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A REVIEW OF LOW-FLOW HYDROLOGY

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ABSTRACT

The purpose of this article is to assess the present state of low-flow hydrology, which is the study of the lowest flow in a river during the dry seasons of the year. The topic begins with an examination of low-flow producing processes under natural circumstances, as well as a description of human variables that influence low flows directly or indirectly. Following that, a review of current low-flow estimate techniques from stream flow time-series is presented, including flow duration curves, frequency analysis of severe low-flow occurrences and continuous low-flow periods, baseflow separation, and stream flow recession characterization. The article goes through a number of low-flow features (indices) and their uses. The connections between low-flow features are shown in a separate section. A regional regression approach, graphical depiction of low-flow features, creation of regional curves for low-flow prediction, and application of time-series simulation methods are among the approaches for low-flow estimate in ungauged river catchments discussed in the article. The article provides an overview of current low-flow-related research efforts from across the world. The issue of fluctuating minimum river flows as a consequence of climatic variability, as well as specific uses of low-flow data in river ecological research and environmental flow management, are also addressed. The review is mainly based on research findings from the previous two decades.

KEYWORDS: *Base, Flow Duration, Curve, Hydrology, Low Flow.*

1. INTRODUCTION

A discussion of low-flow hydrology and associated problems should begin with a definition of the term "low flow." To various interest groups, this word may imply different things. Many people think of it as the actual flows in a river throughout the dry season of the year, while others think of it as the amount of time and circumstances that occur between flood occurrences (for example, in erratic and intermittent semi-arid flow regimes). Others may be curious in the impact of changes in a river's total flow regime on long-term water production or riverine and riparian ecosystems. Low flows may be seen by the latter as a decrease in many elements of the entire flow regime, not only discharges occurring during a dry season[1].Low flow is defined by the World Meteorological Organization (WMO) as "flow of water in a stream during extended dry weather." Low flows and droughts are not clearly distinguished in this concept.

Low flows are a seasonal occurrence and an important part of every river's flow cycle[2]. Drought, on the other hand, is a natural occurrence caused by a prolonged period of below-average precipitation. Droughts may be classified as meteorological, atmospheric, agricultural, hydrological, or water management events. Hydrological droughts, which are marked by a reduction in lake storage, a drop in groundwater levels, and a reduction in stream flow discharge, may last a single year or many years and impact vast regions[3]. The underlying natural physical element in determining the severity of a drought is therefore climate changes, although human activities may also play a role. Drought is usually associated with resource implications of water availability, and it may be described in terms of the different uses for stream flow and the total of the lowest flow needs for each.

Drought is therefore a broader phenomenon that may be defined by a variety of variables other than low stream flows. Low-flow periods are part of droughts, although a continuous seasonal low-flow event does not always equal a drought, however some academics refer to a continuous low-flow episode in one year as an annual drought. Drought analysis and management literature needs particular attention, although it is only briefly mentioned in this study[4]. The article focuses primarily on mechanisms that operate during the dry season, as well as methods for quantifying the different elements of the cumulative output of these processes—the low-flow portion of a continuous stream flow hydrograph. Groundwater discharge or surface discharge from lakes, marshes, or melting glaciers are the most common sources of low flows. Each year, the lowest annual flow occurs in the same season[5].

The magnitudes of annual low flows, the variability of flows and the rate of stream flow depletion in the absence of rain, the duration of continuous low-flow events, and the relative contribution of low flows to the total stream flow hydrograph are just a few of the commonly used characteristics that are dealt with in low-flow hydrology in various ways. These essentially make up the ‘temporal' component of low-flow hydrology and need the study of continuous stream flow time series. The ‘spatial' component is concerned with the geographical distribution of low-flow characteristics and tries to estimate these features in catchments when there are no observed data. Both aspects of low-flow hydrology are intertwined and require a knowledge and consideration of physiographic variables that influence low flows (climate, terrain, geology, soils, and so on), as well as different man-made impacts[6].

Water-supply planning and design, waste-load allocation, reservoir storage design, and the preservation of quantity and quality of water for agriculture, recreation, and animal conservation all need knowledge of the size and frequency of low flows for streams. As a result, low-flow hydrology encompasses a wide range of interconnected issues. Riggs is one of the authors of earlier broad surveys of the topic as well as research that show that low-flow hydrology is a multifaceted and dynamic science with unique physiographic foundations and obvious practical applications[7].

These sources discussed a wide range of topics, including existing low-flow analysis techniques from flow records (flow duration analysis, low-flow frequency analysis, analysis of flow recessions, and storage-yield analysis), areas of application for these techniques, low-flow forecasting, and principles and uses of regional low-flow analysis. A collection of low-flow characteristics computation techniques used in many nations, including case examples to demonstrate some of these approaches and certain theoretical elements of natural and man-made variables influencing low flows. Aspects of low-flow analysis and management, as well as related issues[8].

The goal of this paper is to take a balanced and systematic look at the subject of low-flow hydrology, to provide recent documentation on the subject, to examine the dynamics of its physical and numerical concepts, and to track the most recent trends in low-flow related research, including the emerging interactions of low-flow hydrology with other water-related fields e.g. stream environmental management. To do so, the study analyzes a wide range of contemporary literary sources, particularly from the past two decades[9]. A river's flow is the consequence of intricate natural processes that take place on a watershed size. A river catchment may be thought of as a collection of interconnected reservoirs, each with its own recharge, storage, and outflow components. Precipitation is primarily responsible for system recharge, while storage and discharge are complicated consequences of watershed physiographic features[10].

2. DISCUSSION

Those mechanisms that influence the release of water from storage and the destiny of this discharge are directly important during a dry season. These processes often occur within river channel zones, as opposed to the entire spectrum of hydrological processes that work over wider areas of catchments during times of increased flow. The latter, of course, cannot be overlooked since they influence the catchment's capacity to absorb and store water during rainstorms for subsequent release as low flows. The distribution and infiltration characteristics of soils, the hydraulic characteristics and extent of aquifers, the rate, frequency, and amount of recharge, the evapotranspiration rates from the basin, the distribution of vegetation types, topography, and climate are all natural factors that influence the river's low-flow regime. These variables and processes may be divided into those that influence stream flow gains and losses throughout the dry season of the year.

Anthropogenic impacts on these processes, as well as direct effects on stream flow, should be addressed individually. The bulk of natural increases in stream flow during low-flow times are often generated from groundwater storage releases. In a draining aquifer, this happens when stream channels cross the main phreatic surface. Low flows must meet the following criteria:

- The draining aquifer must be replenished with adequate moisture on a seasonal basis;
- The water table must be shallow enough for the stream to cross; and
- The aquifer's size and hydraulic properties must be sufficient to maintain flows throughout the dry season.

Low flows may also be maintained by drainage of a saturated top soil zone through flow rather than deeper groundwater, according to some writers. When relatively slow moving groundwater drainage in fracture zones above the main water table includes a substantial lateral component that contacts the ground surface in the vicinity of channels, this is an example of groundwater re-emergence (springs). This is more likely to happen on steeply sloping terrain, and it may explain why semi-arid places have extended base flows after rain events, even when the water table is far below the level of stream channels. The size and density of the fractures, as well as the relative significance of the lateral drainage component compared to the vertical component, which recharges the ‘true' groundwater storage, will determine the rate of such outflow.

Drainage of near-surface valley bottom storages, such as more persistently wetted channel bank soils, alluvial valley fills, and wetland regions, may also result in gains to low flows. These are places where water condenses during and shortly after precipitation events, and where sufficient storage levels are maintained throughout the dry season to guarantee continuous lateral drainage into channels. The water stored in these soil and alluvial storages is not technically referred to as "groundwater." This source should be distinguished from the ‘true' groundwater body that lies under the phreatic surface. Of course, direct hydraulic connection between these two water storages is conceivable, as is the case when the phreatic surface meets the ground surface. The difference becomes increasingly difficult to describe at this point.

However, this is not always the case (for example, in many semi-arid settings), and water from these sources may be referred to as "perched" groundwater storage, "alluvial water storage," or "channel bank water storage. Low-flow Rivers may also be maintained by lakes that have a direct hydraulic link to rivers. During the dry season, a sufficient water level in a lake should be maintained to enable lateral outflow into a stream. The research on the impacts of lakes on low flows is sparse, but the inclusion of lake-related factors in low-flow prediction models in certain areas may indicate the significance of lakes in particular regions. Low flows in various dry seasons (e.g. summer and winter) may be caused by different physical processes in highly seasonal climates. Low flows in cold or hilly areas are susceptible to the unique effects of ice and snow melting, in addition to the normal catchment characteristics. The main impact of glaciers on low flows is comparable to that of lakes, and involves a reduction in runoff fluctuation and, as a result, more persistent low flows.

With the inclusion of direct evaporation from channel water bodies, stream flow losses are the inverse of those generating gains. During dry weather periods, stream flow losses can be caused by:

- Direct evaporation from standing or flowing water in a channel, other open water bodies, and wetlands;
- Evaporation and transpiration losses from seepage areas, where groundwater or channel bank soil water is draining into the channel;
- Groundwater recharge from stream flow where the phreatic surface lies below the channel; and
- Groundwater recharge from stream-flow where the 'Transmission losses' or 'river losses' are terms used to describe these processes.

Within the different areas, the proportional significance of transmission losses is mainly unclear. There is localized data from a few well-studied catchments available. Permafrost is a distinct cause of low-flow losses that works in cold areas. The physical aspect of the low-flow generation issue in permafrost areas (including losses from drained aquifers on ice formation, permafrost moisture phase shifts) is poorly understood and measured. Low flows diminish with increasing latitude and distance from the oceans' moderating influence for vast areas at high latitudes. It's difficult to say how various 'gain' and 'loss' processes relate to the vast range of climatic, geographical, and geological variables that occur in nature.

Experimental investigations of different low-flow producing methods are few in the literature. Simultaneously, determining the relative significance of different low-flow generating processes and variables should ideally come before any low-flow study and should also be a component of creating catchment management strategies. Within the sub-surface drainage region, groundwater is extracted. This has a noticeable impact on the phreatic surface level and, as a result, the possibility for groundwater re-emergence in stream channels. Hydraulic gradients and the length of channel that meets the phreatic surface may be affected by localized drops in the water table. Groundwater table depletion may occur from groundwater pumping at the head of a perennial river due to interception of recharge water and induced recharging of the aquifer from the river itself. This leads to significant environmental deterioration of river ecosystems, the loss of naturally supported fisheries, and a decrease in the river's overall amenity value. The impact of groundwater extraction on low flow is addressed in detail. Afforestation of a watershed as a whole or in sections. Commercial plantations typically:

- Increase interception loss due to increased canopy cover, leaf area density, and surface roughness;
- Increase transpiration loss due to increased biomass and total leaf area, deep rooting, and evergreen nature of commercial timber tree species; and
- Increase disturbance of the soil structure, infiltration, and moisture holding cap due to increased biomass and total leaf area, deep rooting, and evergreen nature of commercial timber tree species.
- All of these factors change the way storm water and low-flow producing devices work. Both a rise and a reduction in low flows are theoretically conceivable at the same time.

Decreased evapotranspiration, interception, and infiltration rates as a result of deforestation, for example, may result in greater soil moisture storage and increased surface runoff, resulting in reduced recharging and increased gully erosion. This may eventually lead to a drop in the groundwater table and a reduction in low flows caused by groundwater storage. However, no literary sources have been found that depict this sequence. There are a number of additional factors that may affect the quantities or rates of water accumulated in storage during rainfall, and therefore the levels of storage rates of release from storage during times of low rainfall. Modifications in land use across broad areas of a watershed, for example, may result in changes in infiltration and/or evaporation characteristics, as well as variations in the quantity of groundwater recharge. The catchment urbanization is one example.

Low flows have a propensity to diminish in urbanized catchments owing to the impacts of urban impermeable surfaces on direct runoff, infiltration, and evapotranspiration. Conservation farming is another example. The natural catchment surface is over-utilized in many dry regions due to overgrazing, firewood collection, and grassland burning. As soil retention capacity is reduced, these impacts may result in more rapid runoff and, as a result, greater soil erosion. Contouring, terracing, and mulching are some of the conservation techniques for creating and maintaining healthy ground cover. Many rivers' low-flow regimes have been substantially altered as a result of a number of direct effects, and the source of water in a stream under low-flow circumstances has changed. Many once-perennial streams have become intermittent (because to different abstractions), especially in desert areas.

Low flows have also been created intentionally (e.g., from irrigation return flows or dam releases of imported water for downstream consumers). In different river catchments, the proportional quantitative effects of numerous anthropogenic processes and variables varies significantly. Each combination of dominant natural processes and human effects has a distinct impact on or implications for various elements of the low-flow regime, low-flow analysis, and low-flow management. Depending on the kind of data originally accessible and the type of output information needed, a river's low-flow regime may be analyzed in a number of ways.

As a result, a number of low-flow measurements and indexes exist. The phrase "low-flow measure" refers to the many techniques that have been developed for analyzing, typically graphically, a river's low-flow regime. The phrase "low-flow index" is most often used to describe specific values derived from any low-flow measure (although it may be difficult to distinguish one from the other at times). Each low-flow method is explored in this part, beginning with its basic ideas and interpretation and progressing through current advancements in technique applications in low-flow related fields, as well as the explanation of linked low-flow indices. The Mean Yearly Runoff (MAR), which is a mean value of the available flow time series of annual flow totals and one of the most basic hydrological features, may provide an artificial ‘upper limit' to low-flow hydrology.

The long-term mean daily discharge is calculated by dividing MAR by the number of seconds in a year, and is referred to as Mean Daily Flow in the article (MDF). Different low-flow indices may be represented as a percentage of MAR or MDF. Because stream flow time-series are typically positively skewed, MF is often less than MAR, the middle value in a ranking flow time series—Median Flow (MF)—may indicate a more cautious upper limit for low flows. The positive skewness of the data rises as the temporal resolution of the stream flow data falls from yearly to daily, and therefore the gap between greater mean flow value and lower median flow value grows for the same record length. Some studies hypothesize on MAR and MF's appropriateness for separating droughts and low flows from the rest of the time series.

3. CONCLUSION

Despite the significant amount of specialist knowledge that has been accumulated in the field of low-flow hydrology over the last few decades, our understanding of specific low-flow generating mechanisms and the relevance of different gain and loss processes to a wide range of climatic, topographic, and geological conditions is still limited. This is most likely due to a lack of low-flow experimental investigations. At the same time, every low-flow study should preferably be preceded by a determination of the relative significance of different low-flow producing processes and variables in a certain catchment and/or area. Many rivers' low-flow regimes have been substantially altered, and the source of water in a stream under low-flow circumstances has changed, as a result of a range of direct or indirect human effects on stream flow in river catchments. Low flows have been eliminated from the stream flow in many instances (due to different abstractions) or intentionally produced (from irrigation return flows, discharges, and reservoir releases for downstream users). Similarly, the effects of certain human activities on low flows (e.g., deforestation, groundwater pumping, conservation farming) are not always well known or measured, and need to be studied.

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