

**SCENARIO BASED MODELING FOR EFFECTIVE  
IMPLEMENTATION OF PRINCIPLE OF TRANSBOUNDARY  
WATER MANAGEMENT IN INDIAN SCENARIO**

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IMPLEMENTATION OF PRINCIPLE OF TRANSBOUNDARY WATER  
MANAGEMENT IN INDIAN SCENARIO**

by

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Submitted

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## **Certificate**

This is to certify that the dissertation entitled “**Scenario Based Modeling for Effective Implementation of Principle of Transboundary Water Management in Indian Scenario**” which is being submitted by Mr. Sunil Kumar, for the award of the degree of **Doctor of Philosophy** in Civil and Environmental Engineering, to the Indian Institute of Technology, Delhi is a record of bona fide work carried out by him under our sustained guidance and supervision. The dissertation has reached the standard fulfilling the requirements of the regulations relating to the degree. The results embodied in the dissertation have not been submitted to any other university or institute for the award of any degree or diploma.

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(SUNIL KUMAR)

## **Abstract**

Transboundary water disputes are extremely complex web of issues concerning the allocation and utilization of common waters among co-riparians. These disputes are intensifying over time due to rapid population growth and impact of climate change. India has been endowed with many perennial rivers, sharing with neighbouring countries and has formulated several water sharing mechanism on transboundary rivers with all these countries. Moreover, all 20 river basins of the country which consist of Himalayan and Peninsular rivers are shared by two or more Indian States. Around 95% of the total geographical area of the country is under international or intra-national river basins. To address and adjudicate inter-state water disputes in India, there are several constitutional and legal provisions including River Board Act, 1956 and Inter-State River Water Disputes (ISRWD) Act, 1956. Over the past 200 years, various international treaties and conventions have contributed to the evolution of key principles for managing shared water resources. The principle of "equitable and reasonable utilization" along with the principles of "obligation not to cause significant harm" and "obligation to cooperate" has been established as the foundation for resolving transboundary water disputes. These principles form the main building blocks for widely recognized agreements such as United Nations Watercourses Convention, 1997 and UNECE Water Convention, 1992. In India, there is provision for setting up of water dispute tribunal under ISRWD Act, 1956 for resolving water sharing disputes amongst various states. So far, eight tribunals have been established, with four having issued their final awards and reports, which are currently being implemented. All tribunal awards have sought to ensure equitable and reasonable water allocation among basin states, based on the available data and information. Till this time, there has been substantial global development in international water law through the establishment of numerous principles governing transboundary water management in various treaties and convention. This study develops a scientific methodology for selecting appropriate principles of transboundary

water management in the Indian context using a multi-criteria decision-making approach. It holistically integrates social, economic, and environmental dimensions, drawing on input from leading national experts through survey questionnaire. This study also estimates the ‘equitable and reasonable’ water allocation fraction by incorporating a comprehensive set of factors and assigning relative weights based on expert opinions and statistical methods. A brief assessment of all functional Indian tribunal awards has been conducted based on the aforementioned water allocation fraction. Furthermore, the advent of high-speed processors has led to remarkable advances in hydrological analysis through the use of state-of-the-art software. Despite substantial progress in both transboundary water governance and hydroinformatics, and their strong potential to complement each other, interdisciplinary studies integrating these fields remain limited. To address this gap, an integrated modelling framework has been developed to assess the validity of aforementioned equitable water allocation fractions under diverse scenarios of water availability and demand. Subsequently, a demand management methodology has been devised to address the critical and complex challenge of reducing water demand by co-riparian states during periods of stress or low water availability. The demand management approach applies socio-economic criteria that capture multiple dimensions of water vulnerability and adaptive capacity, offering a comprehensive and well-founded basis for making demand adjustment decisions. Applying a techno legal framework to the Krishna River Basin highlights measurable departures from traditional tribunal mandated allocations. The divergence is most pronounced under drought conditions and when accounting for water quality and socioeconomic disparities. The research shows that fixed volumetric sharing does not adequately address the complexities of a dynamic basin. It underscores the need for tribunals and policymakers to adopt adaptive, quality sensitive, and vulnerability informed allocation mechanisms to ensure long term equity and resilience. The overall framework developed in this study has the potential to serve as an important and much-needed tool for

decision-makers. It will enable them to estimate equitable and reasonable water allocations to co-riparian states and to effectively address unsustainable scenarios arising from water shortages or other influencing factors.

## सार

सीमापार जल विवाद एक अत्यंत जटिल मुद्दों का जाल हैं जो सह-नदीय राज्यों के बीच साझा जल के आवंटन और उपयोग से संबंधित हैं। जनसंख्या में तीव्र वृद्धि और जलवायु परिवर्तन के प्रभाव के कारण ये विवाद समय के साथ और अधिक तीव्र होते जा रहे हैं। भारत में कई ऐसी बारहमासी नदियाँ हैं जो पड़ोसी देशों के साथ साझा की जाती हैं और इन नदियों पर जल बंटवारे के लिए विभिन्न तंत्र विकसित किए गए हैं। इसके अतिरिक्त देश के सभी 20 नदी घाटियाँ जिनमें हिमालयी और प्रायद्वीपीय नदियाँ शामिल हैं दो या अधिक भारतीय राज्यों द्वारा साझा की जाती हैं। देश के कुल भौगोलिक क्षेत्र का लगभग 95% अंतर्राष्ट्रीय या अंतर-राष्ट्रीय नदी घाटियों के अंतर्गत आता है। भारत में अंतर-राज्यीय जल विवादों के निपटारे और न्यायिक समाधान हेतु कई संवैधानिक और कानूनी प्रावधान हैं जिनमें नदी बोर्ड अधिनियम 1956 और अंतर-राज्यीय नदी जल विवाद (आईएसआरडब्ल्यूडी) अधिनियम 1956 शामिल हैं। पिछले 200 वर्षों में विभिन्न अंतर्राष्ट्रीय संधियों और अभिसमयों ने साझा जल संसाधनों के प्रबंधन हेतु प्रमुख सिद्धांतों के विकास में योगदान दिया है। “न्यायसंगत और तर्कसंगत उपयोग” का सिद्धांत “गंभीर क्षति न पहुँचाने का दायित्व” तथा “सहयोग का दायित्व” जैसे सिद्धांतों के साथ सीमापार जल विवादों के समाधान की आधारशिला के रूप में स्थापित हुए हैं। ये सिद्धांत संयुक्त राष्ट्र जलमार्ग अभिसमय 1997 और यूएनईसीई जल अभिसमय 1992 जैसे व्यापक रूप से मान्य समझौतों की प्रमुख आधारशिला हैं। भारत में आईएसआरडब्ल्यूडी अधिनियम 1956 के अंतर्गत विभिन्न राज्यों के बीच जल विवादों के समाधान हेतु जल विवाद न्यायाधिकरण स्थापित करने का प्रावधान है। अब तक आठ न्यायाधिकरण स्थापित किए गए हैं जिनमें से चार ने अपनी अंतिम निर्णय और रिपोर्ट जारी कर दी है जिनका कार्यान्वयन वर्तमान में चल रहा है। सभी न्यायाधिकरण निर्णयों ने उपलब्ध आँकड़ों और सूचनाओं के आधार पर घाटी राज्यों के बीच न्यायसंगत और तर्कसंगत जल आवंटन सुनिश्चित करने का प्रयास किया है। अब तक अंतर्राष्ट्रीय जल कानून में वैश्विक स्तर पर महत्वपूर्ण विकास हुआ है जिसके अंतर्गत विभिन्न संधियों और अभिसमयों में सीमापार जल प्रबंधन

को नियंत्रित करने वाले कई सिद्धांत स्थापित किए गए हैं। यह अध्ययन भारतीय परिप्रेक्ष्य में सीमापार जल प्रबंधन के उपयुक्त सिद्धांतों के चयन के लिए बहु-मापदंड निर्णय-निर्माण दृष्टिकोण के आधार पर एक वैज्ञानिक कार्यप्रणाली विकसित करता है। यह सामाजिक आर्थिक और पर्यावरणीय पहलुओं को समग्र रूप से एकीकृत करता है और प्रशावली सर्वेक्षण के माध्यम से प्रमुख राष्ट्रीय विशेषज्ञों के सुझाव प्राप्त करता है। यह अध्ययन विशेषज्ञ राय और सांख्यिकीय विधियों के आधार पर सापेक्ष भार निर्धारित करते हुए 'न्यायसंगत और तर्कसंगत' जल आवंटन अनुपात का भी आकलन करता है। उपर्युक्त जल आवंटन अनुपात के आधार पर भारत के सभी क्रियाशील न्यायाधिकरण निर्णयों का संक्षिप्त मूल्यांकन किया गया है। इसके अतिरिक्त उच्च-गति प्रोसेसरों के आगमन ने अत्याधुनिक सॉफ्टवेयर के माध्यम से हाइड्रोलॉजिकल विश्लेषण में उल्लेखनीय प्रगति को संभव बनाया है। सीमापार जल शासन और हाइड्रोइन्फॉर्मेटिक्स दोनों क्षेत्रों में पर्याप्त प्रगति और इनके एक-दूसरे का पूरक बनने की प्रबल संभावनाओं के बावजूद इन क्षेत्रों को एकीकृत करने वाले अंतर्विषयी अध्ययन सीमित रहे हैं। इस अंतर को दूर करने के लिए एक एकीकृत मॉडलिंग ढाँचा विकसित किया गया है जो विभिन्न जल उपलब्धता और मांग परिदृश्यों में उपर्युक्त न्यायसंगत जल आवंटन अनुपात की वैधता का आकलन करता है। इसके पश्चात् सह-नदीय राज्यों द्वारा तनाव या कम जल उपलब्धता की स्थिति में जल मांग में कमी लाने की महत्वपूर्ण और जटिल चुनौती का समाधान करने हेतु एक मांग प्रबंधन कार्यप्रणाली तैयार की गई है। यह मांग प्रबंधन दृष्टिकोण सामाजिक-आर्थिक मानदंडों को लागू करता है जो जल संकटग्रस्तता और अनुकूलन क्षमता के कई पहलुओं को समाहित करते हैं जिससे मांग समायोजन निर्णयों के लिए एक व्यापक और ठोस आधार प्राप्त होता है। कृष्णा नदी बेसिन पर एक तकनीकी विधिक ढाँचे का अनुप्रयोग पारंपरिक न्यायाधिकरण द्वारा निर्धारित जल आवंटनों से मापन योग्य विचलन को उजागर करता है। यह अंतर विशेष रूप से सूखे की परिस्थितियों में तथा जल गुणवत्ता और सामाजिक आर्थिक असमानताओं को ध्यान में रखने पर अधिक स्पष्ट होता है। यह शोध दर्शाता है कि स्थिर आयतन आधारित जल बंटवारा एक गतिशील बेसिन की जटिलताओं का पर्याप्त रूप से समाधान नहीं करता। यह न्यायाधिकरणों

और नीति निर्माताओं के लिए अनुकूलनशील, गुणवत्ता संवेदनशील और संवेदनशीलता आधारित आवंटन तंत्र अपनाने की आवश्यकता को रेखांकित करता है, ताकि दीर्घकालिक समानता और लचीलापन सुनिश्चित किया जा सके। इस अध्ययन में विकसित संपूर्ण ढाँचा नीति-निर्माताओं के लिए एक महत्वपूर्ण और अत्यधिक आवश्यक उपकरण के रूप में उपयोगी हो सकता है। यह उन्हें सह-नदीय राज्यों के बीच न्यायसंगत और तर्कसंगत जल आवंटन का अनुमान लगाने और जल संकट या अन्य कारकों से उत्पन्न अस्थिर परिदृश्यों का प्रभावी ढंग से समाधान करने में सक्षम बनाएगा।

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## LIST Of ABBREVIATION

<b>AHP</b>	Analytical Hierarchy Process
<b>BCM</b>	Billion Cubic Meters
<b>CWC</b>	Central Water Commission
<b>CWDT</b>	Cauvery Water Dispute Award
<b>GRMB</b>	Godavari River Management Board
<b>ICJ</b>	International Court of Justice
<b>IIL</b>	Institute of Internatic ✓
<b>ILA</b>	International Law Association
<b>ILC</b>	International Law Commission
<b>IWT</b>	Indus Water Treaty
<b>KRMB</b>	Krishna River Management Board
<b>KWDT</b>	Krishna Water Dispute Award
<b>MCM</b>	Million Cubic Meter
<b>MoWR</b>	Ministry of Water Resources
<b>NCIWRD</b>	National Commission for Integrated Water Resources Development
<b>NRSC</b>	National Remote Sensing Centre
<b>NWDT</b>	Narmada Water Dispute Award
<b>UNDP</b>	United Nations Development Programme
<b>UNECE</b>	United Nations Economic Commission for Europe
<b>UNEP</b>	United Nations Environment Programme
<b>UNESCO</b>	United Nations Educational, Scientific and Cultural Organization
<b>UNGA</b>	United Nations General Assembly
<b>UNWC</b>	United Nations Watercourses Convention

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