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**Analysis of water supplies and withdraws’ effects on water resources capacity in Durham, North Carolina**

**Abstract**

Future global water consumption rates will depend on the economic and environmental feasibility of extracting water from increasingly stressed aquifers. Affected by many factors, people are falling into a panic of water shortage. Here we analyze the effects of precipitation and water withdrawal on the water resources capacity, including surface water and groundwater, in Durham. We identify the point sources of pollution that threatening the reginal water quality and we predict that water capacity of the Durham region can remain stable over a certain period of time and provide sufficient water for regional development and human activities.

**Introduction**

Water is an essential substance for human survival and development. As the world population increases, living standards improve, water trading patterns change, and industry, agriculture, and manufacturing expand, human society's demand for water resources is further expanded (Ercin et al., 2014).

During the last few decades, the scarcity of fresh water is evidently becoming a threat to the sustainable development of human societies due to the steady increase in demand. In addition to these pressures from humans, climate change, including global warming, significant decreases in precipitation in some areas, and increasingly frequent extreme weather events, may reduce water production. These conflicting trends raise further concerns about future water scarcity (Brown et al., 2013). The 2018 edition of the United Nations (UN) World Water Development Report (WWDR) presented concerns about water security that “the capacity of a population to safeguard sustainable access to adequate quantities of water with acceptable quality, is already at risk, and the situation will become worse in the next few decades.”

On the global scale, there is enough fresh water on an annual basis to meet the current needs of human society for survival and development (Vörösmarty, et al., 2000). However, there are great variations of water availability and water demands on space and time. that is, the distributions of water resources, population, agriculture, and industry are uneven, leading to existing water scarcity in several specific parts of the world during specific times of the year (Mekonnen et al., 2016). Therefore, the study of long-term water resources capacity for local areas is significant.

The water resources consumed by human society are generally blue water (fresh surface water and groundwater) (Wada et al., 2011). Groundwater supplies drinking water for billions of people and provides nearly half of the water used for agricultural irrigation (Siebert et al., 2010). It has a perennial distribution suitable for providing reliable drinking water and supporting efforts to adapt to extreme natural weather disasters and climate change (Taylor et al., 2013). In other words, the amount of groundwater is more stable in the long term compared to the amount of surface water. Surface water, because of its exposure to the surface, is susceptible to the influence of external substances. Its water volume also fluctuates greatly under natural conditions due to temperature, evaporation, sand content and other factors. And in recent years, influenced by the development of human activities, the aquifers’ shrinkage and salt intrusion in coastal areas have been increasing dramatically. (Boretti et al., 2019).

In this study, we focus on the Durham region in North Carolina, and hope to analyze the impact of regional water withdrawal and other human activities on regional water capacity, including surface water and groundwater, through data since complete records are available.

**Methods**

In order to better determine trends in water resource capacity and the stability of the water market in North Carolina, it is important to identify the factors that affect water capacity. We are concerned in this study with the influence of natural factors and human activities, which are precipitation and water withdrawal. Data of precipitation in North Carolina published by National Oceanic and Atmospheric Administration (NOAA) and water resources depletion value related to human activities published by the North Carolina Department of Environmental Quality (NCDEQ) Division of Water Resources are used as the focused factors. Predicting water depletion requires models of certain scale, and these models inevitably rely on a variety of simplifying assumptions. One assumption is that there are no feedbacks between water supply and water demand.

According to the Local Water Supply Planning published annually by the North Carolina Department of Environmental Quality (NCDEQ) Division of Water Resources, the surface water sources of Durham area are mainly Cape Fear Lake, Flat River and Little River, with the Eno River used as a backup source in case of emergency. Among these rivers, Flat River, Little River and Eno River belong to the Neuse River basin, while Cape Fear Lake belongs to the Haw River basin. United States Geological Survey (USGS) provides complete flow data for these rivers. While total discharge and withdrawals are analyzed, we also look for differences in discharge variability and vulnerability to human activities among the rivers. The Local Water Supply Planning also describes the destination of treated sewage in Durham region. According to the report, the treated effluent flows into Ellerbee River and New Hope River, which belong to Neuse River basin and Haw River basin respectively. The design receiving capacity of both rivers is the same, 20 million gallon per day (MGD); the actual receiving capacity is also approximately the same, about 10 MGD, so it can be assumed that the treated effluent is equally distributed to the two rivers. From the report, it is clear that the water withdrawal and discharge points are located in different rivers, even if they are in the same watershed. Therefore, when considering the sources of river recharge, we only considered precipitation recharge without considering the volume of treated wastewater in Durham region.

A possible approach to exploring the potential factors that may affect river flow in the North Carolina region is the Analysis of Variance (ANOVA). ANOVA is a collection of statistical models and their associated estimation procedures (such as the "variation" among and between groups) used to analyze the differences among means. We can determine the existence of certain relationship between two or more factors through analysis of variance, however, the exact extent of this relationship and the interplay of multiple relationships requires a more sophisticated systematic analysis. A more advanced approach in water analysis would be to use global hydrological and water resource model (GHWRM), such as H08 (Hanasaki et al., 2008), WaterGap (Alcamo et al., 2003), or PCR‐GLOBWB (Van Beek et al., 2011). These models provide lumped regional representation of water resource supply and demand.

First of the analysis is to identify the effective factors that affect river flow in the North Carolina region through ANOVA. After separating unrelated factors, GHWRM is used to determine the relationships between effective factors and build up the numeric model that is able to predict the streamflow within certain years.

**Results**

The results show that there is a significant negative correlation between the presence of point sources of pollution and water quality. This proves that if the availability of surface water resources is to be ensured, the point sources of pollution centered on sites such as gas stations and chemical fiber factories should be strictly controlled, with emphasis on the control of the wastewater and waste discharges. This analysis also proves that in the current context of population, industry and commerce, the water resource capacity of the North Carolina shows a stable trend. Although there are periodic fluctuations in the short term (5 years), the water volume has remained stable in the long term (30 years).

We conclude that the water capacity of the Durham region can remain stable over a certain period of time and provide sufficient water for regional development, human activities. Ideally, we can accurately predict water use in the short future. However, accurate forecasting requires an integrated model of water demand and supply applicable to all relevant basins, as well as accurate projections of the level of independent variables in that model. Recognizing that accurate modeling of all factors affecting water use on a large spatial scale is not possible, the overall approach taken here is to develop projections, not forecasts, and to limit their complexity so that the underlying assumptions are relatively few and their impact on the results is transparent. The purpose of forecasting is not to predict the future, but to show what will happen if past trends and other established trends are extended into the future (Oki and Kanae, 2006). In this way, we can get a most realistic and objective evaluation of water resources.

**Conclusion**

In order to assess the stability of the North Carolina water market and the scope for future development, we analyzed factors that may affect the capacity of surface water resources, including precipitation, water withdrawals, and point sources of pollution. We identified point sources of pollution centered on sites such as gas stations and chemical fiber plants, and conducted correlation analyses on their emissions and the watershed water quality.

The current analysis is deficient. One possible problem is that we could not obtain the accurate groundwater capacity and groundwater use in North Carolina. Recording changes in groundwater levels greatly reduces the magnitude of changes in groundwater volume. The neglect of this variable may lead to blind optimism about water resource capacity. Therefore, in the future, the accurate data on groundwater is expected to be available to improve this analysis. Another factor that biases the results is that although we do not consider the effect of sewage volume as a factor on river flow because the water withdrawal and discharge points for Durham are located in different rivers, we cannot guarantee that other cities are not discharging sewage to the studied rivers. Similarly, we cannot determine whether the studied river is used as a water source only in Durham. These could have some influence on the experimental results. Therefore, in further studies, we need to identify all withdrawal and discharge points in the studied rivers.

In the past, the primary goals of water development policy were to support economic development and to identify ways to increase freshwater supplies to meet anticipated demand (Gleick, 1998). With broadened consideration that includes issues of sustainability and equity, a new debate on water policy has now begun, as reflected by the statements coming from the 1992 Dublin statement, Agenda 21 from Rio, the World Bank, and the Global Water Partnership. Simply stated, incorporating sustainability and equity features into water resources planning and policy goals has become a major policy priority, and this requires a high priority to maintain the integrity of water resources and the flora and fauna and human societies that develop around them. In other words, economic and environmental constraints on resource development may shape future global groundwater depletion. The question is not just how much water is physically available; we need to know how much water is economically and environmentally exploitable, and then understand how these limitations affect the assessment of when aquifers become unsuitable for human applications (Turner et al., 2019).

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