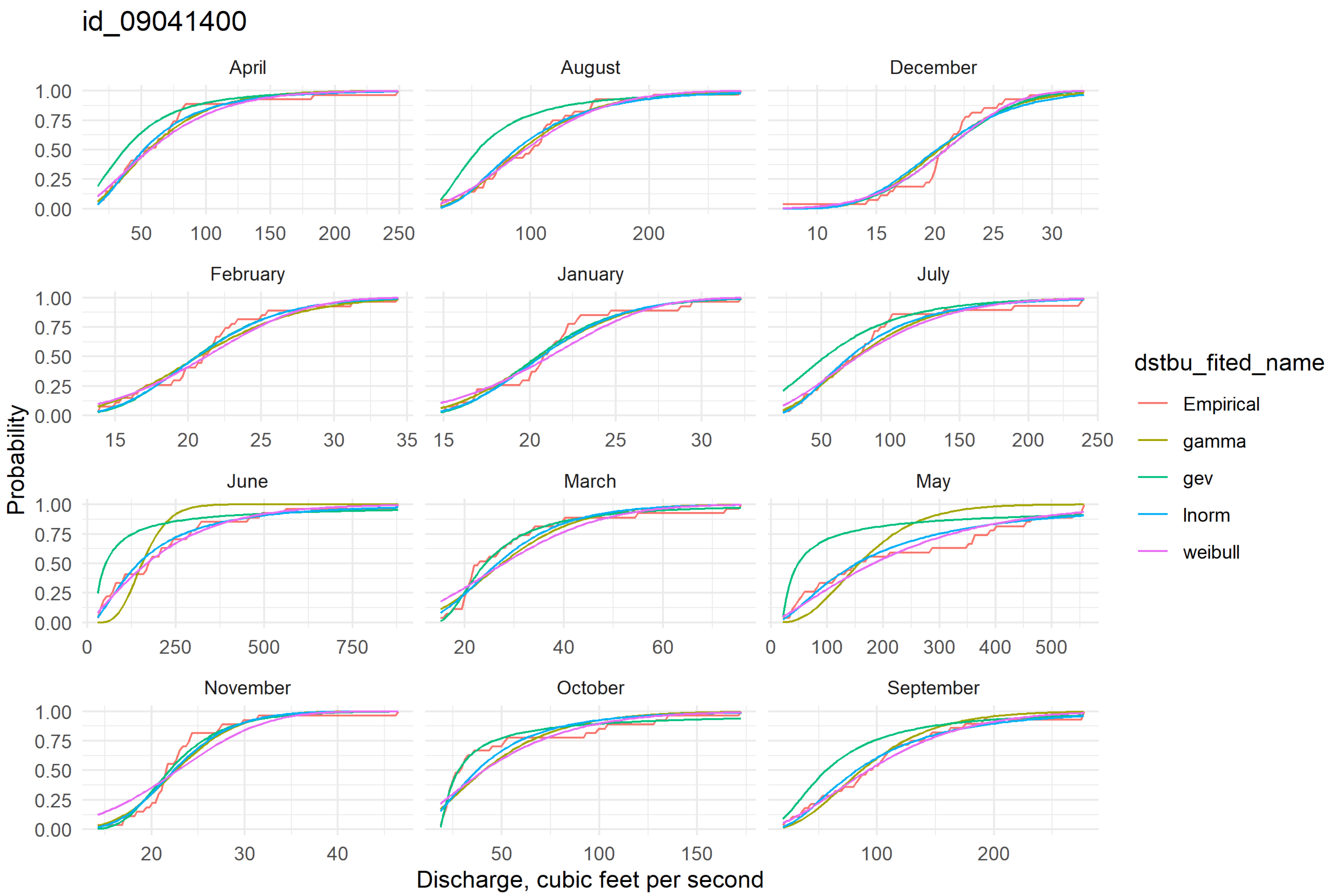
0.00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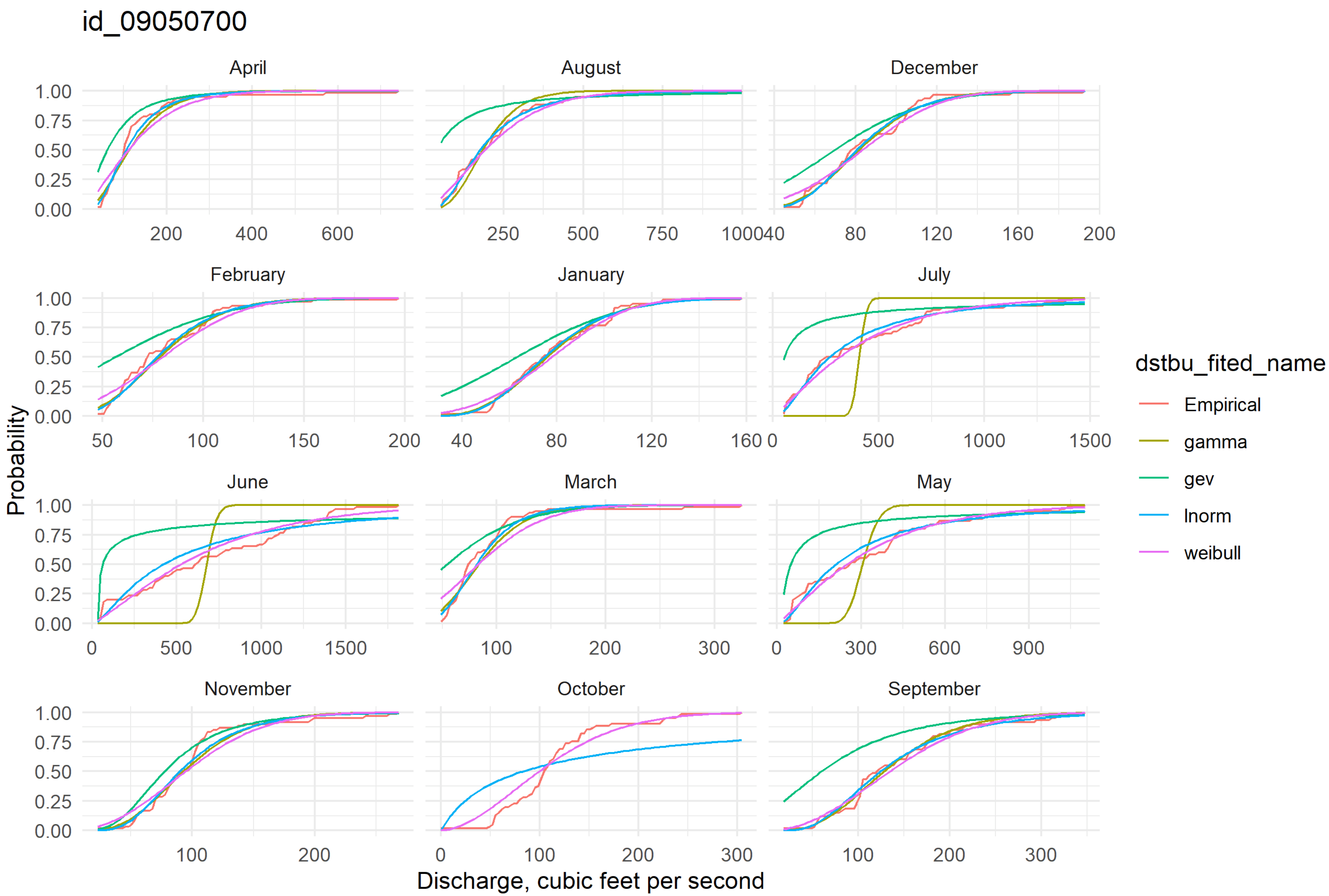
weibull



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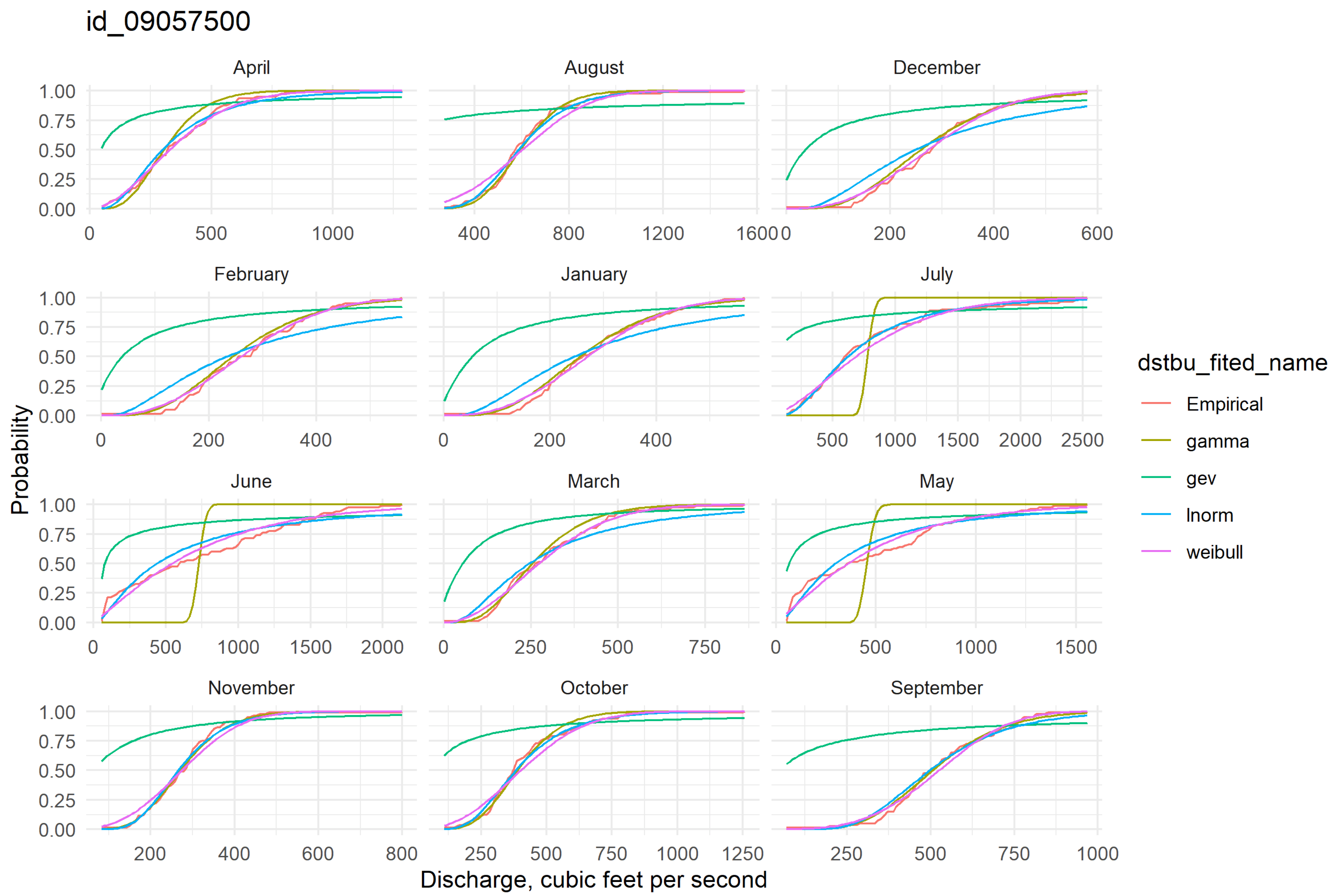
gev
lnorm
weibull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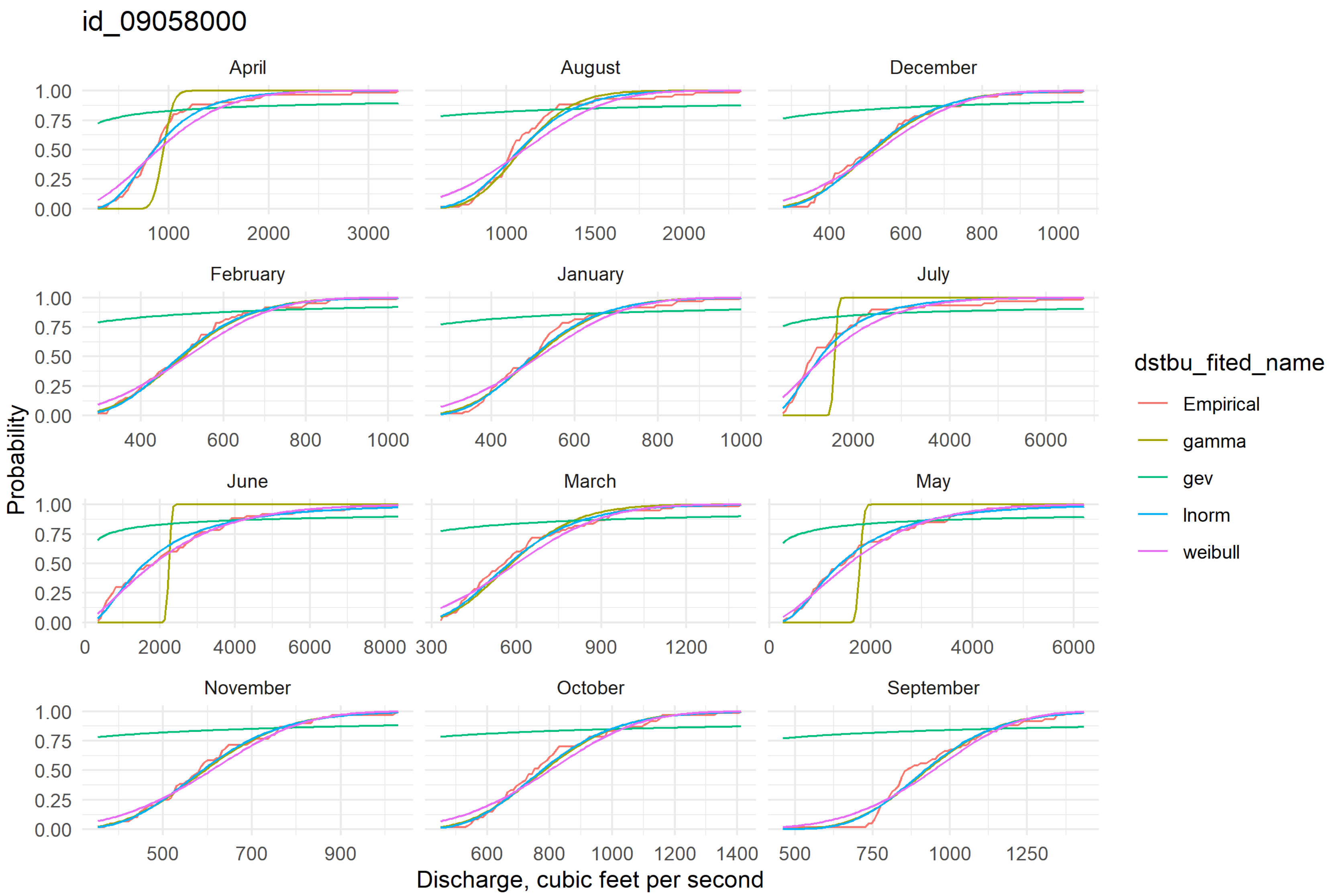
lnorm
weibull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Probability
Discharge, cubic feet per second
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gev
lnorm
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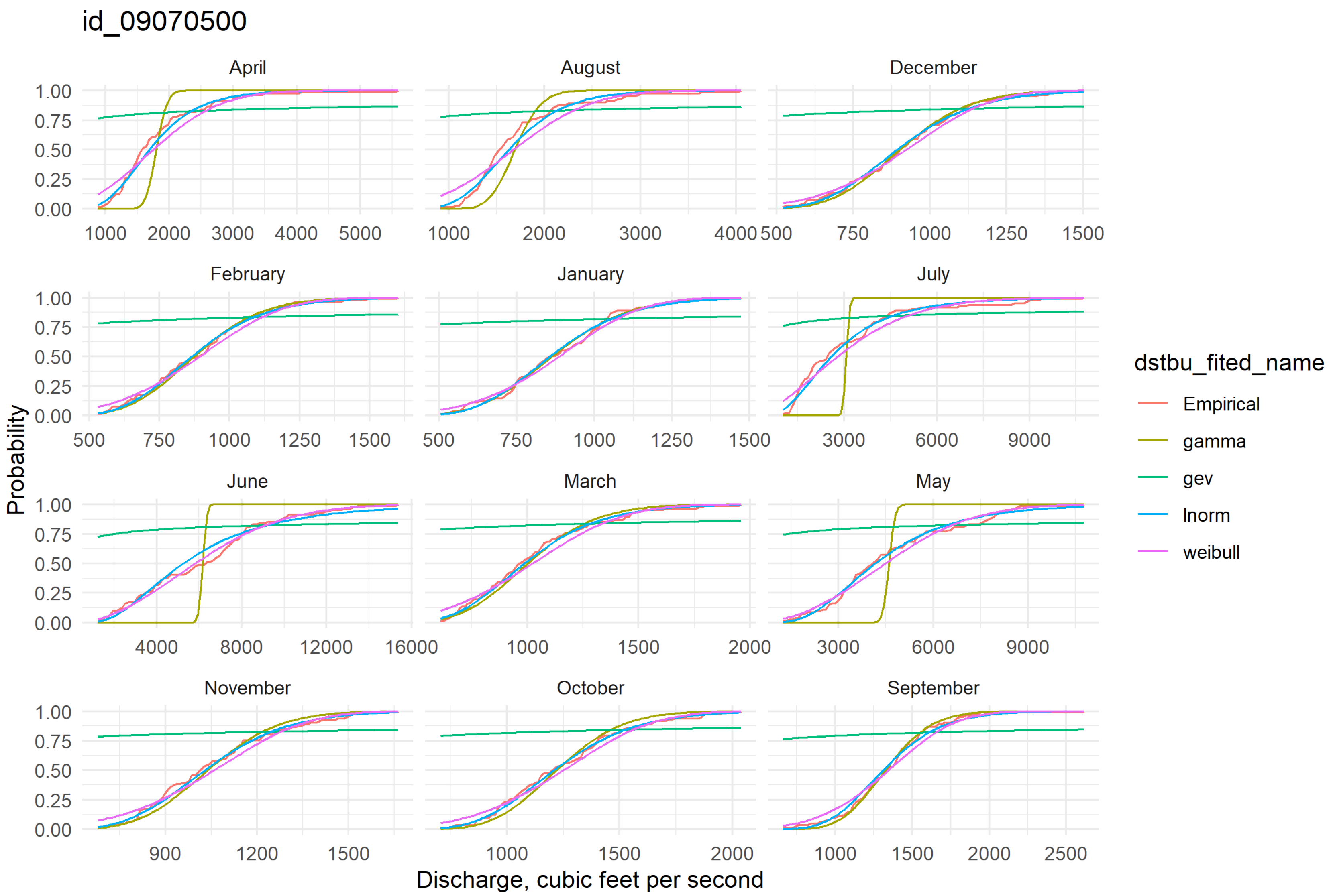
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September
Probability
Discharge, cubic feet per second
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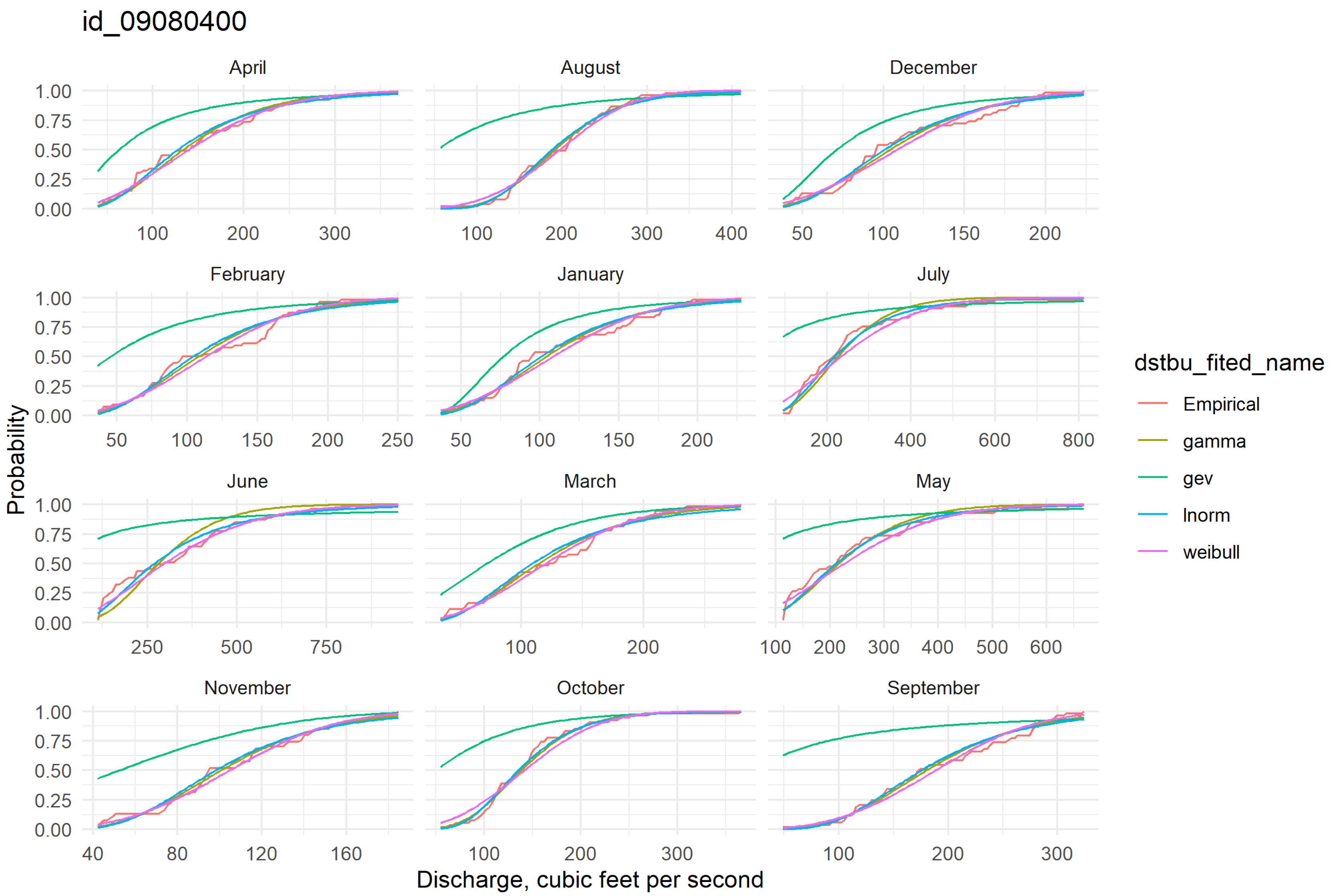
Empirical
gamma
gev
lnorm
weibull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October
September
Probability
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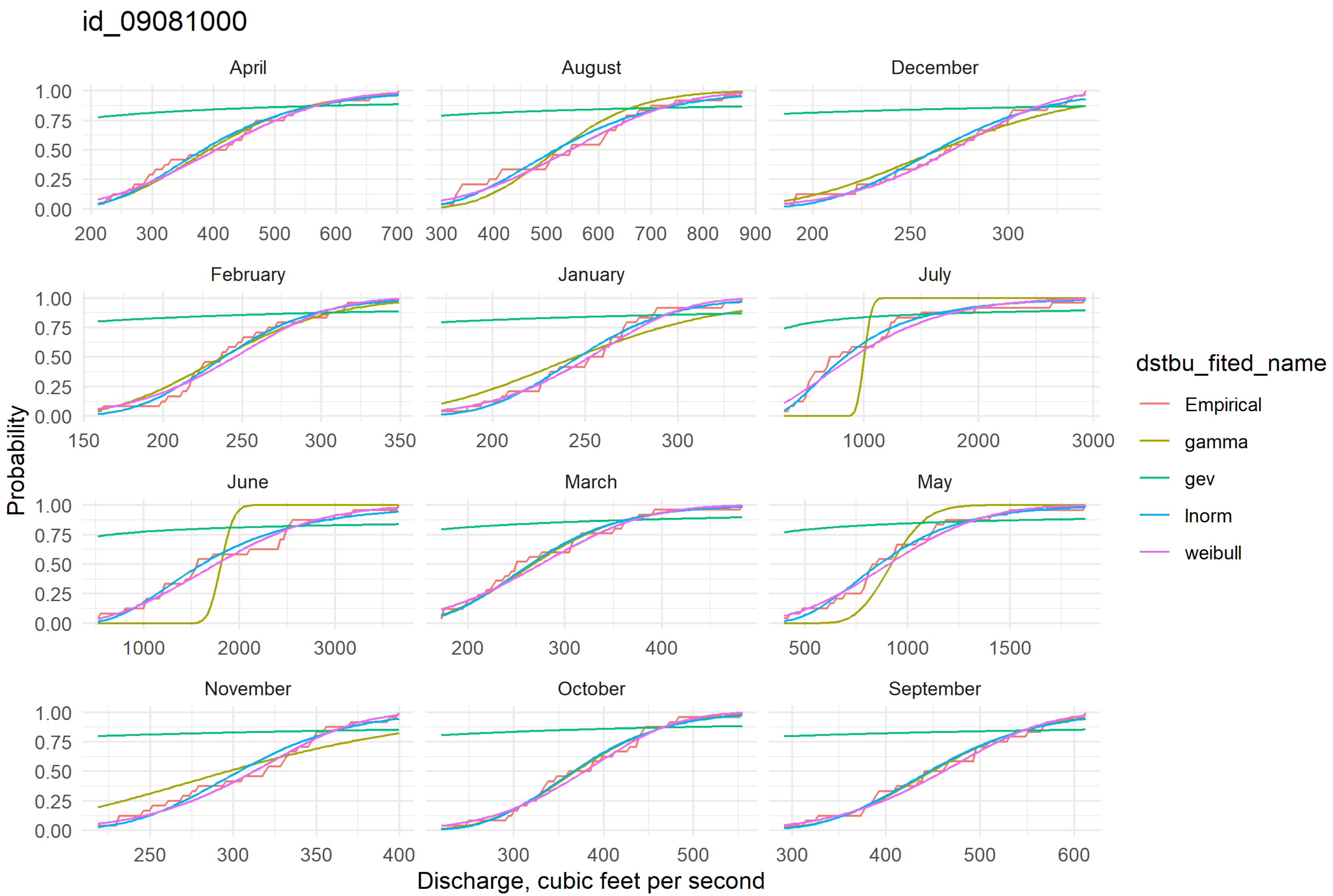
gamma
gev
lnorm
weibull



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lnorm
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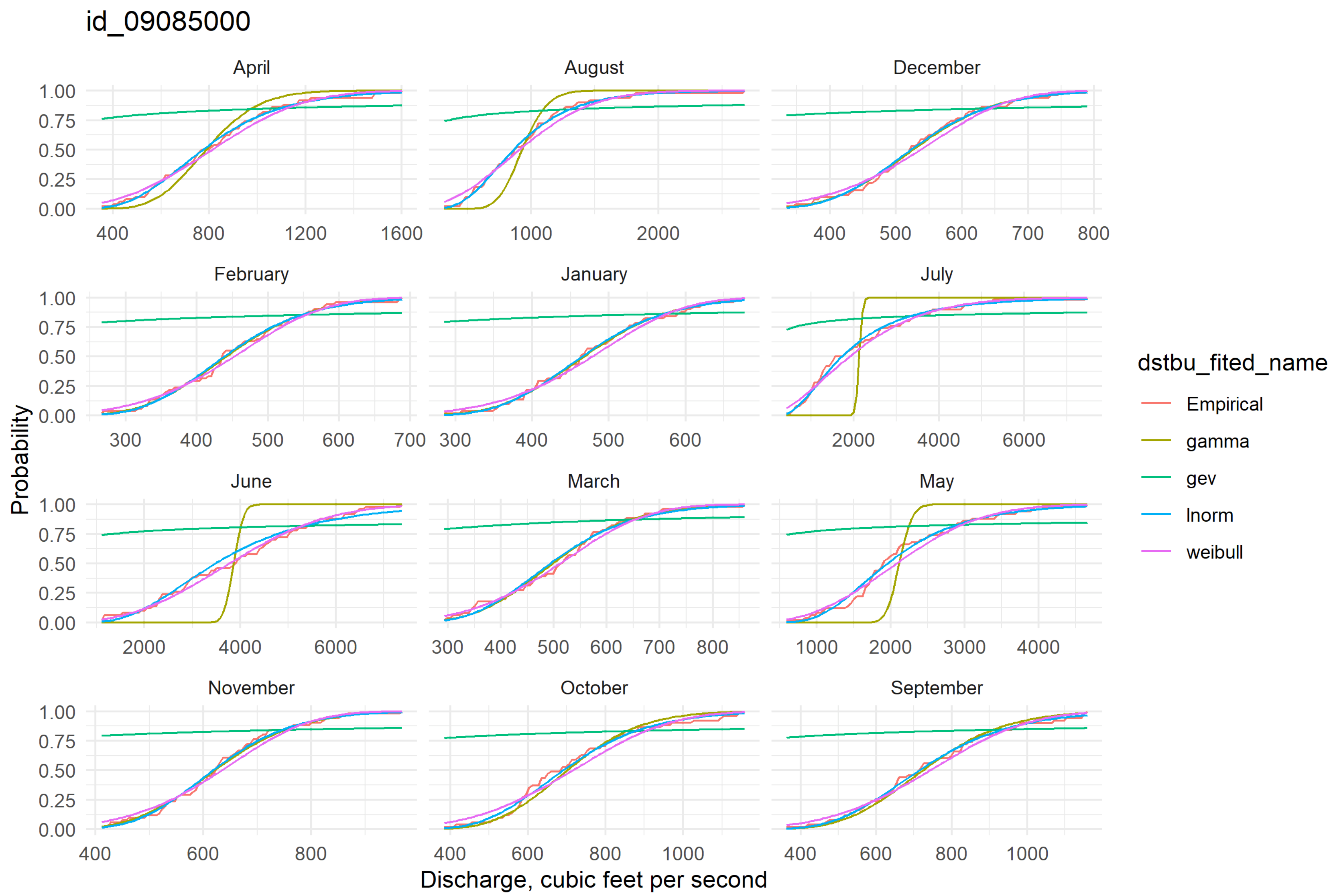
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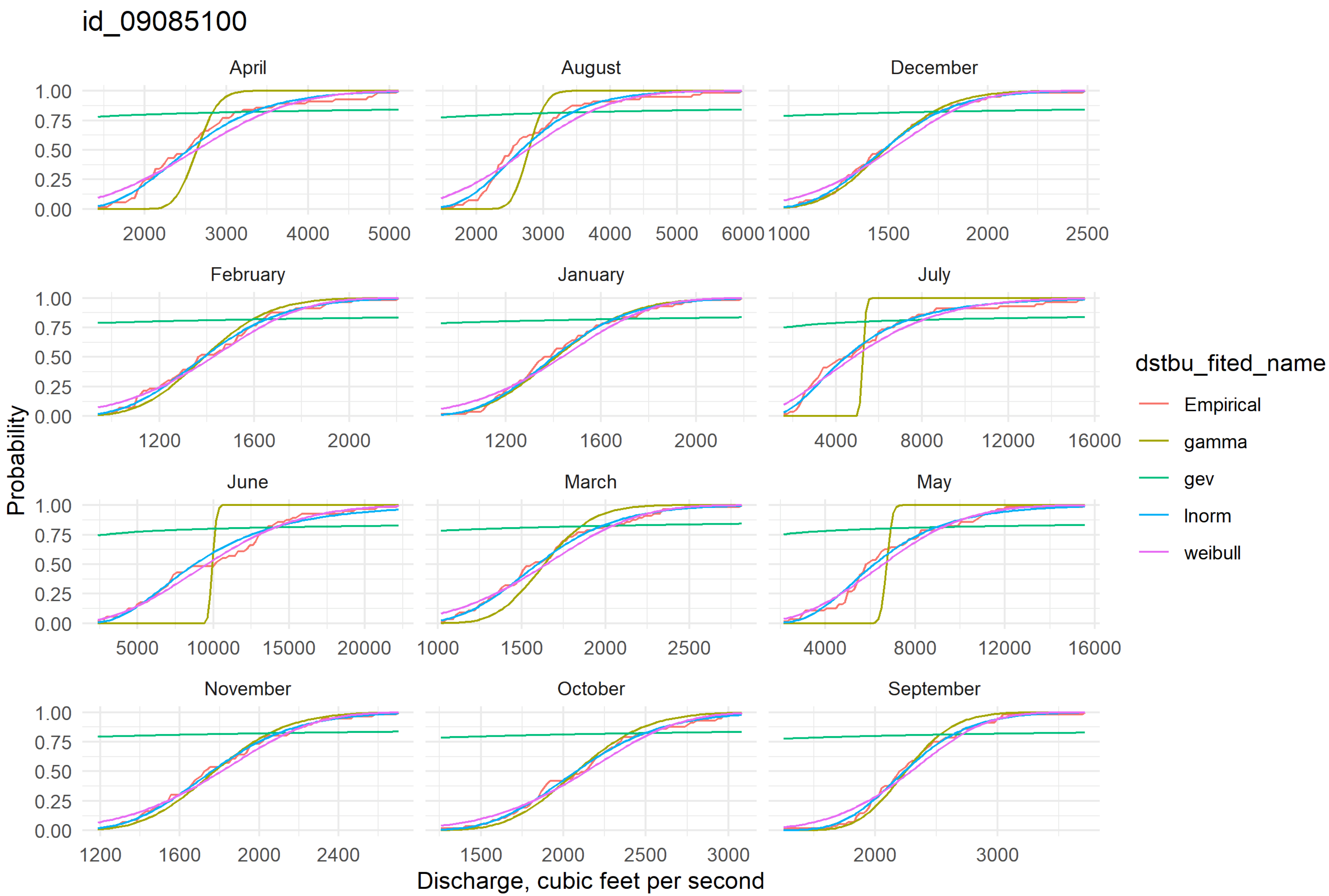
gamma
gev
lnorm
weibull



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March
May
November
October
September
Probability
Discharge, cubic feet per second
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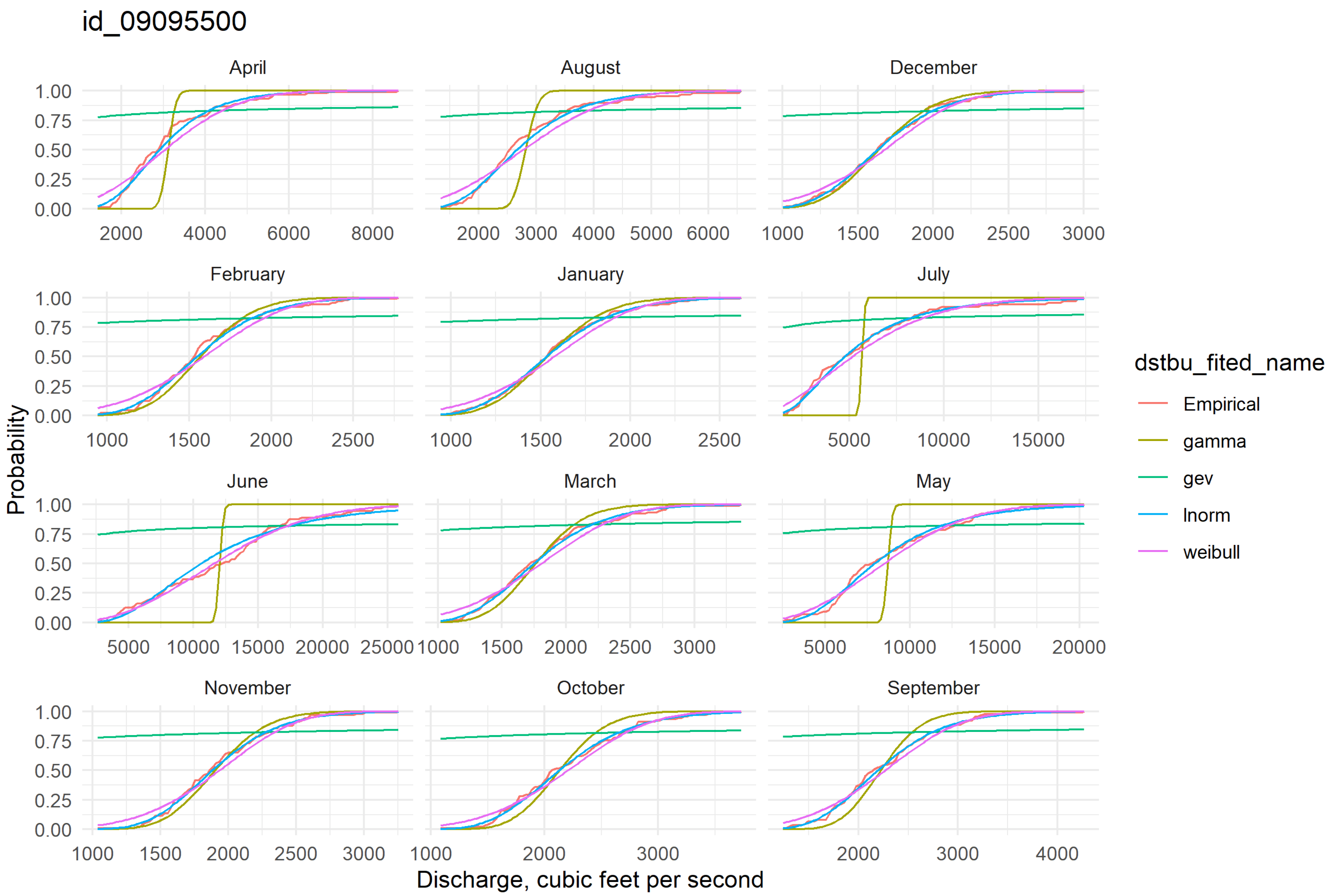
gamma
gev
lnorm
weibull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June
March
May
November
October
September
Probability
Discharge, cubic feet per second
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0.75
0.50
0.25
0.00
2000
4000
6000
8000
2000 3000 4000 5000 6000
1000 1500 2000 2500 3000
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5000 10000 15000
5000 10000 15000 20000 25000
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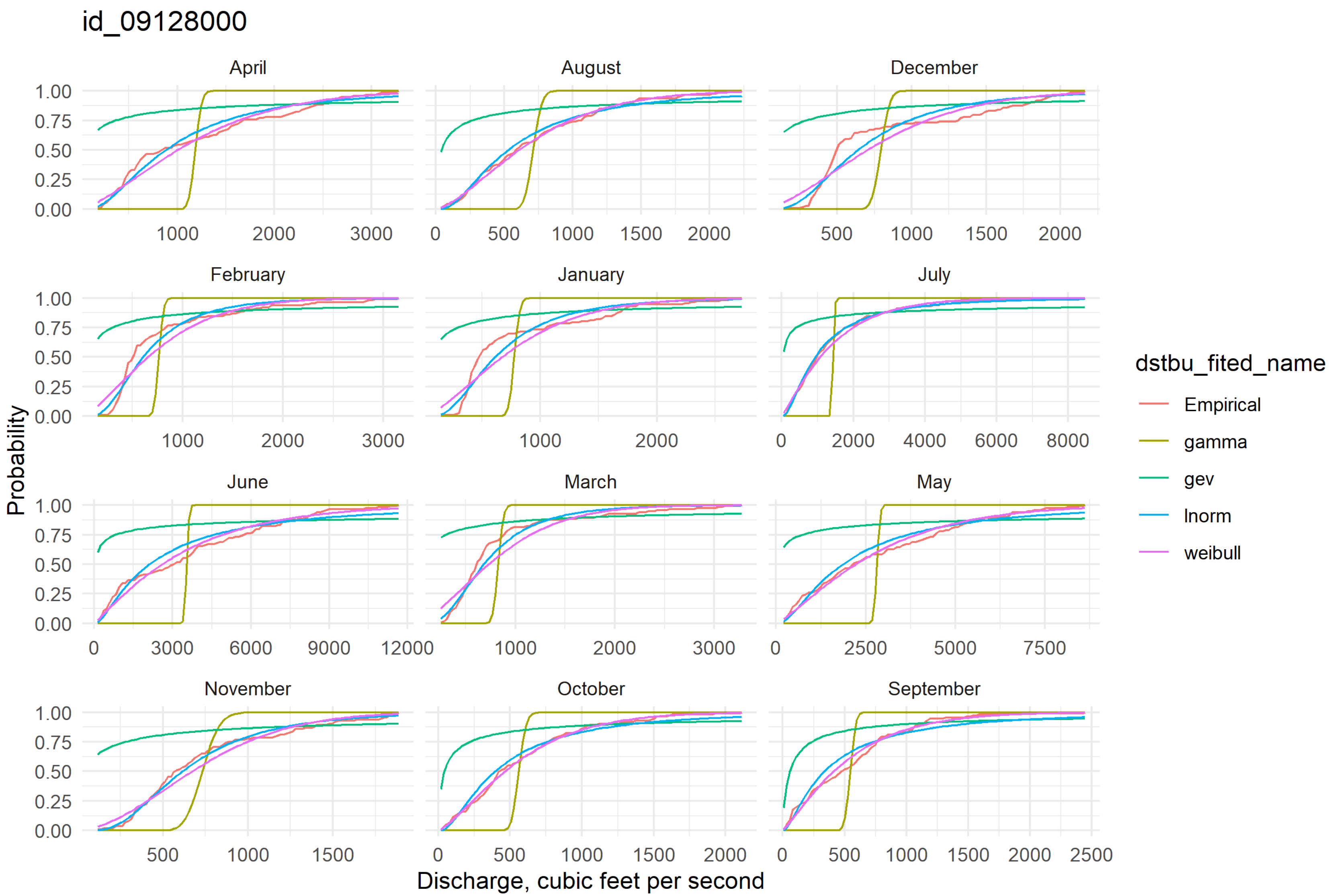
gamma
gev
lnorm
weibull



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Probability
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gamma
gev
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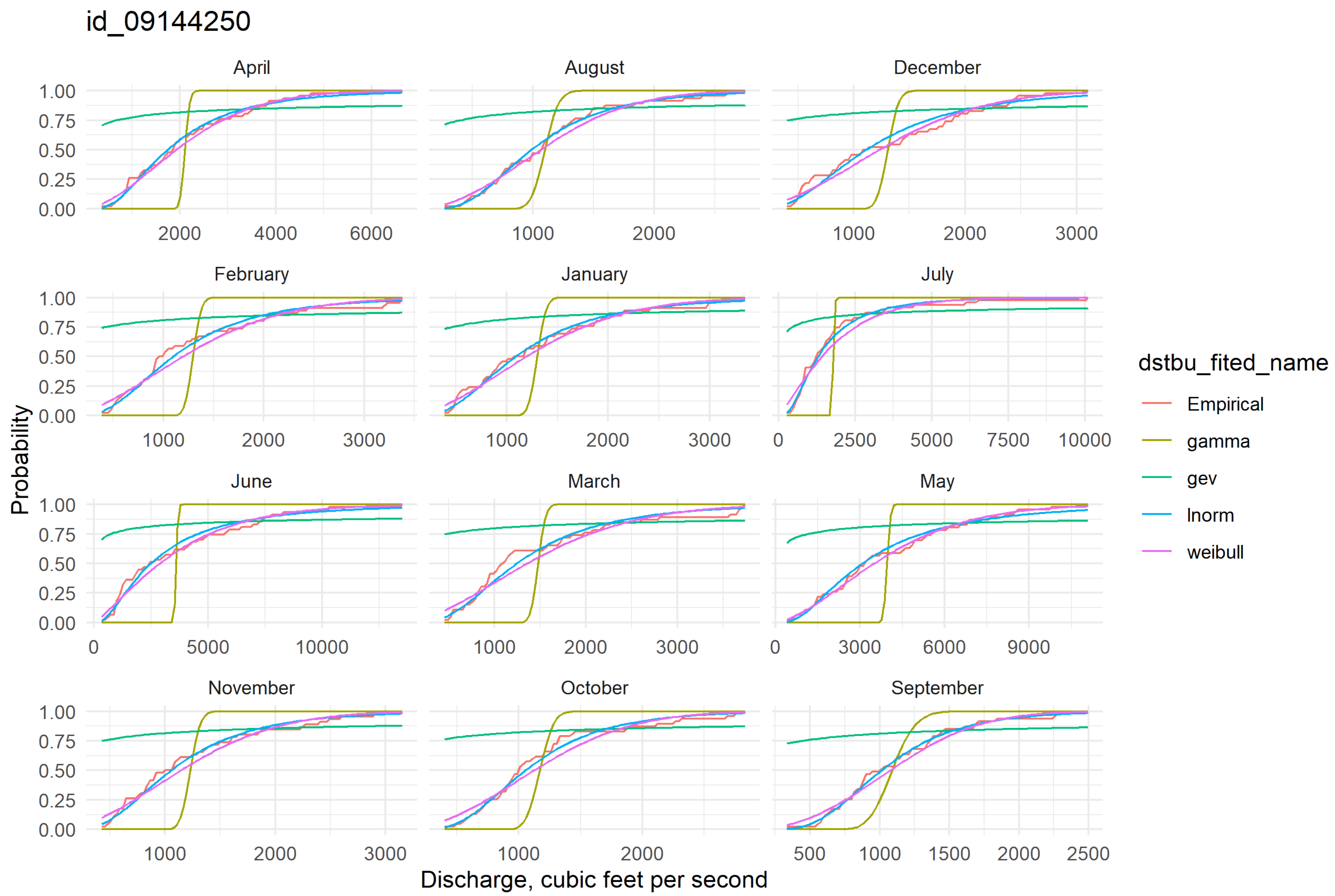
weibull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Probability
Discharge, cubic feet per second
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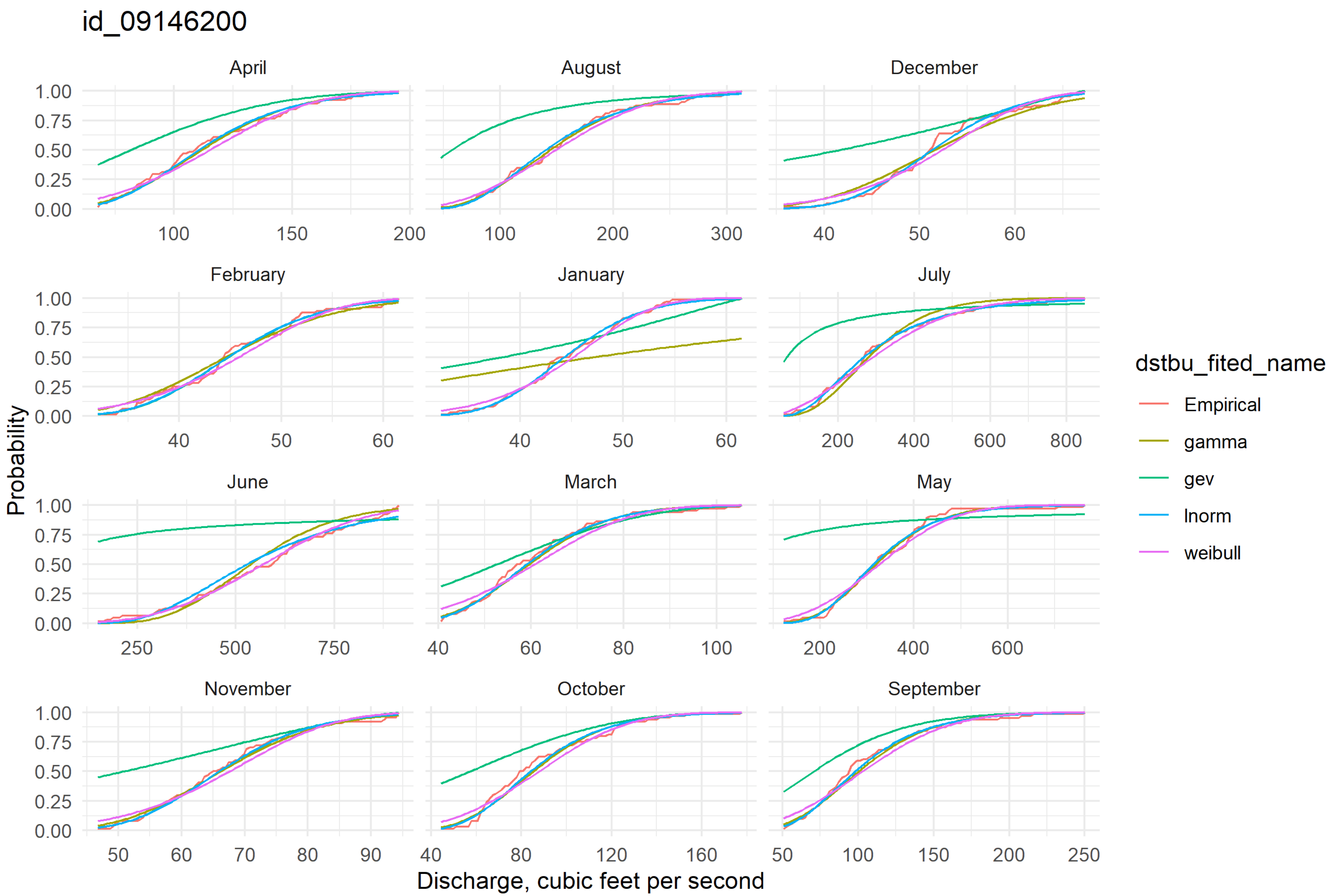
gamma
gev
lnorm
weibull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January
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June
March
May
November
October
September
1.00
0.75
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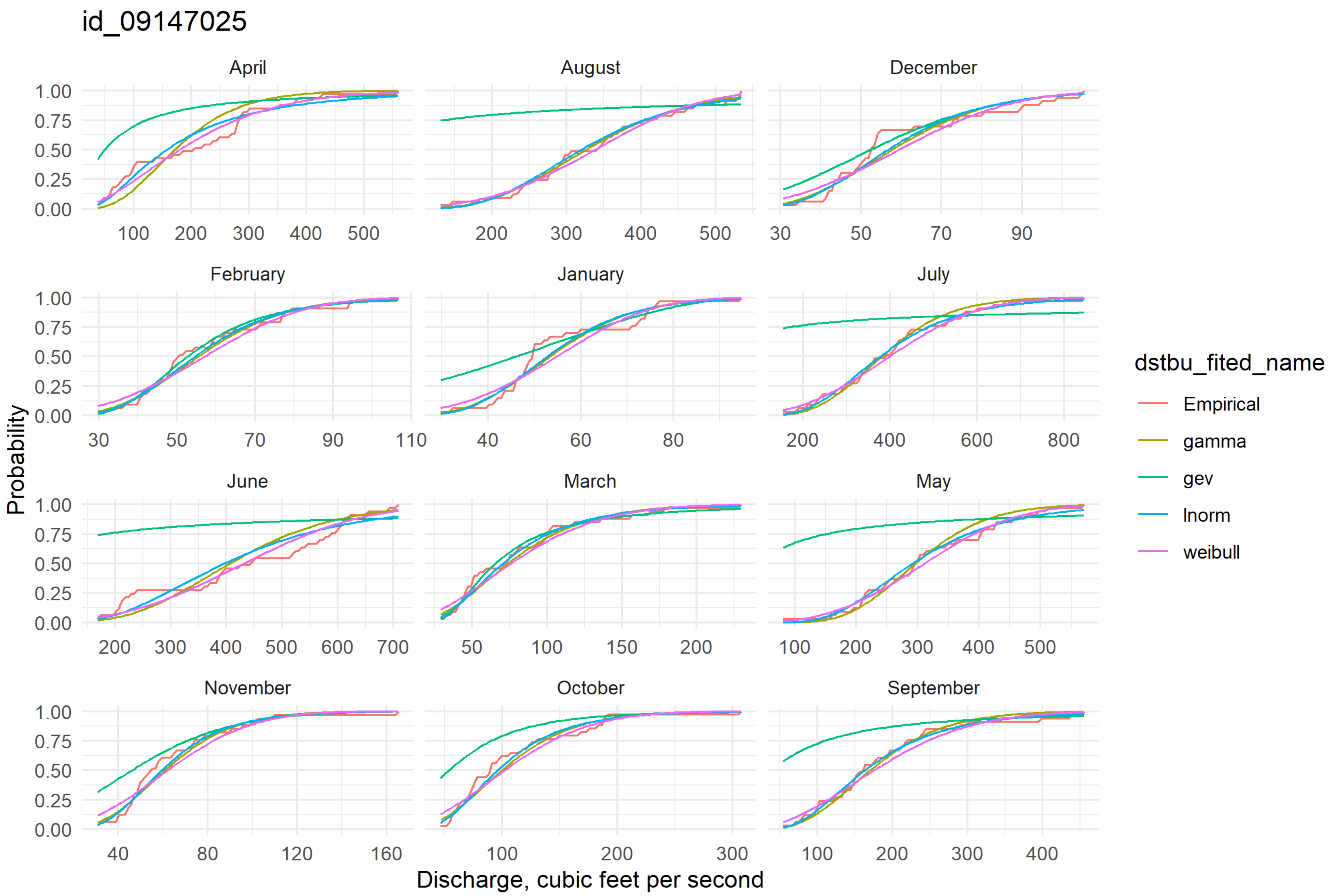
0.00
Probability
Discharge, cubic feet per second
dstbu_fited_name
Empirical
gamma
gev
lnorm
weibull



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March
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November
October
September
Probability
Discharge, cubic feet per second
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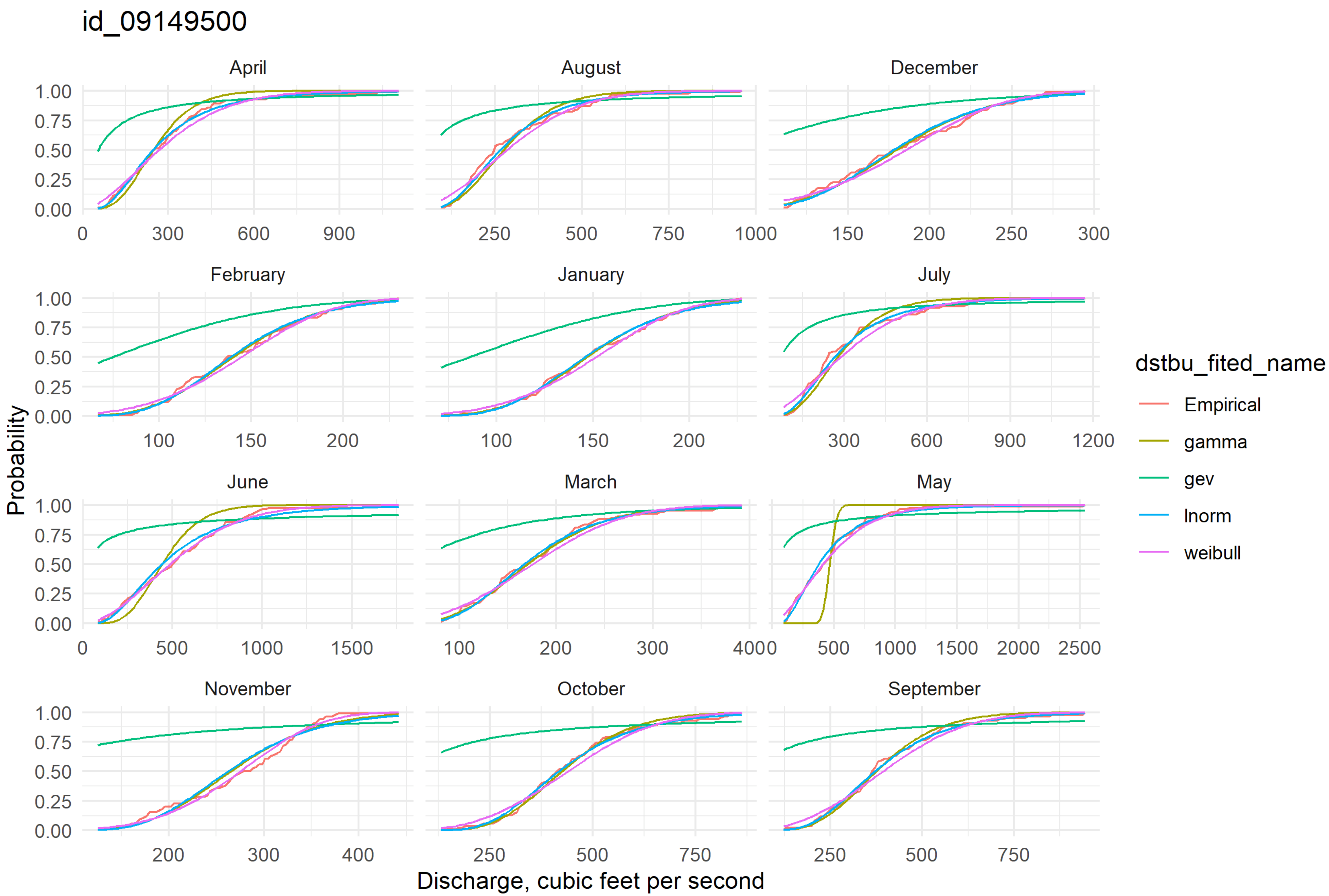
gamma
gev
lnorm
weibull



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April
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October
September
Probability
Discharge, cubic feet per second
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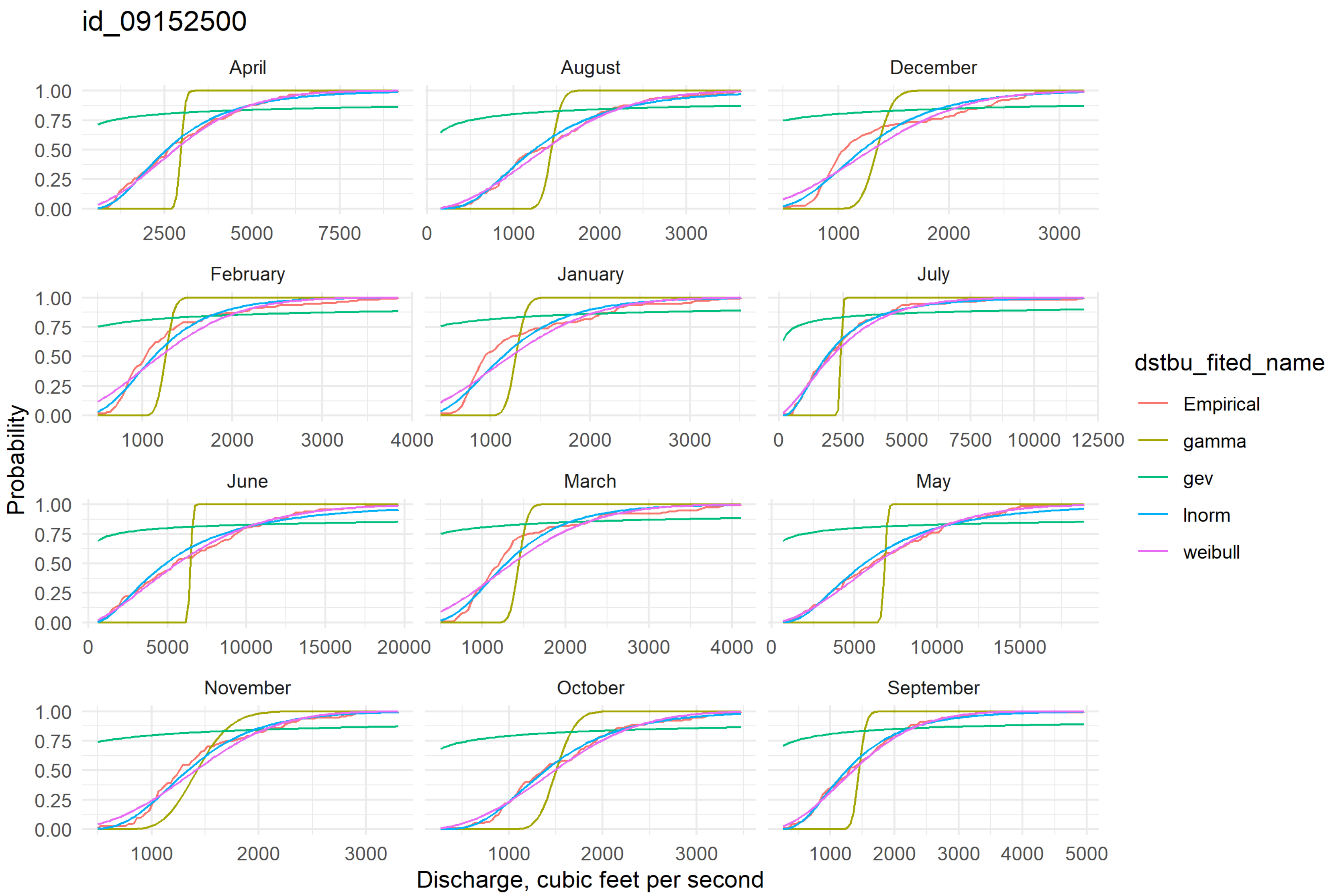
gamma
gev
lnorm
weibull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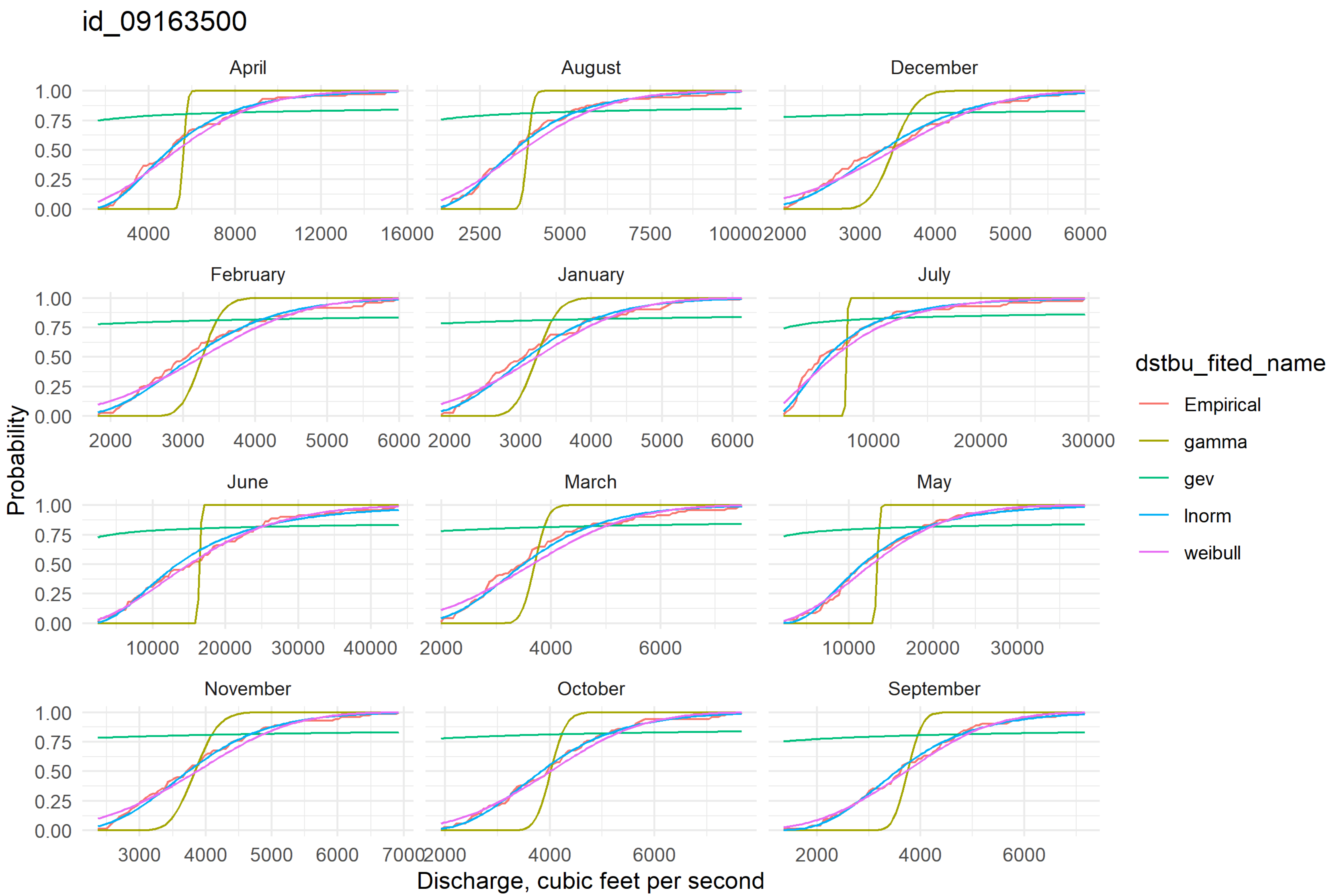
April
August
December
February
January
July
June
March
May
November
October
September
Probability
Discharge, cubic feet per second
dstbu_fited_name
Empirical
gamma
gev
lnorm
weibull
1.00
0.75
0.50
0.25
0.00
2500
5000
7500
0
1000
2000
3000
4000
10000
12500
15000
20000


id_09163500
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August
December
February
January
July
June
March
May
November
October
September
Probability
Discharge, cubic feet per second
dstbu_fited_name
Empirical
gamma
gev
lnorm
weibull
1.00
0.75
0.50
0.25
0.00
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8000
12000
16000
2500
5000
7500
10000
2000
3000
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6000
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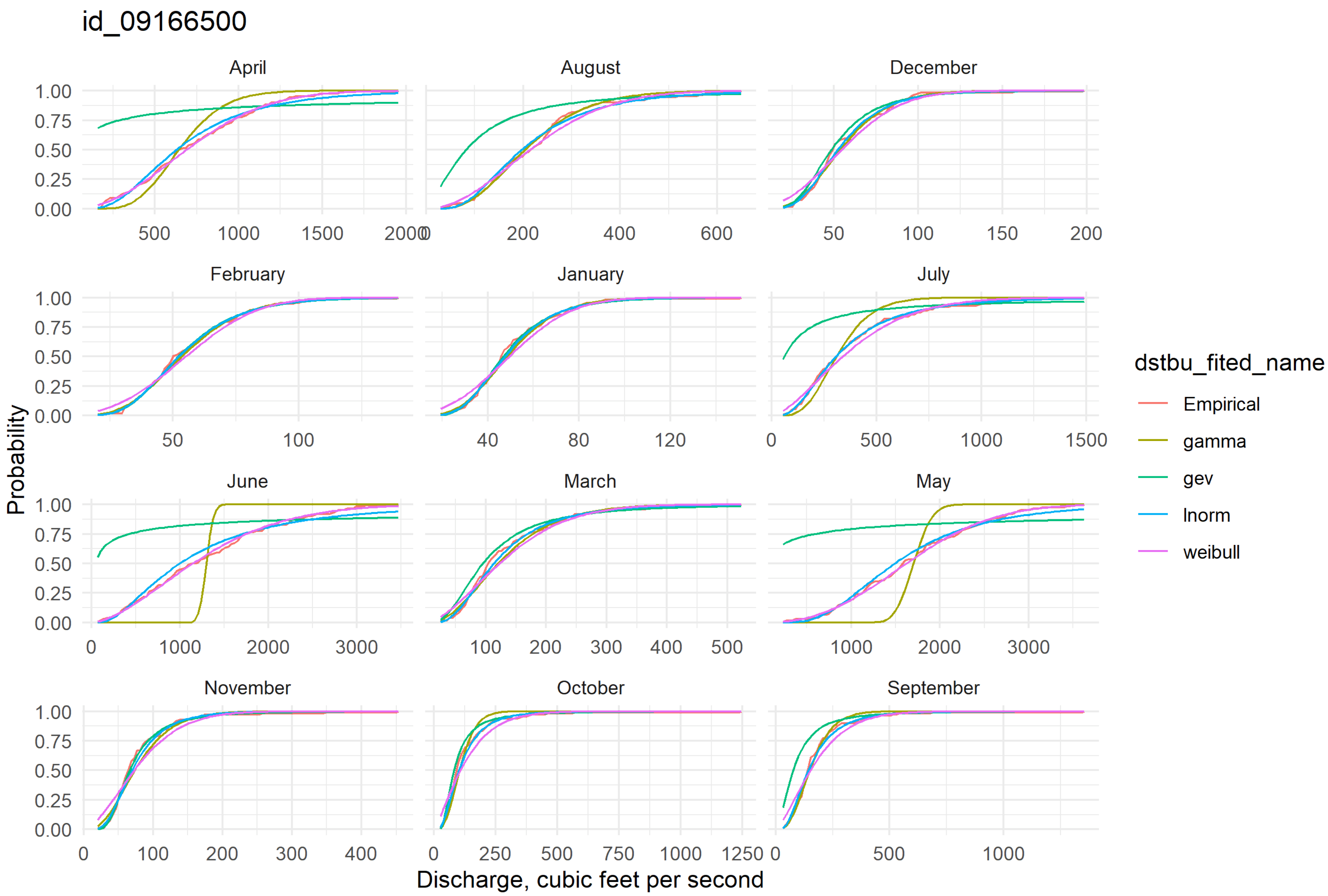
7000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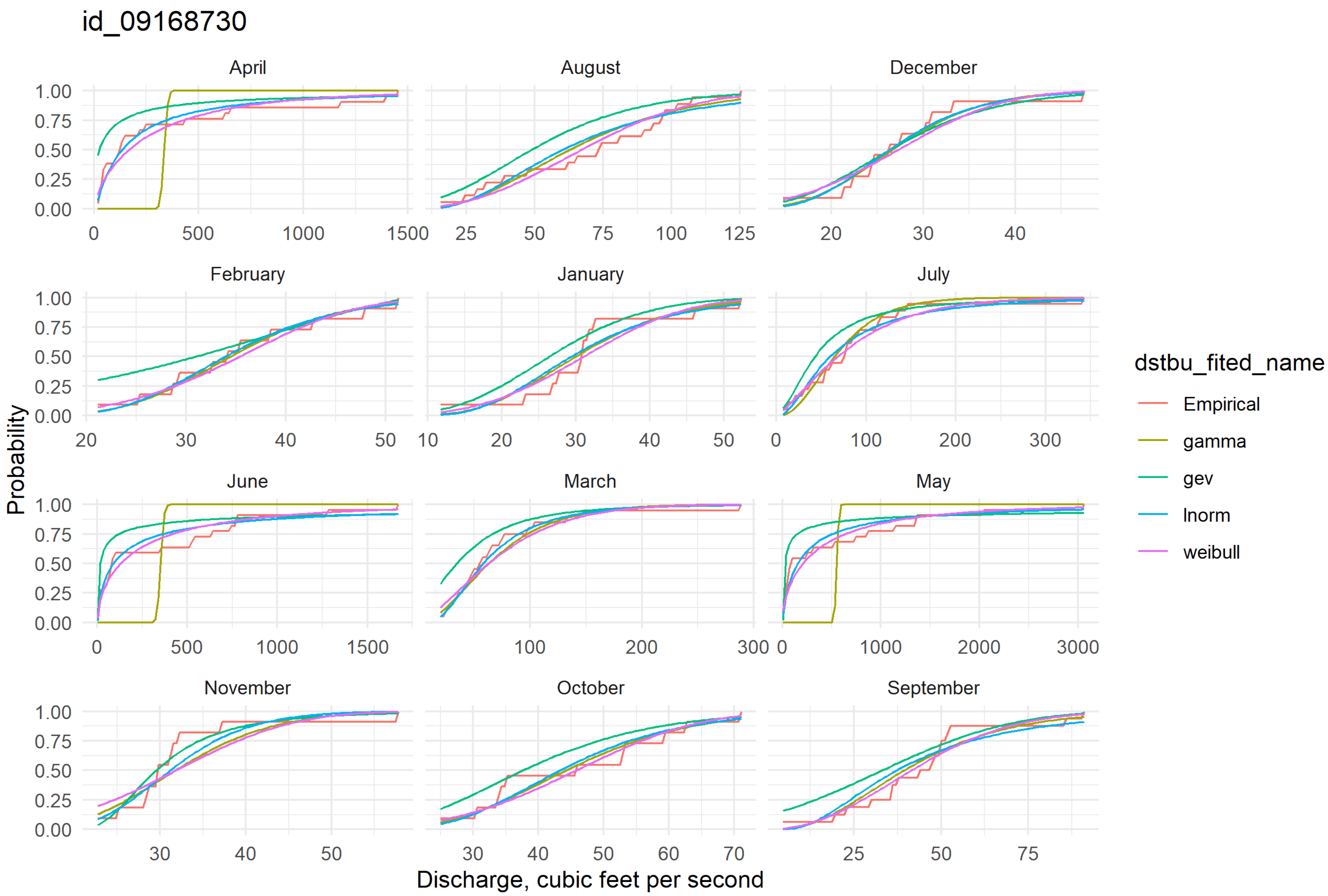
Probability
Discharge, cubic feet per second
dstbu_fited_name
Empirical
gamma
gev
lnorm
weibull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Probability
Discharge, cubic feet per second
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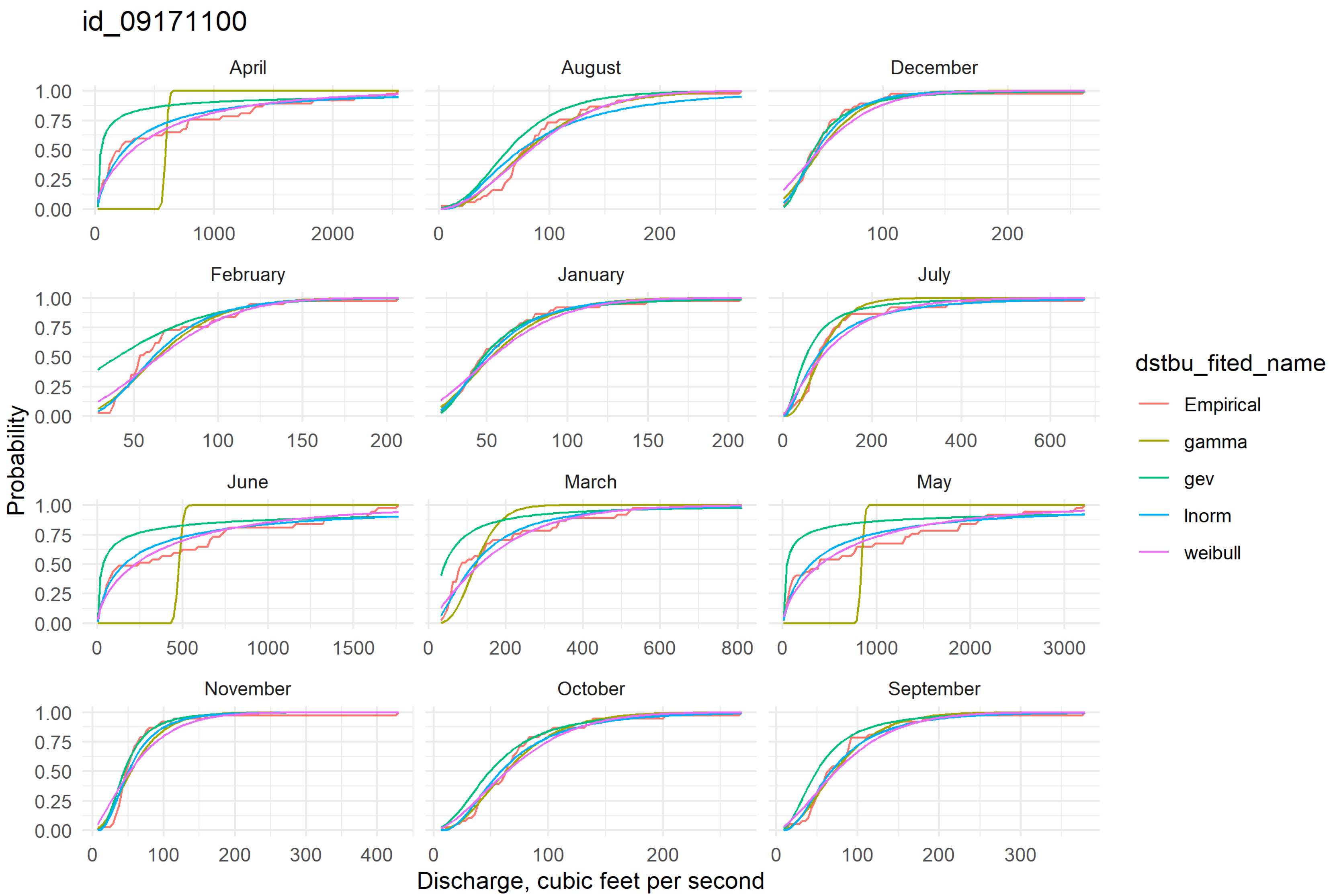
gamma
gev
lnorm
weibull



id_09171100
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October
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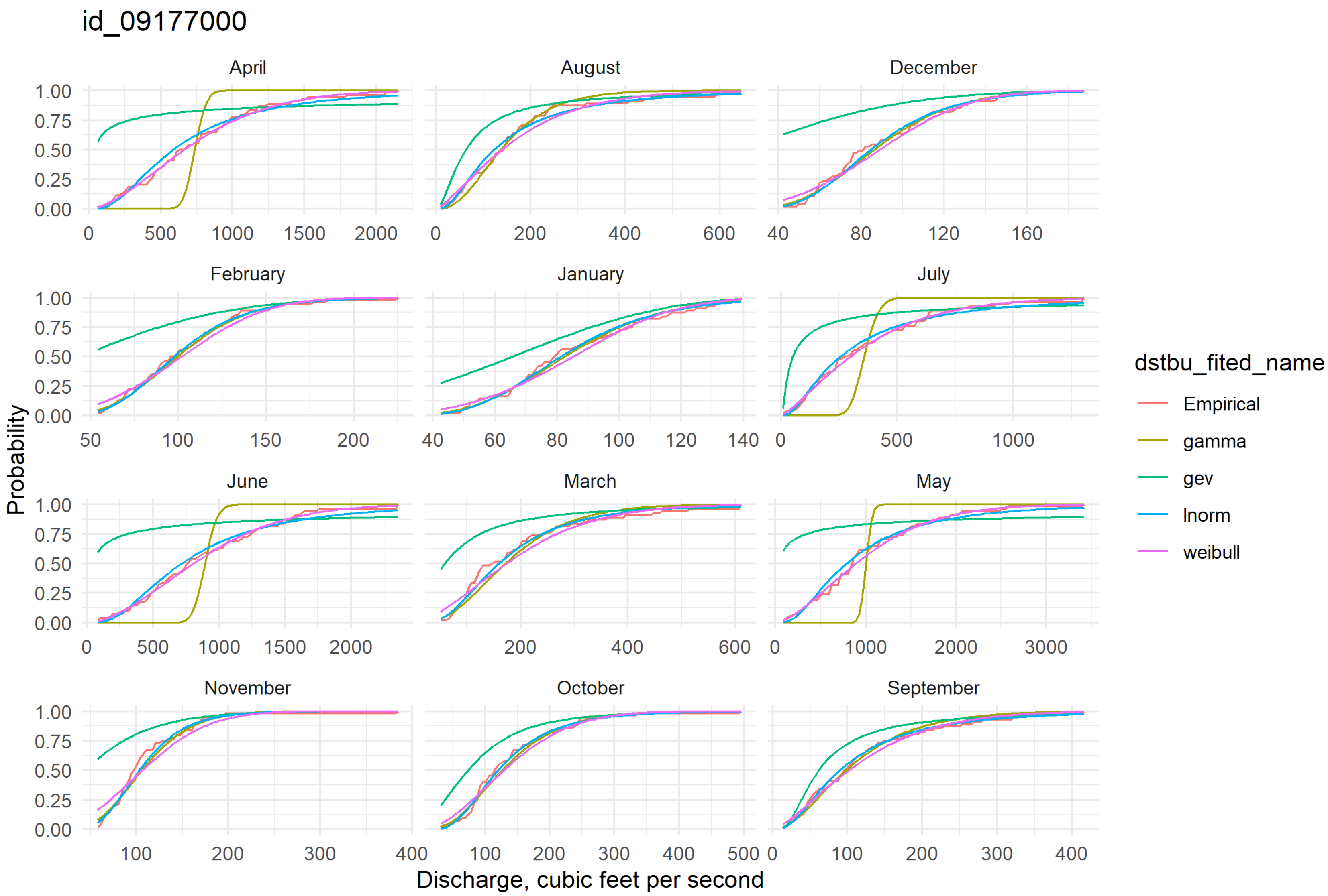
Probability
Discharge, cubic feet per second
dstbu_fited_name
Empirical
gamma
gev
lnorm
weibull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Probability
Discharge, cubic feet per second
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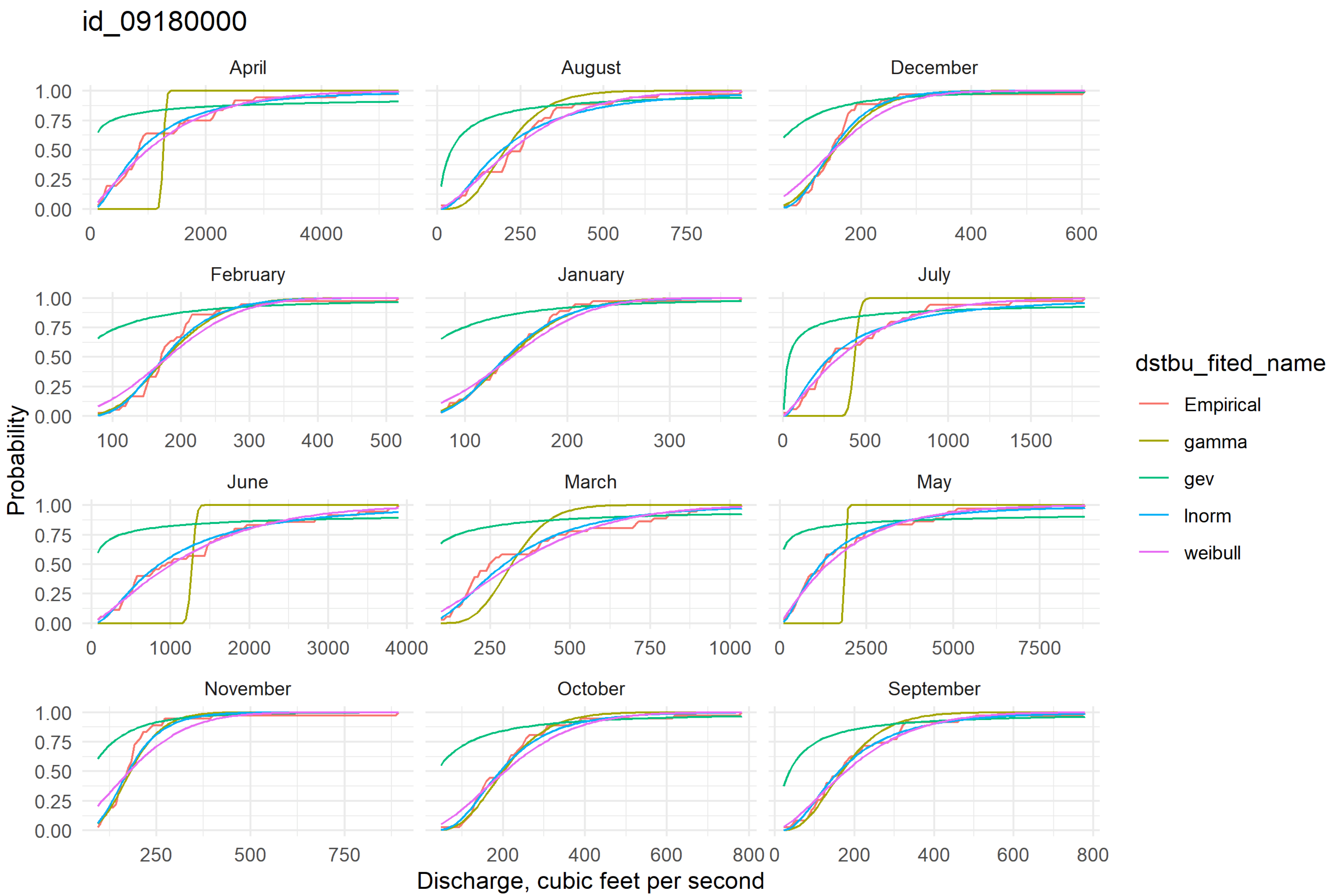
gamma
gev
lnorm
weibull



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October
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Probability
Discharge, cubic feet per second
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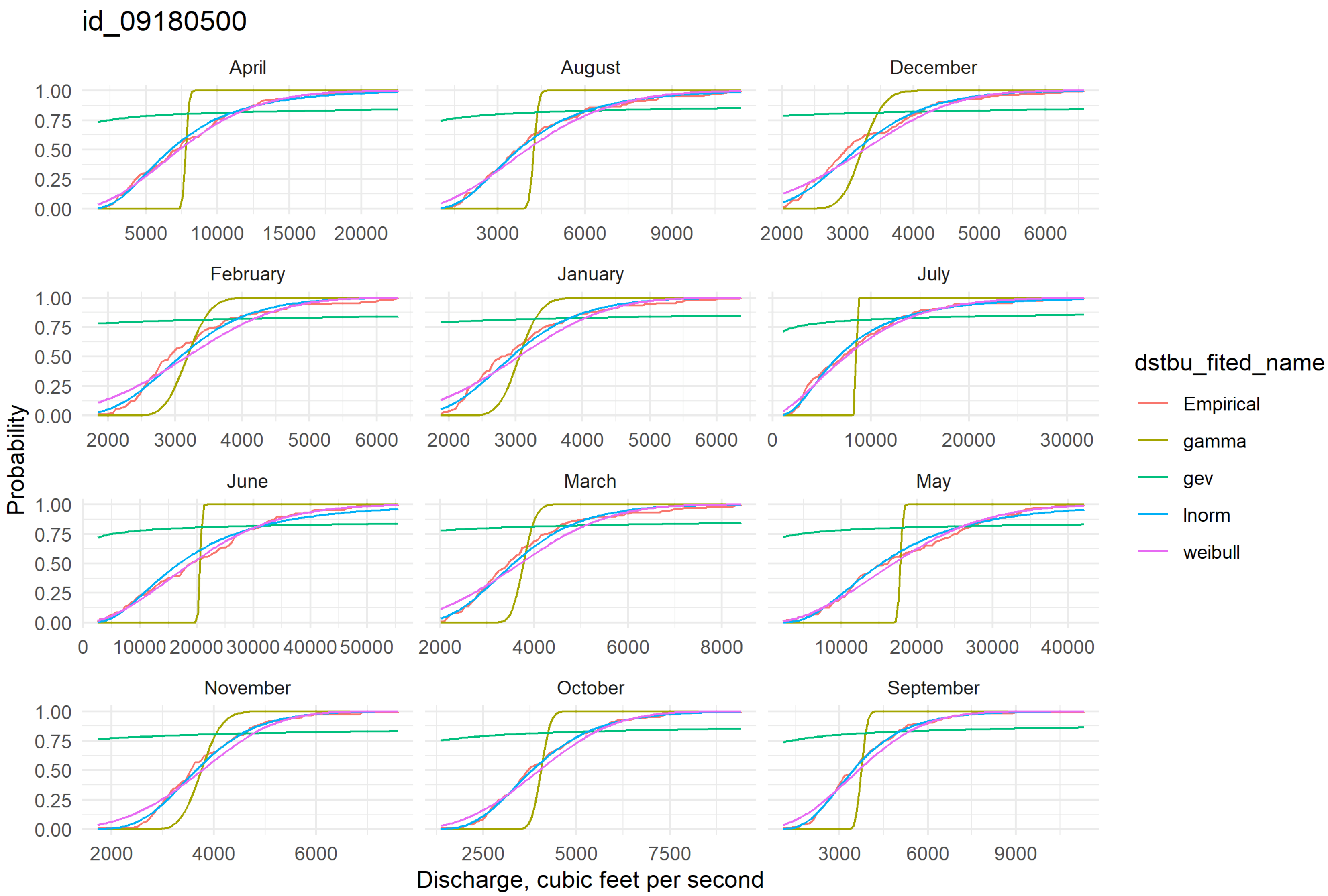
gamma
gev
lnorm
weibull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Probability
Discharge, cubic feet per second
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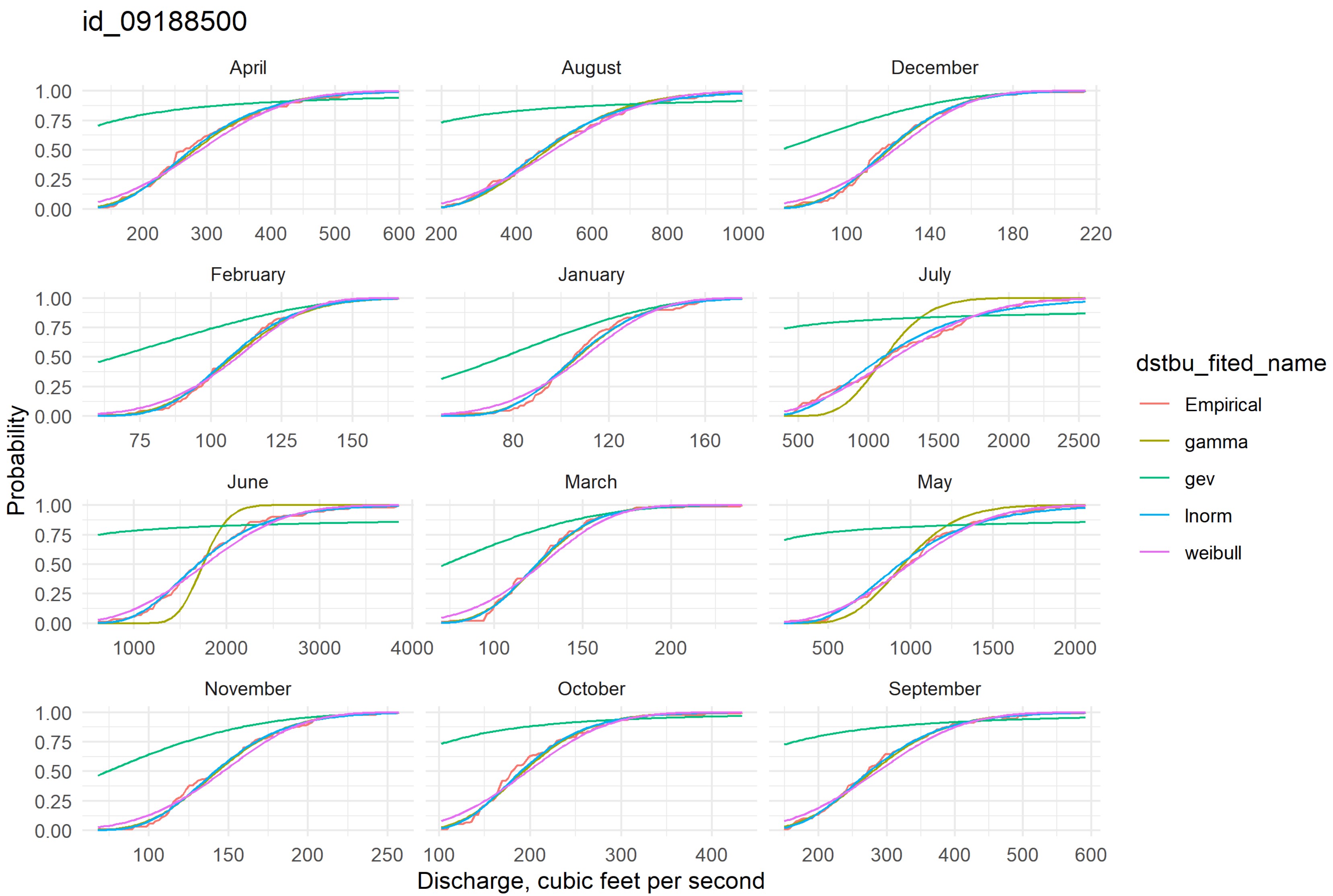
gamma
gev
lnorm
weibull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Probability
Discharge, cubic feet per second
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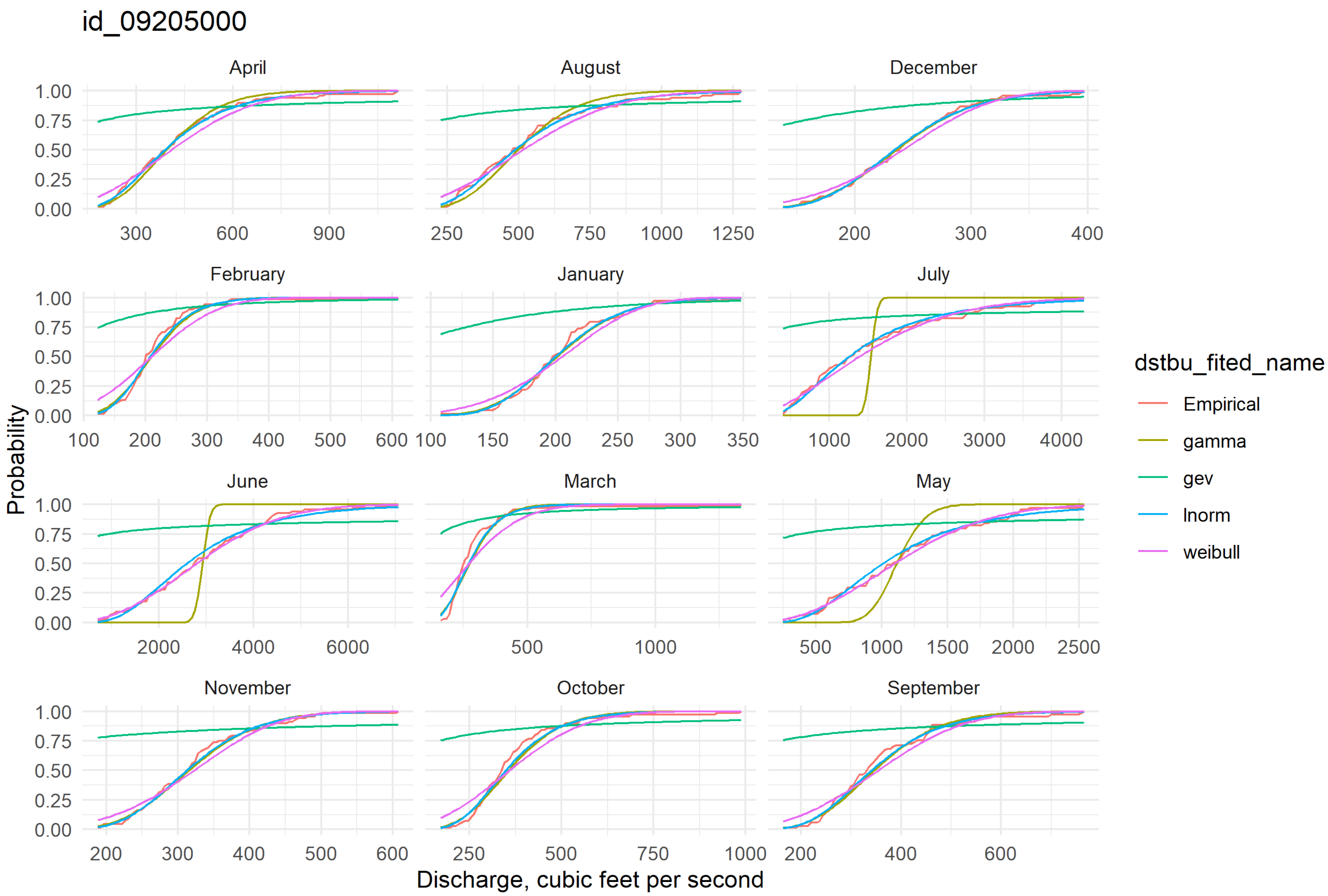
gamma
gev
lnorm
weibull



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October
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Probability
Discharge, cubic feet per second
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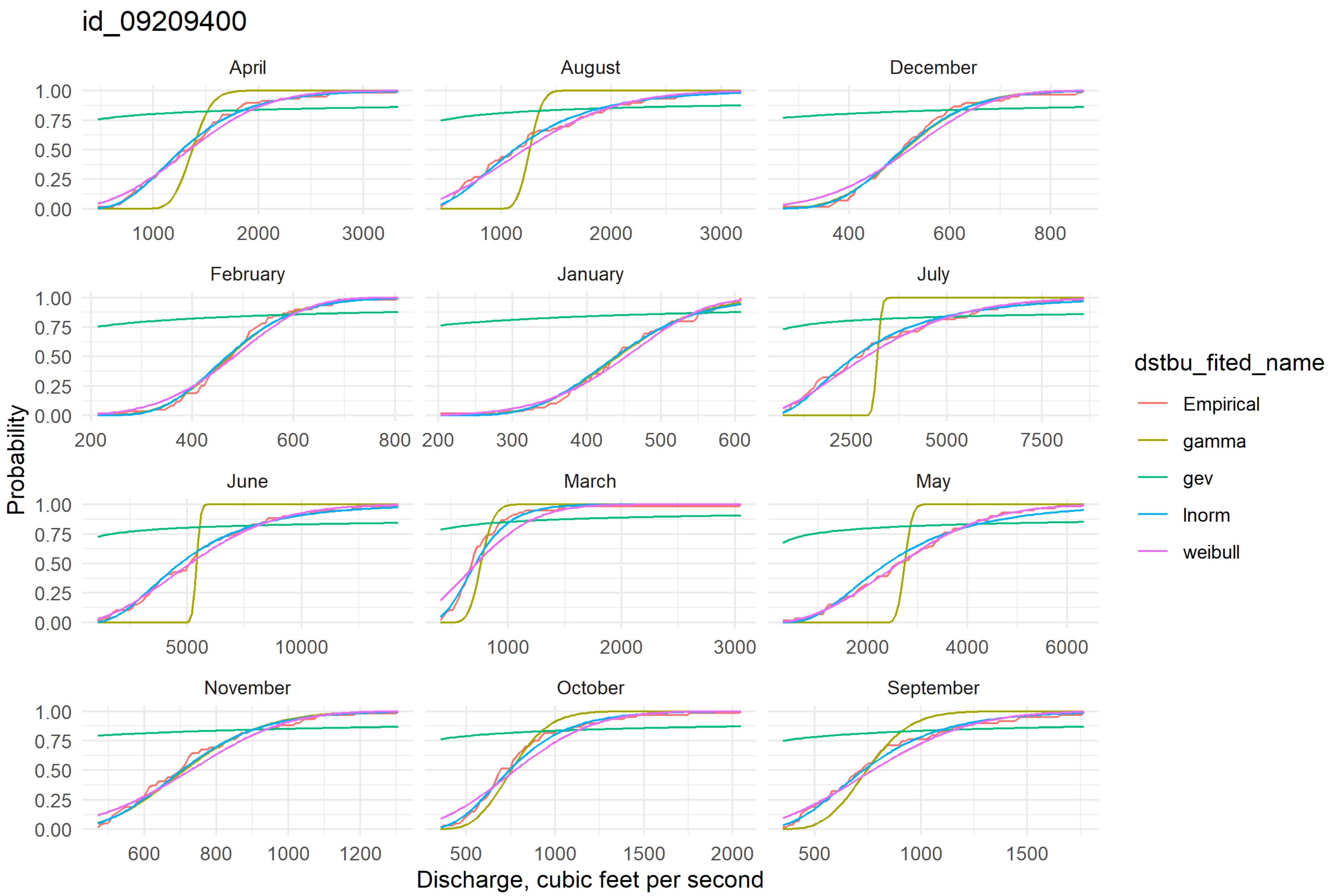
gamma
gev
lnorm
weibull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Probability
Discharge, cubic feet per second
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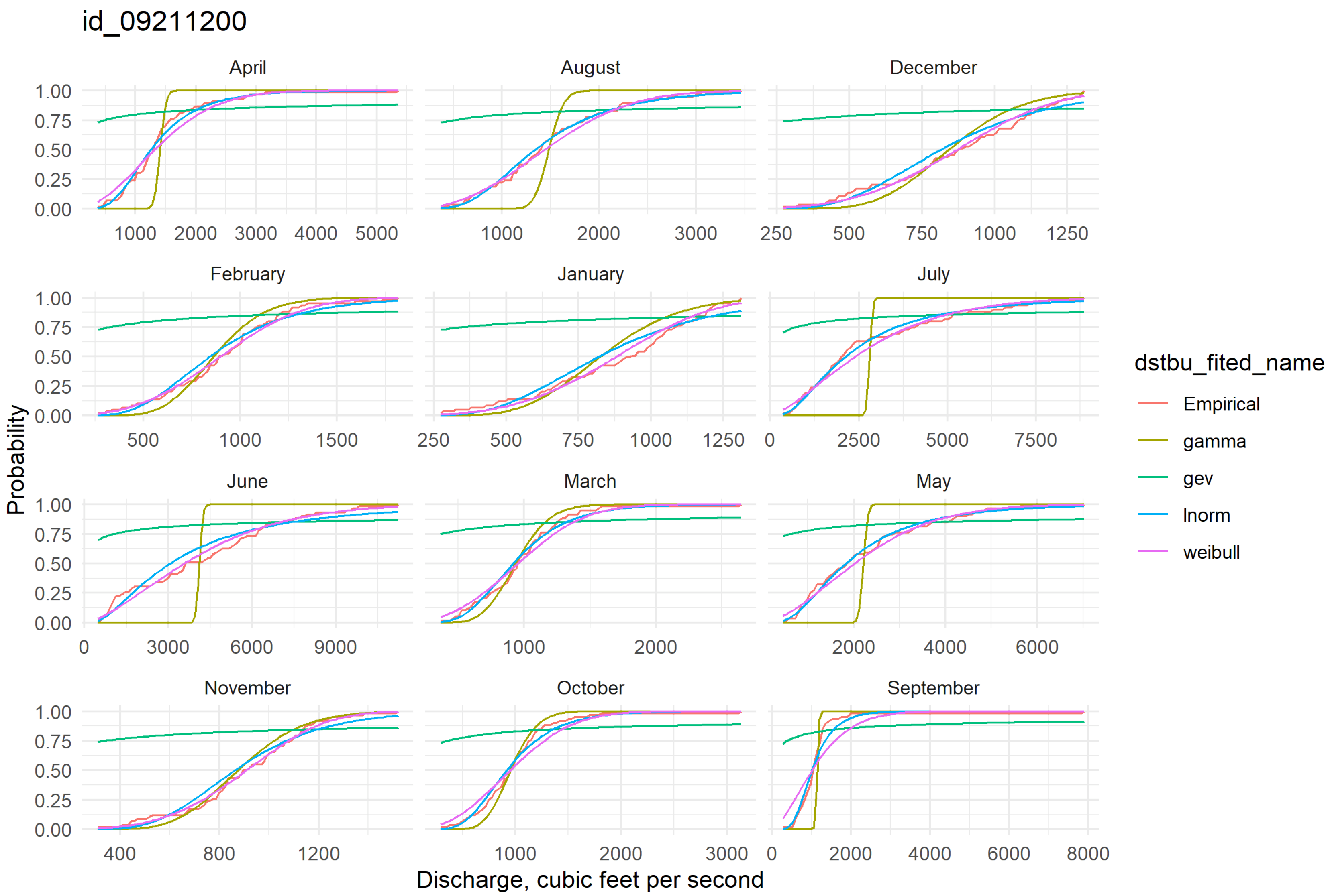
gamma
gev
lnorm
weibull



id_09211200
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December
February
January
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October
September
Probability
Discharge, cubic feet per second
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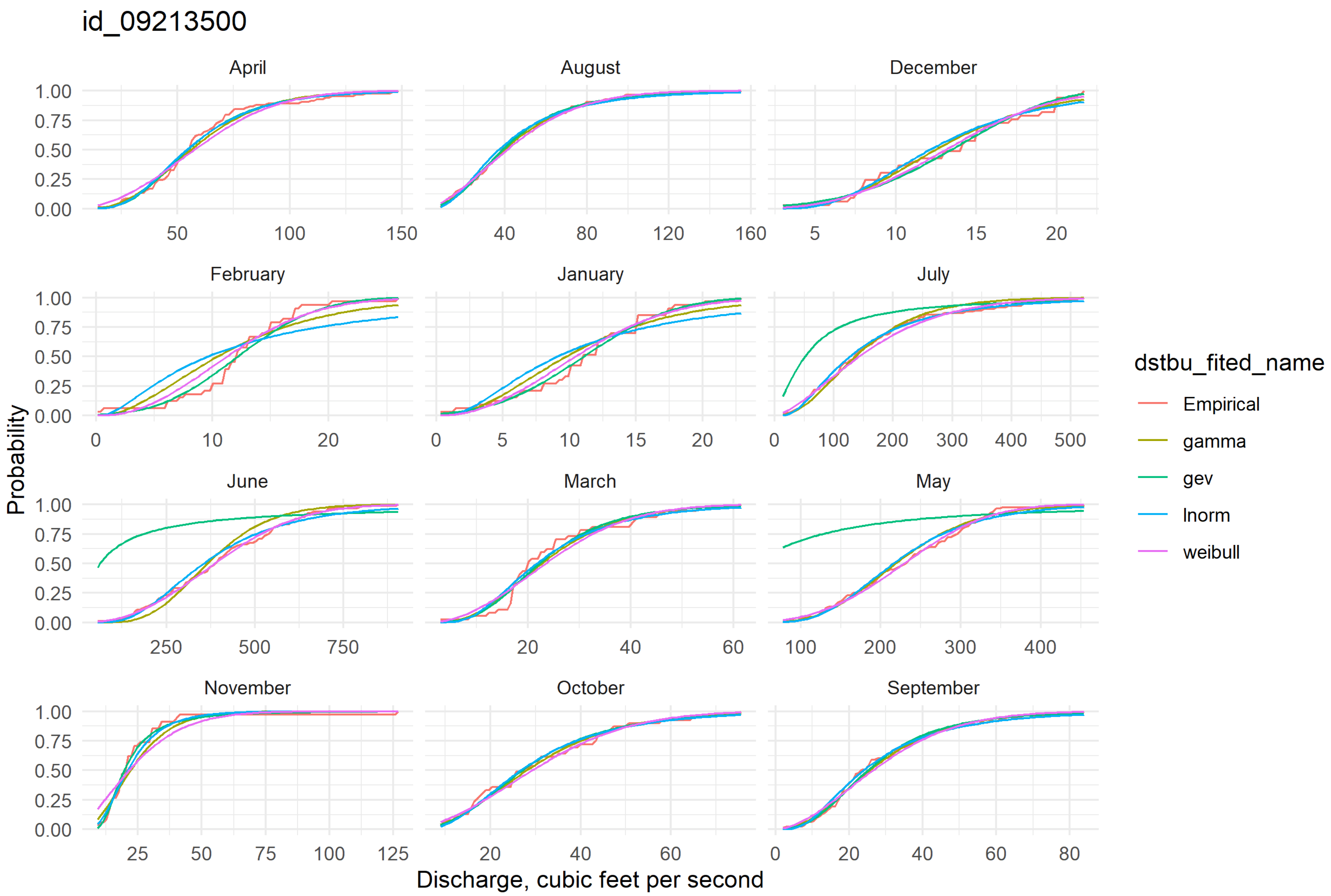
Empirical
gamma
gev
lnorm
weibull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Probability
Discharge, cubic feet per second
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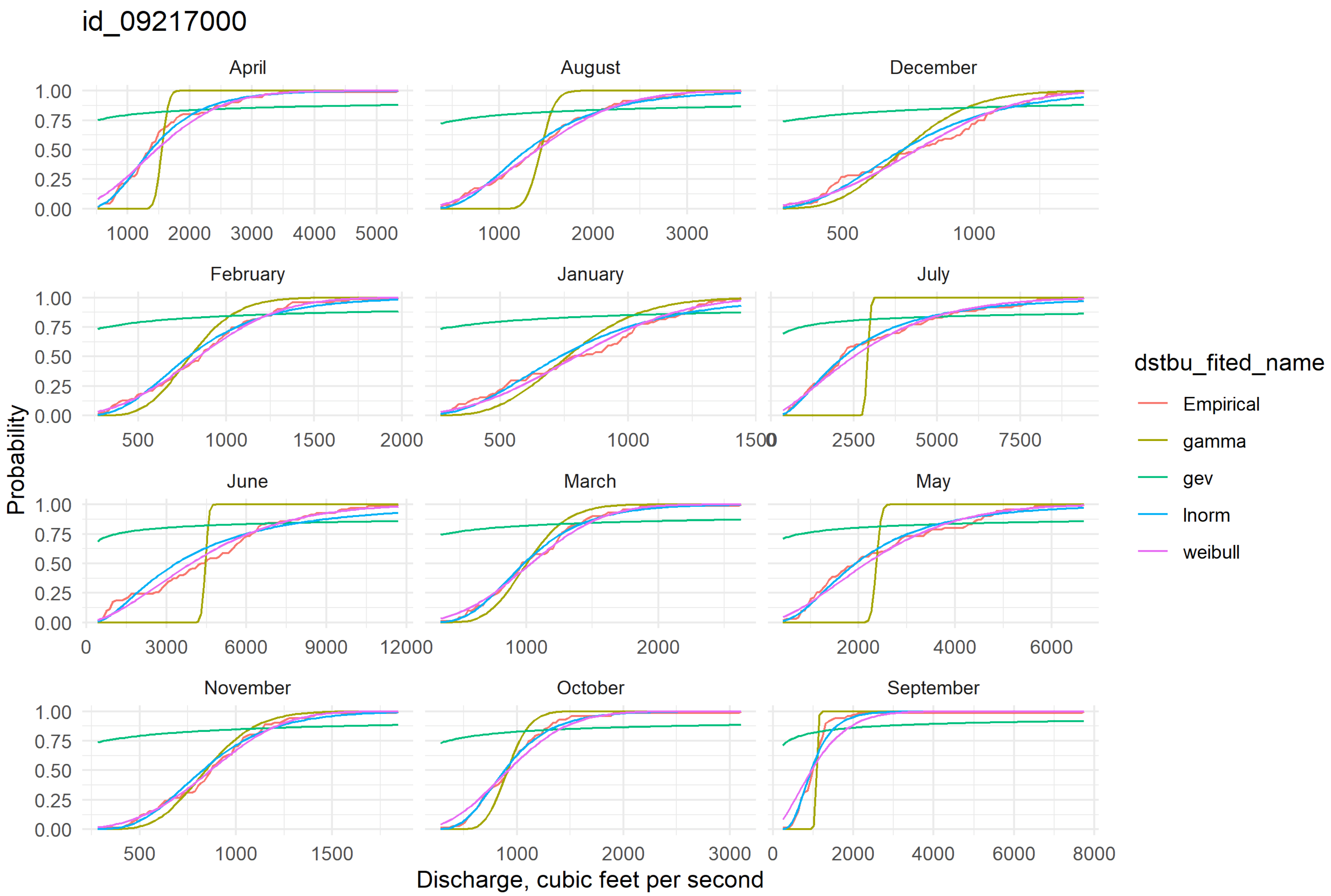
gamma
gev
lnorm
weibull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April
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October
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Probability
Discharge, cubic feet per second
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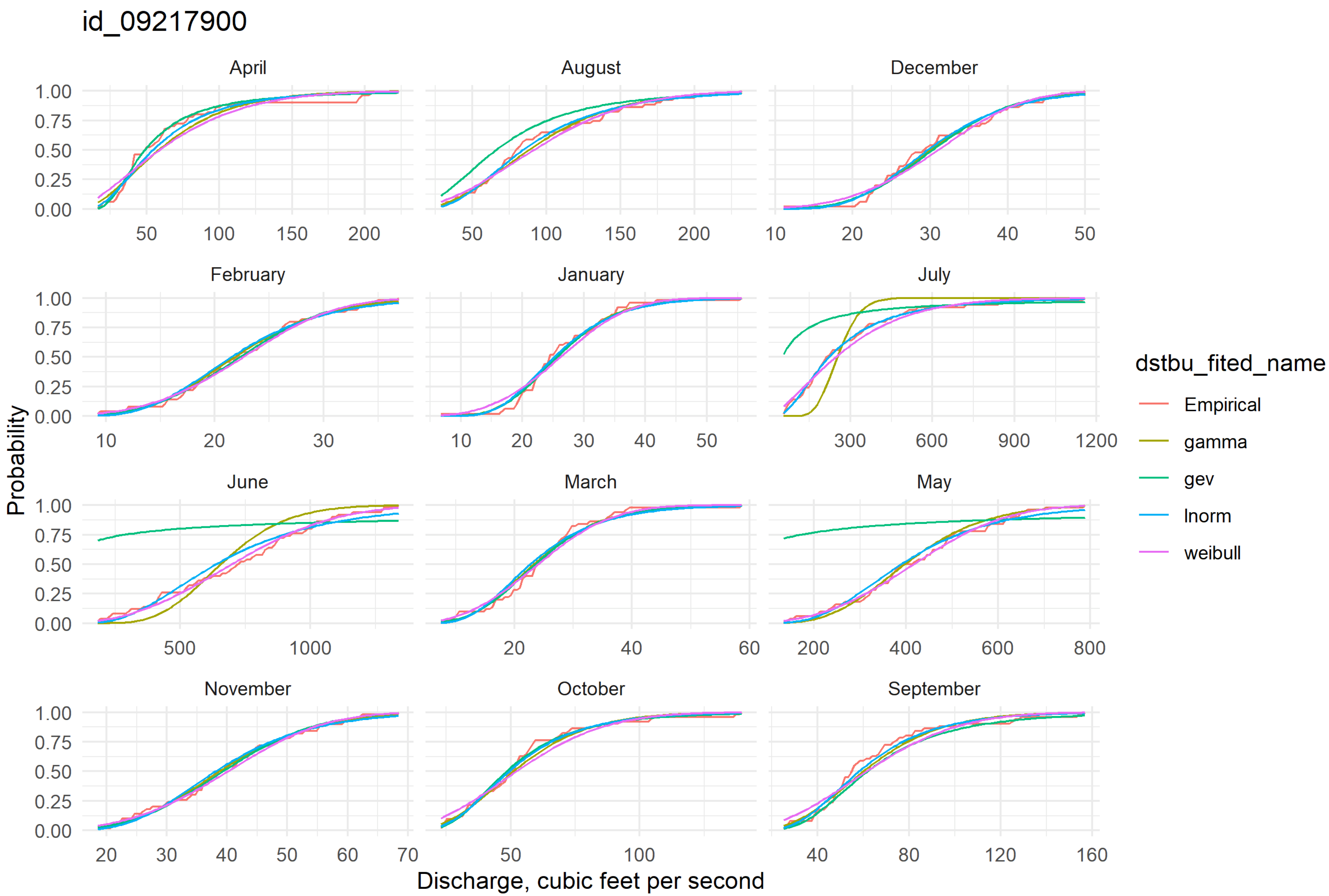
gamma
gev
lnorm
weibull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August
December
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October
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Probability
Discharge, cubic feet per second
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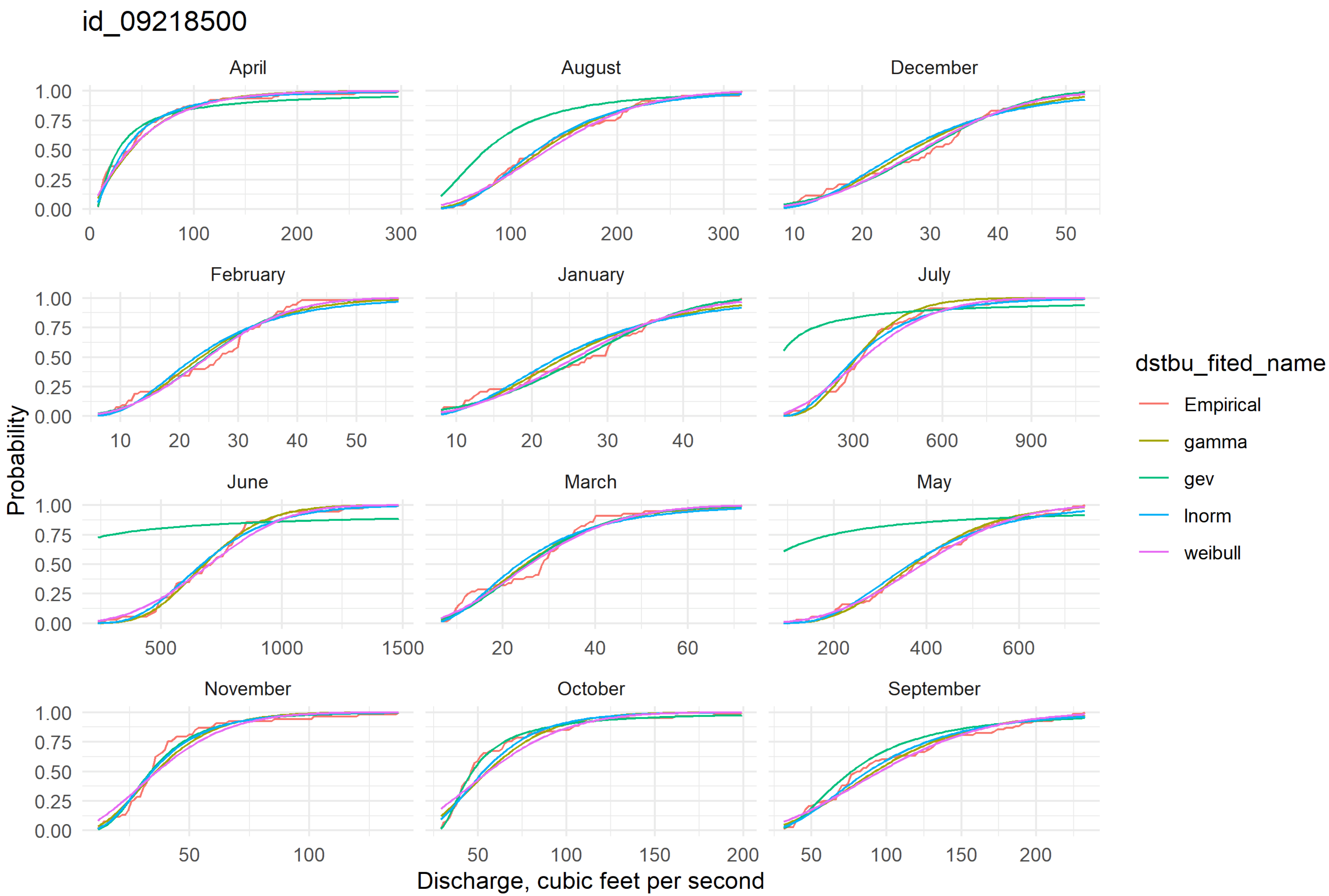
gamma
gev
lnorm
weibull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Probability
Discharge, cubic feet per second
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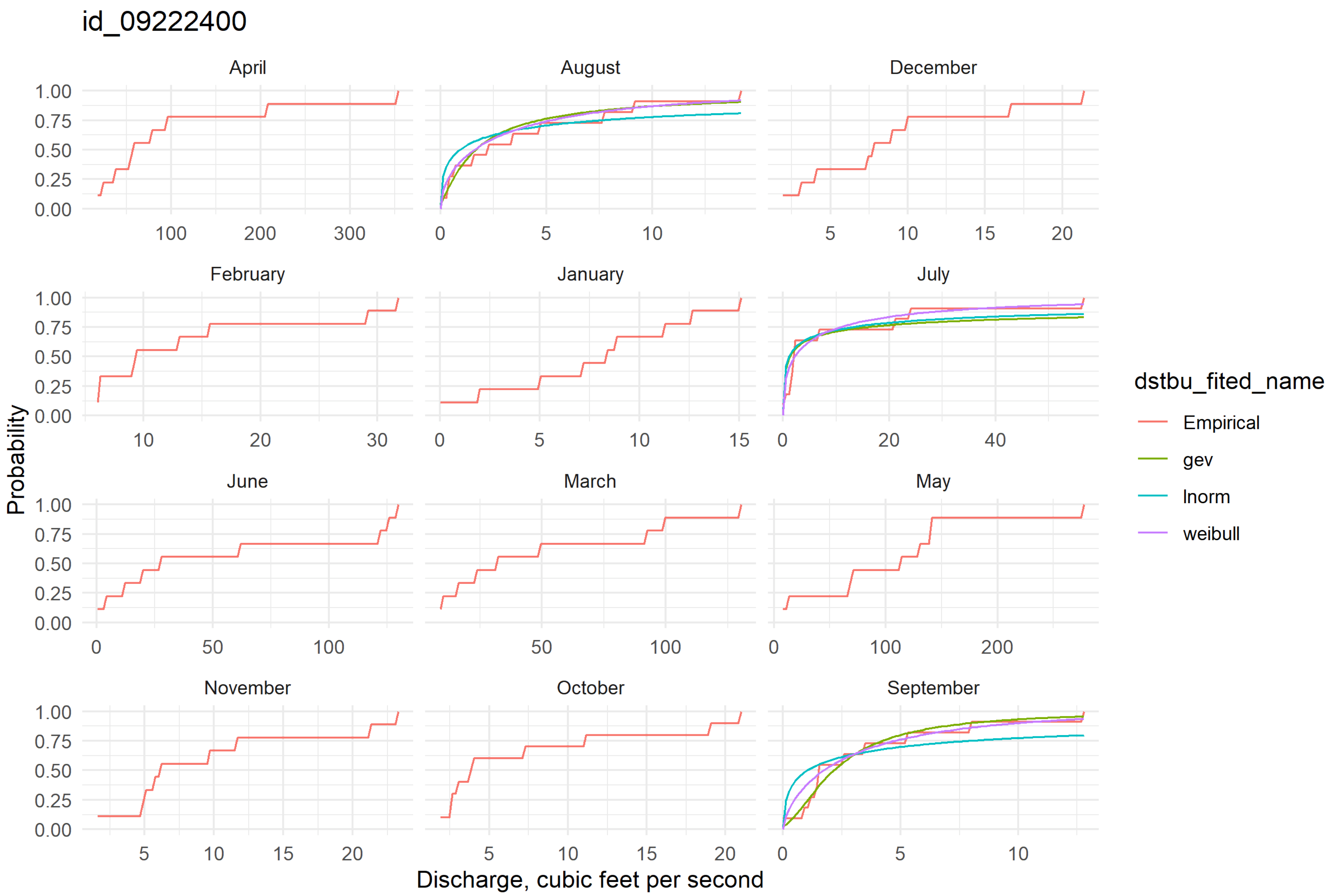
gamma
gev
lnorm
weibull



id_09222400
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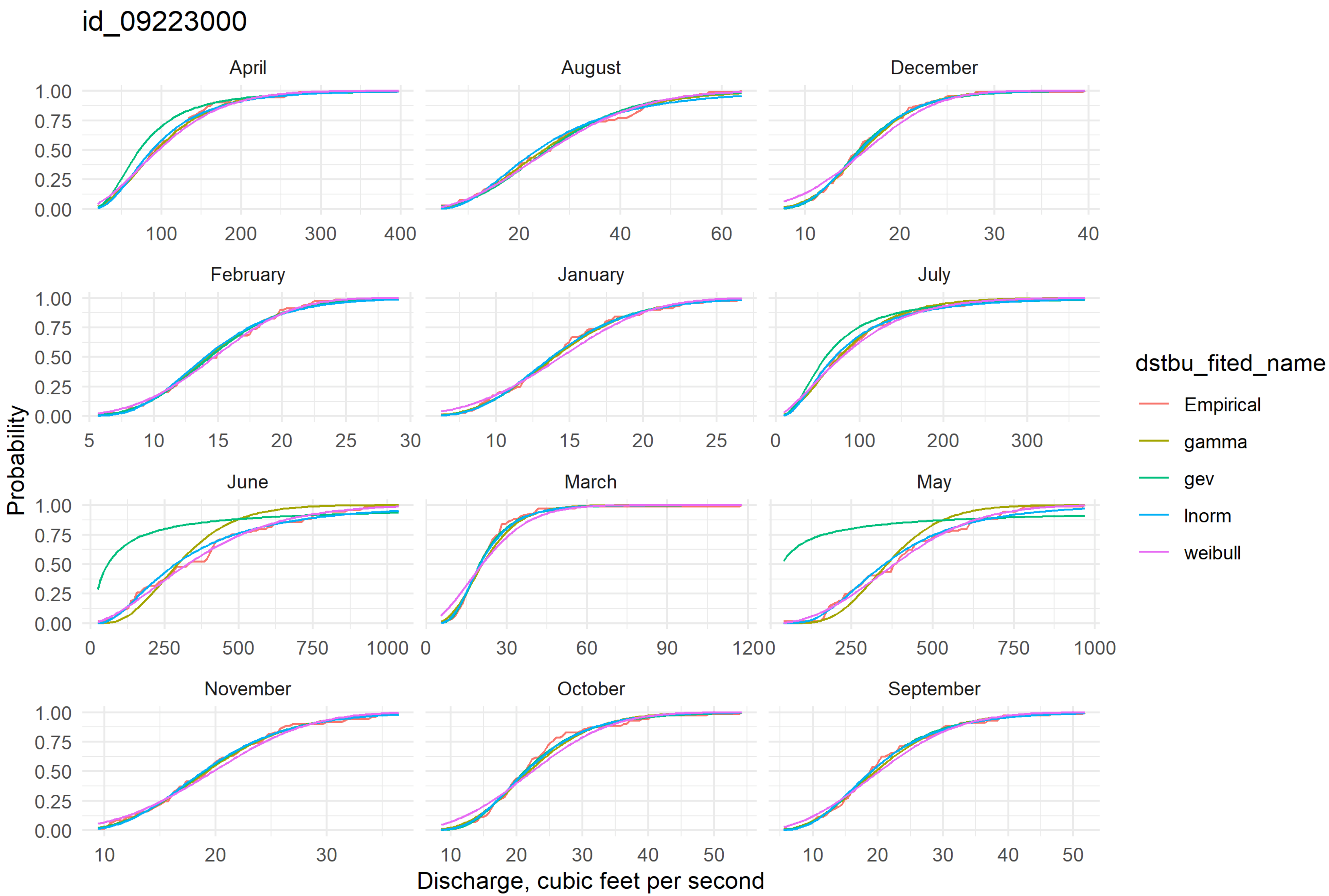
Probability
Discharge, cubic feet per second
dstbu_fited_name
Empirical
gev
lnorm
weibull



id_09223000
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Probability
Discharge, cubic feet per second
dstbu_fited_name
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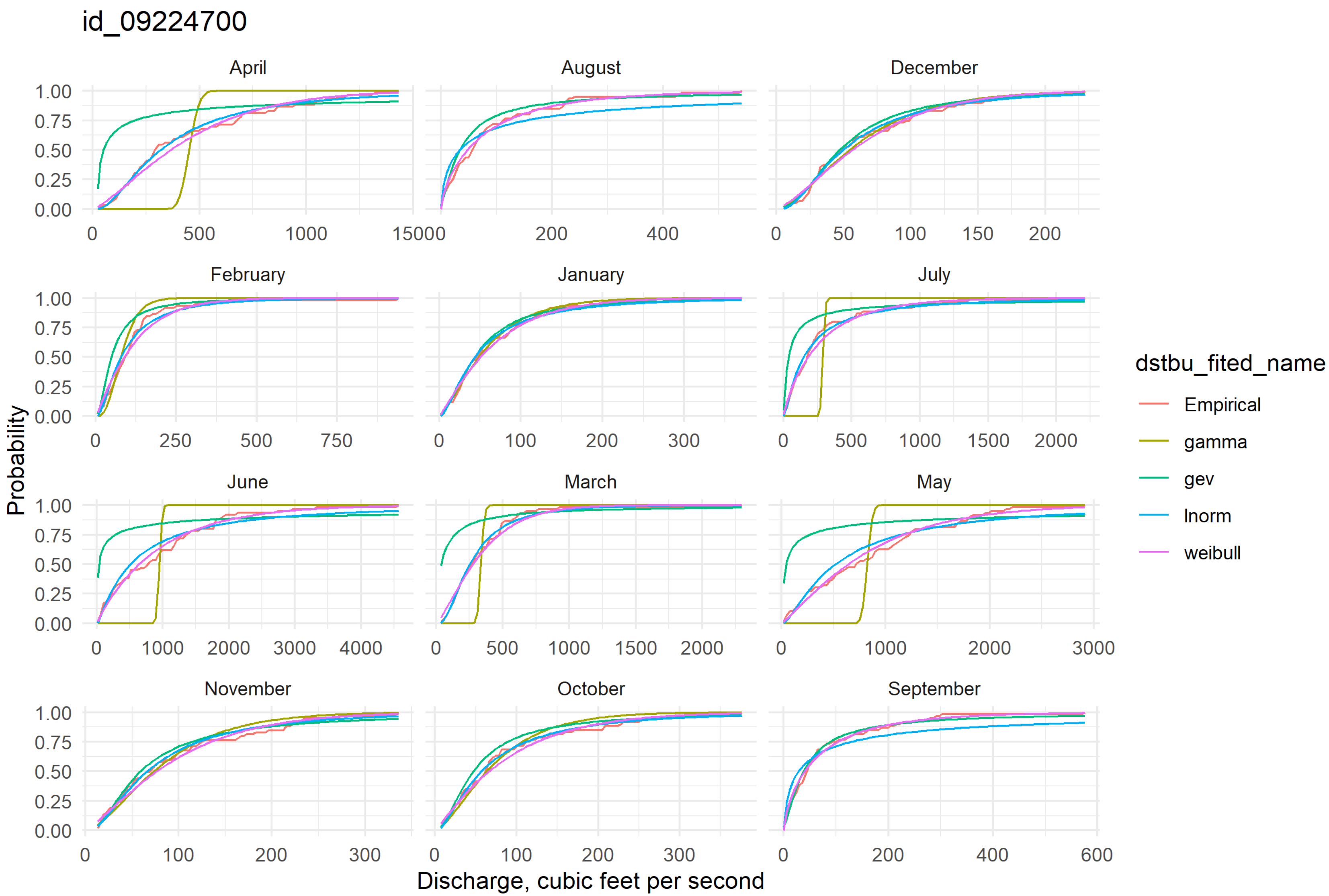
gamma
gev
lnorm
weibull


id_09224700
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December
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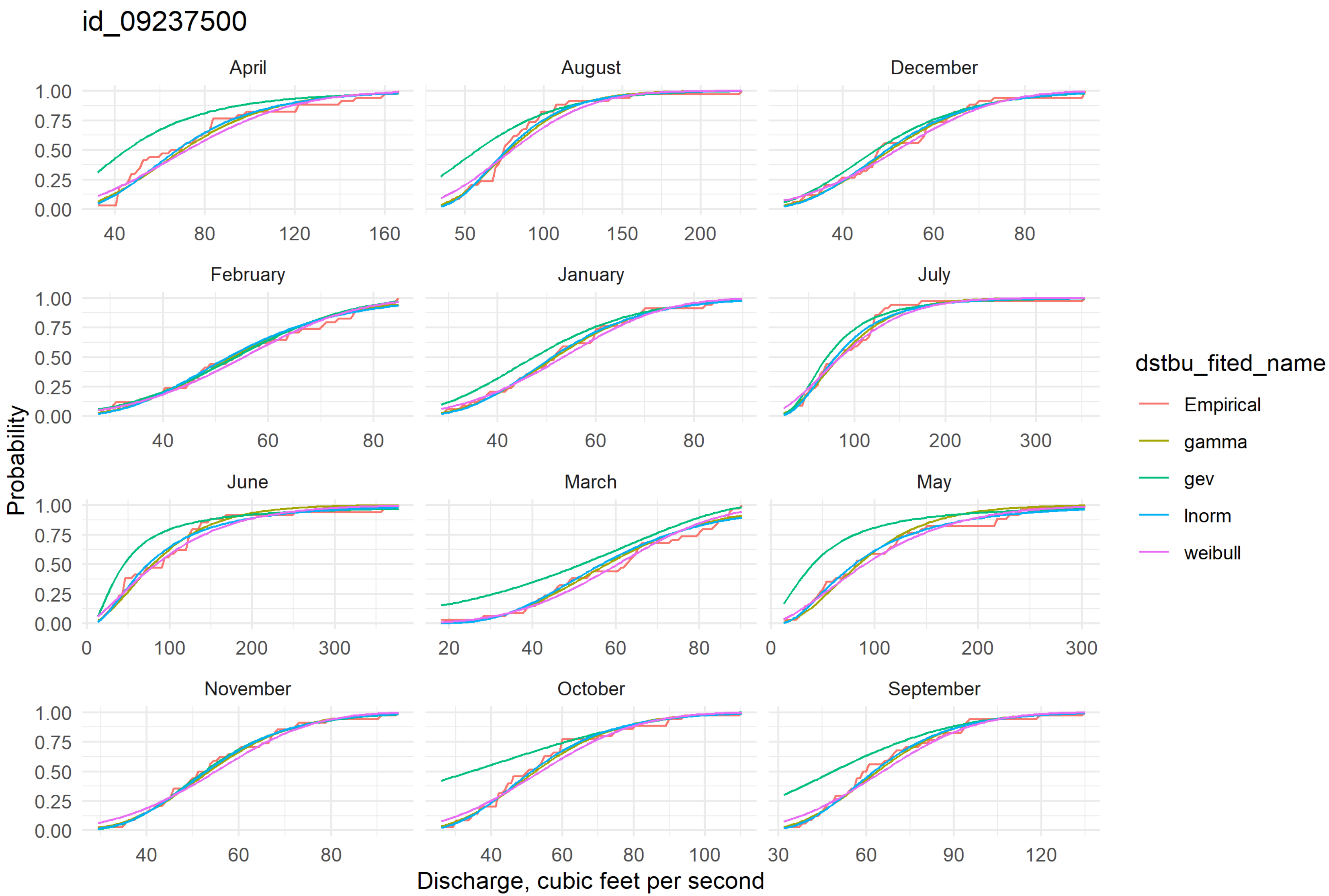
Probability
Discharge, cubic feet per second
dstbu_fited_name
Empirical
gamma
gev
lnorm
weibull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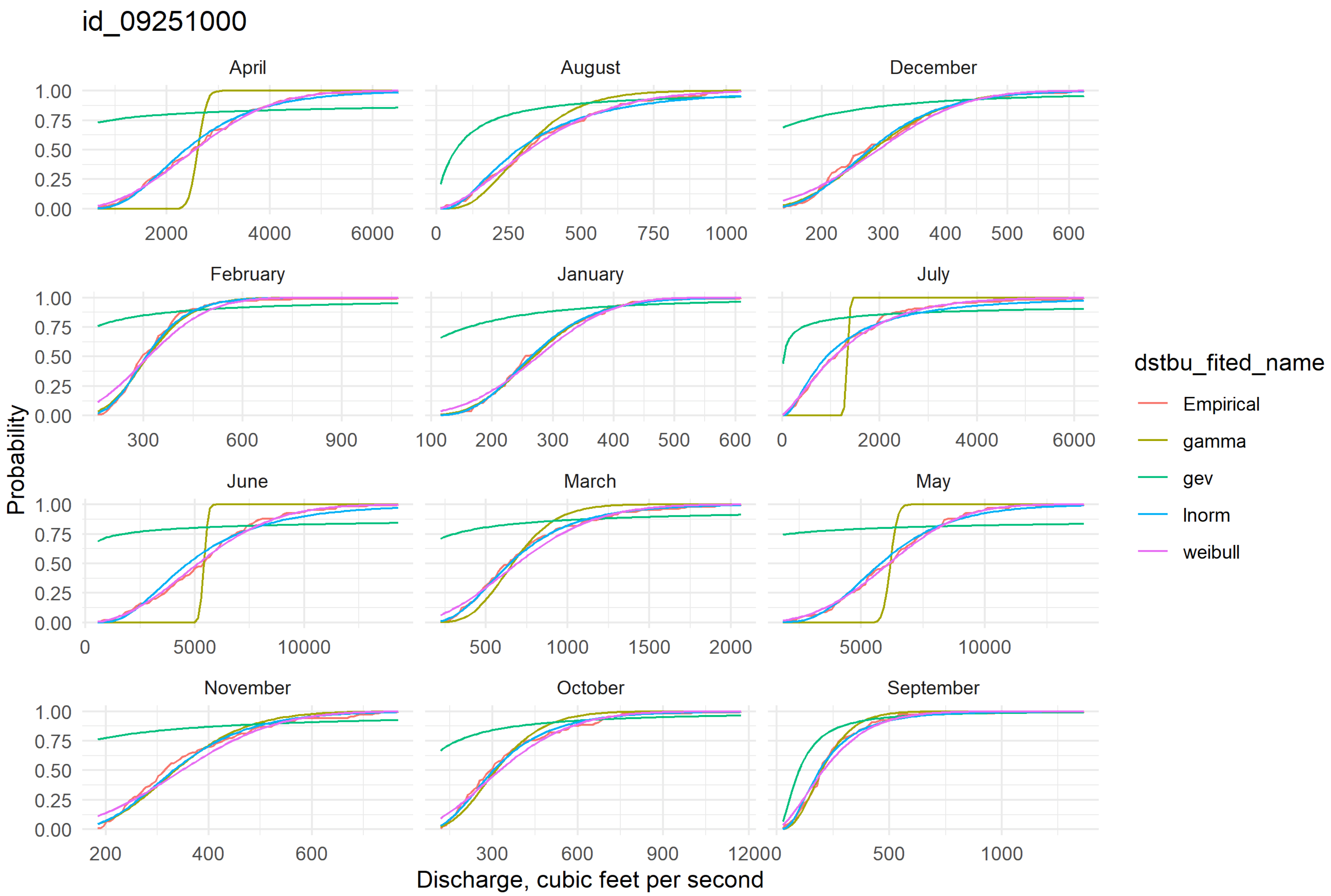
Probability
Discharge, cubic feet per second
dstbu_fited_name
Empirical
gamma
gev
lnorm
weibull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April
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Probability
Discharge, cubic feet per second
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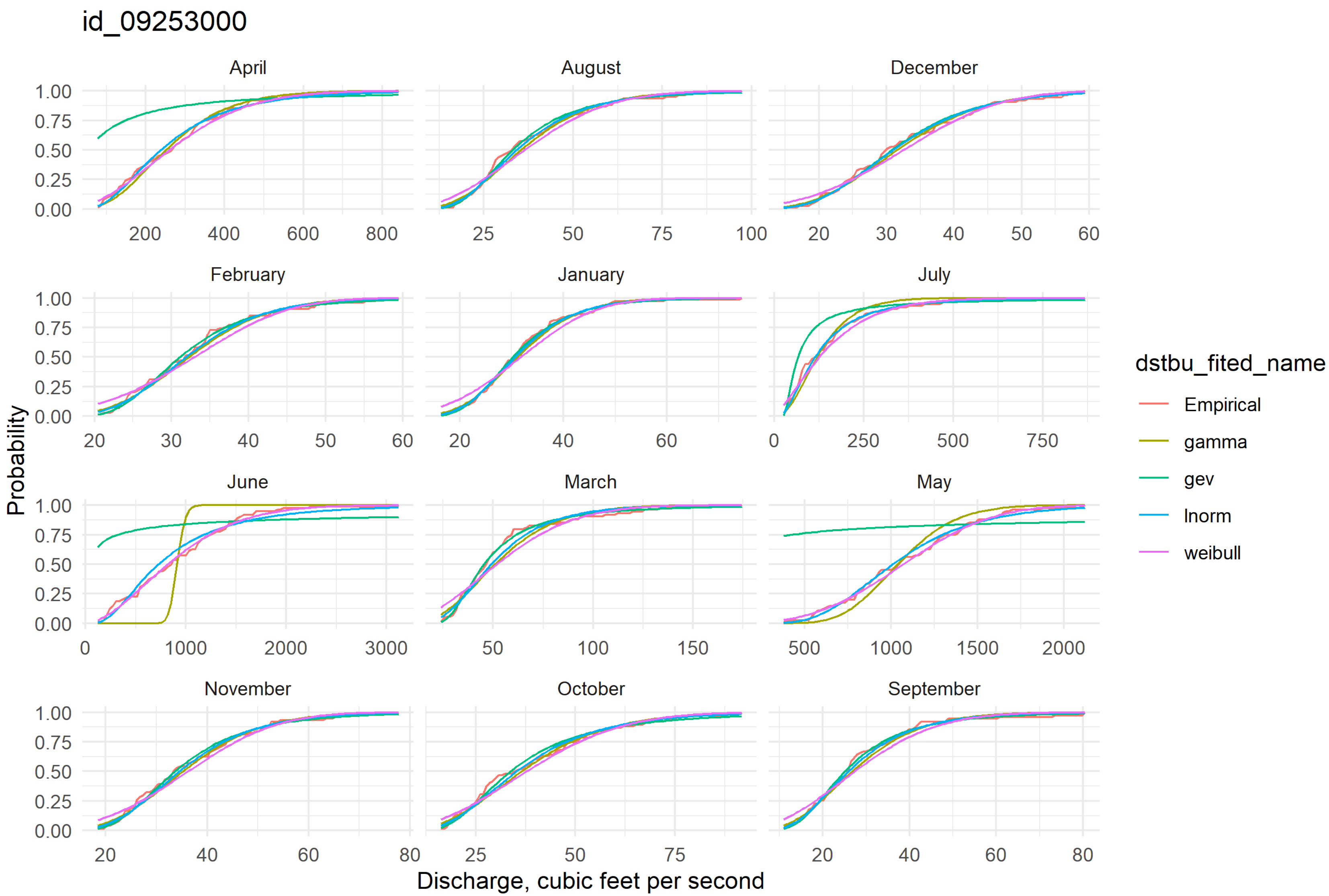
gamma
gev
lnorm
weibull



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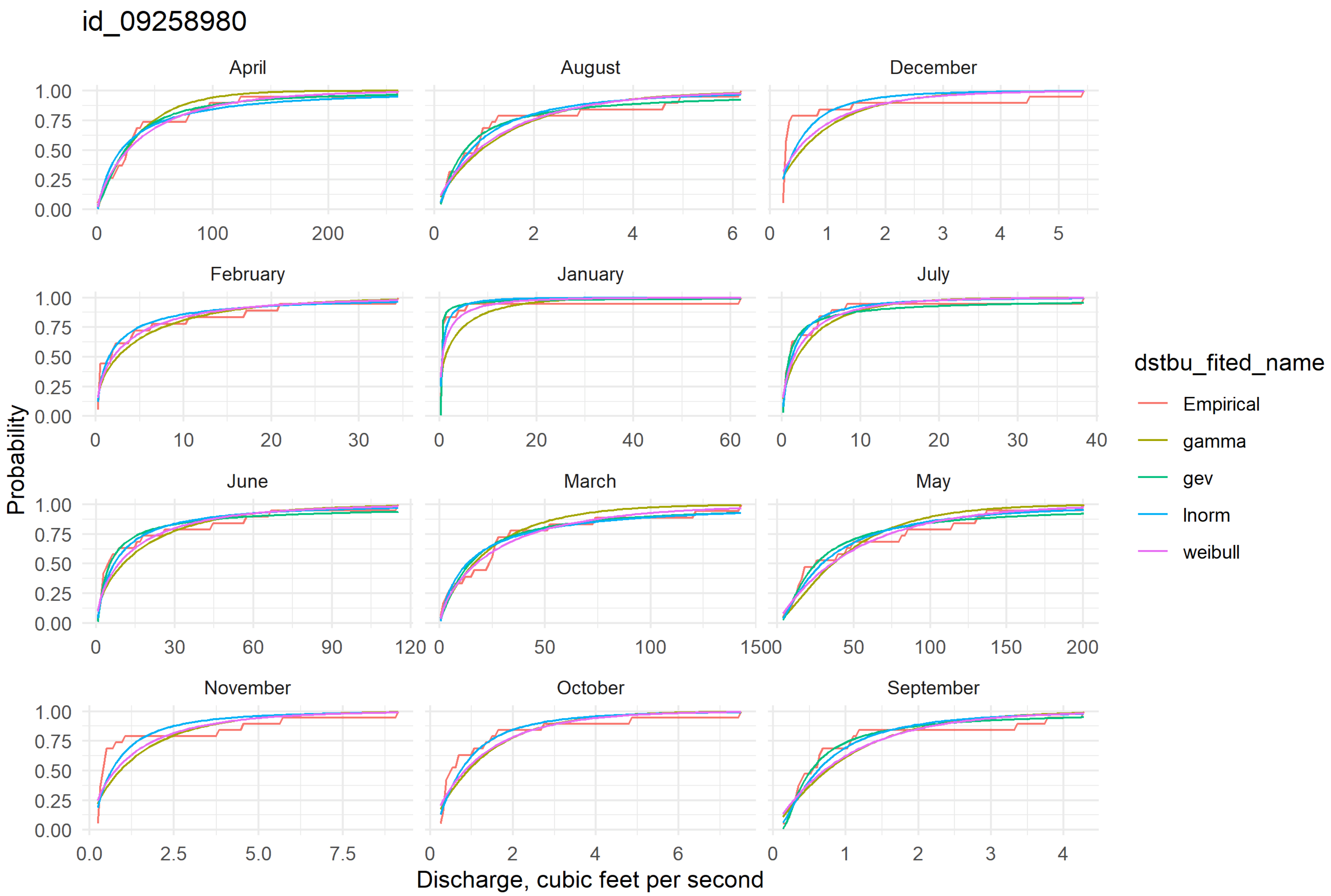
gamma
gev
lnorm
weibull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Probability
Discharge, cubic feet per second
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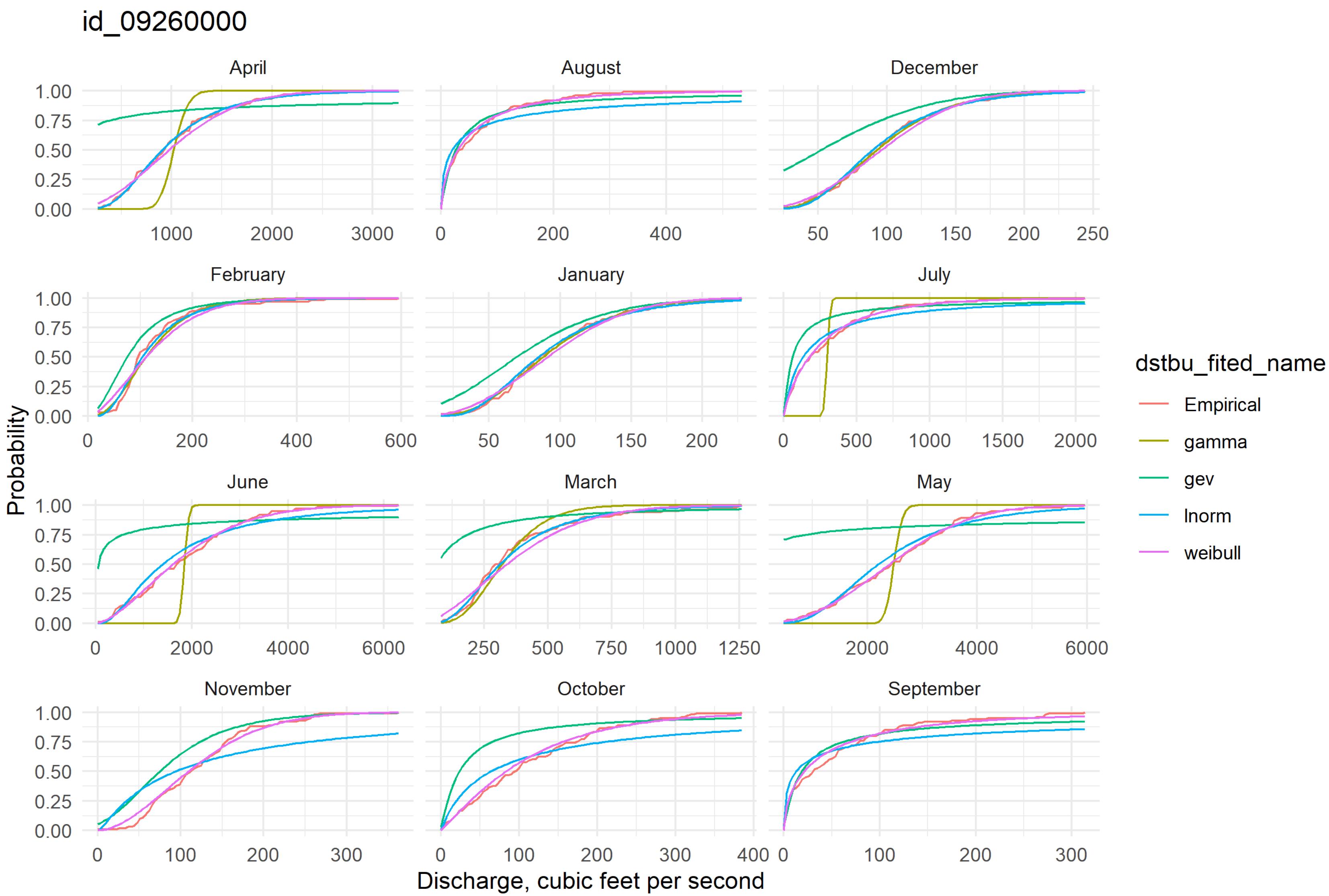
gamma
gev
lnorm
weibull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Probability
Discharge, cubic feet per second
dstbu_fited_name
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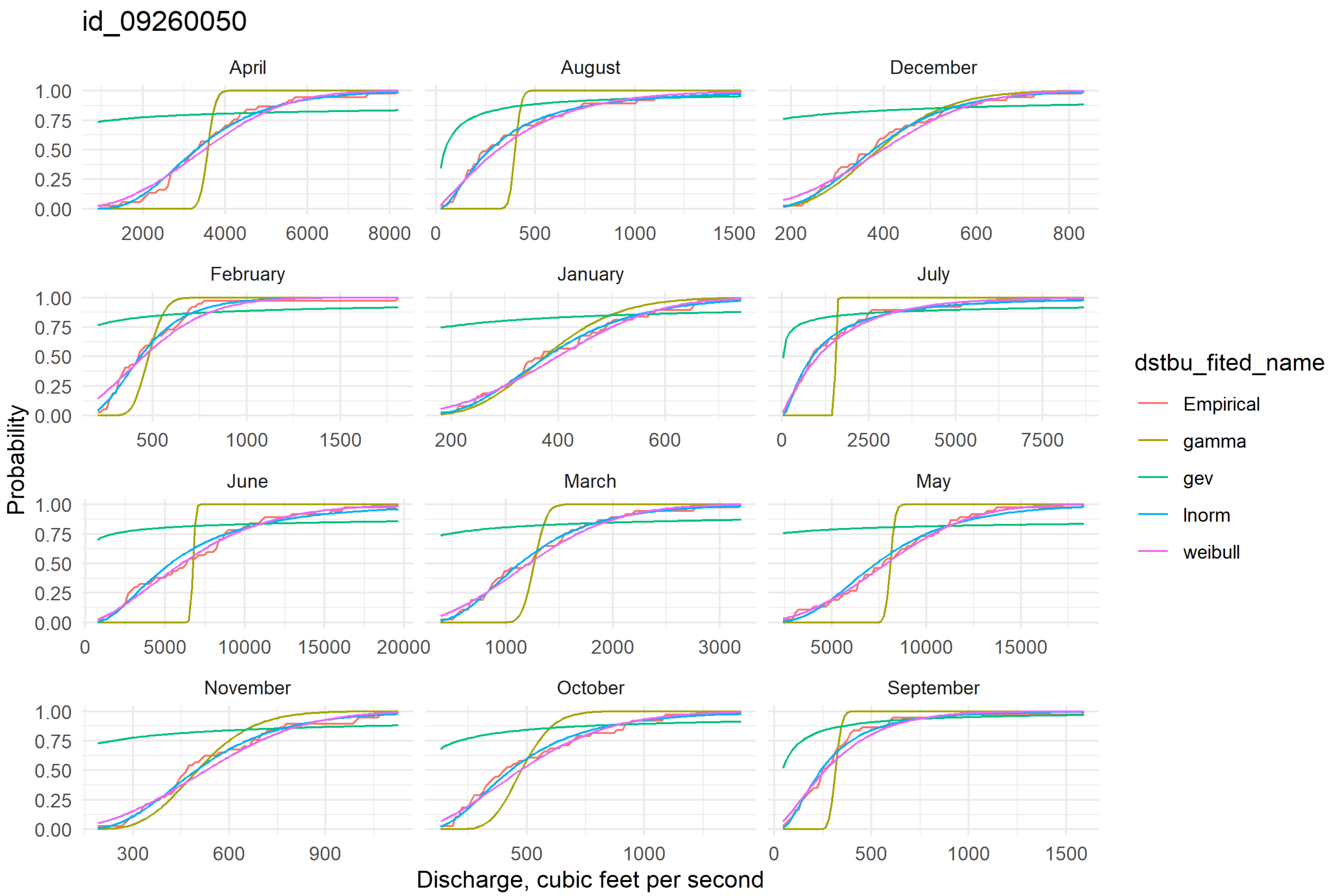
gamma
gev
lnorm
weibull



id_09260050
April
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December
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October
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Probability
Discharge, cubic feet per second
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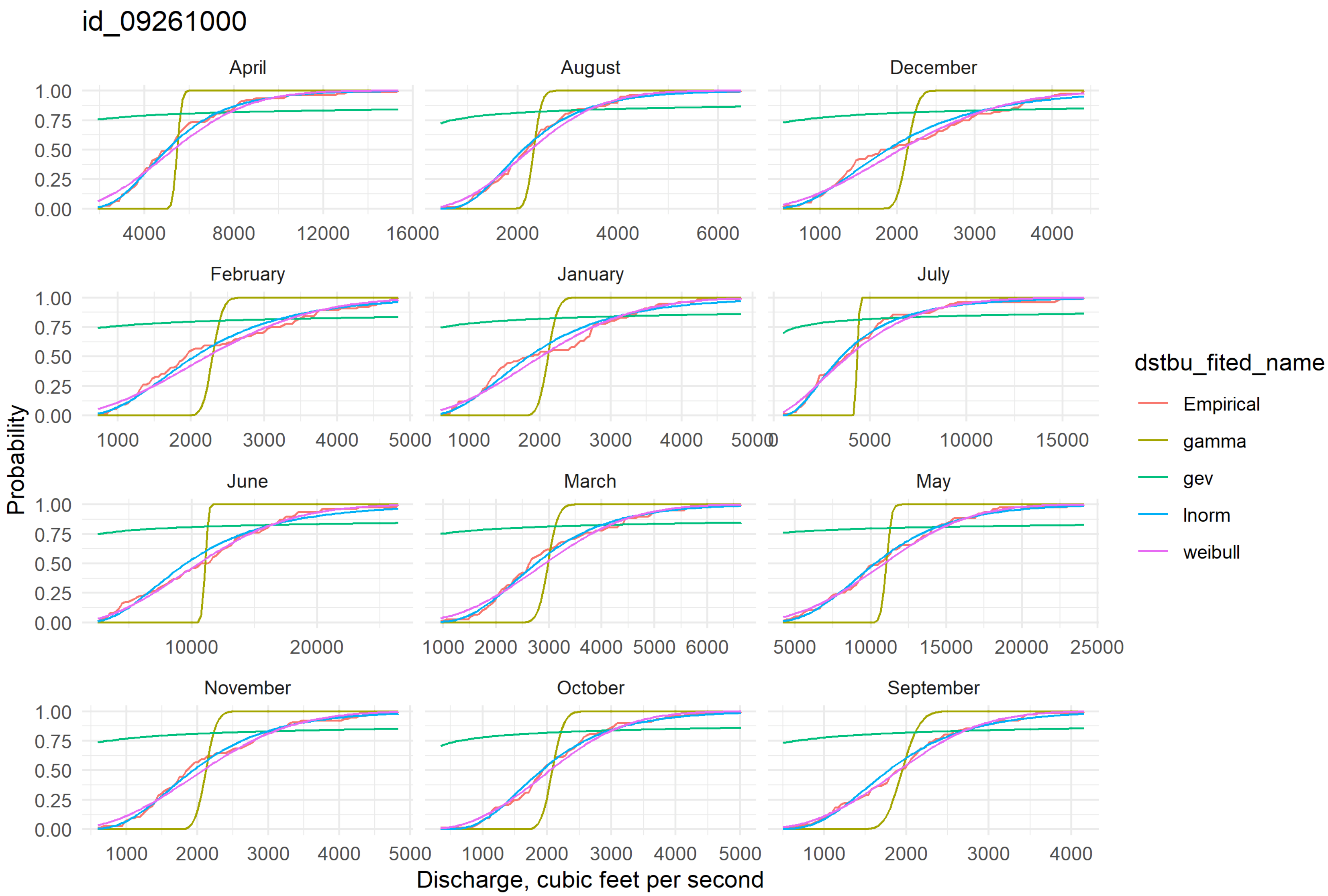
Empirical
gamma
gev
lnorm
weibull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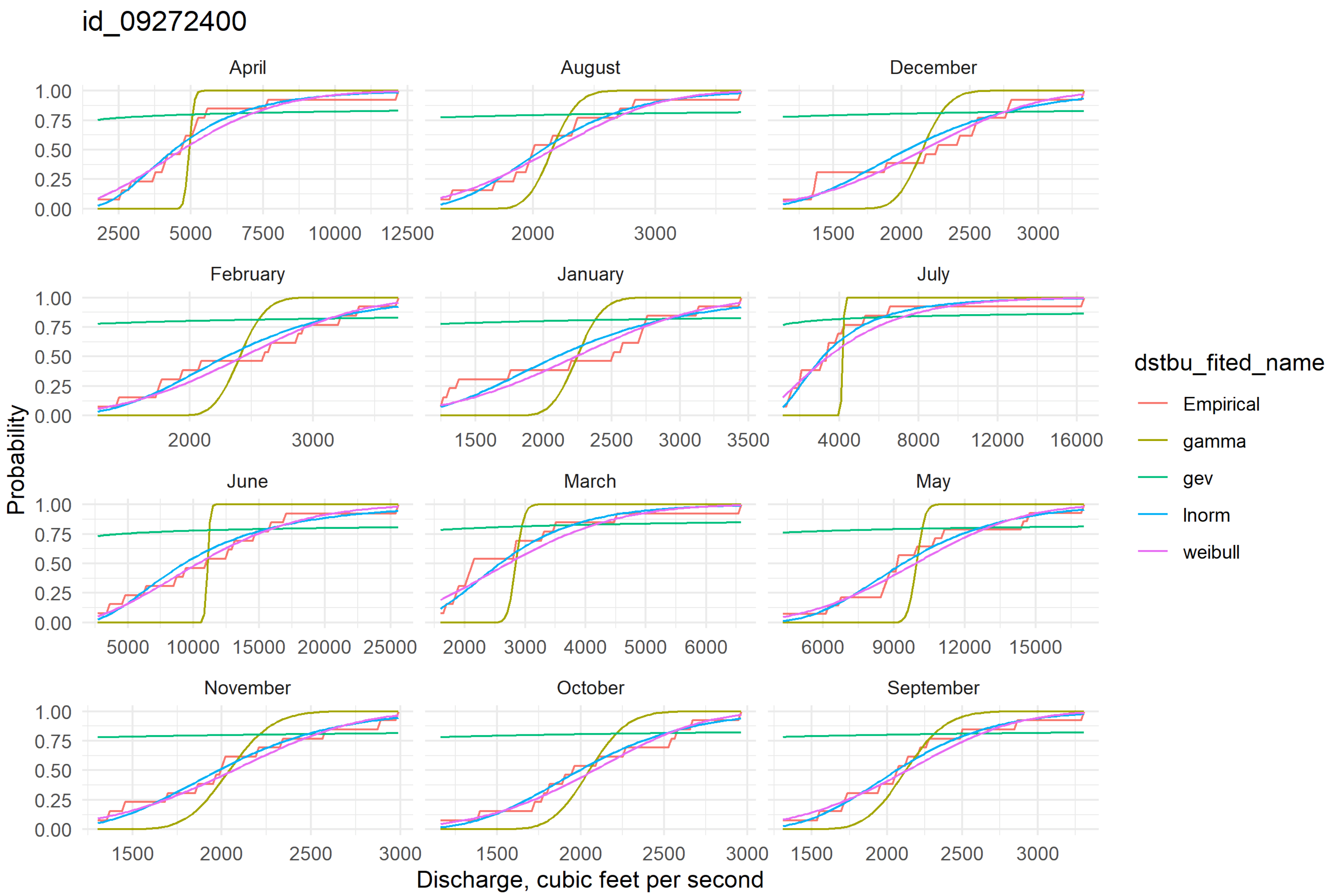
Probability
Discharge, cubic feet per second
dstbu_fited_name
Empirical
gamma
gev
lnorm
weibull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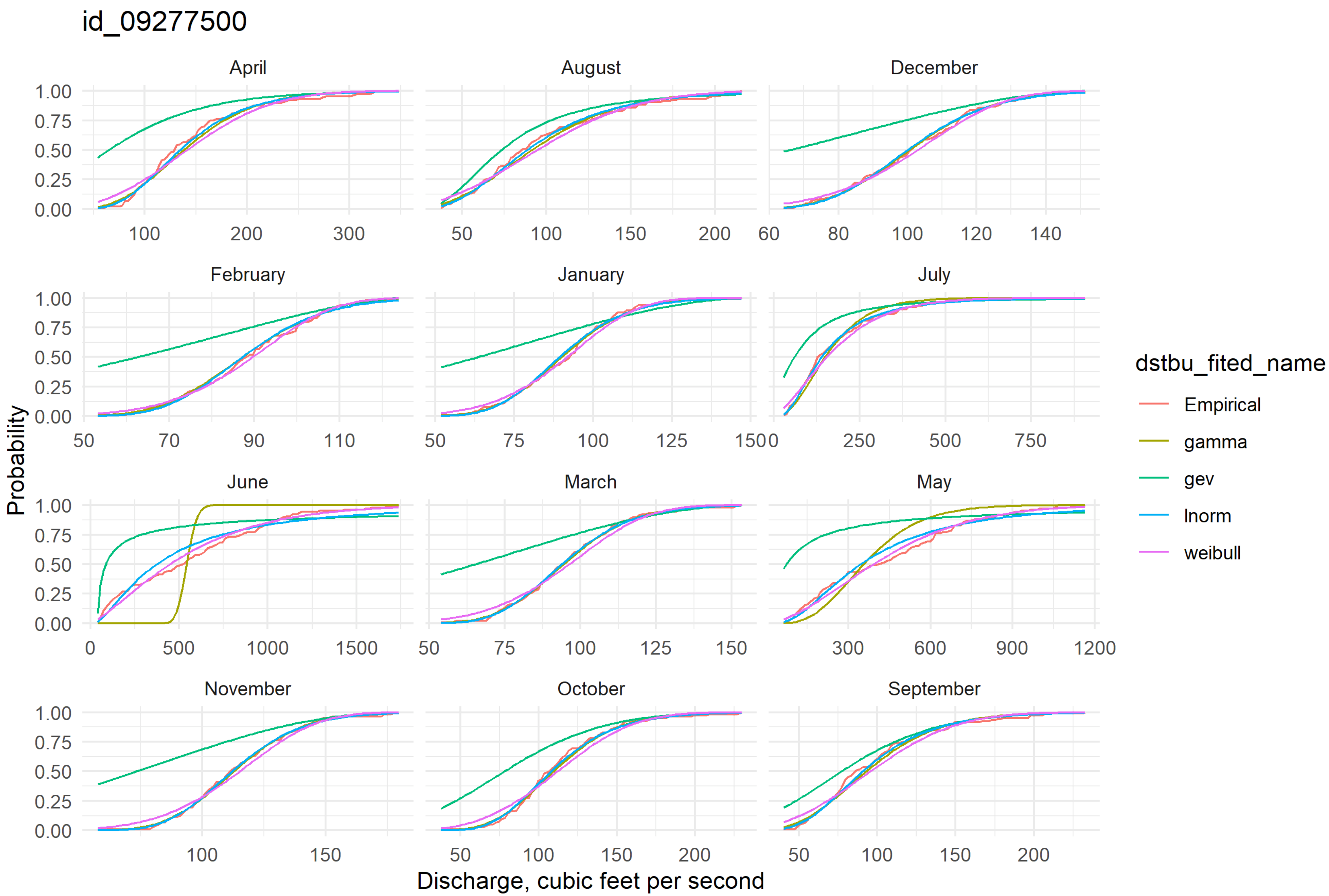
Probability
Discharge, cubic feet per second
dstbu_fited_name
Empirical
gamma
gev
lnorm
weibull



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August
December
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July
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March
May
November
October
September
1.00
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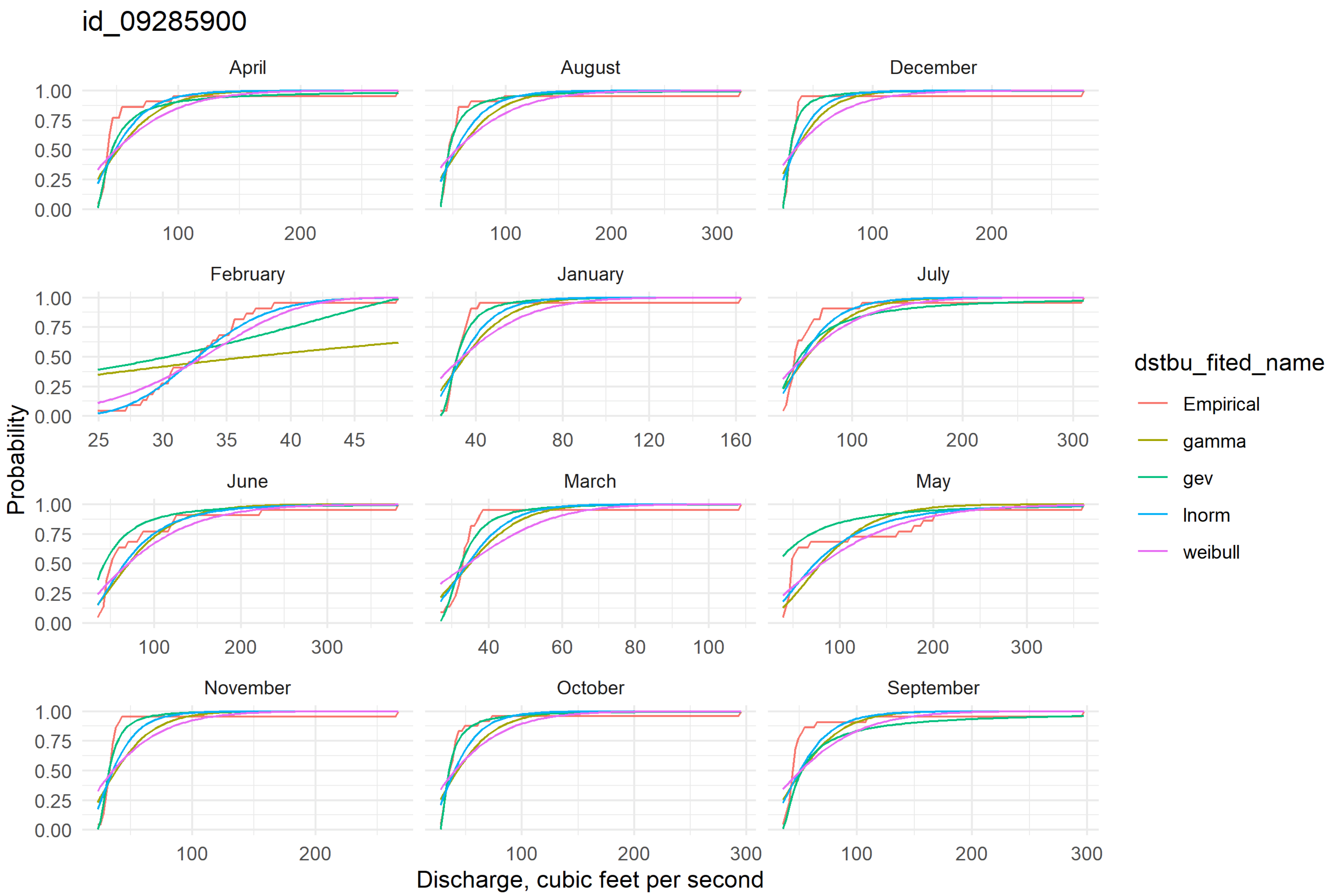
0.25
0.00
Probability
Discharge, cubic feet per second
dstbu_fited_name
Empirical
gamma
gev
lnorm
weibull



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March
May
November
October
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1.00
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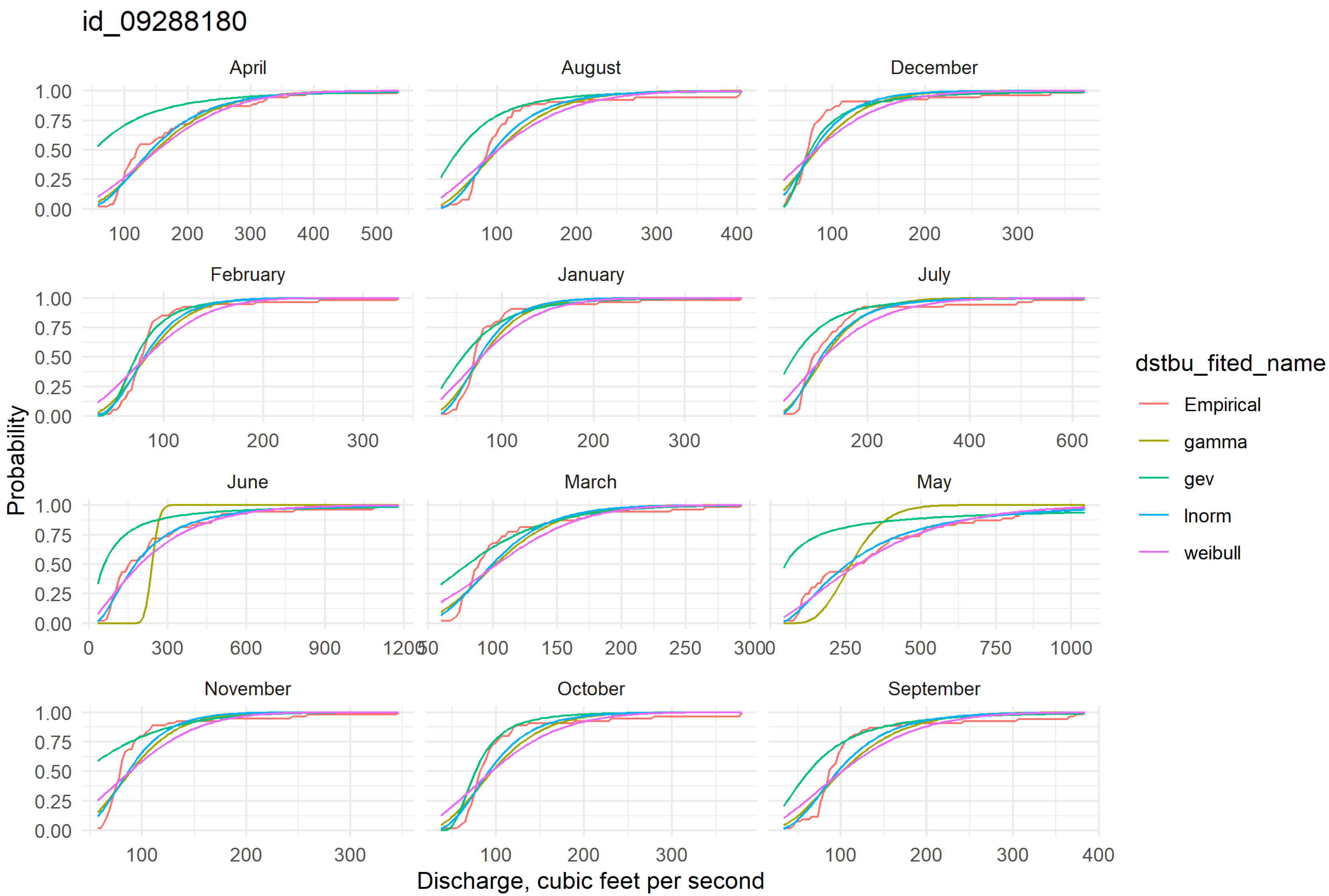
0.50
0.25
0.00
Probability
Discharge, cubic feet per second
dstbu_fited_name
Empirical
gamma
gev
lnorm
weibull



id_09288180
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Probability
Discharge, cubic feet per second
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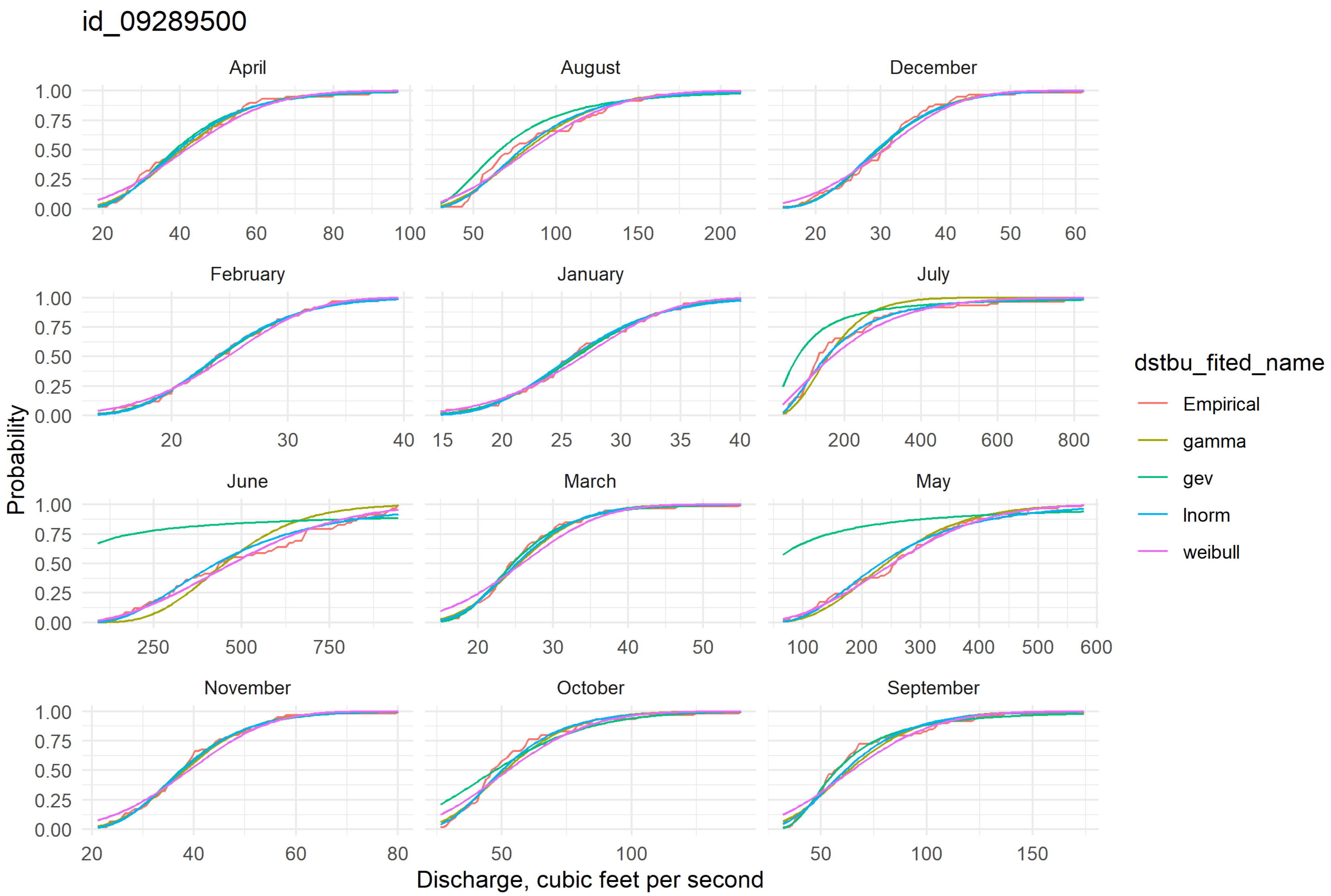
gamma
gev
lnorm
weibull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Probability
Discharge, cubic feet per second
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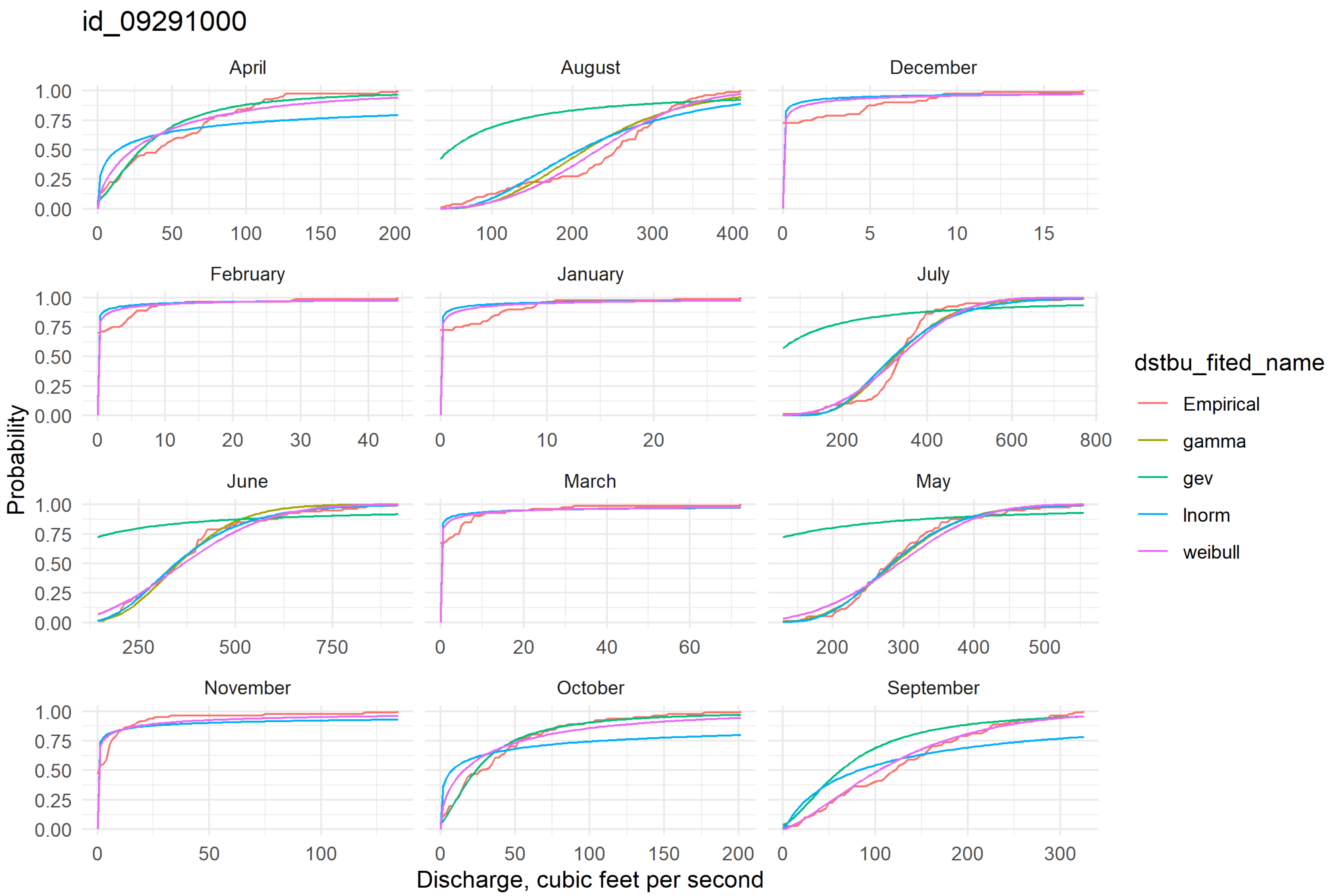
gamma
gev
lnorm
weibull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Discharge, cubic feet per second
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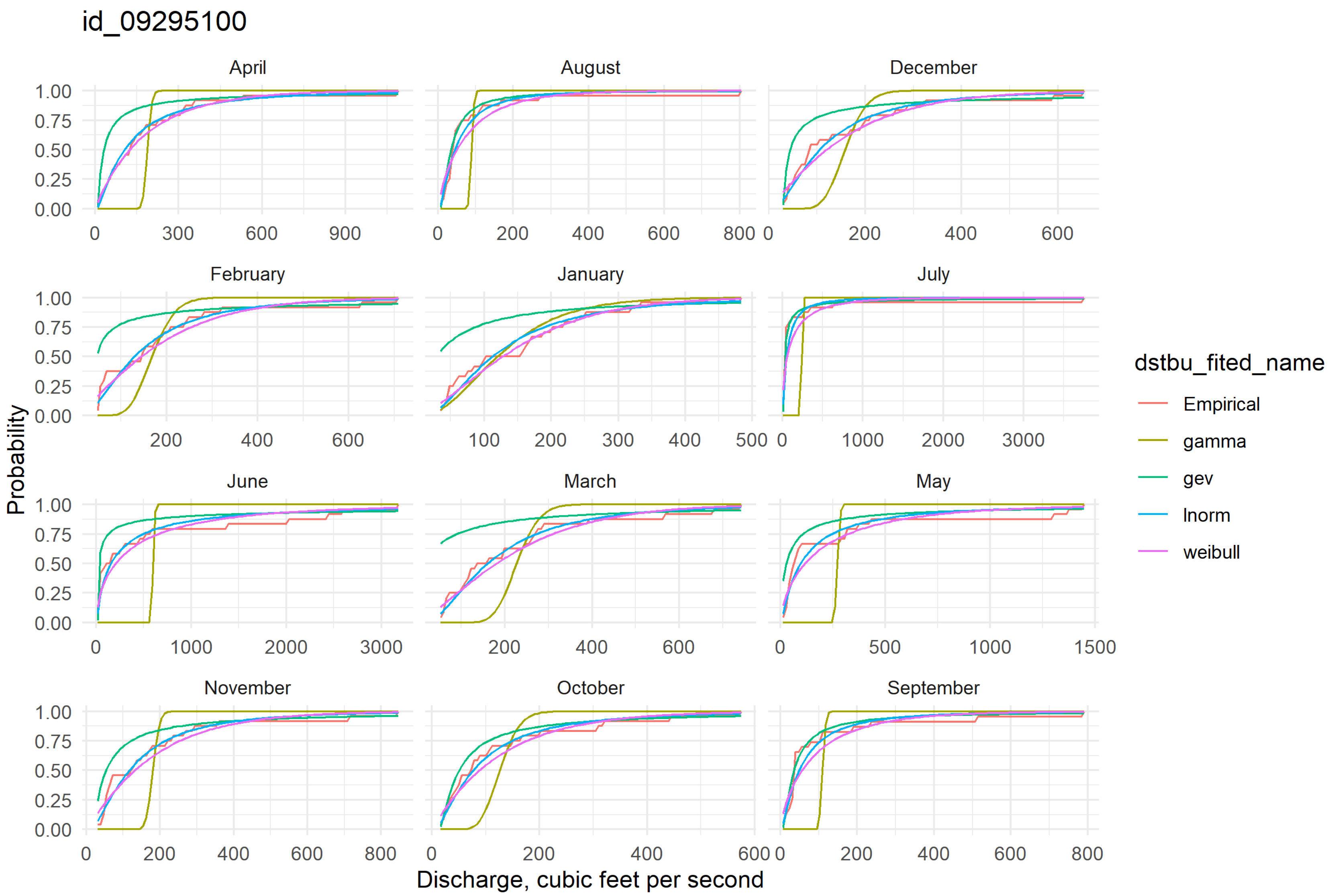
gamma
gev
lnorm
weibull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Probability
Discharge, cubic feet per second
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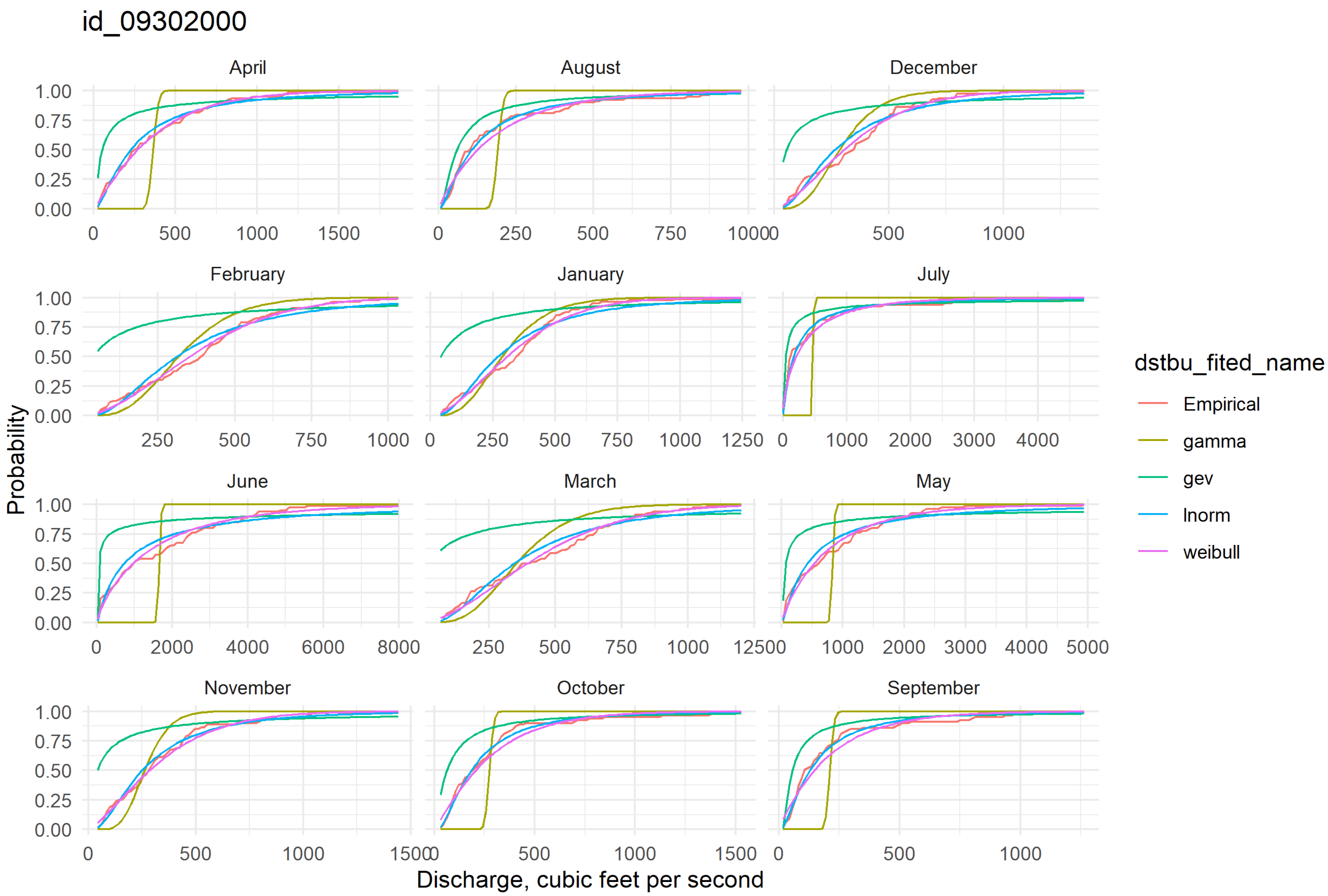
gamma
gev
lnorm
weibull



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Probability
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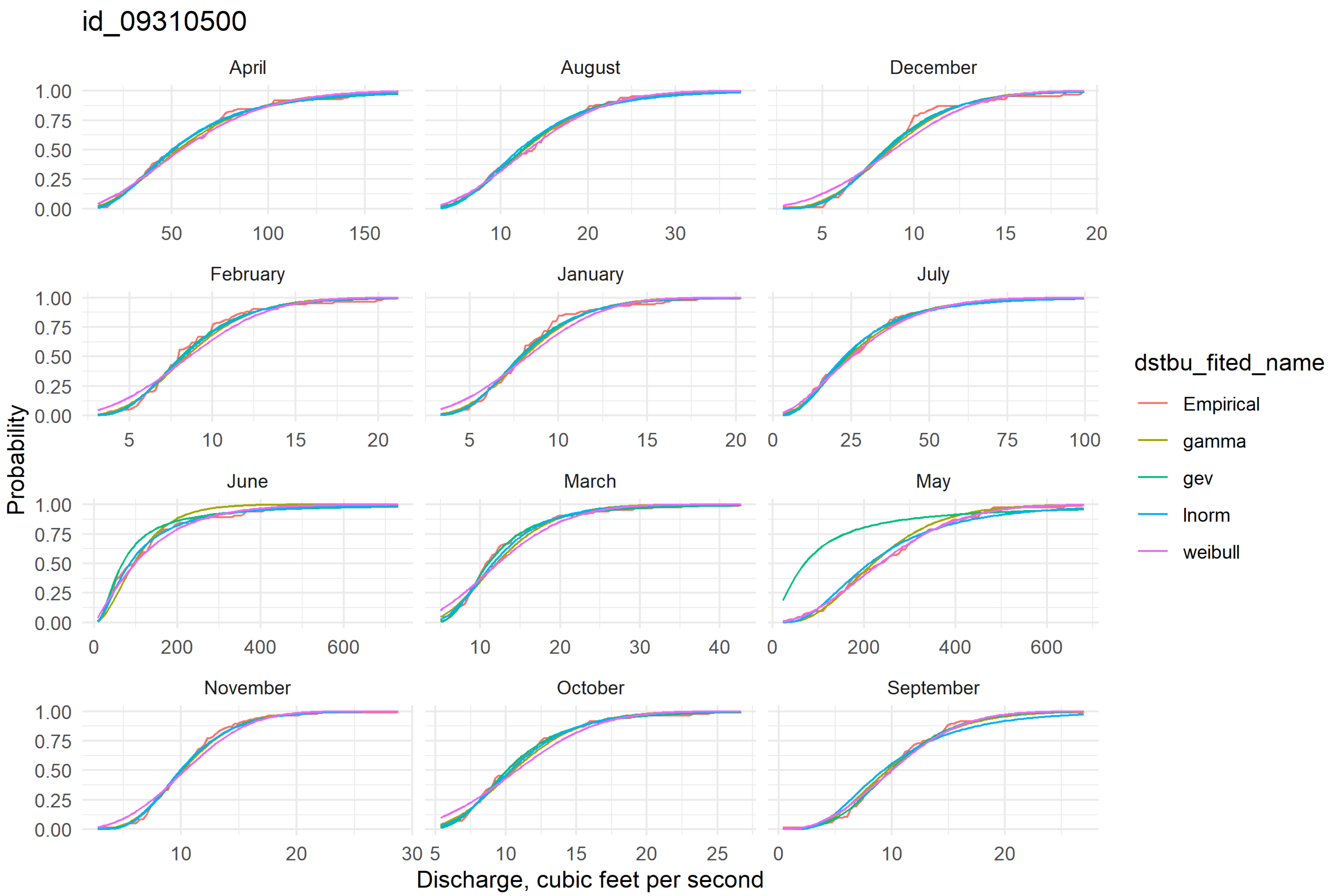
gamma
gev
lnorm
weibull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Probability
Discharge, cubic feet per second
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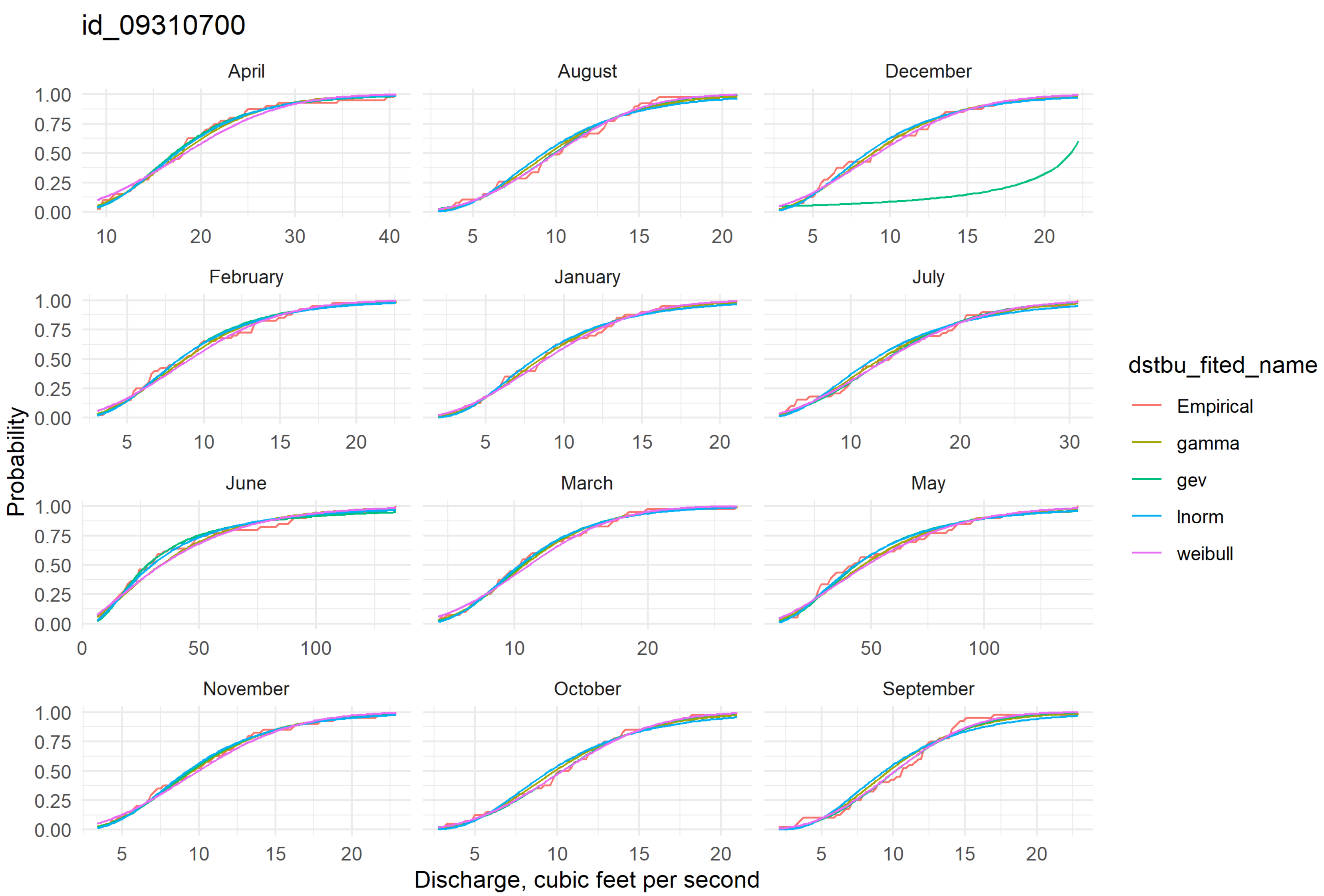
gamma
gev
lnorm
weibull



id_09310700
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Probability
Discharge, cubic feet per second
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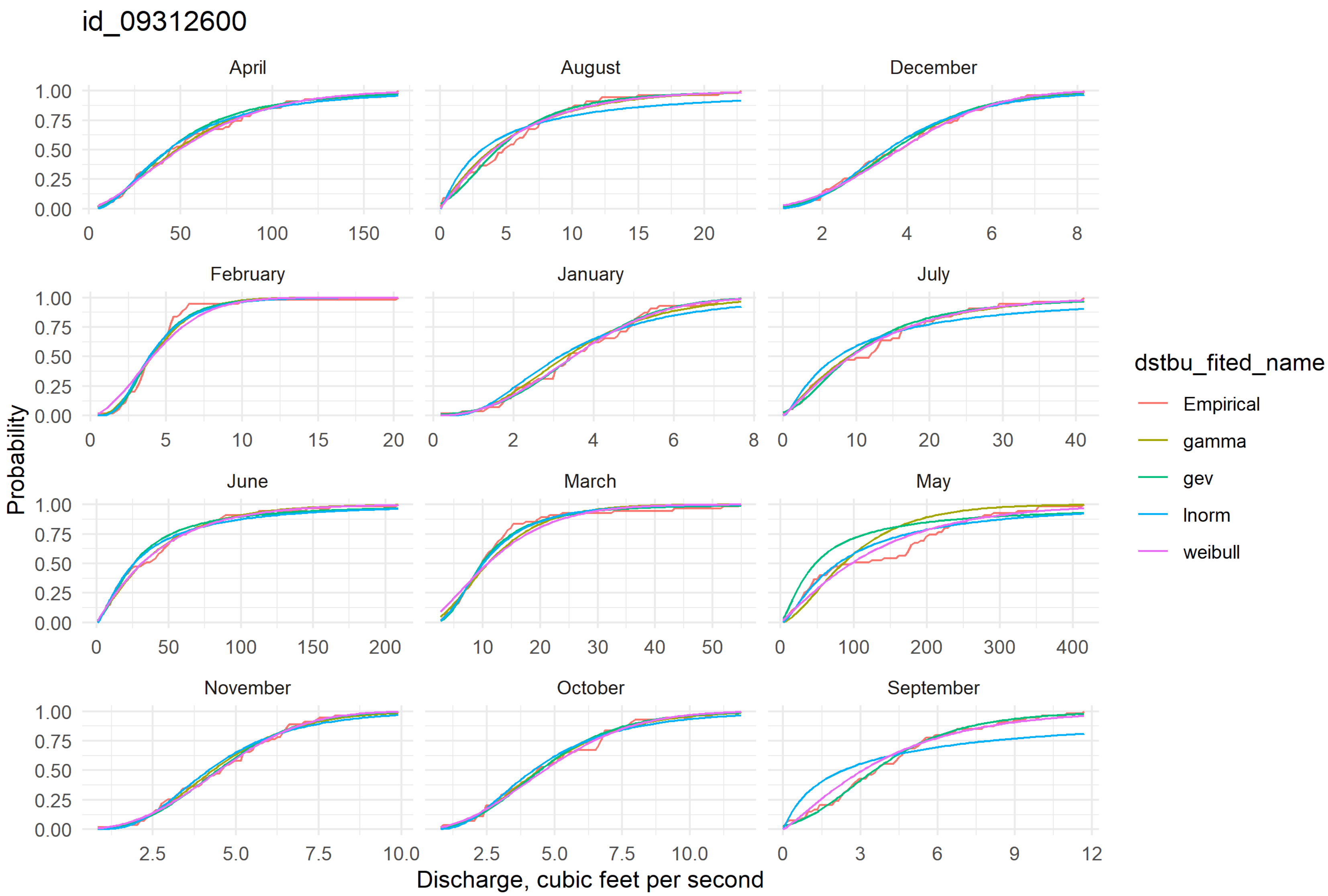
gamma
gev
lnorm
weibull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Probability
Discharge, cubic feet per second
dstbu_fited_name
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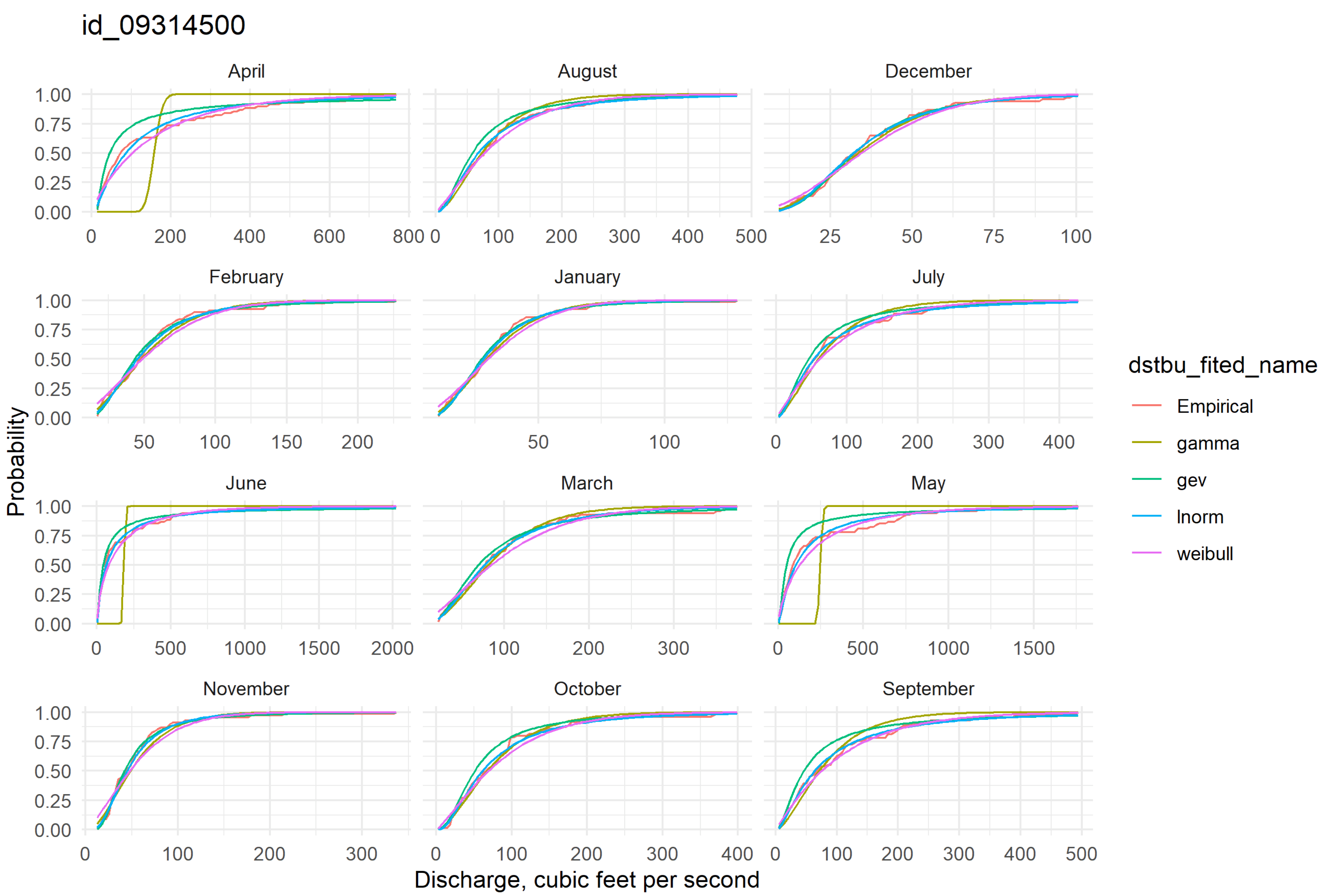
gamma
gev
lnorm
weibull


id_09314500
April
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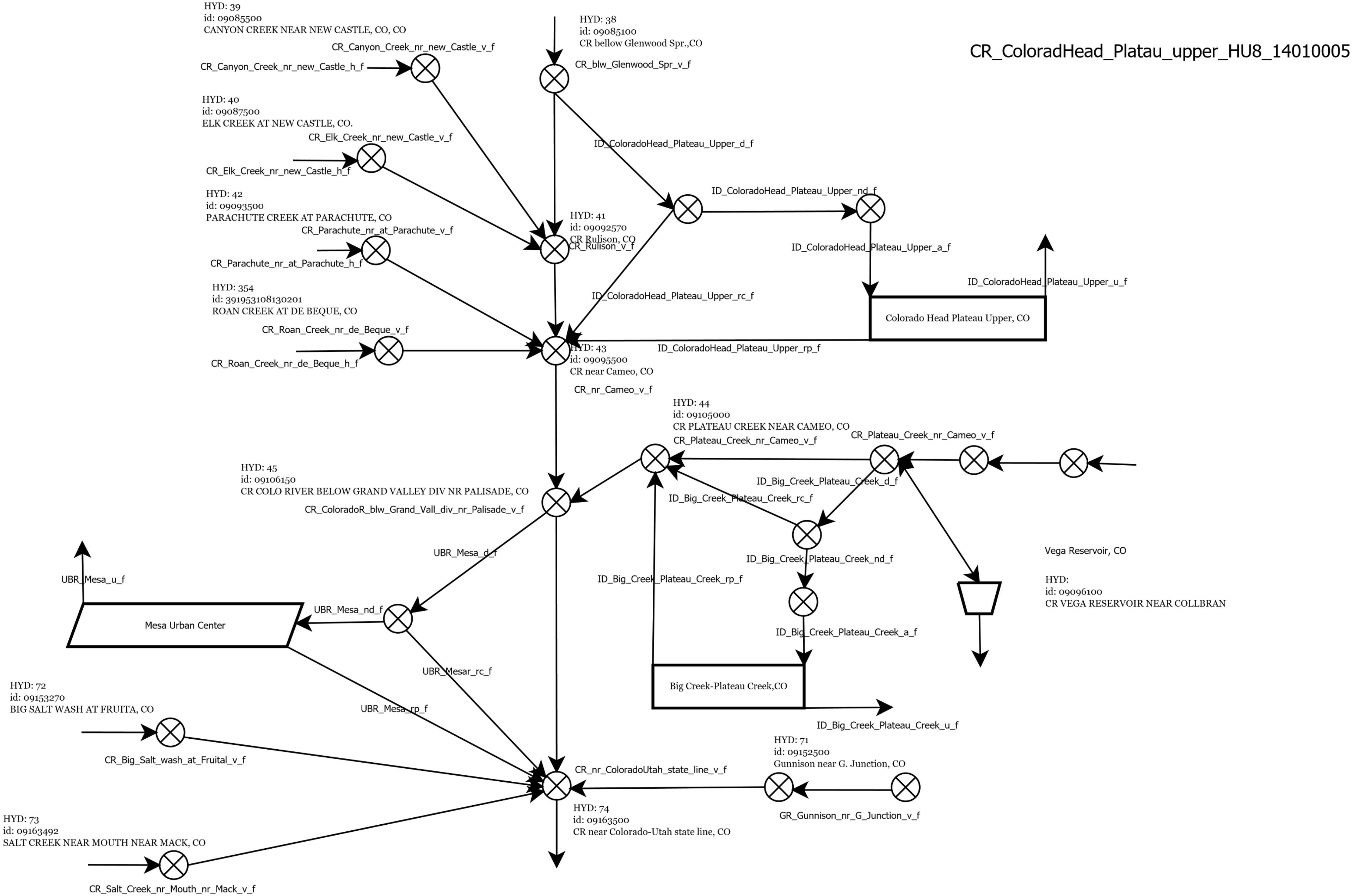
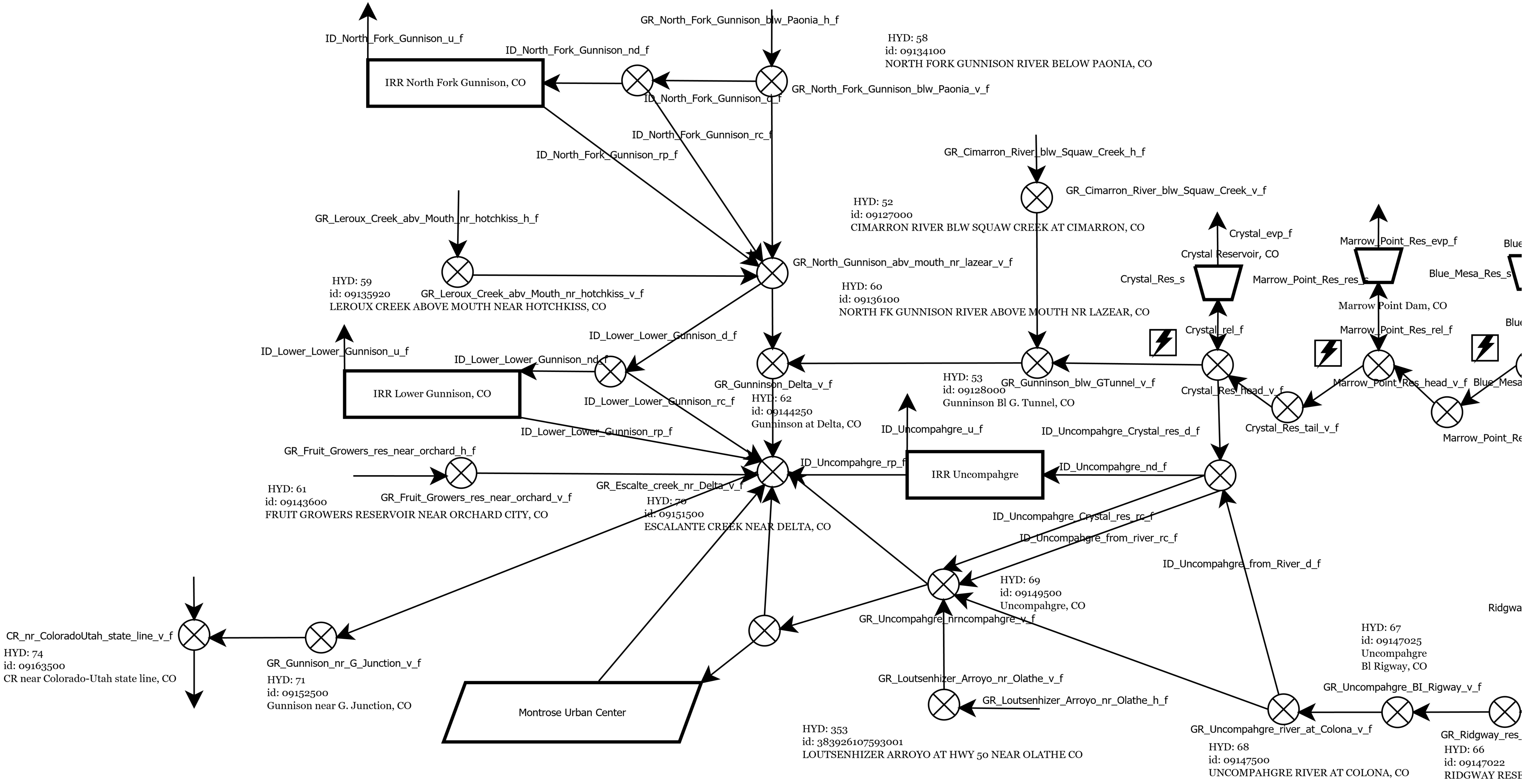
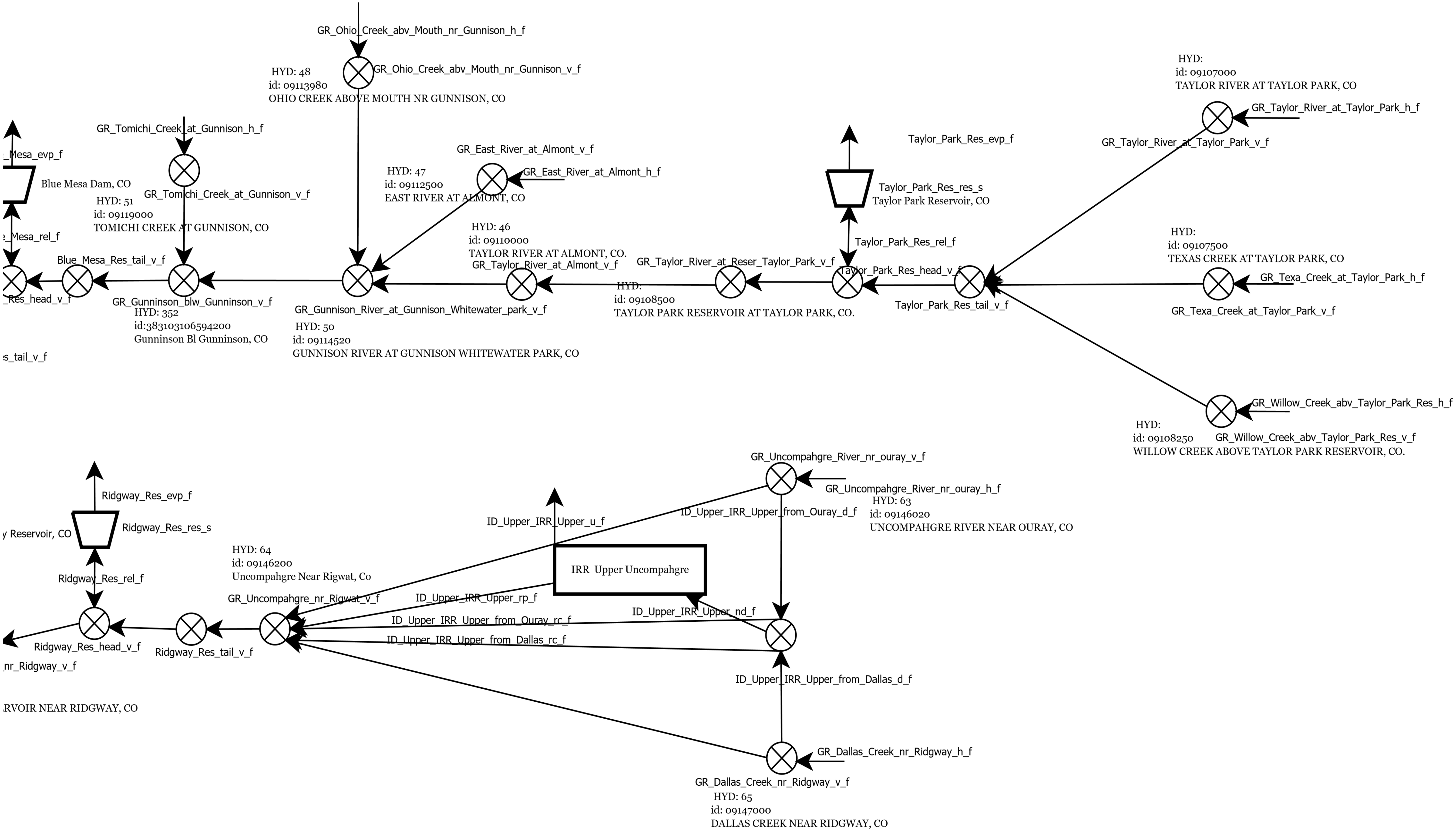
Probability
Discharge, cubic feet per second
dstbu_fited_name
Empirical
gamma
gev
lnorm
weibull

12.3. Hydrological network

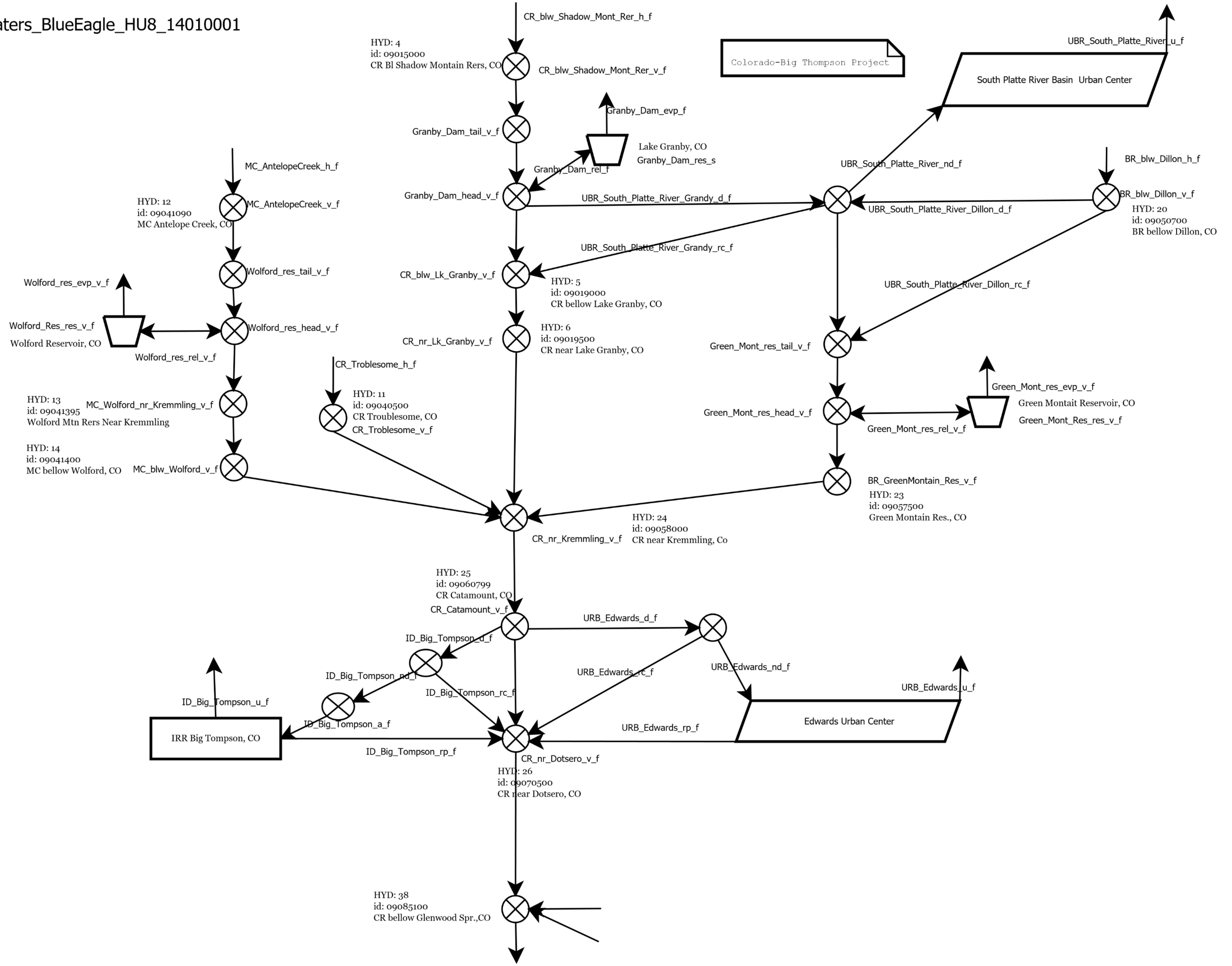



ID_North_Fork_Gunnison_u_f
GR_North_Fork_Gunnison_blw_Paonia_h_f
HYD: 58
id: 09134100
NORTH FORK GUNNISON RIVER BELOW PAONIA, CO
ID_North_Fork_Gunnison_nd_f
IRR North Fork Gunnison, CO
GR_North_Fork_Gunnison_blw_Paonia_v_f
ID_North_Fork_Gunnison_d_f
ID_North_Fork_Gunnison_rc_f
ID_North_Fork_Gunnison_rp_f
GR_Cimarron_River_blw_Squaw_Creek_h_f
GR_Cimarron_River_blw_Squaw_Creek_v_f
HYD: 52
id: 09127000
CIMARRON RIVER BLW SQUAW CREEK AT CIMARRON, CO
GR_Leroux_Creek_abv_Mouth_nr_hotchkiss_h_f
Crystal_evp_f
Crystal Reservoir, CO
Marrow_Point_Res_evp_f
GR_North_Gunnison_abv_mouth_nr_lazear_v_f
HYD: 59
id: 09135920
LEROUX CREEK ABOVE MOUTH NEAR HOTCHKISS, CO
GR_Leroux_Creek_abv_Mouth_nr_hotchkiss_v_f
HYD: 60
id: 09136100
NORTH FK GUNNISON RIVER ABOVE MOUTH NR LAZEAR, CO
Crystal_Res_s
Marrow_Point_Res_res_s
Blue_Mesa_Res_s
Marrow Point Dam, CO
Crystal_rel_f
Marrow_Point_Res_rel_f
ID_Lower_Lower_Gunnison_d_f
ID_Lower_Lower_Gunnison_u_f
ID_Lower_Lower_Gunnison_nd_f
IRR Lower Gunnison, CO
GR_Gunninson_Delta_v_f
HYD: 53
id: 09128000
Gunninson Bl G. Tunnel, CO
GR_Gunninson_blw_GTunnel_v_f
Crystal_Res_head_v_f
Marrow_Point_Res_head_v_f
ID_Lower_Lower_Gunnison_rc_f
HYD: 62
id: 09144250
Gunninson at Delta, CO
Crystal_Res_tail_v_f
ID_Uncompahgre_u_f
ID_Uncompahgre_Crystal_res_d_f
ID_Lower_Lower_Gunnison_rp_f
GR_Fruit_Growers_res_near_orchard_h_f
ID_Uncompahgre_rp_f
IRR Uncompahgre
ID_Uncompahgre_nd_f
HYD: 61
id: 09143600
FRUIT GROWERS RESERVOIR NEAR ORCHARD CITY, CO
GR_Fruit_Growers_res_near_orchard_v_f
GR_Escalte_creek_nr_Delta_v_f
HYD: 70
id: 09151500
ESCALANTE CREEK NEAR DELTA, CO
ID_Uncompahgre_Crystal_res_rc_f
ID_Uncompahgre_from_river_rc_f
ID_Uncompahgre_from_River_d_f
HYD: 69
id: 09149500
Uncompahgre, CO
GR_Uncompahgre_nrncompahgre_v_f
CR_nr_ColoradoUtah_state_line_v_f
HYD: 74
id: 09163500
CR near Colorado-Utah state line, CO
GR_Gunnison_nr_G_Junction_v_f
HYD: 71
id: 09152500
Gunnison near G. Junction, CO
HYD: 67
id: 09147025
Uncompahgre
Bl Rigway, CO
GR_Loutsenhizer_Arroyo_nr_Olathe_v_f
GR_Loutsenhizer_Arroyo_nr_Olathe_h_f
GR_Uncompahgre_BI_Rigway_v_f
Montrose Urban Center
HYD: 353
id: 383926107593001
LOUTSENHIZER ARROYO AT HWY 50 NEAR OLATHE CO
GR_Uncompahgre_river_at_Colona_v_f
HYD: 68
id: 09147500
UNCOMPAHGRE RIVER AT COLONA, CO
HYD: 66
id: 09147022

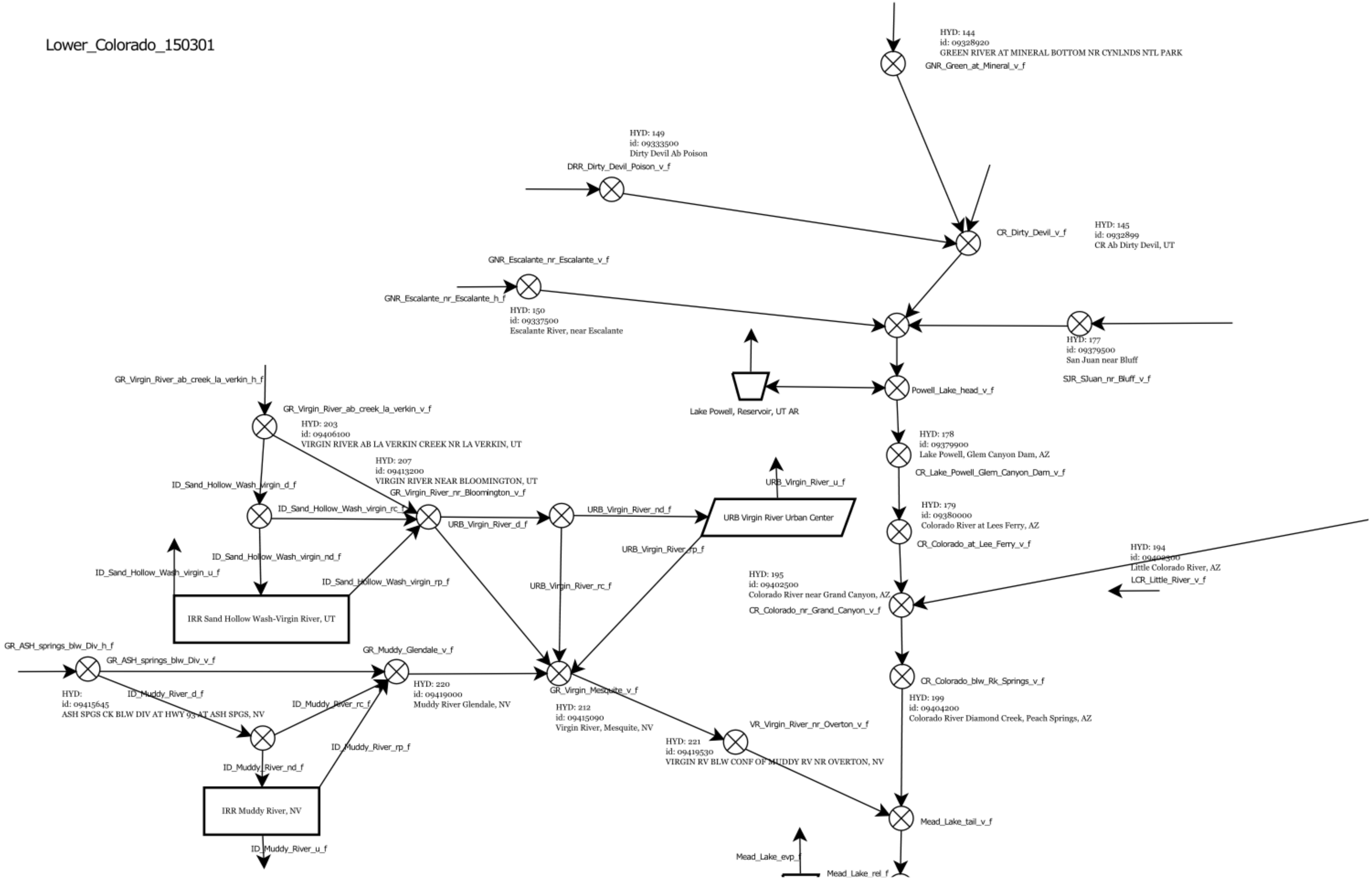


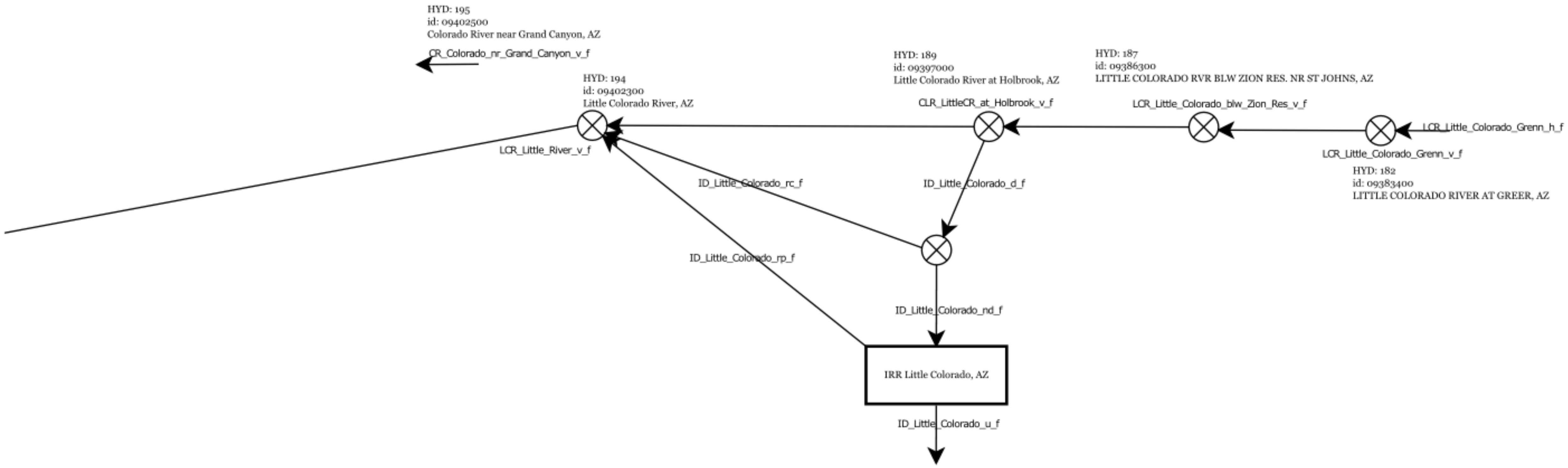
GR_Ohio_Creek_abv_Mouth_nr_Gunnison_h_f
GR_Ohio_Creek_abv_Mouth_nr_Gunnison_v_f
HYD: 48
id: 09113980
OHIO CREEK ABOVE MOUTH NR GUNNISON, CO
HYD:
id: 09107000
TAYLOR RIVER AT TAYLOR PARK, CO
GR_Taylor_River_at_Taylor_Park_h_f
GR_Taylor_River_at_Taylor_Park_v_f
_Mesa_evp_f
Blue Mesa Dam, CO
GR_Tomichi_Creek_at_Gunnison_h_f
GR_Tomichi_Creek_at_Gunnison_v_f
HYD: 51
id: 09119000
TOMICHI CREEK AT GUNNISON, CO
GR_East_River_at_Almont_v_f
GR_East_River_at_Almont_h_f
HYD: 47
id: 09112500
EAST RIVER AT ALMONT, CO
Taylor_Park_Res_evp_f
Taylor_Park_Res_res_s
Taylor Park Reservoir, CO
Taylor_Park_Res_rel_f
Taylor_Park_Res_head_v_f
Taylor_Park_Res_tail_v_f
e_Mesa_rel_f
Blue_Mesa_Res_tail_v_f
_Res_head_v_f
es_tail_v_f
HYD: 46
id: 09110000
TAYLOR RIVER AT ALMONT, CO.
GR_Taylor_River_at_Almont_v_f
GR_Taylor_River_at_Reser_Taylor_Park_v_f
HYD:
id: 09108500
TAYLOR PARK RESERVOIR AT TAYLOR PARK, CO.
HYD:
id: 09107500
TEXAS CREEK AT TAYLOR PARK, CO
GR_Texa_Creek_at_Taylor_Park_h_f
GR_Texa_Creek_at_Taylor_Park_v_f
GR_Gunninson_blw_Gunninson_v_f
HYD: 352
id:383103106594200
Gunninson Bl Gunninson, CO
GR_Gunnison_River_at_Gunnison_Whitewater_park_v_f
HYD: 50
id: 09114520
GUNNISON RIVER AT GUNNISON WHITEWATER PARK, CO
GR_Willow_Creek_abv_Taylor_Park_Res_h_f
GR_Willow_Creek_abv_Taylor_Park_Res_v_f
HYD:
id: 09108250
WILLOW CREEK ABOVE TAYLOR PARK RESERVOIR, CO.
GR_Uncompahgre_River_nr_ouray_v_f
GR_Uncompahgre_River_nr_ouray_h_f
HYD: 63
id: 09146020
UNCOMPAHGRE RIVER NEAR OURAY, CO
Ridgway_Res_evp_f
Ridgway_Res_res_s
y Reservoir, CO
ID_Upper_IRR_Upper_u_f
ID_Upper_IRR_Upper_from_Ouray_d_f
IRR Upper Uncompahgre
HYD: 64
id: 09146200
Uncompahgre Near Rigwat, Co
Ridgway_Res_rel_f
GR_Uncompahgre_nr_Rigwat_v_f
ID_Upper_IRR_Upper_rp_f
ID_Upper_IRR_Upper_nd_f
ID_Upper_IRR_Upper_from_Ouray_rc_f
ID_Upper_IRR_Upper_from_Dallas_rc_f
Ridgway_Res_head_v_f
Ridgway_Res_tail_v_f
_nr_Ridgway_v_f
RVOIR NEAR RIDGWAY, CO
ID_Upper_IRR_Upper_from_Dallas_d_f
GR_Dallas_Creek_nr_Ridgway_h_f
GR_Dallas_Creek_nr_Ridgway_v_f
HYD: 65
id: 09147000
DALLAS CREEK NEAR RIDGWAY, CO

CR_HeadWaters_BlueEagle_HU8_14010001

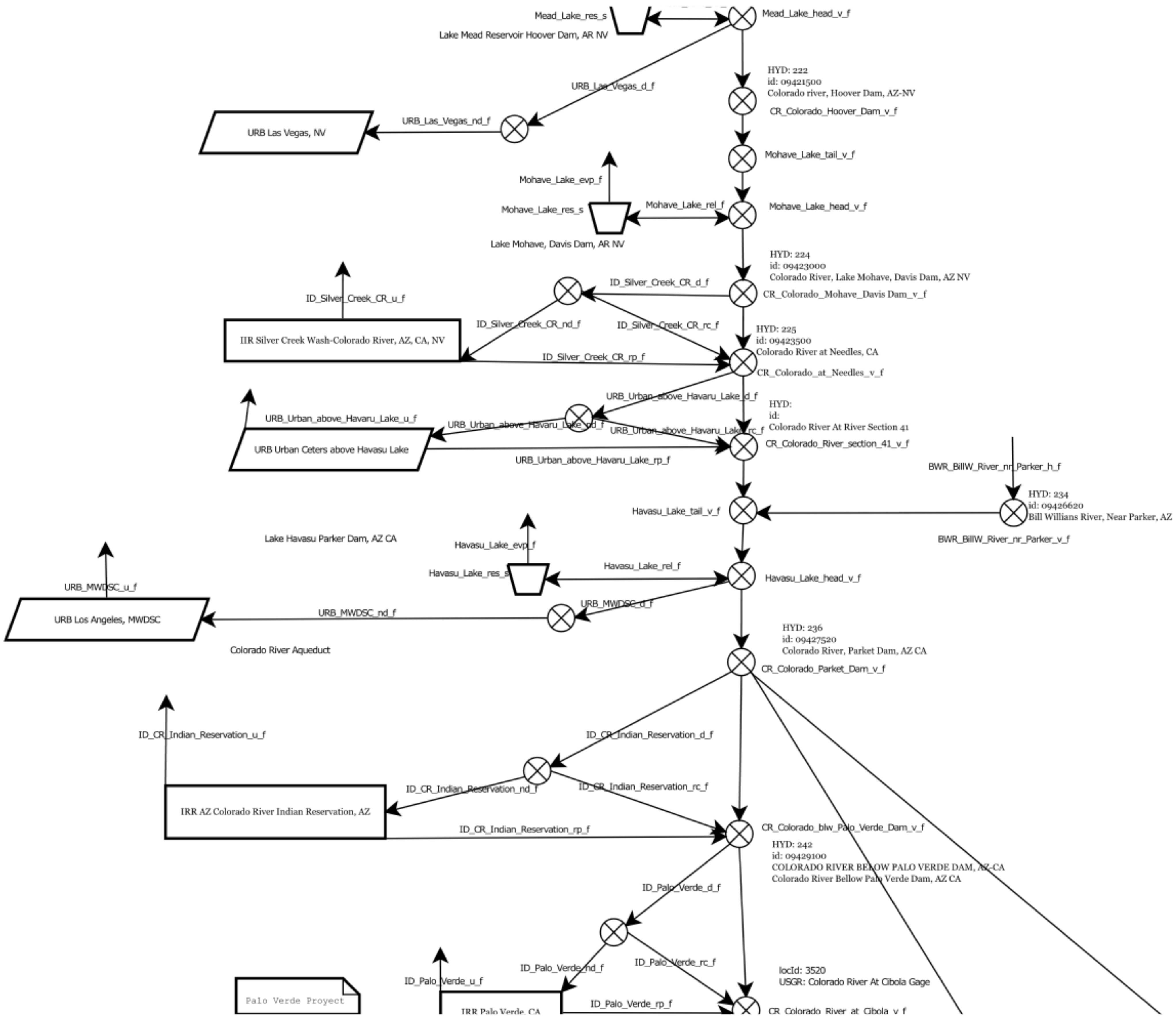


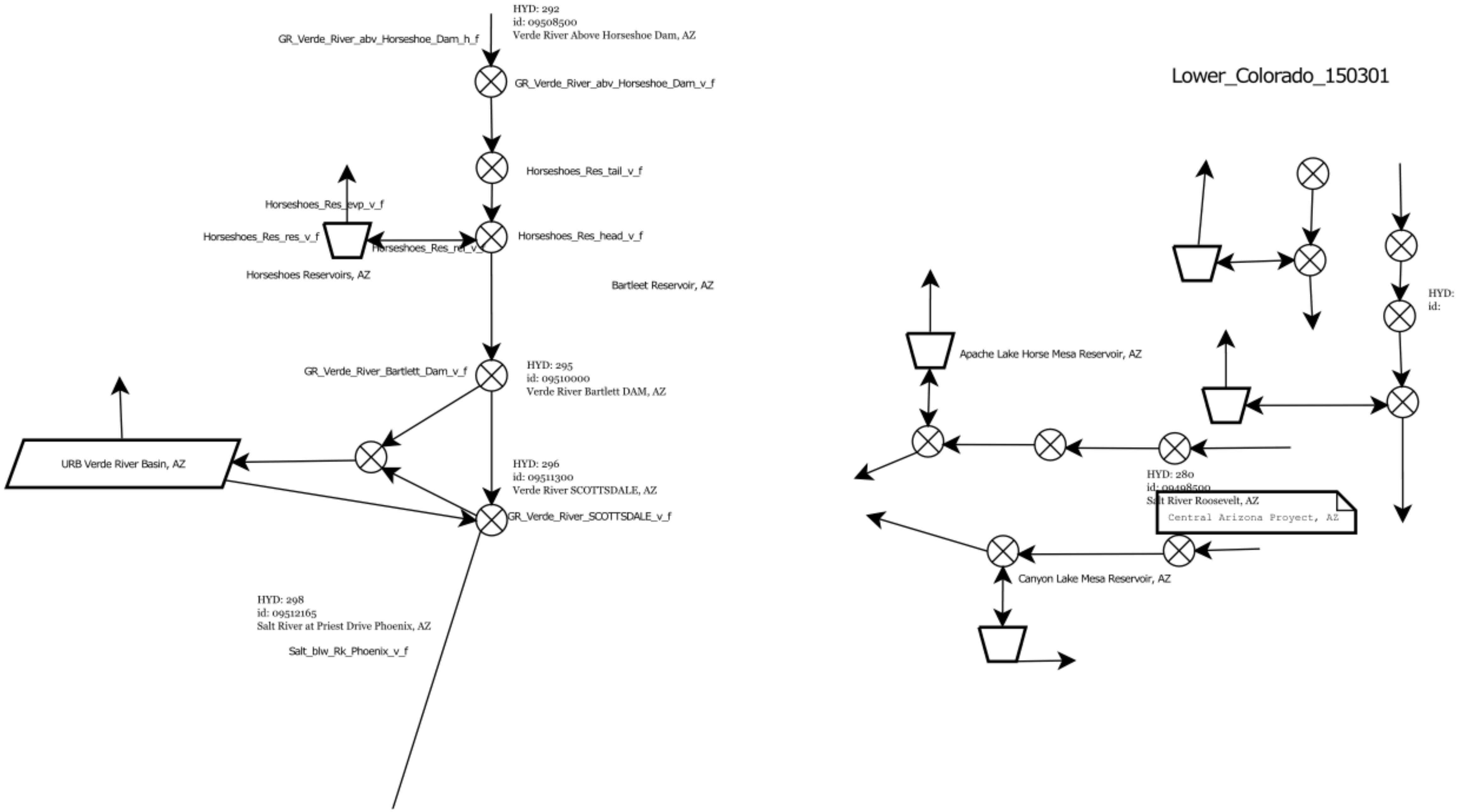
Lower_Colorado_150301

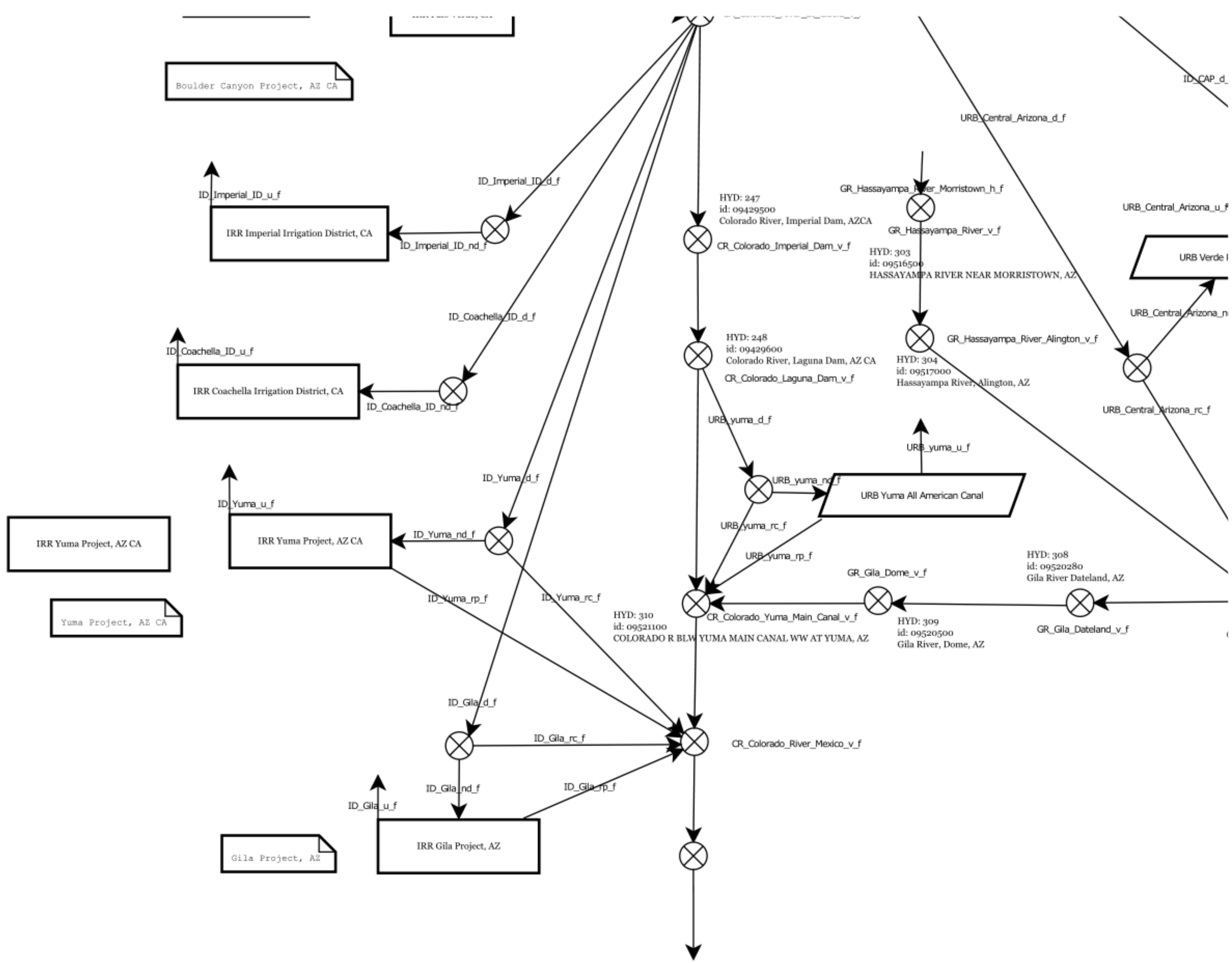



HYD: 195
id: 09402500
Colorado River near Grand Canyon, AZ
CR_Colorado_nr_Grand_Canyon_v_f
HYD: 194
id: 09402300
Little Colorado River, AZ
LCR_Little_River_v_f
HYD: 189
id: 09397000
Little Colorado River at Holbrook, AZ
CLR_LittleCR_at_Holbrook_v_f
HYD: 187
id: 09386300
LITTLE COLORADO RVR BLW ZION RES. NR ST JOHNS, AZ
LCR_Little_Colorado_blw_Zion_Res_v_f
LCR_Little_Colorado_Grenn_h_f
LCR_Little_Colorado_Grenn_v_f
HYD: 182
id: 09383400
LITTLE COLORADO RIVER AT GREER, AZ
ID_Little_Colorado_rc_f
ID_Little_Colorado_d_f
ID_Little_Colorado_rp_f
ID_Little_Colorado_nd_f
IRR Little Colorado, AZ
ID_Little_Colorado_u_f

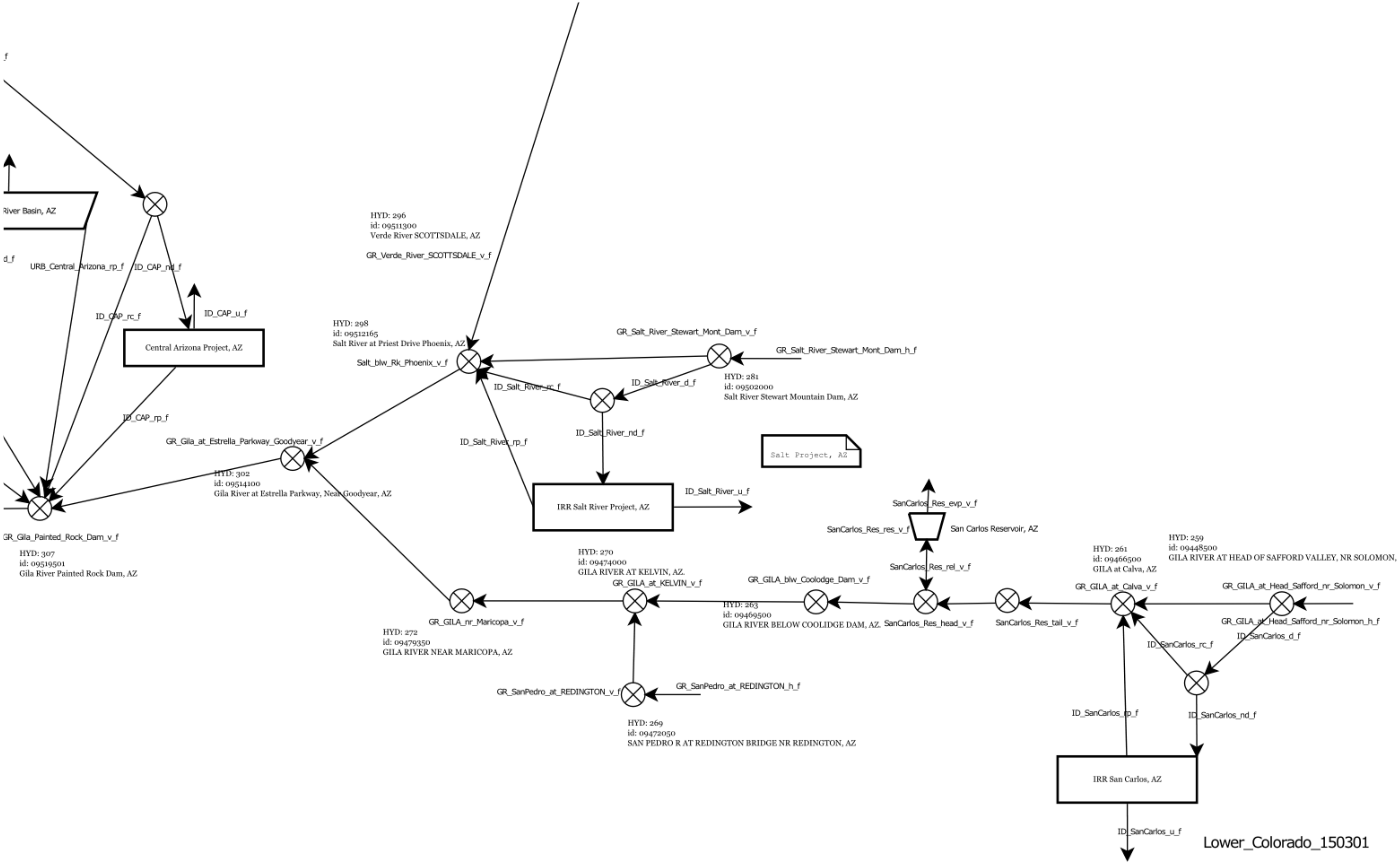
Lower_Colorado_150301

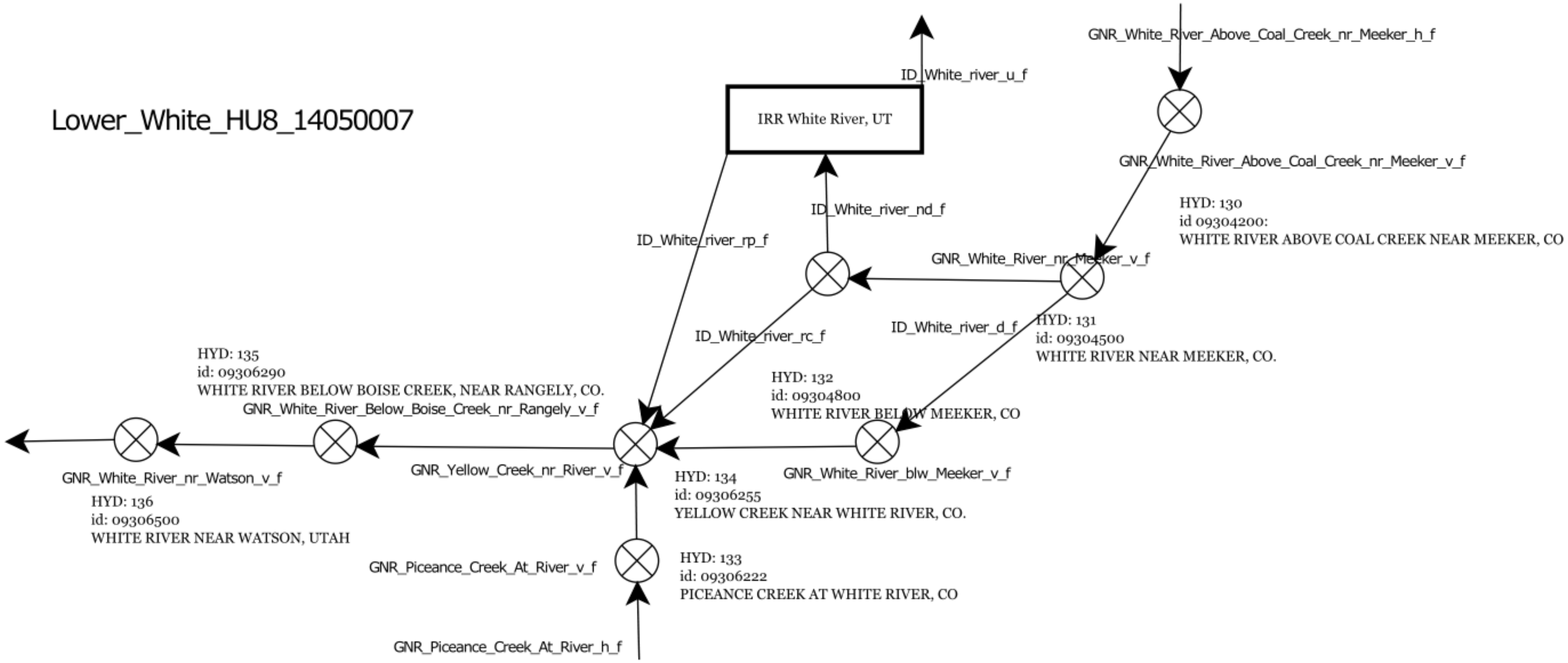



HYD: 292
id: 09508500
Verde River Above Horseshoe Dam, AZ
GR_Verde_River_abv_Horseshoe_Dam_h_f
GR_Verde_River_abv_Horseshoe_Dam_v_f
Horseshoes_Res_tail_v_f
Horseshoes_Res_evp_v_f
Horseshoes_Res_res_v_f
Horseshoes_Res_head_v_f
Horseshoes Reservoirs, AZ
Bartleet Reservoir, AZ
GR_Verde_River_Bartlett_Dam_v_f
HYD: 295
id: 09510000
Verde River Bartlett DAM, AZ
URB Verde River Basin, AZ
HYD: 296
id: 09511300
Verde River SCOTTSDALE, AZ
GR_Verde_River_SCOTTSDALE_v_f
HYD: 298
id: 09512165
Salt River at Priest Drive Phoenix, AZ
Salt_blw_Rk_Phoenix_v_f
Lower_Colorado_150301
HYD:
id:
Apache Lake Horse Mesa Reservoir, AZ
HYD: 280
Salt River Roosevelt, AZ
Central Arizona Proyect, AZ
Canyon Lake Mesa Reservoir, AZ

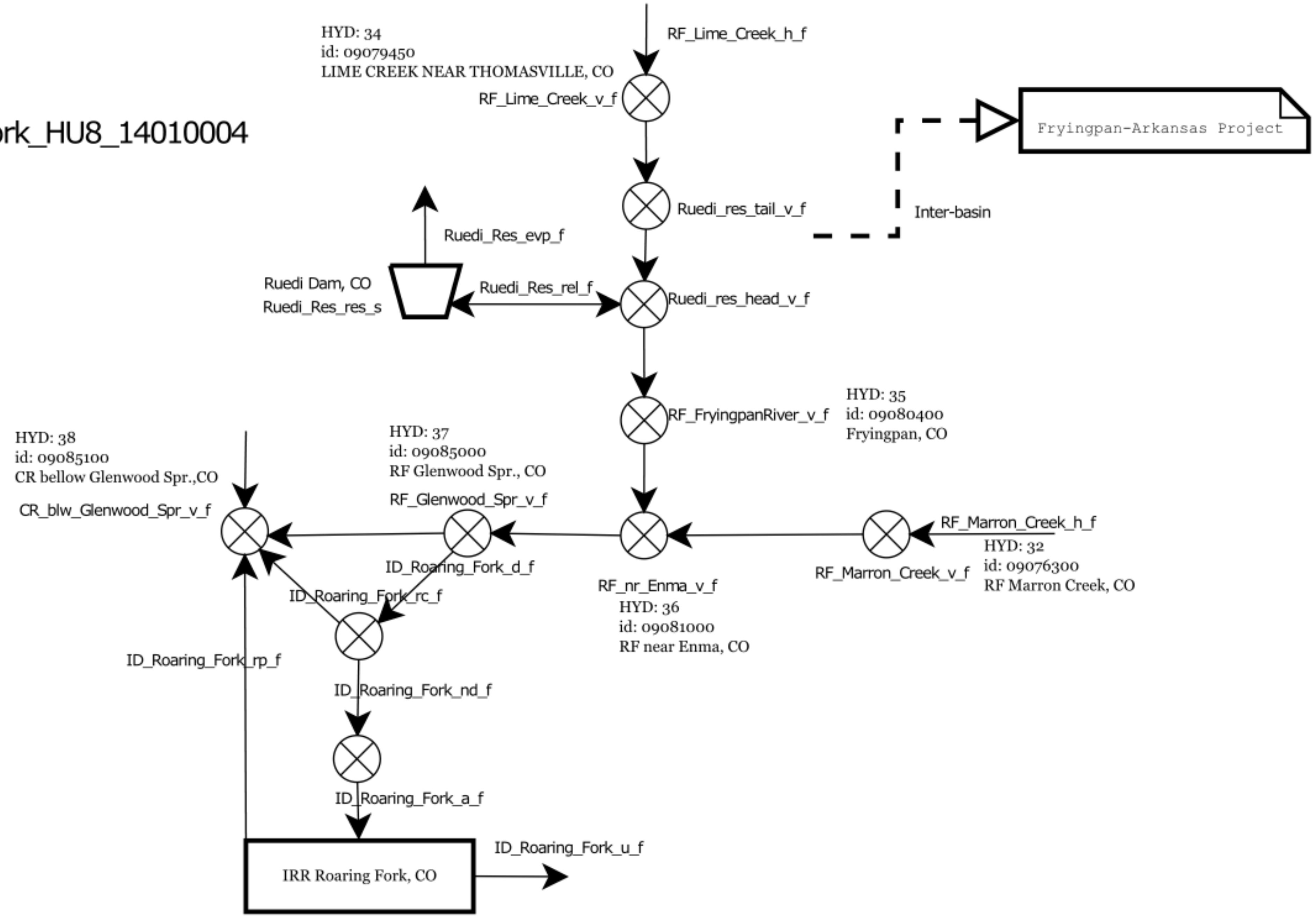


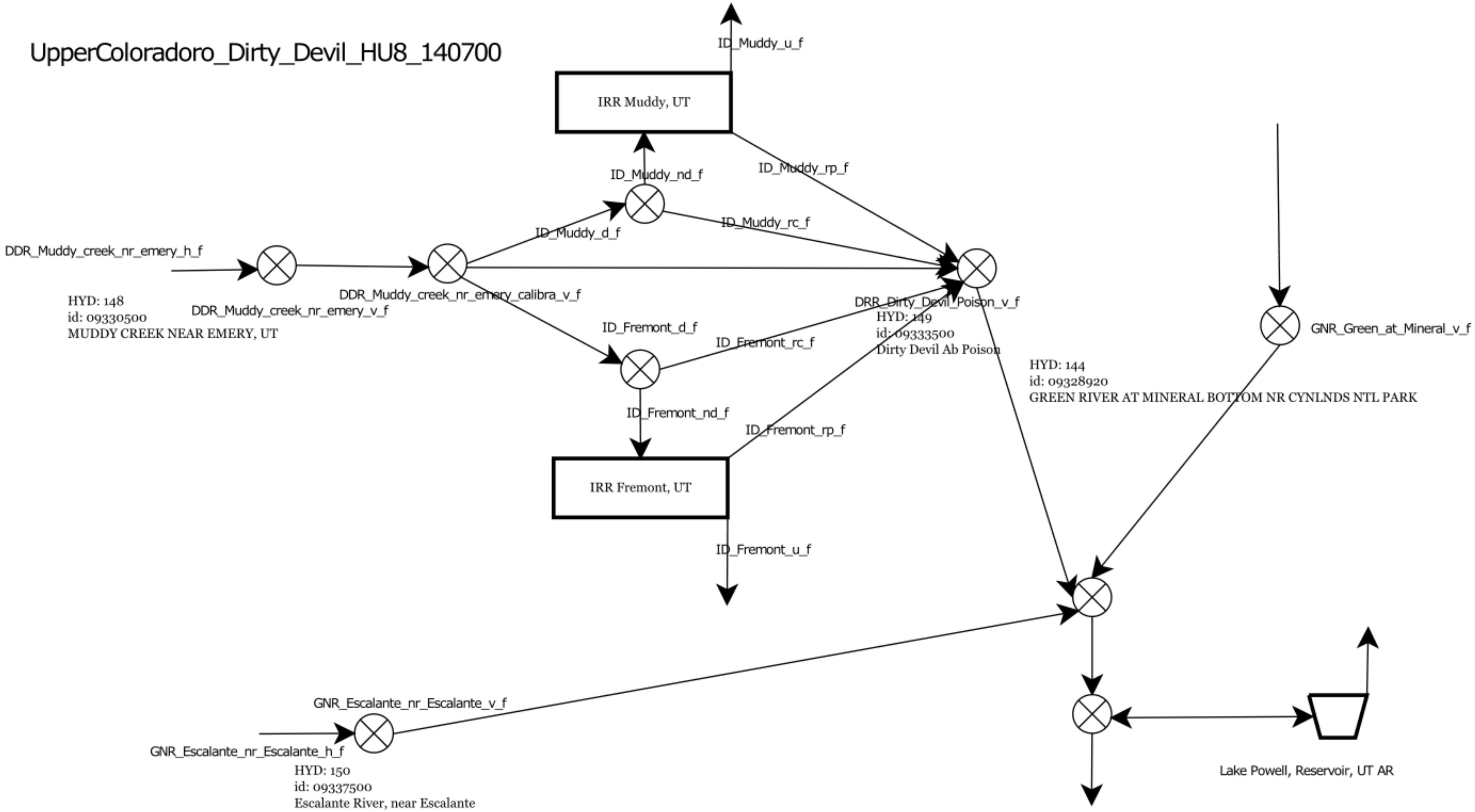
Lower_Colorado_150301


River Basin, AZ
URB_Central_Arizona_rp_f
ID_CAP_nd_f
ID_CAP_rc_f
ID_CAP_u_f
Central Arizona Project, AZ
ID_CAP_rp_f
GR_Gila_Painted_Rock_Dam_v_f
HYD: 307
id: 09519501
Gila River Painted Rock Dam, AZ
HYD: 296
id: 09511300
Verde River SCOTTSDALE, AZ
GR_Verde_River_SCOTTSDALE_v_f
HYD: 298
id: 09512165
Salt River at Priest Drive Phoenix, AZ
Salt_blw_Rk_Phoenix_v_f
GR_Gila_at_Estrella_Parkway_Goodyear_v_f
HYD: 302
id: 09514100
Gila River at Estrella Parkway, Near Goodyear, AZ
GR_Salt_River_Stewart_Mont_Dam_v_f
GR_Salt_River_Stewart_Mont_Dam_h_f
HYD: 281
id: 09502000
Salt River Stewart Mountain Dam, AZ
ID_Salt_River_rc_f
ID_Salt_River_d_f
ID_Salt_River_nd_f
ID_Salt_River_rp_f
Salt Project, AZ
IRR Salt River Project, AZ
ID_Salt_River_u_f
SanCarlos_Res_evp_v_f
SanCarlos_Res_res_v_f
San Carlos Reservoir, AZ
SanCarlos_Res_rel_v_f
HYD: 270
id: 09474000
GILA RIVER AT KELVIN, AZ.
GR_GILA_at_KELVIN_v_f
GR_GILA_blw_Coolodge_Dam_v_f
HYD: 263
id: 09469500
GILA RIVER BELOW COOLIDGE DAM, AZ.
SanCarlos_Res_head_v_f
SanCarlos_Res_tail_v_f
GR_GILA_nr_Maricopa_v_f
HYD: 272
id: 09479350
GILA RIVER NEAR MARICOPA, AZ
GR_SanPedro_at_REDINGTON_v_f
GR_SanPedro_at_REDINGTON_h_f
HYD: 269
id: 09472050
SAN PEDRO R AT REDINGTON BRIDGE NR REDINGTON, AZ
HYD: 261
id: 09466500
GILA at Calva, AZ
GR_GILA_at_Calva_v_f
HYD: 259
id: 09448500
GILA RIVER AT HEAD OF SAFFORD VALLEY, NR SOLOMON,
GR_GILA_at_Head_Safford_nr_Solomon_v_f
GR_GILA_at_Head_Safford_nr_Solomon_h_f
ID_SanCarlos_rc_f
ID_SanCarlos_d_f
ID_SanCarlos_rp_f
ID_SanCarlos_nd_f
IRR San Carlos, AZ
ID_SanCarlos_u_f
Lower_Colorado_150301


Lower_White_HU8_14050007
IRR White River, UT
ID_White_river_u_f
GNR_White_River_Above_Coal_Creek_nr_Meeker_h_f
GNR_White_River_Above_Coal_Creek_nr_Meeker_v_f
HYD: 130
id 09304200:
WHITE RIVER ABOVE COAL CREEK NEAR MEEKER, CO
ID_White_river_nd_f
ID_White_river_rp_f
GNR_White_River_nr_Meeker_v_f
HYD: 131
id: 09304500
WHITE RIVER NEAR MEEKER, CO.
ID_White_river_rc_f
ID_White_river_d_f
HYD: 135
id: 09306290
WHITE RIVER BELOW BOISE CREEK, NEAR RANGELY, CO.
GNR_White_River_Below_Boise_Creek_nr_Rangely_v_f
HYD: 132
id: 09304800
WHITE RIVER BELOW MEEKER, CO
GNR_White_River_nr_Watson_v_f
GNR_Yellow_Creek_nr_River_v_f
GNR_White_River_blw_Meeker_v_f
HYD: 134
id: 09306255
YELLOW CREEK NEAR WHITE RIVER, CO.
HYD: 136
id: 09306500
WHITE RIVER NEAR WATSON, UTAH
GNR_Piceance_Creek_At_River_v_f
HYD: 133
id: 09306222
PICEANCE CREEK AT WHITE RIVER, CO
GNR_Piceance_Creek_At_River_h_f

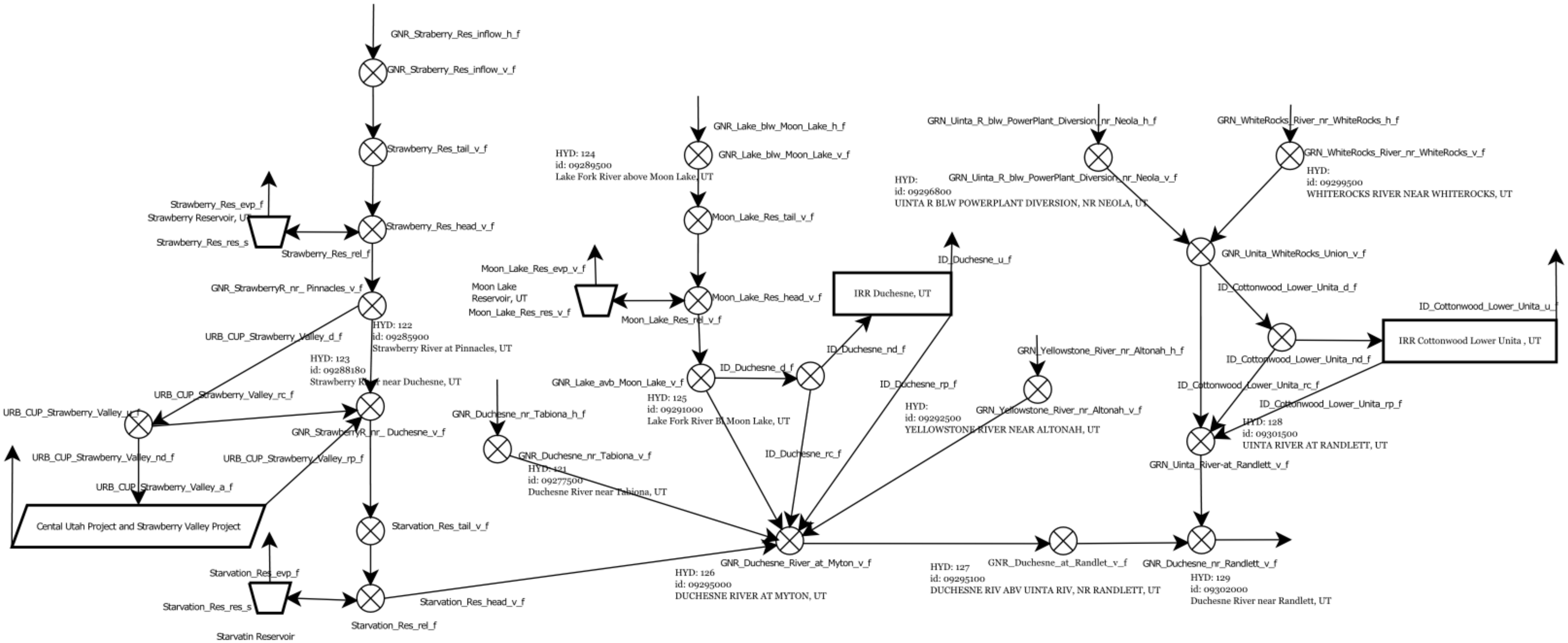
RoaringFork_HU8_14010004

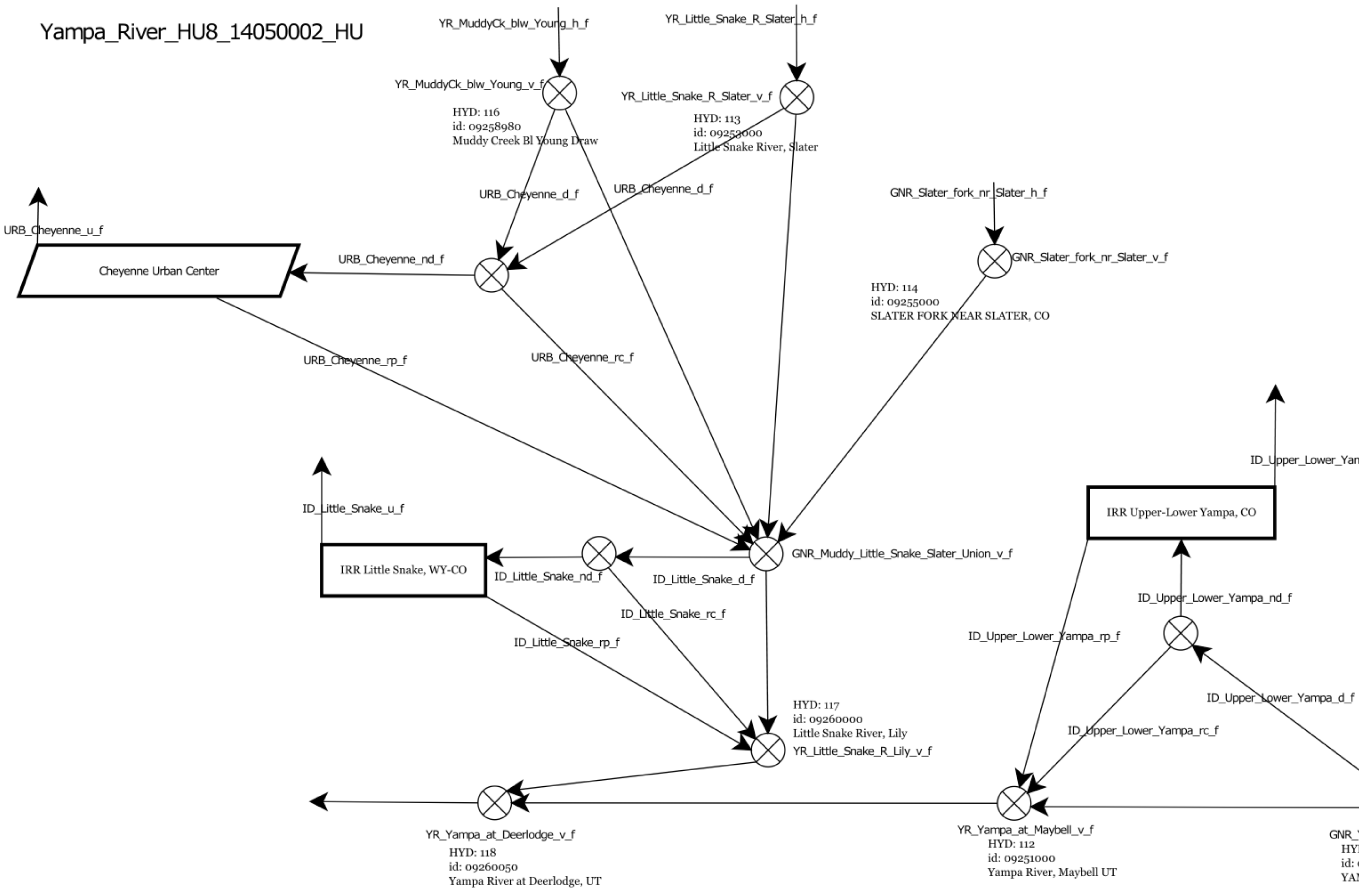




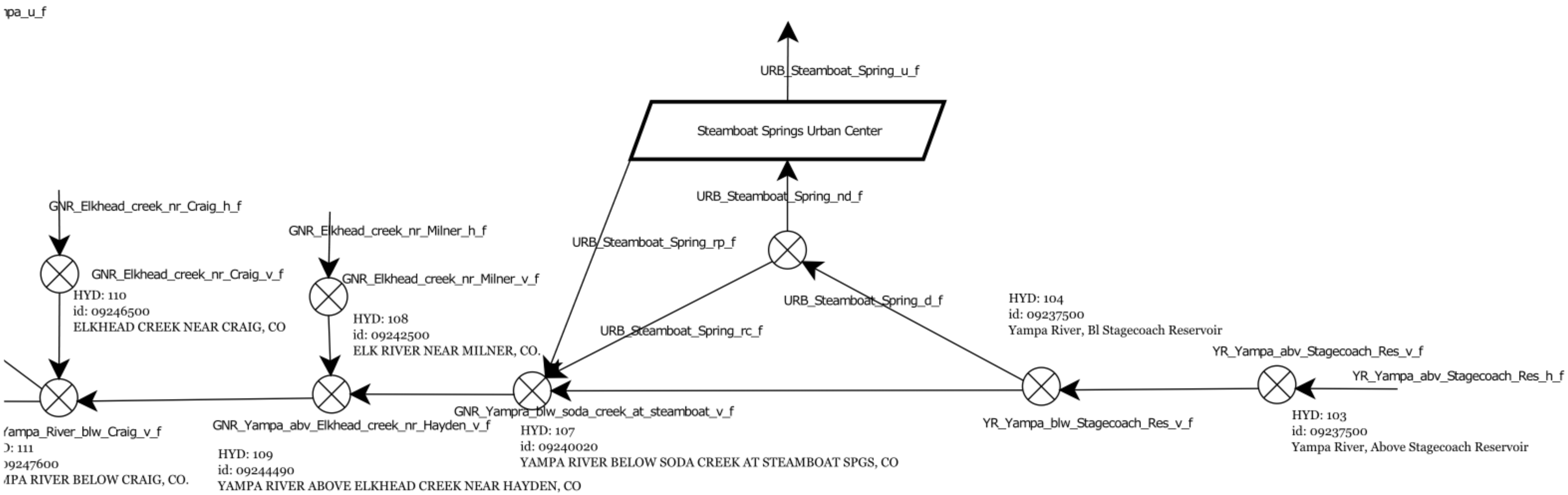
UpperColoradoro_Dirty_Devil_HU8_140700
ID_Muddy_u_f
IRR Muddy, UT
ID_Muddy_nd_f
ID_Muddy_rp_f
ID_Muddy_rc_f
ID_Muddy_d_f
DDR_Muddy_creek_nr_emery_h_f
HYD: 148
id: 09330500
MUDDY CREEK NEAR EMERY, UT
DDR_Muddy_creek_nr_emery_v_f
DDR_Muddy_creek_nr_emery_calibra_v_f
DRR_Dirty_Devil_Poison_v_f
HYD: 149
id: 09333500
Dirty Devil Ab Poison
ID_Fremont_d_f
ID_Fremont_rc_f
ID_Fremont_nd_f
ID_Fremont_rp_f
IRR Fremont, UT
ID_Fremont_u_f
GNR_Green_at_Mineral_v_f
HYD: 144
id: 09328920
GREEN RIVER AT MINERAL BOTTOM NR CYNLNDS NTL PARK
GNR_Escalante_nr_Escalante_v_f
GNR_Escalante_nr_Escalante_h_f
HYD: 150
id: 09337500
Escalante River, near Escalante
Lake Powell, Reservoir, UT AR

Upper_Green_Strawberry_HU8_14060004

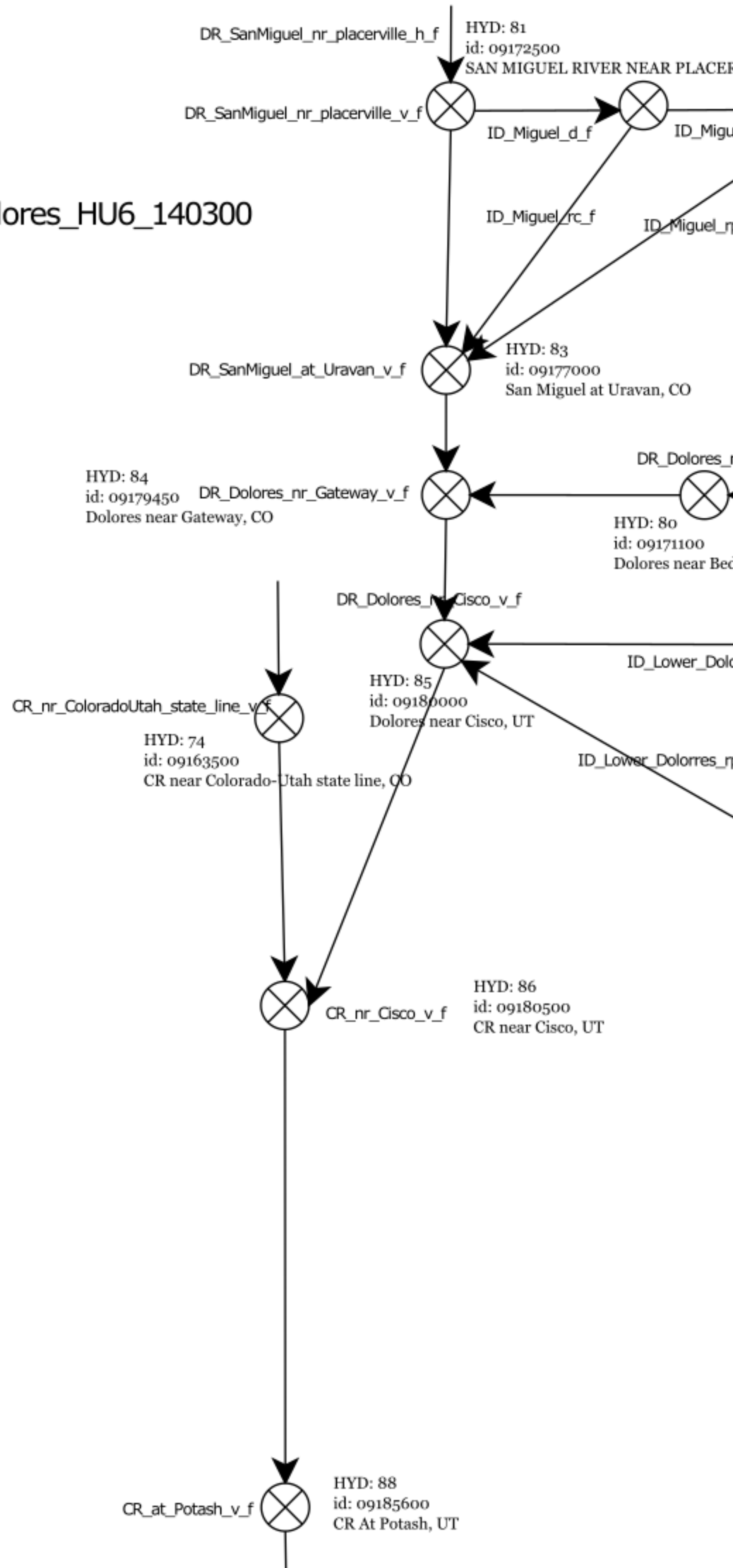



Yampa_River_HU8_14050002_HU
YR_MuddyCk_blw_Young_h_f
YR_Little_Snake_R_Slater_h_f
YR_MuddyCk_blw_Young_v_f
YR_Little_Snake_R_Slater_v_f
HYD: 116
id: 09258980
Muddy Creek Bl Young Draw
HYD: 113
id: 09253000
Little Snake River, Slater
URB_Cheyenne_d_f
URB_Cheyenne_d_f
GNR_Slater_fork_nr_Slater_h_f
URB_Cheyenne_u_f
Cheyenne Urban Center
URB_Cheyenne_nd_f
GNR_Slater_fork_nr_Slater_v_f
HYD: 114
id: 09255000
SLATER FORK NEAR SLATER, CO
URB_Cheyenne_rp_f
URB_Cheyenne_rc_f
ID_Little_Snake_u_f
IRR Little Snake, WY-CO
ID_Little_Snake_nd_f
ID_Little_Snake_d_f
GNR_Muddy_Little_Snake_Slater_Union_v_f
ID_Little_Snake_rc_f
ID_Little_Snake_rp_f
IRR Upper-Lower Yampa, CO
ID_Upper_Lower_Yampa_nd_f
ID_Upper_Lower_Yampa_rp_f
ID_Upper_Lower_Yampa_d_f
ID_Upper_Lower_Yampa_rc_f
HYD: 117
id: 09260000
Little Snake River, Lily
YR_Little_Snake_R_Lily_v_f
YR_Yampa_at_Deerlodge_v_f
HYD: 118
id: 09260050
Yampa River at Deerlodge, UT
YR_Yampa_at_Maybell_v_f
HYD: 112
id: 09251000
Yampa River, Maybell UT

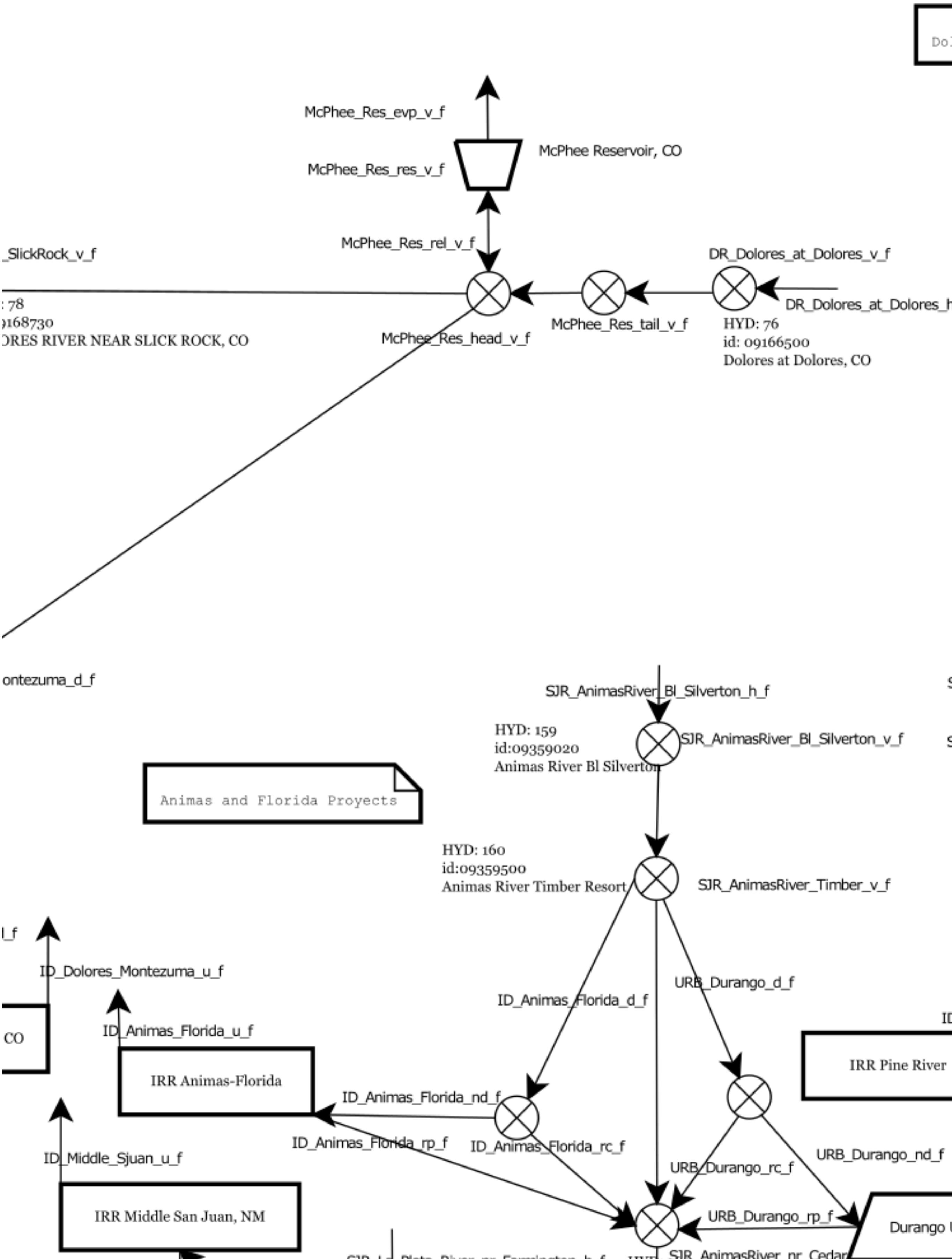
Yampa_River_HU8_14050002_HU



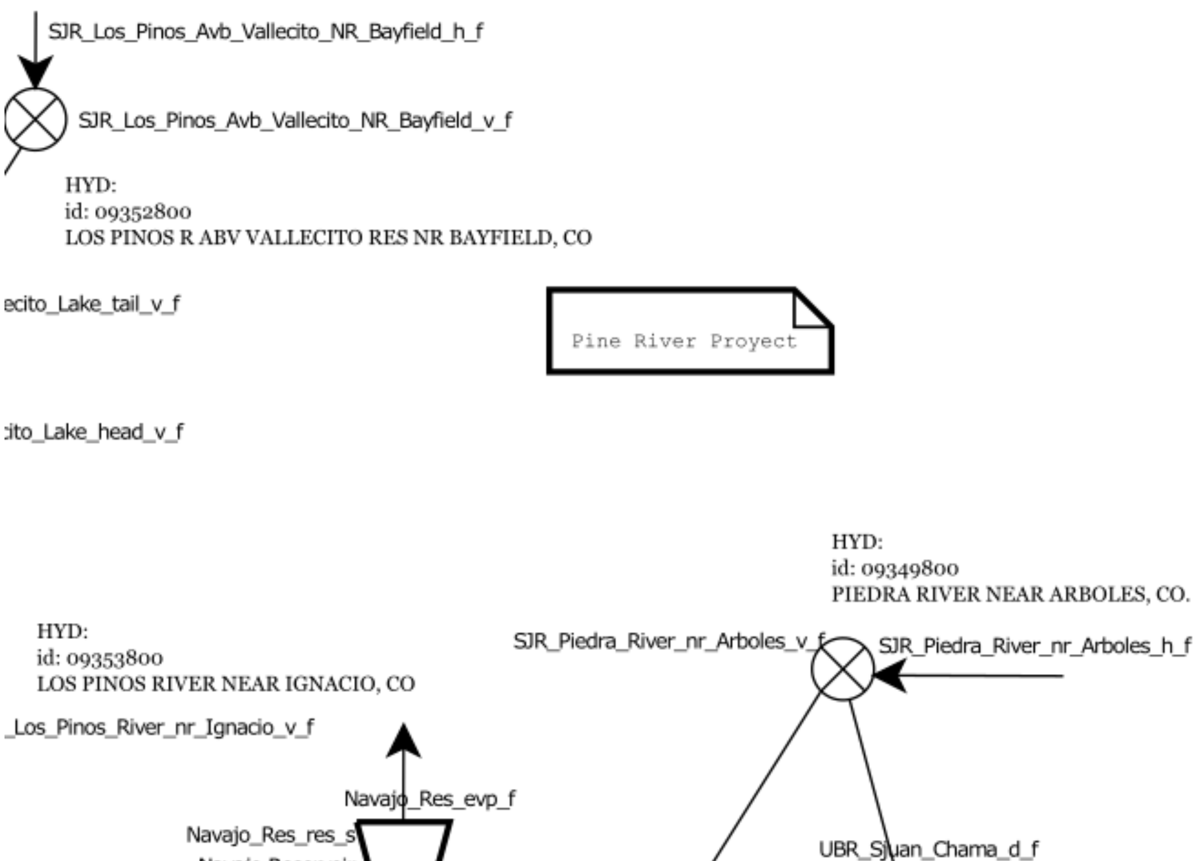
CR_Upper_CO_Dolores_HU6_140300



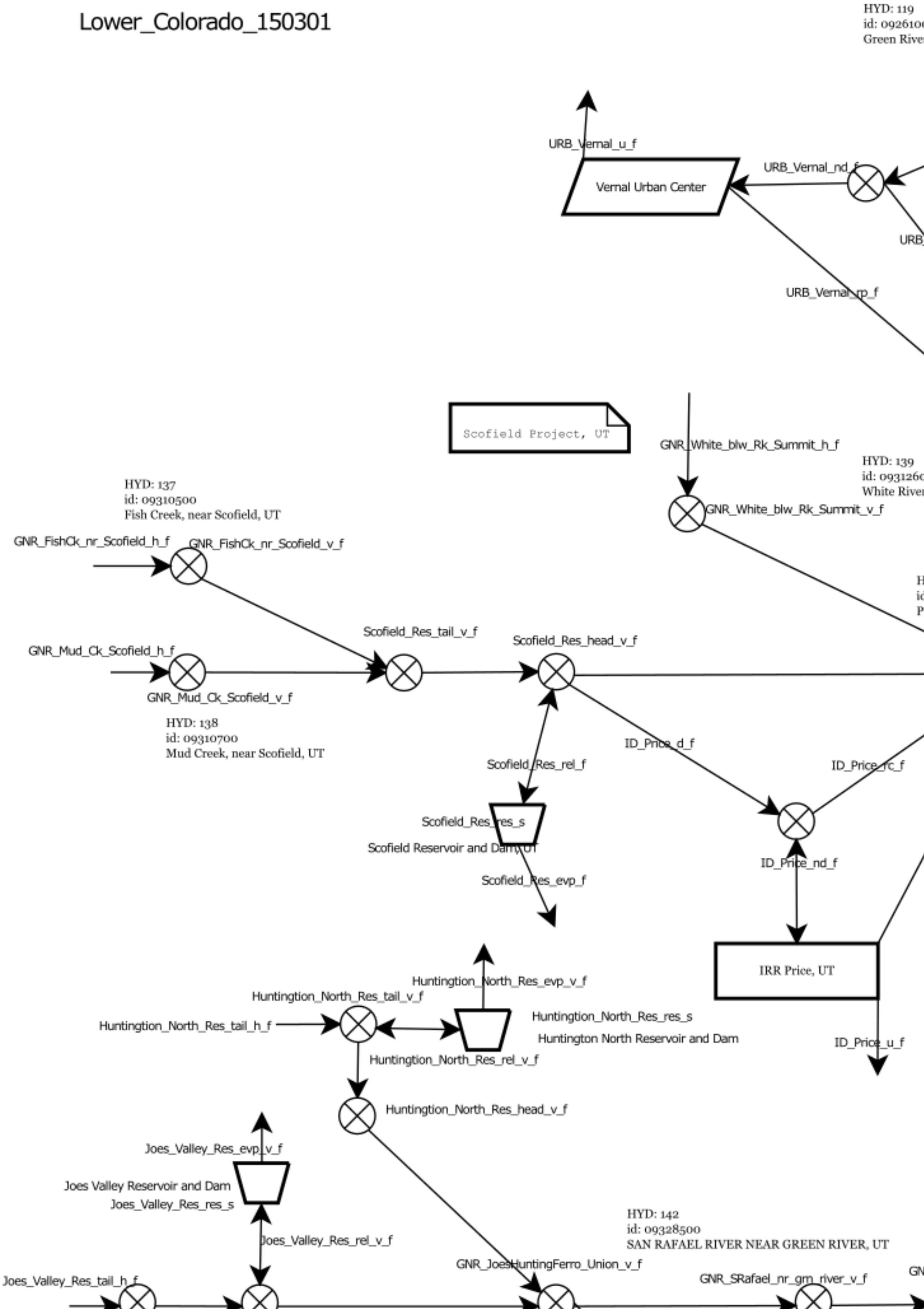
CR_Upper_CO_Dolores_HU6_140300



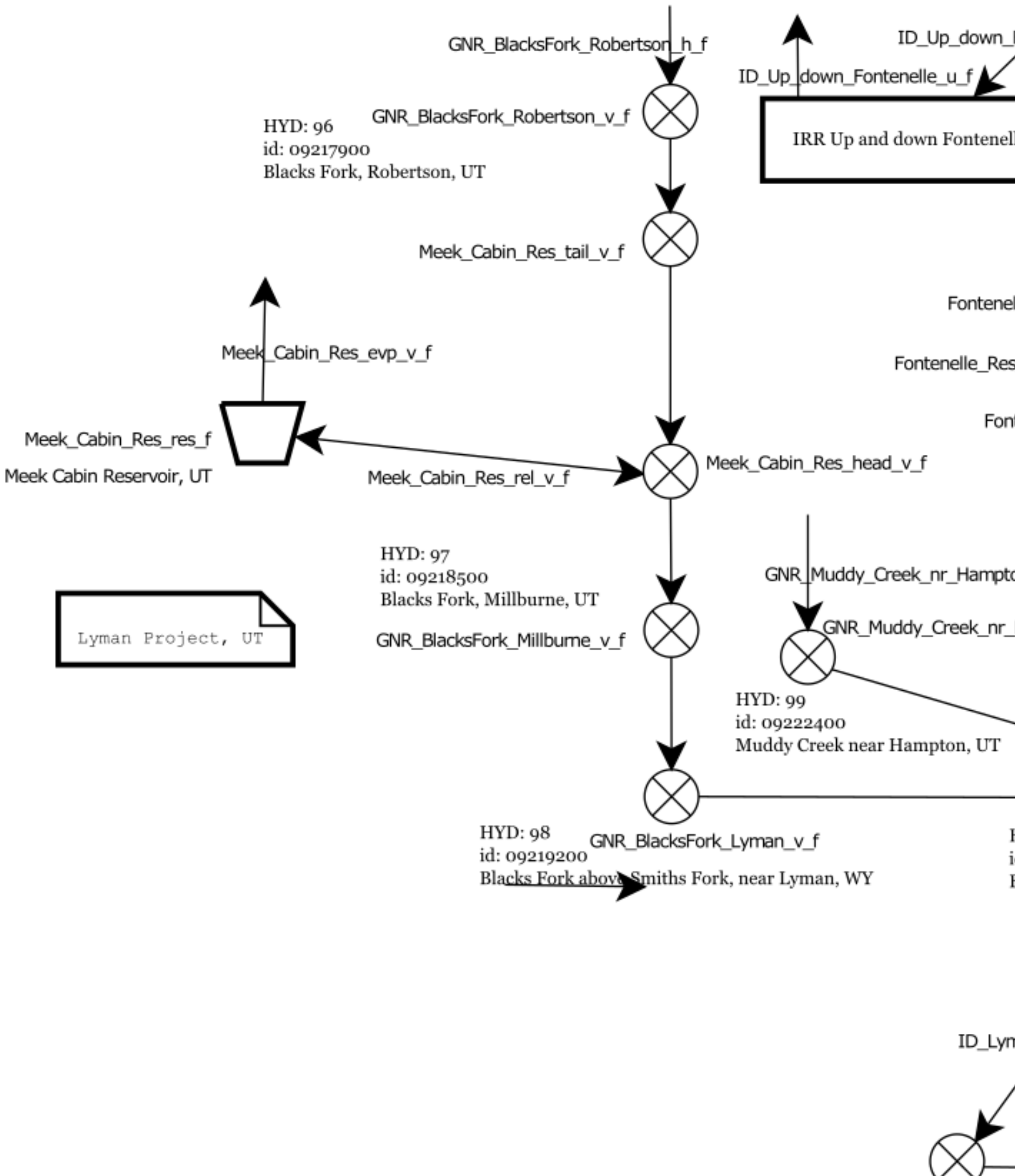
CR_Uppe


SJR_Los_Pinos_Avb_Vallecito_NR_Bayfield_h_f
SJR_Los_Pinos_Avb_Vallecito_NR_Bayfield_v_f
HYD:
id: 09352800
LOS PINOS R ABV VALLECITO RES NR BAYFIELD, CO
ecito_Lake_tail_v_f
Pine River Proyect
cito_Lake_head_v_f
HYD:
id: 09349800
PIEDRA RIVER NEAR ARBOLES, CO.
HYD:
id: 09353800
LOS PINOS RIVER NEAR IGNACIO, CO
SJR_Piedra_River_nr_Arboles_v_f
SJR_Piedra_River_nr_Arboles_h_f
_Los_Pinos_River_nr_Ignacio_v_f
Navajo_Res_evp_f
Navajo_Res_res_s
UBR_Sjuan_Chama_d_f

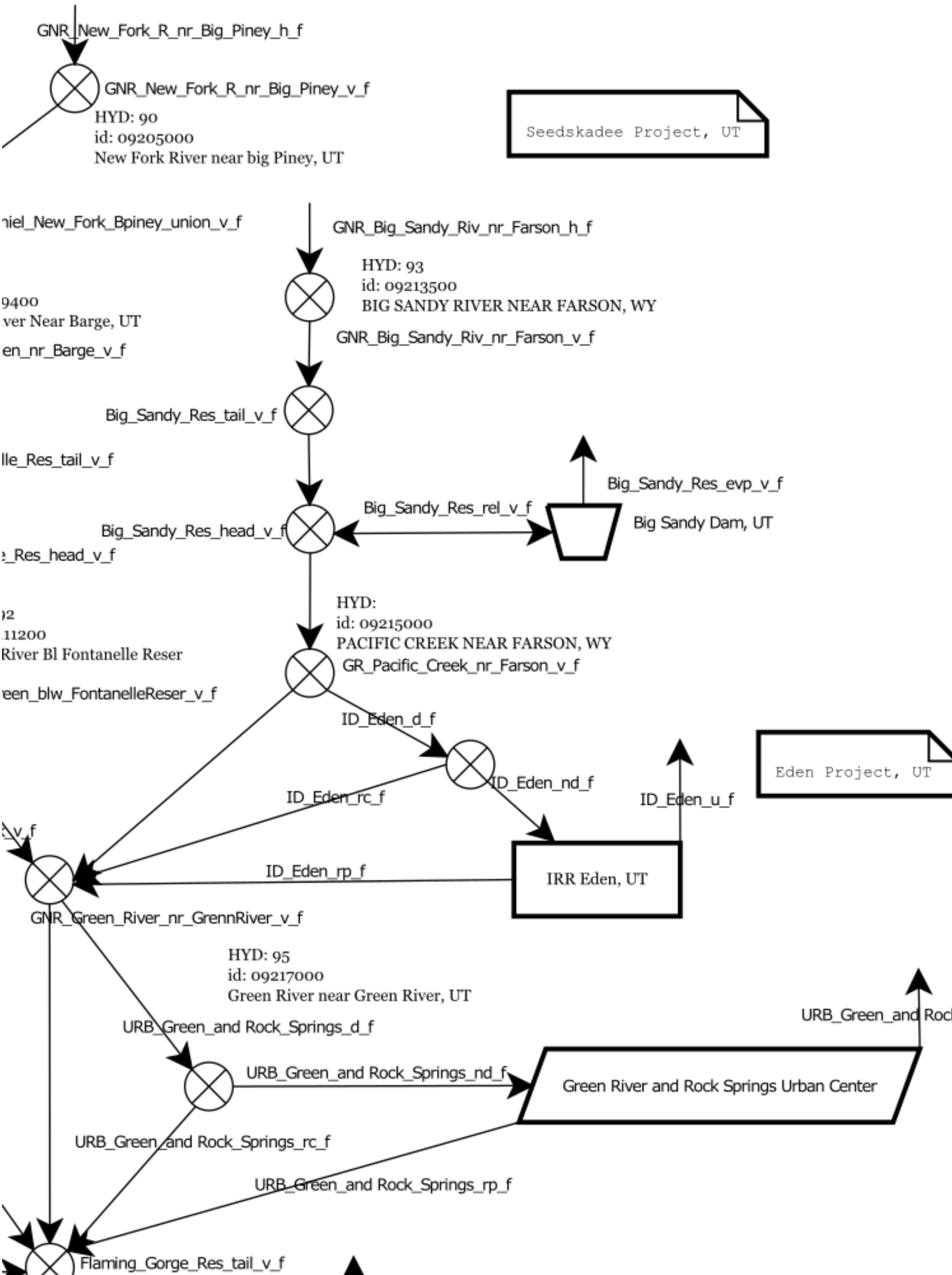
Lower_Colorado_150301



Upper_Green_HU6_140401.dia~



Upper_


GNR_New_Fork_R_nr_Big_Piney_h_f
GNR_New_Fork_R_nr_Big_Piney_v_f
HYD: 90
id: 09205000
New Fork River near big Piney, UT
Seedskadee Project, UT
GNR_Big_Sandy_Riv_nr_Farson_h_f
HYD: 93
id: 09213500
BIG SANDY RIVER NEAR FARSON, WY
GNR_Big_Sandy_Riv_nr_Farson_v_f
Big_Sandy_Res_tail_v_f
Big_Sandy_Res_evp_v_f
Big_Sandy_Res_rel_v_f
Big Sandy Dam, UT
Big_Sandy_Res_head_v_f
HYD:
id: 09215000
PACIFIC CREEK NEAR FARSON, WY
GR_Pacific_Creek_nr_Farson_v_f
ID_Eden_d_f
Eden Project, UT
ID_Eden_nd_f
ID_Eden_rc_f
ID_Eden_u_f
ID_Eden_rp_f
IRR Eden, UT
GNR_Green_River_nr_GrennRiver_v_f
HYD: 95
id: 09217000
Green River near Green River, UT
URB_Green_and Rock_Springs_d_f
URB_Green_and Rock_Springs_nd_f
Green River and Rock Springs Urban Center
URB_Green_and Rock_Springs_rc_f
URB_Green_and Rock_Springs_rp_f
Flaming_Gorge_Res_tail_v_f