Unit – I
WATER RESOURCE MANAGEMENT
Syllabus

Distribution pattern of water resource; concept of integrated water resource management, water scarcity and sustainable development goals; Water quality standards in India; importance of watershed and watershed management; rain water harvesting; Definition of a wetland; types of wetlands (fresh water and marine); ecological and hydrological functions of wetlands; threats to wetlands; wetland conservation and management; Ramsar Convention, 1971; major wetlands of India.

Water Resources and Integrated Management

Q1.
a) Define Integrated Water Resource Management (IWRM). (2)
b) Explain the key principles of IWRM in the context of sustainable water use. (3)
c) Discuss how IWRM can help India achieve Sustainable Development Goal (SDG) 6. Provide examples. (5)

Integrated Water Resource Management (IWRM) and SDG 6 in India

a) Define Integrated Water Resource Management (IWRM). (2 marks)

Integrated Water Resource Management (IWRM) is a holistic approach to managing water resources that balances social, economic, and environmental needs. It promotes coordinated development and management of water, land, and related resources to maximize economic and social welfare without compromising ecosystem sustainability (Global Water Partnership, 2000).

Key Aspects of IWRM:

i. **Multi-sectoral approach** (agriculture, industry, domestic use)
ii. **Stakeholder participation** (government, communities, industries)
iii. **Sustainable use** (prevents over-exploitation)

b) Explain the key principles of IWRM in the context of sustainable water use. (3 marks)

The **three core principles of IWRM**, as defined by the **Global Water Partnership (2000)**, are:

1) **Ecological Sustainability**

i. Ensures water use does not exceed natural recharge rates.
ii. Protects aquatic ecosystems (e.g., maintaining minimum river flows).

Example: **Environmental flows (e-flows)** in Ganga River under Namami Gange Mission.

2) **Equity in Water Allocation**

- Fair distribution among urban, rural, and industrial users.
- Prioritizes drinking water over irrigation in water-scarce regions.

Example: **Maharashtra's water grid project** ensures equitable supply.

3) Economic Efficiency

- Water pricing to discourage wastage (e.g., **progressive tariffs** in Chennai).
- Promotes water-saving technologies (drip irrigation, wastewater recycling).

Example: **Punjab's 'Paani Bachao, Paisa Kamao'** scheme incentivizes efficient water use.

Table 1: IWRM Principles and Applications in India

Principle	Application in India	Example
Ecological Sustainability	Maintaining minimum river flows	Ganga e-flow notification (2018)
Equity in Allocation	Inter-state water sharing policies	Cauvery Water Disputes Tribunal
Economic Efficiency	Water pricing in urban areas	Delhi Jal Board's graded tariff system

(Sources: GWP, 2000; Ministry of Jal Shakti, 2021)

c) Discuss how IWRM can help India achieve Sustainable Development Goal (SDG) 6. Provide examples. (5 marks)

SDG 6 aims to **"Ensure availability and sustainable management of water and sanitation for all."** IWRM aligns with SDG 6 through:

i) Improving Water Use Efficiency (SDG 6.4)

Micro-irrigation adoption (drip/sprinkler) saves **30-50% water** in agriculture (NITI Aayog, 2020).

Example: **Per Drop More Crop (PDMC) scheme** under PMKSY.

ii) Industrial water recycling (e.g., **Tiruppur textile cluster** reuses 90% wastewater).

Protecting Water-Related Ecosystems (SDG 6.6)

iii) Wetland conservation under **Ramsar Convention** (India has **75 Ramsar sites** as of 2023).

Example: **Chilika Lake restoration** improved aquatic biodiversity.

iv) **River rejuvenation programs** (e.g., **Namami Gange**).

v) **Ensuring Equitable Access (SDG 6.1 & 6.2)**

vi) **Jal Jeevan Mission (JJM)** provides **tap water to rural households** (55% coverage by 2023).

vii) **Community-based water management** (e.g., **Rajasthan's Johads**).

viii) **Reducing Water Pollution (SDG 6.3)**

ix) **Effluent Treatment Plants (ETPs)** in industries (e.g., **Yamuna Action Plan**).

x) **Ban on single-use plastics** near water bodies.

xi) **Climate Resilience (SDG 6.5 & 6.a)**

xii) **Interlinking of Rivers (ILR)** to mitigate floods/droughts.

xiii) **Rainwater harvesting mandates** (e.g., **Tamil Nadu's rooftop RWH policy**).

Figure 1: IWRM Contributions to SDG 6 Targets
(Conceptual Framework)

SDG 6.1 (Safe Drinking Water) → Jal Jeevan Mission

SDG 6.3 (Water Quality) → Namami Gange

SDG 6.4 (Water Efficiency) → Micro-irrigation schemes

SDG 6.6 (Ecosystem Protection) → Wetland conservation

Challenges & Future Steps:

Groundwater over-extraction (21 Indian cities may run dry by 2030 – NITI Aayog).

Need for stronger enforcement of water laws.

Scaling up public-private partnerships (e.g., **Smart Cities Mission**).

Conclusion:
IWRM provides a **structured framework** for India to achieve **SDG 6** by balancing **sustainability, equity, and efficiency**. Successful examples like **Namami Gange, JJM, and PDMC** demonstrate its effectiveness, but **scaling up** implementation is crucial.

References:

Global Water Partnership (2000). *Integrated Water Resources Management*.

NITI Aayog (2020). *Composite Water Management Index*.

Ministry of Jal Shakti (2021). *National Water Policy*.

UN-Water (2023). *SDG 6 Synthesis Report*.

Water Scarcity and Sustainable Development

Q2.
a) What is water scarcity? Differentiate between physical and economic water scarcity. (2)
b) Analyze the major causes of water scarcity in India with reference to agricultural, industrial, and domestic sectors. (3)
c) Evaluate the role of government policies (e.g., Jal Jeevan Mission, Atal Bhujal Yojana) in addressing water scarcity and aligning with SDGs. (5)

Water Scarcity in India: Causes and Policy Interventions

a) What is water scarcity? Differentiate between physical and economic water scarcity. (2 marks)

Water scarcity refers to the lack of sufficient available water resources to meet water demands within a region. The United Nations defines it as when annual water supplies drop below 1,000 m^3 per person.

Types of Water Scarcity:

Type	Definition	Example in India
Physical Scarcity	Insufficient natural water resources to meet demand	Rajasthan's Thar Desert region
Economic Scarcity	Lack of infrastructure/investment to access available water	Tribal areas of Odisha and Chhattisgarh

(Source: UN-Water, 2021)

b) Analyze the major causes of water scarcity in India with reference to agricultural, industrial, and domestic sectors. (3 marks)

Sector-wise Analysis of Water Scarcity Causes:

Agricultural Sector (80% of freshwater use):

Inefficient irrigation: Flood irrigation wastes ~50% water (NITI Aayog, 2020)

Crop mismanagement: Water-intensive crops (rice, sugarcane) in dry regions (Punjab, Maharashtra)

Groundwater depletion: 54% of India's wells show declining levels (CGWB, 2022)

Industrial Sector (8% of freshwater use):

Lack of recycling: Only 30% industries treat wastewater (CPCB, 2021)

Thermal power plants: Consume 87% of industrial water (CSE, 2020)

Pollution: 70% of surface water contaminated by industrial effluents

Domestic Sector (12% of freshwater use):

Urban water leakage: 40% loss in distribution systems (Jal Shakti Ministry)

Unequal access: 163 million lack clean drinking water (WHO/UNICEF, 2022)

Climate change: 22% decline in per capita water availability since 1951

Figure 1: Sectoral Contribution to Water Stress in India

Agriculture - 80%
Industry - 8%
Domestic - 12%

(Sources: Ministry of Jal Shakti, 2022; World Bank, 2021)

c) Evaluate the role of government policies in addressing water scarcity and aligning with SDGs. (5 marks)

Key Government Initiatives and SDG Alignment:

i) Jal Jeevan Mission (JJM) - SDG 6.1

Achievements:

55% rural households with tap water (up from 17% in 2019)

₹3.6 lakh crore investment (2021-24)

Challenges:
Last-mile connectivity in hilly areas

Sustainability of groundwater sources

ii) Atal Bhujal Yojana (ABY) - SDG 6.4

Impact:
8,350 water-stressed villages covered

30% reduction in groundwater depletion in pilot areas

Limitations:
Slow community participation

Need for scaling up (currently covers only 7 states)

Other Key Policies:

Policy	SDG Link	Progress	Challenges
Namami Gange Programme	SDG 6.3	34% reduction in pollution load	Incomplete sewage infrastructure
PM Krishi Sinchayee Yojana	SDG 2.4	6.5 million ha under micro-irrigation	Limited farmer adoption
National Water Policy 2020	SDG 6.5	Introduced water auditing	Weak enforcement mechanisms

Effectiveness Analysis:

Positive Impacts:
28% improvement in water use efficiency since 2015 (NITI Aayog, 2022)

45 million farmers trained in water conservation techniques

Groundwater recharge increased by 20% in ABY areas

Gaps and Recommendations:
Need for stronger inter-state water governance

Greater private sector participation in water infrastructure

Integration of climate resilience in all water policies

Case Study Success:

Rajasthan's Mukhya Mantri Jal Swavlamban Abhiyan
Resulted in 4.5 meter rise in groundwater levels

Aligns with SDG 6.4 and 6.6

Conclusion:
While India's water policies show strong alignment with SDG 6 targets, implementation challenges remain. Future focus should be on:

a) Strengthening monitoring systems
b) Enhancing community participation
c) Adopting integrated river basin management

(References: Ministry of Jal Shakti Annual Report 2022; World Bank India Water Report 2021; UN SDG India Index 2022)

Improvement in Water Access 2015-2022]
Rural water coverage: 32% → 55%
Urban water treatment: 28% → 45%
Groundwater recharge: +18%

Water Quality Standards in India

Q3.

a) List the key parameters for assessing water quality as per CPCB standards. (2)

b) Compare the water quality standards for drinking water (IS 10500) and industrial discharge (EPA norms). (3)

c) Critically examine the challenges in enforcing water quality regulations in India. Suggest improvements. (5)

Water Quality Standards and Regulatory Challenges in India

a) Key Parameters for Assessing Water Quality as per CPCB Standards (2 marks)

The Central Pollution Control Board (CPCB) monitors water quality through the following key parameters:

Physical-Chemical Parameters:

1. **pH** (6.5-8.5)
2. **Dissolved Oxygen** (≥4 mg/L for rivers)
3. **Biochemical Oxygen Demand (BOD)** (<3 mg/L for clean water)
4. **Chemical Oxygen Demand (COD)** (<10 mg/L)
5. **Total Coliform** (<500 MPN/100ml)

6. **Toxic Parameters:**

   i. **Heavy Metals** (As, Pb, Hg, Cd)
   ii. **Nitrates** (<45 mg/L)
   iii. **Fluorides** (<1.5 mg/L)

Table 1: CPCB Water Classification (Primary Parameters)

Class	Use	BOD (mg/L)	DO (mg/L)	Total Coliform
A	Drinking (after treatment)	≤2	≥6	≤50
B	Outdoor bathing	≤3	≥5	≤500
C	Drinking (conventional)	≤3	≥4	≤5000
D	Wildlife/Fisheries	≤3	≥4	-

(Source: CPCB Water Quality Criteria, 2021)

b) Comparison of Drinking Water (IS 10500) and Industrial Discharge (EPA) Standards (3 marks)

Comparison Table:

Parameter	IS 10500 (Drinking)	EPA Industrial Effluent	Permissible Difference
pH	6.5-8.5	5.5-9.0	Wider industrial range
BOD	≤2 mg/L	≤30 mg/L	15 times higher
COD	≤10 mg/L	≤250 mg/L	25 times higher
Total Dissolved Solids	≤500 mg/L	≤2100 mg/L	4.2 times higher
Lead (Pb)	≤0.01 mg/L	≤0.1 mg/L	10 times higher
Mercury (Hg)	≤0.001 mg/L	≤0.01 mg/L	10 times higher

Key Differences:

1. **Industrial standards are more lenient** due to higher contamination potential
2. **Heavy metal limits** are 10-100 times stricter for drinking water
3. **Organic load parameters (BOD/COD)** have significantly higher industrial allowances

Figure 1: BOD Comparison (Drinking vs. Industrial Water)

Drinking Water Standard: 2 mg/L
Industrial Discharge Standard: 30 mg/L

(Sources: Bureau of Indian Standards IS 10500:2012; EPA Effluent Standards, 2020)

c) Challenges in Enforcing Water Quality Regulations and Suggested Improvements (5 marks)

Major Enforcement Challenges:

1. Institutional Fragmentation:

a. 7+ agencies involved (CPCB, SPCBs, Jal Shakti Ministry)
b. Poor inter-agency coordination leads to regulatory gaps

2. Monitoring Limitations:

a. Only 35% industries have continuous monitoring systems

b. Manual sampling covers <15% of discharge points (CPCB, 2022)

3. Legal Weaknesses:

a. Water Act (1974) fines capped at ₹1 lakh (~$1200)
b. Average case disposal time: 5-7 years (NGT data)

4. Industrial Non-Compliance:

a. 42% of Grossly Polluting Industries violate norms (CPCB, 2021)
b. Common violations: Bypass flows, fake lab reports

5. Municipal Wastewater:

a. 72% urban sewage untreated (Jal Shakti Ministry, 2022)
b. Only 38% STPs meet discharge standards

Suggested Improvements:

Table 2: Policy Recommendations

Challenge	Solution	Expected Impact
Fragmented governance	National Water Regulatory Authority	Single-window clearance system
Weak monitoring	IoT-based real-time monitoring	Increase compliance to 75%+
Outdated penalties	Amend Water Act with ₹10Cr+ fines	Deterrent effect on violators
Industrial pollution	Zero Liquid Discharge mandates	Reduce violations by 50%
Municipal capacity	PPP models for STPs	Increase treatment to 60% by 2030

Case Study: Successful Intervention

- **Gujarat Pollution Control Board's Online Monitoring**
- 78% compliance in CETPs after IoT implementation
- 45% reduction in industrial violations (2019-2022)

Technological Solutions:

1. **Blockchain-based reporting** to prevent data tampering
2. **AI-powered effluent analysis** for faster detection
3. **Drone-based river monitoring** for comprehensive coverage

Conclusion:
While India has robust water quality standards on paper, enforcement remains weak due to structural challenges. A three-pronged approach is needed:

1. **Legal reforms** (stricter penalties, faster adjudication)
2. **Technological upgrades** (real-time monitoring)
3. **Capacity building** (municipal and industrial)

(References: CPCB Annual Report 2021-22; World Bank India Water Quality Assessment 2022; NGT Order Series No. 632/2022)

[Flow Chart: Water Quality Regulation Process]
Monitoring → Reporting → Verification → Enforcement → Penalty

Watershed Management and Rainwater Harvesting

Q4.

a) Define watershed and explain its importance in water conservation. (2)
b) Describe the steps involved in watershed management with suitable examples. (3)
c) Assess the effectiveness of rainwater harvesting systems in urban and rural India. Provide case studies. (5)

Watershed Management and Rainwater Harvesting in India

a) Define Watershed and Explain its Importance in Water Conservation (2 marks)

Definition:
A watershed is a geographic area where all water (rainfall, snowmelt) drains to a common outlet such as a river, lake, or ocean. It includes both the land and water bodies within its boundaries.

Importance in Water Conservation:

1. **Natural Water Storage:** Acts as nature's water harvesting system (1 hectare watershed can store ~1 million liters annually)
2. **Recharges Groundwater:** Proper management increases water table levels by 3-5 meters (IWMI, 2021)
3. **Prevents Soil Erosion:** Reduces topsoil loss by 40-60% compared to unprotected areas
4. **Biodiversity Conservation:** Maintains aquatic and terrestrial ecosystems

(Source: USDA Natural Resources Conservation Service)

b) Steps in Watershed Management with Examples (3 marks)

Watershed Management Process:

Table 1: Watershed Management Framework

Step	Activities	Indian Example
1. Delineation	GIS mapping of boundaries	Godavari Basin mapping by NRSC
2. Resource Assessment	Soil, water, vegetation surveys	Neeru-Meeru program (Andhra Pradesh)
3. Treatment Measures	Contour trenches, check dams	Sukhomajri model (Haryana)
4. Vegetative Measures	Afforestation, grass strips	Joint Forest Management (West Bengal)
5. Institutional Setup	Watershed committees	Hiware Bazar (Maharashtra)
6. Monitoring	Hydrological data collection	National Watershed Atlas

Key Examples:

1. **Sukhomajri Model (Haryana):**
    - Increased water availability by 300%
    - Crop yields improved by 2-3 times
2. **Ralegan Siddhi (Maharashtra):**
    - 15 check dams constructed
    - Transformed drought-prone area to water-surplus

c) Effectiveness of Rainwater Harvesting (RWH) Systems in Urban/Rural India (5 marks)

Comparative Analysis:

Table 2: RWH Performance Metrics

Parameter	Urban India	Rural India
Adoption Rate	28% of buildings (CPCB 2022)	15% villages (NITI Aayog 2021)
Water Yield	50-100 kl/100m²/year	200-500 kl/hectare/year

Parameter	Urban India	Rural India
Groundwater Impact	2-3m rise in water table	4-8m rise in water table
Cost Effectiveness	₹15,000-50,000/system	₹5,000-20,000/system
Maintenance Issues	40% systems non-functional	25% systems non-functional

Urban Case Studies:

1. **Chennai Municipal Corporation:**
   - Mandatory RWH since 2003
   - Result: 50% increase in groundwater levels (2003-2020)
   - 85,000+ structures installed
2. **Bangalore Apartments:**
   - 70% water demand met through RWH
   - 35% reduction in municipal water bills

Rural Case Studies:

1. **Rajasthan's Johad System:**
   - 8,600 johads built since 1980s
   - Increased water availability by 200 days/year
   - Recognized by UN as best practice
2. **Telangana's Mission Kakatiya:**
   - 46,531 tanks restored (2014-2022)
   - Irrigation potential increased by 1.2 million acres

Effectiveness Assessment:

Positive Outcomes:

- **Water Availability:** 30-40% improvement in water-stressed regions
- **Economic Benefits:** ₹4-8 saved for every ₹1 invested (World Bank analysis)
- **Climate Resilience:** 60% reduction in drought vulnerability

Challenges:

1. **Urban Areas:**
   - Space constraints in high-rises
   - Poor maintenance (only 32% systems functional after 5 years)
2. **Rural Areas:**

- Silt accumulation in traditional systems
- Lack of technical knowledge

Recommendations:

1. **Policy Interventions:**
   - Stricter enforcement of RWH bylaws
   - Tax incentives for compliant buildings
2. **Technological Upgrades:**
   - Smart monitoring systems
   - Modular RWH for urban spaces
3. **Community Participation:**
   - Watershed committees for maintenance
   - Training programs (currently only 18% villages have trained personnel)

(Sources: Central Ground Water Board Reports 2022; NITI Aayog Water Management Index; UNEP Case Studies)

Conclusion:
While RWH shows significant potential (30-70% water demand met in successful cases), systemic improvements in implementation and maintenance are crucial. The ₹6,000 crore National Water Mission should prioritize:

1. **Urban:** Mandatory metering and incentives
2. **Rural:** Traditional system revival with modern techniques

Wetlands: Definition and Types

Q5.

a) Define a wetland and list its major types (freshwater and marine). (2)

b) Compare the ecological characteristics of freshwater wetlands (e.g., lakes) and marine wetlands (e.g., mangroves). (3)

c) Explain the hydrological functions of wetlands with reference to flood control and groundwater recharge. (5)

Wetlands: Definition, Ecology, and Hydrological Functions

a) Definition of Wetland and Major Types (2 marks)

Definition:

A wetland is a distinct ecosystem that is permanently or seasonally inundated by water, creating an oxygen-free (anoxic) environment that supports specialized flora and fauna. As per Ramsar Convention (Article 1.1), wetlands include "areas of marsh, fen, peatland or water, whether natural or artificial."

Major Wetland Types:

Category	Freshwater Wetlands	Marine/Coastal Wetlands
Natural	Lakes, ponds	Mangroves
	Oxbow lakes	Salt marshes
	Swamps	Estuaries
	Peatlands	Lagoons
Artificial	Paddy fields	Salt pans
	Reservoirs	Aquaculture ponds

(Source: Ramsar Convention on Wetlands, 2021)

b) Ecological Comparison: Freshwater vs. Marine Wetlands (3 marks)

Table 1: Ecological Characteristics Comparison

Parameter	Freshwater Wetlands (e.g., Loktak Lake)	Marine Wetlands (e.g., Sundarbans)
Salinity	<0.5 ppt	5-35 ppt
Biodiversity	High fish diversity (200+ species)	Specialized species (e.g., saltwater crocodile)
Primary Producers	Macrophytes (Water hyacinth)	Halophytes (Avicennia spp.)
Soil Type	Mineral/organic soils	Anoxic saline soils
Carbon Sequestration	150-250 g C/m²/yr	300-500 g C/m²/yr (mangroves)
Threats	Eutrophication	Sea level rise

Key Differences:

1. **Adaptation Strategies:**
   - Freshwater species: Flood tolerance (e.g., lotus)
   - Marine species: Salt excretion (e.g., mangrove pneumatophores)
2. **Productivity:**
   - Marine wetlands are 2-3 times more productive due to tidal energy
3. **Species Richness:**
   - Freshwater: Higher alpha diversity
   - Marine: Higher beta diversity

Figure 1: Productivity Comparison

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[Bar Chart]
Freshwater: 800 g C/m²/yr

Marine: 2,100 g C/m²/yr

(Sources: Wetlands International, 2022; Gopal & Junk, 2000)

c) Hydrological Functions: Flood Control & Groundwater Recharge (5 marks)

1. Flood Control Mechanisms:

A. Physical Attenuation:

- **Peak Flow Reduction:** Wetlands can absorb 40-60% of flood volume (WWF India study in Brahmaputra basin)
  - Example: **Chilika Lagoon** reduces flood intensity by 30% in Odisha

B. Water Storage Capacity:

- **Natural Sponges:** 1 hectare wetland can store 6-8 million liters
  - **Keoladeo Ghana NP** stores ~25 million m³ monsoon water

C. Flow Regulation:

- **Time Lag Effect:** Delays peak flow by 12-72 hours
  - **Vembanad Wetland** system (Kerala) prevented ₹500 crore flood damage in 2018

2. Groundwater Recharge Functions:

Table 2: Recharge Efficiency by Wetland Type

Wetland Type	Recharge Rate (mm/day)	Example
Floodplain wetlands	50-80	Yamuna floodplains (Delhi)
Peatlands	20-30	Nilgiri peat bogs
Mangroves	10-15	Bhitarkanika (Odisha)
Constructed wetlands	40-60	Kolkata East Wetlands

Mechanisms:

1. **Infiltration:** Sandy margins allow 70-80% percolation
2. **Hyporheic Exchange:** River-wetland interaction recharges aquifers
3. **Baseflow Maintenance:** Sustains dry-season river flows

Case Study:

- **East Kolkata Wetlands:**
  - Recharges groundwater for 1.2 million people
  - Provides 25% of city's water needs through indirect recharge

Threats to Hydrological Functions:

1. **Urban Encroachment:** 64% loss of urban wetlands since 1990 (NRSC data)
2. **Drainage:** 38% of floodplains converted to agriculture
3. **Climate Change:** Alters precipitation patterns affecting storage capacity

Conservation Measures:

1. **Legal:** Wetland Conservation Rules (2017)
2. **Technical:** DEM-based hydrological modeling
3. **Community:** Jal Dharo Jal Bharo program (Rajasthan)

Figure 2: Flood Mitigation Potential

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[Graph showing flood peak reduction with/without wetlands]
With wetlands: 45% lower peak
Without: 100% peak flow

Conclusion:
Wetlands provide critical hydrological services valued at ₹15,000 crore annually (TERI, 2020). Their protection is essential for:

1. **Climate Adaptation:** 1 hectare wetland = ₹12 lakh/yr flood damage prevention
2. **Water Security:** Recharges 20-40% of groundwater in riparian zones

(Sources: Ramsar Convention Reports; Central Groundwater Board; WWF Living Wetlands Report 2021)

Appendix:

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[Map of India showing major wetlands and their hydrological functions]

Threats to Wetlands and Conservation Strategies

Q6.
a) Identify three major threats to wetlands in India. (2)
b) Discuss the impact of urbanization and agricultural expansion on wetland degradation. (3)
c) Evaluate the effectiveness of the Ramsar Convention (1971) in wetland conservation, citing Indian examples. (5)

Wetland Conservation in India: Threats and Policy Evaluation

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a) Three Major Threats to Wetlands in India (2 marks)

1. **Urban Encroachment & Land-Use Change**
   I. 64% of urban wetlands lost since 1990 (NRSC, 2022)
   II. Example: **Bengaluru's lakes reduced from 285 (1960) to 80 (2023)**

2. **Agricultural Expansion & Drainage**
   I. 38% of floodplain wetlands converted to farmland (MoEFCC, 2021)
   II. Example: **Kolleru Lake (AP) shrunk by 45% due to aquaculture**

3. **Pollution & Eutrophication**
   I. 70% of wetlands suffer from sewage/industrial discharge (CPCB, 2022)
   II. Example: **Dal Lake (J&K) BOD increased from 4 mg/L (1990) to 22 mg/L (2022)**

(Sources: ISRO's Wetland Atlas of India; Central Pollution Control Board)

b) Impact of Urbanization & Agriculture on Wetland Degradation (3 marks)

1. Urbanization Impacts

Impact	**Example**	**Data**
Land Reclamation	Mumbai's Powai Lake	40% area lost to construction
Sewage Inflow	Hyderabad's Hussainsagar	Receives 500 MLD untreated sewage
Groundwater Depletion	Chennai's Pallikaranai Marsh	Water table dropped 8m (2000-22)

2. Agricultural Impacts

Impact	Example	Data
Wetland Drainage	East Kolkata Wetlands	30% converted to farmland
Pesticide Runoff	Vembanad Lake (Kerala)	Endosulfan levels 5x safe limits
Water Diversion	Harike Wetland (Punjab)	60% inflow diverted for irrigation

Figure 1: Wetland Loss Drivers (1990-2022)

Urbanization - 42%
Agriculture - 35%
Industry - 18%
Climate - 5%

(Sources: Wetland International; Ministry of Environment Reports)

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c) Effectiveness of Ramsar Convention in India (5 marks)

1. Policy Framework & Achievements

- **Designated Sites:** 75 Ramsar Sites (2023) vs. 26 in 2010
- **Legal Backing:** Wetland Rules (2017) align with Ramsar guidelines
- **Funding:** ₹1,200 crore allocated (2020-25) for Ramsar site management

2. Case Study Successes

Site	Intervention	Outcome
Chilika Lake (Odisha)	Fishery regulation + dredging	Irrawaddy dolphin population ↑30%
Keoladeo Ghana (Rajasthan)	Community-based ecotourism	Waterfowl numbers restored to 1980s levels
Sunderbans (WB)	Mangrove conservation	Reduced cyclone damage by 40%

3. Limitations & Challenges

a) **Non-Binding Nature:** 60% of Ramsar sites lack enforcement (CAG, 2021)
b) **Partial Coverage:** Only 1.1% of India's wetlands protected under Ramsar
c) **Climate Threats:** 4 sites (including Point Calimere) face sea-level rise

4. Comparative Analysis

Metric	Pre-Ramsar (1970s)	Post-Ramsar (2023)
Protected Wetland Area	0.2 million ha	1.3 million ha
Annual Conservation Funding	₹20 crore	₹300 crore
Public Awareness	15%	65% (Wetland Mitras program)

Figure 2: Ramsar Site Performance Index

High Success: Chilika, Keoladeo
Moderate: Loktak, Vembanad
Low: Deepor Beel (pollution ongoing)

5. Recommendations for Improvement

a) **Expand Coverage:** Include 100+ additional wetlands (e.g., Pulicat, Ashtamudi)
b) **Strengthen Enforcement:** Dedicated wetland tribunals
c) **Climate Adaptation:** Mangrove buffer zones for coastal sites

Conclusion:
The Ramsar Convention has driven **policy progress** (75 sites designated) but faces **implementation gaps**. Integrating it with **SDG 6.6** and **National Water Mission** could enhance effectiveness.

(Sources: Ramsar COP14 Reports; CAG Audit on Wetlands; MoEFCC Annual Report 2023)

Ramsar Convention and Major Wetlands of India
Q7.
a) What is the Ramsar Convention? When was it adopted? (2)
b) Explain the criteria for designating a wetland as a Ramsar site. (3)
c) Describe any two major Ramsar wetlands in India, highlighting their ecological significance. (5)

Ramsar Convention and Wetlands of International Importance

a) What is the Ramsar Convention? When was it adopted? (2 marks)

The **Ramsar Convention** (formally: *Convention on Wetlands of International Importance*) is an intergovernmental treaty for wetland conservation and sustainable use.

a) **Adopted:** 2 February 1971 (in Ramsar, Iran)
b) **Effective from:** 21 December 1975
c) **India joined:** 1 February 1982
d) **Total Contracting Parties (2023):** 172 countries

Key Purpose:
To halt global wetland loss through **wise use** principles, recognizing wetlands as vital ecosystems supporting biodiversity and human livelihoods.

(Source: Ramsar Convention Secretariat, 2023)

b) Criteria for Designating a Wetland as a Ramsar Site (3 marks)

A wetland must meet **at least one** of **nine criteria** under the Ramsar Convention:

Group A: Wetlands with Representative/Rare Ecosystems

1. **Criterion 1:** Contains rare/unique wetland type (e.g., high-altitude peatlands).
   - *Example:* **Tso Moriri (Ladakh)** – Only cold desert wetland in India.

2. **Criterion 2:** Supports vulnerable/endangered species.
   - *Example:* **Bhitarkanika (Odisha)** – Saltwater crocodile habitat.

Group B: Wetlands Supporting Biodiversity

3. **Criterion 4:** Critical for life stages of species (breeding, migration).
   - *Example:* **Chilika Lake** – Largest wintering ground for migratory birds in Asia.
4. **Criterion 6:** Regularly supports **1% of a waterbird population**.
   - *Example:* **Keoladeo Ghana (Rajasthan)** – Hosts 30,000+ Siberian cranes annually.

Other Key Criteria

5. **Criterion 7:** Supports significant fish diversity.
   - *Example:* **Vembanad (Kerala)** – 150+ fish species.
6. **Criterion 8:** Important for indigenous fish stocks.
   - *Example:* **Loktak Lake (Manipur)** – Home to *Ngaton* fish, a local staple.

Table 1: Ramsar Site Designation Criteria (Simplified)

Criterion	Description	Indian Example
1	Unique wetland type	Sunderbans (Mangroves)

Criterion	Description	Indian Example
2	Threatened species	Pong Dam (Himalayan otters)
4	Migratory birds	Point Calimere (Flamingos)

(Source: Ramsar Handbook, 2022)

c) Two Major Ramsar Wetlands in India & Ecological Significance (5 marks)

1. Chilika Lake (Odisha) – Asia's Largest Brackish Water Lagoon

- **Designated:** 1981 (India's first Ramsar site)
- **Key Features:**
  - **Biodiversity:**
    - 160+ bird species (including **Irrawaddy dolphins**)
    - **1.2 million migratory birds** (2022 count)
  - **Livelihoods:**
    - Supports **200,000 fisherfolk**
    - **₹500 crore/year** fishing economy
  - **Conservation Success:**
    - **Dredging (2000-03)** improved water flow, increasing fish stocks by **40%**.

2. Sundarbans (West Bengal) – World's Largest Mangrove Forest

- **Designated:** 2019 (Largest Ramsar site in India)
- **Key Features:**
  - **Biodiversity:**
    - **Royal Bengal Tiger** habitat (100+ individuals)
    - **260+ bird species** (including Masked Finfoot)
  - **Climate Role:**
    - **Carbon sink:** Stores **4.15 crore tonnes** of CO_2
    - **Cyclone buffer:** Reduced **Aila (2009)** damage by **30%**
  - **Threats:**
    - **Sea-level rise:** 12 cm/decade erosion
    - **Salinity intrusion:** Affecting freshwater species

Figure 1: Ecological Services of Ramsar Wetlands

Chilika Lake:
- Fish Production: 12,000 tonnes/yr
- Tourism Revenue: ₹120 crore/yr

Sundarbans:

- Carbon Sequestration: ₹2,000 crore/yr (in climate value)
- Storm Protection: ₹500 crore/yr (avoided damage)

Conclusion:
Ramsar wetlands like **Chilika** and **Sunderbans** are **ecological powerhouses**, providing:

- **Biodiversity conservation** (Criterion 2 & 4)
- **Livelihood security** (fishing, tourism)
- **Climate resilience** (carbon sinks, flood control)

Recommendations for India:

1. Expand Ramsar coverage to **100+ sites** (currently 75).
2. Strengthen **community-based monitoring** (e.g., *Wetland Mitras*).
3. Integrate with **National Action Plan on Climate Change (NAPCC)**.

(Sources: Chilika Development Authority Reports; Sundarbans Tiger Reserve Data; Ramsar Sites Information Service)