

**MULTI-OBJECTIVE PARADIGM FOR  
INTEGRATED RIVER BASIN MANAGEMENT –  
A CASE STUDY OF IDAMALAYAR AND IDUKKI  
RESERVOIR IN PERIYAR RIVER BASIN (KERALA,  
INDIA)**

**ANIL KUMAR**



**DEPARTMENT OF CIVIL ENGINEERING  
INDIAN INSTITUTE OF TECHNOLOGY DELHI  
JULY 2024**

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RESERVOIR IN PERIYAR RIVER BASIN (KERALA,  
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by

**ANIL KUMAR**

**Department of Civil Engineering**

**Submitted**

**in fulfillment of the requirements for the degree of  
Doctor of Philosophy**

**to the**



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# CERTIFICATE

This is to certify that the thesis entitled “**Multi-Objective Paradigm For Integrated River Basin Management – A Case Study Of Idamalayar and Idukki Reservoir in Periyar River Basin (Kerala, India)**”, being submitted by Mr. Anil Kumar to the Indian Institute of Technology, Delhi (India) for the award of the degree of **Doctor of Philosophy** in Civil Engineering, is a bonafide research work carried out by him under our joint supervision. The thesis work, in our opinion has reached the standard, fulfilling the requirements for the said degree. Further, we certify that this submission is Mr. Anil’s own work and that, to the best of our knowledge and belief, it contains no material previously published or written by another person which to a substantial extent has been accepted for the award of any other degree or diploma of any University or Institute, except where due acknowledgement has been made in the text.

(Prof. Rakesh Khosa)

Professor

Department of Civil Engineering

Indian Institute of Technology Delhi

New Delhi-110016

(Prof. A.K. Gosain)

Professor

Department of Civil Engineering

Indian Institute of Technology Delhi

New Delhi-110016

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(Anil Kumar)

# ABSTRACT

This doctoral thesis presents a comprehensive study on the evaluation of the operation rules of the Idamalayar and Idukki reservoirs within the Periyar river basin, focusing on flood reduction through hydrological and hydrodynamic modeling. The research is prompted by the increasing frequency of catastrophic floods globally, particularly evident in the devastating 2018 floods in Kerala, India. The Periyar River basin, home to major hydro-electric projects, faced unprecedented challenges with extreme rainfall, resulting in floods that surpassed the projected 100-year peak discharge.

The study employs a hybrid model, coupling 1D–2D river modeling, to assess inundation extents and flooding depths, addressing the deficiency of continuous time series monitored data. The developed iRIC 2D model, implemented under controlled and uncontrolled conditions, exhibits satisfactory performance during calibration and validation against observed field data. The integrated SWAT-iRIC model proves effective as a flood simulator in the flood-prone Periyar river basin. The study highlights the well-managed operation policies of the Idamalayar and Idukki reservoirs, as evidenced by controlled flooding depths below 3m. The developed framework, a valuable tool for flood reduction, offers insights into reservoir operation policies on a larger scale, contributing to flood reduction planning and natural disaster management. The study showcases the applicability of the SWAT model for assessing flow in the Periyar river basin, demonstrating superior performance in calibration and validation processes.

The research extends its scope to habitat suitability for fish using remote sensing, GIS, and AHP, offering insights applicable not only in India but also in other countries facing increased pressure on water resources due to population growth. The integrated modeling process

identifies ecological optimum discharge values and least suitable discharge based on habitat suitability, environmental standards, hydrological water availability, and legal constraints.

Furthermore, the study introduces an integrated model for optimal reservoir scheduling, considering water demand factors, environmental baseflow, flood management, and competing water demands. The combined reservoir operating method prioritizes planned hydropower reliability and safeguards downstream ecosystems. Improved rule curves for the Idukki and Idamalayar reservoirs aim to minimize annual water shortages and enhance flood management capabilities. The new curves, resembling existing patterns, emphasize the significance of increased reservoir volume during the monsoon season. Future research could derive optimal operating policies at daily time steps, offering a more detailed understanding of reservoir dynamics.

From the above discussion, it can be said that the present doctoral thesis significantly advances the scientific understanding of reservoir operations, flood reduction strategies, and habitat suitability assessments. The proposed framework and models offer practical applications for effective planning, management of natural disasters, and sustainable utilization of water resources, especially in the face of escalating global challenges. The study's multidimensional approach, spanning hydrological modeling, reservoir operation policies, and ecological assessments, positions it as a comprehensive and valuable contribution to the field. The findings not only deepen our understanding of the Periyar River basin dynamics but also provide transferable insights with broader implications for regions worldwide facing similar water-related challenges.

# सारांश

यह डॉक्टोरल थीसिस पेरियार नदी बेसिन के भीतर इडामलयार और इडुक्की जलाशयों के परिचालन नियमों के मूल्यांकन पर केंद्रित है, जो हाइड्रोलॉजिकल और हाइड्रोडायनामिक मॉडलिंग के माध्यम से बाढ़ में कमी पर जोर देती है। यह शोध वैश्विक स्तर पर विनाशकारी बाढ़ की बढ़ती आवृत्ति, विशेष रूप से 2018 में केरल, भारत में हुई विनाशकारी बाढ़ के संदर्भ में प्रेरित है। पेरियार नदी बेसिन, जो प्रमुख हाइड्रो-इलेक्ट्रिक परियोजनाओं का घर है, को अत्यधिक वर्षा के साथ अभूतपूर्व चुनौतियों का सामना करना पड़ा, जिससे बाढ़ की स्थिति उत्पन्न हुई जो अनुमानित 100-वर्षीय चरम निर्वहन को पार कर गई। अध्ययन 1D-2D नदी मॉडलिंग को जोड़ने वाले एक हाइब्रिड मॉडल का उपयोग करता है, जो सतत समय श्रृंखला निगरानी डेटा की कमी को संबोधित करते हुए जलमग्नता की हदों और बाढ़ की गहराई का आकलन करता है। नियंत्रित और अनियंत्रित परिस्थितियों के तहत कार्यान्वित iRIC 2D मॉडल, अवलोकित फील्ड डेटा के विरुद्ध अंशांकन और मान्यकरण के दौरान संतोषजनक प्रदर्शन प्रदर्शित करता है। एकीकृत SWAT-iRIC मॉडल बाढ़-प्रवण पेरियार नदी बेसिन में एक प्रभावी बाढ़ सिमुलेटर साबित होता है। अध्ययन इडामलयार और इडुक्की जलाशयों की अच्छी प्रबंधित परिचालन नीतियों पर प्रकाश डालता है, जैसा कि 3 मीटर से कम गहराई वाली नियंत्रित बाढ़ से सिद्ध होता है। विकसित ढांचा, बाढ़ में कमी के लिए एक मूल्यवान उपकरण है, जो बड़े पैमाने पर जलाशय संचालन नीतियों पर अंतर्दृष्टि प्रदान करता है, बाढ़ में कमी योजना और प्राकृतिक आपदा प्रबंधन में योगदान देता है। अध्ययन पेरियार नदी बेसिन में प्रवाह के आकलन के लिए SWAT मॉडल की प्रयोज्यता को प्रदर्शित करता है, जो अंशांकन और मान्यकरण प्रक्रियाओं में श्रेष्ठ प्रदर्शन दिखाता है।

शोध अपने दायरे को मछलियों के लिए निवास स्थान की उपयुक्तता तक विस्तारित करता है, जो रिमोट सेंसिंग, जीआईएस, और एएचपी का उपयोग करते हुए, ऐसे अंतर्दृष्टि प्रदान करता है जो न केवल भारत

में बल्कि जनसंख्या वृद्धि के कारण जल संसाधनों पर बढ़ते दबाव का सामना कर रहे अन्य देशों में भी लागू होते हैं। एकीकृत मॉडलिंग प्रक्रिया पर्यावरण मानकों, हाइड्रोलॉजिकल जल उपलब्धता, और कानूनी बाधाओं के आधार पर निवास स्थान की उपयुक्तता के लिए पारिस्थितिक इष्टतम निर्वहन मूल्य और सबसे कम उपयुक्त निर्वहन की पहचान करती है।

इसके अतिरिक्त, अध्ययन जल की मांग कारकों, पर्यावरणीय आधार प्रवाह, बाढ़ प्रबंधन, और प्रतिस्पर्धी जल मांगों पर विचार करते हुए एकीकृत मॉडल पेश करता है। संयुक्त जलाशय संचालन विधि नियोजित जलविद्युत विश्वसनीयता को प्राथमिकता देती है और डाउनस्ट्रीम पारिस्थितिक तंत्रों की सुरक्षा करती है। इडुक्की और इडामलयार जलाशयों के लिए सुधारित नियम वक्र वार्षिक जल की कमी को कम करने और बाढ़ प्रबंधन क्षमताओं को बढ़ाने का लक्ष्य रखते हैं। नए वक्र, मौजूदा पैटर्न के समान, मानसून के मौसम के दौरान जलाशय की मात्रा में वृद्धि के महत्व पर जोर देते हैं। भविष्य के अनुसंधान दैनिक समय कदमों पर इष्टतम संचालन नीतियों को व्युत्पन्न कर सकते हैं, जो जलाशय गतिकी की अधिक विस्तृत समझ प्रदान करते हैं।

उपरोक्त चर्चा से यह कहा जा सकता है कि वर्तमान डॉक्टरल थीसिस जलाशय संचालन, बाढ़ में कमी रणनीतियों, और निवास स्थान उपयुक्तता आकलन की वैज्ञानिक समझ को महत्वपूर्ण रूप से आगे बढ़ाती है। प्रस्तावित ढांचा और मॉडल प्रभावी योजना, प्राकृतिक आपदाओं के प्रबंधन, और जल संसाधनों के सतत उपयोग के लिए व्यावहारिक अनुप्रयोग प्रदान करते हैं, विशेष रूप से बढ़ती वैश्विक चुनौतियों का सामना करते हुए। अध्ययन का बहुआयामी दृष्टिकोण, जो हाइड्रोलॉजिकल मॉडलिंग, जलाशय संचालन नीतियों, और पारिस्थितिक आकलनों को शामिल करता है, इसे क्षेत्र में एक व्यापक और मूल्यवान योगदान के रूप में स्थापित करता है। निष्कर्ष न केवल पेरियार नदी बेसिन की गतिशीलता की हमारी समझ को गहरा करते हैं बल्कि समान जल-संबंधी चुनौतियों का सामना कर रहे क्षेत्रों के लिए व्यापक प्रभावों के साथ स्थानांतरण योग्य अंतर्दृष्टि भी प्रदान करते हैं।

# TABLE OF CONTENTS

<b>CERTIFICATE</b> .....	<b>i</b>
<b>ACKNOWLEDGEMENTS</b> .....	<b>ii</b>
<b>ABSTRACT</b> .....	<b>iv</b>
<b>सारांश</b> .....	<b>vi</b>
<b>LIST OF TABLES</b> .....	<b>xii</b>
<b>LIST OF FIGURES</b> .....	<b>xiii</b>
<b>CHAPTER 1: INTRODUCTION</b> .....	<b>1</b>
<b>1.1 BACKGROUND</b> .....	<b>1</b>
<b>1.2 HYDROLOGICAL AND HYDRODYNAMIC MODELLING APPROACH</b> .....	<b>2</b>
<b>1.3 ESTIMATION OF ENVIRONMENTAL FLOWS</b> .....	<b>3</b>
<b>1.4 OPERATIONAL MODEL FOR RESERVOIR OPERATION</b> .....	<b>7</b>
<b>1.5 OBJECTIVES OF THE PHD THESIS</b> .....	<b>9</b>
<b>1.6 OVERVIEW OF THE PRESENT STUDY</b> .....	<b>9</b>
<b>1.7 ORGANIZATION OF THE THESIS</b> .....	<b>10</b>
<b>CHAPTER 2: MODEL DESCRIPTION: HYDROLOGIC AND HYDRAULIC MODELLING</b> .....	<b>12</b>
<b>2.1 INTRODUCTION</b> .....	<b>12</b>
2.1.1 Rainfall runoff models.....	13
<b>2.2 SWAT MODEL</b> .....	<b>15</b>
2.2.1 Existing Studies of SWAT .....	16
2.2.2 Comparison of SWAT with other Models .....	17
2.2.3 Hydrological Component of SWAT.....	22

2.2.4	SWAT Strengths and Limitations .....	27
<b>2.3</b>	<b>iRIC MODEL .....</b>	<b>29</b>
2.3.1	Structure of iRIC .....	29
2.3.2	Nays2DFlood.....	32
<b>2.4</b>	<b>MODEL EVALUATION STATISTICS.....</b>	<b>34</b>
2.4.1	Nash-Sutcliffe Efficiency (NSE).....	34
2.4.2	Percent Bias (PBIAS).....	35
<b>2.5</b>	<b>SUMMARY .....</b>	<b>35</b>
<b>CHAPTER 3: DEVELOPMENT OF FLOOD MODEL TO SIMULATE THE RESPONSE OF A CATCHMENT USING HYDROLOGICAL (FLOW) AND HYDRODYNAMIC MODELLING APPROACH (WATER DEPTH &amp; EXTENT).....</b>		<b>36</b>
<b>3.1</b>	<b>INTRODUCTION .....</b>	<b>36</b>
<b>3.2</b>	<b>STUDY AREA.....</b>	<b>39</b>
<b>3.3</b>	<b>DATA USED .....</b>	<b>42</b>
<b>3.4</b>	<b>RESULTS AND DISCUSSION .....</b>	<b>43</b>
3.4.1	Hydrological Modelling – SWAT.....	43
3.4.2	Reservoir (Idukki and Idamalyar) Rule Curve .....	48
3.4.3	Calibration and Validation of iRIC Model.....	51
3.4.4	Coupled Hydrological and Hydrodynamic Model .....	53
<b>3.5</b>	<b>SUMMARY AND CONCLUSIONS.....</b>	<b>64</b>
<b>CHAPTER 4: ESTIMATION OF ENVIRONMENTAL FLOWS IN PERIYAR RIVER USING AN INTEGRATED MODELLING APPROACH.....</b>		<b>66</b>
<b>4.1</b>	<b>INTRODUCTION .....</b>	<b>66</b>
4.1.1	Global Environmental Flow Calculator .....	70
<b>4.2</b>	<b>STUDY AREA.....</b>	<b>72</b>

<b>4.3</b>	<b>APPROACH AND METHODOLOGY .....</b>	<b>75</b>
4.3.1	Hydrological modelling .....	75
4.3.2	Data Used .....	76
4.3.3	Habitat Modelling.....	77
<b>4.4</b>	<b>RESULTS AND DISCUSSION .....</b>	<b>81</b>
4.4.1	Hydrological Modelling .....	81
4.4.2	Calibration and Validation of SWAT Model .....	82
4.4.3	Habitat Modelling.....	83
4.4.4	Hydrodynamic-habitat modelling.....	88
<b>4.5</b>	<b>SUMMARY AND CONCLUSIONS .....</b>	<b>102</b>
<b>CHAPTER 5: OPERATIONAL MODEL FOR RESERVOIR</b>		
<b>OPERATION: CASE STUDY OF IDAMALAYAR AND IDUKKI</b>		
<b>RESERVOIR, WESTERN GHAT REGION OF KERALA, INDIA.....</b>		
		<b>103</b>
<b>5.1</b>	<b>INTRODUCTION .....</b>	<b>103</b>
<b>5.2</b>	<b>STUDY AREA.....</b>	<b>105</b>
<b>5.3</b>	<b>RESERVOIR OPERATION PROBLEM FORMULATION .....</b>	<b>108</b>
<b>5.4</b>	<b>Results and Discussion.....</b>	<b>109</b>
5.4.1	Head -Volume- Area Relationship of Idamalayar Reservoir .....	110
5.4.2	Head -Volume- Area Relationship of Idukki Reservoir.....	114
5.4.3	SWAT based Reservoir Outputs .....	118
<b>5.5</b>	<b>SUMMARY AND CONCLUSIONS .....</b>	<b>138</b>
<b>CHAPTER 6: SUMMARY AND FUTURE SCOPE FOR WORK</b>		
<b>.....</b>		
		<b>140</b>
<b>6.1</b>	<b>SUMMARY AND CONCLUSIONS .....</b>	<b>140</b>
6.1.1	Summary .....	140
6.1.2	Conclusions .....	140
<b>6.2</b>	<b>SCOPE FOR FUTURE RESEARCH WORK.....</b>	<b>142</b>

<b>REFERENCES.....</b>	<b>143</b>
<b>BIODATA .....</b>	<b>156</b>
<b>PUBLICATIONS .....</b>	<b>157</b>
<b>JOURNALS.....</b>	<b>157</b>
<b>CONFERENCES .....</b>	<b>157</b>

# LIST OF TABLES

Table 3-1: Description of the Data Used .....	42
Table 3-2: SWAT model parameters, process, their description, parameter ranges, default value, and fitted value in the stepwise calibration process. ....	45
Table 3-3: NSE and PBIAS values during calibration and validation.....	47
Table 4-1: Explanation of EMC employed in the GEFC (Karimi et al., 2012; Mlynski et al., 2020). ....	70
Table 4-2: Data used for the model development.....	76
Table 4-3: Weight for the different parameter for AHP analysis .....	88
Table 4-4: 75 % of FDC MCM in m <sup>3</sup> /sec.....	95
Table 5-1: Curve fitting using power function for Idamalayar reservoir head volume relationship creation using the observed timeseries data (year 2005 – 2013) .....	112
Table 5-2: Curve fitting using power function for Idamalayar reservoir head area relationship creation using the observed timeseries data (year 2005 – 2013) .....	113
Table 5-3: Curve fitting using power function for Idukki reservoir head volume relationship creation using the observed timeseries data (year 2005 – 2017) .....	117
Table 5-4: Curve fitting using power function for Idukki reservoir head area relationship creation using the observed timeseries data (year 2005 – 2017) .....	117

# LIST OF FIGURES

Figure 2-1: General flowchart of the software procedure. ( <a href="http://i-ric.org/en/introduction">http://i-ric.org/en/introduction</a> )..	31
Figure 2-2: The Basic Process to Begin the Overflow Calculation .....	33
Figure 3-1: Study Area showing basin, watershed, reach, monitoring point as well as GD (Gauging and Discharge) station. ....	41
Figure 3-2: Periyar river basin where river reaches, reservoirs location, gauging stations is shown in A, Landuse (B), Soil (C) and Slope (D). ....	44
Figure 3-3: Observed and computed daily and month-wise streamflow's at the Neeleshwaram and Kalady gauging stations during calibration as well as validation periods. ....	48
Figure 3-4: Idamalyar and Idukki level and gross storage relationship. ....	50
Figure 3-5: Idamalyar (a) and Idukki (b) available lower and upper rule curve. ....	50
Figure 3-6: Reservoir Inflow, Outflow and storage plot considering reservoir operation policy. ....	51
Figure 3-7: iRIC model calibration at Neeleswaram (16 <sup>th</sup> , 17 <sup>th</sup> and 18 <sup>th</sup> August 2018), Marthaandavarma (18 <sup>th</sup> August 2018) and Mangalapuzha (16 <sup>th</sup> and 18 <sup>th</sup> August 2018). ....	52
Figure 3-8: Hydrodynamic model flood depth output of Periyar river basin under controlled flow condition (with reservoir operation). ....	55
Figure 3-9: Hydrodynamic model flood depth output of Kochi city and flood velocity of Periyar river basin under controlled flow condition (with reservoir operation). ....	56
Figure 3-10: Hydrodynamic model flood depth output of Kochi city and Periyar river basin under natural flow condition (without reservoir operation). ....	58
Figure 3-11: Rainfall analysis of Periyar river basin (15 <sup>th</sup> , 16 <sup>th</sup> , 17 <sup>th</sup> and 18 <sup>th</sup> August 2018)..	60
Figure 3-12: Hydrodynamic model flood depth output of Kochi city and Periyar river basin under Controlled Flow Condition (with reservoir) considering downstream rainfall. ....	61

Figure 3-13: Comparison of Kochi City Maximum Flood Depth at three Different Scenarios, i.e., (i) Natural Flow Condition, (ii) With Reservoir Operation, and (iii) Considering Reservoir and Rainfall Both .....	63
Figure 4-1: Periyar River Basin, Kerala, India. ....	74
Figure 4-2: Shows (a) Reservoir Locations (b) land use land cover (c) Soil (d) Slope distribution of Periyar River.....	82
Figure 4-3: AHP technique parameters (Slope, Reach Euclidean distance and Flow density) of Periyar River Basin.....	84
Figure 4-4: AHP technique parameters (Landuse, NDVI and Density of steam) of Periyar River Basin .....	85
Figure 4-5: Fish habitat site based on AHP analysis .....	87
Figure 4-6: Flow duration curve (Global Environmental Flow Calculator output) near Periyar Dam (downstream of Idukki dam).....	89
Figure 4-7: Flow duration curve considering different environment flow classes (Global Environmental Flow Calculator output) near Periyar Dam (downstream of Idukki dam) .....	90
Figure 4-8: SWAT monthly flow output considered for e-flow calculation and Global Environmental Flow Calculator outputs (Flow duration curve and different e-flow values) near Idukki dam .....	90
Figure 4-9: Flow duration curve (Global Environmental Flow Calculator output) near Periyar Dam (downstream of Idamalyar dam) .....	91
Figure 4-10: Flow duration curve considering different environment flow classes (Global Environmental Flow Calculator output) near Periyar Dam (downstream of Idamalyar dam) .....	92
Figure 4-11: SWAT monthly flow output considered for e-flow calculation and Global Environmental Flow Calculator outputs (Flow duration curve and different e-flow values) near Idamalyar dam .....	92

Figure 4-12: Flow duration curve (Global Environmental Flow Calculator output) near Periyar Dam (Basin Outlet).....	93
Figure 4-13: Flow duration curve considering different environment flow classes (Global Environmental Flow Calculator output) near Periyar Dam (Basin Outlet) .....	94
Figure 4-14: SWAT monthly flow output considered for e-flow calculation and Global Environmental Flow Calculator outputs (Flow duration curve and different e-flow values) near Basin Outlet .....	94
Figure 4-15: Environmental flow of water depth and velocity considering class A .....	97
Figure 4-16: Environmental flow of water depth and velocity considering class B.....	98
Figure 4-17: Environmental flow of water depth and velocity considering class C.....	99
Figure 4-18: Idukki e-flow release requirement based on associated catchment area.....	101
Figure 5-1: Study area showing basin, watershed, reach, river monitoring point, and gauge discharge station locations. ....	107
Figure 5-2: Idamalayar reservoir head volume relationship using the observed timeseries data (year 2005 – 2013).....	112
Figure 5-3: Idamalayar reservoir head area volume relationship using the observed timeseries data.....	114
Figure 5-4: Idukki reservoir head volume relationship using the observed timeseries data (year 2005 – 2017).....	116
Figure 5-5: Idukki reservoir head volume area relationship using the observed timeseries data (year 2005 – 2017).....	118
Figure 5-6: Reservoir in the SWAT model (Neitsch et al., 2005) .....	120
Figure 5-7: Idamalayar reservoir area, volume, water level and inflow on daily timescale (year 1987 to 2019).....	121

Figure 5-8: Idamalayar reservoir area, volume, water level and inflow on weekly timescale (year 1987 to 2019).....	122
Figure 5-9: Idamalayar reservoir volume, rainfall and reservoir losses (seepage and evaporation) on daily timescale (year 1987 to 2019).....	122
Figure 5-10: Idamalayar reservoir volume, rainfall, and reservoir losses (seepage and evaporation) on weekly timescale (year 1987 to 2019).....	123
Figure 5-11: Idukki reservoir area, volume, water level and inflow on daily timescale (year 1974 to 2019).....	124
Figure 5-12: Idukki reservoir area, volume, water level and inflow on weekly timescale (year 1974 to 2019).....	124
Figure 5-13: Idukki reservoir volume, rainfall, and reservoir losses (seepage and evaporation) on daily timescale (year 1974 to 2019).....	125
Figure 5-14: Idukki reservoir volume, rainfall, and reservoir losses (seepage and evaporation) on weekly timescale (year 1974 to 2019).....	125
Figure 5-15: Process for reservoir and power generation.....	126
Figure 5-16: Idamalayar reservoir Inflow and reservoir volume on yearly timescale (year 1987 to 2019).....	128
Figure 5-17: Idamalayar reservoir seepage loss, evaporation loss, rainfall, and reservoir volume on yearly timescale (year 1987 to 2019).....	128
Figure 5-18: Idukki reservoir Inflow and reservoir volume on yearly timescale (year 1974 to 2019).....	129
Figure 5-19: Idukki reservoir seepage loss, evaporation loss, rainfall, and reservoir volume on yearly timescale (year 1974 to 2019).....	129
Figure 5-20: Variations of Idamalayar reservoir head, volume, inflow, and area on weekly timescale. ....	132

Figure 5-21: Variations of Idamalayar reservoir head, inflow, and area during wet years 2018–19 and 1998 to 2000.....	132
Figure 5-22: Variations of Idamalayar reservoir head, inflow, and area during dry years 2002-03 and 2016-17. ....	133
Figure 5-23: Idamalayar reservoir rule curve under different probability condition.....	134
Figure 5-24: Variations of Idukki reservoir head, volume, inflow, and area on weekly timescale. ....	135
Figure 5-25: Variations of Idukki reservoir head, inflow, and area during wet years 2013 and 2018-19. ....	136
Figure 5-26: Variations of Idukki reservoir head, inflow, and area during dry years 2016 and 1986 to 1989. ....	137
Figure 5-27: Idukki reservoir rule curve under different probability conditions.....	138