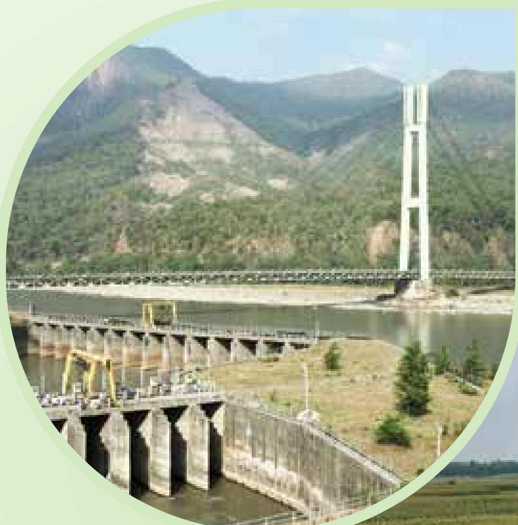
IRRIGATION MASTER PLAN 2019
(Updated 2024)



Government of Nepal
Ministry of Energy, Water Resources and Irrigation
Department of Water Resources and Irrigation

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Irrigation Master Plan 2019 (Updated 2024)

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Hon'ble Shakti Bahadur Basnet
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Government of Nepal

Ministry of Energy, Water Resources & Irrigation

Letter No.

Ref. No.

FOREWORD

It is my great pleasure to announce that we recently approved the Irrigation Mater Plan 2019 (updated 2024), which outlines the strategic vision aimed at transforming our agricultural landscape and prioritizing sustainable water management practices, reflecting the Government's commitment to enhance national food security and economic prosperity.

Agriculture and irrigation contribute significantly to the livelihoods of countless Nepali citizens and are considered at high national priorities. With this recognition, this Master Plan is designed to address the pressing challenges of water scarcity in agricultural land, and it is expected that the sector will be more productive and sustainable after the implementation of the plan. The plan is dedicated to converting all potential irrigable land into irrigated land through available technology, including multi-purpose diversion and reservoir projects, ground water irrigation projects, and lift and pumped irrigation technology. It is expected that these technologies and interventions will have a direct and positive impact on marginalized and small land holding farmers through reliable irrigation facilities and fostering an environment of growth and sustainability.

The successful implementation of this master plan requires a collective effort from all stakeholders, including federal government, provincial government, local government, local communities, private sectors, and other related stakeholders. I am confident that through collaborative efforts and sustained commitments, we will achieve our vision of a resilient and prosperous agricultural sector.

I extend my heartfelt appreciation to all those who have contributed to the formulation of this master plan. Your dedication and expertise have been invaluable in shaping a visionary and actionable documents that will guide our efforts in the years to come.

Together, let us move forward with unwavering determination and a shared sense of to realize the full potential of our agriculture and irrigation sectors, ensuring a future of abundance and sustainability for our nation.

Sincerely,

21/06/2024

Shakti Bahadur Basnet
Minister
Ministry of Energy, Water Resources and Irrigation

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Message

Agriculture sector engages more than 60 % of the workforce in Nepal, yet it contributes only around 24 % in total Gross Domestic Product. Agriculture trade deficit is widening and food production is not enough to cater to the needs of the country.

Nepal has 3.5 million hectare of agricultural land and 2.5 million hectare of land is potentially feasible for irrigation. In the last 3 decades, Government of Nepal, has taken the Integrated Development Approach by emphasizing on rehabilitation, modernization and improvement of Agency and Farmers Managed Irrigation Systems, development of groundwater and lift irrigation systems in participation of beneficiaries and stakeholders and development of large multipurpose surface irrigation systems. Along with the Government investment, Bilateral and multilateral development partners are also involved in irrigation development in the country. However, attainment of the objectives of total irrigation infrastructure development in remaining irrigable lands, reliable water supply, year round irrigation and sustainable production of food and other agricultural produce seems far with the current rate of progress. To achieve the country's objective of increasing production and productivity, first step is to transform all rainfed areas into irrigated areas and to ensure year round irrigation to all arable land. Similarly, as water is becoming a scarce commodity globally, water management strategies, equitable water distribution, efficient use of available water is imperative to ensure the sustainable utilization of the available resources. Similarly, effective holistic approach with involvement of all potential stakeholders is very much needed to achieve the overall national goal.

In this context, This Irrigation Master Plan 2019 (Updated 2024) of Nepal, introduces a 25-year action plan for the development of irrigation sector in the country to help attain broad sectorial goals of reliable water supply to increase production and productivity for overall sustainable economic development. This master plan presents the current status of irrigation development in the country and identifies the priority projects and programs to ensure timely and reliable water supply to all potential irrigable areas. This plan presents the future prospects of multipurpose surface water development projects, Groundwater projects, hill and mountain irrigation projects as well as required interventions needed for improvements in existing surface and Groundwater irrigation systems for attaining long term goals of the irrigation sector.

I thank and congratulate all the experts and officials involved in preparing this Master Plan and express my best wishes for the successful implementation of it.

Sarita Dawadi
Secretary

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Message from Director General

The importance of irrigation in agriculture is profound, with approximately 40% of global food production (including 60% of cereal production) originating from irrigated land, which constitutes just 20% of total cropland worldwide. Studies indicate that yields from irrigated agriculture can nearly double those from rain-fed systems, underscoring its critical role in ensuring food security. Beyond direct farm-level benefits, irrigation significantly impacts socio-economic sectors, particularly in developing countries where two-thirds of its benefits extend to non-farm segments, correlating with reduced poverty rates compared to rain-fed areas.

Nepal boasts a rich history of irrigation development, prominently featuring the Farmers Managed Irrigation System (FMIS), which predominates among surface irrigation methods. Government involvement in irrigation took a structured approach post-1923 with initiatives like the Chandra Canal, expanding to encompass large and medium-sized surface irrigation systems, groundwater schemes, and improvements in management and maintenance services.

A comprehensive land resource mapping update indicates Nepal possesses 3.5 million hectares of agricultural land, of which 2.5 million hectares are deemed feasible for irrigation. However, only 35% of this land receives year-round coverage, highlighting the need for extensive and intensive irrigation development to meet national food demands. The Irrigation Master Plan (IMP) envisions guiding irrigation planning and investments over the next 25 years, anticipating increased urbanization and heightened food requirements. Central to this vision is expanding irrigation facilities and ensuring year-round water access in irrigated areas to bolster food security.

The IMP outlines strategies such as multipurpose projects, inter-basin transfers, groundwater schemes, lift and pumping systems, and modernizing existing infrastructure to achieve its goals. Aligned with existing governmental laws, plans, policies, and regulations, the plan emphasizes periodic reviews to adapt to evolving development needs and incorporate implementation insights. Successful realization of the plan hinges on collaborative efforts involving government agencies, bilateral and multilateral partners, Water Users Associations, and other stakeholders.

Acknowledging the collective effort of consultants, experts, and water resources professionals, the Department of Water Resources and Irrigation expresses gratitude for their contributions to the IMP. It seeks continuous support from all stakeholders to ensure the plan's effective implementation and sustain its impact on Nepal's agricultural landscape and broader socio-economic fabric.

Sanjeeb Baral
Director General

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ABBREVIATIONS

ADS	Agriculture Development Strategy
AMIS	Agency-Managed Irrigation Systems
AMP	Asset Management Plan
CBO	Community Based Organization
CBS	Central Bureau of Statistics
CIP	Community Irrigation Project
CWR	Committee on Water Resources
DBFO	Design, Build, Finance and Operate
DC	Developed Country
DEM	Digital Elevation Model
DoLI	Department of Local Infrastructure
DoA	Department of Agriculture
DoS	Department of Survey
DoWRI	Department of Water Resources and Irrigation
DRM	Disaster Risk Management
DSR	Dry Seeded Rice
DTW	Deep Tube Well
FMIS	Farmer Managed Irrigation Systems
GCA	Gross Command Area
GIS	Geographical Information System
GoN	Government of Nepal
Ha	Hectare
HPP	Hydro Power Plant
IMP	Irrigation Master Plan
IMT	Irrigation Management Transfer
IP	Irrigation project

IRR	Internal Rate of Return
ISF	Irrigation Service Fee
IWRMP	Integrated Water Resource Management Project
JMIS	Joint Managed Irrigation Systems
km2	Square kilometer
LDC	Less Developed Country
LRM	Land Resource Mapping
LRMA	Land Resource Mapping and Assessment
MIIP	Mechanized Irrigation Innovation Project
MIP	Medium Irrigation Project
Mil.	Million
m3	Cubic meter
MoEWRI	Ministry of Energy, Water Resources and Irrigation
MOM	Management Operation and Maintenance
MPP	Multi-Purpose Project
NGO	Non-Governmental Organization
NPR	Nepalese Rupees
NPV	Net Present Value
NVP	Net Value of Production
NWP	National Water Plan
OFWM	On Farm Water Management
PPP	Public-Private Partnership
RBP	River Basin Plan
SIP	Small Irrigation Program
SRI	System of Rice Intensification
SWAT	Soil Water Assessment Tool
TOR	Terms of Reference

USD	United States Dollar
WECS	Water and Energy Commission Secretariat
WRS	Water Resource Strategy
WUA	Water Users' Association
WUC	Water Users' Committee

EXECUTIVE SUMMARY

1. The 'agriculture, forestry and fishing' sector in Nepal provides employment to more than 60% of the national labour force. Still it contributes only 24% to the economy. Only, about 40% of the total arable area is partially or fully irrigated. The growing population requires increased food production in a context of decreasing agricultural workforce in rural areas and increasing urbanization.

2. Surface and groundwater endowments offer high potentials for increased land and water productivities through improved irrigation service, particularly by modernizing the infrastructure coupled with improved water management methods.

3. This Irrigation Mater Plan lays out a Plan for optimum irrigation related investments in various agro-ecological locations for next 25 years by the Government. Nepal has a total of 3,557,764 ha of agricultural land, of which 2,536,319 ha is suitable for irrigation as presented in Table 1.

Table 1: Irrigation Suitability Area (Net ha)

Ecological Region	Agriculture	Irrigation suitability Area (Ha)		Total Suitability Area	IMP-1990
		Type S1-S3	Type S4		
Terai	1,592,504	1,495,939	3,237	1,499,176	1,338,000
Hills	1,564,133	187,068	649,549	836,617	368,000
Mountain	401,127	8,771	191,756	200,526	60,000
Total	**3,557,764**	**1,691,778**	**844,541**	**2,536,319**	**1,766,000**

4. This master plan has identified 5,673 surface and non-conventional irrigation systems with a combined command area of 941,472 ha that vary in terms of development stage, management mode, water source, agro-ecological zone and command area size. Out of the total area, 685,497 ha (73%) is in Terai, 205,195 ha (22%) in the hills, and 50,779 ha (5%) in the mountains. Thirty-two systems commanding about 400,618 ha, mostly in Terai, are jointly managed by the agency and the farmers. Systems managed by the farmer including non-conventional irrigation system account for 540,854 ha (57%) of the total command area under surface water irrigation systems. Terai accounts for 288,539 ha (31%) by area and 1,079 (20%) by number. They cover 252,315 ha (26.8%) of the command area in the hills and mountains as presented in Table 2.

Headworks, Bagmati Irrigation Project

Table 2: Irrigation Command areas under different Categories (Gross Ha)

Agro-ecological Zone	JMIS		FMIS		Non-Conventional		Total	
	Number	Area (ha)	Number	Area (ha)	Number	Area (ha)	Number	Area (ha)
Terai	27	396,958	890	285,292	189	3,247	1,106	685,497
Hill	5	3,660	3,012	194,326	637	7,209	3,654	205,195
Mountain	-	-	700	48,421	213	2,358	913	50,779
Total	**32**	**400,618**	**4,602**	**528,040**	**1,039**	**12,814**	**5673**	**941,472**

5. The groundwater irrigation system contributes to about one third of the total irrigated area. A total of 152,766 shallow tubewells and 1,278 deep tubewells have contributed to irrigate a total area of 493,830 ha as shown in Table 3.

Table 3: Irrigation Command Area under Ground Water (Gross ha)

Tubewell Types	Terai		Hills		Total	
	Number	Area	Number	Area	Number	Area
Shallow Tubewell	149,521	437,388	3,245	7,453	152,766	444,841
Deep Tubewell	1,250	48,489	28	500	1,278	48,989
Total	**150,771**	**485,877**	**3,273**	**7,953**	**154,044**	**493,830**

6. The cumulative total command area covered by irrigation infrastructure is about 1,435,302 ha, of which Terai covers about 81% of the total irrigated area as shown in Table 4. Similarly, the irrigated area in Hill and Mountains cover about 15% and 4% respectively.

Table 4: Total Area covered by Irrigation Infrastructure in Nepal (Gross ha)

S. No.	Ecological Region	JMIS	FMIS	Non-Conventional	GW-STW	GW-DTW	Total
1	Terai	396,958	285,292	3,247	437,388	48,489	1,171,374
2	Hill	3,660	194,326	7,209	7,453	500	213,148
3	Mountain		48,421	2,358			50,779
	Total	**400,618**	**528,040**	**12,814**	**444,841**	**48,989**	**1,435,302**

7. In the last thirty years, it is estimated that a total 12 large irrigation development projects were initiated at a total cost of more than USD 800 million with a combined irrigated area of about 570,000 ha. The average development cost is USD 1,000 per ha. Irrigation development initiatives included both bringing new agricultural lands under irrigation as well as improving irrigation services within existing command areas, i.e. extensive and intensive irrigation development.

8. Following on the footsteps of past experience and practices, continued partial or full irrigation management transfers are foreseen to remain an integral part of this irrigation master Plan. Typically, the process encompasses formation for water users' association, rehabilitation and improvement of canals and control structures, and capacity building and support to the association. The systems under the community management would continue receiving occasional financial and technical assistance, for their operation and maintenance, including for capacity building, from several government or non-government agencies, national and international.

9. Building on the past Plans, the short term investment strategy continues focussing on: (i) management improvements in existing irrigation systems, (ii) development of groundwater irrigation in Terai, (iii) development of small and medium surface irrigation projects (rehabilitation and new) in Terai, (iv) development of small surface irrigation projects (rehabilitation and new) in Hill and Mountain, and (v) development of large irrigation project in Terai districts, both as single and multi-purpose projects. The longer term strategy continues focussing on the broader objectives of: (i) increasing production and benefits through improved agricultural and irrigation management, (ii) improving irrigation efficiency through improvements in institutions and management transfer, (iii) development of small and medium irrigation projects, and (iv) implementation of new large projects in Terai.

10. The last irrigation master Plan developed irrigation in about 200,000 ha, an achievement by 34%. Various strategy and policy documents were also developed including Water Resources Strategy (2002), National Water Plan (2005), etc. An increased attention has been given to cope with climate change in the planning and management of the water resources and irrigation. For improved irrigation management, (i) management of several small projects covering 11,600 ha and 15,500 ha of Hill/Mountain and Terai respectively were transferred to Water User Groups; (ii) assistance was extended to various farmers' systems covering 50,000 ha and 140,000 ha in Hill/Mountain and Terai systems respectively; and (iii) many large projects were commenced.

11. Historically, expansion rate in irrigation area since 2000 to present has been only by about 40%, on average of about 3% and 30,000 ha per annum. To expand irrigation from the present 1.4 million ha to all suitable agricultural land during the period 2019-2044 would require an annual rate of expansion of about 50,000 ha per annum. Prevailing performances of irrigation systems indicate that improving irrigation service (adequate, timely and reliable irrigation) would need increased attention compared to expansion in command areas.

12. Existing legal and policy frameworks for water resources with amendments would continue guiding the development and management of water resources and irrigation. Additional legislative instruments would continue to develop encompassing water resources, irrigation, land use, groundwater, water-induced disaster, climate change adaptation, protection of biodiversity, environment conservation, river basin Planning and management, integrated and multi-purpose projects, allocation and protection of water entitlements, equitable water distribution, gender balance, water use conflict management, water tariffs and cost recovery, and protection of biodiversity and the environment.

13. The guiding principles of these legislations include those of Integrated Water Resource Management, river-basin management, public-private partnership, financial sustainability, sustainability of operation and maintenance of irrigation systems, sustainable groundwater use, watershed protection, climate change adaptation, etc. Synergy and coordination among natural resources related federal ministries, provincial and local governments, with clear roles and responsibilities, would need to be achieved.

14. Aligning itself with the Agriculture Development Strategy (2015-2035), this Plan conforms to the targets of average annual growth rate of 5% from the present 2.3% for the agricultural sector, increased land productivity to USD 5,000 per ha from the current USD 1,600, and reduced rural poverty from 27% to 10% by the year 2035.

15. In line with the new constitution, irrigation sector envisages a framework that separately engages all three tiers of government in Planning, execution, and monitoring irrigation related activities. This would require organizational and legislative adaptation along with restructuring as required. To make it possible, several important laws and policies have been introduced, and more to be formulated or refined, including for revenue generation and resource allocation. This also calls for substantial capacity development, specifically at province and local government levels.

16. According to the constitution, federal government would manage international treaties or agreements, extradition, mutual legal assistance, international borders, and trans-boundary Rivers and would make policies relating to conservation and multiple uses of water resources, based on river basin planning concepts encompassing multi-purpose storage reservoirs, water allocation, licensing, and river management with navigation and non-consumptive uses. Additionally, the federal level government would oversee the 'large' projects, projects extending beyond one province, and projects of national pride. The provincial government would look after the 'medium' projects. All 'small' projects will fall under the jurisdiction of local government. Provincial governments will look after irrigation projects covering geographic areas of the province exclusively and also coordinate irrigation projects covering more than one local government's jurisdiction. Nevertheless, mechanisms are needed to enable both local governments and provincial governments to coordinate on inter-provincial and inter-local governmental projects.

17. The master plan highlights the need of establishment of River Basin Offices in different river basins to implement the River Basin Plan which is under preparation by Water and Energy Commission Secretariat for optimum utilisation of the available water resources in the country.

18. For sustainable irrigation management and to reduce the burden of operation and management cost to the government, the master plan proposes Irrigation service fee to be collected by respective levels of the government, or by the water users association in management transferred systems, upon verification of the service rendered. Requests for various supports solicited by the irrigation schemes from the local/provincial/federal governments may be tied to the irrigation service fee collection efficiency.

19. The estimated annual surface water volume is 172,900 Mm3 (80% reliable flow) and the annual groundwater volume is estimated at 13,215 Mm3 as presented in Table 5, which

could irrigate 6.9 million ha, way more than the potential irrigable land at 2.5 million ha. Unfortunately, the dry season potential of available surface water is only 0.75 million ha, less than the available irrigable potential. To achieve the full potential, storage dams are required, or the use of groundwater is to be mobilised.

Table 5: Water Resource Assessment

Basin	Karnali	Narayani	Koshi	Total
Surface Water Resources (Mm^3)	60,000	57,600	55,300	172,900
Ground Water Resources (Mm^3)	3,368	2,864	6,983	13,215

20. Key approaches considered in this plan focus on increasing year-round irrigation across the country, particularly in Terai and to develop new irrigated areas in the remaining potential irrigable areas. These include (i) Rehabilitation and modernisation of existing infrastructure with the objective of management transfer to user groups, provincial and local government agencies and, where appropriate, to the private sector (ii) development of new gravity systems, and non-conventional irrigation through electric and solar pumping wherever suitable in hills and mountains (iii) Development of groundwater irrigation systems in Terai and valleys (iv) Development of large scale multi-purpose and inter-basin transfer projects In this context significantly increased investments are planned for inter-basin transfers, groundwater development. Development of groundwater has been given priority over the development of surface water alone, except in multi-purpose projects. During the economic analysis it was seen that Terai offers the highest likely returns to irrigation investment, followed by western and eastern hills, and the mountain, being the lowest.

21. National goals for the irrigation subsector include: (i) near full (90%) development of irrigable lands, (ii) increasing cropping intensity to 200% or more, (iii) full management transfer (of agency managed systems), (iv) increasing system efficiency to more than 50%, and (v) increasing irrigation service fee collection to 75%. This plan modifies the targets for improving cropping intensities from the present of 132% to 182% by 2025, 205% in 2030 and finally reach 230% in 2045. It includes (i) intensification of existing irrigated lands (approx. 0.99 million ha), with increased cropping intensities, modernised infrastructure, improved operation and management; and (ii) expansion of irrigated lands (approx. 1.275 million ha) through the development of both surface water and groundwater, and on-farm development.

22. The plan aims to provide irrigation in 100% of all Terai irrigable lands, 1.499 million ha. In Hills and Mountains, 566,000 ha has been identified for further development either by pumping or gravity-fed. At the end of the period of this Master plan (year 2044), there will be still 271,500 million ha unirrigated. The details of existing irrigated area and irrigation development option is presented in Table 6.

Table 6: Development Option

SN	Land Use (ha)	*Terai*	Hill	Mountain	Total
A. Existing Agriculture land and Potential Irrigable Land (net ha)					
1	Total Agriculture Land	1,592,504	1,564,133	401,127	3,557,764
2	Potentially Irrigable Land	1,499,176	836,617	200,526	2,536,319
B. Existing Irrigated Land (Gross)					
1	Surface Water system	682,250	197,986	48,422	928,658
2	Non-Conventional System	3,247	7,209	2,358	12,814
3	Groundwater Irrigation	485,877	7,953		493,830
Total		1,171,374	213,148	50,780	1,435,302
C. Existing Irrigated Land (Net)					
1	Surface Water system	511,688	148,490	36,317	696,494
2	Non-Conventional System	2,435	5,407	1,769	9,611
3	Groundwater Irrigation	364,408	5,965		370,373
Total		878,531	159,861	38,085	1,076,477
D. Development Option (Net)					
1	Improved Surface Water supply (Existing Systems)	341,500			341,500
2	Modernization of Surface Irrigation System (Existing Systems)	170,000	156,000	38,250	364,250
3	Modernization of Groundwater Irrigation System (Existing Systems)	278,500	6,000		284,500
4	Surface Water Supply from on-going large irrigation systems (on-going construction)	86,000			86,000
5	New Surface Water Supply (New construction)	305,000			305,000
6	New Groundwater Supply (New construction)	318,000			318,000
7	Gravity in Hill/Mountain (New construction)		33,700	64,400	98,100
8	Pump/Tank/ Solar in Hill/ Mountain (New construction)		387,900	80,000	467,900
Total		**1,499,000**	**583,600**	**182,650**	**2,265,250**
Remaining Unirrigated			**253,400**	**18,350**	**271,750**
Total Irrigable Area		**1,499,000**	**837,000**	**201,000**	**2,537,000**

23. Several multi-purpose large surface water projects have been identified and assessed, namely: Bheri-Babai Diversion Multipurpose Project; Karnali Diversion Project; Madi-Dang Diversion Project; Naumure Dam: Rapti-Kapilbastu Diversion Project; Kaligandaki-Tinau Diversion Project; Kaligandaki Nawalparasi Diversion Project; Trishuli Shaktikhor Diversion Project; Sunkoshi Diversion Project; Tamor Morang Diversion Project; Kankai Multipurpose Project; Chatara Barrage Project; Seti-Pandul Diversion Project; Seti Diversion project; etc. Seven priority project have been recommended for implementation and the total command area for all projects is about 855,000 ha, of which about 405,000 ha are under existing surface water irrigation systems and 305,000 ha is regarded as new irrigation. The maximum potentially coverable area by these projects would be about 705,000 ha. However, not all projects are economically feasible, and the proposed priority projects cover only 305,000 ha.

24. The proposed priority projects, in sequence of their relative rankings, are: (i)Tamor Morang 2 (Chisang); (ii) Sunkoshi Marin & Sunkoshi Kamala SunKoshi 3 HPP; (iii) Kaligandaki-Tinau Rupandehi 2, Andikola; (iv) Naumure Dam, Rapti; (v) Kapilbastu Diversion; (vi) Karnali Transfer to Kailali Irrigation; (vii) Bheri-Babai Transfer + Nalsingad Dam; and (viii) Chatara Barrage as listed in Table 6. The total estimated capital investment for these major priority projects is USD 9,823 million over the 25-year period. The selected projects for implementation are presented in Table 7.

Table 7: Selected Projects for Implementation

Sce-nario	Projects	Score	NPV (M NPV)	IRR (%)	New Ir-rigation Area (ha)	Rehab Irriga-tion Areas	Irrigation & HP Cost (M NPR/ ha)
E6	Tamor Morang 2 (Chisang)	113	120,963	14.3%	43,743	70,000	889.3
E4	Sunkoshi Marin & Sunkoshi Kamala SunKoshi 3 HPP	108	182,652	15.3%	171,500	169,889	2875.7
C2	Kaligandaki-Tinau transfer for full irrigation in Rupandehi 2, Andikola	88	151,100	16.5%	0	52,455	981.2
W6	Naumure Dam, Rapti Kapilbastu Diversion	59	36,550	11.4%	36,030	15,226	625.3
W4	Karnali Transfer to Kailali Irrigation	50	30,952	13.8%	32,996	7,632	644.1
W2	Bheri-Babai Transfer + Nalsingad Dam	48	41,974	16.7%	2,644	42,467	505.9
E8	Chatara Barrage	45	3,308	10.6%	18,489	47,993	279.9

25. An alternative to multi-purpose projects and large-scale surface irrigation schemes, is groundwater development.

26. For improving the irrigation service level, the plan proposes to rehabilitate about 50% of the existing farmer systems and partial or full management transfer of all agency-managed surface systems at an estimated cost of about USD 1,069 million. The plan further proposes to promote land levelling of individual's lands in irrigation systems together with support for land consolidation and infrastructure development for water augmentation and asset management planning.

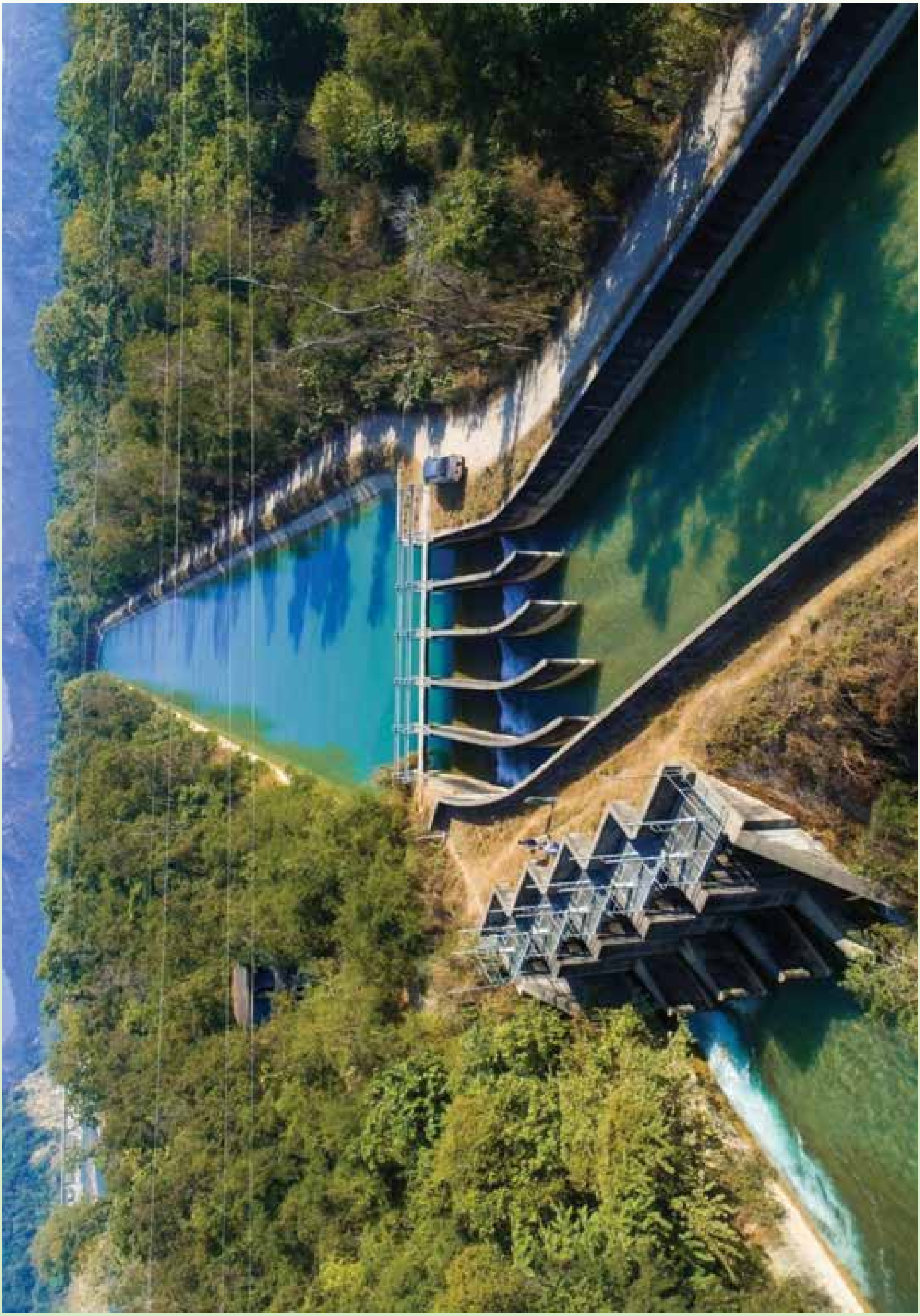
27. Research and development, including technology adaptation, would form an integral part of the Plan covering four priority areas: irrigation and agriculture practices; construction technology, irrigation management, social development in irrigation, and water resources and watershed management.

28. Over 25 years, the estimated capital cost for a total of 318,000 ha groundwater projects is USD 997 million as presented in Table 8. The same for projects proposed in hills and mountains is USD 1,583 million; for program related to irrigation management and modernisation USD 1,069 million; for projects related to multi-purpose and diversion will require USD 9823 million; giving a total outlay of USD 13,472 million. Based on estimated incremental change in cropped area required between 2019 and 2024, and between 2025 and 2029, about 558,500 ha and 538,500 ha will be developed respectively. Similarly, by 2044 from 2030, the total area covered will be 994,500 ha.

Table 8: Irrigation Development Plan

S. No.	Projects	Short Term (2019-24)		Medium Term (2025-29)		Long Term (2030-44)	
		Area (ha)	Cost (USD Mil)	Area (ha)	Cost (USD Mil)	Area (ha)	Cost (USD Mil)
1.	Multipurpose and Reservoir Projects	215,000	1,145	248,500	2,282	248,000	6,396
2.	Groundwater and Pumping	80,000	249	138,000	343	140,000	405
3.	Hill Gravity and Pumping	111,500	401			454,500	1,182
4.	Irrigation Management Modernisation and Rehabilitation	152,000	222.7	152,000	222.7	152,000	623.5
Term Total		**558,500**	**2,018**	**538,500**	**2,848**	**994,500**	**8,607**

29. Finally, this Plan covers a 25-year span with multiple national projects costing billions of dollars. To maximise the benefits, a comprehensive monitoring and evaluation Plan has been proposed together with annual reporting on performance indicators such as: modernised area, efficiency, cropping intensity, equity, land and water productivity and management funding.



Headworks, Babai Irrigation Project

SECTION I: BACKGROUND

1.1 Preamble

1. The 'agriculture, forestry and fishing' sector in Nepal provides direct or indirect employment to more than 60% of the national labour force. Still it contributes only 24% to the GDP[1]. Only, about 40% of the total arable area is partially (seasonally) or fully (round-the-year) irrigated.

2. With a population growth rate of about 1%[2] in 2021, Nepal; already an increasingly food importing country despite all the agricultural potentials; is facing further increases in future food demands.

3. Urban to rural migration rate ratio of 4.7[3] shows an additional constraint of decreasing agricultural workforce in primarily agrarian rural areas. Moreover, peri-urban agricultural lands are increasingly being developed for non-agricultural purposes.

4. With ample water endowments, both surface and groundwater, irrigated agriculture has considerable potentials for improved irrigation service and expansion.

5. While irrigation development has helped increase the cropping intensity, incremental crop yields in irrigated areas have been far less than envisioned. There is much scope for improving land and water productivities of the irrigation system particularly by modernizing the infrastructure coupled with improved water management methods.

6. Moreover, continued changes in food consumption pattern and preferences require diversified and compatible agricultural production systems equipped with improved irrigation services in expanded command areas[4].

7. Nepal's agricultural sector has performed poorly over the past two decades and has been unable to meet the increasing and ever diversifying food requirements.

8. Optimum irrigation related investments in suitable agro-ecological locations linked to the much needed market chains have been missing.

9. Accordingly, this IMP lays out an investment Plan for next 25 years that will guide the irrigation related development and management initiatives by the three tiers of the Government.

10. This IMP builds up on the Irrigation Master Plan of 1990, which has been guiding the planning and implementation of development and management of the irrigation subsector over the past 30 years.

[1]https://cbs.gov.np/national-accounts-statistics-of-nepal-2022-23-annual-estimates/

[2]https://censusnepal.cbs.gov.np/results/population

[3]https://censusnepal.cbs.gov.np/results/downloads/national

[4]The area which can be irrigated from a scheme and is fit for cultivation.

1.2 Milestones of Irrigation Master Plan 1990

11. The 1990 Master Plan, developed under the then national policy and strategy, had the following three principal objectives at its core:

- To provide a long-term strategy for the development of the irrigation subsector that is consistent with the availability of resources and with the development policies of Nepal.
- To develop shorter term investment programs that are consistent with the long-term strategy, based on the identification and ranking of investment opportunities, and an assessment of urgent needs and implementation capabilities.
- To provide a sound database and planning methodology, to facilitate regular updating of the Master Plan.

12. It has been followed by several subsidiary documents outlined below:

- **Water Resources Strategy (WRS) (2002):**[5] This strategy set out a framework for water resources development in Nepal, including irrigation. Its Output 4 titled *'Appropriate and Efficient Irrigation Available to Support Optimal, Sustainable Use of Irrigated Land'* listed various challenges faced by the subsector and a series of corresponding measures, including improvement of system management, crop intensification and diversification, capacity strengthening for Planning and management, development of new irrigation systems and improved groundwater development and management.
- **National Water Plan (NWP) (2005):**[6] It aimed to *'operationalize the outputs of the WRS'*. It covered the whole water sector, including irrigation subsector over the period up to 2027. The outcome related to irrigation stated as *'irrigation systems planned, developed and continued for sustainable management, reliable irrigation service expanded on the basis of sustainability and wealth creation, and appropriate and efficient irrigation available for the optimal use of irrigable land in a sustainable way'*. The Plan listed targets for improvement and expansion of irrigated lands, cropping intensity, irrigation efficiency and irrigated crop yields.
- **Irrigation Policy (2013):**[7] The policy document provided the rationale for subsector development; policy objectives; approach for project development, water user associations, irrigation service charges; and irrigation system operation and maintenance.
- **Sustainable Development Goals 2016-2030 (NPC 2015):** It emphasized the envisioned growth in per capita Gross National Income, improvements in human assets and reduction in economic vulnerability so as to raise Nepal's status of Less Developed Country (LDC) to Developed Country by 2030.

[5] Water Resource Strategy, 2002. Water and Energy Commission Secretariat, Kathmandu
[6] National Water Plan, 2005. Water and Energy Commission Secretariat, Kathmandu
[7] Irrigation Policy, 2060 (BS). Water and Energy Commission Secretariat, Kathmandu

- **Irrigation Policy (2023):** The policy provisions for the establishment of an appropriate authority to manage the resources associated with the multi-purpose project. Similarly, the policy emphasis on the development of ground water and lift irrigation technology along with effective design and implementation of MOM guideline with volumetric water availability.

1.2.1 Existing irrigation systems

13. In this IMP, information of various irrigation systems was evaluated and the classification and the present status of various irrigation systems are summarized in the following Table 9. The total irrigated area in the country is about 1,435,302 ha.

Table 9: Present Status of Irrigation Coverage in Nepal (Gross ha)

Irrigation System		Agro-ecological Zone			
		Terai	Hill	Moun-tain	Total
Farmers Managed Irrigation System	Number	890	3,012	700	4,602
	Area (ha)	285,292	194,326	48,421	528,040
Agency Managed Irrigation System	Number	27	5	-	32
	Area (ha)	396,958	3,660	-	400,618
Non-Conventional	Number	189	637	213	1,039
	Area (ha)	3,247	7,209	2,358	12,814
STW	Number	149,521	3,245	-	152,766
	Area (ha)	437,388	7,453	-	444,841
DTW	Number	1,250	28	-	1,278
	Area (ha)	48,489	500	-	48,989
Total	**Number**	**151,877**	**6,927**	**913**	**159,717**
	Area (ha)	**1,171,374**	**213,148**	**50,779**	**1,435,302**

14. Grouped into three agro-ecological zones (Terai, Hill and Mountain), an inventory of systems compiled during this IMP preparation indicates that there are 5673 irrigation systems with a combined command area of about 941,472 ha as presented in Table 10. The inventory consists of 32 AMIS, 4602 FMIS and 1039 non-conventional irrigation systems.

15. Since the 1980s, Nepal followed a worldwide trend for full or partial irrigation management transfer to water user communities. The rationale behind it has been that the community participation in irrigation management will lead to improved and sustained system performance and agricultural productivity.

Table 10: Status of Surface Irrigation Systems (Gross ha)

Irrigation System		Agro-ecological Zone			Size of Command Area				Development Stage					Total
		Terai	Hill	Moun-tain	Major	Large	Medium	Small	Com-pleted or Oper-ational	Par-tially Com-pleted	Under Con-struc-tion	Defunct or not Com-pleted	No Data	
FMIS	Number	890	3,012	700	39	81	2,501	1,981	2,932	4	133	458	1,075	4,602
	Area (ha)	285,292	194,326	48,721	82,070	58,070	340,392	47,508	337,165	547	22,192	62,982	105,154	528,040
AMIS	Number	27	5	-	22	8	2	-	32	-	-	-	-	32
	Area (ha)	396,958	3,660	-	378,112	21,736	770	-	400,618	-	-	-	-	400,618
Non-Con-ven-tional	Number	189	637	213	-	-	-	1,039	1,039	-	-	-	-	1,039
	Area (ha)	3,247	7,209	2,358	-	-	-	12,814	12,814	-	-	-	-	12,814
Total	**Number**	**1,106**	**3,654**	**913**	**61**	**89**	**2,503**	**3,020**	**4,003**	**4**	**133**	**458**	**1,075**	**5,673**
	Area (ha)	**685,497**	**205,195**	**50,779**	**460,182**	**79,806**	**341,162**	**60,322**	**750,597**	**547**	**22,192**	**62,982**	**105,154**	**941,472**

16. Agency Managed Irrigation Systems (AMISs) have been developed and are being managed by the government agency (federal or provincial levels). Jointly Managed Irrigation Systems (JMISs) have been developed by the agency but its management has been partially handed over to the beneficiary community. Farmer Managed Irrigation Systems (FMISs) have been developed and are being managed by the beneficiary community. These systems are generally smaller, and have been primarily developed by the farmers themselves, with or without the agency's support, as per the community needs with their indigenous knowledge and management techniques. These indigenous knowledge and management techniques is the distinguishing characteristics of irrigation development and management in Nepal. Community cooperation and participation therefore are well established in management of these systems.

17. Table 11 summarizes the present coverage of surface water and Non-Conventional irrigation systems by agro-ecological zones and management modes. There are a total of about 5673 systems with a combined command area of nearly 941,472 ha, of which 685,500 ha (73%) is in Terai, 205195 ha (22%) in hills, and 50779 ha (5%) in mountains. Thirty two systems jointly managed by the agency and the farmer command about 400,618 ha, mostly in Terai. Systems managed by the farmer account for 540,854 ha (57%) of the total command area under surface water irrigation systems. Terai accounts for 288539 ha (31%) by area and 1079 (20%) by number. They cover 252,315 ha (26.8%) of the command area in the hills and mountains.

Table 11: Irrigation Command areas under different Categories (Gross ha)

Agro-ecological Zone	JMIS	FMIS	Non- Conven-tional	Total
Terai	396,958	285,292	3,247	685,497
Hill	3,660	194,326	7,209	205,195
Mountain	-	48,421	2,358	50,779
Total	**400,618**	**528,040**	**12,814**	**941,472**

18. AMIS and JMIS are generally medium to large scale systems[8] with relatively large infrastructures, often equipped with barrages and large main canals that require higher levels of capital investments. They are usually beyond the capacity of local communities to operate and maintain on their own. They also require technically more complex O&M activities, serving a large number of socially diverse water users.

[8]By prevailing policy, 'large' means systems that command above 5,000 ha in terai; 100 ha in hills; and 50 ha in mountains; 'medium' means systems that command in between 200-5,000 ha in terai; and 50-100 ha in hills; and 25-50 ha in mountains. The rest are considered 'small'.

19. Over the past thirty years, 12 large irrigation development projects were initiated at a total cost of more than USD 800 Million with a combined irrigated area of about 570,000 ha. These projects included construction of large structures, main canal development, infrastructure rehabilitation, command area development and Irrigation Management Transfer both in agency- and farmer-managed irrigation systems. The average cost per unit area for all these 12 projects came about USD 1,000 per ha ranging from USD 300 to 4,440 per ha. The investments principally focused on developing relatively large infrastructures.

20. Investments in such large projects have often been mobilized by bi-lateral and multi-lateral development partners. The general approach has been to start with the development of the intake and main canals, followed by progressive development of branch and secondary canals and expansion of the command areas.

21. The AMISs were primarily developed in the interests of national food sufficiency and poverty reduction. The government's commitment to development of irrigation projects goes back to over 100 years and since the 1980s there has been considerable investments in this subsector. The systems are generally of medium to large scales mostly in Terai. Several smaller scale systems have also been developed in Hills. These initiatives included both bringing new agricultural lands under irrigation as well as improving irrigation services within existing command areas, i.e. extensive and intensive irrigation development.

22. Ownership and O&M of the intake and main canal system constructed by the agency remain under agency. In large projects, there is typically a project office with project director and technical and administrative staff. Canals are operated by local staff. The tertiary system and beyond are left to the community to manage with sporadic support of the agency for repairs and maintenance. In such systems, due to the system scale and technical complexity, the agency has a longer term commitment to system O&M.

23. The JMISs have primarily been developed by the agency itself which have been or are in the process of being transferred to water user associations. The IMT and WUA formation have been integral part of the on-going subsector development over the past thirty years. Typically, the process includes WUA formation, rehabilitation and improvement of canals and control structures, and capacity building and support to WUAs.

24. The level of joint management varies between systems dependent on the size and the transfer processes. For relatively larger systems, the agency typically retains the management of the intake and large canals, main and branch, and the community, via WUAs and WUGs, are responsible for managing secondary and tertiary canals. For the smaller scale systems, the ultimate intent of IMT is full management transfer to the community.

25. Table 12 below lists various irrigation systems developed solely by the government agencies at federal or provincial levels. They are operated and maintained by Government with partial involvement of the WUAs and are termed as Agency managed irrigation systems (AMISs). Thirty three such systems command about 420,618 ha out of which thirty two systems are under surface irrigation and one system as Ground water.

Table 12: Agency Managed Irrigation Systems Developed by the DoWRI

S. No.	District	System Name	GCA (ha)	NCA (ha)	Ecological Region	Water Source
1	Jhapa	Kankai IP	10216	8000	Terai	SW
2	Sunsari, Morang	Sunsari-Morang IP	68000	57800	Terai	SW
3	Sunsari	Chanda Mohana IP	2362	1800	Terai	SW
4	Saptari	Chandra Canal IP	13593	10500	Terai	SW
5	Saptari	Koshi West Canal IP	14298	11000	Terai	SW
6	Saptari	Pump Canal IP	15230	11000	Terai	SW
7	Dhanusha, Siraha	Kamala IP	25000	25000	Terai	SW
8	Dhanusha	Hardinath IP	2769	2000	Terai	SW
9	Sarlahi	Manusmara first IP	2828	2200	Terai	SW
10	Sarlahi	Manusmara Second IP	3912	3000	Terai	SW
11	Sarlahi, Rautahat	Bagmati IP	57438	45600	Terai	SW
12	Rautahat	Jhanjh IP	6386	2000	Terai	SW
13	Bara, Parsa	Narayani IP	37411	28700	Terai	SW
14	Chitawan	Narayani Lift IP	5937	4700	Terai	SW
15	Nawalparasi West	Nepal Gandak IP	14112	10300	Terai	SW
16	Rupandehi	Marchawar Lift IP	3500	3500	Terai	SW
17	Kapilbastu	Banganga IP	10734	6200	Terai	SW
18	Banke	Sikta IP	2000	1800	Terai	SW
19	Bardiya	Babai IP	35421	29500	Terai	SW
20	Bardiya	Raja Pur IP	17140	13000	Terai	SW
21	Kailali	Ranijamara IP	15889	14300	Terai	SW
22	Kanchanpur	Mahakali Phase-I IP	5520	4800	Terai	SW
23	Kanchanpur	Mahakali Phase-II IP	8500	6800	Terai	SW
24	Chitawan	Khageri IP	6116	5199	Terai	SW
25	Kaski	Bijaypur IP	1280	838	Hill	SW
26	Kaski	Begnas IP	580	501	Hill	SW
27	Kaski	Seti Project IP	1030	1030	Hill	SW
28	Kaski	Phewa Tal IP	330	320	Hill	SW

29	Parbat	Phalebas IP	440	340	Hill	SW
30	Dang	Pragnna IP	6092	5178	Terai	SW
31	Kailali	Mohana IP	3194	2000	Terai	SW
32	Kailali	Pathraiya IP	3360	2000	Terai	SW
33	Rupandehi	Bhairahawa Lumbini GWP	20000	20000	Terai	GW
Total			**420618**	**340905**		

26. The FMISs generally are surface water irrigation systems developed and managed by the beneficiary farming community. The vast majority of these systems (by number) are farmer managed and often been in existence for many generations and as such form an essential part of the local infrastructure to sustain household food production.

27. They are generally in the Hill zone, small scale systems constructed with local materials and labour and operated and maintained with farmer contributions in kind and labour. However, they periodically receive assistance particularly for rehabilitation and capital works from government agencies notably the DoWRI and DOLI as part of regular support programs or specific development projects such as the SIP, CIP and MIP.

28. The FMISs are widely reported as performing better than AMISs[9] in terms of land water productivities, adequate and equitable water deliveries, and physical sustainability. The reasons being related to better adherence to system O&M rules in these FMISs which in turn results in better system performance. The better adherence to rules reflects a higher level of mutual trust, better rule enforcement at lower cost than those in AMISs[10].

29. With a focus on sustainable agricultural practice in marginal farmers with small land holding and area where surface and groundwater irrigation are not feasible, non-conventional irrigation systems such as tank, pond and reservoir having pipe distribution system with drips and sprinkler has been installed. A total of 1,039 systems were installed covering 12,814 ha and hills and mountains accounting of about 80% of the systems. These systems are developed by agency and handed over to WUA for management.

30. In addition to the community developed surface water systems there are also a large area of irrigated lands supplied from groundwater (mostly from shallow tube wells), which are owned and operated by farmers or local communities. These wells are predominately in Terai and used for irrigation where there is no surface water supply or where the surface water supply is seasonally inadequate. Pumping and distribution systems are often portable and rented according to demand and needs. Table 13 below lists the total area irrigated by Ground Water irrigation systems.

[9] Lam, W. F. 1998. Governing irrigation systems in Nepal: Institutions, infrastructure and collective action. ICS Press Oakland.
[10] Regmi, A. R. 2007. Water Security and Farmer Managed Irrigation Systems of Nepal. Paper presented at the Nepal Water Security Forum, Uppsala, Sweden.

Table 13: Irrigation Command Area under Ground Water

Tubewell Types	Terai		Hills		Total	
	Number	Area (ha)	Number	Area (ha)	Number	Area (ha)
Shallow Tubewell	149,521	437,388	3,245	7,453	152,766	444,841
Deep Tubewell	1,250	48,489	28	500	1,278	48,989

31. In addition, it is estimated that there are about 12,000 small systems with a combined command area of up to 150,000 ha. These systems are under the management of local community or WUAs. They occasionally receive financial and technical assistance, for their operation and maintenance, including for capacity building, from several government or non-government agencies, national and international.

1.2.2 Irrigation Master Plan 2019 (Updated 2024)

32. This proposed master plan builds up on the previous Irrigation Master Plan published in 1990 (IMP-1990). The goals and objectives have been reformulated within the context of fulfilment of national objectives of food production and national food self-sufficiency as well as the emerging ground realities previously described under section 1.1.

33. The IMP-1990 proposed a short term investment program focused on five areas: (i) management improvements in existing irrigation projects, (ii) development of groundwater irrigation in Terai districts, (iii) development of small and medium surface irrigation projects (rehabilitation and new) in Terai districts, (iv) development small surface irrigation projects (rehabilitation and new) in Hill and Mountain districts, and (v) development of large irrigation project in Terai districts, both as single and multi-purpose projects. The program set out potential intervention areas and levels of investments in respective areas.

34. For the large projects in Terai, it specifically cited seven single projects with a combined command area of more than 115,000 ha, including: Bagmati (37,000 ha), Sikta (36,070 ha), and Babai (13,500 ha). The targeted command area under additional seven multi-purpose projects was more than 570,000 ha, which included Karnali (173,950 ha), Bagmati (120,000 ha) and Sun Koshi-Kamala (175,100 ha).

35. While the short term program largely focused on irrigation development, the longer term strategy focused on the broader objectives of: (i) increasing production and benefits through improved agricultural and irrigation management, (ii) improving irrigation efficiency through improvements in institutions and management transfer, (iii) development of small and medium irrigation projects, and (iv) implementation of new large projects in Terai (in addition to those identified under the short term program).

36. While IMP-1990 provided a broad foundation for planning for the subsector particularly in 1990s, it is now over 30 years old. It is estimated that various projects launched during this period have developed irrigation in about 176,000 ha.

37. There have also been significant policy developments in the planning and management of water resources which include the adoption Water Resources Strategy (2002) and

National Water Plan (2005). The National Water Plan goals included an increase in irrigated land (by about 30% by 2027) and expanding the area with year-round irrigation from 38% to 67% of irrigable land, and improving the cropping intensity from 140% to 193%. In addition, from late 1990s an increased attention has been given to cope with climate change in the planning and management of the water resources and irrigation.

38. For improved irrigation management, (i) management of several DoWRI's small projects covering 11,600 ha and 15,500 ha of Hill/Mountain and Terai respectively were transferred to Water User Groups; (ii) assistance was extended to various FMISs covering 50,000 ha and 140,000 ha in Hill/Mountain and Terai systems respectively; and (iii) many DoWRI's large projects in Terai were significantly enhanced.

1.3 Food Self-sufficiency Scenario

39. Nepal is at the risk of food crisis[11]. According to the government data, in the fiscal year, 2078-79 BS, the annual food production in the country was 10.772 million metric tonnes, which was around 7,530,000 metric tonnes by deducing the seeds, livestock preservation and post-harvest loss.

40. According to the 15th five-year Plan in Nepal, 21% population in Nepal has still no access to sufficient food. It says that only 48.2% of the households are basically food secure.

41. The data shows the quantity of food reserve is approximately 1,663,000 metric tons. Despite the food reserve at the national and household level, around 21% still face the situation wherein they are forced to limit their daily calorie intake below the requirements.

42. Further, as per Nepal's constitution, the Right to Food and Food Sovereignty Act, 2075 (2018) has been promulgated by the government. It emphasizes on fundamental rights relating to food, food security and food sovereignty of the citizens.

43. Given this demographic and economic context it is possible to quantify present agricultural productivity and specify what productivity changes will be needed to meet these imminent demographic and economic challenges.

44. The development of scenarios of national food consumption informs analysis of the present and future performance of national irrigation systems by placing upper and lower boundaries on the expectations for their productivity. There are three elements to scenario planning:

- The rate of change of population and urbanization
- The degree to which the national food deficit can be managed
- The change in the demand for food and the quantity demanded

[11] https://www.ngofederation.org/content/439

45. The CBS has estimated median total population of 33.7 Million by 2031, with a possibility of deviation by +/- 1.7%. Similarly, expected change in urban population has been estimated to be by about 9.97 Million in 2031 (CBS). The UN estimates this to be about 8.2 Million in 2031. Thus, urbanization is likely to be more pressing challenge compared to population growth by 2031.

46. The estimated increase in per capita food demand in 2031, without considering likely dietary changes, is moderate. Nonetheless, owing to the Right to Food and Food Sovereignty Act, 2075 (2018), the prevalent and upcoming deficit between total food consumption and domestically produced food consumption will need to come from increased production and productivity.

47. Based on district data, Table 14 below summarizes a projected trend of changes in yields in Nepal during 2014 to 2043.

Table 14: Projected trend of crop yields in Nepal: 2014/15 - 2043

Crop	2014/15 Reported yields, kg/ha	2031 Projected yields, kg/ha	2043 Projected yields, kg/ha
Rice	3,394	3,840	3,903
Wheat	2,496	2,834	2,855
Maize	2,412	2,588	2,588
other cereals	1,126	1,107	1,128
Roots	13,696	13,872	13,907
Cane	43,142	40,415	43,037
Pulses	987	950	1,017
Oilseeds	839	842	841
Vegetables	13,419	13,466	13,742
Fruit	6,874	7,172	7,314

48. An accelerated expansion of the cultivable command areas with improved irrigation service is necessary to eliminate the gap between domestic food production and demand.

49. Historically, expansion rate in irrigation area since 2000 to present has been only by about 40%, on average of about 3% and 30,000 ha per annum. To expand irrigation from the present 1.4 Million ha to all suitable land in the present agricultural area (i.e. to 2.5 Million ha) during the period 2018-2031 would require an annual rate of expansion of about 72,000 ha per annum; a faster rate.

50. Past performances of irrigation systems suggest that improving irrigation service (adequate, timely and reliable irrigation) has been a greater challenge than accelerated expansion in command areas and related constructions. Consequently, the prevailing cropping intensity of 180%, on irrigated land has barely increased, if not declined, over the last 15 years. The cropping intensities are generally decided by the farmers themselves and are closely linked to the level of irrigation service. Hence, there is little possibility for much gains to be made through improving cropping intensity.

Spring Paddy, Rajapur Irrigation System

1.4 Policy and Institutional Landscape

1.4.1 National and Sectoral policies

51. The existing legal and policy frameworks for water resources generally guide this sector/sub-sector. Related instruments have consistently given a high importance to the development of water resources and irrigation in Nepal.

52. Below is a list (not necessarily exhaustive) of some important legislations and regulations being implemented over past years in Nepal in the area of water resources and irrigation.

- Water Resources Act, 1992 (2049) and Water Resources Regulations, 1993
- National Water Resources Strategy, 2002
- Irrigation Regulations, 2003
- National Water Plan, 2005
- Water Supply Act(s): Water Supply Management Board Act, 2006; the Water Supply Tariff Fixation Commission Act, 2006; and the Nepal Water Supply Corporation Act (Amendment), 2007
- Irrigation Policy, 2013, 2023
- Water-induced Disaster Management Policy, 2015
- Disaster Risk Reduction and Management Act, 2017
- National Water Resource Policy 2019
- River and Water-induced Disaster Management Policy, 2023

53. Several more legislative instruments are under development, which encompass water resources, irrigation, agriculture, land use, groundwater, water-induced disaster, climate change adaptation, protection of biodiversity, environment conservation, river basin planning and management, integrated and multi-purpose projects, allocation and protection of water entitlements, equitable water distribution, water use conflict management, water tariffs and cost recovery, and protection of biodiversity and the environment.

54. The guiding principles of these legislations include those of Integrated water resource management, river-basin management, public-private partnership, collection of irrigation service fees, sustainable of operation and maintenance of irrigation, sustainable groundwater use, watershed protection, climate change adaptation and others.

55. The pressing need for synergy and coordination among natural resources related federal ministries, provincial and local governments, with clear roles and responsibilities cannot be overemphasized.

1.4.2 Aligning IMP 2019 (updated 2024) with sectoral policies and Plans

56. Despite all the potentials for increasing agricultural productions and productivities, agricultural trade deficit has been continually growing every year owing to higher imports of agro-based products. The import of cereals during the first six months in fiscal year 2021-22 (mid-July 2021 to mid-January 2022) reached NPR 42.7 billion, up from NPR 41.7 billion during the same period a year ago[12]. Cereal exports, on the other hand, have been miserably low. The export value of cereals in 2020-21 was NPR 5.4 Million, down from NPR 17 Million in 2019-20.

57. The CBS estimates the annual growth in agrarian sector to be 2.3% in 2021/22[13]. There are opportunities both in export and domestic markets. With increases in productions and productivities, Nepal has potentials for import substitution in cereals, vegetables, fruits, beverages, diary and meat.

58. Agriculture development has been a priority of the GoN through its different policies, Plans and programmes in different time periods. These include Agriculture Perspective Plan (APP 1995-2015), National Agriculture Policy-2004, Nepal Agricultural Extension Strategy 2007, Agriculture Development Strategy (ADS 2015-2035), Fourteenth Plan (2016/17-2018/19), The Prime Minster Agriculture Modernisation Project (PMAMP) and others.

59. Despite all the planned development efforts, and the majority of farmers remaining engaged in the agriculture sector, there is still a dominance of traditional and subsistence agriculture and the country's agricultural production is not enough to feed its population. The continued rise in import bills and volume of food products in recent years has been a major challenge for the country.

60. Agriculture Development Strategy (2015-2035) is a long-term strategy of the agricultural sector with twenty years vision and ten years action Plan and strategy focusing on governance, productivity, profitable commercialization and competitiveness. The vision has been stated as self-reliant, sustainable, competitive and inclusive agriculture sector that contributes to economic growth, improved livelihood, and food and nutrition security. It emphasizes on promoting self-sufficiency in food grains and import substitution in a number of commodities where the country has potential for growth.

61. To enhance the agricultural productivity, it stresses on: (i) effective agricultural research and extension; (ii) efficient use of agricultural inputs; (iii) efficient and sustainable practices and use of natural resources (land, water, soils, and forests); and (iv) increased resilience to climate change and disasters.

[12] The Kathmandu Post (2022), Padma Singh, Widening agriculture trade deficit

[13] https://www.nrb.org.np/contents/uploads/2022/08/Current-Macroeconomic-and-Financial-Situation-English-Based-on-Annual-data-of-2021.22-2.pdf

62. It also stresses on the need for "profitable commercialization" through transforming agricultural sector and emphasizes on strengthening the capacity of various service providers (including technical, financial, insurance, and business) along with improvement of physical and institutional infrastructure to promote commercial agriculture (agricultural roads, storage facility and market information system).

63. It has targeted for average annual growth rate of 5% from the present about 2.3% for the agricultural sector, increased land productivity to USD 5,000 per ha from the current USD 1,600 and reduced rural poverty from 27% to 10% by the year 2035. Realizing the importance of irrigation for commercial agriculture, it counts on increasing round-the-year irrigation coverage areas to 80% from the current 18%.

64. One critical limitation to rural and agricultural development in Nepal is the inadequate knowledge and skills in the farmers in terms of modern methods, technologies, farm planning and effective decision. Agricultural research institutions and agricultural extension services are poorly equipped to address it. New methods and technologies are available for increasing food productions and productivities, but limited availability of inputs, credit, and markets have constrained full exploitation of potentials by agricultural producers. Likewise, the focus of research is primarily on production aspects; post-harvest research, including on the value chain, is almost non-existent.

65. Nepal has pluralistic extension services. In addition to DoA, many NGOs and CBOs offer education and training to farmers. However, the existing public agricultural extension system has been inadequate to fulfil the emerging needs of the farmers for diversified technologies, marketing and agri-business, natural resource management, and farm mechanization. Agricultural research and extension services are not linked well.

1.4.3 Rural Poverty

66. Census data indicate that poverty in Nepal has declined by almost one third since 1995. Yet, it still has its 15.1% population below poverty line (earning less than USD 5.5 a day)[14]. A majority of them live in rural areas. This is an improvement from 2018/19 when 17.4 per cent of the population was below the poverty line. 28% of the population in rural areas are experiencing multidimensional poverty. In urban areas, that ratio is low, where 12.3% of the population face multidimensional poverty.

67. Major contributing factors for the decline in poverty include: growth in agricultural sector and rise in farm income, increase in remittance, greater access to rural finance and increase in micro finance institutions, creation of small-scale business and employment, increase in access to facilities such as roads, education, health and markets.

[14] Economic Survey 2022/23, Ministry of Finance, Government of Nepal

68. Poverty in rural areas has been closely linked to low productivity in agriculture sector, lack of access to productive assets, infrastructure, energy, land and water, technical and financial services are the major causes of rural poverty.

1.4.4 Gender

69. Women play an important role in agriculture. Women's participation in agricultural labour force in Nepal has been increasing owing to male migration for work abroad. Higher out-migration of men from rural areas of Nepal have not only severely increased the burden on women but has also increased the feminization of agriculture. Despite women's increasing role in agriculture, traditional social norms and laws that are biased in favour of men act as barriers to women's equitable access to productive resources. Women's access to extension services is also limited due to an inadequate number of women extension workers. Similarly, women have limited access to institutional credit and other production inputs.

70. Most extension workers under DoA are male. Extension services have reached both male and female farmers. There also exist female only farmers' groups. However, improved extension services for women farmers are much needed by ensuring their meaningful participation in the agriculture value chain and by training rural women as extension workers.

1.4.5 Environment and Climate Change

71. Nepal is highly vulnerable to climate change including variability and extreme weather events due to its geographic location, fragile ecosystems, and weak socioeconomic and institutional context. The main environmental challenges in Nepal are (i) freshwater resource depletion and deterioration of water quality and quantity (ii) desertification and erosion; and (iii) climate change. Because the majority of the rural population depends on agriculture for their livelihood, the risks of climate change for the agricultural sector are significant, and the smallholders will be the most exposed to the impacts of climate change, due to the inadequate livelihood assets such as land and livestock, low incomes, low levels of education, and limited access to community and government services. Their higher reliance on rainfed agriculture, limited employment options, possession of lands that are more prone to floods, drought and landslides make them much vulnerable.

72. Adaptation measures to climate-related threats include: controlled and efficient water use; enhanced irrigation/optimized agronomic inputs; improved farm practices; and enhanced capacity of farmers to cope with the adversities of climate change.

73. Nepal is committed to ensuring protections to ecology of surface water systems, including rivers and streams. Regulations on environmental flow requirements must be adhered to along with other prioritized water uses. Projects using surface waters from rivers must leave the minimum ecological flows in stream before water withdrawal or diversion.

74. The Aquatic Animal Protection Act (AAPA 1961 and First Amendment 1998) makes a provision of minimum 5% of yearly minimum flow as environmental flow. Enforcement of this act has remained virtually a defunct due to lack of related bylaws, regulations and enforcement.

75. Nepal Hydropower Development Policy (2001) also has reserved 10% of the minimum monthly average discharge of the river/stream as the environmental flow.

1.4.6 Alignment with the New Constitution

76. The new Constitution of Nepal provides both exclusive and concurrent authorities in its Schedules 5 to 9. The regulatory and institutional mechanisms established in related sectors prior to this constitution, including water resource and irrigation, need to adapt further, both organizationally and legislatively.

77. Accordingly, irrigation sector envisages a framework that separately engages all three tiers of government in planning, execution, and monitoring irrigation related activities. This requires organizational and legislative adaptation, including restructuring where required, at all those three levels of the government.

78. To make it possible, several important laws and policies have been introduced, and many are being formulated. The Inter-Government Financial Management Act 2017 has provided a legislative and regulatory framework for assigning authorities to three tiers of government in matters relating to budgeting, revenue generation, resource allocation and financial management. The Local Government Operation Act 2017, National Natural Resource and Financial Commission Act 2017 and Financial Appropriation Act 2018 do make broad provisions, particularly for annual budgeting, at various government levels in their respective jurisdictions, including for irrigation and water-induced disaster risk reduction. However, several aspects related to revenue generation and resource allocation still need further refinement and fine-tuning.

79. The GoN has recently approved Water Resource Policy, which has further supplement the existing Water Resource Strategy 2002 and National Water Plan 2005. The policy has provided a broader policy framework for utilizing and managing all water resources by adopting an integrated river basin management approach. Yet another, Water Resources and Irrigation Act is under development to guide the federated and decentralized governance model enshrined in the new constitution.

80. While the national policies and federal laws are still evolving, the National Planning Commission has recently set new standards based on size of irrigation projects for adjudicating respective roles and functions related to design, construction, operation and maintenance by three tiers of governments. Accordingly, the federal level government would oversee the 'large' projects, projects stretching extending beyond one province, and projects of national pride. The provincial government would look after the 'medium' projects. All 'small' projects will fall under the jurisdiction of local government. Provincial governments will look after irrigation projects covering geographic areas of the province exclusively and also coordinate irrigation projects covering more than one local government's jurisdiction. Nevertheless, provisions are also made, enabling both local governments and provincial governments to coordinate on inter-provincial and inter-local government projects by developing necessary mechanisms.

81. In response to the needs of federalization of public administration in the country, the GoN has restructured the administrative organizations at all three levels of government, though

provincial and local level governments can make necessary revisions in the centrally designed federal administrative structure for them as per their specific needs. Accordingly, for dealing with the irrigation related functions, there is the MoEWRI at federal level, which is an integrated organization of the then two ministries dealing with energy and irrigation. Likewise, the Water and Energy Commission (WEC) and its Secretariat continue to exist from earlier unitary set-up to extend technical support to the government on the policy matters relating to water resources and energy. Both the above are undergoing restructuring and strengthening processes.

82. The MoEWRI, effective from 16 July 2018, consists of 7 divisions as seen in Figure 1, along with two secretariats (dealing with water resource and energy separately - each led by a secretary) to extend technical support to policy functions at federal level. Its Water Resource Division looks after irrigation matters.

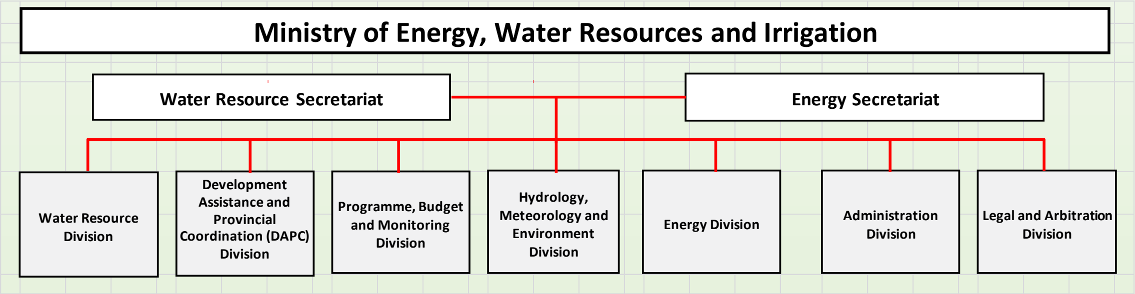


Figure 1: Ministry of Energy, Water Resources and irrigation

83. Under the MoEWRI, there are three departments, i.e., Department of Water Resources and Irrigation (DoWRI), Department of Hydrology and Meteorology (DHM) and Department of Electricity Development (DoED). The elaborated organization structure of DoWRI, which integrates the then Department of Irrigation with the then Department of Water Induced Disaster Prevention, is presented in Figure 2, also indicating its five technical divisions departmental functions and jurisdictions.

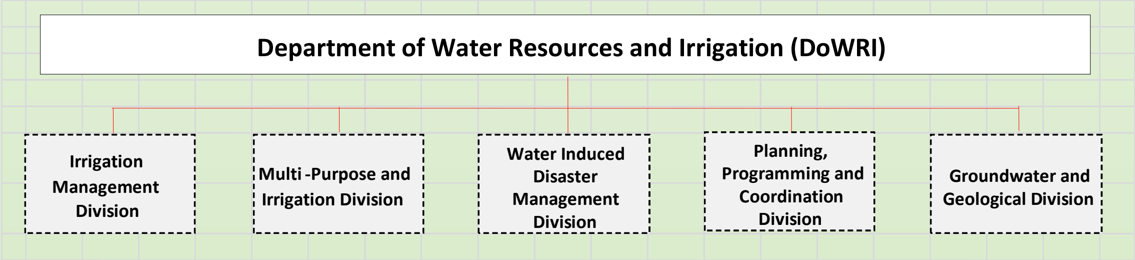


Figure 2: Department of Water Resources and Irrigation

84. At the province level, the Ministry of Physical Infrastructure Development (MoPID) carries out varied functions of physical infrastructure development relating to road, urban development and water resource through its three divisions. The irrigation-related

matters are looked after by the energy and water resources division. Moreover, a number of district offices, divisions, or field offices of the federal government, which earlier carried out infrastructure related functions (including irrigation) in certain geographic areas, have recently been handed over as technical wings to this ministry in each province. Many provincial government has restructured the MoPID and water resources and irrigation ministry has been introduced as a separate entity. At local level, the urban municipality has physical infrastructure development division while the rural municipality has a separate physical infrastructure development section; both of which look after irrigation sector among others.

85. Though the Constitution provides broader authority to each of the three new government levels with regard to the roles and responsibilities in each sub-sector, including in revenue generation, a pressing need for further clarity and synergy have been realized[15].

86. The transfer of responsibilities and duties also obviously calls for substantial capacity development, specifically at province and local government levels, not only for the irrigation sector, but much broadly.

1.4.6.1 Federal Responsibilities

87. The following is a brief overview of the roles and responsibilities related to irrigation and other relevant functional areas like water resource, water use, disaster management, watershed protection, local services, etc., which are assigned to different levels of government under federal structure. This provides a basis for initiating required institutional arrangements, including policy, legal and organizational provisions, for an effective implementation of IMP in the federalized context of the country.

Treaties or agreements related to international boundary rivers

88. The Constitution provides the federal government with the authority and obligation to manage international treaties or agreements, extradition, mutual legal assistance, international borders, and trans-boundary Rivers.

89. This is presently managed through the Nepal-India Joint Committee on Water Resources (JCWR) and the Water and Energy Commission Secretariat, as the national custodian of the water resources. Within the Law and Management Division, a specific Treaty and Agreement Section has been proposed to deal with these international trans-boundary matters.

[15] For example, the disaster management is indicated as authority (or responsibility) at all three levels, inducing risks of being done by none or cause counterproductive overlaps and competitions. Different functions relating to road, irrigation, water supply, sewerage, energy, urban development etc., which are recently transferred to the newly created the MoPID at province level, remain yet to be carried out smoothly for various reasons. Observations on operation of a few provincial governments indicate that implementation wings under the MoPID are still non-existent due to unclear functions, delayed transfer of technical wings from the federal government, causing underutilization of allocated capital expenditure funds.

Policies relating to conservation and multiple uses of water resources

90. The Constitution mandates the federal government to make policies relating to conservation and multiple uses of water resources. Such multiple or inter-sectoral use (and conservation) is to be managed based on River Basin Planning (RBP). It refers to the planning and management of water resources by taking into account the competition and conflicts for water among irrigated agriculture, hydropower, domestic water supply and sanitation, industry and so on. Integrated Planning in this sense triggers initiatives as constructing multi-purpose storage reservoirs and other projects, water allocation and licensing systems, and river management with the view of navigation and other non-consumptive uses.

91. The responsibility for RBP in Nepal has been vested with WECS, which will promote and advance River Basin Planning concepts to optimize water use benefits and minimize conflicts by coordinating with relevant line ministries and departments to implement the concept of IWRM. This will be done through the establishment of River Basin Offices (RBOs) in different major river systems. These RBOs will work closely with the relevant Government institutions implementing water resource development and utilization projects including DoWRI and the technical wings at province and local level.

Large scale and cross-province irrigation development and management

92. Large-scale, technically complex, and cross-province irrigation projects will be planned, designed, implemented and possibly also eventually managed by technically qualified entities/divisions at federal level. The Multi-Purpose and Irrigation Division and the Planning, Programming and Coordination Division – both within DoWRI – will have pivotal roles in the development of large-scale irrigation projects.

93. The large irrigation development and cross province irrigation projects, planned to be implemented by DoWRI, need to be implemented in line with the river basin planning concepts. A frequent communication and participation of the provincial administration will need to be observed in case of cross province irrigation development projects.

1.4.6.2 Provincial and Concurrent Responsibilities

94. The administration in the new seven provinces has been established with varying number of ministries, including the MoPID in each province, with a provision of divisions to look after roads, housing and urban development, energy and water resources, including irrigation and water-induced disaster. The development Plans for the use of water resources within each province will however still need to be in compliance with the overall river basin Plans regarding water availability, allocations, and the prioritised investment Plans, as per the agreed upon decision criteria.[16]

[16]It can be anticipated that the RBPs based on multi-criteria analysis and a decision matrix would guide the government to a set up various utility functions for relative ranking of various investment options or a combination.

Shared water resources

95. The management of cross-province Rivers, meaning rivers spreading over more than one province or river basin needs to be a joint effort by WECS, RBOs and province administration. The scope of management also includes waterways, environmental protection, and biological diversity, which nonetheless needs to be co-ordinated with the Ministry of Forest and Environment at federal level, and designated relevant officials in province and local government administrations.

Preparedness (floods and other water-induced disasters)

96. The Water Induced Disaster Management Division (the previous Department of Water Induced Disaster Management) will have a pivotal and lead role in vulnerability assessment, water induced disaster prevention and control, landslide management and control, as well as steering the emergency flood control, landslide control, rehabilitation of the damaged irrigation and flood control structures, post water-induced natural calamities. This responsibility for preparedness, rehabilitation, resettlement, flood fighting will be supported by several other institutions and divisions at federal level.

97. When implementing disaster reduction and/or mitigation measures, the province (and local level) government staff need to be involved, as this also will include community awareness about disaster management including preparedness, post-event Planning and management of rehabilitation and rebuilding efforts, and resettlement, where the local participation is invaluable.

1.4.6.3 Local Responsibilities

Management of water resources in general

98. The approach to river basin planning will ensure the local governments' participation to effectively identify and Plan for the development needs, including their urgency and priority at each level. The stakeholder consultations will include public institutions, private sector operators, civil society organizations, local communities, political parties, advocacy groups, media and relevant academicians, and researchers.

99. In case of competing and mutually exclusive alternative initiatives or measures, the guiding principles of IWRM and river basin Planning and management set by WECS need to be followed.

Management of local and provincial irrigation services

100. The Constitution authorises the local/provincial government to fully manage, operate and maintain infrastructure, mobilize needed resources including irrigation service fees, within their respective jurisdictions.

101. In case of management transferred irrigation schemes, all of these functions are to be assumed by the respective WUA.

102. The WUA may liaison with the local/provincial government and other stakeholders for occasional supports as provisioned in the prevailing irrigation policies of the local/provincial government.

Local taxes and irrigation service fees

103. The Constitution also authorises the local government to collect local taxes such as wealth tax, house rent tax, land and building taxes, registration fee, motor vehicle tax and also service fees, including for irrigation. This will be appropriated when and if the service levels of local governments can be established and such taxation can be justified.

104. In view to achieve improved irrigation service level to farmers, increased water and land productivities, enhanced water use efficiency, and higher returns to investments, requests for various supports solicited by the irrigation schemes from the local/provincial/federal governments should be tied to the irrigation service fee collection efficiency (collection/assessment).

Protection of local watersheds

105. Managing and protecting local watersheds in a sustainable manner, is of utmost significance to the local governments. The federal and provincial administration may guide the local governments on this, but the local governments will lead and assume the responsibility for watershed management, conservation and protection of soil and water, managing competing use of limited resources, conflict resolution, forest management, and implementing various protection measures.

106. There needs to be a close alignment of the watershed development activities between the local government "technical" staff involved in water resource management and agricultural services – possible the same person. Support from provincial ministerial staff will be desirable.

1.4.7 Organizational arrangements

107. The proposed IMP will require suitable organizational arrangements, besides policy and legal arrangements, to achieve its goals by getting all planned projects and activities, both on-going and new ones, executed effectively and efficiently. These organizational arrangements are to be made compatible with both federal mode of governance and policy and legal arrangements, along with underlying principles, as suggested above.

108. According to Water Resource Policy (2019) and Irrigation Policy (2023), some generic forms of organizations are suggested below. These are based on the envisaged goals, approaches and projects/activities to be undertaken as part of IMP, federalised governance structure of three tiers of government, and the types of irrigation projects and activities expected to be performed at different levels.

1.4.7.1 Organizational arrangements at federal level

109. The existing MoEWRI need to strengthen its existing organizational set-up (wing or division) to lead, coordinate and monitor irrigation sub-sector in line with emerging national policies and standards and to ensure close functional linkages with other sectors/sub-sectors like agriculture, soil conservation, watershed conservation, water-induced disaster management and climate change adaptation.

110. DoWRI's organizational set-up (divisions/sections) needs go through internal periodic reviews to coordinate execution of multi-purpose, large irrigation, and national pride projects as well as those related to water induced disaster management. Its roles and responsibilities in designing, constructing and executing such projects need to be bolstered.

111. DoWRI will require to set-up one office in each province to monitor water resource and irrigation related activities. They will need to ensure implementing their activities based on respective river basin plan in close coordination with River-basin offices being envisaged under WECS.

112. Moreover, DoWRI will also need to reorganize its existing field offices (besides the district irrigation offices transferred to provincial governments) like field offices of People's Embankment Project (Janatako Tatbandha), mechanical offices, district offices of some irrigation projects and river control projects by creating a number of Water Resource Development Offices to work under province based monitoring offices. These offices spread across Nepal need to be in accordance to the proposal developed by the technical team of MoEWRI.

113. These province monitoring offices, will help promote presence of federal government in different parts of the country to carry out its constitutionally assigned roles (i.e., related to large scale projects, coordination of inter-provincial irrigation / water induced disaster management projects, and so on) and ensure functional linkages with the provincial and local government agencies.

114. Presently, the five divisions in DoWRI are sector based divisions. In order to develop the different divisions into an intrinsic and mutually supporting relationship that collectively makes the DoWRI much more efficient, vibrant and to take up the future challenges, the divisions needs to be reconstituted into function based divisions rather than the present sector based division arrangement in order to be in synergy with the new federated Nepal.

115. Considering capacity gaps at provincial and local levels, various capacity building activities, including the use of new technologies and methods need to be disseminated over all the provinces and local governments. DoWRI has key role in it, which requires an elaborate capacity building programme for the whole federated country.

116. Consultations with the directly responsible stakeholders including and MoEWRI and WECS can be greatly beneficial in achieving this objective.

1.4.7.2 Organizational arrangements at the provincial level

117. As the Constitution envisages the provinces with their own sphere and space for irrigation and water resources related activities, the provincial level ministries will need to perform both policy and implementation functions. Generally, the present work force in place at provincial level is significantly below the requirements for undertaking the envisaged roles and responsibilities requiring planned steps to fill this gap.

118. Moreover, the provincial level organization set-up need also have a unit to undertake necessary activities for capacity development of irrigation related actors both at provincial and local levels.

1.4.7.3 Organizational arrangements at the local level

119. Like the provincial government, local government too does not have any separate organizational set-up devoted to irrigation function. In view of multi-task responsibility of local government, such as those related to design and construction of small / local irrigation project, validating irrigation service level, local disaster management, regulating functioning of both system-level or canal level water user groups / associations, fixing and sharing fees for irrigation services and so on, it is highly desirable that local governments, which have much wider geographic coverage, need to build its capacity.

120. However, as they have their own constitutionally defined jurisdictional space, they need to be encouraged to engage in incentive driven capacity building programmes at offer or on demand at provincial and federal levels.

1.4.8 Synchronizing irrigation and flood management efforts

121. The creation of DoWRI in 2018 brought back together the Department of Irrigation (DoI) and Department of Water Induced Disaster Management (DoWIDM) under one umbrella. Synergies are still required and achievable between these two functions, also linked to drainage. As also stated earlier, the DoWRI will need to revisit its functions across its divisions, in particular, to optimize its functions and delivery of effective service with respect to irrigation and flood management.

122. Moreover, DoWRI has key roles to integrate its activities with those of the National Disaster Risk Reduction and Management Authority, as provisioned under the DRRM Act 2017. Such synchronizations need to be ensured at both province and local levels.

1.4.9 Transboundary cooperation

123. Riparian water rights and prior use right of India, Nepal's southern and downstream neighbour, are key considerations for any large scale irrigation development in Nepal. Nepal has signed a number of treaties with India on major rivers crossing the border, or adjacent; Mahakali Treaty (1920, 1991 and 1996), Gandak Treaty (1959 and 1964) and Koshi Treaty (1954 and 1976).

124. A version of the **Mahakali Treaty** was signed in 1920, and a more comprehensive treaty was finalized in 1996. Initial agreement gives exact extraction quantities for two periods of the year, Kharif 28.35 m^3/s (15-May to 15-Oct) and Rabi (16-Oct to 14-May) at 4.25 m^3/s. In 1991, the Tanakpur Agreement allowed the additional extraction of 4.25 m^3/s for the Rabi period, and 10 m^3/s for Dodhara-Chandani area. This has allowed Nepal to start construction of Mahakali Phase 3, upstream of the Sarada Barrage, and irrigate the remaining part of irrigable land in Kanchanpur. India and Nepal signed an understanding regarding the construction of the Pancheshwar Multi-Purpose Project to build a 315 metre high rock fill dam, for flood control, hydro-power and irrigation. Once the dam is built, it could supply year-round irrigation to all the irrigable land of about 93,000 ha in Kanchanpur and Kailali districts. The Pancheshwar project is not considered in the IMP scenarios as Mahakali phase 3 is already under construction utilising the additional water from the Tanakpur agreement.

125. **The Karnali Basin** has not been subject to any treaty or agreement. There are a number of transfer schemes and dams considered. The Karnali High Dam considers a 290 m high dam with 36,000 ha of inundation. The installed hydropower would be of 10,800 MW capacity. The Rani-Jamara Kulariya irrigation scheme currently being developed uses a free intake in the Karnali River downstream of the Chisapani Bridge with enough water for year-round irrigation of 57,000 ha (gross). An additional project is the Karnali Diversion project which would transfer 58 m^3/s to irrigate 40,600 ha (gross) and generate 80 MW of power.

126. **The Gandak Treaty** signed originally in 1959, and amended in 1964 set out provisions for the Gandak barrage in Nepal to extract water on a specified monthly schedule for India. The west canal pass through Nepal before entering India while the east canal passes through India and then one branch enters Nepal. The minimum canal extractions for the west canal is 163 m^3/s in April and 104 m^3/s in March for the east canal. Nepal is entitled to extract 8.5 m^3/s through Nepal West Canal and 24.1 m^3/s from the east canal. A key aspect of the agreement for Nepal is that any trans-valley use of water will be the subject of a separate agreement. This means the Kaligandaki-Tinau diversion whose drainage water does not re-enter the Gandak before the barrage is included in this trans-valley condition. Any water diverted by Kaligandaki-Tinau will have to be compensated by supplementary flows from other storage reservoirs (like Budhi-Gandaki project) when flows do not meet the agreed diversion schedule set out in the 1959 agreement. Two other diversions have been considered in this basin, the Kaligandaki-Nawalparasi diversion and the Trishuli-Shaktikhor Diversion, but both were found to be un-economical at present. Both these projects are not trans-valley though.

127. **The Koshi Agreement** in 1954 and revised in 1976 allowed the construction of the Chatara Barrage on the border with India. Nepal has the right to withdraw water as it may be required from time to time. Therefore, there is no limitation on extractions for irrigation. There are three transfer projects considered in the IMP: i) Sunkoshi-Marin transfer to Bagmati irrigation project, ii) Sunkoshi-Kamala transfer to Kamala irrigation project, and iii) Tamor-Morang transfer to new irrigation lands.

Bheri Babai Diversion Multipurpose Project

SECTION II: ASSESSMENT OF AVAILABLE LAND AND WATER RESOURCES

2.1 Irrigable Land

128. For the purposes of description and planning (for the Master Plan), Nepal is divided into three main river basins[17] (Koshi, Narayani and Karnali). Table 15 shows a summary of the basins by area, population, administrative units (district), as well as number of sub-basins.

Table 15: River Basins

Basin	Area (km^2)	Population (Millions)	Districts (No)	Sub-basins (No)
Karnali	62,299	6.10	25	4
Narayani	38,749	6.58	22	2
Koshi	46,742	13.81	30	5
Total	**147,790**	**26.49**	**77**	**11**

Note: These areas are based on District boundaries from DoS values, and not physical catchment.

129. The Koshi basin have about one third of the land area and 52% of the population, largely due to the Kathmandu Valley being located within the basin. The Narayani Basin has about 25% of each land area and population, and Karnali Basin about 42% of land area and 23% of population.

130. For planning purposes three agro-ecological zones are identified: Terai - the lowlands to the south and adjacent to the border with India, on which most of the large scale irrigation systems are located, Hill - being hill country running east to west, with a large number of small farmer managed systems; Mountain - to the north and higher altitude with small number of small farmer managed systems.

131. While Terai is the smallest zone (23% of total area), it has the highest population (13 Million and nearly 50% of total). The Mountain zone is relatively large (35% of area) however understandably with low population (8%). It also shows that the Hill zone has more than 40% of total area and is reasonably populous with about 40% of the population as presented in Table 16.

[17]The river basins are hydrological units, and in cases combination of adjacent basins (as is the case with the Karnali basin).
Areas are based on DoS data.

Table 16: Agro-ecological Zones

Zone	Area (km²)	Population (Millions)	District(No)
Mountain	52,007	2.10	16
Hill	62,348	11.39	40
Terai	33,435	13.00	21
Total	**147,790**	**26.49**	**77**

2.1.1 Land Resources

132. The following mapping and assessment tools were used to analyse and identify optimal approaches to irrigation development in Nepal for the plan period:

- An updated soil map
- An updated land use map
- Irrigation suitability assessment
- A digital elevation model (DEM) of the study area

2.1.1.1 Soil Order

133. Based on the information and data collected, soil order in the whole country has been assessed. Table 17 presents the ecological zone distribution of various soil order in Nepal.

Table 17: Soil Order (km²)

Zone	Alfisol	Aridsol	Entisols	Inceptisls	Mollisols	Rock	Spodosols	Ultisols	Water	Total
Terai	1,931	0	12,394	16,817	1,157	0	0	132	1,004	33,435
Hills	3,000	18	23,691	28,599	1,024	4,752	418	605	242	62,349
Mountain	50	2,263	17,283	9,767	180	22,139	198	92	35	52,007
Total	**4,981**	**2,281**	**53,368**	**55,183**	**2,361**	**26,891**	**616**	**829**	**1,281**	**147,790**

2.1.1.2 Land Use

134. Seven different classes of land (Table 18, based primarily on the classification adopted by the Department of Survey, Nepal) were used to identify and assess the land use.

Table 18: Classes for supervised classification

SN	Class name	Description
1	Agriculture	Crop fields and fallow lands (including irrigated land)
2	Built-up	Residential, commercial, industrial, transportation, roads, mixed urban
3	Barren land	Land areas of exposed soil and barren area influenced by human influence
4	Forest	Mixed forest lands (including heath land etc.)
5	Water	River, open water, lakes, ponds and reservoirs
6	Snow/ Glacier	Snow, Glacier
7	Shrubland / Grassland	Grassland, shrubs, grazing

135. As Table 19 below shows, when compared to 1986, the land use pattern in the country has significantly changed with agricultural use going down by 11%, while residential use increasing by 986%. Also significant is the fact that the agricultural land use in Hills is decreasing at a much faster rate than in Terai.

Table 19: Land Use Summary (ha)

Source Area (ha)	Agriculture Level Terraces	Agriculture-Sloping Terraces	Agriculture- Valley, Tar Terai	Total Agriculture	Barren Land	Forest	Residential	River / Waterbody	Shrubland /Grassland	Snow / Glaciar	Total
Total IMP-2018 (ha)	1,034,806	678,619	1,844,378	3,557,803	1,473,954	6,422,772	130,977	353,767	1,512,222	1,363,402	14,814,897
Total LRMP-1986 (ha)	1,213,860	914,940	1,863,477	3,992,277	1,950,381	5,646,411	12,059	228,295	2,412,844	536,796	14,779,063
Change (%)	-15	-26	-1	-11	-24	14	986	55	-37	154	

2.1.1.3 Irrigation Suitability

136. Irrigable land is land initially classified as arable (potentially irrigable) that is subsequently found to be economically justified (benefits exceed costs) under a specific Plan of development which includes the water and other facilities necessary for sustained irrigation [USBR Terminology]. The country falls under five different ecological zones which consist of variability in elevation, soil type, soil texture and irrigation potential. All these factors were considered in the irrigation suitability mapping process and have come up with a model using soil depth, soil texture from soil maps, slope from DEM, and Land Use derived from the supervised classification of LANDSAT imagery.

137. There are seven criteria identified for the classification of irrigable land as shown in Table 19. The approach used in this study was to apply Boolean logic based on the limiting factor. The land characteristics are matched sequentially against the criteria for each class. No divergence from the class membership was permitted.

138. Using the classification criteria, four different types of irrigation suitability were assessed as presented in Table 20.

- **S1:** Highly suitable for surface irrigation, deep soil > 90 cm, flat land <3% slope, medium textured soils
- **S2:** moderately suitable for surface irrigation, medium depth, 60-90 cm, lighter soils, on slopes 3-10%
- **S3:** marginally suitable for surface irrigation, shallow depth, but greater than 30 cm, light soils on radical terrace, slopes 10-25%
- **S4:** this is a new category not used and identified in the IMP-1990, to include those steep level terraces that are irrigated for paddy. Slopes up to 60% are acceptable provided the land is identified as level terrace.
- **NS:** all sloping terraces deemed unsuitable for surface irrigation was included in a new suitability class for pumping (non-Conventional) irrigation. This is because mechanized irrigation can be used to irrigate sloping terrace, and all classifications S1 to S3 are available to be classified as pumping suitable provided it meets the requirements of less than 140 Meters above the river source, and within the 3.0 km.

Table 20: Irrigation Suitability Criteria

SN	Criteria	Unit	S1	S2	S3	S4	Not Suitable
1	Effective depth	cm	>90	60-90	30-60	>30	<30
2	Texture	Textural Group	SL, SICL, SIL, CL, L, SCL	SC, SI	S, SIC, LS	S1-S3	Cv, Cm, SiCm, gravel, G
3	Flooding		None	Non Excep-tional	Exceptional	S1-S3	Frequent/Severe
4	Erodibility	K	<2	2-6	6-13	S1-S3	>13
5	Drainage		Well	Moderate	Imperfectly	S1-S3	Poor, Excessive, Rapid
6	Terrace Irrigation (Slop)	%	<3	3-10 Progressive Terrace	10-25 Radical Terrace	25-60	>25
7	Land Use		Arable			Level Ter-race	Urban, river channels, perma-nently flooded land, National Forest conservation or protected areas, slopping terrace
8	Pumped Irrigation	m above River bed	A Special category Meeting the above criteria, but located less than the economic pumping head El <140m				

139. Table 21 presents the ecological zone wise distribution of various types of suitable area for irrigation. Nepal has a total of 3,557,700 ha of agricultural land, of which 2,536,000 ha is suitable for irrigation. Out of this irrigable land, type S1 to S3 occupy 1,691,800 ha and the remaining 844,500 ha is of type S4.

Table 21: Irrigation Suitability Area (ha)

Ecological Region	Total S1-S3	Total S4	Total	IMP-1990	IMP-1990 to IMP-2018
Terai	1,495,939	3,237	1,499,176	1,338,000	12%
Hills	187,068	649,549	836,617	368,000	127%
Mountain	8,811	191,756	200,567	60,000	234%
Total	**1,691,818**	**844,542**	**2,536,360**	**1,766,000**	**44%**

2.1.1.4 Pumping Suitability

140. The suitable irrigation area would further be restricted from the point of view of supply of economically viable irrigation system, especially when a suitable area is in mountain or hill ecological zone where pumping would be needed to lift the water high above the water source. Considering this fact, a pumping suitability analysis has been carried out.

141. There are two types of pumping: (i) groundwater pumping, and (ii) lift irrigation in hills and mountains. GW is mainly confined to Terai. To determine the areas suitable for lift irrigation, a GIS model was developed. The basis of this process was to start with a river flow accumulation that would sustain irrigation in the minimum flow month. For this the specific unit discharge was obtained from the new MIP regions. The minimum flow value chosen was 60 l/s, which is roughly equivalent to a level 3 river.

142. The second criterion in the model was the pumping head. Determination of the economical pumping head was derived from the cost of energy, capital cost and the incremental net benefit of irrigation. It is expected that these parameters are quite different around the country, but for national analysis average figures were used. A finer approach can be used on a local level, but then more detailed analyses would be required.

143. A cropping pattern of maize, potato, vegetables and oilseed with a cropping intensity of 170%, an irrigation efficiency of 80% was used to determine a unit Crop Water Requirement of 0.49 l/s/ha. The Annual Pumped Volume comes to 4,125 m3/ha/y. Using figures from the Hills pre-feasibility report gives a Net Benefit of USD 1,261 ha/yr. The Economical Pumping Head is therefore considered as 140 m.

144. Based on the above criteria, pumping suitability of the agricultural land in Nepal has been determined and district wise distribution of the area has been presented Table 22 below. In hills and mountains Nepal has pumping suitability of 92,836 ha of land of type S1 to S3 and 186,757 ha of type S4 in Hill and Mountain zones. There is, however, a significant area of sloping terrace of 286,445 ha which is categorized as suitable in pumping suitability criteria. This indicates that the productivity of this area can also be increased with pumping associated with appropriate technology such as mechanical irrigation and cropping under green houses.

Table 22: Pumping Suitability Area (ha)

Districts	Sloping Terrance	Valley/Tar (S1+S2)	Valley/ Tars (S3)	Level Ter-race (S4)	Total
Total Hills	206,409	33,653	54,033	127,451	421,546
Total Mountain	80,036	532	4,618	59,306	144,492
Total Hills and Mountains	**286,445**	**34,185**	**58,651**	**186,757**	**566,038**

2.1.1.5 Irrigation Domain

145. The final aim of the LRMA and the inventory of irrigation projects is to allocate all agricultural land to a particular irrigation potential. By mapping[18] all existing irrigation schemes alongside the irrigable land, the remaining land was identified, and suitable irrigation methods allocated. This concluded in the following potential irrigation domains[19]:

- Existing Irrigation Projects
- Potential surface irrigation
- Potential Transfer Irrigation Schemes
- Identified Potential Pumping Irrigation
- Classified Potential Pumping Irrigation
- Rainfed Agriculture (possible solar or tank Irrigation)

146. The total land area is approximately 14.7 Million ha[20] (Table 23) of which 3.56 Million ha is classified as agricultural. The balance of non-agricultural land (11.52 Million ha) includes forest (43%), grassland/shrub-land (10%), barren land (10%), and snow/glacier (9%) (Residential land is about 1%).

Table 23: Land Use by Agro-ecological Zone

Land Use (M ha)	Mountain	Hill	*Terai*	Total
Agricultural	0.401	1.563	1.592	3.556
Non-agricultural	4.799	4.672	1.752	11.223
Total	5.201	6.235	3.344	14.779
%	**35%**	**42%**	**23%**	

[18]The land resources mapping and classification systems used a high-resolution digital elevation model (DEM) derived from topographic maps and satellite images. The main satellite imagery used to generate the DEM is CARTOSAT and 79 such images were processed.

[19]A domain is a sub-set of a land category with a common purpose.

[20]Land Resources Inventory Report (May 2018)

147. Table 24 lists the summary of principal land uses by river basin, of which 44% of agricultural land (1.614 Million ha) is located in Koshi and 29% and 27% respectively in Narayani and Karnali basins, with 0.96 and 1.00 Million ha, respectively.

Table 24: Land Use by River Basin

Basin (M ha)	Agriculture	Agriculture %	Non-Agriculture	Total
Karnali	0.991	27%	5.239	6.230
Narayani	1.084	29%	2.790	3.874
Koshi	1.614	44%	3.060	4.674
Total	**3.689**		**11.090**	**14.779**

2.2 Water Resources Mapping and Assessment

2.2.1 Surface Water Resources

148. For describing the physical and social resources, the country is divided into three main river basins, as shown in Figure 3. These are from west to east: Karnali, Narayani, and Koshi.

Figure 3: River Basins

149. For the assessment and Planning of projects the key units (in addition to basin) are the sub-basins (for assessment of water resources), agro-ecological zones (Terai, Hill, and Mountain), and administrative boundaries (district and province). All boundaries are based on physical hydrological catchments and are therefore different than presented earlier. In addition, these areas are only those within the national Nepal boundary, not the full hydrological catchment, all of which extend into neighbouring countries.

2.2.1.1 Karnali Basin

150. The Karnali Basin is located in western Nepal bordering China and India to the north and south respectively, and Narayani basin and India to the east and west respectively. It has a total area of about 62,657 km2 (about 42% of the total area of Nepal) and is principally the Karnali, West Rapti, Babai and Mahakali River basins.

151. **Population and Administration:** The basin has a total population of more than 6 Million (about 23% of the national total) of which more than 87% live in Terai and in the Hill zone (2.7 and 2.6 Million, respectively) and less than one Million in the Mountain zone. Population density varies widely between the agro-ecological zones with more than 200 per km2 in Terai, and less than 120 and 30 per km2 in Hill and Mountain zones, respectively.

152. The basin fully encompasses Karnali and Sudurpaschim provinces, and partially Gandaki and Lumbini provinces which extend into the Narayani Basin. There are a total of 25 districts within the basin of which 5 are in *Terai*, and 12 and 8 in Hill and Mountain zones respectively. Major population centres include cities like Dhangadi (Province Sudurpaschim) and Nepalgunj in *Terai*, and Birendranagar (Province Karnali) in Hill zone.

153. **Topography:** The topography ranges from the lowland plains of Terai with mean elevation of 400 masl to the Himalaya Mountains of the upper basin (to the north) of more than 7,000 masl. The Hill zone is an extensive area of hills intersected by river valleys with river terraces (referred to as Tar) and with a mean elevation of 1,700 masl.

154. **Precipitation:** Rainfall distribution within the basin ranges from about 300 to more than 2,700 mm per annum. Terai and within the Hill zone the annual rainfall is approximately 1,900 mm on average but locally can reach up to 2,700 mm per year. In the Mountain zone the annual rainfall is generally less than 1,500 mm; however, is 2,700 mm in the north-western extreme. Furthermore, the annual rainfall amount is substantially decreasing towards the Tibetan Plateau in the North, reaching a minimum of only 285 mm per year close to Nepal's border with China.

155. **Soil Suitability:** Approximately 10% of the basin is classified as having soils suitable for irrigation (suitability classes S1 to S4) (approximately 0.62 Million ha). In Terai 30% of land (0.35 Million ha) is suitable, and in Hill and Mountain zones 10% (0.21 Million ha) and 2% (0.06 Million ha), respectively.

156. **Land Use:** The total land classed as agriculture use (level terrace, sloping terrace and valley/tar/Terai) is 16% of the total (approx. 1 Million ha) and 46% as forests (2.9 Million ha). In Terai agriculture use accounts for about 31% lands and forests 56%, while in the Hill zone 20% is agriculture use (level and sloping terrace, valley and tar) and forests 67%. In the Mountain zone agriculture land use is less than 6% of the total area.

157. **Water Resources:** The total annual surface water resources are approximately 60 Bm3 with the volume per sub-basin ranging from less than 1,000 to more than 14,000 Mm3 per annum. Total annual groundwater resources are approximately 3.4 Bm3, which is mainly located within Terai districts.

2.2.1.2 Narayani Basin

158. The Narayani Basin is located in central Nepal bordering China and India to the north and south respectively, and Koshi and Karnali basin to the east and west, respectively. It has a total area of about 38,749 km2 (about 25% of the total area of Nepal) and is principally the Narayani river basin and the West Churia.

159. **Population and Administration:** The basin has a total population of about 6.58 Million (about 25% of the national total) of which more than half (3.7 Million) live in the Hill zone, and 2.6 Million in Terai and less than 1% in the Mountain zone. Population density varies widely between the agro-ecological zones with more than 360 per km2 in Terai, and about 170 and 8 per km2 in Hill and Mountain zones respectively.

160. The basin almost fully encompasses Gandaki Province and partially Bagmati and Lumbini Provinces (which extend into the Koshi and Karnali basins respectively). There are a total of 22 districts within the basin of which 4 are in Terai, and 15 and 3 in Hill and Mountain zones, respectively. The principal administrative centres include cities in Terai such as Hetauda (Bagmati Province capital) and Siddarthanagar, and Pokhara (Gandaki Province capital) in the Hill zone.

161. **Topography:** The topography ranges from the lowland plains of Terai with mean elevation of 280 masl to the Himalaya Mountains of the upper basin (to the north) of more than 8,000 masl. The Hill zone is an extensive area of hills intersected by river valleys with river terraces and with a mean elevation of 1,900 masl.

162. **Precipitation:** Rainfall distribution within the basin ranges from less than 200 mm to almost 5,000 mm per annum. In Terai, annual rainfall is about 2,200 mm and evenly distributed. Within the Hill zone the annual rainfall varies widely and reaches a maximum of more than 4,900 mm in Kaski district. In the Mountain zone mean rainfall is less than 1,000 mm and decreases towards the North and Nepal's border with China to less than 200 mm.

163. **Soil Suitability:** Approximately 16% of the basin is classified as having soils suitable for irrigation (suitability classes S1 to S4) (approximately 0.58 Million ha). In Terai 43% of land (0.31 Million ha) is suitable, and 12% (0.25 Million ha) in the Hill zone. In the Mountain zone less than 2% (0.02 Million ha) is suitable.

164. **Land Use:** Total land classed as agriculture use (level terrace, sloping terrace and valley/tar/Terai) is 26% of the total (approx. 0.95 Million ha) and 40% as forests (1.47 Million ha). In Terai, agriculture use accounts for about 43% lands and forests 44%, while in the Hill zone 27% is agriculture use (level and sloping terrace, valley and tar) and forests 49%. In the Mountain zone agriculture land use is less than 2% of the total area.

165. **Water Resources:** The total annual surface water resources are approximately 57.6 Bm3 with the volume per sub-basin ranging from less than 1,000 to more than 12,000 Mm3 per

annum. Total annual groundwater resources are approximately 2.8 Bm3 which is mainly located within Terai.

2.2.1.3 Koshi Basin

166. The Koshi Basin is located in eastern Nepal bordering China to the north and India to the south and east. It has a total area of about 46,742 km2 (about a third of the total area of Nepal) and principally comprises of the Koshi and Kankai river basins, as well as a section of the East Churia.

167. **Population and Administration:** The basin has a total population of nearly 14 Million (about half of the national total) of which more than half (7.9 Million) live in Terai, and 5 Million in the Hill zone and less than one Million in the Mountain zone. Population density varies widely between the agro-ecological zones with more than 550 per km2 in Terai, and less than 300 and 60 per km^2 in Hill and Mountain zones, respectively.

168. The basin fully encompasses Koshi and Madhesh Provinces and partially Bagmati Province (which extends into the Narayani basin). There are a total of 30 districts within the basin of which 11 are in *Terai*, and 14 and 5 in Hill and Mountain zones respectively. The principal administrative centres include Kathmandu (national capital) within Bagmati Province, to the west, and seven major cities in *Terai*, including Janakpurdham (Madhesh Province capital) and Biratnagar (Koshi Province capital).

169. **Topography:** The topography ranges from the lowland plains of Terai with mean elevation of 160 masl to the Himalaya Mountains of the upper basin (to the north) of up more than 8,000 masl. The Hill zone is an extensive area of hills intersected by river valleys with river terraces and with a mean elevation of 1,200 masl.

170. **Precipitation:** Rainfall distribution within the basin ranges from about 1,500 to more than 4,000 mm per annum. In Terai, annual rainfall is generally less than 2,000 mm however is 3,000 mm on the eastern extreme. Within the Hill zone mean rainfall is about 1,900 mm and in the Mountain 2,400 but with maximum of more than 4,000 mm.

171. **Soil Suitability:** Approximately 26% of the basin is classified as having soils suitable for irrigation (suitability classes S1 to S4) (approximately 1.23 Million ha). In Terai, 63% of land (0.89 Million ha) is suitable, and in Hill and Mountain zones 12% (0.22 Million ha) and 7% (0.11 Million ha), respectively.

172. **Land Use:** Total land classed as agriculture use (level terrace, sloping terrace and valley/tar/*Terai*) is 35% of the total (approx. 1.66 Million ha) and 43% as forests (2.04 Million ha). In Terai, agriculture use accounts for about 62% lands and forests 24%, while in the Hill zone 30% is agriculture use (level and sloping terrace, valley and tar) and forests 62%. In the Mountain zone agriculture land use is less than 15% of the total area.

173. **Water Resources:** The total annual surface water resources are approximately 55.3 Bm^3 with the volume per sub-basin ranging from less than 1,000 to more than 20,000 Mm^3 per annum. Total annual groundwater resources are approximately 6.9 Bm3 which is mainly located within Terai districts.

174. The primary purpose of the assessment was the determination of the surface water resources, and in particular determination of availability for irrigation, as part of current and future irrigation water demand, including the potential impacts of climate change on water resources.

175. The approach was based on two principal activities, first, the use of SWAT models to model surface water run-off, and secondly MIKE HYDRO Basin model for determination of water availability taking into consideration run-off and current and future water uses (consumptive and non-consumptive). Figure 4 outlines the boundary of the basin considered in the modelling for water resources assessment.

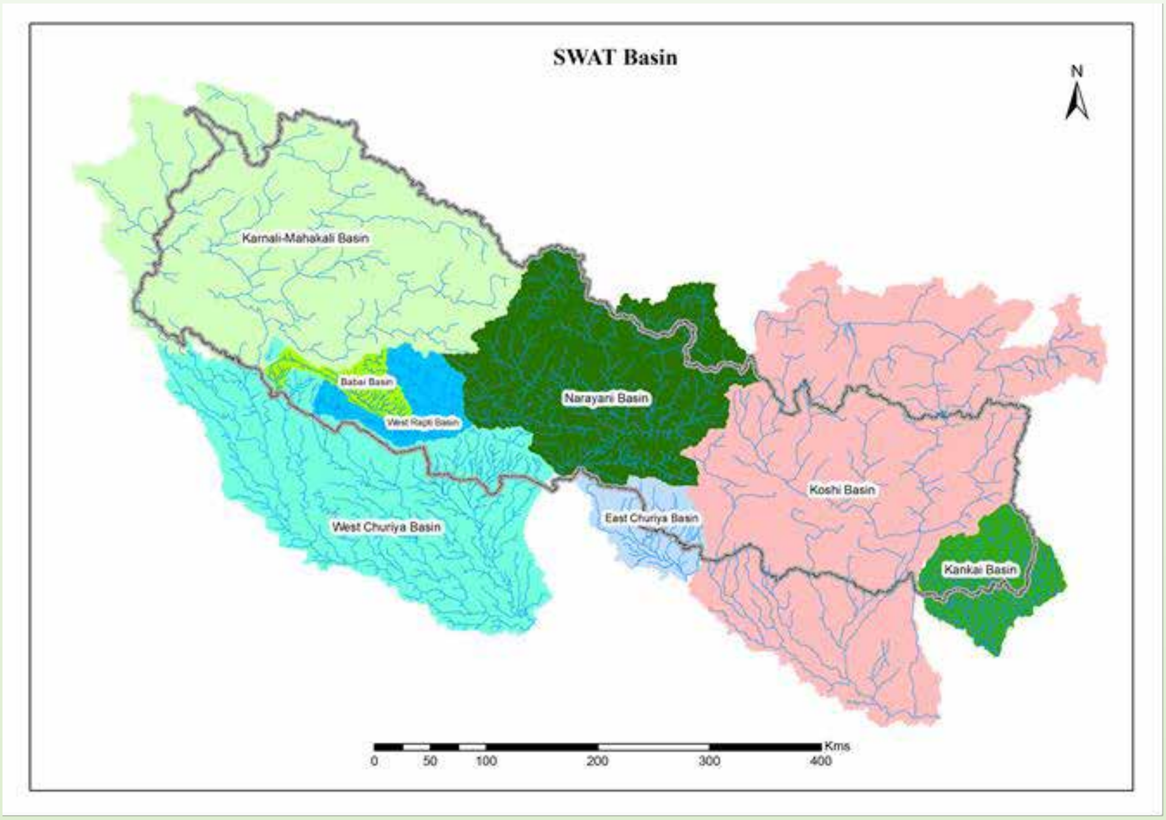


Figure 4: Extent of Basins in the SWAT Models

176. Figure 5 shows the specific discharge, in litres per second per square kilometres (l/s/km^2), based on the 80th percentile reliable flow for April (within 38 sub-basins). The Siwalik hill catchments have not been calculated, although included in the SWAT model. The flows from these catchments are considered less reliable because of the lack of calibration data. In addition, the water resources of these catchments are considered in the groundwater resources assessment, prepared under a separate report. A slightly different presentation of the water resources is done by the “blue water” map of the country, which gives the volume of the water resource. This is done on an annual volume basis.

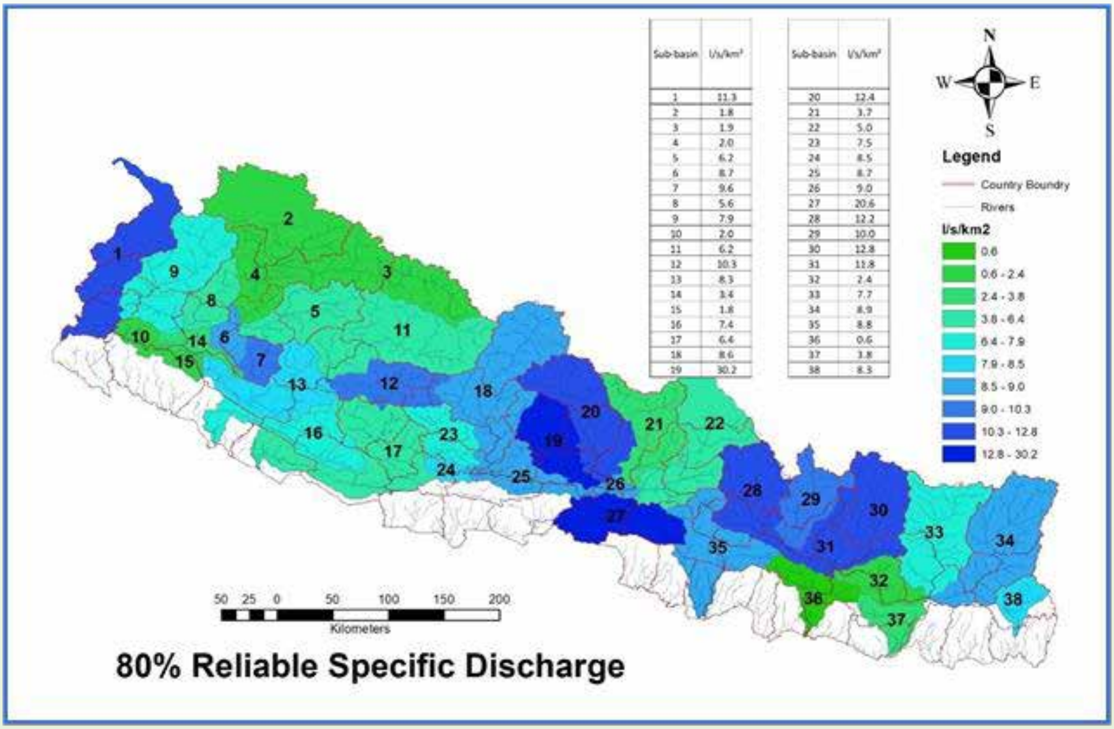


Figure 5: 80th Percentile Reliable Specific Discharge

177. The estimated annual surface water volume is 173,000 Mm³ and the annual groundwater volume 13,215 Mm³.

178. Table 25 lists a summary of the assessment of surface water showing the average annual volume of run-off. The reliability level of surface flow (at 80th percentile level) is approximately 173 Bm³ per annum. However, more than 70% of this resource occurs during the period from June to September.

Table 25: Surface Water Assessment

	Karnali	Narayani	Koshi	Total
Resource (Bm³) 80th Percentile	60.0	57.6	55.3	173.8
	35%	**33%**	**32%**	

179. The available surface water volume represents a huge potential, at an annual Crop Water Requirement of 25,000 m³/ha, this could irrigate 6.9 million ha, way more than the potential irrigable land at 2.5 million ha. However, based on the flows available in March, the dry season potential is only 0.75 million ha, less than the available irrigable potential. To achieve the full potential, storage dams are required, or the use of groundwater is to be mobilised. The water availability map of Nepal is presented in Figure 6.

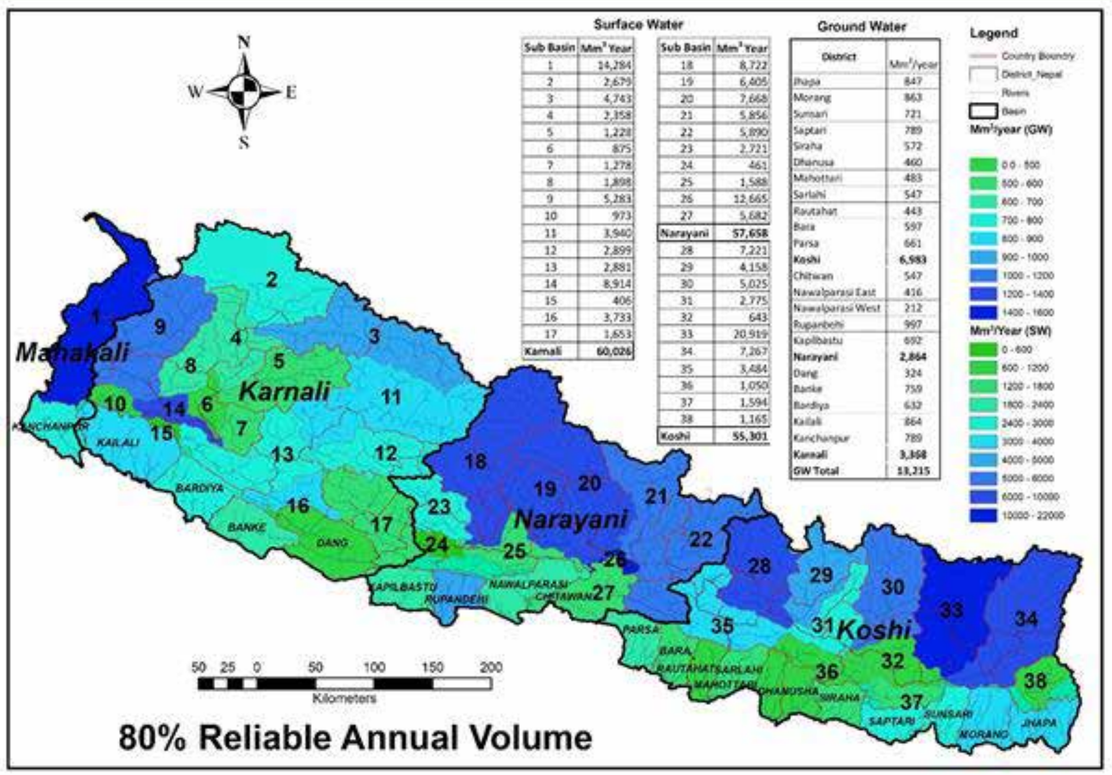


Figure 6: Water Availability Map of Nepal

2.2.2 Ground Water Resources

2.2.2.1 Groundwater Assessment

180. The objective of the groundwater resource assessment is to determine the available groundwater resource in the alluvial plain of the Lower Terai.

181. The approach is based on a district basis, except for two districts, Rautahat and Sarlahi, which have been subjected to detailed groundwater modelling. An overview of the model components, are as follows:

- Three interconnected reservoirs are included, comprising from north to south the Bhabar Zone, the Seepage Zone and Terai Zone extending to the border with India. These zones are based on the conceptual geological model.
- Surface runoff from the Siwalik Hills is simulated and the resulting inflow into the Bhabar Zone is allowed to infiltrate into this zone. The simulation of runoff is calculated on a spreadsheet and results exported to a model input file.
- The calculation of recharge and groundwater demand for irrigation (if required) is calculated on a separate spreadsheet. Potential recharge is derived based on a soil

moisture balance approach and is not constrained by groundwater table conditions. Recharge includes natural recharge from precipitation and return flow from applied surface water and groundwater irrigation (if included). The potential recharge as well as the derived gross groundwater demand for irrigation is exported into model input files.

- Within the three zones, groundwater storage changes are simulated.
- Groundwater outflow to springs and rivers is included in the model.
- Lateral groundwater flow is simulated across the boundaries that separate the three zones and across the external boundaries to the north (between Bhabar Zone and Siwalik Hills) and the south (the border with India).
- The model comprises three layers within each of the three zones: the deep aquifer, and overlying aquitard, and the shallow aquifer, in the same manner as the Package 6 detailed Bagmati model.
- Capillary upward flow is simulated from a relationship between the depth to the groundwater table in the shallow aquifer and the soil physical characteristics within each zone. When the groundwater table rises to ground surface so-called 'aquifer full' conditions established and part (or all) of the potential recharge would be 'rejected'.

182. The results are presented by district which includes:

- Overview of District and Zoning
- Processing of GIS and Climate Data
- Potential Recharge and Groundwater Abstraction
- Surface Water Runoff from the Siwalik Hills
- Numerical Model Setup
- Numerical Model Simulation
- Presentation and Discussion of Model Results

183. Table 26 lists a summary of average annual renewable groundwater resources for the three main basins; Koshi, Narayani, and Karnali. The total annual volume is of the order of 13,215 Mm^3, of which about 6,983 Mm^3 (more than 50%) are within the Koshi basin, and close to 2,864 Mm^3 and 3,368 Mm^3 in the Narayani and Karnali basins respectively. This represents a significant potential for development for irrigation demand (both as conjunctive use and primary source), which based on an average annual irrigation demand of 18,400 m3 per ha, would be an equivalent irrigated area of more than 725,000 ha.

Table 26: Renewable Groundwater Resources

Basin (MCM/yr)	Net total groundwater recharge (MCM/yr)			
	Half of cultivable area irrigated with groundwater water			
	Bhabar Zone	Seepage Zone	Terai Zone	Total
Jhapa	434	155	258	847
Morang	418	100	345	863
Sunsari	264	100	357	721
Saptari	342	197	250	789
Siraha	247	112	213	572
Dhanusha	176	65	219	460
Mahottari	234	49	200	483
Sarlahi	261	124	162	547
Rautahat	220	88	135	443
Bara	361	41	195	597
Parsa	470	37	154	661
Koshi Basin	3,427	1,068	2,488	6,983
Chitwan	222	63	262	547
Nawalparasi East	133	124	159	416
Nawalparasi West	68	59	85	212
Rupandehi	263	256	478	997
Kapilbastu	280	175	237	692
Narayani Basin	966	677	1,221	2,864
Dang	130	9	185	324
Bardiya	211	185	363	759
Banke	320	167	145	632
Kailali	522	73	269	864
Kanchanpur	320	135	334	789
Karnali Basin	1503	569	1296	3,368
Total	**5,896**	**2,314**	**5,005**	**13,215**

Ground Water Outlet, Jhapa

SECTION III: IRRIGATION MASTER PLAN 2019 (UPDATED 2024)

3.1 Strategic Approaches to Irrigation Master Plan 2019 (Updated 2024)

184. Given the developmental challenges discussed in Section I and recognizing that Nepal's food security, food sufficiency, alleviation of rural poverty, and employment generation the future course heavily depends on how fast the country modernizes its agriculture, which in turn depends on how significantly its irrigation infrastructure transforms itself in the coming years, this master plan has put forth an ambitious Plan to rapidly develop Nepal irrigation infrastructure.

185. Key approaches to meet that challenge are:

- Increase year-round irrigation across the country with a particular focus in Terai. To get to this objective, GoN Plans to significantly increase investments on:
  - Inter-basin transfers that bring adequate quantities of water to large pockets of drier lands in Terai in a cost-effective manner;
  - Groundwater development, for either independent or conjunctive use, in the shorter-term to off-set longer implementation periods required for large projects.
- In hills and mountains, the focus will be on development of new gravity systems. Concurrently, also to develop non-conventional irrigation through electric and solar pumping wherever suitable.
- A key focus of the plan will also be on rehabilitation and modernisation of existing infrastructure with the objective of transferring management of irrigation systems to user groups, provincial and local government agencies and, where appropriate, to the private sector under PPP schemes. The private sector will also be encouraged to invest in irrigation systems through PPP arrangements, where such arrangements are feasible.
- The master plan will also promote improved environmental standards in water management and -construction, while supporting programs that improve on-farm water management practices.

3.1.1 Locational Priorities

186. Districts where the economic return to irrigation is likely to be relatively higher were ranked. Very broadly and on average, Terai has three to four times greater expected incremental net value of production than the Hills (with the exclusion of the Kathmandu Valley, where population growth and urbanization will be greatest). Highest returns to irrigation investment can therefore be expected from Terai. In addition, the west and central districts have higher expected incremental net values of production.

187. The Western Hills districts have a slightly higher expected incremental net value of production than the Eastern. Both together, the return to irrigation investment might be only one third to one quarter obtained in Terai. The capacity for returns on irrigation investment is significantly lower in Hills.

188. The Mountain districts have very low incremental net value of production estimates, only about one fifth of that of the Hills. Some districts have negative values, despite the application of economic pricing which gives a proportionally higher value to crops to account for the opportunity cost of local imports. One basic reason for this is projected depopulation in the more remote districts. Other reasons include low land suitability, cropping intensities and yields. The potential economic return on irrigation investment is therefore low. Nevertheless, some districts are expected to have better returns to investment than others, there may be niche market opportunities not captured in this broad analysis and there may also be pressing social reasons for irrigation investment.

3.1.2 Technological Priorities

189. Under present levels of input and outputs, the development of groundwater would always be given priority over the development of surface water alone (i.e. excluding the development of surface water irrigation as part of multi-purpose projects). Various regression models were tested to explain the difference of present Net Value of Production (NVP) between Terai Districts. Only the distribution of the irrigated area and suitable land between Districts proved to be statistically significant variables, as shown in Table 27.

Table 27: Explanatory Variables for Net Value of Production by District (NPR Million)

Model Description	Explanatory variable			Model significance		
	Description	Coefficient	t stat	R2	F	F sig
NVP Million surface ha (X1) groundwater and conjunctive irrigation ha (X2) and % suitable land	Intercept	6.197	1.71	0.68	4.62	1.65%
	Surface irrigation, ha	0.0637	1.19			
	Groundwater and Conjunctive irrigation, ha	0.2208	2.99			
	S1 and S2 suitability, % of NCA	7.240	1.85			

The results give a moderately robust model that explains 68% of the variation of District NVP.[21] . The model suggests that, under present conditions of productivity and prices:

- An additional ha of surface irrigation raises District NVP by only USD 560, but the coefficient is not significant;

[21]The exPlanatory variables were tested for normal distribution using SPSS. Although the sample number is small (n=20) no serious issues were detected with skewness and kurtosis of variables using a histogram plot against the normal curve. The model was tested for autocorrelation, though this is normally used to test for correlation within a time series. The Durbin Watson statistic is 1.483, which indicates minimal concern with autocorrelation of exPlanatory variables. Variance Inflation Factor statistics testing for collinearity were estimated as less than 1.1. Therefore, the model appears robust. Measurement of exPlanatory variables came from widely different sources, but there is always the possibility of correlated exPlanatory variables – for example, irrigation is developed on areas of land relatively suitable for irrigation. In this model this type of bias appears to be absent.

- An additional ha of groundwater or conjunctive use leads to an increase of USD 2,044; the coefficient is highly significant;
- An additional percent of S1 or S2 land raises NVP by USD 67; the coefficient is significant.

190. The present area and distribution of existing surface water irrigation schemes in Terai only partially and weakly explains the annual net value of production of *Terai* Districts. The contribution of surface water irrigation to District NVP is only about 30% of that of groundwater and conjunctive use. This is likely because the irrigation service surface schemes provide is insufficient, less timely and less reliable. The incremental value of production from an additional ha of surface irrigation would only be associated with an increase in District net value of production of about USD 560 per ha, and the coefficient to derive this is not significant.

191. Under present conditions, expanding groundwater irrigation (including in existing surface schemes as conjunctive use) appears to be a much better strategy. An additional ha with groundwater irrigation can increase the net value of district production by around USD 2,044. If the development cost of an additional ha of groundwater irrigation is in the range of USD 2,000-3,000 per ha the pay-back potential is obvious, when investments are made in improved infrastructure and other input supplies.

3.1.3 Temporal Priorities

192. The inclusion of population growth, urbanization, expected economic growth and changing food markets as drivers for irrigation investment is a demand led approach which diverges from historical supply led irrigation investment in Nepal. By using the estimated incremental change in the gross cropped area required between 2018 and 2031, and between 2031 and 2043, about 535,184 ha would be developed by 2031 and an additional 345,041 ha in the period 2031-43.

193. Converting the gross ha estimated to be required by the food market demand estimates into net irrigated ha is very sensitive to the cropping intensity expected to be achieved. The statistics suggest that irrigated cropping intensity has gradually risen from 160% (from 1999/2000 up to 2009/10) and thereafter been variable around 180% it is apparent that unless crop intensification is achieved, it will be impossible to meet the demand targets.

194. The estimate of 880,225 new irrigated ha in 2043 is within the estimated 908,000 ha of suitable land not yet irrigated, but 90% of the most suitable irrigable land (S1-S3) in Nepal is in Terai and has mostly been developed. The necessity to raise irrigation productivity from present levels is very clear, because it will not be possible to reduce the food deficit, or to satisfy food demand under conditions of accelerated economic growth

3.2 Goals and targets for Irrigation Master Plan 2019 (Updated 2024)

3.2.1 Development Goals

195. National goals for the irrigation subsector are set out in the Water Resource Strategy (2002) and National Water Plan (2005) and these are for full development of the irrigable lands and full realisation of irrigation system performance and productivity. Specific goals include (i) near full (90%) development of irrigable lands, (ii) increasing cropping intensity to 200% or more, (iii) full management transfer (of agency managed systems), (iv) increasing system efficiency to more than 50%, and (v) increasing irrigation service fee collection to 75%.

196. The IMP will direct irrigation planning and investment for the next 25 years (to 2044) and covers an important period in the development of Nepal. A period during which the country approaches its expected demographic maximum (of 36 Million in 2055, up from 29 Million in 2021), and increasing urbanisation. Consequently, food demand will increase over this period due to population growth and changing dietary habits for a more urban population. To meet this additional food demand, it is estimated that, in addition to improvements in cropping intensities, the irrigated lands need to expand by more than 340,000 ha.

3.2.2 Pathways to Achieve IMP 2019 (updated 2024) Goals

197. The development potential for irrigated agriculture includes (i) intensification of existing irrigated lands (990,250 ha), with increased cropping intensities, modernised infrastructure, and improved operation and management; and (ii) expansion of irrigated lands (1,275,000 ha) through the development of both surface water and groundwater, along with lift and pumping and associated farm development. To attain the national goals for the subsector, it will require substantial investments in water resources development and modernisation of existing systems. The options as presented in Table 28 are:

- **Improvement of existing irrigated area (systems):** there is potential to improve the performance of the existing 990,250 ha of irrigated lands (improvement of irrigation systems), to increase cropping intensities, conveyance efficiency, distribution equity and productivity. This requires investment to increase water supply during the dry season (October to June), either from surface water and/or groundwater sources, improvement in system performance through modernisation and improved on-farm production. The options are grouped by the following principal water sources:

    - Surface water systems: it is provisionally estimated (based on the current study) that there is potential for large-scale projects for development of surface water, principally by improved water transfer, to meet the deficit water supply to 341,500 ha under existing systems. Furthermore, the modernizing of existing areas of 170,000 ha, 156,000 ha and 38,250 ha in Terai, Hills and Mountains respectively will improve the service of existing irrigation systems. The total area covered by system modernization will be 364,250 ha.

- Groundwater systems: for existing areas irrigated from groundwater, mainly in Terai, there is potential for improvements through upgraded infrastructure and system management, and on-farm enhancements for 284,500 ha.

- **Development of new irrigated lands:** there is potential for further expansion of irrigated lands (of the order of 1,275,000 ha). The options are categorised by agro-ecological zone;

  Terai: the on-going irrigation system unaccounted for existing command area is expected to add additional 86,000 ha for surface irrigation. These include Sikta Irrigation System (37,000 ha), Mahakali Irrigation System (31,400 ha), Rani Jamara Kularia Irrigation System (13,900 ha) and Badkapath Irrigation System (3,700 ha). The cost for these on-going construction is not accounted in this plan.

  Terai: there is potential for expansion of the surface irrigated area in Terai by about 305,000 ha (when considering 7 priority projects) and selected groundwater projects for additional 318,000 ha.

  Hill and Mountain: there is potential for expansion of irrigated lands in Hill and Mountain zone (of more than 566,000 ha), principally from pumped water sources, of which about 467,900 ha is coverable from pumping, and 98,100 ha from gravity feed.

198. The Plan aims to provide irrigation in 100% of all Terai irrigable lands, 1,499,000 ha. For the Hill and Mountains, there is 1,038,000 ha suitable for surface irrigation (out of about 1,965,260 Agricultural land), but not all of this is covered in this plan. Assessments identified 566,000 ha as suitable for irrigation development, either by pumping or gravity-fed, leaving 271,750 ha unirrigated.

Table 28: Development Options

SN	Land Use (ha)	Terai	Hill	Mountain	Total
A. Existing Agriculture Land and Potential Irrigable Land (net ha)					
A.1	**Total Agriculture Land**	1,592,504	1,564,133	401,127	3,557,764
A.2	**Potentially Irrigable Land**	1,499,176	836,617	200,526	2,536,319
B. Existing Gross and Net Irrigated Command Area					
B.	**Existing Irrigated Land (Gross)**				
B.1	**Surface Water Systems**				
B.1.1	Farmers Managed Irrigation System	285,292	194,326	48,422	528,040
B.1.2	Agency Managed Irrigation System	396,958	3,660		400,618
B.1.3	Non-conventional Irrigation System	3,247	7,209	2,358	12,814
B.2	**Groundwater Irrigation System**	485,877	7,953		493,830

SN	Land Use (ha)	Terai	Hill	Mountain	Total
	Subtotal	**1,171,374**	**213,148**	**50,780**	**1,435,302**
C.	**Existing Irrigated Land (Net)**				
C.1	**Surface Water Systems**				
C.1.1	Farmers Managed Irrigation System	213,969	145,745	36,317	396,030
C.1.2	Agency Managed Irrigation System	297,719	2,745		300,464
C.1.3	Non-conventional Irrigation System	2,435	5,407	1,769	9,611
C.1.4	Groundwater Irrigation System	364,408	5,965		370,373
	Subtotal	**878,531**	**159,861**	**38,085**	**1,076,477**
Development Options (Net ha)					
D	**Existing Irrigated Land**				
D.1	**Surface Water Systems**				
D.1.1	Improved Surface Water Supply[1]	341,500			341,500
D.1.2	Modernisation[2]	170,000	156,000	38,250	364,250
	Subtotal	**511,500**	**156,000**	**38,250**	**705,750**
D.2	**Groundwater Systems**				
D.2.1	Modernization	278,500	6,000	0	284,500
For Existing Systems		790,000	162,000	38,250	990,250
E	**New Irrigation Systems/Lands**				
E1	***Terai***				
E.1.1	Suface Water Supply from on-going large irrigation systems	86,000			86,000
E.1.2	Surface Water Supply[3]	305,000			305,000
E.1.3	Groundwater Supply[4]	318,000			318,000
F.2	**Hill/Mountain**				
F.2.1	Gravity		33,700	64,400	98,100
F.2.2	Pumped/Tank/Solar		387,900	80,000	467,900
Total of New Systems		**709,000**	**421,600**	**144,400**	**1,275,000**
Remaining Unirrigated[5]		-	253,400	18,350	271,750
Total Irrigable Land		**1,499,000**	**837,000**	**201,000**	**2,537,000**

(1) Includes modernisation of existing systems. (2) Includes lower reach groundwater development for improved water supply. (3) New Surface systems covering 305,000 ha under 7 priority projects, (4) Groundwater systems in 16 districts covering 318,000 ha. (5) Unirrigated 271,750 ha in hills and mountains or unaccounted FMIS.

3.2.3 Potential Projects

199. This section presents the development projects central to this IMP investment Plan, aimed at meeting the national goals for the irrigation subsector. These fall in four principal groups: multipurpose surface water development projects, groundwater projects, hill and mountain irrigation projects, and modernisation projects (for existing surface water and groundwater irrigation systems).

3.2.3.1 Multipurpose and Large-scale Surface Water Projects

200. The surface water development scenarios refer to a group of potential projects for the development of surface water principally to increase water availability in the dry season for irrigated agriculture in *Terai*. They are generally of large scale, with high infrastructure construction costs, and, which mostly include hydropower generation, and therefore referred to as multipurpose projects. While delineating the potential irrigable areas for development, the maximum additionally coverable area has been explored without overlapping with the already targeted areas under the projects such as the Sunkoshi-Marin diversion, which has the command area of 170,000 ha.

201. Five out of 11 projects have alternative infrastructure options (variants) to increase water supply and expand irrigated area, and in some cases also to generate power. Table 29 lists the projects by location, west to east, and grouped by zone (west, central and east, more or less corresponding to the Karnali, Narayani and Koshi Basins, respectively).

202. Total command area for all projects is about 855,000 ha, of which about 405,000 ha are under existing surface water irrigation systems and 305,000 ha is regarded as new irrigation. The maximum potentially coverable area by these projects would be about 700,000 ha. However, not all projects are economically feasible, and the selected priority projects cover only 305,000 ha.

203. These projects include hydropower generation, where possible, indicating that there is sufficient operating head. Nine of such projects include options for hydropower stations, in some cases with the addition (variant) of a storage dam. The combined installed capacity of all stations (exclusive of mutually exclusive variants) is approximately 920 MW. Not all projects are recommended for inclusion in the IMP.

<u>Bheri-Babai Diversion Multipurpose Project</u>

204. The project will divert water from the Bheri River to the Babai River via a transfer tunnel (12.3 km long with design flow of 40.0 m^3/s), which will increase flows for extraction for the Babai irrigation system. A hydropower Plant (46 MW) is also proposed at the tunnel outlet for power generation. The project will supply water to an irrigable area of about 45,100 ha, of which 42,500 ha is currently irrigated and additional 3,000 ha would be irrigated. Overall, it will entail irrigation area development in 51,000 ha, including 10,000 ha of Sikta Irrigation command area.

205. There are three project variants: transfer tunnel only, and two options for dams at Nalsingadh and Uttar Ganga to increase water supply, primarily to increase hydropower production.

Table 29: Surface Water Development Scenarios (ha)

SN	Ref	Project/Option (ha)	Irrigable Area (ha)	Existing Area (ha)	Water Available	New Area	Installed MW
			1	2	3	4	5
1	W	Bheri-Babai Diversion Multipurpose Projects	45,111	42,467	45,111	2,644	46
	W.1	Transfer only					
	W.2	Transfer + Nalsingad Dam					
	W.3	Transfer +Uttar Gan-ga Dam					
2	W.4	Karnali Diversion	40,628	7,632	40,628	32,996	80
3	W.5	Madi Danga Diversion	35,639	19,458	17,107		61
4	W.6	Naumure Dam, Rapti Kapilvastu Diversion	86,874	15,226	51,256	36,030	343
		Sub-toal West	**208,252**	**84,783**	**154,102**	**71,670**	**530**
5	C	Kaligandai Tinau Diversion	149,830	52,455			
	C.1	No Reservoir			31,464		244
	C.2	Andhikhola Dam			41,953		424
6	C.3	Kaligandaki Nawal-parasi Diversion	11,539	2,080	11,539	9,459	4
7	C	Trishuli Shaktaikhor Diversion	34,892	12,785			
	C.4	No Reservoir			20,586		no HP
	C.5	Budhi Gandaki Dam			34,892	22,107	1200
		Sub-total (Centre)	196261	67320	88384	31566	1628
8.	E.1	Sunkoshi Marin Diver-sion	170,462	108,880	54,548		33
	E.2	Sunkoshi Kamala Diversion	181,802	61,009	129,079	68,070	44
	E	Sunkoshi Marin + Kamala	352,264	169,889			
	E.3	Dudhkoshi HPP			236,350	66,461	
	E.4	Sunkoshi 3 HPP			341,389	171,500	

SN	Ref	Project/Option (ha)	Irrigable Area (ha)	Existing Area (ha)	Water Available	New Area	Installed MW
			1	2	3	4	5
9	E	Tamor Morang Diversion	113,743	70,000			117
	E.5	No Reservoir			45,497		
	E.6	Tamor 3 HPP			113,743	43,743	
10	E.7	Kankai Multipurpose	39,639	6,643	39,639	32,996	90
11	E.8	Chatara Barrage	66,482	47,993	66,482	18,489	
		Sub-total (East)	**572,128**	**294,525**	**561,253**	**266,728**	**284**
Grand Total			976,641	446,628	803,739	369,964	2,442
Selected Priority Projects Total			854,932	405,662	700,562	305,402	893

1 Net Irrigable Area (ha) from GIS
2 Existing Irrigated Area (ha) from Inventory (DoWRI, AFMIS, FMIS)
3 Available Water Area (ha) from MIKE model
4 3 - 2 = New Irrigated Area Scenario E4 limited to 171,500 ha

Karnali Diversion Project

206. The project would divert water from the Karnali River to Terai via a 19 km tunnel (design flow 59 m3/s) to supply additional water to an irrigable area of about 41,000 ha, of which 33,000 ha would be newly irrigated lands and 7,600 ha irrigated is already under the Khutia irrigation system. The project includes a hydropower Plant of approximately 80 MW. This system would cover the irrigable land between the ends of the Mahakali III project in the west, ending at the Mohana River to the Rani-Jamara-Kulariya project extending from the east at Kandra River.

Madi-Dang Diversion Project

207. The proposed development is for the diversion of water from the Madi River to the Dang valley via a 25 km tunnel (design flow of 24 m3/s), with a dam on the Madi River and hydropower Plant of 61 MW. It would supply sufficient water for irrigation to about 17,000 ha, of which a significant proportion falls under existing irrigation systems. This project was found to be uneconomical, however, the WECS RBP is reassessing the dam location with additional storage and alternative shorter tunnel, which may be more economical. This will have to be revised once the RBP is complete.

Naumure Dam: Rapti-Kapilbastu Diversion Project

208. The project would divert water from the West Rapti River to Kapilbastu for irrigating about 87000 ha. The remaining flow will flow downstream, augmenting water supplies to 15,000 ha already under Kapilbastu irrigation system command and new irrigable areas. The infrastructure includes: Naumure storage dam (169 m), regulation dam (13 m), hydropower station (approx. 343 MW), and transfer tunnels (23 km). Being economically feasible, this project is recommended in the short list of the Plan.

Kaligandaki-Tinau Diversion Project

209. The project comprehends transferring water from the Kaligandaki River to Rupandehi District, via a tunnel (25 km and design flow of 66 m3/s). There are two project options: (i) transfer tunnel only, with an irrigated area of about 31,500 ha, and (ii) addition of Andhikola storage dam with an irrigated area of 42,000 ha. There are five existing irrigation systems (Banganga, Char Tapaha, Sorah Chattis Kulo, Marchawar and Nepal Gandak) with a combined command area of more than 62,000 ha.

210. This is a trans-valley project, and as such would require agreement with India. The diversion needs to be compensated in the Narayani Valley by releases from the proposed Budhi-Gandaki Hydropower Project.

Kaligandaki Nawalparasi Diversion Project

211. The project would divert water by tunnel (approx. 6 km long with 17 m3/s design flow)) from the Kaligandaki River to irrigate approximately 11,500 ha in Nawalparsi-East District. The area is envisaged to be covered by groundwater or lift irrigation. The project also includes a small hydropower station of about 4 MW. This project is not a trans-valley diversion type, so no extraction compensation is required under the Gandak Agreement. This project has been found to be uneconomical.

Trishuli Shaktikhor Diversion Project

212. The project would divert water from the Trishuli River to Chitwan District, for which there are two options: (i) diversion tunnel only, with an irrigated command area of about 21,000 ha, and (ii) tunnel (18 km long with design flow of 51 m^3/s) and a storage dam (Budhi-Gandaki) which would increase the irrigated area to nearly 35,000 ha. The project has no hydropower component. The command area includes three existing irrigation systems: Khageri, Narayani Lift and East Rapti systems, with a combined irrigated area of about 13,000 ha. This project was found uneconomical and is not included in the Plan.

Sunkoshi Diversion Project

213. The project considers diverting water from the Sunkoshi River to Marin and Kamala Rivers for irrigation of 352,000 ha in Terai. There are four project options: Sunkoshi diversion to the Marin River via tunnel (14 km; 77 m^3/s), dam (16m) and hydropower station (MW 33) for irrigation of about 55,000 ha (the command area includes the existing irrigation systems of Narayani and Bagmati); (ii) Sunkoshi Kamala; diversion to the Kamala River via tunnel (17 km; 72 m3/s) for irrigation of about 129,000 ha (the command area includes the existing irrigation systems of Kamala D and Kamala S); (iii) Sunkoshi Marin + Kamala (with Dudhkoshi dam); is a combination with a dam on the Dudhkoshi River to increase water supply reliability irrigable area of 236,000 ha; and (iv) Sunkoshi Marin + Kamala (with Sunkoshi 3 dam); a combination with a dam on the Sunkoshi River, resulting in an increase in irrigated area to about 342,000 ha.

Tamor Morang Diversion Project

214. The project aims at diverting water from the Tamor River to the Chisang River in Morang District for irrigation. There are two project options; (i) tunnel only (31 km) and hydropower station, with an irrigated area of about 45,000 ha, and (ii) tunnel, hydropower station and storage dam, for irrigation of about 114,000 ha (with installed capacity of 117 MW). The Tamor 3 HPP reservoir would also provide power of 732 MW.

Kankai Multipurpose Project

215. The project would irrigate an area of about 40,000 ha in Jhapa District (which includes the command area of existing systems (Kankai Irrigation system). The infrastructure includes a dam on the Kankai mai River, of 85 m height, and hydropower station (90 MW). This project, besides social and environmental concerns, was found to be uneconomical, and hence does not fall under priority. Alternatively, irrigation by groundwater will be considered. The dam remains a stand-alone project.

Chatara Barrage Project

216. The project conceptualize constructing a barrage on the Koshi River at Chatara to provide water for irrigation to about 66,000 ha in Saptari District on the right bank. An additional benefit will be year-round supply to the existing system of Sunsari-Morang for 68,000 ha on the east bank. There is no hydropower component in it.

Seti-Pandul Diversion Project

217. The Seti Diversion project in the Karnali Basin with a tunnel of 42 km would generate 280 MW of power, and potentially irrigate up to 300,000 ha. However, this area is already covered by ongoing projects, Mahakali III and Rani-Jamara-Kulariya. This project has been found to be very expensive and cheaper alternatives are available, like the Karnali Diversion project, which can fill the gap between Mahakali III and Rani-Jamara-Kulariya projects.

218. The results of the cost benefit analyses of the above projects have been comparatively assessed for their relative ranking.

3.2.3.2 Calibrating Economic Viability of Large-scale Surface Water and Ground Water Projects

219. An alternative to multi-purpose projects and large-scale surface irrigation schemes, is groundwater development. Comparative assessments are necessary for ascertaining relative costs and benefits of the two strategies.

220. Economic investment and MOM costs for each of the MPP and large-scale surface water schemes recommended for implementation in IMP are compared against the investment and MOM costs required for groundwater development. At locations where the electric grid and is less developed, the investment costs for groundwater development t would be considerably higher.

221. Another issue is the proportion of the command area which can be developed by groundwater. The calculations assume that the whole command area can be developed, but this may not be so, resulting in a smaller project (when measured by NPV) than the alternative surface water development. In addition, a deep aquifer, more common in the upper Terai, will increase operational costs.

222. Even without taking into account these potential cost increases, the investment and replacement costs of groundwater (about USD 4,125/ha) compared with investment costs for the irrigation component of MPP (i.e. excluding the investment costs for hydropower) are overall 170% higher than surface water (about USD 2,440/ha, though this estimate assumes that upstream costs incurred for hydropower generation (dams, intakes, tunnels) are sunk. The estimated investment costs of groundwater development are consistently greater than the same for surface water in all proposed project areas.

223. The MOM costs for groundwater (USD 175/ha pa), which are typically 50-60% of undiscounted total costs, are also about 4.5 times greater than MOM costs for surface water (USD 40/ha pa); largely due to energy costs for pumping.

224. With respect to the costs related to the irrigation component of MPP (noting that Chatara Barrage would be developed strictly for irrigation, while Naumure MPP has benefits from both irrigation and power generation) groundwater development is more expensive option.

225. With the same benefit stream for groundwater and surface water, the economic indicators for groundwater development (represented by NPV and IRR in TBL) will be reduced compared with those estimated for surface water.

226. One argument for maintaining a similar benefit stream for surface water and groundwater development is that the surface water irrigation systems will provide full dry-season irrigation and thus would offer an improved irrigation service (in terms of adequacy, timeliness and reliability) equivalent to sourcing water from tube wells. However, at present productivity levels and prices, an additional ha under surface irrigation raises *Terai*'s net value of production only by USD 560, while an additional ha under groundwater or conjunctive use leads to an increase of USD 2,044. Benefits from groundwater irrigation are over three times greater. Notably, most existing surface irrigation schemes were designed and constructed only for supplementary irrigation.

227. The second argument is that since the future crop benefits calculated on the basis of future consumer demand over time at District level based on projections of total population and urban and rural dietary change as described in the IMP report[22], benefits would be defined

[22] Annex G: Investment and Economic Analysis; Part 2, Population and Food Demand for Irrigation Planning. April 2019

by the future food market size and be relatively fixed. Nevertheless, the counterargument is that given the improved irrigation services from groundwater over surface water, and with the diversification and increased value of cropping, the benefits will only increase. Thus, groundwater can result in an increased share in future crop benefits.

228. An account of the econometrics used to estimate this increased share is provided in this IMP. The future net incremental value of production by District (based on estimated future food demand generated by increased population, urbanization and disposable income) is raised by a coefficient, also calculated at District level that reflects the present contribution of groundwater irrigation in explaining districts' net value of production. Calculating for all Terai districts, this "groundwater premium" generates an incremental 30% value.

229. Also, tube wells can access available benefits more rapidly than the proposed surface water schemes, mainly because of much shorter construction time: a tube well can be installed within a season and benefits from tube well irrigation can be attained soon after commissioning. A 40,000 ha field of tube wells could be developed within about three or four years. In contrast, MPPs take six to nine years before delivering irrigation benefits. This earlier groundwater benefit stream can increase the IRR by one or two percentage points. Nevertheless, this advantage is insufficient to surpass the economic benefits from surface irrigation.

230. Despite these adjustments, groundwater irrigation remains slightly less-preferred economic development alternative compared to MPP for nearly all schemes analysed. If an MPP is congruent with national level hydropower production planning, it is suggested that the surface irrigation "by-product" of the MPP will be more economically attractive than groundwater irrigation. This argument holds for the proposed Chatara Barrage Project – constructed solely for irrigation use, where IRR is substantially lower than if the command area was developed by groundwater irrigation.

231. Finally, it must be emphasized that the cost and benefit streams on which these comparative assessments are based are at pre-feasibility level. Full feasibility study of each MPP will provide a more definitive picture.

3.2.3.3 Small-scale Ground Water Projects

232. Groundwater offers quick solutions for increasing irrigation coverage in the short term. This is because of its shorter construction time, smaller command areas and relatively low energy requirement. The key features of such projects are:

- Electric-powered submersible pumps, with variable speed drives;
- Piped distribution with the option for non-conventional irrigation, drip and micro-sprinkler;
- 40 ha command area, 4 blocks of 10 ha pre-paid meters, with discharge of 10 l/s;

- A smart card for ISF which covers electricity, demand charge, O&M plus an asset replacement fund for sustainability; and
- Total dynamic head of between 26.4 m to 31.4 m, and a pump power requirement of 20 kW per pump.

233. The advantages of the tube well irrigation against the surface water canal irrigation are:

- Water can be supplied on demand adequately, timely, reliably, and equitably at the requested locations with higher efficiency leading to higher land and water productivities;
- Quicker deliveries - time between requesting water and receiving is much shorter;
- With 10 ha command blocks, the WUA is smaller, with fewer users per block;
- With the pre-paid meter system, there is less potential of big farmers dominating the water supply - all pay equitably;
- Faster construction and commissioning; and
- Possibility for installing pre-paid meters aiding full cost recovery and sustainable irrigation.

234. The disadvantage of the Groundwater irrigation is that it costs 1.5 times more to construct, needs 1.29 MWh/year energy to operate, while surface water schemes can also generate power. The MOM of groundwater is 4.5 times more expensive than that of surface water, mainly due to the cost of energy and asset replacement.

235. Despite some drawbacks, groundwater holds a promising prospect for irrigation in Nepal. With more surface water schemes providing year-round irrigation, there will be enhanced groundwater recharge together with higher water logging chances, particularly in the south.

236. Flooding of the south of Terai is therefore a serious concern combined with higher water tables with more of water diversion schemes. This makes groundwater extraction in the south essential to keep groundwater levels down and reduce the risks of water logging, flooding and salinity.

3.2.3.4 Gravity and Pump Irrigation Projects for Hill and Mountain Areas

237. The LRMA study prepared a pumping suitability model originally for a head of 140 m with a radius of 5.0 km and a stream discharge of 30 l/s (based on the cumulative flow in GIS). Based on feedback from beneficiaries and DoWRI, these criteria were changed to a pumping head of 200 m, with a radius of 5.0 km, and a stream discharge of 60 l/s. This was intersected with the identified agricultural land and then classified according to the irrigable suitability.

238. For the hills and mountains, the total of 566,000 ha was identified as suitable for pump irrigation. These areas are also suitable for surface water irrigation. The distribution by class and ecological zone is given in Table 30.

Table 30: Results of IMP-2019 (Updated 2024) Pumping Suitability Identification

Districts	Sloping Terrance	Valley/Tar (S1+S2)	Valley/Tars (S3)	Level Terrace (S4)	Total
Total Hills	206,400	33,700	54,000	127,500	421,600
Total Mountain	80,000	500	4,600	59,300	144,400
Hills and Mountains	**286,400**	**34,200**	**58,600**	**186,800**	**566,000**

239. The Plan has divided the 566,000 ha into two categories:

(i) IMP-2018 GIS Identified Schemes

(ii) IMP-2018 GIS Classified Schemes

Category 1: IMP-2018 GIS Identified Schemes

240. The GIS identified areas of pumping suitability was used as a basis for visual identification of both gravity and pumping systems. The areas were confirmed using satellite images, and determining the pumping head, and command area. A total of 261 gravity schemes were identified covering an area of 93,847 ha and 92 pumping schemes for an area of 17,710 ha. The distribution by province is given in Table 31.

Table 31: Category 1: Summary IMP-2018 GIS Identified Schemes

Province	Gravity		Pumping		Total	
	No	ha	No	ha	No	ha
Koshi	66	27,550	25	5,972	91	33,522
Madhesh	45	29,951	-	-	45	29,951
Bagmati	70	17,059	20	2,477	90	19,536
Gandaki	17	3,071	35	6,859	52	9,930
Lumbini	8	1,357	3	329	11	1,686
Karnali	31	7,561	8	1,883	39	9,444
Sudurpash-chim	24	7,288	1	190	25	7,478
Total	**261**	**93,837**	**92**	**17,710**	**353**	**111,547**

Category 2: IMP-2019 (Updated 2024) GIS Classified Schemes

241. The pumping suitability identifies all agricultural land within the parameters set. These areas will include surface irrigation suitability, also classified into Class S1 to S4. The total suitable in Hills and Mountains is 566,000 ha. Deducting Category 1 from this total gives the remaining Category 2 land available:

Category 1	111,500 ha
Category 2	454,500 ha
Total Suitable:	**566,000 ha**

242. Therefore, the balance, Category 2 is 454,500 ha. At this stage, this is not differentiated into gravity or pumping, but identifies the approximate location and area of land available for future development. Supporting and complementary components for capacity building of stakeholders would be necessary in conjunction with the infrastructure development.

3.2.4 Prioritized Projects

243. From the consideration of the water availability, in all cases the addition of storage dams has greatly increased the irrigable land. In one case, the combination of two transfer schemes, Sunkoshi Marin and Kamala combined with storage dam Sunkoshi 3 gives the largest dry-season irrigable area, and is also the second highest ranking project. The combined irrigable area is 352,300 ha and the list of projects are presented in Table 32.

244. The Tamor-Morang transfer (E.5) covers only 45,500 ha of irrigable land with Run-of-the River scheme. However, adding the storage dam of Tamor 3 (E.6), the dry season irrigable area increases to 113,700 ha, by 250%, and puts this MMP at the top rank.

245. The Kaligandaki-Tinau transfer (C.2) does not reach its full potential with the Andikhola storage dam, with 42,000 ha only about 44% of potential. Other dam storage options, like the Kaligandaki-1 storage dam would need to be considered in future in more details in WECS RBP master Plan.

246. The Naumure Dam MPP gives positive net present value and is a potential project to irrigate the dry area of kapilvastu district.

247. The Karnali transfer scheme can bring 40,600 ha under dry season irrigation, filling a useful gap between the Mahakali Stage 3 in the west, and Rani-Jamara project in the east.

248. The Tamor-Morang transfer (E.6) would need to be combined with GW schemes in Jhapa District.

Table 32: Selected Projects for Implementation

Scenario	Project	Score	NPV (M NPV)	IRR (%)	New Irrigation Area	Rehab Irrigation Areas (ha)	Irrigation & HP Cost (M NPR/ ha)
E6	Tamor Morang 2 (Chisang)	113	120,963	14.3%	43,743	70,000	889.3
E4	Sunkoshi Marin & Sunkoshi Kamala SunKoshi 3 HPP	108	182,652	15.3%	171,500	169,889	2875.7
C2	Kaligandaki-Tinau transfer for full irrigation in Rupandehi 2, Andikola	88	151,100	16.5%	0	52,455	981.2
W6	Naumure Dam, Rapti Kapilbastu Diversion	59	36,550	11.4%	36,030	15,226	625.3
W4	Karnali Transfer to Kailali Irrigation	50	30,952	13.8%	32,996	7,632	644.1
W2	Bheri-Babai Transfer + Nalsingad Dam	48	41,974	16.7%	2,644	42,467	505.9
E8	Chatara Barrage	45	3,308	10.6%	18,489	47,993	279.9

Note: Total New Irrigation Area is 305,402 ha

3.2.5 Irrigation Management

249. Plans required for improving the irrigation service level, the management of irrigation system is grouped into following four components:

- Irrigation system modernisation
- Irrigation management transfer (IMT)
- On Farm Water Management (OFWM)
- Enhanced maintenance of AMISs and increased ISF collection

250. The first two components (modernisation and management transfer) would need an integrated approach. The other two components (OFWM and maintenance support to AMISs) focus mainly on building institution and knowledge base, can be implemented as standalone projects (or programs). If these latter components are merged with the infrastructure development components, their significance could be diluted during the implementation. Paragraphs below describe the proposed development Plan along the above four components.

3.2.5.1 Irrigation system modernisation

251. The aim of the proposed irrigation system modernisation is to enhance irrigation services and coverage by achieving the desired operational objectives. Besides the hardware aspect, all four components would need to be implemented together with institutional capacity building, both of the agency and the farmers.

252. In terms of targets for the IMP 2019 (Updated 2024), following objectives have been set:

- Rehabilitate about 50% of the existing FMISs (covering about 264,000 ha) during the IMP period, while the remaining 50% will be improved through targeted interventions. In addition, about half of the FMISs that would be rehabilitated will also be modernized (132,000 ha) with a focus on dry season irrigation.
- All exiting surface AMISs (400,500 ha), except those recently rehabilitated for management transfer (33,900 ha) under component B of IWRMP that totals 371,000ha will receive one time rehabilitation during this IMP period.
- Main system management of about two third of the above areas (245,000 ha) will be transferred to any of the four identified organizational entities. In addition, management transfer of lower distribution units (tertiary and below) will be transferred to respective WUGs (or WUA).
- Estimated total cost for different components of irrigation management improvement works is about USD 1069 Million.

<u>Modernisation of FMISs</u>

253. This master Plan categorizes the modernisation of FMISs in following three categories as presented in Table 33, which in turn will shape their support modalities. The DoWRI in due course will develop their support modalities.

Table 33: Modernisation categories of FMISs

SN	Modernization Category	Modernization Focus
1	Modernization of FMISs with a focus on dry season irrigation	Focus will be on dry season irrigation of high value crops, rather than earlier focus on wet season supplementary irrigation of monsoon paddy. Accordingly, innovative technological intervention will be promoted. Examples are piped canals, on farm reservoir, lift from adjoining rivers, semi mechanized drip / sprinkler irrigation and so on. The Water Resource Research and Development Center (WRRDC) under the MoEWRI has identified promising areas in hills and mountains that can be irrigated by solar lift systems.
2	Rehabilitation of FMISs	Rehabilitation will focus on increasing the efficiency of existing canal irrigation and thereby coverage under year-round irrigation. In FMISs, where expansion of command areas is likely, rehabilitation will require renovation of existing infrastructure with appropriate technology. However, where expansion of system area is not likely, rehabilitation will focus on upgrading of infrastructure with a view to increase cropping intensity.
3	Critical repair of FMISs	This will focus on providing support for critical repair (rehabilitation to bring back the system like before) of existing irrigation systems on sporadic basis. The works will be planned, designed, and implemented by provincial or local governments, possibly at relatively low costs. Its main objective is to maintain the present level of production, which otherwise may decline in absence of such support.

Modernisation of AMIS (or JMIS)

254. Modernisation of AMIS in Nepal will have following two principal sub-components:

- Undertaking deferred maintenance of irrigation system to enhance structural stability of its infrastructure; and
- Modernisation of irrigation system to enhance irrigation deliveries at all levels of irrigation system, irrigation efficiency and productivities.

255. The deferred maintenance of AMIS can be undertaken as per a normal maintenance/ rehabilitation procedure. Table 34 presents four processes of modernizing AMIS.

Table 34: Modernisation process

SN	Process: irrigation modernization	Description
1	Define project objectives	Design of irrigation modernization process will be shaped by the project objectives. For example, if the objective is to increase production per unit of land, a system will deliver irrigation water as per crop needs. While, if the objective is to achieve equitable delivery of irrigation water, a fixed proportionate system may be designed with limited flexibility.
2	Design canal operation modality	Canal operation modality is shaped by the likely water delivery schedule, which can be described in terms of its frequency, rate and duration at all level of irrigation systems. Accordingly, canal operation modality[23] needs to be designed considering: existing design of canal system; agro-ecological situation of the system area, and institutional capacity of water users and system managers for managing system operation.
3	Design control structures for modernization	Following the agreement on water delivery schedule and canal operation modality, existing design of key irrigation infrastructure (including control structures) needs to upgraded (or redesigned) for modernization. Such infrastructure includes: flow control structures (regulators, dividers, outlets etc.); flow measuring devices; canal configuration (if needed).
4	Actualization of modernization	Irrigation system needs to be modernized jointly or in parallel with other aspects of irrigation modernization like: regular maintenance; OFWM; institutional strengthening and capacity building; and management transfer. Subsequently, the modernized systems would need to be operated as per the designed canal operation modality under close monitoring.

3.2.5.2 Management Transfers

256. The main objectives of Irrigation management transfer in Nepal are:

- To relieve governments from continued financing of the maintenance of irrigation system by involving water users in irrigation management and thereby creating their sense of ownership over the system so that water users start financing irrigation maintenance; and

[23]Some such canal operation modalities are: (a) traditional proportional (delivery varies as per incoming flows), (b) arranged proportional: Intermittent full supply (e.g. structured irrigation system in Sunsari Morang Irrigation System, stage II or warabundi in India and Pakistan), (c) Demand based "on request": variable delivery (highly flexible system), (d) Arranged rotation: Intermittent full supply based on crop needs.

- To enhance performance of irrigation system by involving irrigation users in managing their own system.

257. Recognizing the ongoing irrigation transformation worldwide and considering the outcomes of the past irrigation management transfer projects in Nepal, the master plan aims to transfer management of AMIS to two organizational entities. While doing so, management of lower level of AMIS (usually tertiary canal and below) will invariably be transferred to the block level WUA, referred to as WUG[24]. Thus, formation and strengthening of WUAs continue to be an integral part of irrigation management transfer.

258. The management of the main system (main and branch canals) may be transferred to any of the following organizational entities, with a view to enhance reliable bulk delivery of water to WUGs.

- Local government
- Private operator under management contract
- Water users' cooperative (WUC)
- Agency-WUA joint management

259. It is to be noted that not all these organizational entities will be suitable for undertaking management of all irrigation systems. Their suitability will be shaped by the characteristics of the concerned irrigation systems and local contexts, which needs to be examined before proceeding on management transfer. Paragraphs below outline likely model for irrigation management transfer to above entities.

Irrigation management transfer to local government

260. As per the constitution of Nepal, the public irrigation systems (or their sub-systems) whose hydraulic boundary remains within the geographical jurisdiction of local governments may be transferred to them for their management.

261. In a situation, where the hydraulic boundary of an irrigation system falls within the geographical jurisdiction of more than one local governments, such a system will be managed in coordination of the concerned local governments. Depending on the needs, provincial government may play a coordinating role.

262. Weaknesses of this model are of two folds. First, irrigation system often crosses the administrative boundaries of local government. Second, local governments have so many other responsibilities. Despite these weaknesses, as local governments are more accountable to local water users, they can ensure that the irrigation management practices are consistent with the aspirations of the general water users.

[24]Objective of this transfer is to enhance water management at block level and allow WUG collect ISF from farmers by creating their sense of ownership over the system.

263. Further, transferring irrigation management to local government does not mean that the local governments themselves need to deliver irrigation service. Considering their other responsibilities, local governments will be free to decide management options on their own, which however need to be in line with the management transfer framework to be provided by the DoWRI at the federal level. The success of management transfer rests on the establishment of practical arrangements for financing operation and maintenance of transferred irrigation system. Local governments are in better position to ensure this.

264. Management transfer to local government will be supported by modernisation of irrigation system, OFWM, financing options for irrigation management, formation and strengthening of WUA, and capacity building of local government(s).

Irrigation management transfer to private operator under management contract

265. Involvement of private sector in irrigation management, especially in the form of management contract, is not new to Nepal. In many farmer managed irrigation systems, farmers have been awarding management contract of their irrigation system to private party. The private party can be a group of people either belonging to members of a household or a couple of likeminded people in the same village. This group undertakes regular maintenance of the canal, divert water from the source river to canal on daily basis, and deliver waters to farmers' field on agreed schedule and modalities[25]. Such an experience is not available in the case of Nepal's large-scale public irrigation system.

266. Scope of works of management contract will be limited to operation and maintenance of the main and secondary canal for a period of 3 to 4 years. In general, the private operator will keep the physical system intact and will deliver irrigation water to WUGs at tertiary inlets on agreed schedule. As in the case of other contract, the government will pay the agreed amount to the private operator for the service rendered on monthly basis or as agreed. The contract and the process will be supervised jointly by both the government (DoWRI) and the concerned WUA.

267. Presently, the DoWRI is mobilizing civil work contractors for the annual maintenance of the main and secondary canals. Similarly, a group of short-term operators are recruited for operating the system during irrigation seasons. Essentially, services for both the activities – maintenance and operation – are being procured on contractual arrangement. However, there exists no relationship between the two service providers. The maintenance contractor is not responsible for operational difficulties due to poor maintenance. Similarly, operators do not care for likely increase in maintenance needs due to poor operation. In any hydraulic system, as both these activities – operation and maintenance – are interrelated, a private operator can come up with a cost-effective solutions. Thus, in totality, the O&M cost is likely to be reduced with increased reliability of irrigation service delivery in time and space.

[25]Water users pay them in commodities, mainly food grains. Thus, operators in turn can maintain their livelihoods.

268. Further, as delivery of water in time and space will be within the scope of works of the private operator, such deliveries will be systematically documented, mainly for contractual reasons. Presently, in the existing DoWRI-WUA joint management arrangements, such deliveries are not documented as there are no contractual or financial obligations envisaged.

269. Management transfer to private operator requires that such an operator (or company) exists in the country. Although there are several professional (engineering) companies and NGOs providing agriculture related services, such irrigation operators are presently non-existent. Thus, private sector institution building will be one main component. Further, transferring irrigation management to private operator will involve essential structural improvements to support the management contract. As this is a new approach for Nepal, it may be implemented on a trial basis in a couple of medium scale irrigation systems.

Irrigation management transfer to water users' cooperative (WUC)

270. Water users cooperative (WUC) is one of the documented organizational entity to whom irrigation management can be transferred. FAO 58 (1999) notes that transfer of irrigation management to WUC is most suitable for small-scale irrigation systems or sub-systems, where management requirements are relatively simple and non-intensive.

271. In Nepal, as conventional mode of DoWRI-WUA joint management has not been that successful compared to the designed expectation, irrigation management transfer to WUC is being advocated. This advocacy is further supported by the provision made by the draft Irrigation Act (2015)[26] that would allow WUAs to transform themselves to irrigation water user cooperatives under the Cooperative Act. Its main objectives are to ensure better access to government support and external donor funded assistance.

272. The WUCs will be the general cooperatives of irrigation water users. Unlike WUAs, which tend to be a semi-formal organization with no legal authority to apply sanctions and enforce rules, irrigation cooperatives will be more formal organizations that can effectively perform both the governance and management functions.

273. Farmers' cooperatives have been successful mainly for production industries like dairy cooperative, vegetable cooperative and so on. Irrigation being a service industry, success of such cooperatives is yet to be documented. This Plan suggests that irrigation cooperatives would not only look at irrigation management, it would rather have much broader responsibilities to handle and manage crop production, coordination of the use of fertilizers, marketing, transport of agricultural goods and sales to consumers.

274. As irrigation management transfer to WUCs is a new approach for Nepal, it may be implemented on a trial basis in a couple of medium scale irrigation systems, preferably

[26]The draft Irrigation Act (2015) was prepared and approved by the then Ministry of Irrigation and was placed before Parliament. This has not been enacted as of now and has become outdated in the context of new federated structure of governance in Nepal.

in mechanised systems like pump schemes in the hills. Further, management transfer to WUCs will be supported by modernisation of irrigation system, OFWM, and institutional capacity building of WUCs.

Irrigation management transfer to DoWRI-WUA joint management

275. Most large scaled AMISs in Nepal are operating under the joint management model. The IMD (as DoWRI representative) manages operation and maintenance of the main system in coordination with the concerned WUA. The concerned WUA provides field level information on cropped area, crop type and so on to the IMD for each irrigation season. The IMD prepares canal operation Plan, and operate the main system accordingly. The IMD is responsible for delivering water at each tertiary inlet (management terminal point), which is monitored by WUA.

276. The WUA (or WUG) in turn takes responsibility of managing irrigation within the tertiary command. Management activities include water allocation and distribution; coordinate with concerned farmers; maintaining tertiary and field level canals; and ISF collection from farmers.

277. Unlike management transfer to the first three organizational entities noted above[27], the DoWRI-WUA joint management mode of irrigation is considered promising for managing large-scale irrigation systems mainly due to their technical complexity. However, management of main system by IMD (or DoWRI) has not been that reliable and efficient due to several reasons, which in turn is undermining performance of irrigation management by WUA at lower level.

278. This master Plan proposes to continue irrigation management transfer to the DoWRI-WUA joint management mode as one of the options. However, management modality of the main system will follow a performance-oriented management with well-defined performance indicators and regular monitoring systems. The management modality will also include appropriate incentive systems for rewarding the outstanding services provided by IMD water managers and members of WUA.

279. Management transfer to DoWRI-WUA joint management mode will be supported by modernisation of irrigation system, OFWM, and formation and strengthening of WUAs.

Formation and strengthening of WUAs for irrigation management transfer

280. Irrespective of the organizational entities selected for management transfer of the main system as outlined earlier, management of lower level of distribution system (usually a block of 100 ha or less irrigated by a tertiary canal), will invariably be continued by the concerned WUA (or WUG). In Nepal, they are formed under society registration act, and

[27] Local government, water users cooperative, and private operator.

they can be registered with the government either at the office of Chief District Officer (CDO) or at concerned irrigation division.

281. The hierarchies of canal networks in any irrigation systems shape the tiers of water users committee required to manage them. The committee at lower level of irrigation system – a block consisting of 100 ha or below irrigated by a tertiary canal – is usually termed as WUG, while the committee at the level of main system is termed as WUA. Depending on the hierarchies of canal network, branch level WUA or sub-system level WUAs also exist. The formation of WUA would start from the lowest level to allow adequate representation of farmers at their higher level organization.

282. Functions of WUA and its subsidiary committees in any irrigation system are shaped by the management transfer agreement of the concerned system. Below are some of the key functions of WUA / WUG in many IMT projects.

283. WUG will be responsible for all water management activities on its own within the block. Activities include water allocation, water distribution, canal maintenance, collection of ISF, resources mobilization for maintenance, etc. The WUG in turn receives irrigation water on agreed schedule and quantum at the respective delivery points by the upper level.

284. WUA and its subsidiary committees at higher level of canal system (above WUG) are responsible for: (a) providing basic information to the agency (DoWRI) in designing canal operation Plan; (b) support agency (DoWRI) in participatory irrigation management; (c) monitor canal operation and irrigation management activities; (d) liaison with farmers; and (e) maintain closer linkage between irrigation and agricultural development, and value enhancement.

Performance of WUAs

285. Recognising the fact that lack of legal authority is one of the main reasons why WUAs are not able to collect ISF from farmers, though they are authorized to do so through IMT agreement. In the changed political context (federated structure of governance), a revised irrigation act will be needed to resolve this.

286. The master Plan proposes the following strategies for enhancing performance of WUA and its subsidiary units:

- Empower WUA (WUG) legally: WUG would be the focal institution for exercising legal authority. For this, WUGs may be registered with the local government for governance support. Accordingly, local government would empower WUGs with required authority. One such approach is to make WUG recommendation mandatory for any business transaction of agricultural land (for taking loan against land, purchase / sell of lands, payment of land tax etc.).
- Enhance capacity of WUAs through trainings.
- Assist formation of robust, user-governed and well-functioning WUAs.
- Support WUAs for enhancing coordination between agriculture, irrigation and other value enhancement sectors at local levels.

3.2.5.3 On Farm Water Management

287. On Farm Water Management (OFWM) refers to management of water within a tertiary command[28] with an objective of enhancing its irrigation efficiency therein. It integrates management of main system (main and branch canals) with in-field water management for crop production at farmers' field. In a tertiary command, water users collectively manage water up to farmers' field; while management of water within farmers' field (for crop production) is shaped by individual interests. Thus, OFWM is shaped by both the collective and individual actions and includes multiple activities.

288. Some of the common activities of the OFWM are: (i) water allocation and distribution within tertiary command, (ii) maintenance of tertiary canal and below and upgrade to pre-caste parabolic canals, (iii) agricultural practices and water uses for crops in farmers' field, and (iv) related organizational activities within tertiary command (decision-making, resources mobilization, dispute resolution etc.).

289. OFWM is one of the most important components of irrigation development that links irrigation with agriculture development. OFWM mainly focuses on building institution and knowledge base on improved water management and agronomic techniques. This component would be implemented as a standalone project (or program). If merged with the infrastructure development component, its significance will be diluted during implementation due to several practical reasons.

290. OFWM needs to be implemented in all areas of irrigation development like AMISs, FMISs, tube wells and even private irrigation. In any area, activities of OFWM would be started with diagnostic assessment[29] of the concerned system or subsystem that helps determine its detailed activities. Program on "On Farm Water Management" will includes following activities:

- Capacity building of agency personnel, water managers and farmers;
- Improving O&M of tertiary canals including essential infrastructure development within tertiary command, by installing pre-cast parabolic tertiary canals;
- Land levelling and improved irrigation methods;
- Demonstration of improved OFWM and agronomic techniques;
- Infrastructure support for water augmentation: farm storage, solar powered tube wells etc.;
- Capacity building of Engineers, WUAs and farmers; and

[28]Depending on the existing landscape, a tertiary canal usually commands an area between 30 and 100 ha or less.

[29]Diagnostic assessment is a process in which a set of PRA techniques are used to help understand the agronomic, engineering, managerial, and socio-institutional aspects of an irrigation system or its parts with a view to design detailed activities of OFWM.

- Improving O&M of tertiary canals and essential infrastructures.

291. The proposed OFWM component helps developing a site-specific O&M Plan for each tertiary canal in a participatory approach. Such Plan covers all cropping cycles of a complete calendar year. The O&M Plan usually includes:

- Calibration of tertiary inlet structure for time series measurement of incoming flows;
- Water distribution schedule within the tertiary command;
- Monitoring actual operation of water distribution within tertiary command; and
- Maintaining tertiary canal and resources mobilization.

292. Preparation of participatory O&M Plan also helps in identifying essential structural improvement works that are required for achieving equitable distribution of waters. Likely structural improvement works may include:

- Field channel within tertiary command area (extent and alignment);
- Field channel structures like division box, farm road crossing, and drainage crossing;
- Drainage channels and its structures; and
- Flow measuring structure at the tertiary inlet where calibration of existing structure is not feasible.

3.2.5.4 Improving ISF Collection

293. Table 35 presents a Plan of action for enhancing collection of ISF. The Plan of action will be detailed out by the DoWRI while implementing this master Plan, which will be supported by a federal level project for enhancing collection of ISF.

Table 35: Way forward for enhancing the collection of ISF

Causes of Poor Collection of ISF	Plan of Actions
Poor service delivery and hence little incentive to pay ISF	Enhancement of irrigation service delivery through various models of irrigation management transfers Transparent and well-publicized regime of setting tariffs and charges which linked to the level of irrigation service Agreed mechanisms, involving WUAs, DoWRI and local government, for monitoring irrigation service performance Local implementation (of nationally agreed formulas) to ensure local conditions reflected in irrigation fees Equitable water distribution to encourage all WUA members to pay
Lack of legal authority for WUA to enforce rules of irrigation management and ISF collection	Register WUAs with local government for governance support Establish bylaws and other supporting legislations/rules to uphold principles of payment for irrigation service Support WUAs in institutionalizing irrigation rules and concept of "service – for – fee"
Inadequate capacity of WUAs (or WUGs)	Enhance capacity of WUAs (or WUGs) in all aspects of ISF collection
Payment avoidance by some influential members	Define the legal basis of WUAs for setting fees in relation to service and its collection A graduated system of sanctions in place to realize payments Legal action to collect arrears
Lack of incentive to pay ISF	Incentive to pay by ensuring adequate levels of service provision Clear agreement about the set of exceptional circumstances under which ISF may be waved or reduced at the farm level
Current system of fee collection involves high cost and low collection efficiency	Involve WUAs in fee collection on an incentive-earning basis Create legal and procedural basis for delegated fee collection by WUAs/ local government agencies Allow partial retention of fee by fee collectors to provide incentives for improved collection

3.2.6 Land levelling and land consolidation

294. The Master Plan proposes to promote laser land leveller for levelling individual's lands in irrigation systems. Laser leveller is a one such proven technology that is highly useful in conservation of irrigation water. In terms of its advantages, laser land levelling saves irrigation water by 25 to 30% and improves crop establishment and uniformity of crop maturity, which in turn will increase crop yield by 10 to 20%.

295. Though the laser land levelling is a proven technology, individual farmers cannot afford to use this technology for levelling their lands. Further, this activity provides benefits to individuals rather than the community. Therefore, until the private sector become capable in providing land levelling services at low costs, it is proposed that the government procures a couple of laser land leveller and handover the equipment to WUA for providing regular land levelling services to its users. The WUAs will then provide such services to users at subsidized rate following a pre-set guidelines.

296. Farmers commonly own two or more adjoining plots, but not at same levels. In such a situation, as in the case of laser land levelling, adequate support, including subsidy, needs to be provided to individual farmers at subsidized rate for consolidating their lands into one larger plot for enabling them to use farm machinery aiding efficient uses of water.

3.2.7 Infrastructure support for water augmentation

297. Most irrigation systems in Nepal are run-of-the river system. Thus, water scarcity is inevitable mainly during dry season. Several low-cost proven technologies are available to meet address this that benefit individual farmers. Certain subsidy mechanism needs to be established for their utilization at larger scales. Some such technologies to be supported under IMP are:

- Farm ponds;
- Solar powered tube wells; and
- Semi mechanized drip irrigation, and other applied innovations in the field.

3.2.8 Maintenance of major hydraulic structures

298. Irrigation infrastructure like barrage, major weirs, tunnels, pump house, big syphon etc. can be categorized as major hydraulic structures and their maintenance will be planned separately. Maintenance these are complicated structure require thorough understanding of their hydraulics and specialized technical skill. It is thus proposed that a technical unit will be established at federal level (may be DoWRI) for maintenance of major hydraulic structures in the country. This technical unit will create an inventory of major hydraulic

structure covering both the AMIS and FMIS, develop guidelines for their maintenance Planning, undertake their periodic maintenance[30] in coordination with the project office, and document success and failure stories of maintenance. The concerned project office will however undertake their regular maintenance[31] following the guidelines provided by the major hydraulic maintenance unit at federal level.

299. As maintenance of such structures are beyond the technical and financial capacity of users, their maintenance will be undertaken solely by utilizing the government funds. Concerned WUAs will however be involved in their maintenance.

3.2.9 Maintenance of general irrigation infrastructure

300. All irrigation infrastructure that do not fall within the category of "major hydraulic structure" will be considered as general irrigation infrastructure, and their maintenance will be undertaken under a systematic maintenance Planning process. Paragraph below presents its concept and activities needed for maintenance planning is presented in Table 36.

Table 36: Activities of maintenance Planning (or preparing AMP)

Irrigation asset survey	Carrying out systematic inspection of structures, canals and mechanical parts of an irrigation system to identify their physical and functional state, and subsequently maintenance requirements
Maintenance Categorization	Categorizing maintenance requirement in terms of (a) routine or regular maintenance, (b) periodic maintenance, and (c) emergency maintenance
Maintenance Prioritization	Identifying priorities so that maintenance can be Planned and budgeted. Detailed guidelines need to be developed. A couple of general guidelines for deciding maintenance priorities are: The larger the impact on water delivery due to targeted infrastructure, the higher would be the maintenance priority. The higher the probability of structural failure due to lack of maintenance, the higher would be the maintenance priority.
Cost estimation and benefit assessment	Preparing cost estimation based on agreed prioritization Simultaneously, assess likely coverage of irrigated areas, crops to be grown, likely benefits from agriculture, and contribution to maintenance from the incremental benefits from agricultural benefits
Budget approval	Approval of maintenance budget based on their agreed prioritization
Survey & design	Detailed survey, design, and procurement of maintenance contractor

[30]Periodic maintenance works are not required to be done regularly but needs to be undertaken in a cyclic manner at an estimated schedule. Periodic maintenance encompasses those large and medium repair works that require greater resources. Such works usually require detail Planning, engineering design, drawings, detail cost estimates, and close supervision of maintenance execution. Some periodic maintenance works are major repair of structures; replacement and addition of structures; replacement of steel gate plates, spindle, and bushes.

[31]Regular maintenance includes all works necessary to keep the infrastructure functioning satisfactorily. The work generally involves greasing of gate spindles, removal of silt / debris from structures, small repairs, painting structural steel etc. Regular maintenance is the most critical and cost effective maintenance activities, since small repairs identified and carried out at early stages would prevent major problems later.

Maintenance execution	Carrying out the maintenance / modernization activities
M&E and technical audit	Maintenance categorization, prioritization, and budgeting will be monitored and evaluated. Likewise, their technical audit will be conducted following a procedure to be developed by DoWRI.

301. Maintenance Planning (or asset management Plan): Maintenance Planning is a process that starts from defect identification to pre-maintenance task. In recent years, aspects related maintenance Planning of an irrigation system has grown into a thematic area of "asset management Plan[32] (AMP)." Principle objectives of irrigation system maintenance (or asset management) are:

- To upkeep the system to allow optimal delivery of irrigation waters in time and space; and
- To minimize deterioration of structures, canals, and their movable mechanical parts to the extent that they last for their economic life.

302. The maintenance Planning (including budgeting) and execution procedures will be applicable to all the AMISs or JMISs irrespective of their modes of management transfer. Its detailed guidelines and procedures will be developed by DoWRI, which will then be institutionalized throughout the country through a federal level "irrigation maintenance improvement program (or project)". A process of technical audit of maintenance Planning and execution will be mandatorily established.

3.2.10 River Basin Planning

303. Irrigation would be planned, operated and managed in a river basin context – that is, one that considers the hydrological boundaries as the most appropriate Planning unit[33].

304. Modern strategic river-basin Planning needs to address increasingly complex water challenges, including climate change adaptation and disaster risk management. Moreover, river basin Plans need to recognize national water resource policies and, at the same time, inform and incorporate local and provincial Plans and policies. It encompasses, besides technical aspects, socio-economic and environmental concerns.

305. Various water resources projects, implemented on a conventional sectoral project-by-project approach has several limitations and deficiencies. With a river basin approach, many related sectors/ sub-sectors like hydrology, climate, ecosystem, floods and droughts,

[32]Asset Management Plan (AMP) has its origin in finance and business sector, and it is now applied to irrigation sector as well. In infrastructure sector, asset management comprises of several activities like regular maintenance, rehabilitation (upgrading), modernization or replacement with new technologies, and disposal of assets. All these activities include costs, and its integrated activities are termed as asset management Plan.

[33]River basin Planning is a process of strategic Planning by which decisions are made over the competing uses and different demands for water resources and associated systems within a basin. Basin Plans set a vision and objectives and the measures for developing, protecting and harnessing the resources of the basin in order to achieve these objectives and health and safety of the river itself.

erosion and sedimentation, hydropower production, irrigation, and upstream and downstream linkages, among others, can be considered in their totality.

306. Proper harnessing of available water resources through a river basin Planning and management approach could increase agricultural and hydropower productivity. This would need comprehensive and reliable scientific data/knowledge base of water resources in a given river basin. Likewise, both current and future scenarios of the concerned basin need to be well explored. By projecting the basin's future state with a reasonable degree of confidence, the drivers of change can be identified and guided to ensure positive impacts.

3.2.11 Capacity Development

307. Frequently, lack of required institutional capacity has been pointed out to be constraining the development and improvement of irrigated agriculture, both in rural and urban areas. This also holds true in management transferred schemes, which would need a restructured partnership among farmers, government and the private sector in the regulation, provision, financing and utilization of irrigation services to sustainably achieve desired reforms.

308. Building the capacity of the federal (MoEWRI, WECS and DoWRI), the provincial governments, local municipalities and WUAs and possibly also farmer cooperatives through on-the job training and formal training package on irrigation service development and management will be crucial to ensure the sustainability of the investments made under this master Plan.

309. At the WUA level, capacity development would make the WUAs capable of managing irrigation infrastructure under their responsibility technically, financially and institutionally.

310. Capacity development, besides enhancing the knowledge and skills of individuals, also involves creating robust and cost efficient institutions, both in terms of rules and tools.

311. Related initiatives would also include: (i) design and construction of irrigation infrastructure; (ii) MOM of those infrastructures; (iii) disaster risk management (Planning, response, and recovery); (iv) irrigation development initiatives adaptive and resilient to climate change; and (v) entrepreneurship development of farmers.

312. Target groups would include MoEWRI and DoWRI at federal level, MoPID at province level, local governments and WUAs at local level, and sectoral agencies related to agriculture, environment, forestry, and watershed and soil conservation at national, province and local levels.

3.2.11.1 Federal level

313. Recognizing the need for synchronized and integrated river basin Planning and management under the federated administrative arrangements, WECS would disseminate the guiding principles for river basin Planning and management in line with IWRM principles to all the concerned, including RBOs. WECS, with suitable restructuring, would pursue: (i) sector-wide capacity building; (ii) designing and implementing social, environmental and safeguards; (iii) exploring and responding to likely impacts of climate change and disasters;

(iv) instigating needed policy reforms; and (v) compiling and maintaining a comprehensive database at province level.

3.2.11.2 Provincial level

314. The provinces in due time would gradually gain expertise and assume their respective roles in (i) river basin Planning as per the guiding principles; (ii) social, environmental and safeguard management; (iii) responding to the impacts of climate change and disaster risk management.

315. Two or more provinces sharing water from a given river basin would need mutual cooperation, shared vision, Planning, and water management to address competing water demands. WECS may instigate and facilitate such initiatives.

3.2.11.3 Local government level

316. Capacity deficiency, in terms of knowledge, skills, and staffing, at local levels is recognized, particularly in irrigation sector. Local government staff would need capacity building support from provincial and federal levels particularly to: (i) oversee the management of existing systems; (ii) Plan for effective and efficient rehabilitation, expansion and implementation of new systems; and (iii) ensure sustainability through efficient and effective cost recovery for management, operation and maintenance.

317. Staffs at municipality level would need capacity to:

- mobilize and facilitate farmers at distribution canal level;
- ensuring efficiency and effectiveness in water delivery within their boundaries;
- train staff and WUA members in different technical and managerial aspects of system O&M;
- assist in preparing action Plans of WUAs for equitable distribution of water and maintenance of channels, with minimum irrigation service fees; and
- Encourage and facilitate private sector service providers in acquiring necessary knowledge and skills required for O&M of irrigation systems to help increase farmers' productions and returns from irrigated agriculture.

3.2.11.4 WUA Level

318. Training for WUAs/WUGs would be needed in: (i) basic organizational management issues such as their roles in irrigation management; (ii) preparing action Plans for O&M of irrigation and drainage system; (iii) rules, regulations and bylaws of their WUA or WUG; (iv) provisions of the IMT agreement; and (v) basic financial management, including maintenance of proper records including minutes book, cash and receipt book and so on.

319. Effective irrigation asset management Planning would be needed to break the cycle of neglect of proper O&M and consequently, replacement at a high cost.

320. Conflict management capacity of WUAs/WUGS would need to be improved to resolve:

- disputes in irrigation systems resulting from water use activities and resource mobilization;
- dominance of influential members over economically and socially disadvantaged members;
- issues of shifting of upstream intakes closer to downstream ones;
- unfair claims for share water;
- conflicts on water rights with upstream systems;
- users' reluctance to participate in maintenance and repair works;
- arrear irrigation service fees;
- Undue political influences in WUA/WUG.

321. Taking cognizance of fact of poor financial management at WUA level, key members and staffs of WUG/WUA would also need comprehensive trainings, including Training of Trainers, on basic book keeping, basic financial management measures, Planning and budgeting for small specific projects, internal control, audit requirement, etc.

322. A synergetic support policy and legal environment would be crucial to the sustainability of WUAs. Government's policies for administrative and financial decentralization have provided the impetus for many management transfer programmes which undermine the role of the province and expand the role of WUAs. Ensuing conflicts would need to be addressed through articulation of policies and laws at province and local levels.

3.2.12 Prioritized Research and Development Areas

323. Research and development, including technology adaptation, would form an integral part of IMP. This needs to be a prime function of the federal government, i.e., MoEWRI, DoWRI and other think tank institutions like WECS. This would include; designing legal and organizational frameworks; and setting suitable standards for designing, constructing, operating and maintaining irrigation projects, both at province and local levels. The knowledge gained and lessons learned would enrich capacity-building initiatives.

324. The following are four priority areas for research for improving irrigation and agriculture practices in line with IWRM, agricultural development strategy, and climate change adaptation. Each of these priority areas consists of a number of sub-themes and issues worth examining.

<u>Irrigation and agricultural practices</u>

325. *Integration of irrigation, agriculture and conservation:* Irrigation is just one of several inputs in the overall agricultural sector value chain. Close interaction is required to ensure sustainable development and management of water resources and agriculture with cross-

cutting environmental issues. Particularly in the context of federal mode of governance, a pilot intervention in a system with close integration of all above sectors would establish a basis replications elsewhere and upscaling.

326. *Index-based crop insurance coverage:* Crop failures are often attributed to man-made and natural disasters, exacerbated by climate change impacts. Consequently, farmers become unable to pay back loans, falling into "debt trap" for years. To avoid this, the prospects of institutionalizing an index based crop insurance would need to be explored at selected sites.

327. *Appropriate use of water, fertilizer, seeds and other agricultural inputs:* For enhancing productivity from irrigated agriculture, appropriate use of water together with timely provision of fertilizer, improved seeds and other agricultural inputs are essential. Experimental researches on soil testing and recommending specific crop/seed, fertilizer and proper mixes would be desirable.

Management of Irrigation

328. *Pilot on functional "tar" irrigation system to benefit upland areas.* Providing irrigation water to tar[34] areas in hills may substantially improve local food security the socio-economic status of local farmers. Some pilot initiatives for increased water efficiency together improved agricultural practices may be undertaken at selected places to learn lessons.

329. *Quality assurance and harmonization of irrigation system development and MOM:* Besides inferior design, quality assurance in development and/or during construction of irrigation schemes has often been a challenge. Further, MOM activities also need to match the design and construction. Experiences show that a user group's involvement from the early stage of the project cycle helps mitigate these shortcomings. Mobilization of community-based Question and Answer teams can be experimented in different settings for initiating appropriate measures.

330. *Irrigation service fee system for sustainable MOM:* Irrigation water is an economic good that needs to be purchased by users. In Nepal, irrigation service fees generally are fixed quite low, insufficient even to fund regular MOM of the system in most cases. Continued use of the taxpayers' money for subsidized is unsustainable and hard to justify. So, irrigation service fees need to be reviewed periodically.

331. *Practical modality of sustainable MOM of irrigation systems:* Most irrigation systems in Nepal are built by the government through funds mobilized internally or from external sources. Generally, MOM is being carried out and paid for by the government, also in some transferred systems. Experiments of fully self-supporting MOM initiatives supported by

[34]The big terraces and plains land developed in alluvial fans in the process of river changing its course in hills are called "tar" in local dialect in Nepal.

full ownership of the assets would help explore the prospects and constraints so as to relieve the financial burden of governments at each level.

332. *Exploring potential for private sector participation:* Experimental research on certain PPP-based irrigation projects can be value-adding exercises.

Social development in irrigation

333. *Effective participation of women and other disadvantaged users in MOM:* To ensure women's participation in irrigation systems, some existing regulations require a WUA to have at least 33% females among its members. However, in most cases, it has been found that women's role in Planning and management, particularly in decision making, is rather weak. A series of research works in this area will help generate new knowledge and validate the existing ones, feeding into future reform initiatives at all levels.

334. *Maximization of returns from irrigated agriculture:* Increased incomes from irrigated agriculture, greater responsibility of farmers in financing O&M of irrigation systems, and transforming WUAs into water user cooperatives are key aspects which may help improving agricultural practices supported by crop diversification, higher cropping intensity, improved seeds and fertilizers, superior harvesting, better storage techniques and swifter access to markets. All these constitute a number of areas/ themes worth researching and disseminating the generated knowledge for various reform purposes.

Water resources and watershed management

335. *Rejuvenating irrigation:* Nepal's irrigation sector has hardly changed its developmental paradigm for over 60 years – that is, public fund is used for capital investment, combined with public management and supply of water resources to farmers at highly subsidized rates, with little considerations to financial viability and physical sustainability. Several already constructed systems are falling in despair. It is high time to revisit this general approach and consider other options, in line with the concept of participatory and integrated river basin Planning. Research on different possible modes of revitalizing irrigation is needed that can help make positive changes.

336. *Healthy watersheds:* Watersheds are under increasing threats due to haphazard urbanization, unPlanned industrial and processing activities, deforestation, together with pressures emanating from climate change. The linkage between the irrigation system development and watershed management has largely been overlooked. Developing some pilot projects where these two interdependent components are closely linked would be desirable.

337. *Mainstreaming climate change adaptation in irrigation Planning and management:* Rapidly retreating glaciers, rises in temperatures, erratic rainfalls and increased incidences of extreme events such as floods and droughts are some of the effects of climate change Nepal has been facing during the last few years. It is necessary to adapt to these changes and reduce their adverse impacts on lives and livelihoods to the possible extent. Irrigation Planning and management must mainstream climate change adaptation and integrated flood management by undertaking various research studies.

338. *Sustainable storage development in the Greater Himalayan Region:* The knowledge gap concerning sustainable water storage will have to be addressed through fresh research studies. Such studies may include: potential utilization of water storage in the Greater Himalayan region to address climate change issues; harnessing natural systems in the biosphere through initiatives such as wetlands conservation and improved watershed management in hills and mountains; groundwater aquifer recharge in the foothills; and developing small ponds and tanks for rainwater harvesting built on hill farms and around hill communities; construction of large reservoirs on the downstream plains.

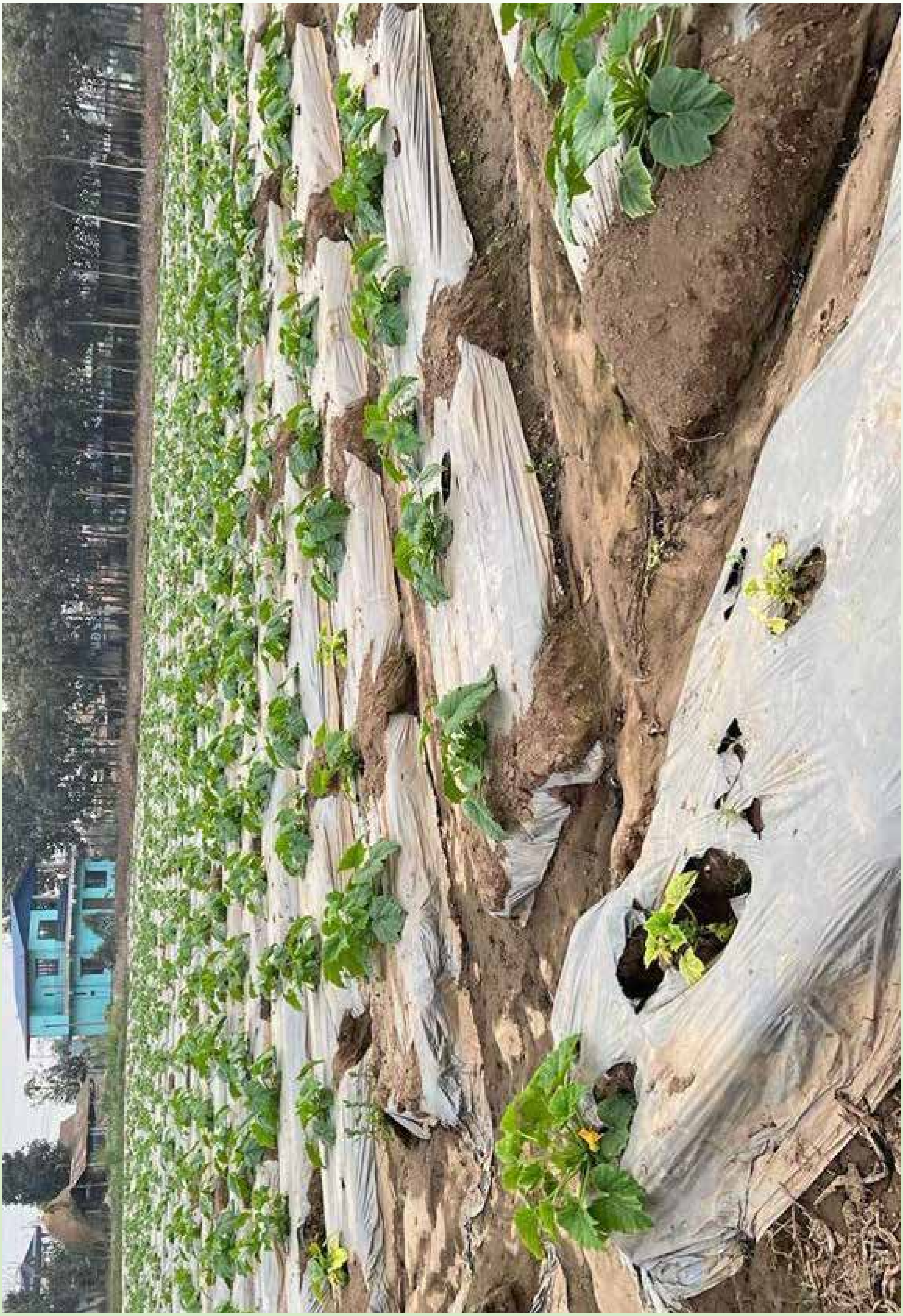
339. *Water to protect the environment and biodiversity:* Water erosion and silting have significant impacts on river basins, downstream flows, biological balances, natural ecosystems, habitats and all socio-economic activities. These phenomena, amplified over time with recurrent floods, have weakened the biodiversity and living conditions of the populations of the river basins. Various adaptation actions might be required to increase the capacity to preserve and ensure the sustainable management of natural resources, which can be supported by relevant research studies.

3.3 Provincial and Local Government Level Plans

340. Province, now being responsible for its development, is expected to develop its own irrigation master Plan. Subsequently, the project duration was extended to allow the preparation of independent provincial master Plans, cutting up the relevant information by province, and presenting them to each province. It would be desirable to get the IMP out to the provinces at the earliest allowing them to have a say in its development.

3.4 Consultation and Conflict Resolution

341. The need for mutual interactions between provinces, particularly when inter-boundary transfer or projects are concerned, is obvious. Provinces that have a source of water or hydro-power would claim a share from the benefitting irrigation projects, as in the Sunkoshi-Marin diversion project. Also the Kaligandaki-Tinau diversion, and to some extent the Karnali diversion would require inter-province interactions and understandings in the coming years as the federal system evolves.



Vegetable farming, Groundwater Irrigation Project, Chitwan

SECTION IV: FINANCING IRRIGATION MASTER PLAN 2019 (UPDATED 2024)

4.1 Prioritised Large-scale Projects

342. Based on economic analysis and ranking of all projects, 7 large-scale projects (6 MPPs and 1 Barrage Project) have been identified for financing with priority. The following implementation Plan lays out the timeline for these projects as outlined in Table 37.

Table 37: Major Prioritized Projects

SN	No.	Project Name	Total Hydro, 2018 Financial Cost (NPRm)	Total Irrigation Development (Net Costs) NPR m	Total Hydro+Irrigation, 2018 Financial Cost (Million NPR)	Total 2018 Financial (Million NPR)	Total 2018 Financial (Million USD)	Total New and rehab irrigated area (ha)	MOM Hydro (US $ m) 1.5%	MOM Irrigation (US m) 2.5%	Total MOM (US $ m)	Years of MOM Costs year	Total MOM Costs (US $ m)
1	E6	Tamor Morang Transfer with Tamor 3 Dam MPP	164,096	22,293	186,389	272,687	2,351	113,743	21.22	4.80	26.02	4.00	104.10
2	E4	Sunkoshi Marin and Sunkoshi Kamala with Sunkosshi 3 Dam	154,172	58,114	212,286	310,574	2,677	341,389	19.94	12.52	32.46	16.00	519.37
3	C2	Kaligandaki-Tinau transfer for full irrigation on Rupandehi Andhikhola Dam, MPP	125,460	8,109	133,569	195,411	1,685	41,953	16.22	1.75	17.97	1.00	17.97
4	W6	Naumure Dam, Rapti Kapilvastu Diversion, MPP	130,647	9,046	139,693	204,372	1,762	51,256	16.89	1.95	18.84	10.00	188.44
5	W4	Karnali Transfer to Kailali Irrigation, MPP	37,726	9,818	47,544	69,558	600	40,628	4.88	2.12	7.00	9.00	62.95
6	W2	Bheri-Babai Transfer+Naisinggad Dam, MPP	27,623	9,721	37,344	54,634	471	45,111	3.57	2.10	5.67	21.00	119.01
7	E8	Chatara Barrage	7,861	12,805	20,666	30,234	261	66,482		2.76	2.76	15.00	41.40
Total Cost			**647,585**	**129,906**	**777,491**	**1,137,470**	**9,807**	**700,562**	**82.72**	**28.00**	**110.72**	**76.00**	**1,053.24**

Note: 1. Tamor Morang is actually Tamor Chisang Diversion 2. Koshi Barrage is located at Chatara 3. E4: Sunkoshi marin+ Kamala MPP will only develop 171,500 ha of new area and 169,889 ha of rehabilitation area, making a total area of 341,389 ha 4. W2 Bherai-Babal will develop 51,000ha, which includes about 10,000 h from Sikta IP.

343. The ongoing project of Bheri-Babai will continue until 2024. The Sunkoshi MPP with Sunkoshi 3 hydropower storage dam and 2 transfer tunnels to Marin and Kamala is the next on priority. Others will be developed concurrently in different stages as shown in the implementation Plan. Smaller projects and GW Schemes will continue to be developed and financed all along the Plan period.

344. The schedule of implementation is itemised below:

Sunkoshi MPP	2020-2027
Bheri-Babai MPP	2019-2024
Chatara Barrage	2024-2029
Naumure Dam MPP	2027-2033
Karnali Transfer MPP	2029-2034
Tamor Morang MPP	2033-2039
Kaligandaki Tinau MPP	2037-2042

345. The total estimated capital investment for these major priority projects is USD 9,823 Million over the 25-year period.

4.2 Groundwater Projects

346. These multipurpose projects will be supplemented by groundwater projects both within the command areas of these MPP where there is a long time lag between now and implementation, and standalone groundwater projects. The standalone groundwater projects are:

Sarlahi-Rautahat	2020-2024
Jhapa-(Morang)	2021-2024, and 2029-2033
Parsa-Chitwan	2023-2026
Dang	2032-2035

347. Those supplementing MPP projects are:

Kapilbastu, Nawalparasi,	2024-2028
Sunsari, Mahottari, Dhanusha,	2026-2029
Siraha, Bara	
Nawalparasi	2028-2033
Banke, Kailali	2031-2034

348. The estimated capital cost for a total of 318,000 ha of groundwater projects is USD 997 Million over 25 years.

4.3 Hills and Mountain Projects

349. The two categories of Hills and Mountains projects are: (i) IMP-2018 GIS Identified, and (ii) IMP-2018 GIS Classified. These are mostly mechanized irrigation.

350. The IMP team used GIS results of the pumping suitability to identify 111,500 ha using GIS and Google images to verify the project suitability. Both gravity and pump systems were identified during this process. In Category 2, the remaining classified pumping suitability assessment is left for future verification and design. The area to identify is 454,500 ha as shown in Table 38.

Table 38: Capital Costs of Hills and Mountains Category Projects

Category	Project	Development Area (ha)	Capital Cost (USD/ha)	Total Cost (USD M)
1	IMP-2018 GIS Identified	111,500	3,600	401.4
2	IMP-2018 Clas-sified	454,500	2,600	1,181.7
Total		**566,000**		**1,583.10**

351. The total cost of this program is USD 1,583.1 Million as presented in Table 39 over the 25-year period.

4.4 Irrigation Management, Modernisation, and Rehabilitation

352. The DoWRI has three projects which can be either merged of rebranded under an umbrella of Modernisation, Rehabilitation and MOM. These are CMIASP-AF, ISIP and IWRMP. The rebranding would be the inclusion of IMT, combined with ISF collection. The systems firstly would need to be modernised or rehabilitated before the next steps can be taken. While doing so, managers and farmers need to be trained in operating and maintaining the system at all levels. A key component of this program will be the focus on improving efficiencies at all levels.

353. The program will continue for the whole 25 years, at an annual cost of USD 43 Million with a total of USD 1,069 Million.

4.6 IMP Implementation Plan and Costs

354. The investment framework cost is shown in Table 39. The total outlay is USD 13,472 Million. There are three peaks of investment: 2025 for USD 844.4 Million, in 2024 for USD 825.4 Million and 2038 for USD 728.4 Million.

355. Not included in this framework is the annual MOM costs of each project once they become operational.

356. As part of the implementation, there must be an M&E program to keep track of progress, review status and success of each program, and recommend the way forward based on lessons learn

Table 39: Investment Cost and Time Frame

MPP and Koshi Barrage: Investment and Operating Costs, USD m current 2018 prices		Total Cost $ m	Start	End	Year																								
					2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043
Tamor Morang (Chisang) 2		2,350.00	2033	2039															203.8	203.8	391.6	391.6	386.4	386.4	386.4				
Sunkoshi Marin and Sunkoshi Kamala 2		2,696.00	2020	2027		227.0	227.0	288.2	288.2	579.1	579.1	404.3	103.1																
Kaligandagi-Tinau transfer for full irrigation in Rup		1,684.00	2037	2042																			224.0	231.5	195.2	377.1	377.1	279.1	
Naumure Dam, Rapti Kapilbastu Diversion		1,762.00	2027	2033									151.6	151.60	219.6	227.5	393.3	414.0	204.4										
Karnali Transfer to Kailali Irrigation		600.00	2029	2034											68.6	99.6	90.5	90.5	125.4	125.4									
Bheri-Babai Transfer + Nalsingad Dam		471.00	2019	2024	80.2	80.2	92.6	92.6	92.6	32.8																			
Chatara Barrage		260.00	2024	2029						56.2	56.2	49.2	49.2	49.2															
Total		**9,823.00**			**80.2**	**307.2**	**319.6**	**380.8**	**380.8**	**668.1**	**635.3**	**453.5**	**303.9**	**200.8**	**288.2**	**327.1**	**483.8**	**504.5**	**533.6**	**329.2**	**391.6**	**391.6**	**610.4**	**617.9**	**581.6**	**377.1**	**377.1**	**279.1**	
Groundwater: Investment Costs		**Total Cost $ m**	**Start**	**End**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**	**2032**	**2033**	**2034**	**2035**	**2036**	**2037**	**2038**	**2039**	**2040**	**2041**	**2042**	**2043**
Rautahat, Sarlahi	Package 8	99.5	2020	2024		0.1	26.3	31.6	31.8	9.7																			
Jhapa, Phase 1	Package 9	149.2	2021	2025			26.3	26.3	31.6	31.8	33.2																		
Parsa, Chitwan	Package 10	109.4	2023	2027					14	27.6	33.2	33.3	1.3																
Kapilbastu, Rupendehi	Package 11	121.9	2024	2028						10.5	32.2	38.7	38.9	1.6															
Sunsari, Mahottari, Bara, Dhanusha, Siraha	Package 12	111.9	2026	2029								23	23	27.6	27.8	10.5													
Nawalparasi	Package 13	109.4	2028	2033										18.3	26.3	31.6	31.8	1.4											
Jhapa, Phase 2	Package 14	171.6	2029	2032											34.3	34.3	34.3	34.3	34.4										
Banke, Kailali	Package 15	54.7	2031	2034													4.6	14.5	17.4	17.5	0.7								
Dang	Package 16	69.6	2032	2035														11.9	11.9	15.9	15.9	14							
Groundwater: Investment Costs	**Total**	**997**				**0.1**	**52.6**	**57.9**	**77.4**	**79.6**	**98.6**	**95**	**63.2**	**47.5**	**88.4**	**76.4**	**70.7**	**62.1**	**63.7**	**33.4**	**16.6**	**14**							
Gravity and Pumped Schemes Hills	**Total**	**1,583**				**65**	**66**	**66**	**66**	**66**	**66**	**66**	**66**	**66**	**66**	**66**	**66**	**66**	**66**	**66**	**66**	**66**	**66**	**66**	**66**	**66**	**66**	**66**	**66**
Irrigation Managemement Modernization and Rehabilitation	**Total**	**1,069**				**44.54**	**44.5**	**44.54**	**44.54**	**44.54**	**44.54**	**44.54**	**44.54**	**44.54**	**44.54**	**44.54**	**44.54**	**44.54**	**44.54**	**44.54**	**44.54**	**44.54**	**44.54**	**44.54**	**44.54**	**44.54**	**44.54**	**44.54**	**44.5**

4.7 Targets for Year-Round Irrigation

357. Two main national policies, the ADS (2015) and the NWP (2005), have provided targets for water use, productivity, cropping intensities and year-round irrigation in this IMP. Accordingly, it has indicated the targets into the plan, together with an M&E Plan.

358. This IMP has added a new date to these targets, which is the long term date of 2045, the end of the plan. The cropping intensities are to be increased from the present of 132% to 182% by 2025, 205% in 2030 and finally reach 230% in 2045. The NWP target for this is 193% in 2027, which matches with the IMP proposed targets.

359. Year round (YR) irrigation is one of the main thrusts of this IMP. The ADS proposed YR irrigation targets of 60% in 2025 and 80% in 2030. The NWP aimed at 64% by 2017, and 67% by 2027. This IMP has an ambitious Plan of starting at the present estimated YR percentage of 39%, and reaching 60% by 2025, 80% by 2030 and 100% by 2045. The National policy targets are presented in Table 40.

Table 40: National Policy Targets

Policy Targets	ADS 2015		NWP 2005		IMP-2019 (updated 2024)	
	CI %	YR %	CI %	YR %	CI %	YR %
2005				<30%		
2007			>160%	49%		
2015		30%				
2017			170%	64%		
2020					132%	39%
2025		60%			182%	60%
2027			193%	67%		
2030		80%			205%	80%
2045					230%	100%

360. The proposed program for the MPP, groundwater and hills and mountain developments is given in Figure 7. Using this data, the annual increment of surface irrigation and ground water development is plotted. There will be a conversion of monsoon irrigation to YR with the implementation of the transfer systems, groundwater is considered YR irrigation, so the percentage of YR irrigation can be determined. This is plotted in Figure 7, and shows that by the end of the project, 2045, 100 % YR irrigation will be achieved in Terai. In short term by 2025, YR will have reached 60%, by medium term 2030 the percentage will be 80 %.

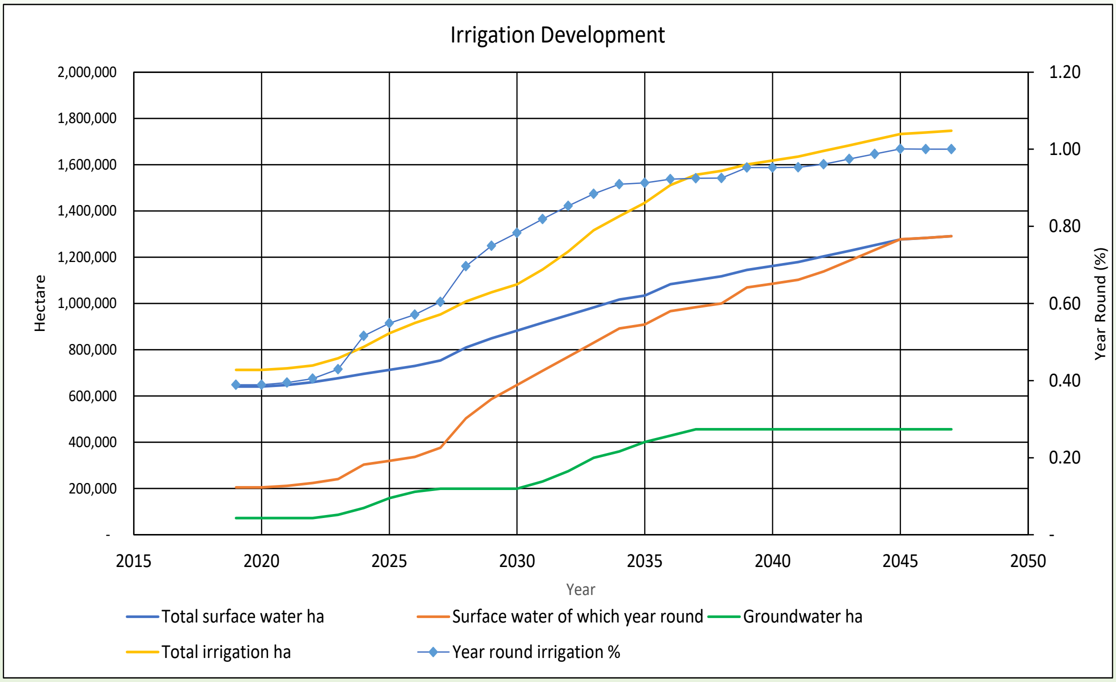


Figure 7: Irrigation Development Progress in IMP-2018

4.8 Private Sector Participation and PPP Options

361. The Government enacted PPP Act 2019 to provide a framework of PPP in infrastructure and services from both domestic and foreign private parties, particularly with the aim of attracting foreign investment. This law is an integrated version of Private Investment in Construction and Operation of Infrastructure Structure Act 2006 and Investment Board Act 2010, with provisions 10 PPP modalities (each involving transfer), including: construction-transfer, construction- operation-transfer, management-operation-transfer, maintenance/ rehabilitation-operation-transfer. It has designated the Investment Board of Nepal (IBN) as a PPP knowledge centre and facilitating body for regulating PPP, though all related federal agencies (e.g., ministries) and provincial and local governments have roles in approving, regulating and promoting PPP in their respective fields according to the volume of investment required. The law does not make specific arrangements for irrigation-specific PPP, but it provides a basis on which to choose any form of PPP even in irrigation sector.

362. A number of options exist for PPP. The most commonly used contractual forms of PPP in the irrigation sector are: (i) management, performance-based and Design-Build-Operate Contracting (DBO); (ii) private sector infrastructure Design, Build, Finance and Operate (DBFO); (iii) farm (non-irrigation) service agreement; (iv) hub farm agreement; and (v) farmers' participation in the PPP contract . In irrigation PPP, farmers will be the recipients of irrigation services, and in some cases the farmers will be forming WUAs to support management, operation and maintenance of PPP undertaking. In order to attain

sustainability, farmers' active involvement can generate the links which are missing between the public and private partners. Farmers' active participation can bring certainty to a stable demand for irrigation services.

363. Various types of irrigation schemes have been identified for possible inclusion in the proposed IMP. As the exact funding mechanism is still to be decided, it can be expected that the financing of some large, medium and special types of projects would involve a mix of funding through government, donor, NGO, cooperatives and farmers, and hence open adopting PPP options, including private financing. Based upon the characteristics of the PPP structures and the considerations as suggested above, the PPP options for various irrigation projects of IMP have been provisionally proposed in Table 41 with the time frame in Table 42.

Table 41: PPP options for the irrigation schemes to be included in the IMP

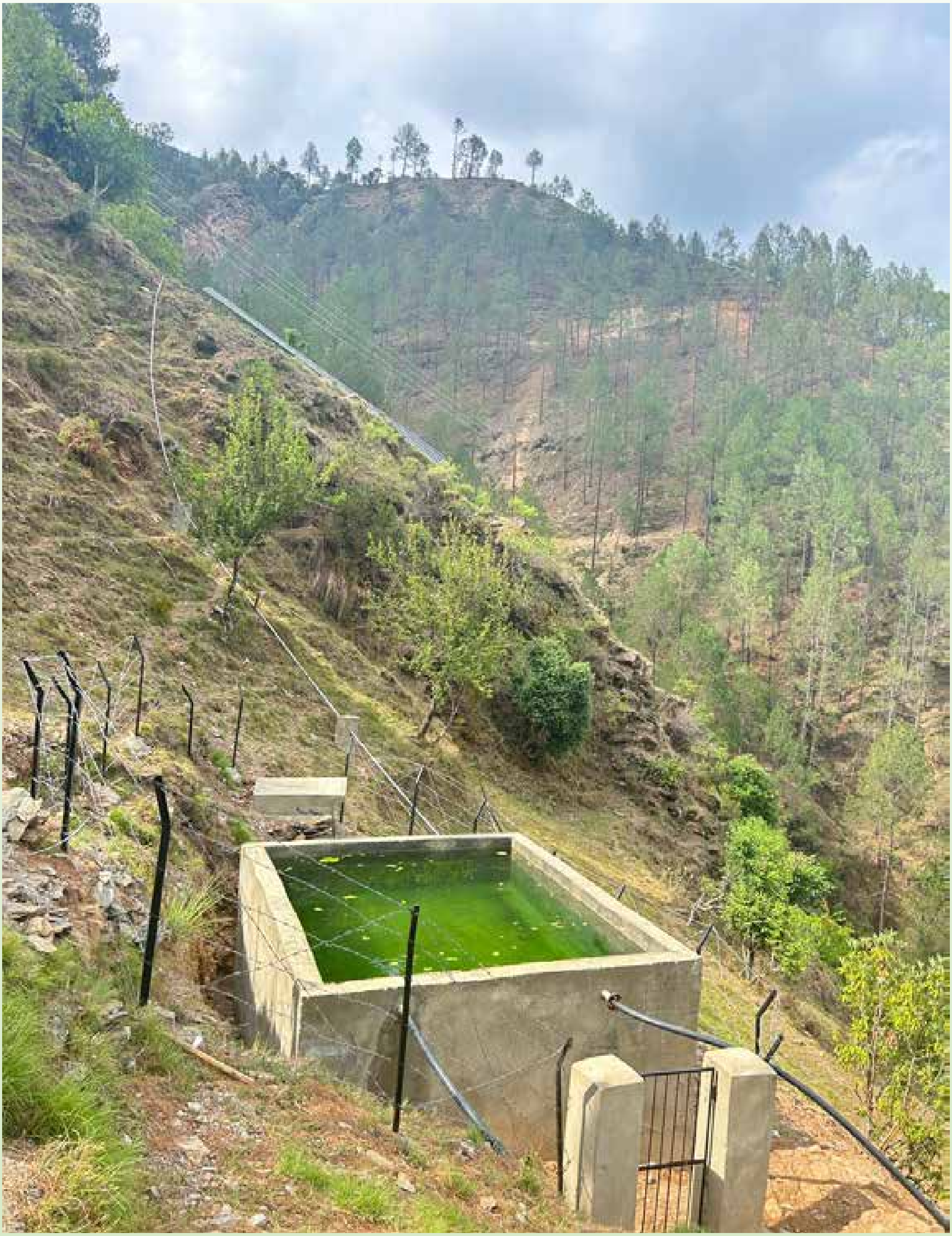
No.	Description	Financ-ing	Possible PPP structure
1	Large Scale IS	GoN	DBO (for 3-5 years) – and possible subsequent lease contract
2	Medium Sized IS	GoN	DBO (for 3-5 years) – and possible subsequent lease contract (LC) or management or performance based contract
3	Rehabilitation of IS	GoN	DBO (for 3-5 years) – and possible subsequent lease contract (LC) or management or performance based contract
		Private	DBFO, Concession or BOOT/BOO
4	Small Scale IS	GoN	DBO (for 3-5 years) – and possible subsequent lease contract (LC) or management or performance based contract
		Private	DBFO, Concession or BOOT/BOO
5	Transfer IS	GoN	DBO (for 3-5 years) – and possible subsequent a performance based contract
6	Groundwater Irrigation	GoN	DBO (for 3-5 years) – and possible subsequent lease contract (LC) or management or performance based contract
7	Pumped Hill Irrigation	GoN	DBO (for 3-5 years) – and possible subsequent lease contract (LC) or mgt. or performance based contract

Table 42: Timeframe periods, Development Areas and Costs (USD Million)

Scenario	Projects	Short Term		Medium Term		Long Term	
		2019-2024		2025-2029		2030-2044	
		Area (ha)	Cost (USD Mil)	Area (ha)	Cost (USD Mil)	Area (ha)	Cost (USD Mil)
E.6	Tamor Morang with Tamor HPP					114,000	2,350.00
E.4	Sunkoshi Marin and Sunkoshi Kamala with Sunkoshi 3 HPP	170,000	674				
E.4	Sunkoshi Marin and Sunkoshi Kamala with Sunkoshi 3 HPP			182,000	2,022.00		
C.2	Kaligandaki Tinau transfer. Rupandehi Irrigation and Andikhola Dam					42,000	1,684.00
W.6	Naumure Dam, Regulation Dam, Rapti Kapilbastu Tunnel, Powerhouse and Irrigation Area					51,000	1,762.00
W.4	Karnali Diversion Tunnel Project					41,000	600
W.2	Bheri-Babai transfer and Nalsingad Dam	45,000	471				
E.8	Chatara Barrage			66,500	260		
1	Groundwater: Rautahat, Sarlahi	40,000	99.5				
2	Groundwater: Jhapa, Phase 1	40,000	149.2				
3	Groundwater: Parsa, Chitwan			44,000	109.4		
4	Groundwater: Kapilbastu, Rupundehi			49,000	121.9		
5	Groundwater: Sunsari, Mahottari, Bara, Dhanusha, Siraha			45,000	111.9		
6	Groundwater: Nawalparasi					44,000	109.4
7	Groundwater: Jhapa, Phase 2					46,000	171.6
8	Groundwater: Banke, Kailali					22,000	54.7
9	Groundwater: Dang					28,000	69.6
10	Hills Gravity and Pumping - Category 1	111,500	401.4				
11	Hills Gravity and Pumping - Category 2					454,500	1,182.00
12	Irrigation management Modernisation and Rehabilitation	152,000	222.7	152,000	222.7	152,000	623.5
Term Total		**558,500**	**2,018**	**538,500**	**2,848**	**994,500**	**8,607**

Selected Project	Scenario	Project	Score	Economic EIRR (re-schedule)	Economic NPV, 9% NPR m	New Irrigation Area (ha)	Rehab Irrigation Area (ha)	Total Development (ha)	Construction Period	Start	End
1	E.6	Tamor Morang (Chisang) with Tamor HPP	113	12.9%	85,142	43,743	70,000	113,743	6	2033	2041
2	E.4	Sunkoshi Marin and Sunkoshi Kamala with Sunkoshi 3 HPP	108	15.3%	182,652	171,500	169,889	341,389	10	2020	2030
3	C.2	Kaligandaki Tinau transfer. Rupandehi Irrigation and Andhikhola Dam	88.2	14.0%	85,477		52,455	52,455	6	2037	2043
4	W.6	Naumure Dam, Regulation Dam, Rapti Kapilbastu Tunnel, Powerhouse and Irrigation Area	59.3	11.4%	36,778	36,030	15,226	51,256	6	2030	2036
5	W.4	Karnali Diversion Tunnel Project	50.2	14.0%	32,579	32,996	7,632	40,628	7	2029	2036
6	W.2	Bheri-Babai transfer and Nalsingad Dam	48.3	16.7%	41,974	2,644	42,467	45,111	5	2019	2024
7	E.8	Chatara Barrage	44.6	11.0%	4,749	18,489	47,993	66,482	5	2024	2029
8	1	Groundwater: Rautahat, Sarlahi		16.6%	10,744			40,000	3	2020	2023
9	2	Groundwater: Jhapa, Phase 1		9.2%	246			40,000	3	2021	2024
10	3	Groundwater: Parsa, Chitwan		13.3%	6,148			42,000	3	2023	2026
11	4	Groundwater: Kapilbastu, Rupandehi		12.8%	4,147			49,000	4	2024	2028
12	5	Groundwater: Sunsari, Mahottari, Bara, Dhanusha, Siraha		7.1%	2,089			35,000	3	2026	2029
13	6	Groundwater: Nawalparasi		10.4%	2,391			40,000	3	2028	2031
14	7	Groundwater: Jhapa, Phase 2		8.1%	1,636			35,000	4	2029	2033
15	8	Groundwater: Kanke, Kailali		6.7%	3,001			22,000	3	2031	2034
16	9	Goundwater: Dang		11.3%	2,166			15,000	3	2032	2035
17	10	Hills Gravity and Pumping - Category 1		11.3%	2,166			111,500	7	2020	2027
18	11	Hills Gravity and Pumping - Category 2		11.3%	2,166			454,500	18	2027	2045
19	12	Irrigation Management Modernization and Rehabilitation		11.3%	2,166			511,500	25	2020	2045

Figure 8: Proposed Implementation Plan



Solar Lift Irrigation System, Rolpa

SECTION V: MONITORING AND EVALUATION PLAN

364. This IMP covers a 25-year span with multiple national projects costing about 13,500 billions of dollars. In order to maximise the benefits, a comprehensive M&E Plan is required to keep the progress on track. There are three basic time steps, 5, 10 and 25 years in addition to annual monitoring. The monitoring of year-round irrigation percentage would follow these time steps. In addition, it is recommended that the plan be reviewed and updated every 10 year, rather than wait until the end of the 25 year period.

365. The existing development projects need to be monitored on an annual basis and the progress reported in the annual year book. There are six transfer projects proposed in the plan, which would be monitored in the three time periods. Ground water development and hills and mountains gravity and pumping schemes would be monitored annually and reported in the yearbook. In addition, the inventory will need to be updated annually.

366. Finally, there are performance indicators such as: modernisation area, efficiency, cropping intensity, equity, productivity, and O&M funding, which would be reported in the annual yearbook. All these O&M tasks are shown in Table 43.

Table 43: Monitoring and Evaluation Plan

Goal	Indicator	Unit	Current Baseline	Target	Frequency	Responsible Reporting
ADS (2013)	Year Round Irrigation	Percent-age	18% (2013)	2018, 2023, 2033 30%, 60%, 80%	2018, 2023, 2033	Annual year book
NWP (2005)			30% (2005)	2007, 2017, 2027	2007, 2017, 2027	Annual year book
IMP (2019)			39% (2019)	2025, 2030, 2045	2025, 2030, 2045	Annual year book
Completion of Con-struction Schemes	Bheri-Babai	Ha con-structed	35,000	45,000	5 years 2025	Annual year book
	Rani Ja-mara		14,300	38,300	5 years 2025	Annual year book
	Mahakali III		5,000	42,000	5 years 2025	Annual year book

Goal	Indicator	Unit	Current Baseline	Target	Frequency	Responsible Reporting
New Scheme Transfer	Sunkoshi Marin	Ha con-structed	0	122,000 ha	2020 to 2029	5, 10 and 25 year review
	Naumure Dam, Kapilbastu transfer	Dam, Transfer tunnel, CAD	0	51,000 ha	2027 to 2033	5, 10 and 25 year review
	Sunkoshi Kamala	Tunnel, CAD	0	230,000 ha	2020 to 2029	5, 10 and 25 year review
	Tamor Morang	Dam, Transfer tunnel, CAD	0	114,000	2034 to 2040	5, 10 and 25 year review
	Karnali Transfer	Tunnel, CAD	0	40,000 ha	2029 to 2035	5, 10 and 25 year review
Barrage Scheme	Chatara Barrage	Barrage and CAD	0	66,000 ha new	2024 to 2028	5, 10 and 25 year review
Groundwa-ter	Sarlahi and Rautahat	Ha con-structed	0	40,000 ha	2020 to 2025	Annual year book
	Other GW schemes	Ha con-structed	0	278,000 ha	2020 to 2025	Annual year book
Hills and Mountains	Gravity and Pumped, Identified	Ha Con-structed	0	160,000 ha	2020 to 2026	Annual year book
	Gravity and Pumped, Classified	Ha Con-structed	0	360,000 ha	2027 to 2045	Annual year book
Inventory	Ha irrigated	Ha under YR and MS irriga-tion	1,435,000 ha	Annual up-date of sur-face an GW irrigation	Annual	Annual year book

Goal	Indicator	Unit	Current Baseline	Target	Frequency	Responsible Reporting
Management and Efficiency	Modernization	Ha modernized	0	Surface 364,250 ha GW 284,500	Annual	Annual year book
	Efficiency	Percentage	About 25%	2025, 2030, 2045 29%, 35%, 40%	Annual	Annual year book
	Cropping Intensity	Percentage	132%	2025, 2030, 2045 182%, 205%, 230%	Annual	Annual year book
	Equity: Delivery Performance Ratio	$DPR = \frac{V_a}{V_i(m^3)}$	Relative Water Supply Ratio	50%	Annual	Annual year book
	Productivity	$LP = \frac{Y_c}{A_a}$	Actual yield/ intended yield or area	80%	Annual	Annual year book
	O&M fraction	$O\&M = \frac{C_{o\&m}}{I_S}$	Cost of O&M/ Budget for sustainable MOM	80%	Annual	Annual year book

SECTION VI: ASSUMPTIONS AND RISKS

367. This master plan is prepared based on the inventory of the irrigation systems database collected before 2019. Subsequently the development options are designed as per the total irrigated area and remaining potential irrigable area. The irrigated area and the development options need to be updated regularly, based on construction of planned respective projected irrigation systems and subsequent updated inventory.

368. A central information system need to be developed for integrating information of the irrigated area developed by the three tiers of the Governments.

369. It is expected that the Government of Nepal will allocate the resources as projected in the master plan to complete the planned projects and achieve the targets as envisioned in this master plan.

370. The institutional arrangements including restructuring of the Department of Water Resources and Irrigation will be done in the future to meet the targets envisioned in this master plan.

371. The capacity of DoWRI, province, local level institutions and WUA are enhanced to implement the planned projects and respective activities.

372. There is good mutual understanding and co-ordination among three tiers of the Government in terms of irrigation systems planning, design, development, operation and management.

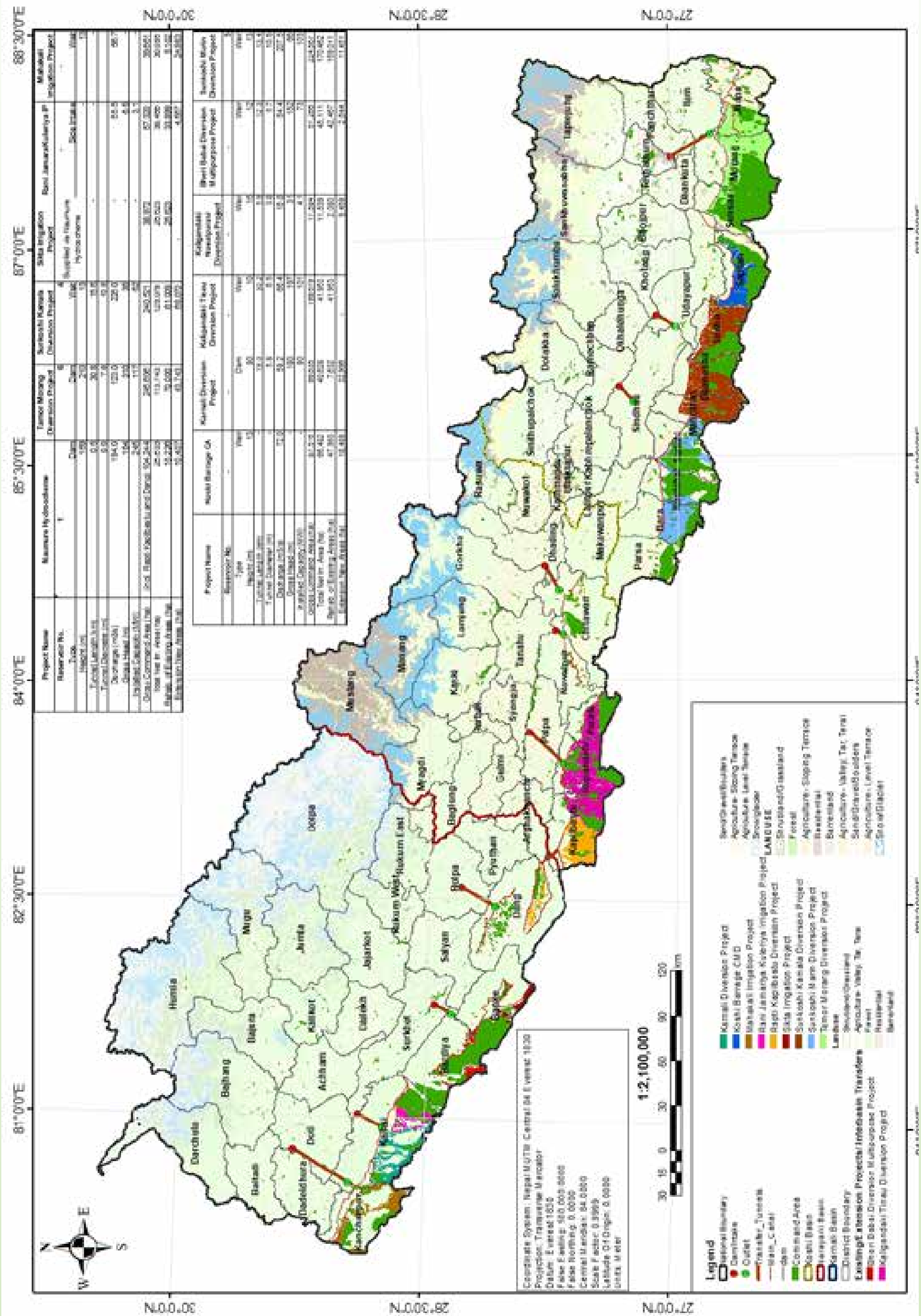


Figure A1: Overview of Potential Transfer and Diversion Projects

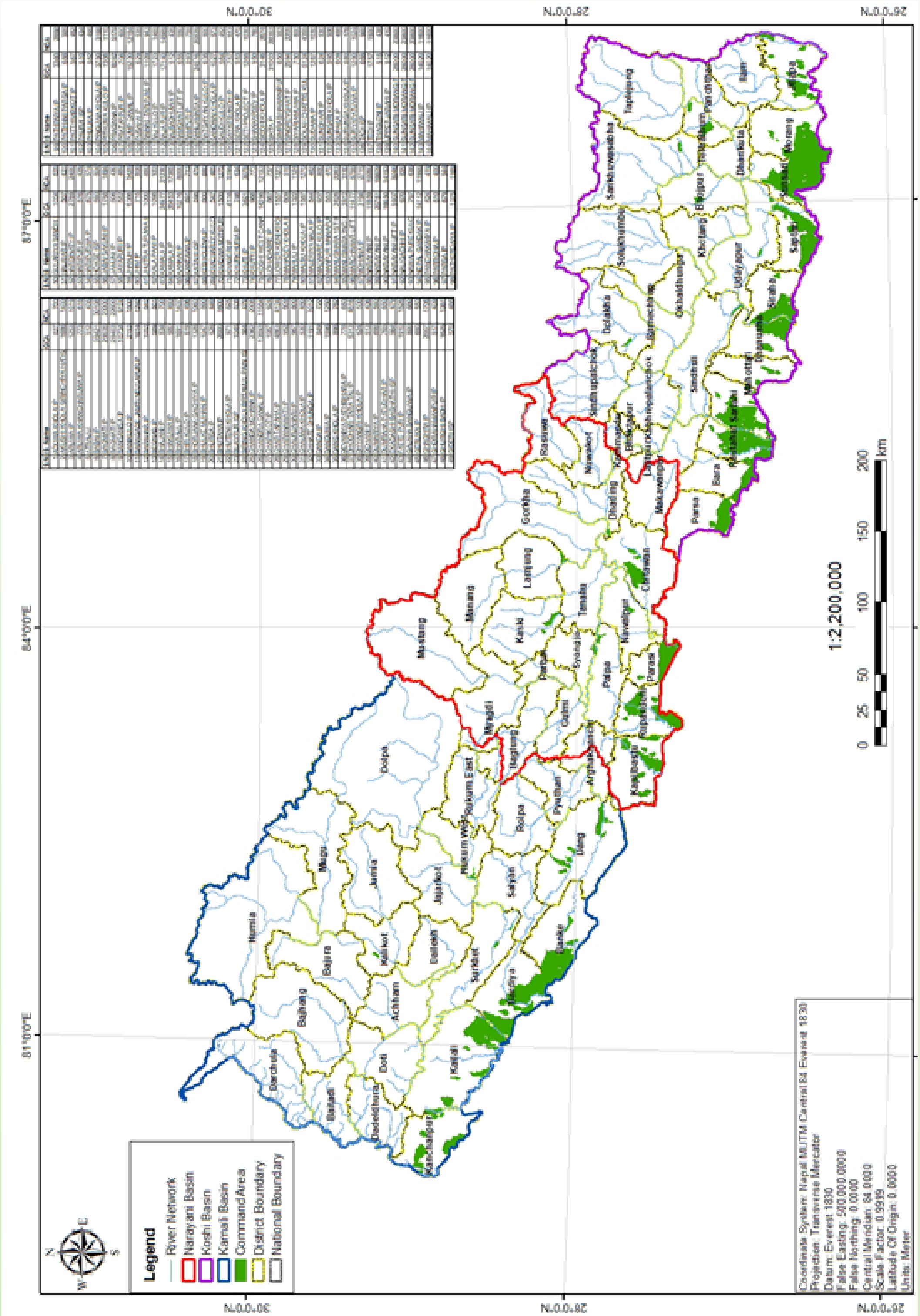


Figure A2: Selected existing Irrigation Projects

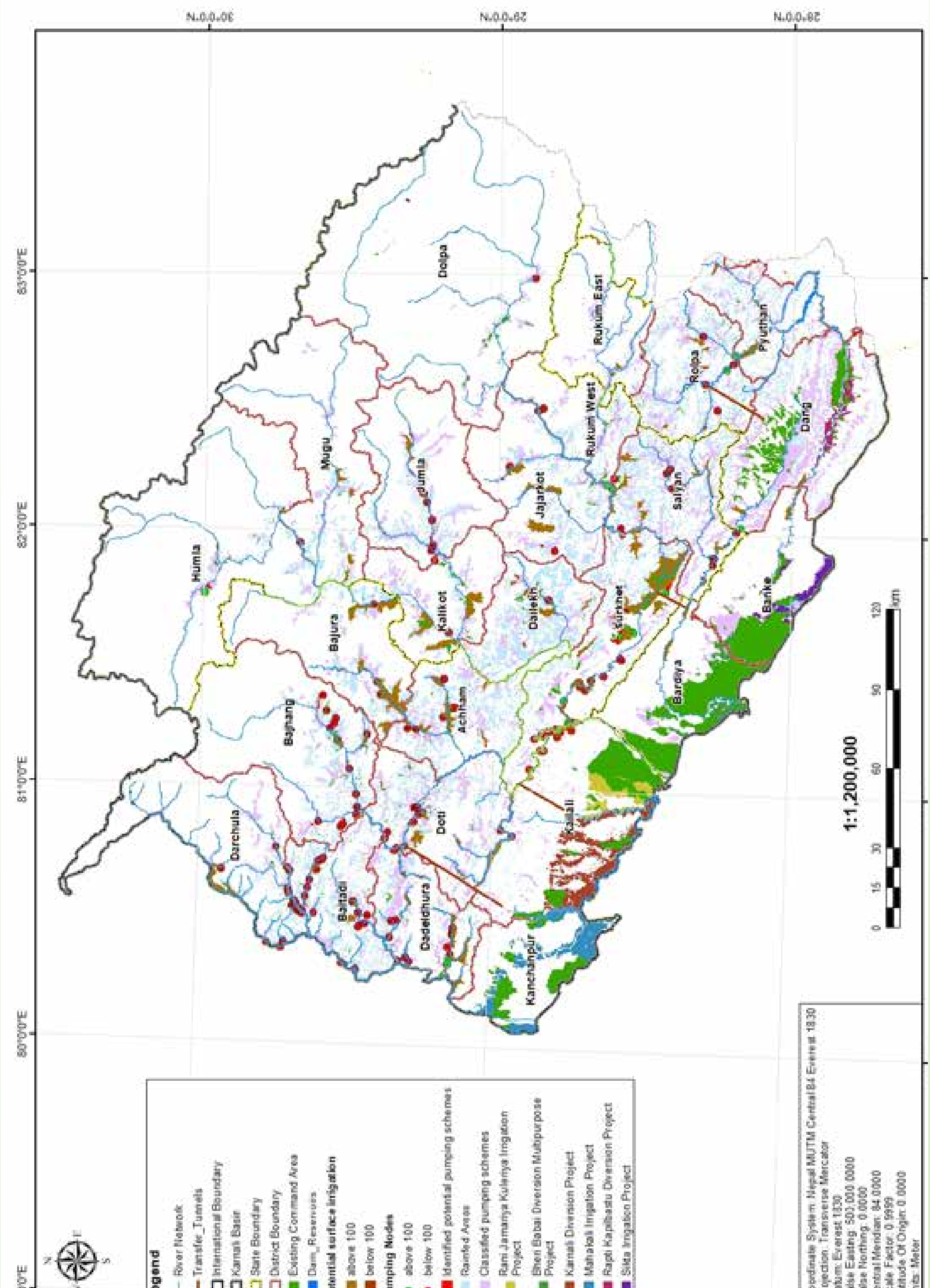


Figure A3: Irrigation Domain, Karnali

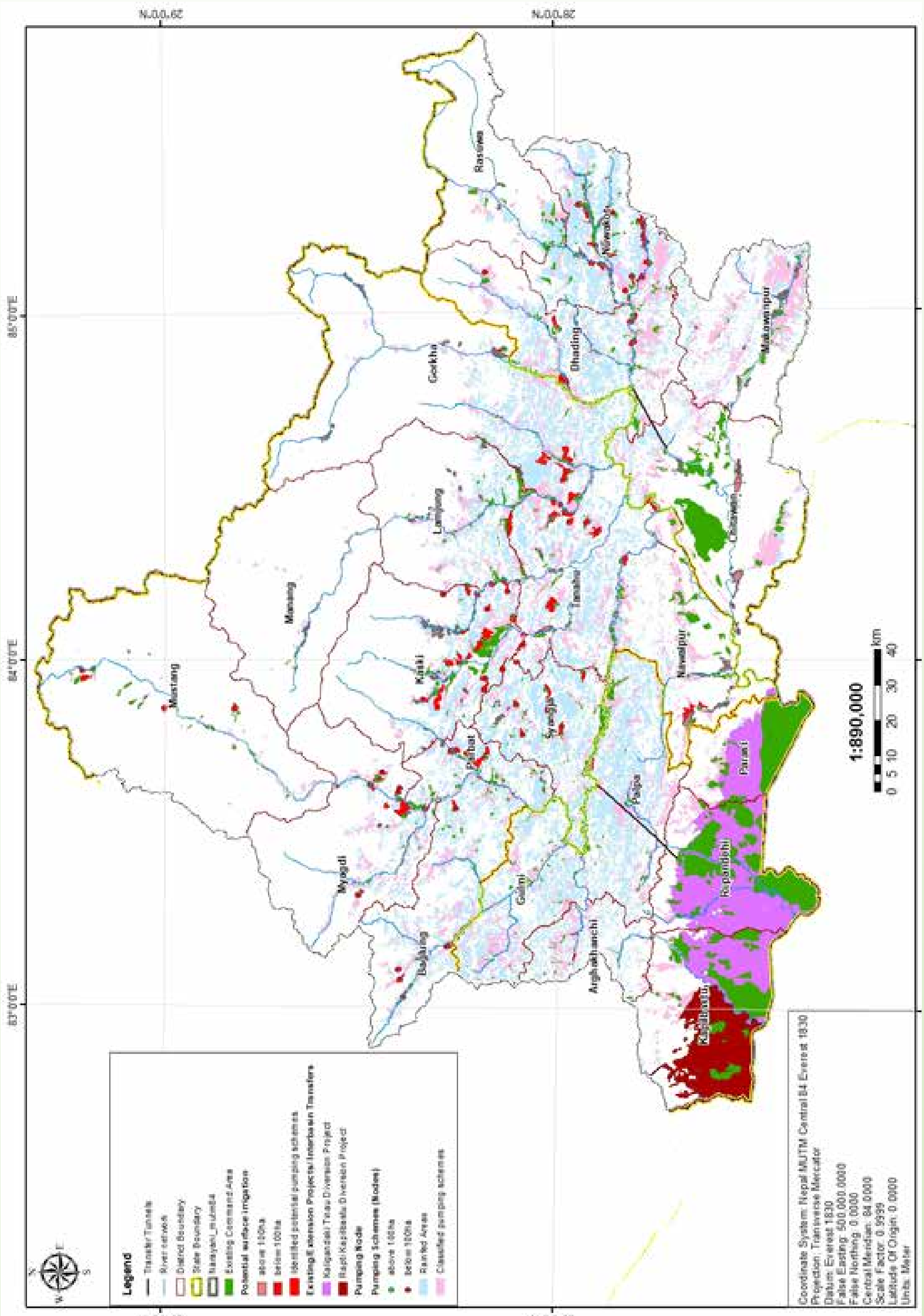


Figure A4: Irrigation Domain, Narayani

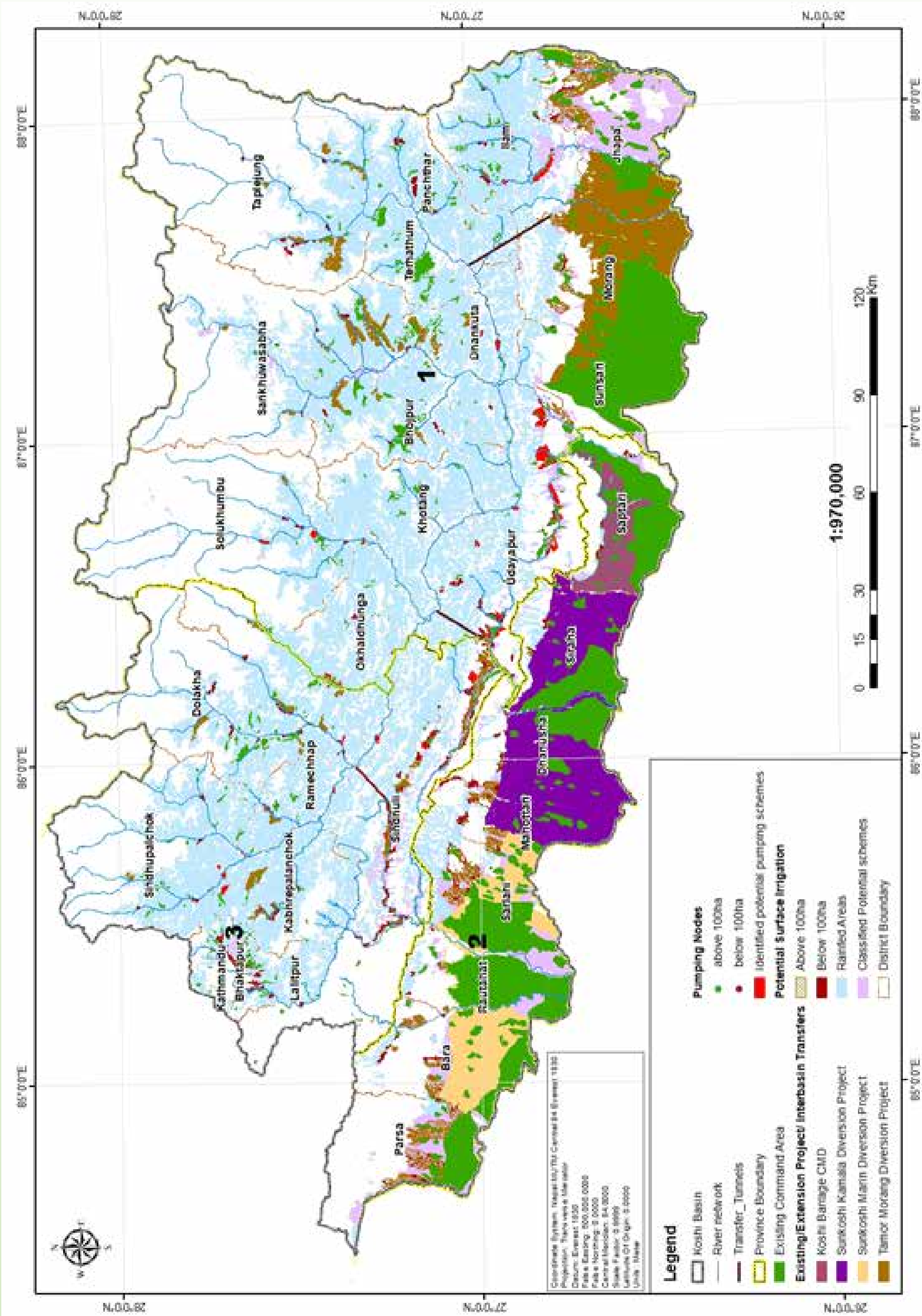


Figure A5: Irrigation Domain, Koshi

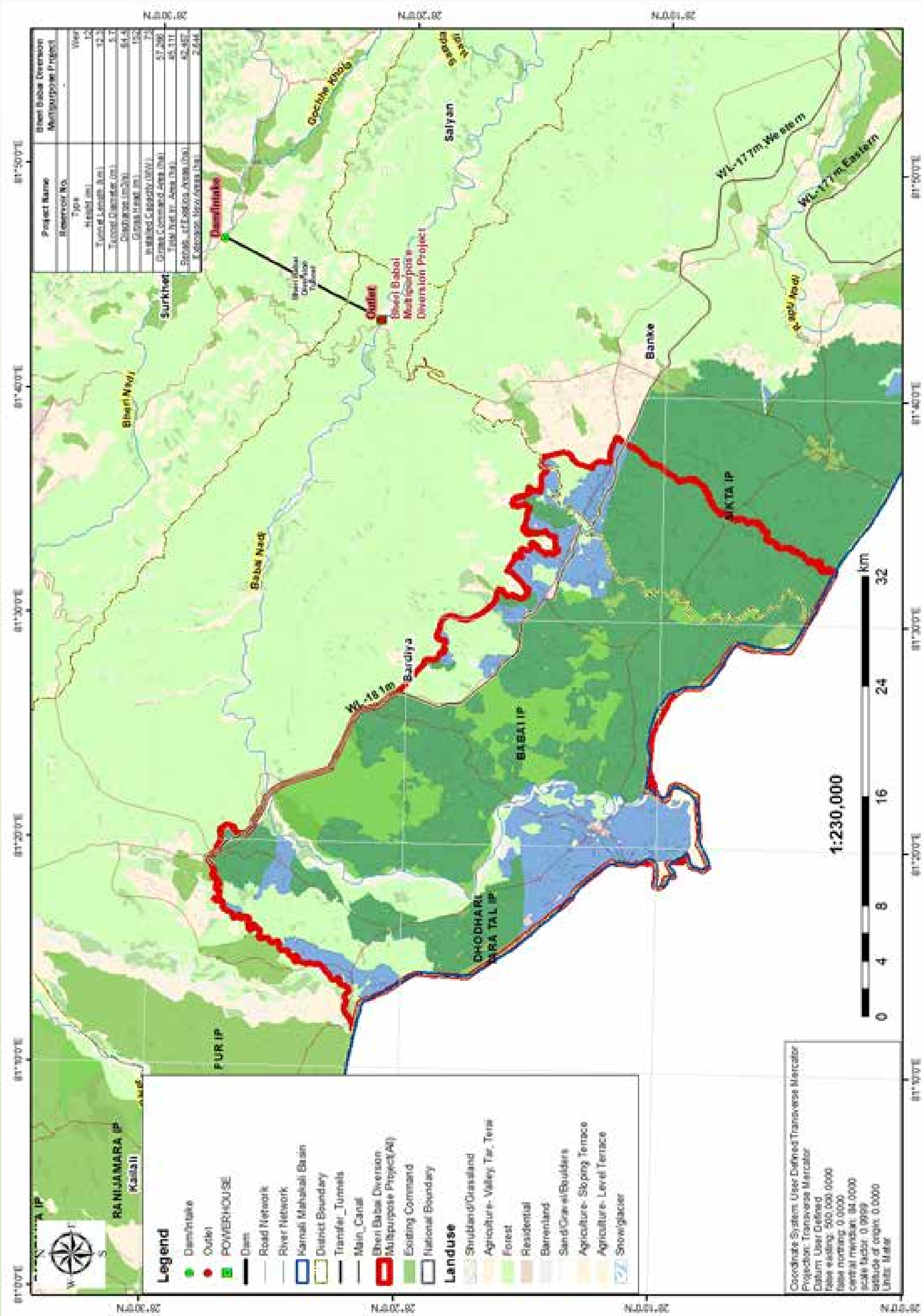


Figure A6: Bheri Babai Diversion Multipurpose Project

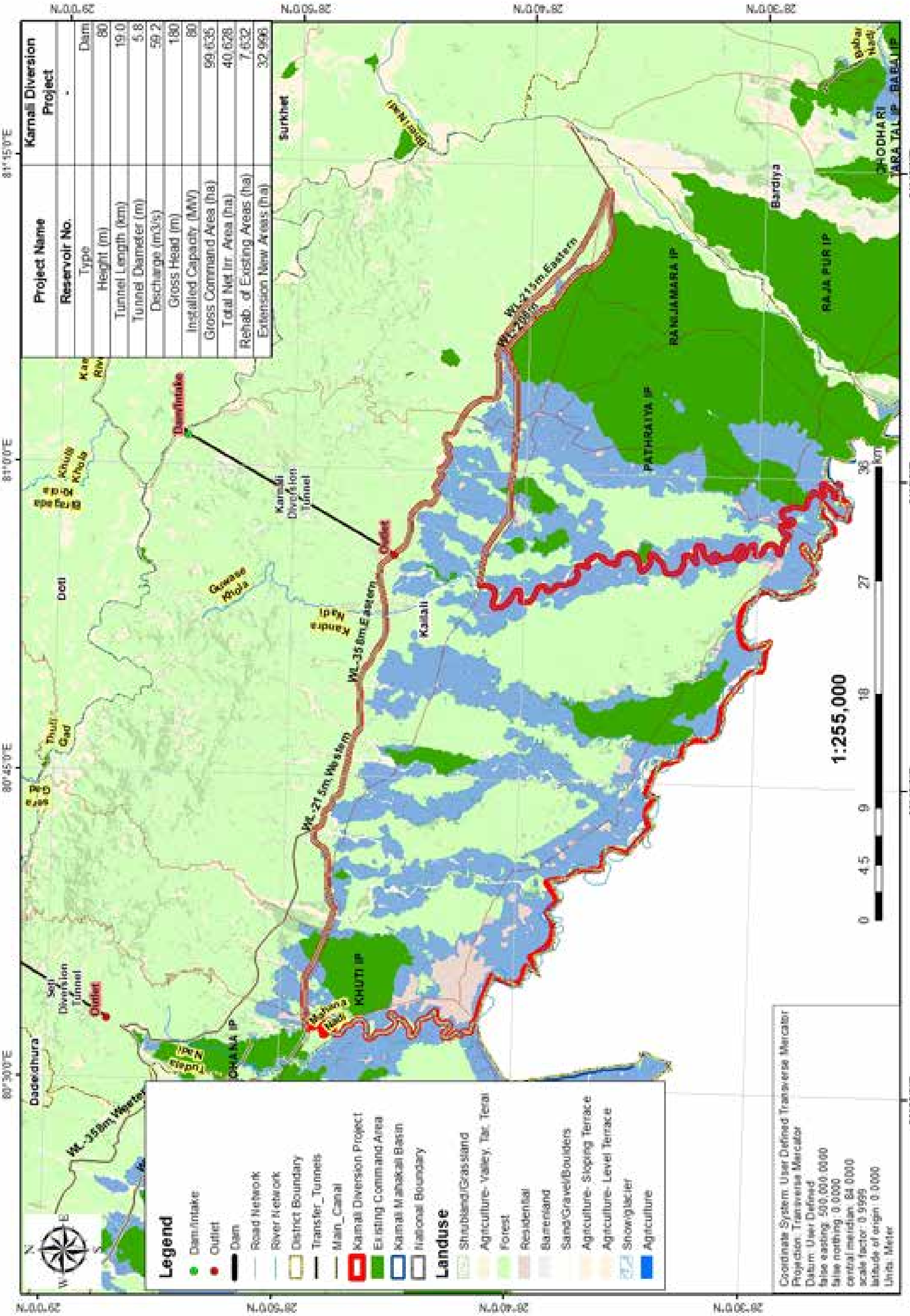


Figure A7: Karnali Diversion Project

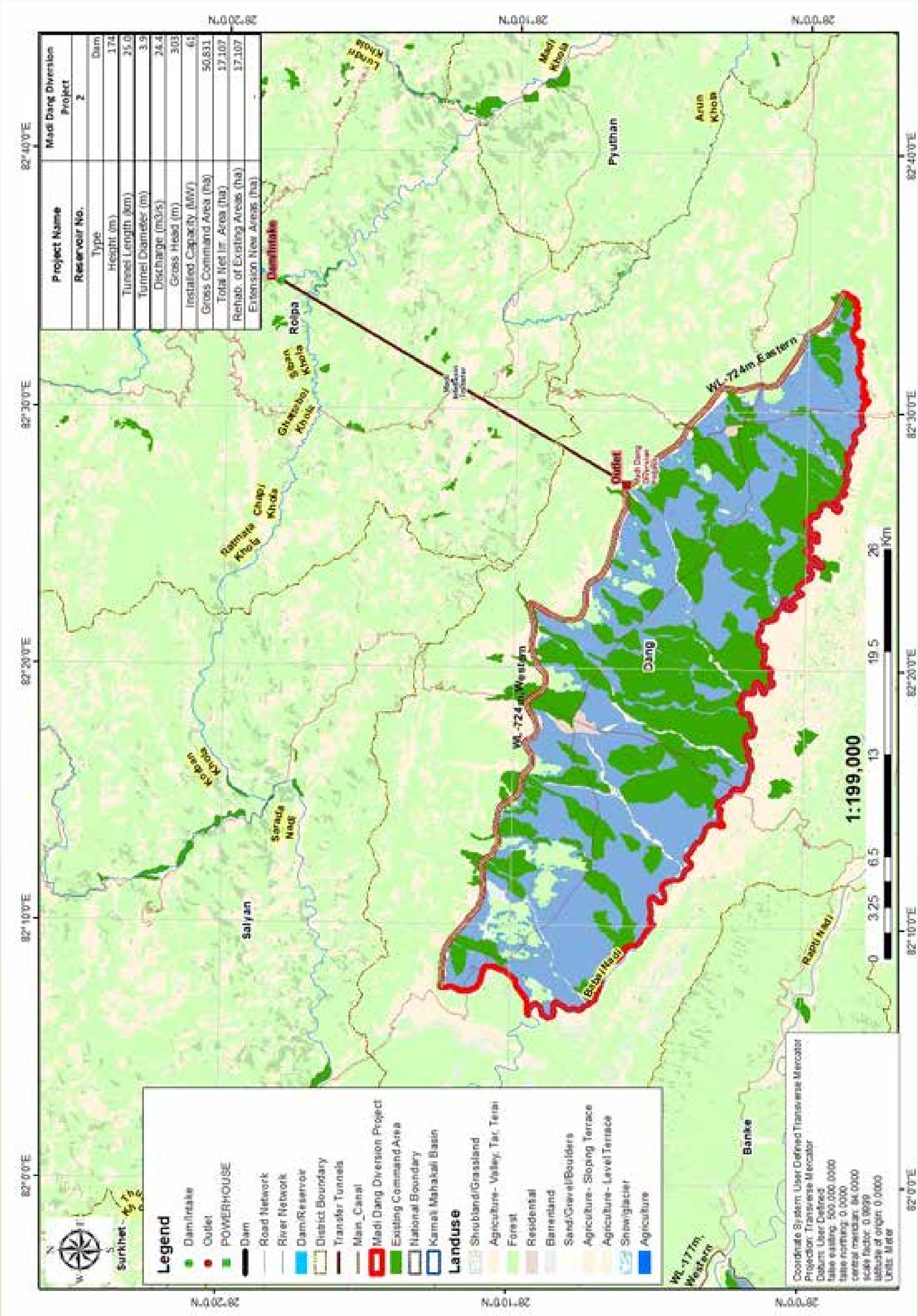


Figure A8: Madi Dang Diversion Project

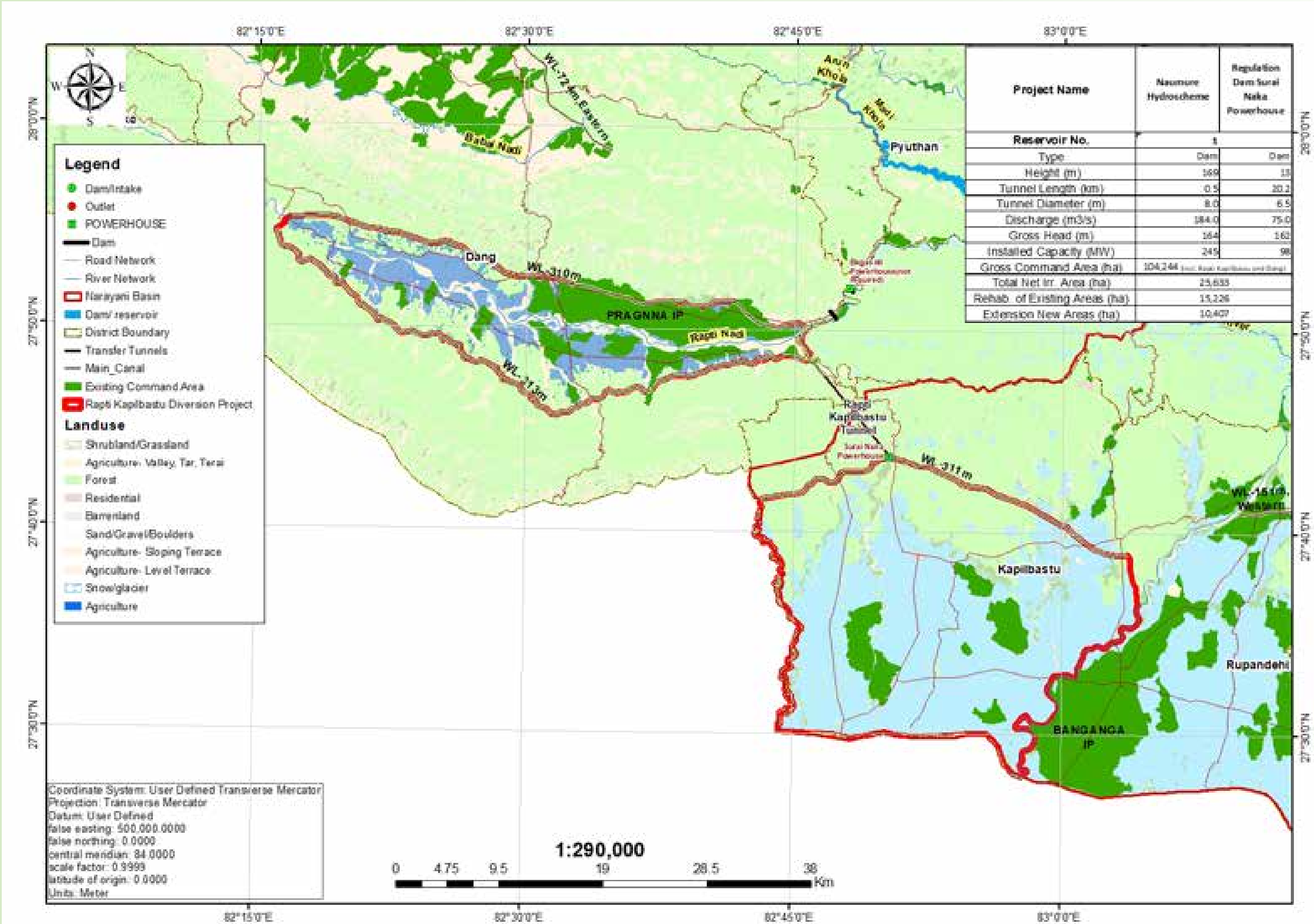
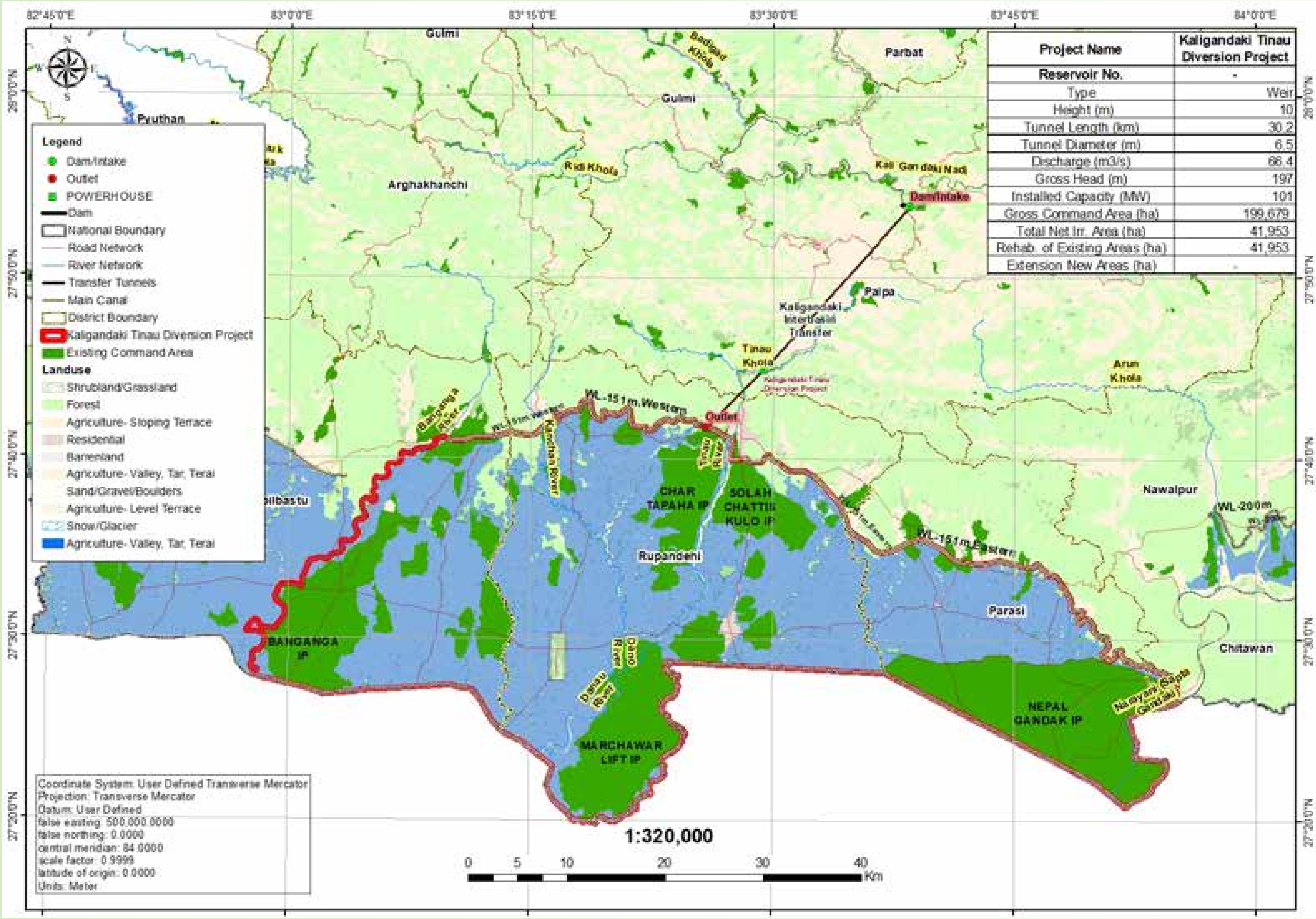


Figure A9: Rapti Kapilbastu Diversion Project



Project Name	Kaligandaki Tinau Diversion Project
Reservoir No.	-
Type	Weir
Height (m)	10
Tunnel Length (km)	30.2
Tunnel Diameter (m)	6.5
Discharge (m3/s)	66.4
Gross Head (m)	197
Installed Capacity (MW)	101
Gross Command Area (ha)	199,679
Total Net Irr. Area (ha)	41,953
Rehab. of Existing Areas (ha)	41,953
Extension New Areas (ha)	-

Figure A10: Kaligandaki Tinau Diversion Project

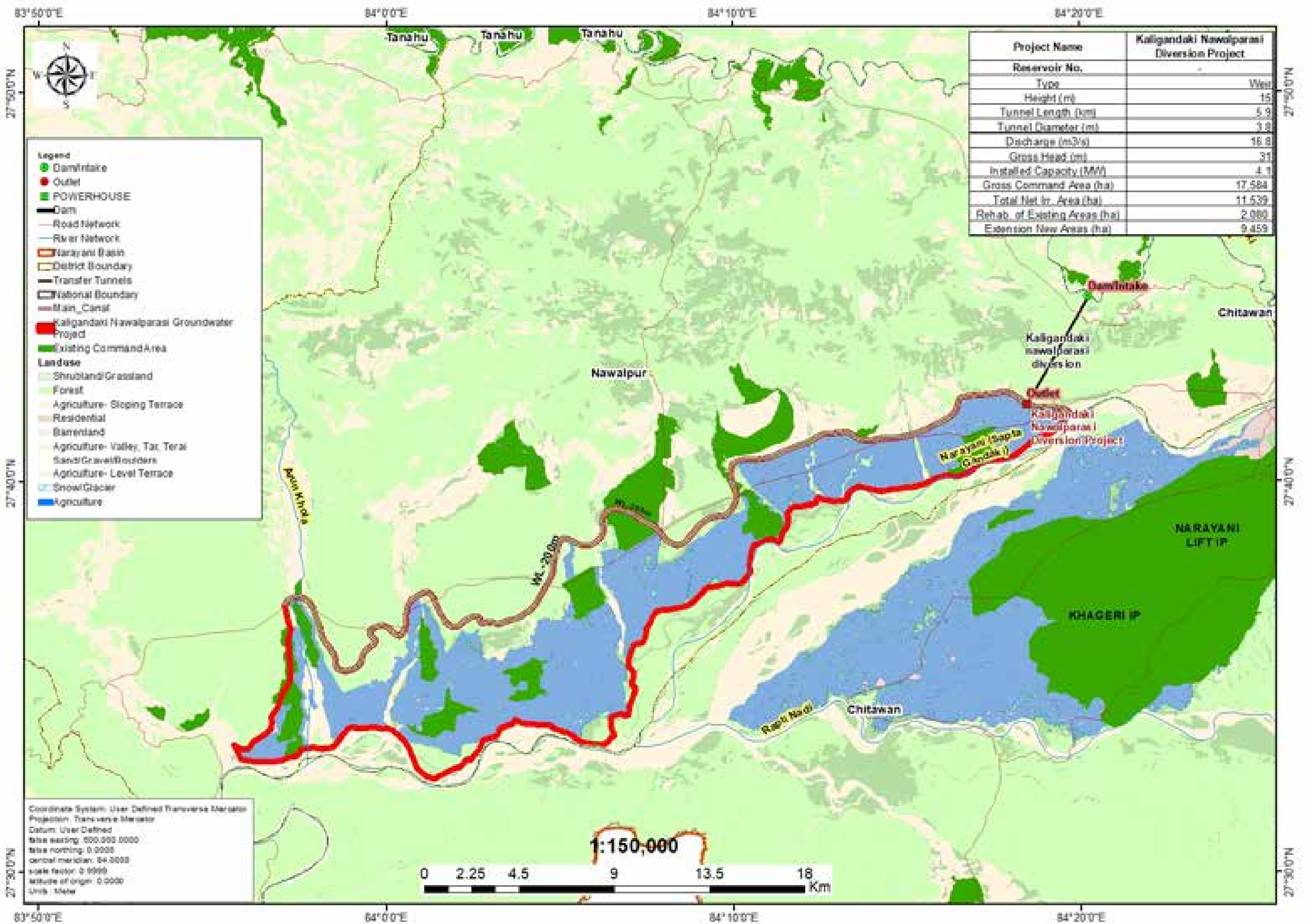
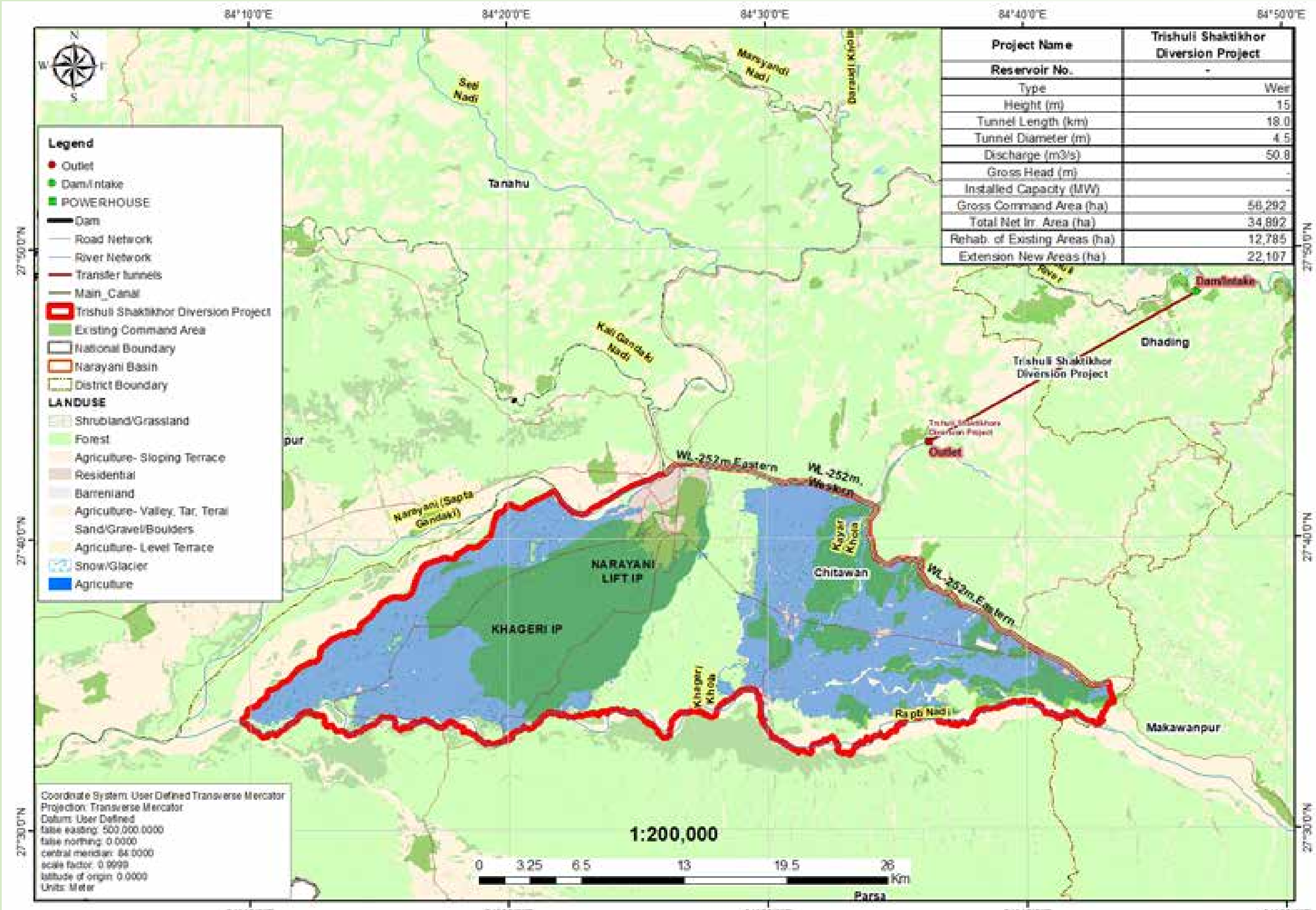


Figure A11: Kaligandaki Nawalparasi Diversion Project



Project Name	Trishuli Shaktikhor Diversion Project
Reservoir No.	-
Type	Weir
Height (m)	15
Tunnel Length (km)	18.0
Tunnel Diameter (m)	4.5
Discharge (m3/s)	50.8
Gross Head (m)	-
Installed Capacity (MW)	-
Gross Command Area (ha)	56,292
Total Net Irr. Area (ha)	34,892
Rehab. of Existing Areas (ha)	12,785
Extension New Areas (ha)	22,107

Figure A12: Trishuli Shaktikor Diversion Project

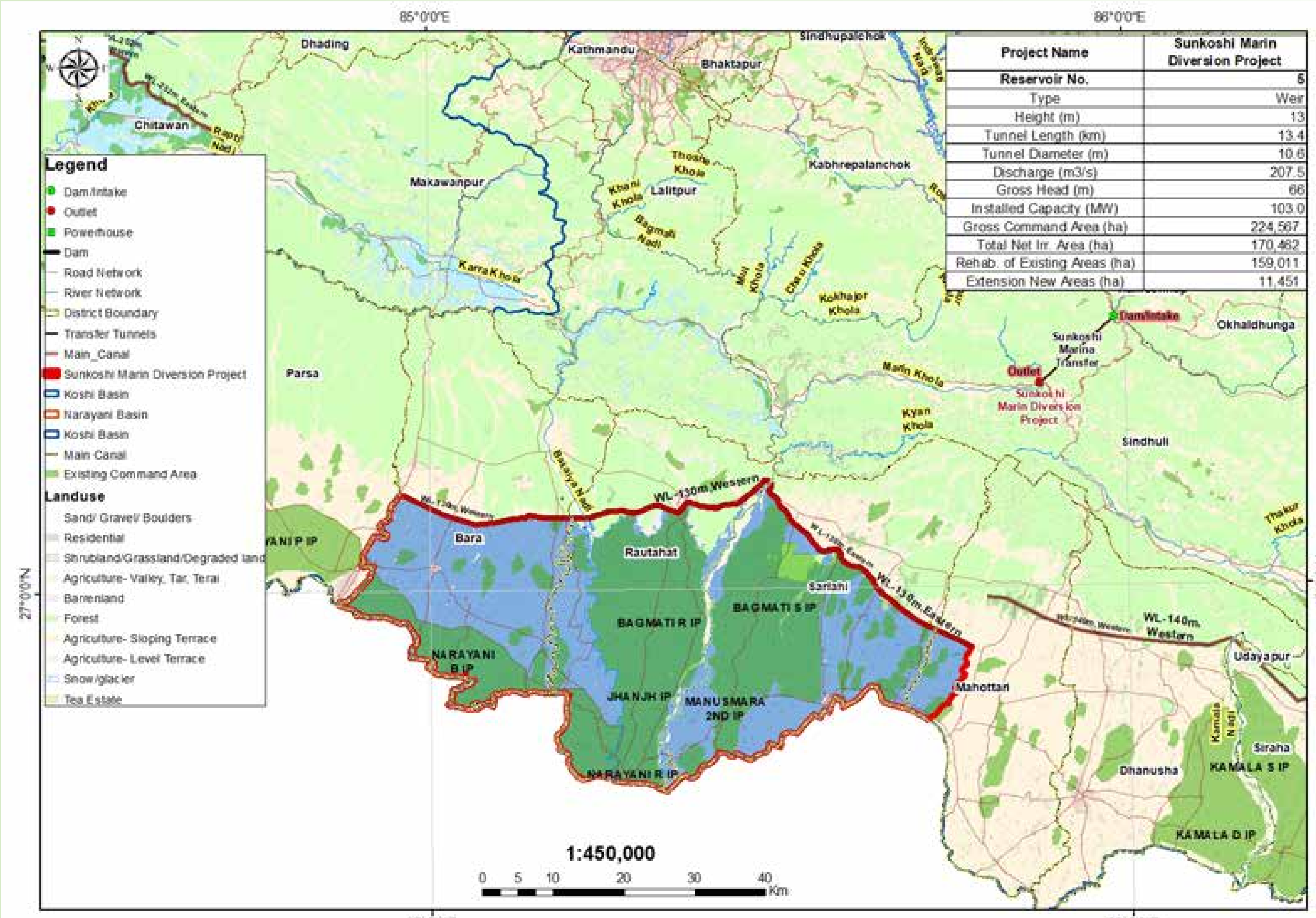
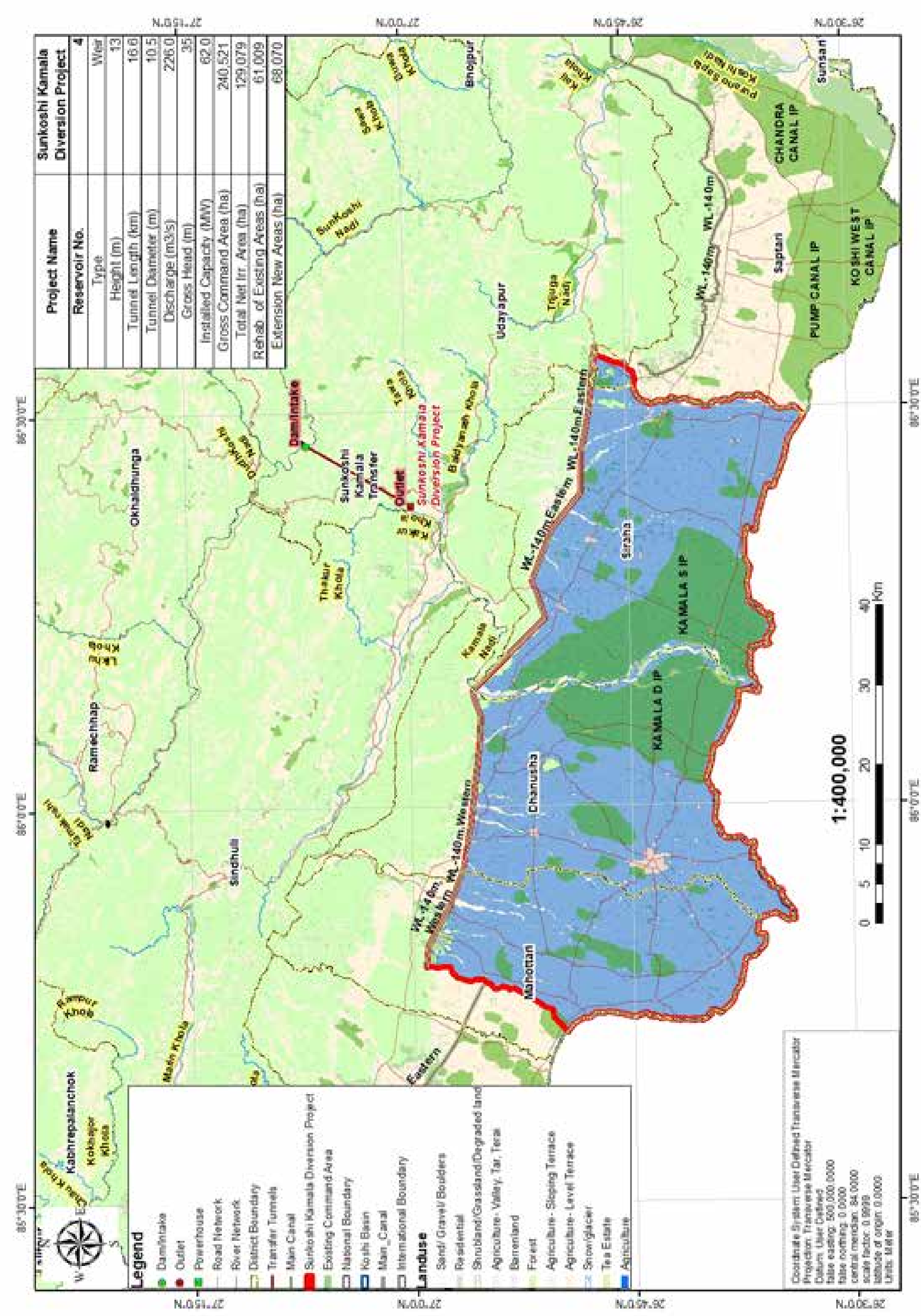


Figure A13: Sunkoshi Marin Diversion Project



Project Name	Sunkoshi Kamala Diversion Project
Reservoir No.	4
Type	Weir
Height (m)	13
Tunnel Length (km)	16.6
Tunnel Diameter (m)	10.5
Discharge (m3/s)	226.0
Gross Head (m)	35
Installed Capacity (MW)	62.0
Gross Command Area (ha)	240,521
Total Net Irr. Area (ha)	129,079
Rehab. of Existing Areas (ha)	61,009
Extension New Areas (ha)	68,070

Figure A14: Sunkoshi Kamala Diversion Project

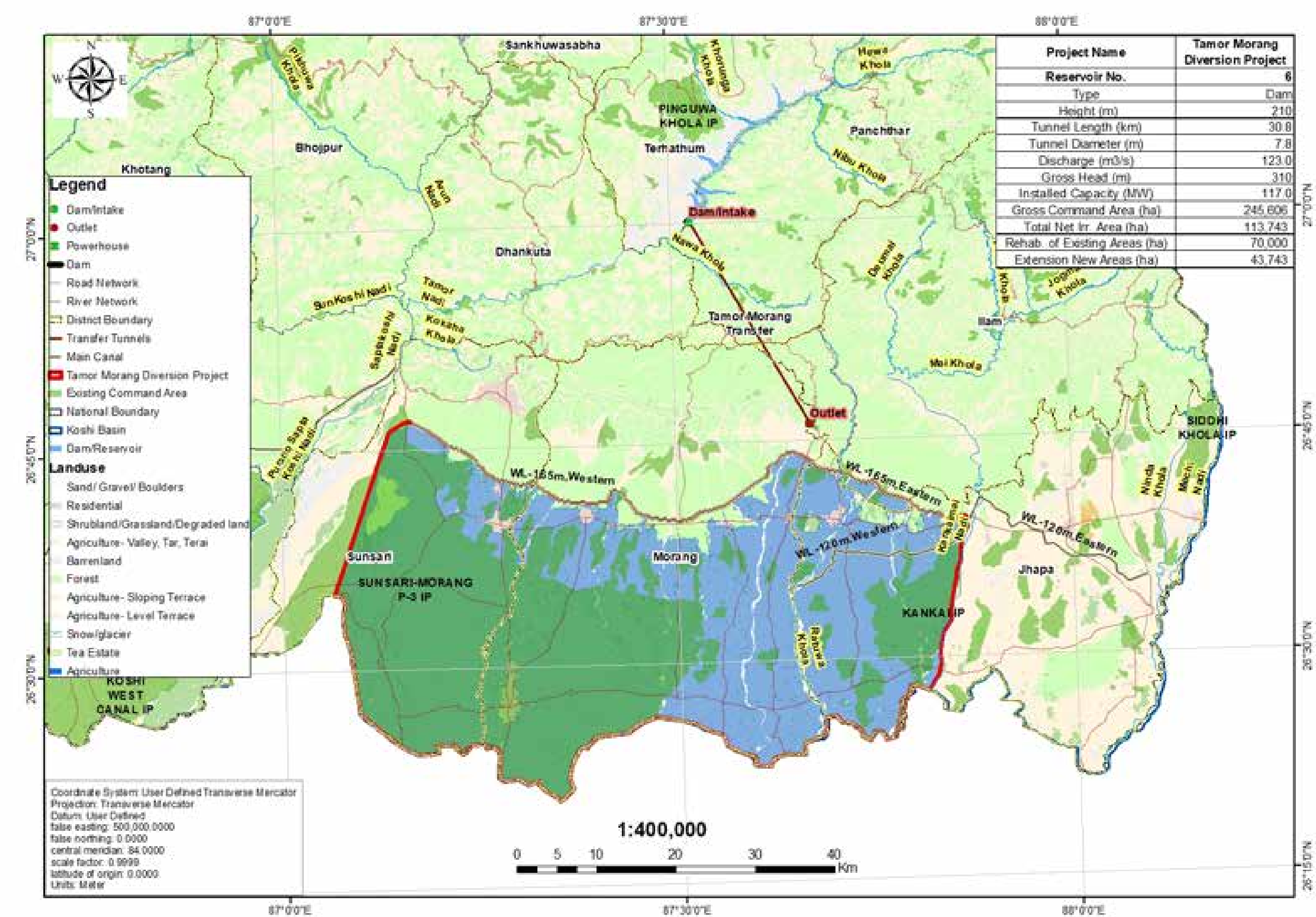
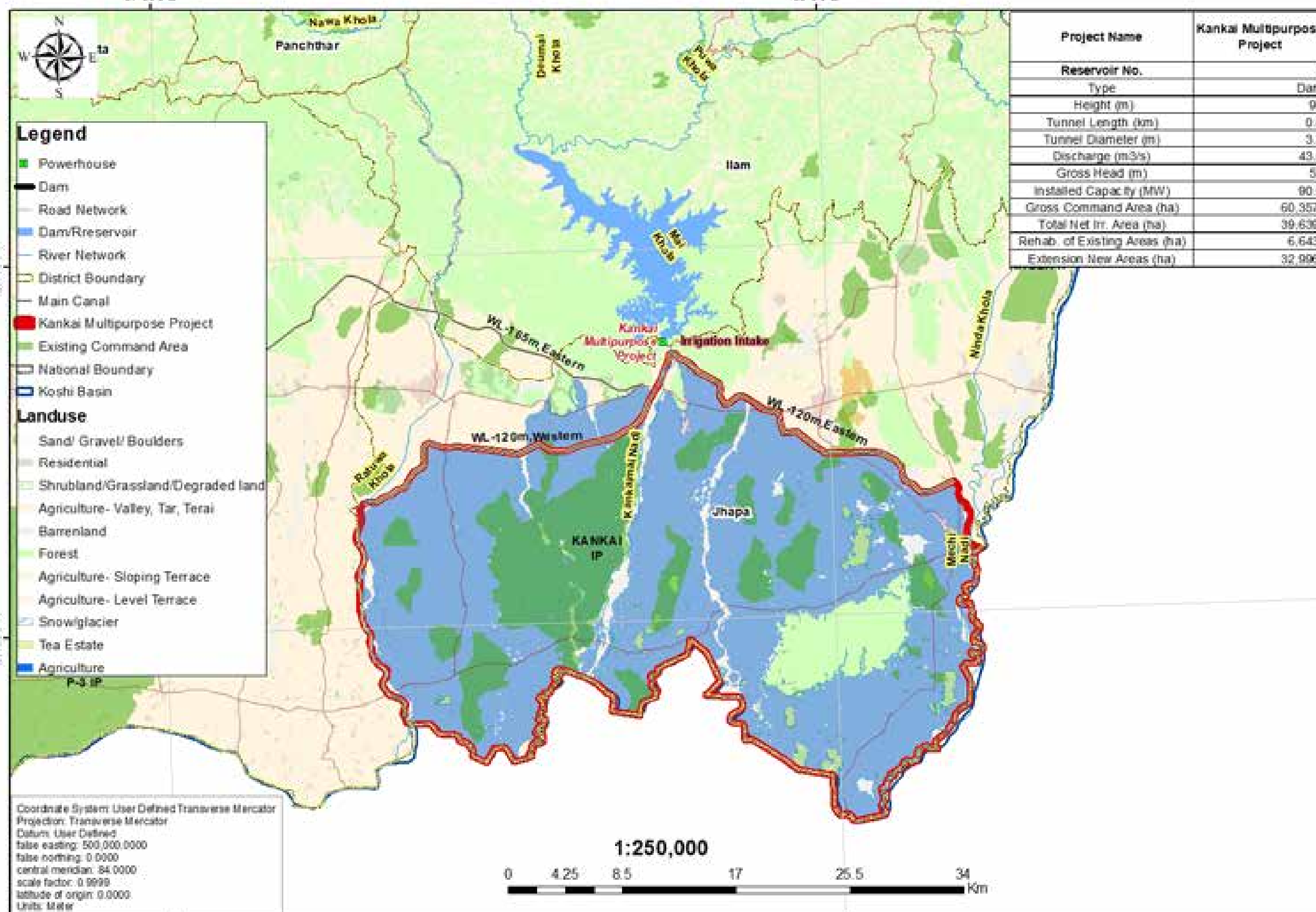


Figure A15: Tamor Morang Diversion Project



Project Name	Kankai Multipurpose Project
Reservoir No.	3
Type	Dam
Height (m)	90
Tunnel Length (km)	0.6
Tunnel Diameter (m)	3.3
Discharge (m3/s)	43.0
Gross Head (m)	58
Installed Capacity (MW)	90.0
Gross Command Area (ha)	60,357
Total Net Irr. Area (ha)	39,639
Rehab. of Existing Areas (ha)	6,643
Extension New Areas (ha)	32,996

Figure A16: Kankai Multipurpose Project

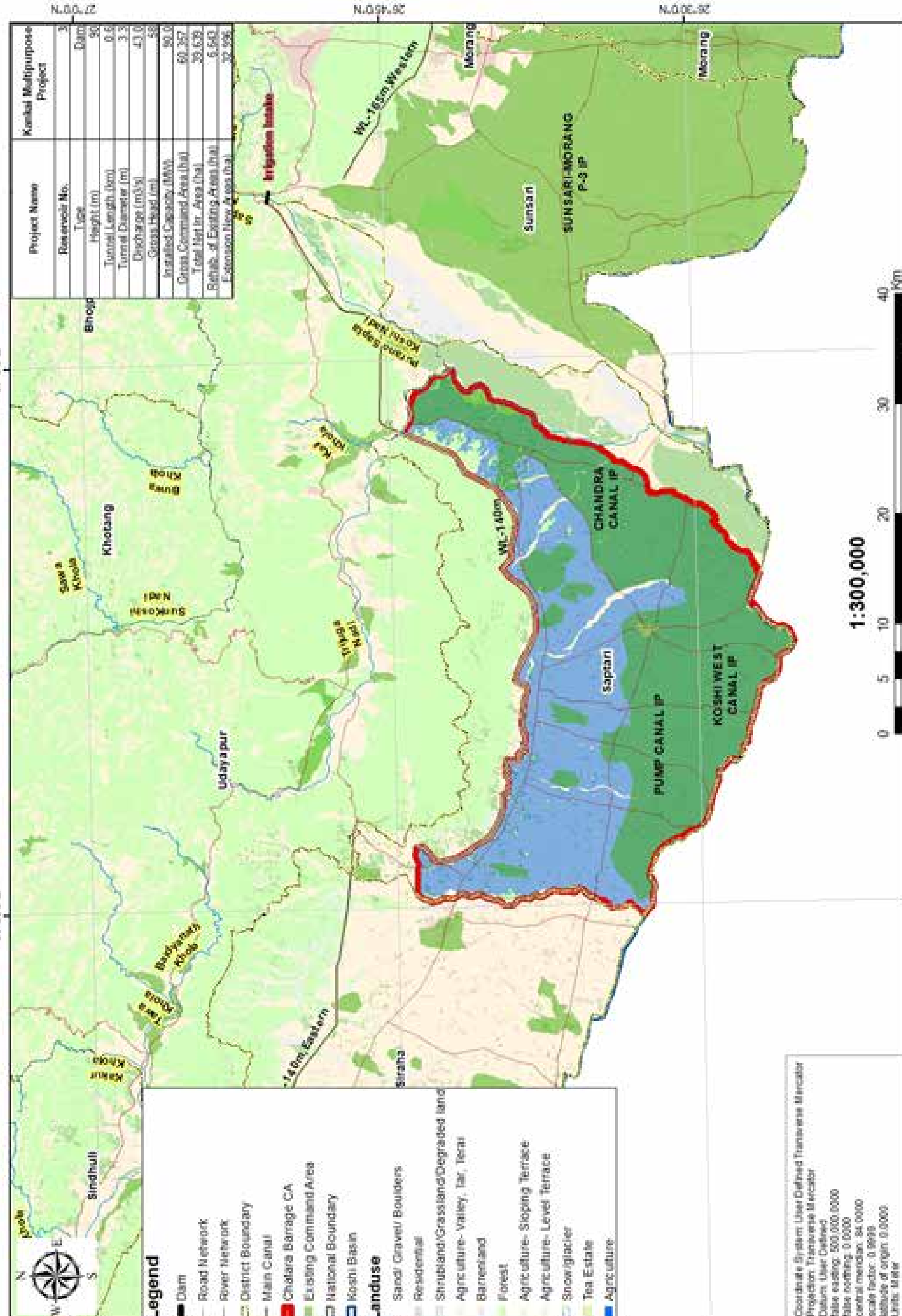


Figure A17: Chatara Barrage Project

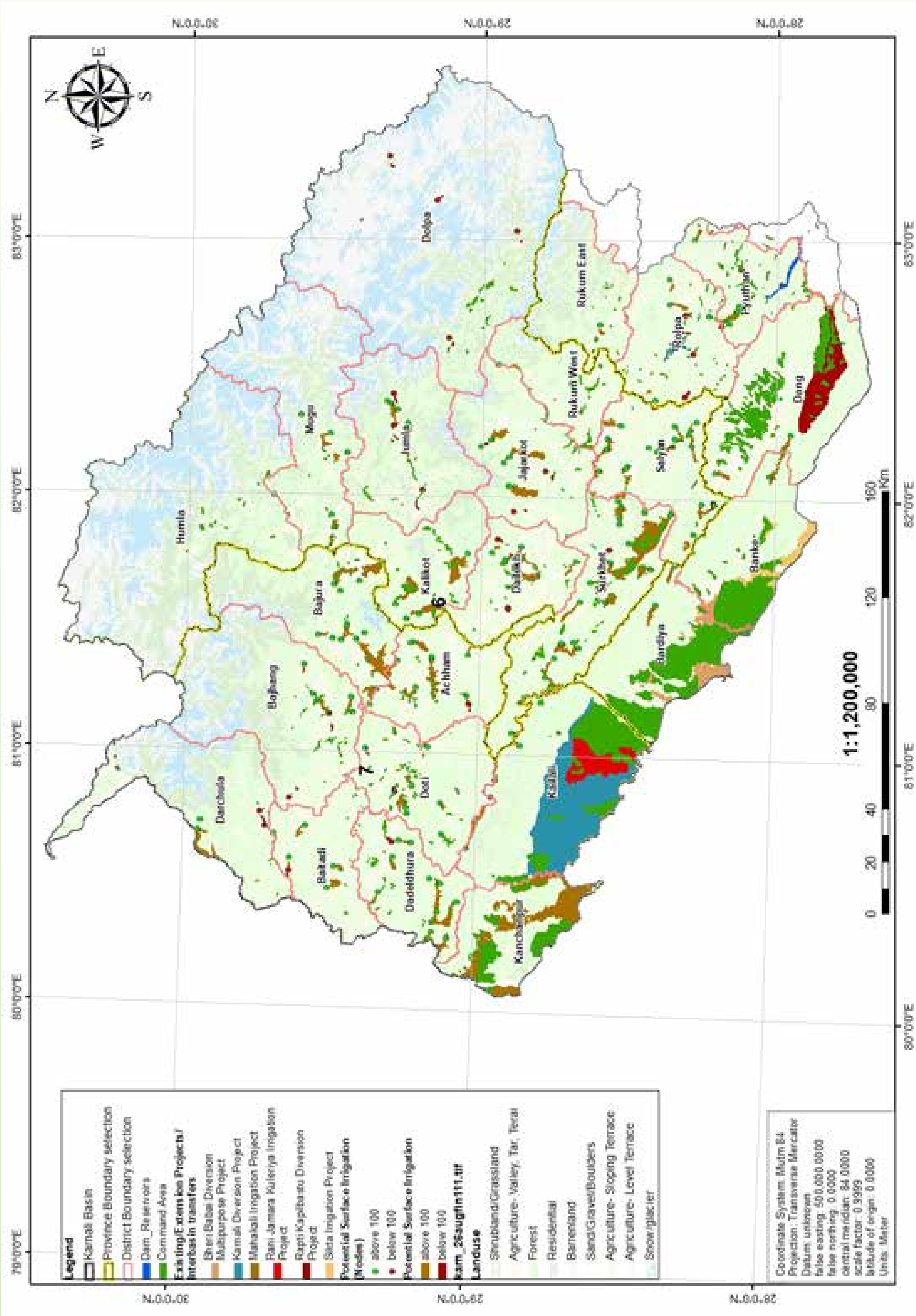


Figure A18: Overview of CA, Potential Surface Irrigation Area, Karnali Basin

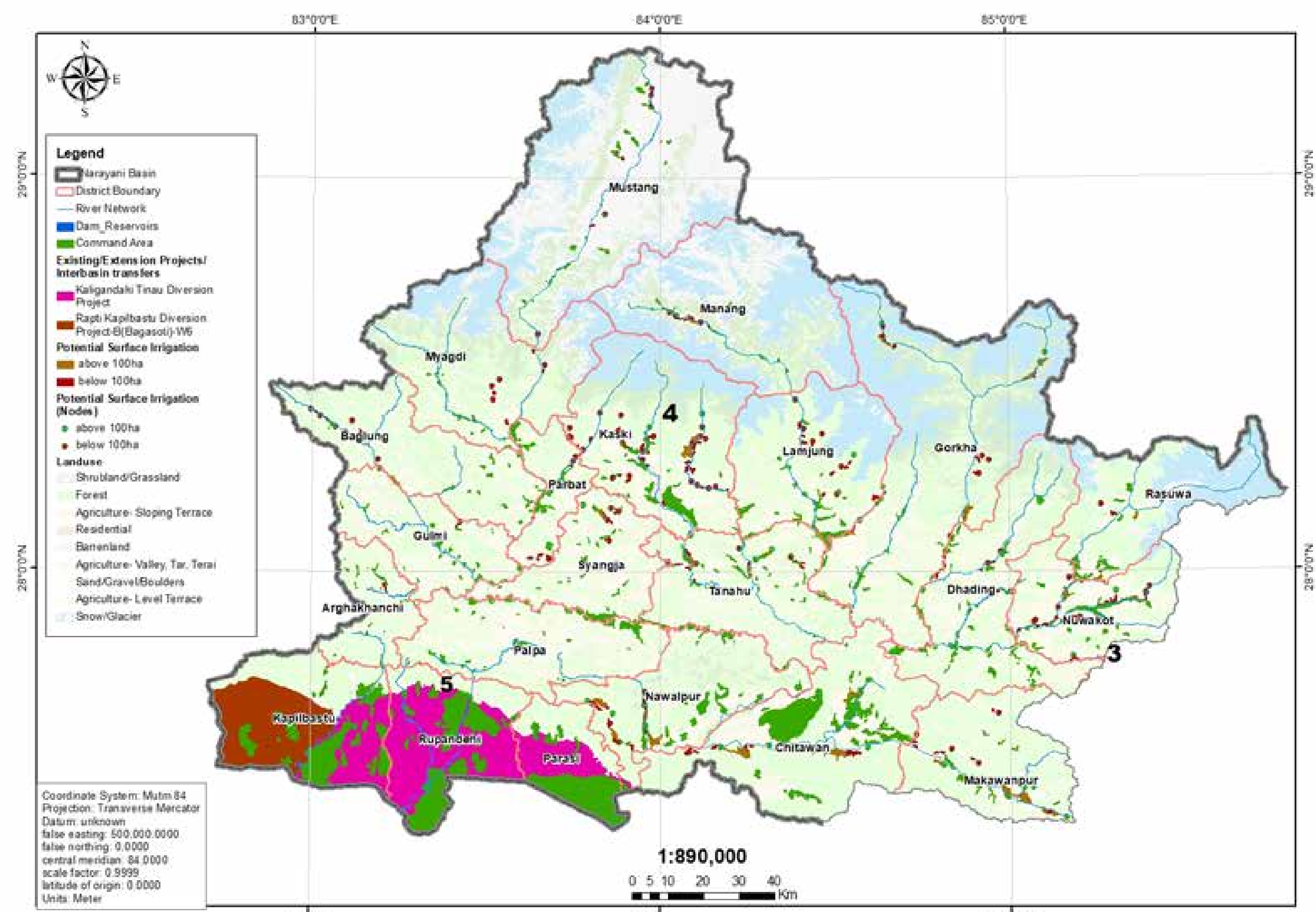


Figure A19: Overview of CA, Potential Surface Irrigation Area, Narayani Basin

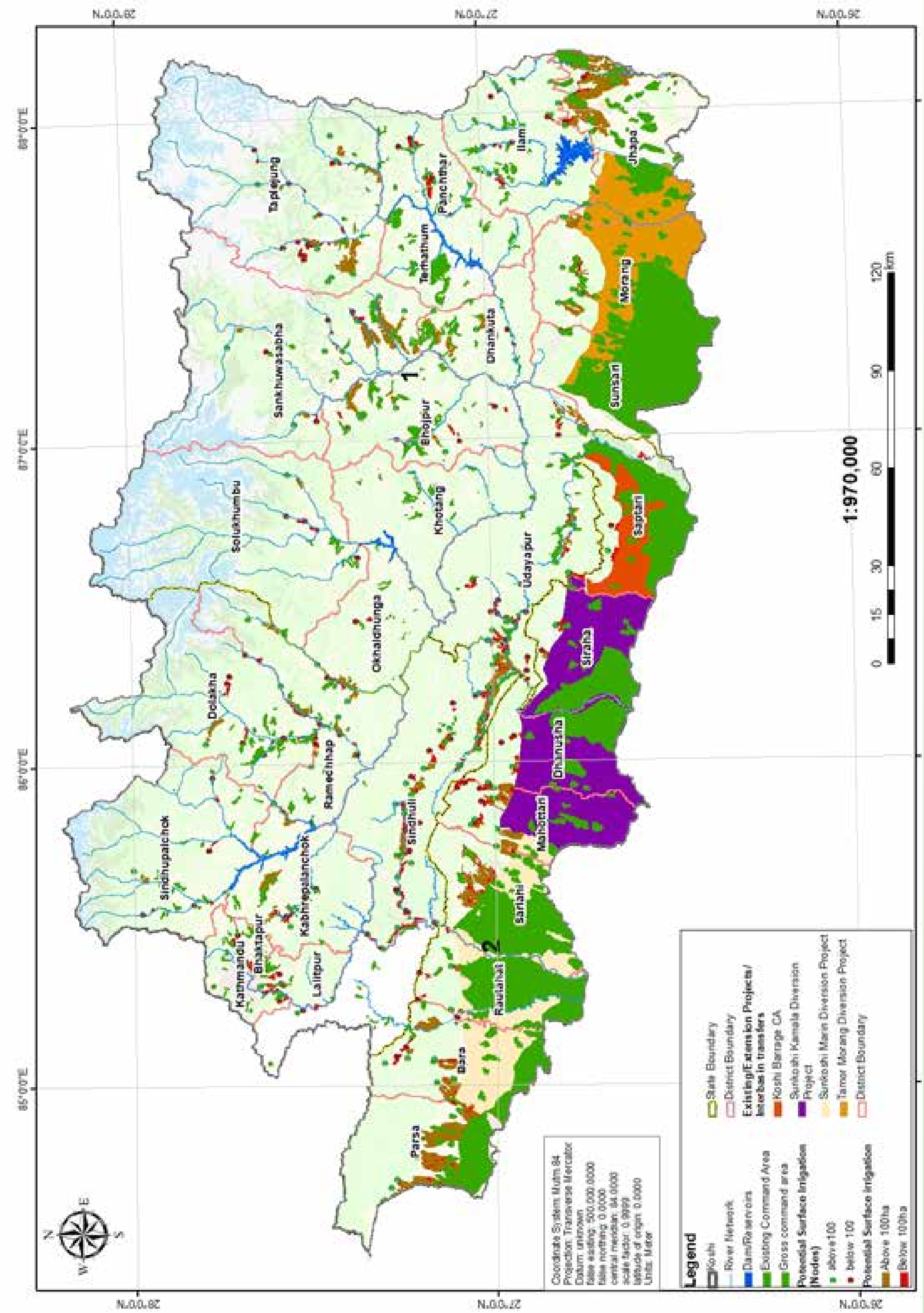


Figure A20: Overview of CA, Potential Surface Irrigation Area, Koshi Basin

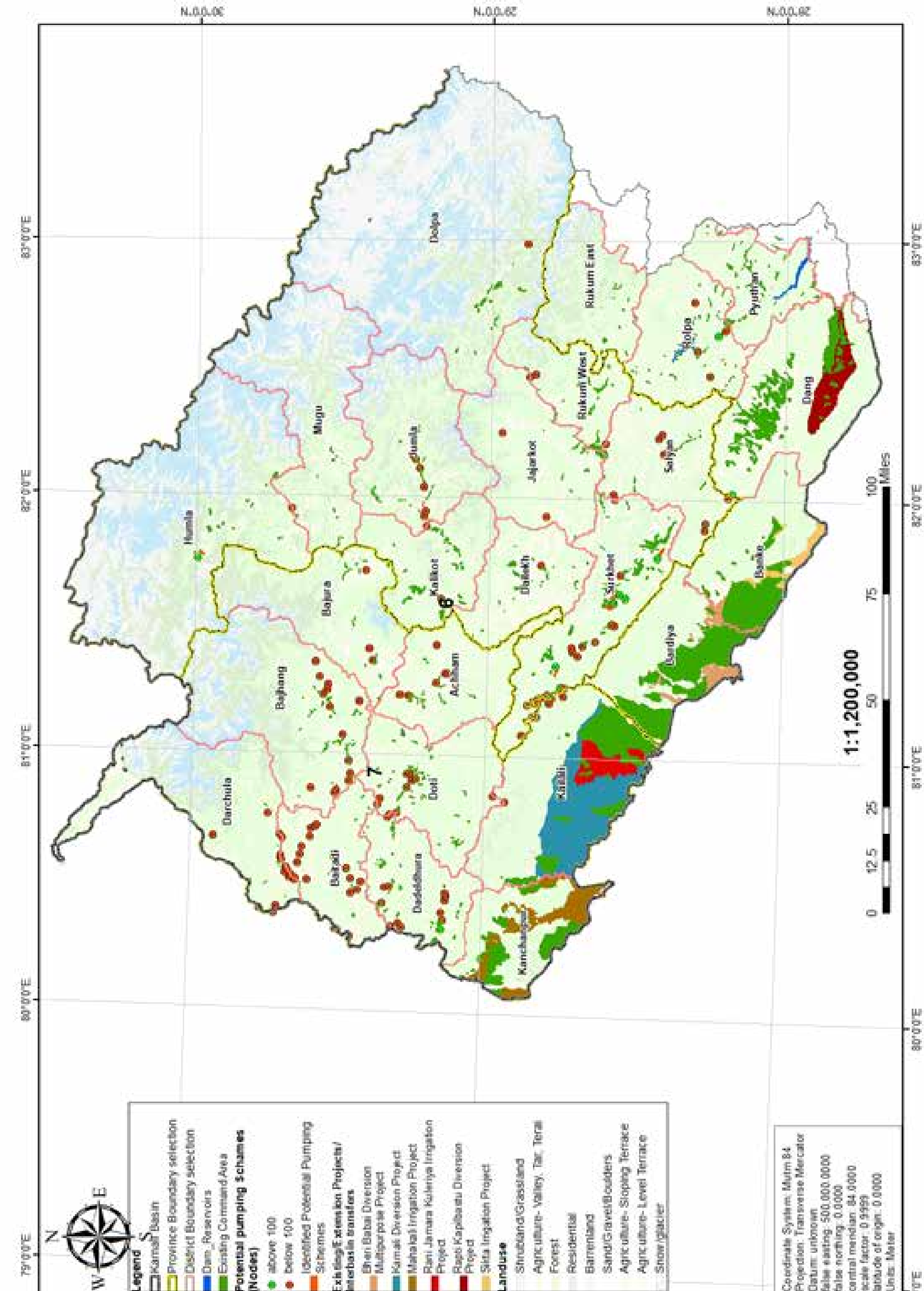


Figure A 21: Overview of CA, Potential Pumping system, Karnali Basin

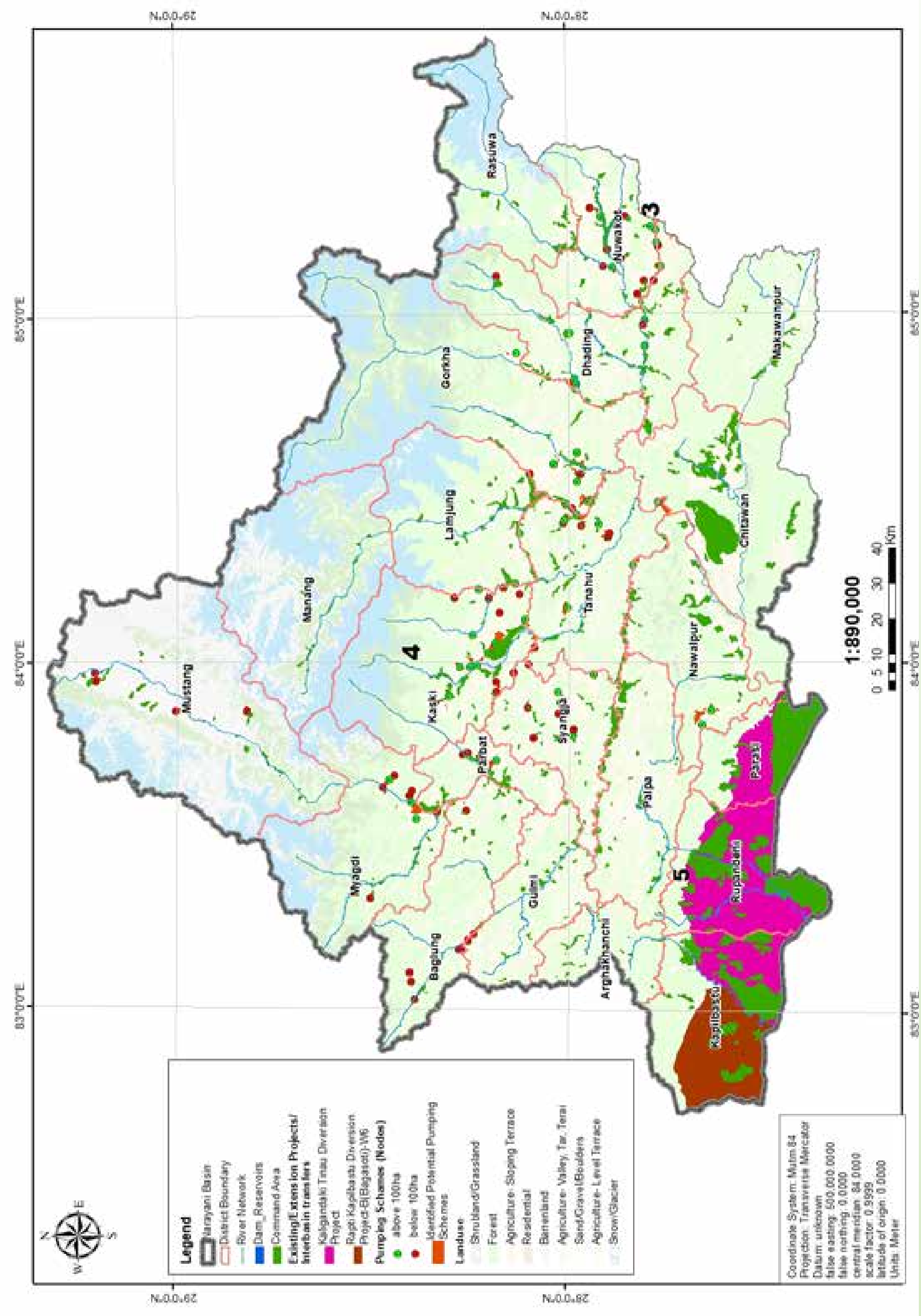


Figure A22: Overview of CA, Potential Pumping system, Narayani Basin

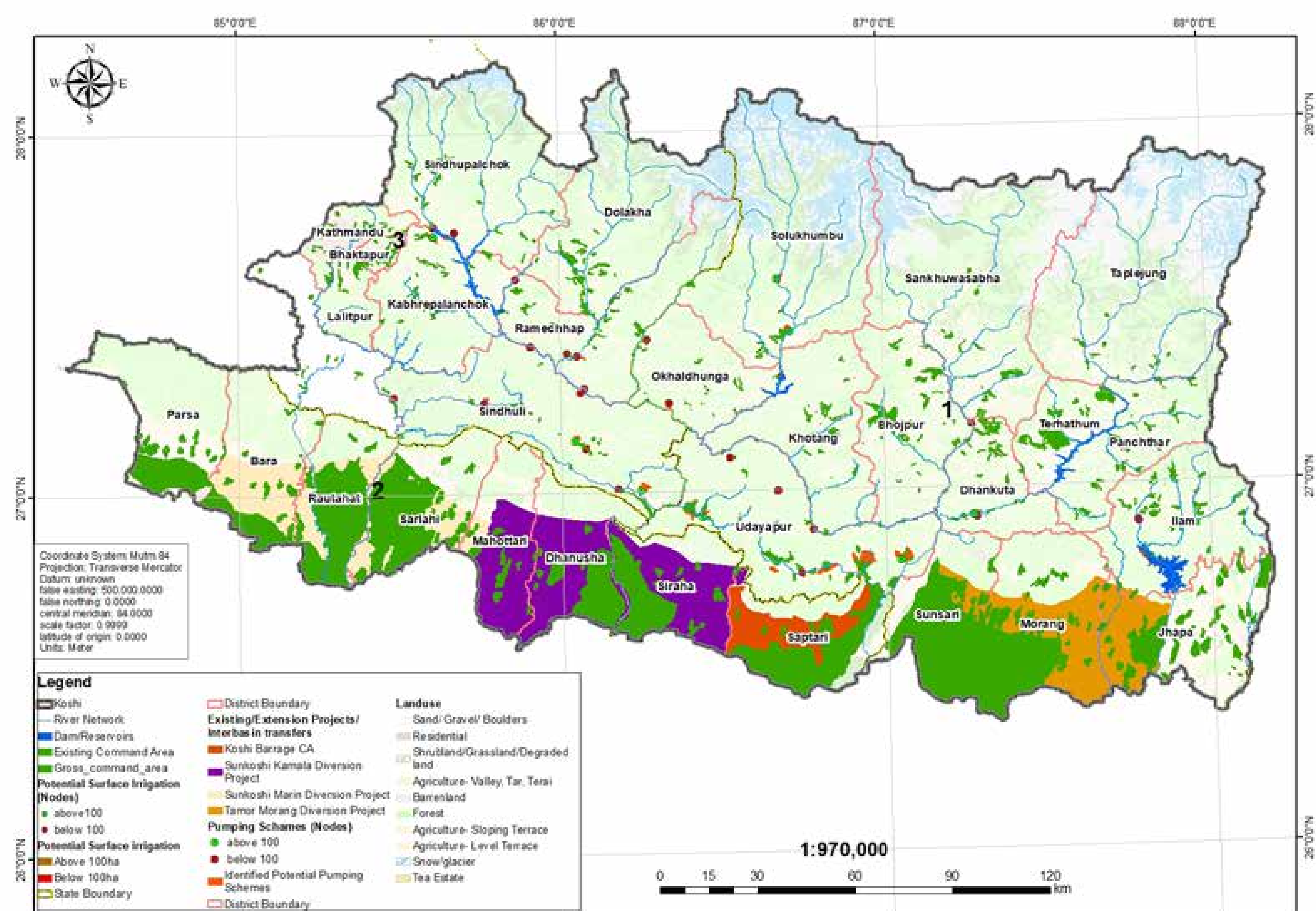


Figure A23: Overview of CA, Potential Pumping system, Koshi Basin

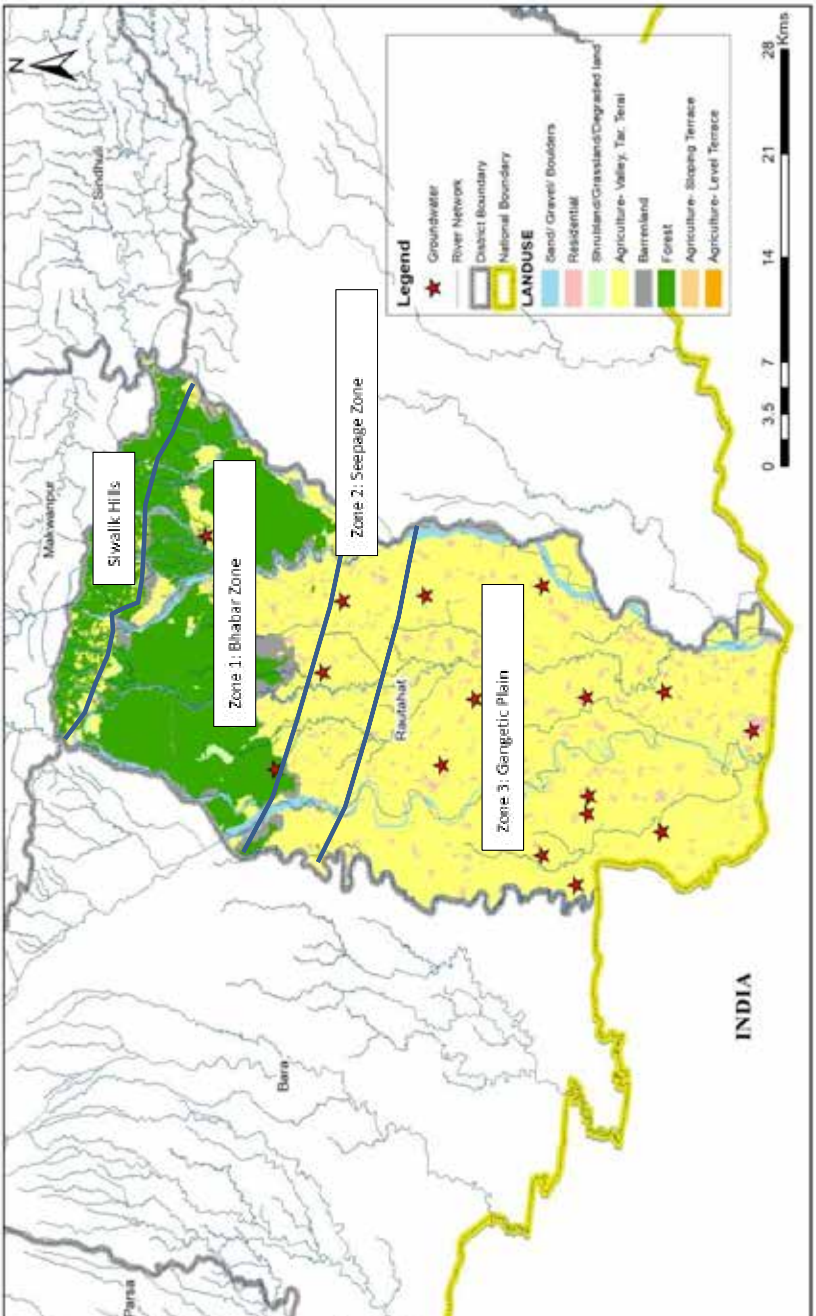


Figure A24: Conceptual Model Overview

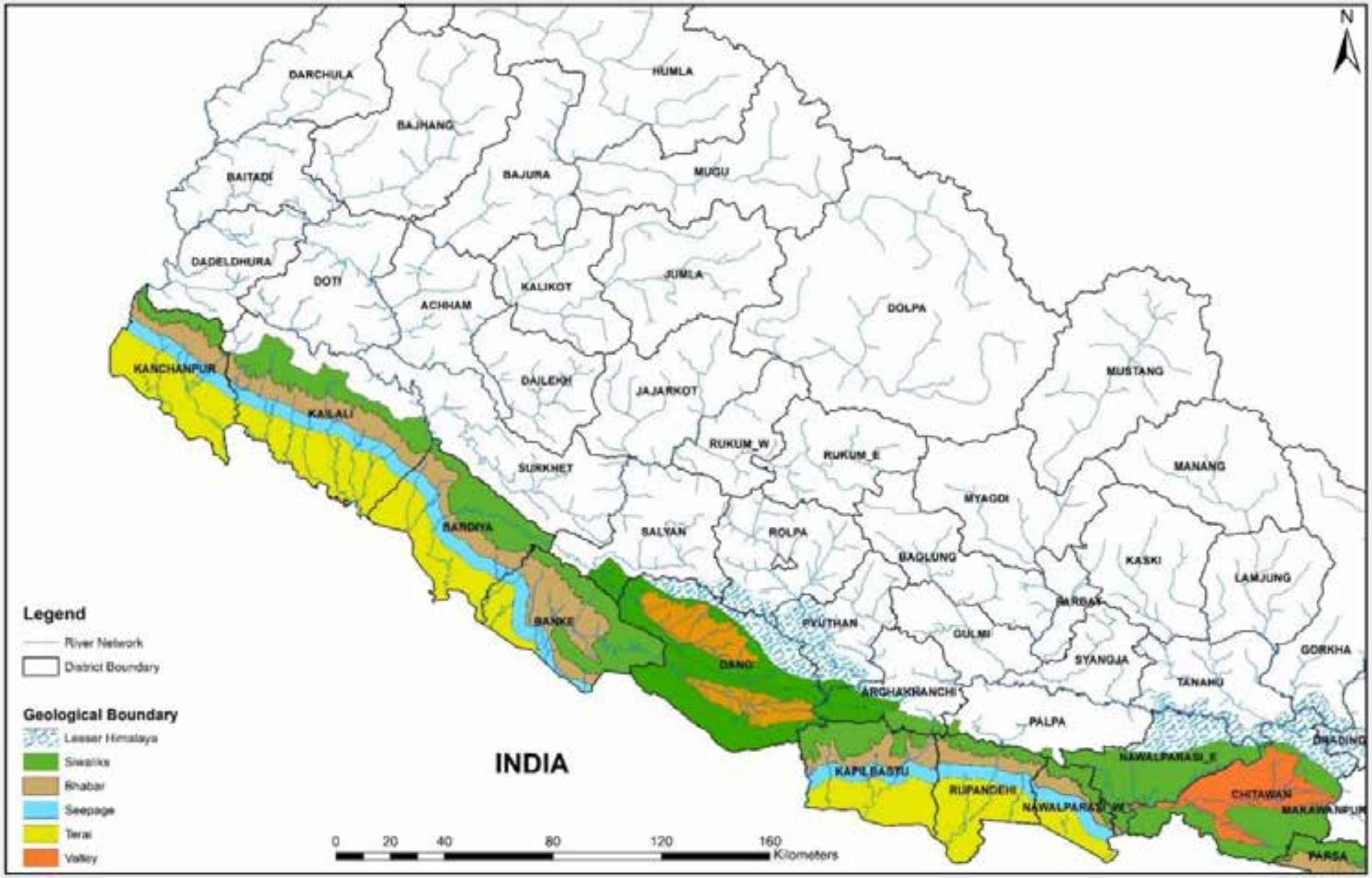


Figure A25: Conceptual Model of Geology and Model Zones for West (Karnali and Narayani Basin)

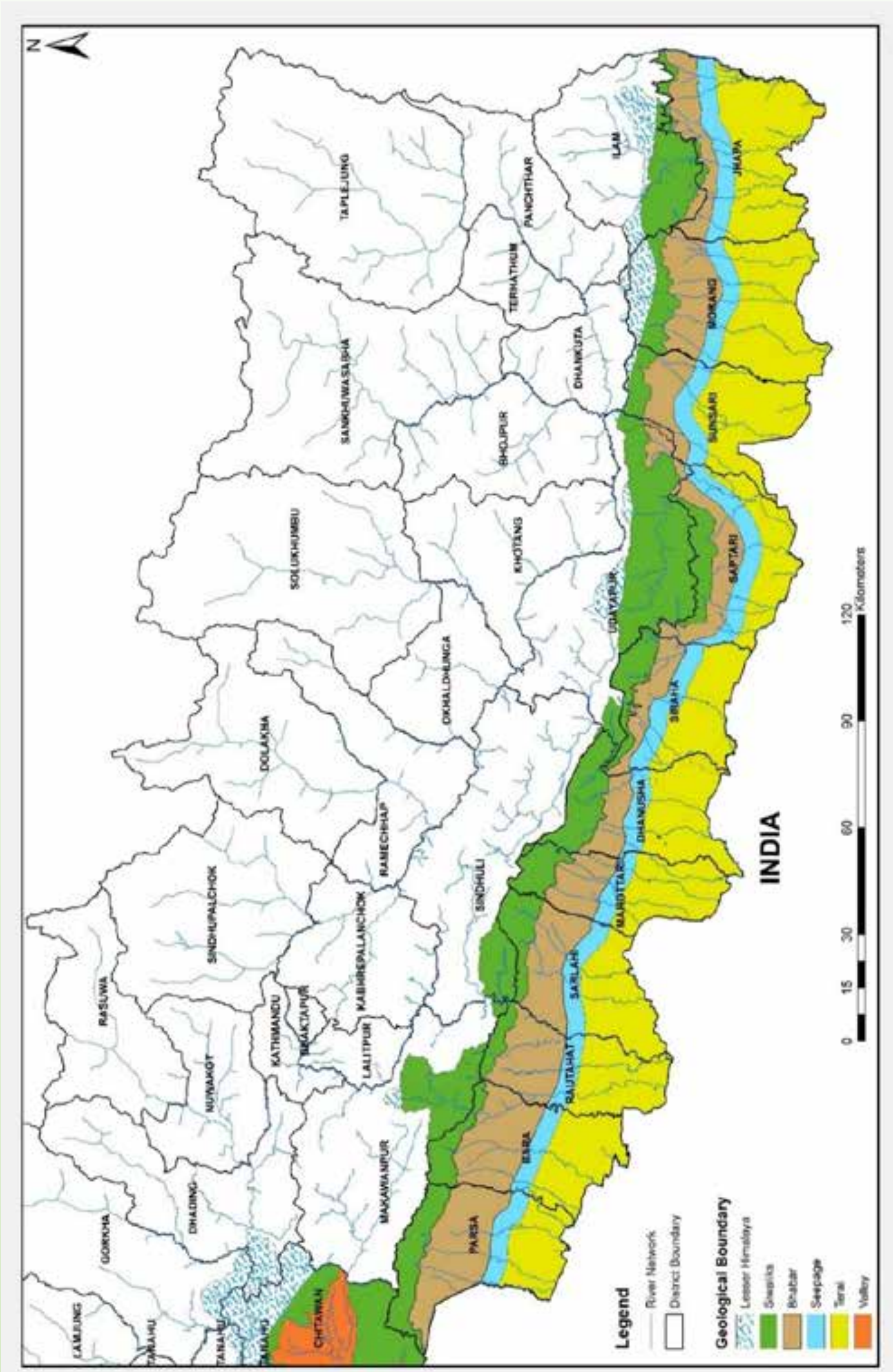


Figure A26: Conceptual Model of Geology and Model Zones for East (Koshi Basin)