P11 Hydrological Study on Low Streamflow and Its Severity - With A Case Application in Atsuma River Basin, Southern Hokkaido -
低水流量に基づく低水度区分とその評価に関する一考察 - 北海道南部厚真川流域の事例 -

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Introduction

The low streamflow is an important aspect in water resources planning amid a variety of competing use for achieving sustainable water resources. This paper attempts to interpret the low streamflow parameter which would be useful for developing procedure in recognizing and appraising the low streamflow. Since every river basin has its own characteristics, a case application on Atsuma River Basin (ARB) was briefly discussed.

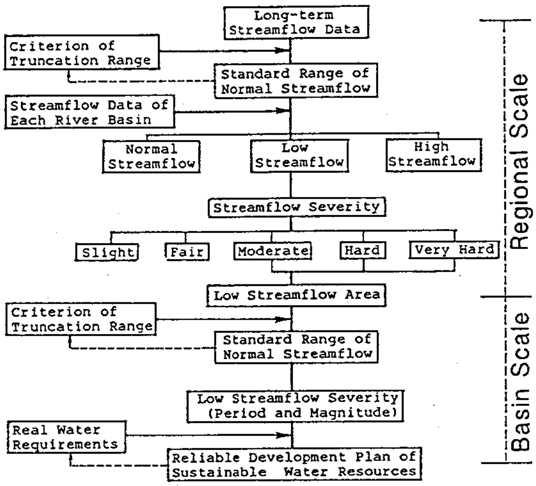

Fig.1. Procedures for Identifying and Appraising Low Streamflow and Severity

Perception of Low Streamflow

Perception of low streamflow is measured to be closely related with water shortage or drought. For interpreting the perception, there are several drought definitions due to the concept of many field studies. The hydrologist is concerned on the low streamflow, most meteorologist deals with the abnormal precipitation whereas agronomist is interested on insufficient soil moisture for supporting agricultural crops.

For a comparative reference the results of previous works concerning to water shortage proposed by Linsley and Franzini (1964), Harr and Krygier (1972), Linsley et al (1975), Dracup et al (1980) Takeuchi (1988), Moye et al (1988), Cleaveland and Stahle (1989) were examined. It was conclusively agreed that the basic significance of the water shortage or drought is concerned to the low precipitation, low streamflow and low soil moisture or the combination of each other.

Proposed Procedure for Identifying and Appraising Low Streamflow and its Severity

The basic conception is schematically shown in Fig.1, describing the procedures on region and basin scales successively. To estimate the water shortage, low streamflow was termed as streamflow deficiency from standard range of normal streamflow determined from

$$X_o = | X_m \pm 0.5\ Sd | \quad \ldots \text{(Eq.1)} \qquad CD = \sum^{n} ML_i \quad \ldots \text{(Eq.2)} \qquad LS = \frac{CD}{N} \quad \ldots \text{(Eq.3)}$$

the average of long-term streamflow record. Additionally, how severe water shortage due to low streamflow was expressed in term of low streamflow severity. For this purpose, the truncation range of standard (X_o) was determined from the mean streamflow (X_m) which is sensitive to the extreme values of data distribution and measures the average of standard deviation (Sd), in which attributed by 0.5 as a selected optional scaling factor. By using this criterion, streamflow of each river basin might be classified into three categories which termed as (1) High streamflow ($X > X_o$), (2) Normal streamflow ($X = X_o$) and (3) Low

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streamflow ($X < X_o$). The regional standard range of normal streamflow based on streamflow data of 70 river basins in Hokkaido within 12 years measurements was established (Fig.2.). Concurrently, streamflow data series of ARB was arranged to examine its low streamflow. Referring to low streamflow examination, the cumulative deficiency (CD) of low streamflow was obtained by summing each discrete deficiency (ML) as described in (Eq.2). Furthermore, to express the annual low streamflow severity (LS) from long-term streamflow measurement, CD was divided by each period of measurement (N) as suggested in (Eq.3).

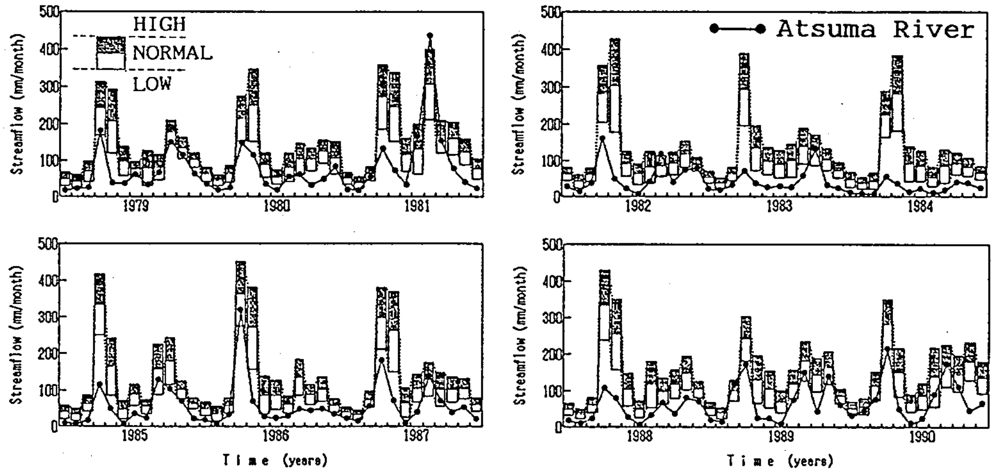

Fig.2. Standard Range of Normal Streamflow in Hokkaido and Streamflow in Atsuma River Basin

The distribution of LS magnitude was ranging from 0 to 490 mm/year with the average of 123 mm/year. Thereafter, to identify the low streamflow areas, LS was classified into five grades of severity index of low streamflow (SIL) termed as SIL-1 (<100 mm), SIL-2 (100 - 200 mm), SIL-3 (200 - 300 mm), SIL-4 (300 - 400 mm) and SIL-5 (>400 mm). Gradually, they express the more greater SIL indicates the more severe of low streamflow.

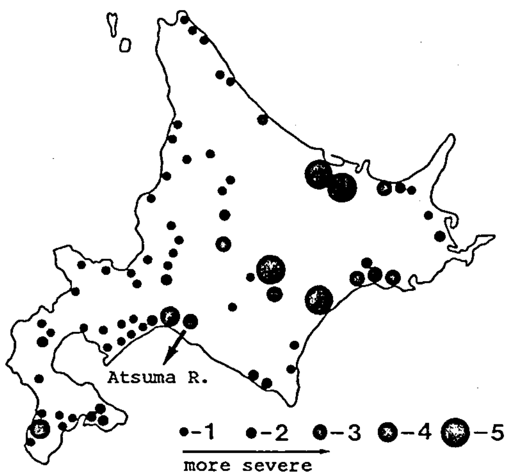

Fig.3. Distribution of Low Streamflow Severity in Hokkaido

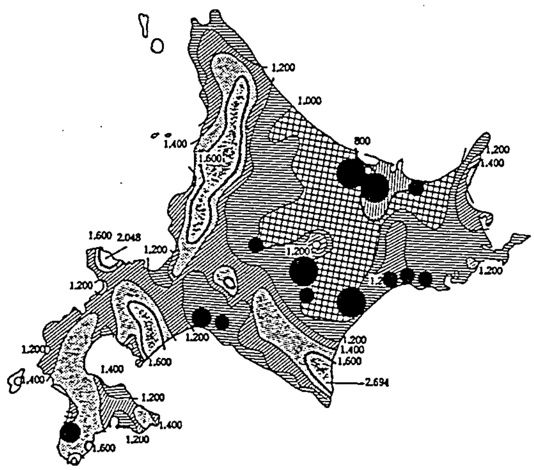

Fig.4. Distribution of Regional Precipitation and Severe Areas in Hokkaido

Interpretation of Low Streamflow and Its Severity in Hokkaido

Due to streamflow characteristic is quite inherent in nature, SIL was arranged in a map to describe their extent and distribution (Fig.3). This map is considered to be useful providing research hydrologist basic information for selecting river basin concerning to further studies of low streamflow. In general view, the eastern region was more severe compared with the western. The main factor influencing LS should be low precipitation due to the eastern region was having much less precipitation than the western part. As shown in Fig.4, SIL-3 and SIL-4 were found in area with precipitation of 1200 mm/year, whereas most of the SIL-5 distributed in areas of 800 - 1000 mm/year. However, the local physiographic basin characteristics should also be observed in further studies to reveal the low streamflow characteristics of each basin comprehensively.

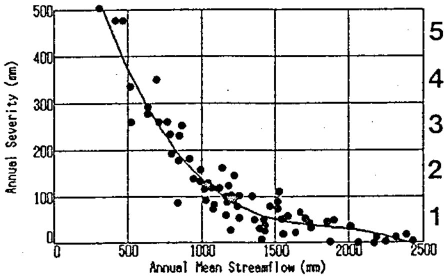

Fig.5. Mean Annual Streamflow and Annual Severity

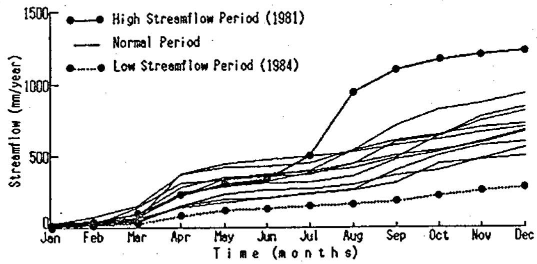

Fig.6. Cumulative Streamflow Mass Curve of Atsuma River Basin

The relation between mean annual streamflow (MS) and LS in which related with its SIL (Fig.5) might be used for verbally clarifying how severe the low streamflow severity. Base on the consecutive measurement, the regional MS of river basins in Hokkaido was found to be 1000 - 1300 mm/year. Referring to the considerable relation, LS which lower than 200 mm (SIL-1 and SIL-2) may be termed as slight to fairly severe due to they might be procured from the normal and high flow periods. Adversely, for the LS to which greater than 200 mm (SIL-3, SIL-4 and SIL-5) should be considered as moderate, hard and very hard severe of low streamflow.

Application of The Proposed Procedure in Atsuma River Basin (ARB)

As shown in the SIL arrangement map, ARB was recognized as low streamflow area by SIL-3 grade. It is located in the southern part of central Hokkaido on 42°43'15" North Latitude and 141°52'53" East Longitude occupying 406 km^2 area. The geological condition is composed of tertiary mudstone, partially combined with quaternary volcanic ashes and peat land.

By interpreting streamflow data series (1979-1990), there were two extremes of high and low streamflow periods of 1981 and 1984 which could be learned from Fig.6. These extremes were then arranged into standard range of normal streamflow (Fig.7). The high streamflow period was mostly higher, whereas most of low streamflow period was lower than standard. During low streamflow period (1984), the most severe low streamflow was April (62 mm) and September (48 mm) respectively. Apparently, there was a high fluctuation on both of seasonal and annual streamflow in which possibly become hydrological predicament during low streamflow period. For this reason, the development of procedure in how to accomplish with low streamflow severity for achieving a sustainable water resources is necessary.

Classification for Water Resources Requirements

To accomplish with low streamflow severity to which closely related with water supply - requirement, a reliable water resources allocation planning should be a major concern. In this paper, water supply was interpreted as the amount of natural streamflow potentially available and possibly used. Moreover, the various use of water requirements might be classified to be consisting of agricultural irrigation needs, domestic water consumption (industry and municipal) and hydroelectric power generation. However, due to there was no data on the amount of real water requirements in ARB, the examination of water supply - requirement could not be quantitatively performed. Recently, streamflow in ARB is mostly intended for agricultural irrigation while serving a complementary domestic water supply.

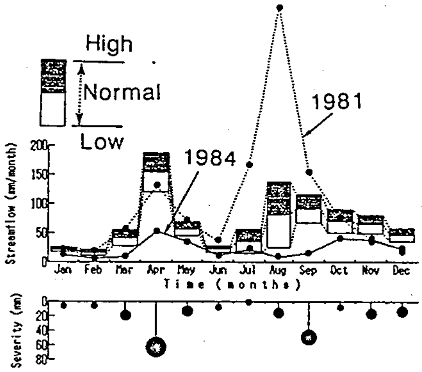

Fig.7. Standard Range of Normal Streamflow and Severity in Atsuma River Basin

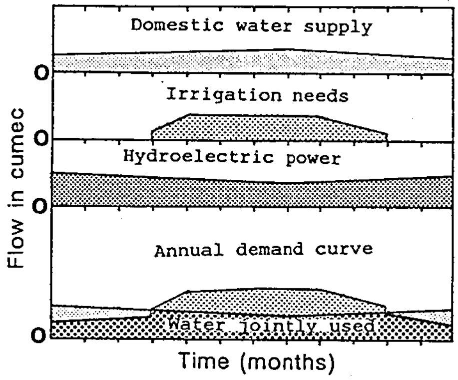

Fig.8. Graphical Synthesis of Water Requirements Compatibility

Compatibility of Water Resources Allocation

The limiting amount of water resources in the low streamflow area must be made on optimum use. For this objective, concept of multipurpose use which principally based on a compromise is required. For achieving a joining use of water resources, it depends upon the extent to which various purposes are compatible. Therefore, it is essential to observe various uses and to consider the ways in which these uses may be coexisted.

Tab.1 - Tentative Classification and Compatibility of Major Water Requirements

No.	Purpose	Timing	Compatibility
(1)	Hydroelectric Power	Constant	(2) and (3)
(2)	Domestic Water Supply	Nearly Constant	(1)
(3)	Agricultural Irrigation	Seasonal	(1)

Starting from this concept, the examination of water use compatibility should be based on their major classification. As maybe shown in Tab.1, the hydroelectric power was considered to be compatible with domestic supply and irrigation needs. Adversely, domestic water supply and the irrigation require an exact volume which can not be jointly used. Consequently, they must be provided allocation to each use. Considerable water requirements were graphically outlined in Fig. 8, simply depicting the synthesis of the magnitude, timing, and its compatibility.

Concluding Remark

The procedure for identifying low streamflow and severity was discussed. Regarding to water resources development planning and its allocation, the estimated standard normal streamflow should be based on the real water requirements in order able to perform the real analysis of potential water resources and its requirement. Further studies on a river basin scale should be insisted clarifying low streamflow and its alternative control for assessing sustainable water supply by proposing a reliable allocation of water resources.

References

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