IMP 2019

Irrigation Master Plan 2019

Department of Water Resources and Irrigation
Ministry of Energy, Water Resources, and Irrigation
Government of Nepal
November 2019

FOREWORD

ABBREVIATIONS

ADB	Asian Development Bank
ADS	Agriculture Development Strategy
AMIS	Agency-Managed Irrigation Systems
AMP	Asset Management Plan
AND/N	Agriculture Development Bank, Nepal
AWD	Alternate Wetting and Drying
CCA	Climate Change Adaptation
CWR	Committee on Water Resources
DBFO	Design, Build, Finance and Operate
DC	Developed Country
DEM	Digital Elevation Model
DoLIDAR	Department of Local Infrastructure Development and Agriculture Roads
DoS	Department of Survey
DoWRI	Department of Water Resources and Irrigation
DRM	Disaster Risk Management
DSR	Dry Seeded Rice
DTW	Deep Tube Well
EUR	Euro
FCs	Farmer Cooperatives
FDC	Flow Duration Curve
FHRMP	Flood Hazard Mapping and Risk Management Project
FMIS	Farmer Managed Irrigation Systems
GCA	Gross Command Area
GESI	Gender Equality and Social Inclusion
GIS	Geographical Information System
GON	Government of Nepal
HMIP	Hill and Mountain Irrigation Project
HMWAA	Hydraulic Modelling and Water Availability Assessment
HPP	Hydro Power Plant

HVAP	High-Value Agriculture Project
ICID	International Commission on Irrigation and Drainage
ICIMOD	International Centre for Integrated Mountain Development
IMP	Irrigation Master Plan
IMT	International Experience Indicated
IP	Irrigation project
IEE	Initial Environmental Examination
ISF	Irrigation Service Fee
IWMI	International Water Management Institute
IWRMP	Integrated Water Resource Management Project
JMIS	Joint Managed Irrigation Systems
km^2	Square kilometre
KUBK-ISFP	Kisankalagi Unnat Biu-Bijan Karyakarm- Improved Seed for Farmers Program
LDC	Less Developed Country
LGOA	Local Governance Operation Act
LRM	Land Resource Mapping
LSIS	Large Scale Irrigation Systems
MCA	Multi Criteria Analysis
MHB	Mike Hydro Basin
MIIP	Mechanized Irrigation Innovation Project
MIP	Medium Irrigation Project
Mil.	Million
m	metre
m^2	Square metre
m^3	Cubic metre
MoEWRI	Ministry of Energy, Water Resources and Irrigation
MoI	Ministry of Irrigation
MPP	Multi-Purpose Project
NAES	Nepal Agricultural Extension Strategy
NARC	National Agricultural Research Council

NEA	Nepal Electricity Authority
NITP	Non-Conventional Irrigation Technology Project
NLUP	National Land Use Project
NPR	Nepalese Rupee
NWP	National Water Plan
OFWM	On Farm Water Management
PACT	Project for Agriculture Commercialization and Trade
PAD	Performance Assessment and Diagnosis
PCPS	Pre-cast Parabolic Sections
PIM	Participatory Irrigation Management
PPP	Public-Private Partnership
RBP	River Basin Plan
RISMFP	Raising Incomes of Small and Medium Farmers Project
SESA	Strategic Environmental and Social Assessment studies
SIP	Small Irrigation Program
SPV	Special Purpose Vehicle
SRI	System of Rice Intensification
SWAT	Soil Water Assessment Tool
TOR	Terms of Reference
USD	United States Dollar
UTM	Universal Transverse Mercator
VDC	Village Development Committee
WECS	Water and Energy Commission Secretariat
WRPPF	Water Resources Project Preparatory Facility
WRS	Water Resource Strategy
WUA	Water User Association
WUC	Water Users Cooperative
WUE	Water Use Efficiency

Table of Contents

1. SECTION I: POLICY CONTEXT

1.1 Irrigation Sector and Development in Nepal

1. Agriculture is an important part of the Nepali economy and social fabric, contributing an estimated 27% of the GDP in 2017 (source: indexmundi) and providing employment to more than 70% of the labour force. Approximately 40% of the total agricultural areas are irrigated. Agriculture and particularly irrigated agriculture is facing a number of challenges and have considerable potential for improvement and expansion. While Nepal has ample water resources the challenge is how best to develop both surface water and groundwater resources for intensification of existing irrigated lands and for development of new lands, and to improve the performance and productivity of irrigation system more generally through the adoption of modern infrastructure and management methods.

2. Nepal has goals for improvement and expansion of irrigated agriculture and will face increasing demand for food over the next 25 years, the planning horizon of the IMP. Therefore, the challenge that the IMP addresses is to provide an investment plan that will guide the development of investment and management over this period to achieve these goals.

3. The report Sustainable Development Goals 2016-2030 (NPC 2015) emphasizes the importance of growth in per capita Gross National Income, improvement in human assets and reduced economic vulnerability in order to raise Nepal from LDC to DC status by 2022. IMP will direct irrigation planning and investment over the next 25 years to about 2044. The Plan will cover an important period in the development of Nepal, as the country approaches its expected demographic maximum in 2055 (36 Mil. people, up from about 29 Mil. in 2016). The urban population is projected to increase from 4.52 Mil. to 9.97 Mil. by 2031 (an increase of 120%) and the number of cities with population greater than 100,000 will increase from the present 23 to about 52. At least 30% of the population will be urban in 2031, compared with 18% now. Because of the expected high level of rural to urban migration, the best estimate of the increase in the rural population over the period 2011-2031 is 9% and it is likely that the rural growth rate could be zero, or even negative.

4. In the context of an expanding economy, the quantity of food demanded increases with the growth of population and the demand for food changes according to consumer preference with increasing household consumption. Urban populations have different food consumption habits from rural populations; urban consumers take in less kilocalories but eat a greater proportion of higher value, seasonal and more perishable crops and livestock products. Rural households have diets that can deliver the generally higher food energy required for rural lifestyles while relying on their land base for providing a reliable supply of staple foods.

5. Further, and as identified in the National Planning Commission Report Demographic Changes of Nepal: Trends and Policy Implications, (2017), Nepal faces not only the challenges of rapid urbanisation, but also, within the next four decades, a progressive ageing of the population and the closure of the "demographic window of opportunity" - to equip children and those children born in the future to achieve the levels of productivity that an increased labour force dependency ratio will entail. The window of opportunity, while the labour force is numerically maximized is calculated to be in the period 1992-2047. The time horizon of this Master Plan is to 2044. The Plan must contain initiatives to exploit the opportunity. The NPC report concludes "the investments now that will reap most benefits in the future are ones that strengthen the workforce of the future". In the agricultural sector irrigation is the obvious target for investment. Investing "now" becomes even more critical given the extended time scale required to develop the infrastructure required to manage water resources on a large scale.

6. The IMP needs to be developed in this economic context. Earlier irrigation planning emphasized the importance of irrigation in achieving national food security but despite an increase in the irrigated area from 0.933 million ha (IMP 1990) to about 1.435 million irrigated ha in 2019 (IMP estimates 2019)

the food produced and available for consumption in Nepal (i.e. total food available minus imports and exports) provided only 2,106 kcals per capita per day in 2011, implying that 17% of the national food energy requirement was satisfied by food imports. In 1988 Nepal was 90% food self-sufficient, so in 2011 with 83% food self-sufficiency the situation was markedly worse. Fuelled by increasing household income from remittances, food import dependency rates are increasing, especially for non-cereals; so as non-cereals increase as a proportion of the average diet, it can be expected that this trend will continue, unless the agricultural sector can deliver a wider range of food crop diversity.

7. These trends have significance for the IMP. In order to plan for irrigation, it is necessary to quantify the economic context through an estimate of future food requirements of a developing economy with a growing population and an increasingly urban society. Trends in national food consumption are identified from cited literature in the IMP Report Annex G, Part 2 (IMP Final July 2019), distinguishing between urban and rural diets. In summary, in 2011, 564 kg per capita per annum of food was available with characteristics 2,525 kcal/day, 64.4 gm per capita/day of protein, and 51.8 gm per capita/day of fat. In 2031 the overall available diet of 650 kg per capita is expected to be 2,641 kcals/day, 72 gm per capita/day of protein, and 64 gm per capita/day of fat. Overall, the share of cereals in the diet declines from 33% to 27% by weight and from 64% to 57% by energy. The projected diet is the weighted composite of urban and rural diets.

8. Scenarios about how the food requirement in 2011 is met from domestic production, food stocks and trade, and how and over what time scale the future diet may be achieved are important, not for their accuracy but to provide indicative results of a range of development options. IMP is concerned with irrigation planning, so a key task described in this report required establishing an estimate of the contribution of irrigation to agricultural productivity at national level. At the most optimistic level, assuming a marked deterioration of the productivity of rainfed land (due to over expansion onto marginal land in the early 2000s, followed by land abandonment and declining labour inputs due to out-migration driving cropping intensity down to barely over 100% at present) cropping intensity on irrigated land appears to have remained static at about 180% in the period 1999/2000 to present. Overall cropping intensity has declined from 140% to 130% in the last 25 years.

9. Differential yields of irrigated and rainfed land were developed based on MoA estimates of overall yields, suggesting that incremental yields on irrigated land are less than about 25% over rainfed yields. The major benefit from irrigation is increased cropping intensity and not significant yields. A national irrigated cropping pattern in 2011 was established, guided by MoA's annual estimates of the proportion of cereal crops irrigated. The analysis suggests that low value cereals continue to dominate the irrigated cropping pattern. The conclusion is that Nepal's agricultural sector has performed sluggishly over the past two decades and fell short in meeting increasing demand for food and the different types of food demanded. Two technical reasons for this are likely to be inadequate, un-timely and unreliable provision of irrigation on the existing irrigation area and insufficient investment allocated to expanding irrigation command area. A third, economic reason is that irrigation is not being developed in optimum locations to give the maximum responsiveness to growing food markets.

1.2 Stocktaking of Key Achievements under Irrigation Master Plan 1990

10. The IMP follows on from the Irrigation Master Plan of 1990, which formed the basis for the planning and implementation of development and management of the irrigation subsector over the past 30 years.

11. The 1990 Master Plan set out a program for the irrigation development intended to fulfil three principal objectives:

- 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. The 1990 Master Plan was a valuable instrument for irrigation planning but after nearly 30 years since it has been established, it is outdated in many parts. However, review of the proposed projects reveals many are achieved, with some still under construction, or consideration in this master plan.

13. The IMP was prepared within the context of the current national policy and strategic planning documents generated during the 1990 Master Plan period for the development and management of irrigated agriculture and land and water resource management, and where relevant the national economy. In summary these include:

- **Water Resources Strategy (WRS) (2002):**[1] the strategy set out a systematic framework for water resources development in Nepal, included use for irrigation. Output 4 titled *'Appropriate and Efficient Irrigation Available to Support Optimal, Sustainable Use of Irrigated Land'* listed challenges faced by the subsector and a series of activities to be promoted to address these challenges, including; improvement of system management, intensification and diversification, capacity strengthening for planning and management, implementation of new irrigation systems and improved groundwater development and management.
- **National Water Plan (NWP) (2005):**[2] builds on the WRS, to '*operationalize the output of the WRS'.* It covers the whole water sector, inclusive of the irrigation subsector with a planning horizon to the year 2027. The irrigation goals include '*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 lists targets for improvement in expansion of irrigated lands, cropping intensity, irrigation efficiency and crop yields under irrigation.
- **Irrigation Policy (2013):**[3] the policy document sets out the rationale for subsector development and policy objectives and approach for project development, water user associations, irrigation service charges and irrigation system operation and maintenance.
- **Sustainable Development Goals 2016-2030 (NPC 2015):** emphasizes the importance of growth in per capita Gross National Income, improvements in human assets and reducing economic vulnerability in order to raise Nepal from the status of LDC to DC by 2020.

14. Over the past thirty years there have been twelve major irrigation development projects in Nepal at a total cost of more than NPR 67 billion (approx. USD 800 million) and combined irrigated area of about 570,000 ha. Annex F presents detailed description of the development projects. The projects included both agency and farmer managed irrigation systems. These projects have included investment in infrastructure rehabilitation, command area development and IMT. The outcomes of these projects provide value lessons for the planning and implementation of future projects to better achieve sustainable management of systems and improvements in system performance.

15. The average cost per unit area for all 12 projects is about NPR 93,000 per ha (USD 1,000 per ha) but range from less than NPR 18,000 to more than NPR 300,000 per ha (USD 300 to 4,440 per ha). The average

[1]Water Resource Strategy, 2002. Water and Energy Commission Secretariat, Kathmandu
[2]National Water Plan , 2005. Water and Energy Commission Secretariat, Kathmandu
[3]Irrigation Policy, 2060 (BS). Water and Energy Commission Secretariat, Kathmandu

unit area costs are relatively modest for system development and possibly reflect the fact that the investments were principally focused on large structures and main canal development.

1.2.1 Present irrigation coverage under different management systems

16. Table lists a summary of surface water irrigation systems by agro-ecological zone and management system, derived from the IMP Annex B Irrigation Inventory. There are a total of about 2,254 systems with a combined area of nearly 728,000 ha (JMIS and FMIS only), of which 81% of the irrigated area (of surface water systems) 591,000 ha are on the Terai. The Hill zone accounts for 15% of irrigated area and the Mountain zone 4% of irrigated area. JMISs irrigate about 357,000 ha most of which is on the Terai in 24 systems. FMISs account for 51% of the total surface water irrigation systems. On the Terai FMIS are 33% (240,213 ha) of the area and 97% (809) by number. In the Hill and Mountain they make up 18% of the irrigated area (131,181 ha).

Table 1: Irrigation coverage under different management systems

Ecological Zone	JMIS	FMIS	Total
	Area (ha)	Area (ha)	Area (ha)
Terai	350,926	240,213	591,139
Hill	4,275	105,109	109,384
Mountain	1,852	26,072	27,924
Total	**357,053**	**371,394**	**728,447**

17. AMISs and JMISs are almost exclusively medium to large scale systems which encompass multiple communities. For these reasons they tend to have relatively large infrastructural works, often with river barrages and large main canals which require high levels of capital investment, normally beyond the capacity of local communities to operate and maintain. They are also complex in terms of developing community participation in O&M activities due to both social diversity between communities and large number of water users.

18. FMISs by contrast are generally smaller and more socially homogenous. They have been developed as a result of community needs by community cooperation and participation therefore are well established and mature in terms of organisation and O&M management.

1.2.2 Irrigation Systems

19. The IMP development activities include an inventory of irrigation systems which forms the basis of classification of system typology by agro-ecological zones (Terai, Hill and Mountain) and management system.[4] For the purposes of the inventory, systems are classified as having a command area of greater than 25 and 10 ha on the Terai and Hill/ Mountain zones respectively. The results from the inventory show that there are approximately 3,100 systems with a combined command area of about 1 Mil. ha.

Table 2: AMIS maintained by DoWRI

[4] The definitions of management system adopted for this report and the IMP are: Agency Managed Irrigation System (AMIS); systems principally and largely operated by the Department of Irrigation (DoWRI), Farmer Managed Irrigation System (FMIS); systems solely developed and operated by the beneficiary community, and Joint Managed Irrigation System (JMIS); systems developed by the DoWRI (or other government agency) and partially handover to the beneficiary community.

S.N.	District	System Name	GCA	NCA	Ecological Region	Water Source
1	Bara	Narayani Ip	16,650	12,238	Terai	SW
2	Bardiya	Babai Ip	35,421	29,500	Terai	SW
3	Bardiya	Rajapur Ip	17,140	13,000	Terai	SW
4	Chitawan	Narayani Lift Ip	5,937	4,700	Terai	SW
5	Dhanusha	Kamala Ip	12,500	12,500	Terai	SW
6	Jhapa	Kankai Ip	10,216	8,000	Terai	SW
7	Kailali	Ranijamara Ip	11,300	11,300	Terai	SW
8	Kanchanpur	Mahakali Phase-I Ip	5,520	4,800	Terai	SW
9	Kanchanpur	Mahakali Phase-Ii Ip	8,500	6,800	Terai	SW
10	Kapilbastu	Banganga Ip	10,734	6,200	Terai	SW
11	Morang	Sunsari-Morang P-3 Ip	28,000	23,800	Terai	SW
12	Nawalparasi_W	Nepal Gandak Ip	14,112	10,300	Terai	SW
13	Parsa	Narayani Ip	20,761	16,462	Terai	SW
14	Rautahat	Bagmati Ip	29,035	23,000	Terai	SW
15	Rupandehi	Marchawar Lift Ip	3,500	3,500	Terai	SW
16	Saptari	Chandra Canal Ip	13,593	10,500	Terai	SW
17	Saptari	Koshi West Canal Ip	14,298	11,000	Terai	SW
18	Sarlahi	Bagmati Ip	28,403	22,600	Terai	SW
19	Sarlahi	Manusmara 1St Ip	2,828	2,200	Terai	SW
20	Sarlahi	Manusmara 2Nd Ip	3,912	3,000	Terai	SW
21	Siraha	Kamala Ip	12,500	12,500	Terai	SW
22	Sunsari	Chanda Mohana Ip	2,362	1,800	Terai	SW
23	Sunsari	Sunsari-Morang P-3 Ip	40,000	34,000	Terai	SW
24	Rupandehi	Bhairahawa Lumbini GWP	20,000	20,000	Terai	GW
Total			**367,222**	**303,700**		

20. For these systems approximately a third are under Agency or Joint management of which the majority are large systems, greater than 1,000 ha, on the Terai (covering 90% by area), though the number of systems is relatively small (less than 2% of all systems). The balance of the systems under

farmer community management are generally small per unit and occur mainly in the Hill and Mountain zones though they make up the majority by number (of the order of 98%).

21. While there is limited information on the category of small systems not included in the above-mentioned irrigation inventory, it is estimated that there of the order of 12,000 systems with a combined command area of up to 150,000 ha. These systems, while under local community management, periodically receive assistance for repair and rehabilitation of canals and control structures and technical assistance for capacity building on system operation and on improvements farming practices, particularly related to productivity to improve household food security and income. This assistance is provided by several government agencies or non-government agencies - international and national.

1.2.3 Irrigation Management

22. The reference point for the current IMP development is the Irrigation Master Plan published in 1990 referred in this chapter as IMP-1990. This formed the basis of the proposed program for development of the irrigated agriculture sector from that date to the present day. IMP-1990 had three principal objectives: (i) provision of a long-term strategy for development of the irrigation subsector consistent with water resource availability and government development policies, (ii) to develop short term investment programs (consistent with the strategy) based on identified and ranked investment opportunities as well as priority needs assessment, and (iii) provision of a sound database and methodology for further updating of the Plan. The Plan objectives were drafted within the context of and goals of contributing to achievement of national objectives of food production and national food self-sufficiency.[5]

23. At the time of its preparation, the agriculture sector accounted for more than 50% of GDP and majority of national employment. While up to this time Nepal had been self-sufficient in grains, demand was increasing due to population growth and the country was moving out of self-sufficiency.

24. The IMP-1990 proposed short term investment program was focused on five areas: (i) management improvements on existing irrigation projects, (ii) development of groundwater irrigation in the 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 a level of intervention (area) and rates of investment per unit area. For the large projects on the Terai it specifically cited seven single projects with a combined area of more than 115,000 ha, including the projects - Bagmati (37,000 ha), Sikta (36,070 ha) and Babai (13,500 ha). The combined area for the 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).

25. While the short term program largely focused on irrigation development, the longer term strategy was 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 privatisation of management, (iii) development of small and medium irrigation projects, and (iv) implementation of new large projects on the Terai (presumably in addition to those identified under the short term program).

26. While IMP-1990 provided a good foundation for planning for the subsector particularly through to the period of 1990s, it is now over 30 years old. It is estimated that 200,000 ha were implemented, as indicated in, over this period representing 34% achieved.

27. There have also been significant policy developments in the planning and management of water resources which include the adoption Water Resources Strategy (2002)[6] and National Water Plan (2005).[7]

[5] A Basic Needs Programme (BNP) was established in 1985, which included goals for production of grain and area of irrigation development.
[6] Water Resources Strategy
[7] National Water Plan

The National Water Plan goals include an increase in irrigated land (by about 30% by 2027) and a doubling in the area with year-round irrigation (from 38% to 67% of irrigated land), and as a result an increase in cropping intensity from 140% to 193%. In addition, since 1990 climate change has become an important consideration in natural resource management in planning and management of the water sector, including irrigation.

28. The plan recognized the high potential in terms of economic improvements and food production benefits from improvements in irrigation management with several irrigation management investment options. These included (i) turn-over management of DoWRI's small projects to Water User Groups (11,600 ha and 15,500 ha of Hill/Mountain and Terai system respectively), (ii) assistance to FMIGs (50,000 ha and 140,000 ha in Hill/Mountain and Terai systems respectively, and (iii) improvement of DoWRI's large projects on the Terai.

29. From the perspective of general management arrangements, irrigation systems in Nepal are categorized into two types namely the Agency Managed Irrigation Systems (AMISs) and Farmer Managed Irrigation Systems (FMISs).

1.2.3.1 Agency managed irrigation systems

30. The AMISs are systems developed by the DoWRI in the interests of national food sufficiency and poverty reduction. The GoN commitment to development of irrigation projects goes back nearly 100 years and since the 1980s there has been considerable interest and investment in the subsector. The systems are generally medium to large scale mostly on the Terai, however also with several smaller scale systems in the Hill zone. In some cases, they are the conversion of un-irrigated lands and in others improvement and expansion of existing systems.

31. Over the past thirty years, there have been several projects for the development and improvement of these systems often with support from development banks and agencies. The approach to the project development is usually staged with initial development of the intake and main canals and followed by progressive development of branch and secondary canals and expansion of the command areas.

32. Ownership and O&M of the intake and main canal system constructed by the DoWRI are under DoWRI management. For large projects there is typically a project office with project director and technical and administrative staff. Canal operation is by local staff under contract to the DoWRI. The tertiary system is left to the community to manage with periodic support of the DoWRI assistance for repairs and maintenance.

33. Since the 1980s, Nepal followed a worldwide trend for irrigation management transfer to user communities. The rationale being that community participation will lead to improved and sustained system performance and agricultural productivity. Since then AMISs are also termed as joint managed irrigation systems (JMIS). Figure 43 presents locations of key AMIS (or JMIS) in Nepal.

1.2.3.2 Joint managed irrigation systems

34. The JMISs are those irrigation systems developed by the DoWRI which have been or are in the process of being transferred to user associations. The IMT and formation of WUAs has been part of the on-going subsector development over the past thirty years. Typically, the process includes rehabilitation and improvement of canals and control structures as pre-requisite and capacity building and support to WUAs.

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

and on the large scale systems, due to the system scale and technical complexity DoWRI has a longer term commitment to system O&M.

1.2.3.3 Farmer managed irrigation systems

36. The FMIS 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.

37. 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 DoLIDAR as part of regular support programs or specific development projects such as the SIP, CIP and MIP.

38. The FMIS are widely reported as performing better than AMIS[8] in terms of productivity, water delivery and physical condition. The reasons being related to better adherence to system O&M rules on FMISs which in turn results in better system performance in terms of equity and adequacy of water distribution. The better adherence to rules reflects a higher level of mutual trust and that under certain conditions, local community groups are more able to craft optimal rules and enforce them at lower cost than centrally governed irrigation systems.[9]

39. 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 on the 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 potable and rented according to demand and needs.

1.3 Food Security Scenarios

40. Based on the known distribution of the population (CBS Population Census 2011) and known dietary consumption (FAO Food Balance 2011) the geographical food consumption pattern for 2011 has been approximately established[10] (see Annex G Part 3). Based on that, an attempt was made to calculate what the <u>incremental</u> distribution of food consumption might be in 2031, based on the projected urban, municipal and rural population and applying assumptions of the dietary trends applicable to a middle income South Asian country. A very rough value could be put on this, expressing by District and cross tabulating by region and basin, as shown in **Error! Reference source not found.**.

41. The value of incremental food demand is expected to be greatest in the Terai part of the Koshi basin: this is unsurprising given this area is expected to have the greatest absolute numbers of incremental population of which a relatively higher proportion will be urban. Further, and important because the Terai produces a marketable surplus for the Hill and Mountain regions, the Hill region of the Koshi Basin has the highest incremental value of food demand of the Hill region by basin: it includes the Kathmandu urban conurbation. Development of irrigation in the Koshi Terai would be expected to benefit the population of its hinterland. It is likely that this population will not only be numerically larger than the hinterlands of the Narayani and Karnali (see **Error! Reference source not found.**) but will also

[8] Lam, W,F. 1998. Governing irrigation systems in Nepal: Institutions, infrastructure and collective action. ICS Press Oakland.

[9] Regmi, A, R. 2007. Water Security and Farmer Managed Irrigation Systems of Nepal. Paper presented at the Nepal Water Security Forum, Uppsala, Sweden.

[10] Without allowing for different dietary consumption between Districts and regions: for example, Mountain and Hill Districts staples include a larger proportion of "other grains": for those Districts a shift in consumption from staples to other foods implies a reduction in consumption of "other grains" rather than rice

consume the higher value type of diet that irrigated agriculture can provide more efficiently than rainfed, through higher yields and longer seasons of production.

42. 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.

43. 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

44. High, medium and low estimates of total population in 2031 have already been made by CBS. The high and low estimates are +1.7% and -1.7% of the median estimate of the total population estimate of 33.7 mil. The stated uncertainty attached to total population growth is very small. CBS calculates only a single rate of change for urbanization, but this can be compared with the UN estimate that uses a slightly lower rate, which would result in an urban population of about 8.2 mil in 2031, compared with 9.97 mil estimated by CBS. The uncertainty attached to the rate of urbanization is therefore relatively high, though urbanization tends to drive economic change rather than the reverse.

45. The estimate of incremental per capita food demand in 2031 (see Table 11 and Table 12 in Annex G, Part 2), if taken as a measure of the target for domestic production, assumes the national food deficit (food imports) will not worsen, since it includes the nutritional value of imported food in 2011. But because the food deficit is known by food group for 2011, food consumption can be expressed for both total food consumption and domestically produced food consumption in kg per capita per annum. To model incremental food consumption in the period 2011-2031 under the assumption that food imports will be eliminated during the period requires increasing the increment by the difference between total food consumption and domestically produced food.

46. There are two components to consider in developing scenarios for changes in the demand for food and the quantity demanded; rate of change and degree of change. The food consumption estimates for 2031 assume Nepal achieves the diet of a "typical" South Asian MIC in 2031 (though no country is "typical" and allowance had to be made for this). However, this may happen more quickly if the remittances fuelling the demand for food imports continue to increase: evidence that the average Nepali diet is converging to South Asian norms more rapidly in recent years is clear at least through gross measures of consumption such as the adequacy of dietary energy sufficiency.

47. The second component is the change in composition of diet expected. In the "business as usual" development trajectory less dietary change would be expected than on the "accelerated economic growth" trajectory. This report adopts three scenarios for dietary change, (i) low change in diet (which is a baseline that is intuitively understandable), (ii) medium dietary changes referred to above and described in Annex G, Part 2, and (iii) a "high" dietary change. The characteristics of the three scenarios are shown in Table.

Table 3: Characteristics of Low, Medium and High Diets for Scenario Analysis

	Food demand quantity (kg/capita/year)	Food supply (kcal/capita/day)	Protein supply quantity (g/capita/day)	Fat supply quantity (g/capita/day)

Urban Low	564.10	2,525.00	64.00	51.80
Urban Medium	690.64	2,564.61	74.37	70.70
Urban High	713.94	2,584.51	76.43	77.74
Rural Low	564.10	2,525.00	64.00	51.80
Rural Medium	622.42	2,662.79	70.27	61.23
Rural High	689.55	2,944.69	78.78	68.97

48. A summary of present (2015) and future District-wise yields, production and area is given by crop group in Table, the purpose here being to confirm national level yields at present. The data is extracted from present and future gross margins prepared for each crop group at District level. Monetary values of the aggregated present crop gross margins have been compared to sectoral estimates of value added and found to correspond reasonably well.

Table 4: Present (2014/15) and Projected (2030/31) Yields, kg/ha

Crop group	National level yield estimates				
	2014/15 from reported yields by district, kg/ha	2031 projected district yields, kg/ha	2043 projected district yields, kg/ha	MoA 2014/5 national yields kg/ha	Projected MoA national yields to 2031 kg/ha
Rice	3,394	3,840	3,903	3,371	3,513
Wheat	2,496	2,834	2,855	2,591	3,337
Maize	2,412	2,588	2,588	2,431	2,815
other cereals	1,126	1,107	1,128		
Roots	13,696	13,872	13,907	12,572	20,475
Cane	43,142	40,415	43,037	42,454	51,242
Pulses	987	950	1,017	1,072	1,022
Oilseeds	839	842	841	899	1,029
Vegetables	13,419	13,466	13,742	13,412	17,981
Fruit	6,874	7,172	7,314	8,770	10,314

49. The table suggests that there is no available alternative to accelerated expansion of the irrigation system to meet food demand in 2031 without substantially reducing food imports. The historical irrigation area expansion from 2000 to present has been only 40%, an average of about 3% and 30,000 ha per annum. To expand irrigation from the present 1.4 Mil. ha to all suitable land in the present agricultural area (i.e. to 2.3 Mil. ha) during the period 2018-2031 would require an annual rate of expansion of 3.7%, or 65,000 ha per annum; a slightly faster rate but more than double the area opened per annum.

50. Past performance suggests that improving irrigation efficiency will be a greater challenge than accelerated construction. The cropping intensity on irrigated land has remained flat or even declined over the last 15 years and is unlikely to be more than 180% now. This estimate is optimistic - any relaxation of the assumptions of poor productivity on rainfed land would lower the estimate. Improving cropping intensity significantly seems a remote hope. Nevertheless, cropping intensity is determined by farmers, not planning. Given adequate, timely and reliable irrigation such an increase is achievable,

which would lower the rate at which new irrigation command should be opened to meet incremental demand for food and the type of food demanded.

1.4 Policy and Institutional Landscape

1.4.1 National and sectoral policies

51. The existing legal and policy framework for water resource in general and irrigation in particular manifests how this sector/sub-sector is envisaged and regulated. The legal and policy instruments that have been put in place over the years also show the importance accorded to the development of water resources in Nepal. These have repeatedly emphasized the role that water resources sector can play in the overall development of country and in the enhancement of level of income of people.

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

- Water Resources Act, 1992 (2049) and Water Resources Regulations, 1993
- Disaster Risk Reduction and Management Act, 2017
- 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 Regulations, 2003
- Irrigation Act (draft), 2015

53. The main policies already implemented in the water sector include the following:

- National Water Plan, 2005
- National Water Resources Strategy, 2002
- Irrigation Policy, 2013
- Water-induced Disaster Management Policy, 2015

54. As far as irrigation policy is concerned, it is very much tied with the agriculture sector and hence for attaining the objectives and targets of the Agricultural Development Strategy 2015. The four expected outcomes of this strategy are concerned with: improved governance; higher productivity; profitable commercialization; and increased competitiveness. It seeks to increase coverage of year-round irrigation from 18% (in 2010) to 30% in short term (5 years), 60% in medium term (10 years) and 80% in long term (20 years). Policy, legislation and regulations

55. It is important that a new Water Resource Policy, as briefly highlighted above, should be finalised and formally adopted to provide a broader framework for managing water resource sector in an integrated way by providing a basis for designing necessary policies and master plans and laws for its various sub-sectors in line with the needs of execution of new federal and inclusive constitution of the country. Likewise, as indicated earlier, the existing policies for irrigation and land use need to be updated to meet the demands of agriculture modernization, proper use of land resources, including groundwater, water-induced disaster management, climate change adaptation, environment conservation and federal structure of governance.

56. As also envisaged in the draft of new Water Resource Policy, the following laws are to be in place for regulating and managing irrigation sub-sector, either by designing new laws or making necessary amendments in the existing ones:

- Water Resource Act and Rules (new)

- Irrigation Act and Regulations (new)
- Groundwater Use Act and Rules (new)
- Amended Environment Conservation Act and Rules
- Amended Land Use and Rules

57. New legislation relating to river basin planning and management based on IWRM principles is long overdue. Several policies and regulations mentioned in the earlier sections have identified the need for having a more integrated and sustainable IWRM framework, but an "umbrella law", which can provide a solid legal basis for future reforms in the development of the water resource sector, is still lacking. For this, the Water Resource Act, which is reportedly in drafting process, should be designed as a substantive or umbrella law in such a way that provides a broad framework to regulate water resource sector, including irrigation, as a whole ensuring linkages among all its sub-sectors like energy, watershed protection, both groundwater and surface water, disaster management, climate change, and financial sustainability of the systems, through design of other related federal laws, provincial laws and local laws. Specifically, this should take into consideration principles on issues such: (i) development of integrated and multi-purpose projects; (ii) ensuring effective and efficient management, operation and maintenance; (iii) allocation and protection of water entitlements; (iv) equitable water distribution and minimization of conflicts; (v) water tariffs and cost recovery; and (vi) protection of biodiversity and the environment in general.

58. It is important that all the suggested legal provisions for irrigation should allow irrigation sector to be linked with integrated water resource management and river-basin management on one hand and the mechanisms of harmony, partnership and coordination among three tiers of government on the other. This should also facilitate public-private partnership keeping growth and development of the agriculture sector in perspective. Likewise, it should provide a basis for regulation of collection of irrigation service fees, their distribution and use for sustainability of operation and maintenance of irrigation. New laws are also required to ensure proper use of groundwater for both drinking water and irrigation from the perspective of climate change adaptation and watershed protection.

59. Moreover, all the existing acts related with other natural resources including agriculture, forest, watershed, soil conservation, and so on, also need to be amended, so as to align with the envisioned "umbrella law" for water resource. This is necessary in order to include sections on IWRM and river basin development and management in it. Attention should be given to amend any sections that could potentially contradict the spirit of the "umbrella law" and create barriers for its effective implementation.

60. It is imperative that political leadership at all three tiers of governments need to be fully aware of and understand need for changes in the legal framework relating to water resources planning and management. This will help mitigate any possible clash between legal frameworks emanating from federal parliament and those from provincial legislature. The capacity development efforts at each level need to encompass this very important issue.

61. Coordination among natural resources related ministries in Nepal has been less effective in the past. Now, its importance is even more prominent in the light of the restructuring of governance into a federal system and the alignment to IWRM and river basin planning and development principles. Not only that, provincial and local governments should also become the party to this process. Clarity on roles, responsibilities and accountabilities regarding "who is doing what" has to be clearly spelled out in legislation and policies. Any new legislation and policies on water resources will have overarching impacts on the management of other natural resources and vice versa. This fact has to be internalized by all related ministries at concerned level of governance structure when they are engaged in reforming policy, legal and organizational arrangements.

1.4.2 Aligning IMP 2019 with sectoral policies and plans

62. Agriculture provides around two third of country's employment, and its share of the Gross Domestic Product (GDP) is estimated at 28.9 percent (2016). Nepal's agricultural trade comprises about 15.6 percent of total trade. Trade deficit have been continually growing every year owing to higher imports of agro-based products. Currently, the ratio of exports to imports has been 1:13 (MoF, 2017). Major exportable agricultural commodities from Nepal are lentils, tea, cardamom, fruits, ginger and medicinal and aromatic plant products. Likewise, Nepal mainly imports fruits, cereals, vegetables, dairy products, meat and oilseeds.

63. The Government aimed for annual growth of agrarian sector of 4.7% in the period of 14th three-year interim plan (2016/17 to 2018/19). There are opportunities both in export and domestic markets. There is good potentiality for import substitution in cereals, vegetables, fruits, beverages, diary and meat, if due attention is given for production and productivity increase.

1.4.2.1 Sectoral Policies and Plans in Agriculture

64. Agriculture development has been the continuing priority of the GoN through its different policies, plans and programmes in different time period. These includes 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 Modernization Project (PMAMP).

65. Despite the planned development effort in agriculture sector, significant achievement has not been achieved to increase production and productivity of agricultural commodities. Some of the reasons behind it are poor delivery mechanism not effective and capable to fulfil the growing demands for technologies and other support services, lack of desirable and quality inputs in required quantity, lack of reliable irrigation facility inadequate agricultural infrastructures, weak linkages and coordination among stakeholders and youth migration from rural areas leading agriculture to feminization.

1. **National Agriculture Policy 2004**: This policy envisions the sustainability in agricultural production through commercial and competitive agricultural system contributing to food security and poverty reduction. Three major objectives outlined for the agriculture sector under the policy include:
    - Increasing production and productivity to ensure food security and alleviate poverty
    - Making agriculture competitive in the regional and world markets with the development of prerequisites for agricultural commercialization and diversification
    - Conserving and managing natural resources for environmental sustainability
2. **Nepal Agricultural Extension Strategy** 2007 (NAES): NAES primarily outlines the mechanism to expedite the implementation envisioned by the Agriculture Perspective Plan (1995-2015) and emphasizes efficient and effective services to agricultural producers through a participatory process by enabling learning among them. The Strategy focuses primarily on institutional pluralism, privatization and decentralization of extension services. The Strategy is expected to contribute to improved food security, increased income, environmental balance, inclusive agricultural development, commercialization, sustainable livelihoods, value addition and quality control of agricultural products.
3. **Agricultural Perspective Plan** (APP): In 1995 the GoN had adopted a 20-year Agricultural Perspective Plan (APP) intending to accelerate national growth through diversification and commercialization of agriculture. The APP emphasizes realigning investments in selected priority inputs, particularly: (i) shallow tube-well for irrigation in the Terai (ii) agricultural roads (iii) fertilizer and(iv) technology development and delivery (research and extension).

The plan has also directed new investments to priority outputs, especially rice, citrus, apple, vegetables, livestock, and forestry products and agribusiness was emphasized as part of a commercialization strategy. However, the final results of APP were not satisfactory mainly due to ambitious targets and huge investments. The performance of APP is found sub-optimal due to a lack of investment and organizational weaknesses. Further, inadequate growth of year-round irrigated areas and use of prioritized inputs and political instability also caused the poor growth of the agricultural sector.

4. **Agriculture Development Strategy** (2015-2035): ADS is the 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 of the ADS has been stated as self-reliant, sustainable, competitive and inclusive agriculture sector that contributes to economic growth, improved livelihood, and food and nutrition security. ADS emphasizes to promote self-sufficiency in food grains and import substitution in a number of commodities where the country has potential to growth.

66. To enhance the agricultural productivity, ADS has stressed: (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.

67. It also stresses on the need for “profitable commercialization” through transforming agricultural sector as an important outcome and emphasizes the necessity to strengthen the capacity of service providers (including technical services providers, financial service providers, insurance service providers and business service providers) along with improvement of physical and institutional infrastructure to promote commercial agriculture (agricultural roads, storage facility, market information system).

68. The ADS has targeted enhancing the average annual growth rate to 5% from the present 3% for the agricultural sector, increase land productivity to USD 5,000 per hectare from the current USD 1,600 and reduce rural poverty from 27% to 10% by the year 2035. Realizing the importance of irrigation for commercial agriculture the ADS has envisaged increasing round-the-year irrigation coverage areas to 80% from the current 18%. The details of ADS target with projected production and food availability are presented in the following tables.

1.4.2.2 Agricultural Research and Development (R&D)/Extension

69. One critical limitation to rural and agricultural development in Nepal is the lack of modern skills in farm production. In addition, the inadequate knowledge of farm planning and decision-making. Agricultural research institutions and agricultural extension services are poorly equipped to fill the knowledge gap of farmers. New technologies, in terms of varieties and practices, are available for food crops to increase productivity, but limited availability of inputs, credit, and markets have constrained full exploitation of technologies 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.

70. 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 inefficient, stagnant and not able to cater the emerging needs of the farmers for diversified technologies, marketing and agri-business, natural resource management and farm mechanization. Extension service suffers from a lack of suitable technology to transfer to farmers and agribusiness operators. Agricultural research and extension services are not linked well.

1.4.3 Rural Poverty

71. National data refer that poverty level in Nepal has declined by almost one third since 1995 (from 42% to 23.8% in 2012/13). Despite the remarkable decline in overall poverty level, poverty in rural Nepal

is still higher than urban Nepal, even though rural poverty is declining at a faster pace than urban poverty. Major contributing factors for decline in poverty included 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, markets etc.

72. In 2011, poverty in rural areas accounted for 27.4% compared to 15.5% among the urban population. The low productivity of agriculture, 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 Food Security

73. Nepal having population more than 27 million and being a developing nation is confronting the challenge of Food security and hunger. Food security and nutrition in the context of Nepal is very critical. Nepal is struggling to produce sufficient food to meet their increasing demand and adequate supply of food for its citizen. The problems of food insecurity are not limited to the production but also physical access for food due to limited road access. The food scarcity caused, due to ever-increasing natural disaster, climate change, population increase and, out-migration has serious impacts in economic and societal health of the people. Nepal's government has given high priority to increase production of food grains, horticulture, fisheries and livestock product through sustainable use of resources to ensure food and nutritional security. To improve food security the project calls for improve productivity, improve connectivity to increase market access resulting to reduce the transaction costs of getting inputs and services from market to farm and farm to market, promote processing, develop and strengthen business enterprise services, and improve marketing efficiency.

1.4.5 Gender

74. Women play an important role in agriculture. Women's participation in agriculture labour force in Nepal had increased from 36 percent in 1981 to 45% in 1991 and, by 2016, it had reached over 50%. The decade long (1996 to 2006) armed conflicts and 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. Most agricultural lands are still under the control of men due to the traditional Hindu law of succession, whereby male offspring are entitled all the parental property including land. 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.

75. Most extension workers under DoA are male. Extension services have reached both male and female farmers. They have formed farmers' groups having only women farmers. However, there is a need to improve extension services for women farmers by ensuring meaningful participation in the agriculture value chain and by training rural women as extension workers.

1.4.6 Environment and Climate Change

76. Nepal is highly vulnerable to climate including variability and extreme weather events due to its geographic location, fragile ecosystems, 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 (iv) 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 predicted impacts of climate change, due to the fewer livelihood assets such as land and livestock, receive a low income, and have a low level of education and limited access to community and government services. They are also likely to be reliant on rainfed agriculture and occupy land that is prone to floods, drought and landslides.

77. Adaptation measures to climate-related threats include (i) improved water use efficiency and enhanced irrigation/ optimized agronomic inputs; (ii) improved farm practices; with (iii) enhanced the capacity of farmers to enable them to cope with the adversities of climate change.

78. Nepal is committed to ensuring broadest possible protections to ecology of surface water systems, including rivers and streams. Regulations on environmental flows are founded typically on legislation, policies, local needs (local water uses including religious needs) and river ecology with much debate remaining on the different approaches and suited flow regimes. However, one of the main principles that the different stakeholders agree is that the choice of environmental flow requirements should be based on informed scientific decision and broad societal acceptance.

79. Typically, IEEs and EIAs both include some level of alternative analysis providing for (i) a zero alternative for a scenario where the Project is not implemented, and (ii) alternatives in terms of sites, technologies and scales of Project implementation. One of the most important environmental factors in hydropower and other Projects using surface waters from rivers is defining environmental flows that are the minimum ecological flows remaining downstream for social and ecological river functions after water withdrawal or diversion by the Project.

80. In GoN legislation, Aquatic Animal Protection Act (AAPA 1961 and First Amendment 1998) has been set for protecting aquatic animals in natural water bodies including rivers, reservoirs and lakes. AAPA Section 5a defines pesticide use for catching aquatic life while Section 4a, 4b and 5 empower the government to prohibit catching, killing and harming certain aquatic animals in different scenarios. Section 5b requires building fish ladder not to affect movement of aquatic animals or where fish ladder is not possible, the act suggest hatchery and nursery in such places or in an area in vicinity thereof for the purpose of having artificial breeding of aquatic animals. The Act sets also a provision of minimum 5% of yearly minimum flow as environmental flow for water diversion points. In practice AAPA has remained virtually a defunct law in Nepal due to lack of related bylaws, regulations and enforcement. Since the year of its promulgation in 1961 there are no known cases of prosecution for breaching AAPA in Nepal demonstrating a lack of monitoring and enforcement of conservation of aquatic life.

81. Nepal Hydropower Development Policy (2001) recommends 10% of the minimum monthly average discharge of the river/stream or the minimum required quantum as identified in the EIA study reports. By the amount of water volume, the provisions in the Hydropower Development Policy are better than the AAPA although also the policy lacks scientific basis in setting environmental flow requirements to sustain the natural social and ecological functions of rivers.

1.4.7 Alignment with the New Constitution

82. As per relevance to irrigation, disaster management and water resource management, the powers assigned to three tiers of government have been highlighted in **Error! Reference source not found.** (details are in Annex E).[11] Since the new Constitution of Nepal provides both exclusive and concurrent powers as listed in its Schedules 5 to 9, almost all regulatory and institutional mechanisms made before the constitution for all sectors of the country, including water resource and irrigation, are naturally subject to change and such a change process has already begun.

83. Accordingly, power devolution for irrigation sector constitute a framework for both planning, execution and monitoring irrigation related activities in particular and water resource and agriculture in general at all three levels of government. Moreover, such an allocation of power, along with unbundling of these constitutionally devolved powers, have not only given clarity to powers of each tier of governments in federal structure in as much exclusive term as possible but also offered a basis for

[11] Institutions, Policy, Public Private Partnership, River Basin Planning, Financing Irrigation, Capacity Development, Research, Roles and Responsibilities Report (April, 2019)

formulating related laws, policies and other institutional arrangements, including revenue collection, resource allocation and organizational restructuring, staffing.

84. For smooth execution of the constitutional provisions, a number of important laws and policies are introduced, and many are in their formulation process. The Inter-Government Financial Management Act 2017 has provided a legislative and regulatory framework for exercising devolved powers by three tiers of government in the matters relating to budgeting, revenue generation, resource allocation across governments and other financial management functions. Moreover, the Local Government Operation Act 2017, National Natural Resource and Financial Commission Act 2017 and Financial Appropriation Act 2018 (annual budget) have also provided some broad frameworks for both federal and sub-national governments to exercise their financial power and formed a basis for their sectoral development planning and programming in their respective jurisdiction, including those related to irrigation and water-induced disaster risk reduction. However, many of the issues related to revenue generation and resource allocation remain to be resolved.

85. The GoN is also in the process of finalizing a new Water Resource Policy, which is expected to replace the existing Water Resource Strategy 2002 and National Water Plan 2005. This will provide a broader policy framework for utilizing and managing water resource in an integrated approach, pursuing river basin-based approach for all water resource-related sub-sectors including irrigation, river control and environmental diversity management. Moreover, GoN is also drafting Water Resource Act and Irrigation Act to meet the needs of federal modes of governance as well as development goals envisaged by the new constitution. These require design, construction, operation and maintenance, including transfer of the irrigation projects/ systems to be in line with the constitutionally devolved powers to the tree tiers of government. Also, these set standards for determining the size of large, medium and small-scale irrigation project/system in Terai and hills, by which large means covering 2000-5,000 ha in Terai and 300-1,000 ha in hills, whereas medium size means 100-2,000 ha in Terai and 10-300 ha in hills.

86. While the national policies and federal laws are in drafting process, the National Planning Commission has recently set new standards of size of projects for carrying out the functions related to design, construction, operation and maintenance of irrigation projects by three tiers of governments for clarity of their respective roles. Accordingly, federal government would be looking after the irrigation projects covering more than 5,000 in Terai, 300 ha in hills and 100 ha in mountain, while the provincial government will be responsible for the irrigation projects covering 200-5,000 ha in Terai, 50-100 ha in hills and 25-50 ha in mountain. All irrigation projects / schemes and systems covering areas less than what federal and province are responsible for will be looked after by the local governments. The NPC standards also clarify the following points: (i) federal government will look after all irrigation projects of national pride and those projects covering more than one province; and (ii) provincial government 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 inter-province and inter-local government projects by developing necessary mechanisms.

87. 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 sub-national governments (province and local levels) can make necessary revisions in the centrally designed model federal administrative structure for them as per their specific needs. Accordingly, for dealing with the irrigation related functions, there is the MoEWRI at central level, which is the integrated structure 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. This is however going through restructuring and strengthening processes.

88. The MoEWRI, effective from 16 July 2018, consists of 7 divisions as seen in Figure (details in Annex E), along with two secretariats (dealing with water resource and energy separately - each led by a

secretary) to extend technical support to policy functions at national level. Its Water Resource Division looks after irrigation matters.

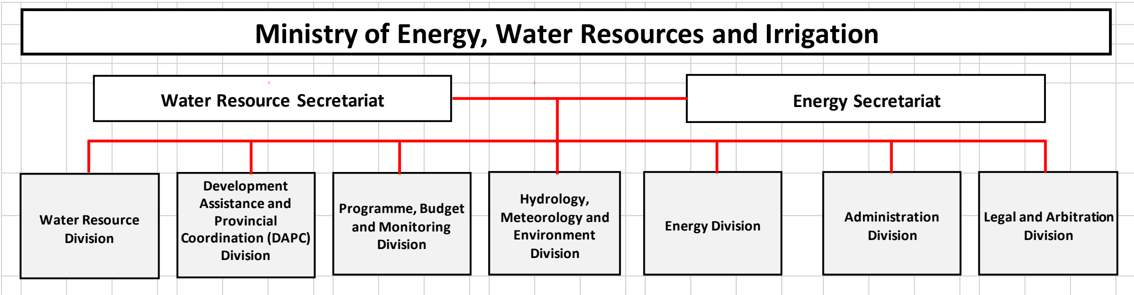


Figure 1: Ministry of Energy, Water Resource and irrigation

89. Under the MoEWRI, there are two departments, i.e., DoWRI 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 enclosed in Figure 1. This is however summarized below in terms of five technical divisions indicating coverage of major departmental functions and jurisdiction.

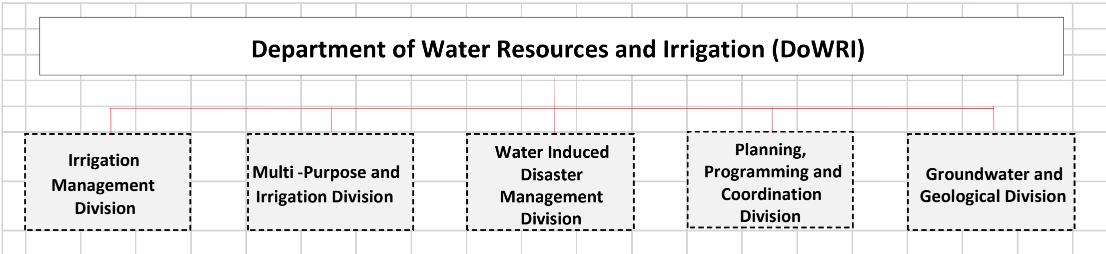


Figure 1: Department of Water Resources and Irrigation

90. 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 resource division. Moreover, dozens of districts offices/division or field offices of central government, which were carrying out infrastructure related functions (including irrigation) focusing on certain geographic areas, are recently handed over to this ministry in each state as its their technical hands. At local level, the urban municipality has physical infrastructure development division while the rural municipality has a separate physical infrastructure development section; both look after irrigation sector among others.

91. Though the Constitution provides powers to each of the three new levels, there is no clarity over the division of roles and responsibilities for each and every sub-sector and the division of revenue generation. For example, the disaster management is indicated as a power (or responsibility) at all three levels, which risks of being left “between cracks.” 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 to be carried out smoothly for various reasons. Observations on operation of a few provincial governments by the consulting team indicate that implementation wings under the MoPID are still non-existent due to clarity in functions, delayed transfer of technical offices and programs/projects and staff from the federal government, which has resulted in underutilization of even allocated capital expenditure budget.

92. The transfer of responsibilities and duties also obviously calls for substantial capacity development, specifically at state and local government levels and this will not just be within the irrigation sector, but on a much larger and broader scale.

1.4.7.1 Federal Responsibilities

93. The following is a brief review 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 (as shown in **Error! Reference source not found.**). This provides a basis on which to suggest any required institutional arrangements, including policy, legal and organizational provisions, for IMP in relation to federalized context of the country.

<u>Treaties or agreements related to international boundary rivers</u>

94. The Constitution mentions that the central government has the power and obligation to manage international treaties or agreements, extradition, mutual legal assistance and international borders and boundary rivers.

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

<u>Policies relating to conservation and multiple uses of water resources</u>

96. The Constitution clearly mandates “the central” to make policies relating to conservation and multiple uses of water resources. Such multiple or inter-sectoral use (and conservation) is best managed through river basin planning (RBP), which has been presented in some depth in Annex E. It refers to the planning and management of water resources 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 leads to such things as multi-purpose storage reservoirs and other projects, water allocation and licensing systems, and river operations which provide specifically for navigation and other non-consumptive uses.

97. 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 as well as to coordinate relevant line ministries and departments to implement the concept of IWRM. This will be done through the establishment of River Basin Offices in Western, Central and Eastern Nepal. These RBOs will need to work closely together with the relevant divisions with the DoWRI and the technical departments at state level.

<u>Large scale and across state boundary irrigation management</u>

98. Large-scale and technically superior irrigation schemes will need to be planned, designed, implemented and possibly also eventually managed, operated and maintained by technically qualified entities/divisions at central level. It is suggested and expected that the Multi-Purpose and Irrigation Division and the Planning, Programming and Coordination Division – both within DoWRI – will have a pivotal role in steering development of large-scale irrigation projects.

99. It should be emphasized that the major projects need to be aligned with the river basin planning concepts administrated by WECS and the newly-established RBOs. A strong and close dialogue with the state administration needs to be put in place for full cooperation.

1.4.7.2 Provincial and Concurrent Responsibilities

100. The administration in the new seven states is presently being established with a number of ministries (initially seven as modelled by federal government), including the MoPID in each State, with a provision of six divisions to look after roads, housing and urban development, energy and water resource, including irrigation and water-induced disaster. The development plans for the use of water resources within each state will however still need to be in compliance with the overall river basin plans regarding water availability and allocation, and the priority investment regime as set out in these plans, decided and governed under agreed decision criteria.[12]

Shared water resources

101. The management of state boundary rivers, meaning rivers defining the administrative border between two states and/or river basins shared between two states needs to be a joint effort by WECS, RBOs and state 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 central level, and designated relevant officials in state and local government administrations.

Preparedness (floods and other water-induced disasters)

102. The Water Induced Disaster Division (the previous Department of Water Induced Disaster Management) will still have a pivotal and strong role to play in vulnerability assessment, early preparedness, rescue and relief management, as well as steering the rehabilitation and re-settlement post water-induced natural calamities. It will be evident later that this responsibility for preparedness will be supported by several other divisions at central level and the Consultant is strongly advocating for the close coordination and synchronization of efforts and activities.

103. When implementing disaster reduction and/or mitigation measures, the state (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 and involvement is paramount.

1.4.7.3 Local Responsibilities

Management of water resources in general

104. As per discussion with the WECS, the approach to river basin planning will be to involve the local governments in a fully participatory manner to identify and plan for the development needs, which are most urgent and prioritized at each level. The emphasis on stakeholder consultations is substantial and this also will include public institutions, private sector operators, civil society organizations, local communities, political parties, advocacy groups, media and relevant academicians and researchers.

105. Nonetheless, it needs to be pointed out that not all identified development needs can be attended to – at least not immediately – and there will be a need to make some compromises among local bodies (urban and rural municipalities) to comply with guiding principles of IWRM and river basin planning and management.

Management, operation and maintenance of the local irrigation services

106. The Constitution provides a clear mandate for local government to fully manage, operate and maintain infrastructure, including irrigation schemes, within their respective jurisdictions. Often this may

[12] It can be anticipated that the RBPs with tools for multi-criteria analysis and a decision matrix method enables the government to establish a set of weighted criteria that can be used to score various investments for ranking.

create a dilemma when local governments and WUAs are being handed over infrastructure of either inferior quality, too expensive to operate or of no use. They are supposed to manage, operate and maintain such infrastructure in a sustainable manner. This “paradox” therefore strongly encourages decision-making and implementation, including supervision, at lowest possible level. This approach has dramatically improved the quality of the completed infrastructures being taken over by the communities as the appointed village QA controllers will ensure that simple but crucial QA measures are taken at each stage of the implementation – for example, ensuring that the right amount of cement is being utilized per unit, proper curing of concrete is being done and standards for proper depth for pipe-laying and assembly of pipes are being observed.

Local taxes and irrigation service fees

107. The Constitution mentions that the local government has the power to collect local taxes such as wealth tax, house rent tax, land and building, registration fee, motor vehicle tax and also service fees, such as for irrigation. This will be appropriated when and if the service levels of local governments can be established up to that level where such taxation can be justified. In the case of irrigation, imposing irrigation service fees needs to be clearly though out, because the traditional approach until now in Nepal has been that the government has planned and constructed irrigation without due consideration to gaining economic efficiency in utilizing the available water resources and to improve water use efficiency. Farmers simply do not see the benefits of irrigated water where it is supplied. This lack of sense of the economic viability or simply common sense can be improved when and if local government takes charge of irrigation investments, including planning and construction.

Protection of local watersheds

108. Managing and protecting local watersheds will be an absolute core function of local governments. The central and state administration will be able to guide the local governments with respect to watershed management practices and conservation and protection of soil and water, but it will be the local governments that will be “on the front line” and directly involved in managing competing use of limited resources, conflict resolution, ensuring sustainable forest management and implementing various protection measures.

109. 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 state ministerial staff is expected to be required within the next three to five years.

1.4.8 Organizational arrangements

110. Administrative federalization, i.e., restructuring organizations, staffing and other related working procedures in line with the needs of three-tier governance system, has been almost completed as part of the execution of federal constitution after the formation of elected government at all three levels. This has been done, however, only as initial arrangements to restructure the existing unitary governance system into federal one and to provide model organizational arrangements for all governments, particularly provincial and local levels, so that the elected bodies can start performing their constitutionally assigned roles and at the same time modify those structure based on their emergent needs. It is therefore MoEWRI, like other federal agencies, have been undertaking a review of its organization and management (O & M Study) to bring about necessary organizational reforms, besides initiating and leading policy and legal reforms as indicated above, to perform their assigned roles. Likewise, even provincial governments are reviewing their existing organizational arrangements (initially prescribed by federal government as a model 7-ministry set-up) to meet their growing need, e.g., Gandaki Provincial Government has been reportedly considering expanding its seven ministries to 11 ministries.

111. Undoubtedly, the proposed IMP requires 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. It is important to acknowledge the fact that these organizational arrangements are to be compatible with both federal mode of governance and policy and legal arrangements, along with consideration principles, as suggested above.

112. Accordingly, though it is not practically feasible to suggested specific organizations in the absence of finalised new water resource policy and revised irrigation policy, some generic forms of organizations are suggested below considering particularly the envisaged goals, approaches and projects/activities to be undertaken as part of IMP, federalised power structure of three tiers of government and the types of irrigation projects and activities expected to be performed at different levels.

1.4.8.1 Organizational arrangements at federal level

113. The existing MoEWRI should strengthen its existing organization set-up (wing or division) to lead, coordinate and monitor irrigation sub-sector with IWRM approaches through national policies and standards and to ensure close functional linkages of irrigation with other sectors/sub-sectors like agriculture, soil conservation, watershed conservation, water-induced disaster management and climate change adaptation. It also needs a strengthened a think-tank institution like WECS or lobby for creating a high-level institution for natural resource management, covering more than water resource sector.

114. DoWRI should also strengthen its present organization set-up (divisions/sections) through periodic reviews to coordinate execution of national pride projects for irrigation as well as those related to water induced disaster management. It should continue designing, constructing and executing irrigation projects covering one province and other large scale irrigation projects (covering more than 5000 ha in Terai, 300 ha in hills and 100 ha in mountain), but the functions related to such large scale projects falling within one province should remain with federal government only for the time-being as these should be handed over once the provincial governments are capable to do so. Nevertheless, DoWRI will require to set-up one office in each of three major river basin areas (such as Koshi, Gandaki/ Narayani and Karnali), i.e., in the east (Province 1), central (Province 3) and west (Province 5), to monitor water resource and irrigation related activities, which can ensure undertaking of its activities in close coordination with River-basin offices being envisaged under WECS.

115. 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 its three-major river basin-based monitoring offices. The number of such offices can be around 19 spread across all seven provinces as being proposed by a technical team of MoEWRI. These offices, including river-based 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 sub-national government agencies. However, these offices too will need periodic review to ascertain whether these can be merged into provincial government agencies.

116. The five divisions in DoWRI should have an intrinsic relationship that makes the department much more efficient. There is often doubt on which particular division has the mandate to lead the activities and take the responsibility for the output and impact of the service provided. However, what might be much less apparent is whether other divisions/sections within DoWRI could contribute and support to any specific activities – simply to make the performance of the activity less time-consuming, increase the level of any informed decision (through information sharing) and/or improve the sustainability of outputs due to broad consensus and collaboration of given activities. WECS or similar institution in outside MoEWRI needs to facilitate creating synergies among the DoWRI divisions.

1.4.8.2 Organizational arrangements at the provincial level

117. As stated earlier, the provincial Ministry of Physical Infrastructure Development has been looking after the irrigation sub-sector through irrigation and water induced disaster section under its water resource division (which is one of its six divisions concerned with roads, transport, housing and urban development, drinking water, etc) without having any separate entity like department dedicated to design, construction, operation and monitoring of irrigation projects. At the policy level, it has to be clear whether or not this ministry is a policy making body at provincial level and whether an implementing unit (like a department in the central government hierarchy) needs to be established there. If provincial level ministries should perform both policy and implementation functions, this has to be clear now at policy level. In addition, human resources with adequate capacity have to be provided accordingly. Generally speaking, the present work force in place at provincial level is considered to be significantly below the requirements for undertaking the roles and responsibilities as envisaged by the new constitution.

118. In this context, it is highly desirable for provincial ministry to consider designing and executing intra province large and medium irrigation projects by setting up separate project offices and provisioning 2 to 3 provincial irrigation offices to monitor and coordinate execution of provincial level irrigation activities as well as the irrigation activities undertaken jointly with other province or local government or jointly by two or more local governments. Moreover, the provincial level organization set-up should also have an unit to undertake necessary activities for capacity development of irrigation related actors at both provincial and local levels as a matter of priority.

1.4.8.3 Organizational arrangements at the local level

119. Like the provincial government, local government too do not have any separate organization set-up devoted to irrigation function, which is looked after by its physical infrastructure development division/section. In view of multi-task responsibility of local government, such as those related to design and construction of small / local irrigation project, irrigation services, 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 requires to develop and deliver irrigation services with wider geographic coverage, should create an extended irrigation service unit within its either physical infrastructure section or agriculture section. This unit can also coordinate and facilitate design, construction and monitor operation of inter-local government irrigation projects. Moreover, this unit will also need to design and execute a robust financial management system for regulating irrigation fees in transparent and accountable manner, which will be executed mainly through water user associations at irrigation system level.

1.4.9 Synchronizing irrigation and flood management efforts

120. The creation of DoWRI in 2018 brought back together the Department of Irrigation (DoI) and Department of Water Induced Disaster Management (DoWIDM) in one umbrella, which also looks more logical and efficient arrangement. Synergies are required and achieved between these two functions. So clearly the DoWRI will need to seek cooperation and collaboration across its divisions to optimize its functions and delivery of effective service with respect to irrigation and flood management. Moreover, DoWRI has roles to integrate its activities with those of the yet-to-be-established National Disaster Risk Reduction and Management Authority, as provisioned under the DRRM Act 2017. Such synergies and synchronization should also be ensured at both province and local levels.

1.4.10 Transboundary cooperation

121. A key consideration of any irrigation development in Nepal is the consideration of riparian water rights and the prior use of water by India, Nepal’s southern and downstream neighbour. Nepal has signed a number of treaties with India in regard to major rivers crossing the border, or adjacent;

Mahakali Treaty (1920, 1991 and 1996), Gandak Treaty (1959 and 1964) and Koshi Treaty (1954 and 1976).

122. 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 with 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 Kanchanpur irrigable land. 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. However, if the dam is built, it could supply full year-round irrigation to all the irrigable land about 93,000 ha in Kanchanpur and Kailali districts. The Pancheshwar MPP is not considered in the IMP scenarios as Mahakali phase 3 is already under construction utilising the additional water from the Tanakpur agreement.

123. **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 10,800 MW. 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.

124. **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 MPP) 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.

125. **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 may be required from time to time. Therefore, there is no limitation of 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. These projects are discussed in more detail below.

2. SECTION II: ASSESSMENT OF AVAILABLE LAND AND WATER RESOURCES

2.1 Irrigable Land

126. For the purposes of description and planning (for the Master Plan), Nepal is divided into three main river basins[13] (Koshi, Narayani and Karnali). Table lists a summary of the basin by area, population, administrative units (district), as well as number of sub-basins.

127. The table shows the relative distribution of land and population between the basins, with Koshi having about one third of the land area and 50% of the population, largely due to the Kathmandu Valley being located within the basin. The Narayani Basin is about 25% of land area and population, and Karnali Basin about 42% of land area and 23% of population.

Table 5: River Basins

Basin	Area (km^2)	Population (M)	Districts (#)	Sub-basins (#)
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.

128. For planning purposes three agro-ecological zones are identified (as listed in Table); Terai the lowlands to the south and adjacent to the border with India, on which the large scale irrigation systems are located, and about 80% of the total existing area, Hill being hill country running east to west, with a large number of small farmer managed systems, and Mountain to the north and higher altitude with small number of small farmer managed systems.

129. While the Terai is the smallest zone (23% of total area) it has the highest population (13 million and nearly 50% of total), while the Mountain zone is relatively large (35% of area) however understandably with low population (8%). It also shows that the Hill zone is more than 40% of total area and is reasonably populous with about 40% of the population.

Table 6: Agro-ecological Zones

Zone	Area (km^2)	Pop (M)	District (#)
Mountain	52,007	2.10	16
Hill	62,348	11.39	40
Terai	33,435	13.00	21
Total	**147,790**	**26.49**	**77**

[13]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.

2.1.1 Land Resources Mapping and Assessment

130. The following mapping and assessment tools were used to analyse and identify optimal approaches to irrigation 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 Survey and Order

131. Based on the information and data collected, soil order has been determined and Table presents the ecological zone distribution of various soil order in Nepal.

Table 7: Soil Order

Zone	Alfisols	Aridsols	Entisols	Inceptisols	Mollisols	Rock	Spodosols	Ultisols	Water	Total
Terai	193,148		1,239,446	1,681,692	115,703			13,151	100,384	3,343,526
Hills	299,999	1,784	2,369,148	2,859,864	102,411	475,183	41,781	60,515	24,162	6,234,847
Mountain	5,033	226,338	1,728,305	976,656	18,030	2,213,890	19,753	9,222	3,467	5,200,694
Total Nepal	**498,180**	**228,122**	**5,336,898**	**5,518,212**	**236,144**	**2,689,073**	**61,535**	**82,888**	**128,013**	**14,779,067**

2.1.1.2 Land Use Assessment

132. Land use can be defined as the purpose for which a parcel of land is being used, e.g. agriculture, fallow land or fruit tree cultivation whereas land cover refers to the physical appearance of the parcel of land, e.g. forest, residential, grassland. Naturally, there is considerable overlap between the land use and land cover categories. The actual cropping patterns that are recorded on any parcel of land designated as 'agricultural' are a furthermore detailed level of land use classification. In this study "land use" includes the term "land cover."

133. Seven different classes of land use as shown in Table are based primarily on the classification adopted by the Department of Survey, Nepal, to identify the land use of the area. For each of the predetermined land cover/use types, training samples were selected by delimiting polygons around representative sites. Spectral signatures for the respective land cover types derived from the satellite imagery were recorded.

Table 8: 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	Barrenland	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

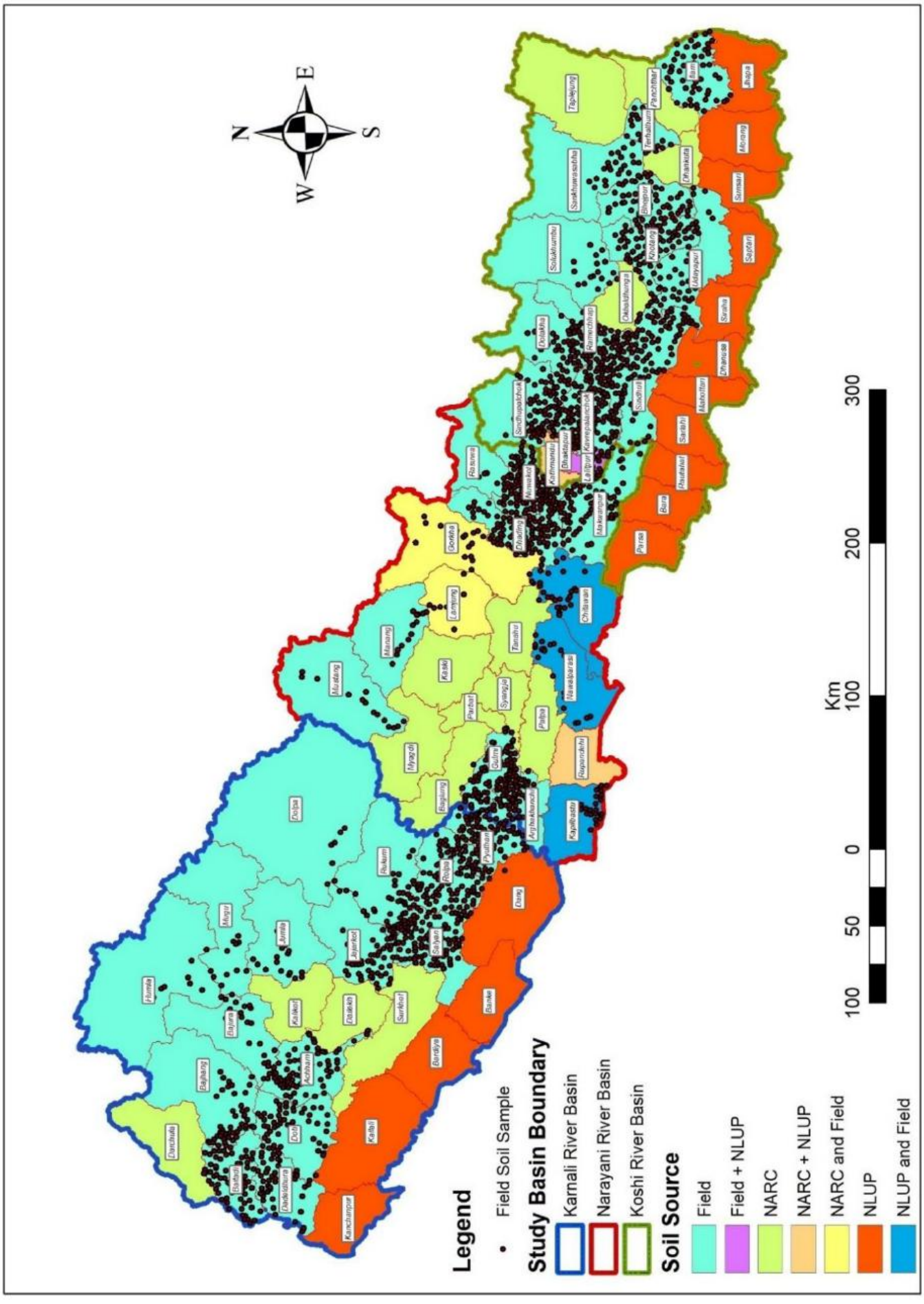


Figure 2: Soil data input: NARC digitized data, NLUP and field samples

134. District wise land use area as calculated above has been presented in **Error! Not a valid bookmark self-reference.**. Spatial details of the land use are shown in **Error! Reference source not found.**. The table shows that out of a total of 2,612,500 ha of land in Province 1, agriculture land occupies 773,500 ha and forest area occupies 1,103,000 ha. Similarly, residential area, river/water body, shrubland, Barrenland, snow/glacier occupy 16,000 ha, 63,000 ha, 223,000 ha, 264,000 ha, and 168,500 ha respectively.

Table 9: Land Use Summary (ha)

Source Area (ha)	Agriculture-Level Terrace	Agriculture-Sloping Terrace	Agriculture-Valley, Tar, Terai	Totoal Agricultural	Barrenland	Forest	Residential	River/water body	Shrubland/ Grassland	Snow/Glacier	Total
Total IMP-2018 (ha)	1,034,806	678,619	1,844,338	3,557,764	1,455,825	6,422,513	130,905	353,669	1,512,222	1,346,164	14,779,062
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	14,779,062
Change (%)	-15%	-26%	-1%	-11%	-25%	14%	986%	55%	-37%	151%	

2.1.1.3 Irrigation Suitability

135. 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 where we used soil depth and soil texture from soil maps, slope from DEM and Land Use derived from the supervised classification of LANDSAT imagery.

136. There are seven criteria identified for the classification of irrigable land as shown in Table 8. 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 is permitted.

137. Using the classification criteria, four different types of irrigation suitability were assessed.

- **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 in the IMP-1990, to include those steep level terraces that are irrigated for paddy. This was not identified as irrigable area in IMP 1990. Slopes up to 60% are acceptable provided the land is identified as level terrace.
- **NS:** all sloping terraces we deemed unsuitable for surface irrigation, but 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 Mil. above the river source, and within the 3.0 km.

138.

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

Table 10: 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-exceptional	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 (Slope)	%	<3	3 – 10 Progressive Terrace	10 – 25 Radical Terrace	25-60	>25
7	Land Use		Arable,			Level Terrace	Urban, river channels, permanently flooded land, National Forest conservation or protected areas, sloping terrace
8	Pumped Irrigation	m above River bed	A Special category Meeting the above criteria, but located less than the economic pumping head El < 140 m				

Table 11: 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	-49%
Mountain	8,771	191,756	200,526	60,000	-85%
Total	**1,691,778**	**844,541**	**2,536,319**	**1,766,000**	**-4%**

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 system of irrigation, 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 the hills and mountains. GW is mainly confined to the Terai and inner 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-2019 regions. The minimum flow value chosen was 60 l/s, with is roughly equivalent to a level 3 river.

142. The second criteria 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 appreciated that these parameters are quite different around the country, but this is a national study, and therefore average figures were used. A finer approach can be used on a local level, but then more detailed feasibility would be undertaken in this situation.

143. A cropping pattern of maize, potato, vegetables and oilseed with a cropping intensity: 170%, an irrigation efficiency: 80% was used to determine a unit CWR of 0.49 l/s/ha. The Annual Pumped Volume comes to 4,125 m^3/ha/y. Using figures from the Hills pre-feasibility report gives a Net Benefit of NPR 141,900 per ha/y. 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 in Table. In the hills and mountains Nepal has pumping suitability of 92,796 ha of land of type S1 to S3 and 186,758 ha of type S4 in Hill and Mountain districts. There is, however, a significant area of sloping terrace of 286,446 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 12: Pumping Suitability Area (ha)

Ecological Zone	Sloping Terrance	Valley/Tar (S1+S2)	Valley/Tars (S3)	Level Terrace (S4)	Total
Total Hills	206,409	33,653	54,033	127,451	421,547
Total Mountain	80,036	532	4,578	59,306	144,453
Hills and Mountains	**286,446**	**34,185**	**58,611**	**186,758**	**566,000**

2.1.1.5 Irrigation Domain

145. The final result of the LRMA and the inventory of irrigation projects is to allocate all agricultural land to a particular irrigation potential. By mapping all existing irrigation schemes alongside the irrigable land, the remaining land can be identified, and suitable irrigation methods allocated. This gives rise to potential irrigation domains. A domain is a sub-set of a land category with a common purpose. The following domains have been selected:

1. Existing Irrigation Projects
2. Potential surface irrigation
3. Potential Transfer Irrigation Schemes
4. Identified Potential Pumping Irrigation
5. Classified Potential Pumping Irrigation
6. Rainfed Agriculture (possible solar or tank Irrigation)

146. 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 for the country.

147. The total area of land resources are approximately 14.7 Mil. ha[14] (Table) of which 3.56 Mil. ha are classified as agricultural. The balance of non-agricultural land (11.52 Mil. ha) includes forest (43%), grasslands/scrubland (10%), barren lands (10%), and snow/glacier (9%) (residential lands is about 1%).

Table 13: Land Use by Agro-ecological Zone

Land Use (M ha)	Mountain	Hill	Terai	Total
Agricultural	0.401	1.566	1.594	3.561
Non-agricultural	4.799	4.669	1.749	11.218
Total	**5.201**	**6.235**	**3.344**	
%	**35%**	**42%**	**23%**	

148. Table lists the summary of principal land use by river basin, of which 45% of agricultural land (1.62 Mil. ha) is located in Koshi and 27% and 28% respectively in Narayani and Karnali basins, with 0.96 and 1.00 Mil. ha, respectively.

Table 14: Land Use by River Basin

Basin (M ha)	Agric.	Agric. %	Non-Agric.	Total
Karnali	0.991	28%	5.239	6.230
Narayani	0.955	27%	2.920	3.875
Koshi	1.615	45%	3.059	4.674
Total	**3.561**		**11.218**	

2.2 Water Resources Mapping and Assessment

2.2.1 Surface Water Resources

149. For purposes of the description the physical and social resources in this report and the IMP the country is divided into three main river basins, as shown in Figure . These are from west to east: Karnali, Narayani and Koshi.

150. For the purposes of 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) (for assessment and planning of project interventions) and administrative boundaries (district and state) (for the planning of plan and project implementation). All boundaries given in this section are based on physical hydrological catchments, and are therefore different to those presented in Table and Table. 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

151. The Karnali Basin is located in central 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

[14] Land Resources Inventory Report (May 2018)

63,700 km^2 (about 43% of the total area of Nepal) and is principally the Karnali and, West Rapti, Babai and Mahakali river basins (as shown in Figure 4).

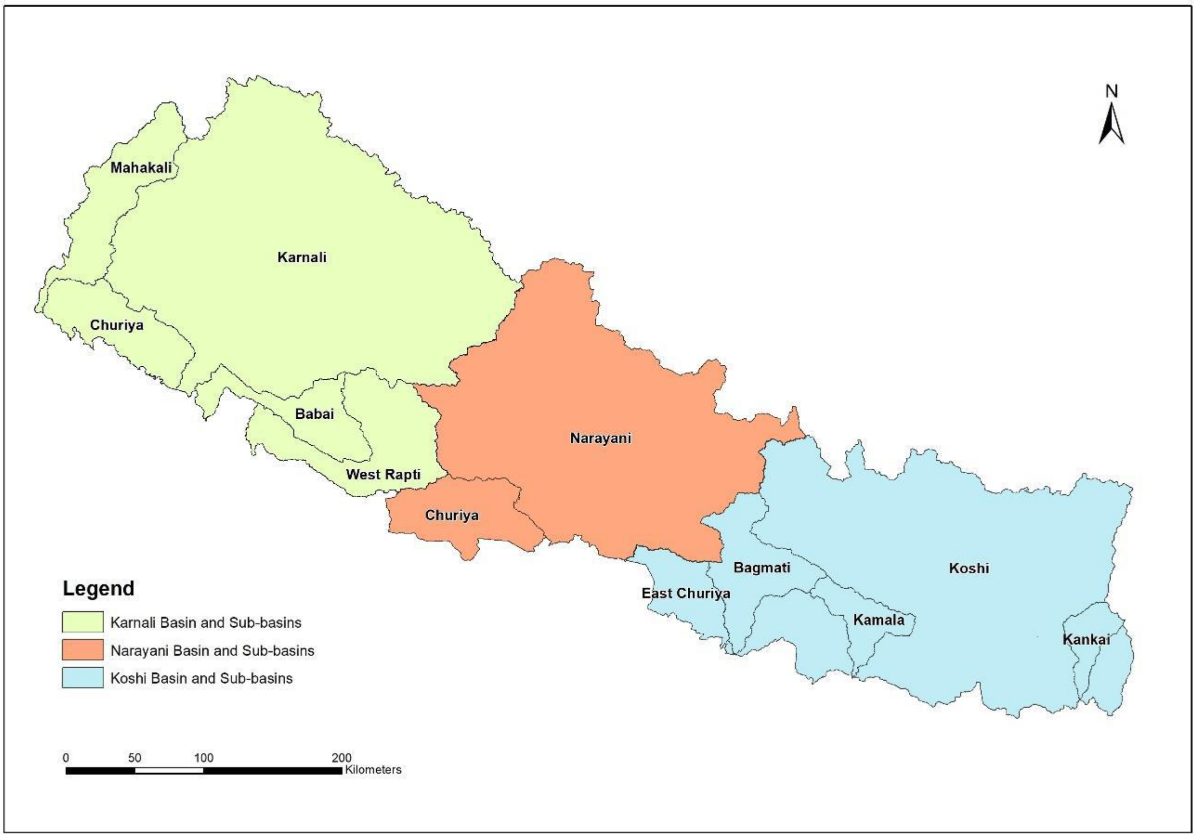


Figure 4: River Basins

152. **Population and Administration**: the basin has a total population of more than 6 million (about 24% of the national total) of which more than 87% live on the Terai and in the Hill zone (2.7million 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 km^2 on the Terai, and less than 120 and 30 per km^2 in the Hill and Mountain zones, respectively.

153. The basin fully encompasses Provinces 6 and 7, and partially Provinces 4 and 5 which extend into the Narayani Basin. There is a total of 24 districts within the basin of which 5 are on the Terai, and 11 and 8 in the Hill and Mountain zones respectively. Major population centres include cities like Dhangadi (State 7 capital) and Nepalgunj on the Terai, and Birendranagar (State 6 capital) in the Hill zone.

154. **Topography**: the topography ranges from the lowland plains of the 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.

155. **Precipitation**: rainfall distribution within the basin ranges from about 300 to more than 2,700 mm per annum. On the 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 on 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.

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

157. **Land Use**: total land classed as agriculture use (level terrace, sloping terrace and valley/tar/Terai) is 16% of the total (approx. 1 Mil. ha) and 46% as forests (2.9 Mil. ha). On the 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.

158. **Water Resources**: the total annual surface water resources are approximately 60 Bm^3 with the volume per sub-basin ranging from less than 1,000 to more than 14,000 Mm^3 per annum. Total annual groundwater resources are approximately 3.4 Bm^3, which is mainly located within the Terai districts.

2.2.1.2 Narayani Basin

159. 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 36,400 km^2 (about 25% of the total area of Nepal) and is principally the Narayani river basin and the West Churia (as shown in Figure).

160. **Population and Administration**: the basin has a total population of about 6.4 million (about 24% of the national total) of which more than half (3.7 million) live in the Hill zone, and 2.6 million on the Terai and less than 1% in the Mountain zone. Population density varies widely between the agro-ecological zones with more than 360 per km^2 on the Terai, and about 170 and 8 per km^2 in the Hill and Mountain zones respectively.

161. The basin almost fully encompasses Province 4 and partially Provinces 3 and 5 (which extend into the Koshi and Karnali basins respectively). There are a total of 20 districts within the basin of which 4 are on the Terai, and 13 and 3 in the Hill and Mountain zones, respectively. The principal administrative centres include cities on the Terai such as Hetauda (Province 3 capital) and Siddarthanagar, and Pokhara (State 4 capital) in the Hill zone.

162. **Topography**: the topography ranges from the lowland plains of the 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 (referred to as Tar) and with a mean elevation of 1,900 masl.

163. **Precipitation**: rainfall distribution within the basin ranges from less than 200 mm to almost 5,000 mm per annum. On the 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.

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

165. **Land Use**: total land classed as agriculture use (level terrace, sloping terrace and valley/tar/Terai) is 26% of the total (approx. 0.95 Mil. ha) and 40% as forests (1.47 Mil. ha). On the 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.

166. **Water Resources**: the total annual surface water resources are approximately 57.6 Bm^3 with the volume per sub-basin ranging from less than 1,000 to more than 12,000 Mm^3 per annum. Total annual groundwater resources are approximately 2.8 Bm^3 which is mainly located within the Terai districts.

2.2.1.3 Koshi Basin

167. The Koshi Basin is located in eastern Nepal bordering China and India to the north and south respectively. It has a total area of about 47,500 km^2 (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 (as shown in Figure).

168. **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 on the 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 km^2 on the Terai, and less than 300 and 60 per km^2 in the Hill and Mountain zones, respectively.

169. The basin fully encompasses States 1 and 2 and partially State 3 (which extends into the Narayani basin). There are a total of 31 districts within the basin of which 11 are on the Terai, and 15 and 5 in the Hill and Mountain zones respectively. The principal administrative centres include Kathmandu (national capital) within State 3, to the west, and seven major cities on the Terai including Janakpur (State 2 capital) and Biratnagar (State 1 capital).

170. **Topography**: the topography ranges from the lowland plains of the 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 (referred to as Tar) and with a mean elevation of 1,200 masl.

171. **Precipitation**: rainfall distribution within the basin ranges from about 1,500 to more than 4,000 mm per annum. On the 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.

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

173. **Land Use**: total land classed as agriculture use (level terrace, sloping terrace and valley/tar/Terai) is 35% of the total (approx. 1.66 Mil. ha) and 43% as forests (2.04 Mil. ha). On the 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.

174. **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 Bm^3 which is mainly located within the Terai districts.

175. 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.

176. 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 5: Extent of Basins in the SWAT Models

177. 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, see Figure 6. Note that this annual volume is also based on the 80th percentile reliable volumes, as all water resources are with specific reference to irrigation potential. Each value is determined from individual catchments and not accumulative.

178. The estimated annual surface volume is 173,000 Mm^3 and the annual groundwater volume is estimated at 13,072 Mm^3.

179. Table 15 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 Bm^3 per annum. However, more than 70% of this resource occurs during the period from June to September, a period of less irrigation demand.

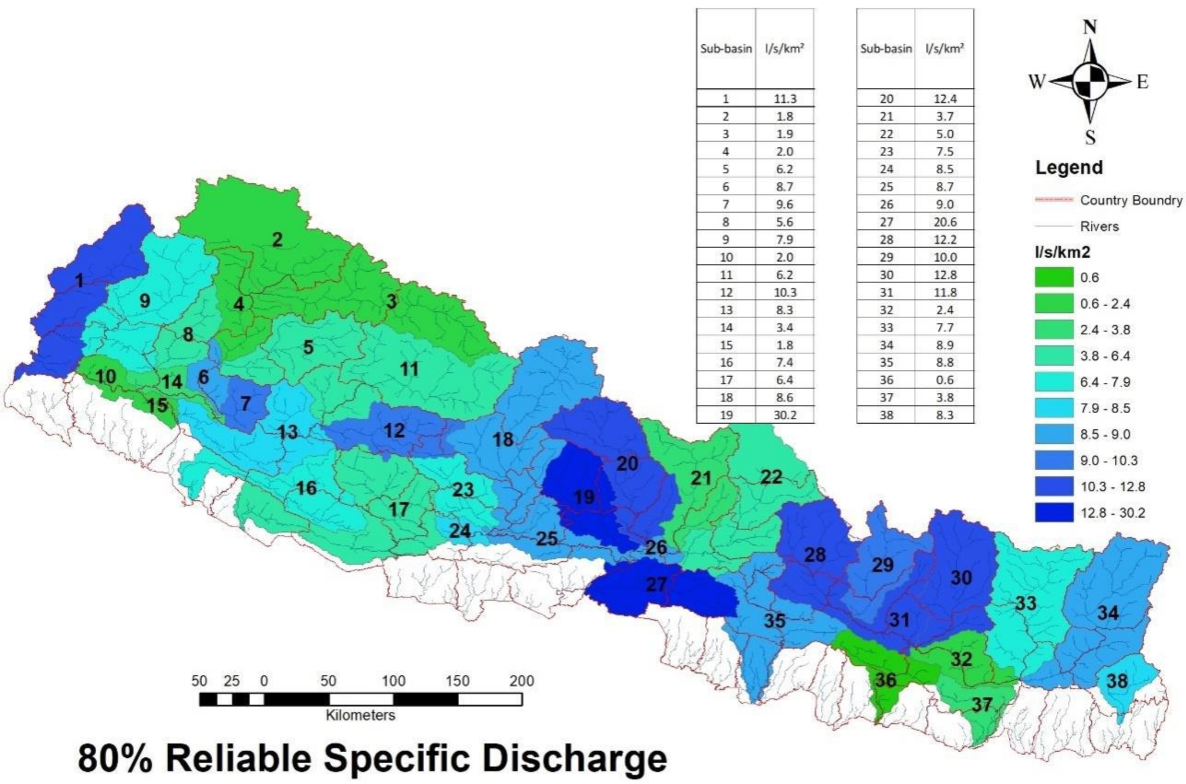


Figure 6: 80th Percentile Reliable Specific Discharge

180. The available volume represents a huge potential, at an annual CWR of 25,000 m^3/ha, this could irrigate 6.9 mil. ha, way more than the potential irrigable land at 2.3 mil. ha. However, based on the flows available in March, the dry season potential is only 0.75 mil. ha, less than the available irrigable potential. To achieve the full potential, storage dams are required, or the use of groundwater is mobilised.

Table 15: Surface Water Assessment

	Karnali	Narayani	Koshi	Total
Resource (Bm^3) 80th Percentile	60.0	57.6	55.3	173.0
	35%	33%	32%	

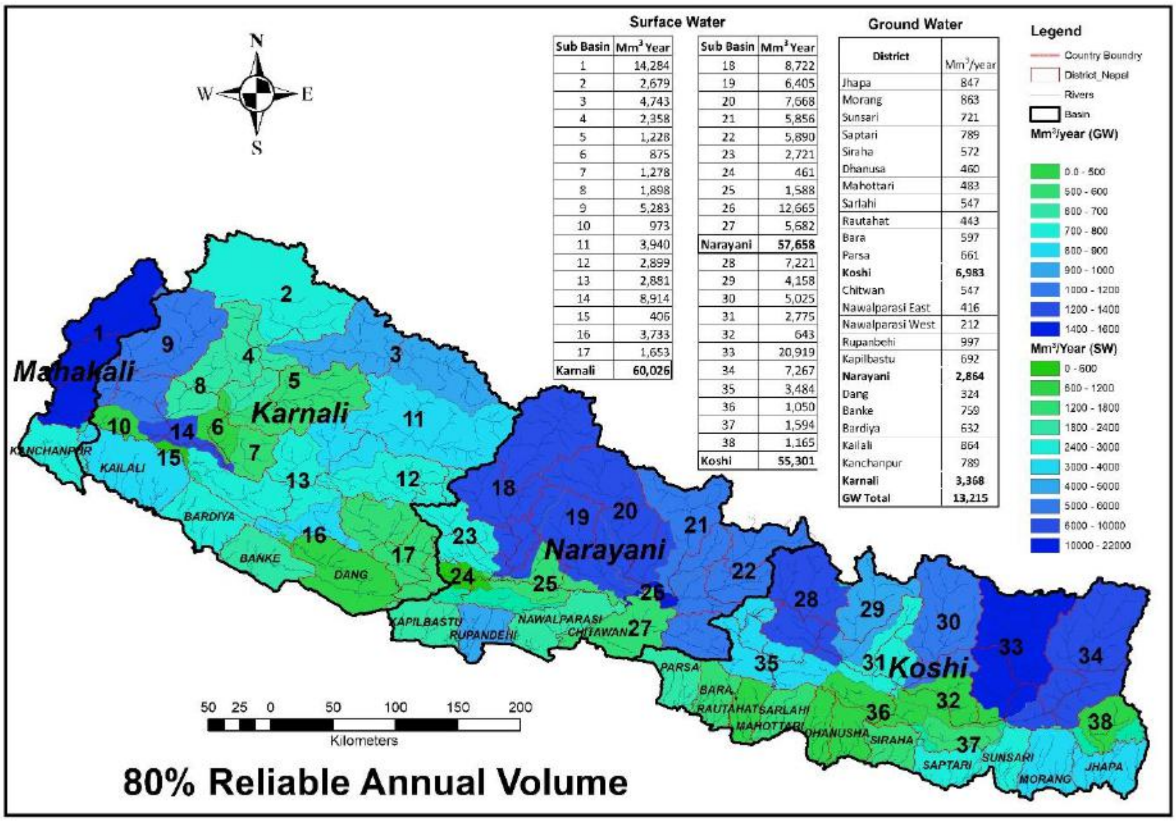


Figure 7: Water Availability Map of Nepal

2.2.2 Ground Water Resources

2.2.2.1 Groundwater Assessment

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

182. 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 the Terai Zone extending to the border with India. These zones are based on the conceptual geological model (**Error! Reference source not found.** and **Error! Reference source not found.**).
- 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 in a spreadsheet and results exported to a model input file.
- The calculation of recharge and groundwater demand for irrigation (if required) is calculated in 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'.
- The model is run for 20 years from 1990 to 2009.

183. 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

184. Table 16 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 13,072 Mm^3, of which about 6,945 Mm^3 (more than 50%) are within the Koshi basin, and close to 2,768 Mm^3 and 3,359 Mm^3 in the Narayani and Karnali basins respectively.

185. 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 m^3 per hectare, would be an equivalent irrigated area of more than 725,000 ha.

Table 16: 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
Mahotari	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	3427	1068	2487	6983
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	1221	2864
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	3368
Total	**5,896**	**2,314**	**5,004**	**13,215**

3. SECTION III: IRRIGATION MASTER PLAN 2019

3.1 Strategic Approaches to Irrigation Master Plan 2019

186. Given the developmental challenges discussed in Section I and recognizing that Nepal's food security, food sufficiency, alleviation of rural poverty, and employment generation challenges heavily depend on how fast the country modernizes its agriculture, which in turn depends on how significantly its irrigation infrastructure transforms itself in the coming years, the IMP 2019 has put forth an ambitious plan to rapidly develop Nepal irrigation infrastructure. Key approaches to meet that challenge are:

Increase year-round irrigation across the country with a particular focus in the 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 the Terai in a cost-effective manner;
- Emphasize groundwater development, for either independent or conjunctive use, in the shorter-term to off-set longer implementation periods required for large projects

In the hills and mountains, the focus will on development of new gravity systems. Concurrently, IMP 2019 also plans to develop non-conventional irrigation through electric and solar pumping wherever suitable.

A key focus of the IMP 2019 will also be on rehabilitation and modernization of existing infrastructure with the objective of transferring management of irrigation systems to user groups, sub-national bodies 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 IMP 2019 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

187. Districts where the economic return to irrigation is likely to be relatively higher were ranked. Very broadly and on average, the Terai districts have 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 the Terai. In addition, the west and central districts have higher expected incremental net values of production.

188. 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 on the Terai. The capacity for returns on irrigation investment is significantly lower in the Hills.

189. 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

190. Under present levels of input and outputs, the development of groundwater should 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 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 17.

Table 17: Explanatory Variables for Net Value of Production by District (NPR M)

Model description	Explanatory variable			Model significance		
	Description	Coefficient	t stat	R2	F	F sig
NVP Mil. on 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.[15.] The model suggests that, under present conditions of productivity and prices:

- An additional ha of surface irrigation raises District NVP by only NPR 63,000 (USD 560), but the coefficient is not significant
- An additional ha of groundwater or conjunctive use leads to an increase of NPR 220,500 (USD 2,044); the coefficient is highly significant
- An additional percent of S1 or S2 land raises NPV by NPR 7,240 (USD 67); the coefficient is significant.

191. So, the present area and distribution of existing surface water irrigation schemes on the 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 to be because the irrigation service surface schemes provide is insufficient, less timely and less reliable. The incremental value of production from an additional hectare of surface irrigation would only be associated with an increase in District net value of production of about US$ 560 per ha, and the coefficient to derive this is not significant.

192. Under present conditions, expanding groundwater irrigation (including in existing surface schemes as conjunctive use) appears to be a much better strategy. An additional hectare of groundwater opened can be expected to be associated with an increase in net value of District production of around NPR 221,000 (USD 2,044). If the development cost of an additional hectare of groundwater irrigation is in the region of US$ 2,000-3,000 per ha the pay-back potential is obvious, though the investment costs may have to be associated with improved infrastructure, input supply etc.

[15] 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. VIF 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.

3.1.3 Temporal Priorities

193. 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. An indication of not only where and what needs to be done is helpful in decision making. By using the estimated incremental change in the gross cropped area required between 2018 and 2031, and between 2031 and 2043, about 535,000 ha should be developed by 2031 and an additional 345,000 ha in the period 2031-43.

Table 18: Estimate of New Irrigated Areas Required in 2035 and 2041, ha

	2015	2018-31	2031-43
2015 Irrigated net ha	1,357,000	1,357,067	1,357,067
2015 Rainfed net ha	2,204,000		
existing irrigated CI	176%	176%	176%
existing rainfed CI	105%	105%	105%
2015 Irrigated gross ha	2,388,000	2,388,519	2,388,519
2015 Rainfed gross ha	2,314,000		
new irrigated net ha		535,184	880,225
reduced rainfed net ha		1,669,071	1,324,030
new irrigated gross ha		941,956	1,549,249
reduced rainfed gross ha		1,752,524	1,390,231
Gross ha required		5,083,000	5,328,000
Gross ha achieved	4,702,000	5,083,000	5,328,000

Note: “expected” economic growth scenario, no increase in food deficit

194. 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 irrigated cropping intensity has risen from a low of about 160% in 1999/2000 up to 2009/10 and thereafter been variable around 180%. It has never been consistently above 200% since before the mid-1990s. However, it will be apparent that unless crop intensification is achieved, it will be impossible to demand targets.

195. The estimate of 880,000 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 the 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 market demand under conditions of accelerated economic growth. To satisfy the estimated gross requirement of 6,277,000 gross ha in 2041 development of all remaining suitable land and a cropping intensity of 214% is needed.

3.2 Goals and targets for Irrigation Master Plan 2019

3.2.1 Development Goals

196. National goals for the irrigation subsector are set out in the Water Resource Strategy (2002) and National Water Plan (2005) and these are full development of the irrigable lands and full realisation of irrigation system performance and productivity. Specific goals include (i) near full (97%) 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%. Additionally, the national development goals[16] emphasize the importance of growth per capita Gross National Income, improvement in human assets and reduced economic vulnerability in order to raise Nepal from LDC to DC status by 2022.

197. 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 2016), and increasing urbanisation. Consequently, food demand will increase over this period to meet population growth and changing dietary habits for a more urban population. To meet this additional food demand it is estimated that, in additional 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 Goals

198. The development potential for irrigated agriculture includes (i) intensification of existing irrigated lands (approx. 1.435 Mil. ha), through development of water resources to increase cropping intensities and modernisation of system infrastructure and operation and management; and (ii) expansion of irrigated lands (approx. 1.189 Mil. ha) through the development of water resources, both surface water and groundwater, and associated system and farm development. To attain the national goals for the subsector, it will require substantial investment in water resources development and modernisation of existing systems. In summary, the options are:

- **Improvement of existing irrigated area (systems):** there is potential to improve the performance of the existing 1.435 Mil. 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 principal water source, these are the following:
  - 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 supply about 0.341 Mil. ha of existing systems and modernisation for 0.170 Mil. in the Terai.
  - Groundwater systems: for existing areas irrigated from groundwater, mainly in the Terai, there is potential for improvement through improvement of infrastructure and system management, and on-farm improvements for 0.364 Mil. ha.
- **Development of new irrigated lands:** there is potential for further expansion of irrigated lands (of the order of 1.189 Mil. ha). The options are categorised by agro-ecological zone;
  - Terai: there is potential for expansion of the surface irrigated area in the Terai by about 0.305 Mil. ha (when considering 7 priority projects) and selected groundwater projects for additional 0.318 Mil. ha.

[16] As stated in the 'Sustainable Development Goals 2016-2030' (NPC 2015)

- Hill and Mountain: there is potential for expansion of irrigated lands in the Hill and Mountain zone (of more than 566,000 ha, principally from pumped water sources, of which about 0.467 Mil. ha is from pumping, and 0.098 Mil. ha from gravity feed.

199. While the above presents an assessment of the potential for the country as a whole, for the identification of investment options for the IMP, the approach and presentation presented in this report is focused on the assessment of projects for development of water resources for intensification of existing systems and development of new irrigated lands.

200. The Plan aims to complete 100% irrigation of all Terai irrigable lands, 1.499 Mil. ha. For the Hill and Mountains, there is 1.038 Mil. ha of suitable surface irrigation (out of 1.967 Mil. Agricultural land), but not all of this will be irrigated in the Plan. The pumping and gravity irrigable assessment identified 0.566 Mil. ha as suitable for development, leaving 0.272 Mil. ha not irrigated (with 0.200 Mil. ha net existing irrigation).

Table 19: Development Options

SN	Land Use (ha) Option	Terai	Hill	Mountain	Total
A	**Existing Irrigated Land (net)**				
A.1	**Surface Water Systems**				
A.1.1	Improved Surface Water Supply[1]	341,500			341,500
A.1.2	Modernisation[2]	170,000	156,000	38,250	364,250
	Subtotal	**511,500**	**156,000**	**38,250**	**705,750**
A.2	**Groundwater Systems**				
A.2.1	Modernisation	364,500	6,000	0	370,500
	Total Existing Systems	**876,000**	**162,000**	**38,250**	**1,076,250**
B	**New Irrigation Systems/Lands**				
B1	**Terai**				
B.1.1	Surface Water Supply[3]	305,000			305,000
B.1.2	Groundwater Supply[4]	318,000			318,000
B.2	**Hill/Mountain**				
B.2.1	Gravity		33,700	64,400	98,100
B.2.2	Pumped/Tank/Solar		387,900	80,000	467,900
	Total of New Systems	**623,000**	**421,600**	**144,400**	**1,189,000**
	Remain Unirrigated[5]	-	253,400	18,350	271,750
	Total Irrigable Land	**1,499,000**	**837,000**	**201,000**	**2,537,000**

(1) Option includes modernisation of existing systems, (2) Option may also include lower reach groundwater development to improve water supply, (3) New Surface systems of 305,000 ha is from 7 priority projects, (4) Groundwater from 16 districts for 318,000 ha, (5) unirrigated land is 271,750 ha in hills and mountains

3.2.3 Potential Projects

3.2.3.1 Multipurpose and Large-scale Surface Water Projects

201. This section presents the development projects proposed as the core element of the IMP investment plan, and as identified as contributing to the meeting national goals for the irrigation subsector. These fall within 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).

202. 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 on the

Terai. They are generally large scale, with high infrastructure and costs, and in most cases they include hydropower generation, and therefore referred to as multipurpose projects. When delineating the potential areas for development, the maximum area possible has been identified. This means that areas proposed in the water availability study represent maximum areas, and do not reflect already selected areas, like for the Sunkoshi-Marin diversion, which has used a command area of 122,000 ha. The irrigable area identified for the study is 170,000 ha. Detailed design will be able to fine tune the areas to what is technically and economically feasible.

203. There is a total of 11 projects of which 5 projects have alternative infrastructure options (variants) to increase water supply and expand irrigated area, and in some cases generate power. Table 20 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)).

Table 20: Surface Water Development Scenarios (ha)

SN	Ref	Project / Option (ha)	Irrigable Area	Existing Area	Water Available	New Area	Deficit Area	Installed MW
			1	2	3	4	5	6
1	W	Bheri-Babai Diversion Multipurpose	45,111	42,467	45,111	2,644	0	73
	W.1	Transfer only						
	W.2	Transfer + Nalsingad dam						
	W.3	Transfer + Uttar Ganga dam						
2	W.4	Karnali Diversion	40,628	7,632	40,628	32,996	0	80
3	W.5	Madi Dang Diversion	35,639	19,458	17,107		18,532	61
4	W.6	Naumure Dam, Rapti Kapilbastu Diversion	86,874	15,226	51,256	36,030	35,618	343
		Subtotal (West)	**208,252**	**84,783**	**154,102**	**71,670**	**54,150**	**312**
5	C	Kaligandaki Tinau Diversion						
	C.1	No reservoir	149,830	52,455	31,464		118,366	244
	C.2	Andikhola dam			41,953		107,877	424
6	C.3	Kaligandaki Nawalparasi Diversion	11,539	2,080	11,539	9,459	0	4
7	C	Trishuli-Shaktikhor Diversion						
	C.4	No reservoir	34,892	12,785	20,586	7,801	14,306	no HP
	C.5	Bhudhi-Gandaki dam			34,892	22,107	0	1,200
		Subtotal (Central)	**196,261**	**67,320**	**88,384**	**31,566**	**107,877**	**1,628**
8	E.1	Sunkoshi Marin Diversion	170,462	108,880	54,548		115,914	33
	E.2	Sunkoshi Kamala Diversion	181,802	61,009	129,079	68,070	52,723	44
	E	Sunkoshi Marin + Kamala						
	E.3	Dudhkoshi HPP	352,264	169,889	236,350	66,461	115,914	
	E.4	Sunkoshi 3 HPP			352,264	171,500	0	
9	E	Tamor Morang Diversion						117
	E.5	No reservoir	113,743	70,000	45,497		68,246	
	E.6	Tamor 3 HPP			113,743	43,743	0	
10	E.7	Kankai Multipurpose	39,639	6,643	39,639	32,996	0	90
11	E.8	Chatara Barrage	66,482	47,993	66,482	18,489	0	
		Subtotal (East)	**572,128**	**294,525**	**572,128**	**333,189**	**0**	**1,628**
		Grand Total	**976,641**	**446,628**	**814,614**	**436,425**	**162,027**	**3,568**
		Selected Priority Projects Total	**854,932**	**405,662**	**711,437**	**305,402**	**143,495**	**727**

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, see **Error! Reference source not found.**, **Error! Reference source not found.**, **Error! Reference source not found.**
4 3 - 2 = New Irrigated Area Scenario E4 limited to 171,500 ha
5 Deficit 3 - 1 (could be used for TW Irrigation Development)

204. Total command area for all projects is about 855,000 ha, of which about 405,000 ha are under command of existing surface water irrigation systems and 305,000 ha is regarded as new irrigation. The maximum potential area for the project should they all be implementable would be about 711,000 ha. However, as shown in the cost-benefit analysis not all projects are economically feasible, and therefore the actual number of projects and irrigated area is based on selected priority projects for 305,000 ha.

205. As mentioned above, the project includes hydropower generation, where possible, that there is sufficient operating head. Nine of the 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 730 MW, however, not all project are recommended for inclusion in the IMP.

Bheri-Babai Diversion Multipurpose Project

206. The project will divert water from the Bheri River to the Babai River via a transfer tunnel (12.3 km length and design flow of 40.0 m^3/s), which will increase flows for extraction for the Babai irrigation

system. It is also proposed to construct a hydropower plant (46 MW) at the tunnel outlet for power generation. The project will supply an irrigated area of about 45,100 ha, of which 42,100 ha are currently irrigated and about 3,000 ha would be new irrigated lands. This design considers potential maximum water use of the river discharge according to water availability. The project is currently under construction for a design discharge of 40 m^3/s. With this design discharge, hydropower plant capacity will be 46.8 MW and irrigation area development 51,000 ha. This development area includes about 10,000 ha of Sikta Irrigation commend area, which was not considered in the water available analysis.

207. There are three project variants: (i) transfer tunnel only, and two options for dams to increase water supply, principally to increase hydropower production, the options for dams include; (ii) Nalsingad and (iii) Uttar Ganga.

Karnali Diversion Project

208. The project would divert water from the Karnali River to the Terai via a 19 km tunnel (design flow 59 m^3/s) to supply an irrigated area of about 46,000 ha, of which 33,000 ha would be new irrigated lands and 7,600 ha irrigated under the Khutia irrigation system. The project includes a hydropower plant of approximately 80 MW. This system would infill the irrigable land between the end 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

209. 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 m^3/s), dam (on the Madi River) and hydropower plant (61 MW). It would supply sufficient water for irrigation of about 17,000 ha, of which a significant proportion could be to existing irrigation systems. This project was found to be uneconomical under the above design parameters. However, the WECS RBP project is reviewing 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

210. The project would divert water from the West Rapti River to Kapilbastu for the irrigation of about 40,849 ha on the Terai (out of 51,000 ha available for irrigation, the remaining flow going downstream), of which about 15,000 ha is under existing irrigation system command (Kapilbastu system) and the balance new irrigated land. The infrastructure includes: Naumure storage dam (169 m), regulation dam (13 m), hydropower station (approx. 100 MW) and transfer tunnels (23 km) (as shown in **Error! Reference source not found.**). This project has been found economical and is recommended in the short list of the plan. It is being studied by DoED and will be available for detailed design soon. The WECS RBP should consider the Madi-Dang and Naumure Dam integrated projects for optimum water use and best economic solution.

Kaligandaki-Tinau Diversion Project

211. The project concept is transfer of water from the Kaligandaki River to Rupandehi District, via a tunnel (25 km and design flow of 66 m^3/s) (as shown in **Error! Reference source not found.**). 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 area of more than 62,000 ha within the project command, and which would benefit from the development.

212. 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 HPP. The WECS

RBP should consider the integrated water resource to include the Uttar-Ganga Dam diverting to the Gandak basin.

Kaligandaki Nawalparasi Diversion Project

213. The project also would divert water by tunnel (approx. 6 km length and 17 m^3/s design flow)) from the Kaligandaki River for the irrigation use (approximately 11,500 ha) on Nawalparsi-East District (as shown in **Error! Reference source not found.**). The project also includes a small hydropower station of about 4 MW. This project is not trans-valley, so no extraction compensation is required under the Gandak Agreement. However, it was found to be uneconomical, and not included in the short list of projects. The area will be covered by groundwater irrigation or lift irrigation.

Trishuli Shaktikhor Diversion Project

214. The project would divert water from the Trishuli River to Chitwan District (as shown in **Error! Reference source not found.**), 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 length and design flow of 51 m^3/s) and storage dam (Budhi-Gandaki) which would increase the irrigated area to nearly 35,000 ha. The project does not include hydropower generation. 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

215. The project concept is for the diversion of water from the Sunkoshi River to the Marin and Kamala Rivers for the irrigation of up to 352,000 ha on the Terai. There are four project options Sunkoshi Marin; diversion to the Marin River via tunnel (14 km and 77 m^3/s), dam (16 m) and hydropower station (MW 41) for irrigation of about 55,000 ha, (the command area includes the existing irrigation systems of Narayani and Bagmati) (as shown in **Error! Reference source not found.**); (ii) Sunkoshi Kamala; diversion to the Kamala River via tunnel (17 km and 72 m^3/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 the addition of a dam on the Dudhkoshi River to increase water supply reliability, which increase the irrigated area to more than 236,000 ha; and (iv) Sunkoshi Marin + Kamala (with Sunkoshi 3 dam); a combination with the addition of a dam on the Sunkoshi River, resulting in an increase in irrigated area to about 352,000 ha.

Tamor Morang Diversion Project

216. The project concept is the diversion of water from the Tamor River to the Chisang River in Morang District for irrigation. There are two project options; (i) tunnel only (31 km length) 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 90 MW). The Tamor 3 HPP reservoir would also provide power of 732 MW.

Kankai Multipurpose Project

217. The project would irrigate an area of about 40,000 ha in Jhapa District (which includes the command area of existing systems (Kankai and Jhapa). The infrastructure includes a dam on the Kankaimai River, of 85 m height, and hydropower station (90 MW). This project was found to be uneconomical and combined with social and environmental issues is not selected for priority. This area will be irrigated by groundwater. The dam is a stand-alone project.

Chatara Barrage Project

218. The project concept is the construction of a barrage on the Koshi River at Chatara to provide water for irrigation of about 66,000 ha on Saptari District on the right bank. There is no development of

hydropower as part of the project. An additional benefit will be year-round supply to the existing system of Sunsari-Morang for 68,000 ha on the east bank.

Seti-Pandul Diversion Project

219. There is the Seti Diversion project within the Karnali Basin which would entail a tunnel of 42 km, could generate 280 MW of power, and have a maximum potential irrigation area of 300,000 ha. However, this area is already covered by existing project under construction, Mahakali III and Rani-Jamara-Kulariya. This project has been found uneconomical at present because it is very expensive and other cheaper alternatives are available, like the Karnali Diversion project, which fills the gap between Mahakali III and Rani-Jamara-Kulariya project.

220. The results of the cost benefit analysis of the above projects is used for comparative purposes for ranking of projects on economic feasibility.

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

221. The alternative to multi-purpose projects and large-scale surface irrigation schemes, is groundwater development. It is important to compare the costs and benefits of the two strategies to determine the economic benefits of each.

222. Economic investment and MOM costs for each of the MPP and large-scale surface water schemes recommended for implementation in IMP is compared with investment and MOM costs required for development by ground water. In locations where the grid and distribution is less developed, investment costs for groundwater development could be a considerable higher.

223. 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.

224. Even without taking into account these potential cost increases, the investment and replacement costs of groundwater (about NPR 480,000/ha or 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 NPR 282,000/ha or USD 2,440/ha, though this estimate assumes that upstream costs incurred for hydropower generation (dams, intakes, tunnels) are sunk). The estimated investment cost of development by groundwater rather than surface water are consistently greater for each proposed project area. One explanation for this is the significant replacement costs required for tubewell components.

225. The MOM costs for groundwater (NPR 20,400/ha pa, or 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 (NPR 4,550/ha pa or USD 40/ha pa); one explanation is the cost of energy for pumping.

226. Therefore, in respect of costs and comparing like with like (the costs attached 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 without doubt the more expensive option.

227. If the same benefit stream is assumed for groundwater and surface water, it is clear that the economic project indicators for groundwater development (represented by NPV and IRR in TBL) will be reduced compared with those estimated for surface water. The issue is, will the benefit streams be the same.

228. One argument for maintaining a similar benefit stream for surface water and groundwater development is that the surface water irrigation facilities proposed will provide full dry-season irrigation and thus should offer a service (in terms of volume, timeliness and reliability) equivalent to sourcing from tubewells. However, this is not the case at present. Under present conditions of productivity and prices, an additional ha of surface irrigation raises Terai District net value of production by only NPR 63,000 (USD 560) while an additional ha of groundwater or conjunctive use leads to an increase of NPR 220,500 (USD 2,044). Benefits from groundwater irrigation are over three times greater. This is believed to be because of maintenance and management issues, allied to the important point that existing surface irrigation schemes were designed to provide supplementary irrigation only

229. The second argument is that future crop benefits were 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.[17] Thus, benefits are defined by future food market size and relatively fixed. Nevertheless, the counter-argument is that given the improved timeliness and reliability of groundwater irrigation over surface water (and with the diversification and increased value of cropping these advantages will only increase), then groundwater will take an increased share of future crop benefits

230. An account of the econometrics used to estimate this increased share is provided in this IMP Report. Basically, 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% of value.

231. Also, tube wells can access available benefits more rapidly than the proposed surface schemes, because of the much shorter construction time: a tube well can be installed in a season and benefits from tube well irrigation will be attained in the year after commissioning. A 40,000 ha field of tube wells could be developed within about three or four years. In contrast, MPP have a lead time of up six to nine years before the first year of irrigation benefit. This adjustment to the groundwater benefit stream increases IRR by one or two percentage points. Nevertheless, this advantage is not sufficient to raise the economic benefit above surface irrigation.

232. Despite these adjustments, groundwater irrigation remains the slightly less 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 is borne out in the case of the proposed Chatara Barrage Project – constructed solely for irrigation use – where IRR is estimated to be substantially lower than if the command area was developed by groundwater irrigation.

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

3.2.3.3 Small -scale Ground Water Projects

234. Groundwater is seen as an answer to quick solutions for increasing irrigation coverage in the short term. This is because of its short construction time, small area command and relatively low energy requirement. The key features of the project are:

- Electric-powered submersible pumps, with variable speed drives
- Piped distribution with the option for non-conventional irrigation, drip and micro-sprinkler

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

- 40 ha command, 4 blocks of 10 ha pre-paid meters, with discharge of 10 l/s
- A smart card with ISF which covers electricity, demand charge, O&M plus an asset replacement fund for sustainability
- Total dynamic head of between 26.4 m to 31.4 m, and a pump power requirement of 20 kW per pump

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

- Water can be supplied on demand with high efficiently, using less water per crop.
- Time between requesting water and receiving is minutes as opposed to hours, or even days
- With 10 ha command blocks, the WUA is small, with limited number of user per block
- With the pre-paid meter system, there is less potential of big farmers dominating the water supply, all have to pay equally.
- Time between design and commissioning 3-4 years, is less than half the time as opposed to 6-8 years for transfer surface irrigation.
- A new concept of pre-paid meters for full cost recovery could lead to sustainable irrigation, which has not been seen in surface irrigation.

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

237. Despite some drawbacks in the system, groundwater definitely has a large place in the future of irrigation in Nepal. This is because:

- With the increase of surface water now providing year-round irrigation, there will be considerable groundwater recharge and potential water logging, particularly in the south. Flooding of the south of the Terai is therefore a serious potential, and high water tables with raise with the increase in transfer schemes. Groundwater extraction in the south is therefore essential to keep groundwater levels down and reduce the risk of salinity.
- With the introduction of the pre-paid meter in tube well irrigation, there is the potential to create a sustainable system not seen in Nepal. The success of this system can be replicated elsewhere in the Terai.

3.2.3.4 Gravity and Pump Irrigation Projects for Hill and Mountain Areas

238. 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). After feedback from beneficiaries and DoWRI, this criteria was 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.

239. For the hills and mountains, the total of 566,000 ha was identified as suitable for pumping. Whatever is suitable for pumping is also suitable for surface gravity irrigation. The distribution by class and ecological zone is given in Table 21.

Table 21: Results of IMP-2018 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**

240. 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

241. 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 93 pumping schemes for an area of 17,710 ha. The distribution by province is given in Table 22.

Table 22: Category #1: Summary IMP-2018 GIS Identified Schemes

State	Gravity		Pumping		Total	
	#	ha	#	ha	#	ha
1	66	27,550	25	5,972	91	33,522
2	45	29,951			45	29,951
3	70	17,059	20	2,477	90	19,536
4	17	3,071	35	6,859	52	9,930
5	8	1,357	3	329	11	1,686
6	31	7,561	8	1,883	39	9,444
7	24	7,288	1	190	25	7,478
Total	**261**	**93,837**	**92**	**17,710**	**353**	**111,546**

Category #2: IMP-2018 GIS Classified Schemes

242. 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 the 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**

243. 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. The development should include supporting and complementary components for capacity building of stakeholders in conjunction with the infrastructure development.

3.2.4 Prioritized Projects

244. 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 greatest dry-season irrigable area, but also the second highest ranking project. The combined irrigable area is 352,300 ha.

245. Similarly, the Tamor-Morang transfer (E.5) gives only 45,500 ha of irrigable land with RoR; 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 of the ranking list.

246. 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 should be considered in future in more details in WECS RBP master plan.

247. The Naumure Dam MPP gives negative NPV and less than 9% IRR. This MPP project should be given greater study to improve the economics and bring this promising project to fruition.

248. 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.

249. The Kankai MPP is not included in

250. Table is not economical, and should not be considered further due to the social and environmental issues. The land commanded by the project should be filled by the Tamor-Morang transfer (E.6) with the addition of GW schemes in Jhapa District.

Table 22: Selected Projects for Implementation

Scenario	Project	Score	NPV (M NPV)	IRR (%)	New Irrig Area (ha)	Rehab Irrig Areas (ha)	Irrg & HP Cost (M NPR/ha)
E6	Tamor Morang 2 (Chisang)	113	120,963	14.3%	43,743	70,000	889.3
E4	Sunkoshi Morin & 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	41,953	981.2
W6	Naumure Dam, Rapti Kapilbastu Diversion	59	36,550	11.4%	51,256	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 305,000 ha (from E.6, E.4, C.2, W.6, W.4 and W.2)

3.2.5 Irrigation Management

251. Plans required for improving irrigation efficiency and subsequently management of irrigation system are grouped into following four thematic areas (or components):

- Irrigation system modernization
- Management improvement through irrigation management transfer (IMT)
- On Farm Water Management (OFWM)
- Enhancing maintenance of AMISs and ISF collection

252. The first two components of the proposed plan (irrigation modernization and management improvement) need to be implemented in a combined and holistic approach. Their interventions in an isolation will not be effective. However, the other two components (OFWM and maintenance support of AMISs) that focus mainly on building institution and knowledge base, need to be implemented separately as a stand along project (or program). If these components are merged with the infrastructure development components, their significance could be diluted during implementation. Paragraphs below describe the proposed development plan under above thematic areas.

3.2.5.1 Irrigation system modernization

253. The aim of the proposed irrigation system modernization is to enhance irrigation services for achieving the desired operational objectives. This includes only the hardware aspect, which however needs to be implemented in parallel (or jointly) with other aspects of irrigation management grouped under other thematic areas.

254. In terms of targets for the IMP 2019, following objectives have been set:

- It is proposed to rehabilitate about 50% of the existing FMISs (covering about 261,960 ha) during the IMP period, while the remaining 50% will be improved through bottleneck intervention. In addition, about half of the FMISs that would be rehabilitated will also be modernized (130,960 ha) with a focus to dry season irrigation.
- All exiting surface AMISs (341,500 ha), except those recently rehabilitated for management transfer (33,900 ha) under component B of IWRMP that totals 225,310 ha will receive one time rehabilitation during this IMP period.
- Main system management of about two third of the above areas (148,700 ha) will be transferred to any of the four identified organizational entities. In addition, manager transfer of lower distribution units (tertiary and below) will be transferred to respective WUGs (or WUA)
- Detailed cost estimations for different components of irrigation management improvement works with total cost of about US$ 1,138.4 million.

<u>Modernization of FMISs</u>

255. This master plan proposes to categorize modernization of FMISs in following three categories, which in turn will shape modalities to support them. The DoWRI in the coming period will develop their support modalities.

Table 23: Modernization categories of FMISs

SN	Modernization Category	Modernization Focus

1	Modernization of FMISs with a focus to dry season irrigation	Focus will be more 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 WRRDC18 under the MoEWRI has already identified tens of thousands of ha in the hills and mountains that can be irrigated by solar lift as one of the technologies.
2	Rehabilitation of FMISs	Rehabilitation will focus in 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 re-engineering 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	Bottleneck repair of FMISs	This will focus on providing support for bottleneck repair of existing irrigation systems on piecemeal basis. Bottleneck repair here refers to a lot more than the annual system maintenance that is being performed by the local communities. Annual maintenance is defined as that level of maintenance required to keep the system like new. Deferred or bottleneck maintenance is defined as rehabilitation maintenance required to bring back the system like new. Bottleneck repair of irrigation system will be designed and implemented locally by local governments at relatively low costs. Its main objective is to maintain the present level of production, which otherwise may decline in absence of such support.

Modernization of AMIS (or JMIS)

256. Modernization of AMISs in Nepal will have following two principal sub-components

- Undertaking deferred maintenance of irrigation system to enhance structural stability of its infrastructure
- Modernization of irrigation system to enhance irrigation delivery at all levels of irrigation system and thereafter overall irrigation efficiency

257. As the deferred maintenance of AMISs can be undertaken through a normal maintenance / rehabilitation procedure, it does not require any elaboration here. Table 24 presents 4 stepped process of modernizing AMISs.

18 The Water Resources Research and Development Centre

Table 24: Modernization process in a sequential order

SN	Process: irrigation modernization	Description
1	Define project objective	Design of irrigation modernization will be shaped by the project objective. For example, if the objective is to increase production per unit of land, a system should be able to deliver irrigation 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 modality19 needs to be designed based on following considerations. 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	Accordingly, irrigation system needs to be modernized jointly or in parallel with other aspects (or components) of irrigation modernization like (a) regular maintenance, (b) OFWM, (c) institutional strengthening and capacity building, and (d) management transfer Subsequently, the modernized system needs to be operated as per the designed canal operation modality, which then needs close monitoring

19 Some such canal operation modality are: (a) traditional proportional (delivery varies as per incoming flows), (b) arranged proportional: Intermittent full supply (Example: 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.

3.2.5.2 Management Transfers

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

- To relieve governments from continuing financing 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
- To enhance performance of irrigation system by involving irrigation users in managing their own system

259. 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 AMISs (usually tertiary canal and below) will invariably be transferred to the block level WUA, referred to as WUG.20 Thus, formation and strengthening of WUAs continue to be an important part of irrigation management transfer.

260. 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

261. 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 of irrigation management transfer to above entities.

<u>Irrigation management transfer to local government</u>

262. Considering the spirit of the constitution of Nepal, the public irrigation systems (or their sub-systems) whose hydraulic boundary remain within the geographical jurisdiction of local government may be transferred to them for continuing their management. Worldwide, there are examples of local government managing irrigation system, especially the small-scale irrigation systems or sub-systems of larger systems (FAO 58, 1999). Further, transfer of irrigation management to local government has been successful in Turkey and many other countries.

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

264. Weaknesses of this model are of two folds. First, irrigation system often cross the administrative boundaries of local government. Seconds, local governments have so many other responsibilities. Despite these weaknesses, as local governments are more accountable to local water users, they can

20 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.

ensure that the irrigation management practices are consistent with the aspirations of the general water users.

265. 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 Department of Irrigation at the federal level. Another important aspect is that the fundamentals of the success of IMTP rests on the establishment of practical arrangements for financing operation and maintenance of transferred irrigation system. Local governments are in better position to meet this need.

266. Management transfer to local government will be supported by modernization 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

267. 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 undertake regular maintenance of the canal, divert water from the source river to canal on daily basis, and deliver waters to farmers' field in agreed schedule and modalities[21]. This experience is, however, not available in the case of Nepal's large-scale public irrigation system.

268. 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 in 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.

269. Presently, the department of irrigation 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. Theoretically, services for both the activities – maintenance and operation – are being procured on contractual arrangement. However, there exist 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.

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

271. Management transfer to private operator requires that such operator (or company) exist in the country. However, this is not the case. Although there are several professional (engineering) companies

21 Water users pay them in commodities, mainly food grains. Such operators in turn can maintain their livelihood with the food grains they receive from the water users

and NGOs providing agriculture related services, such irrigation operators are presently not available. Thus, private sector institution building will be one of the 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 in trial basis in a couple of medium scale irrigation systems.

Irrigation management transfer to water users' cooperative (WUC)

272. 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.

273. 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)[22] that would allow WUAs to transform themselves to irrigation water user cooperative under Cooperative Act. Its main objectives were to ensure better access to government support and external donor funded assistance.

274. The said 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 cooperative will be a more formal organization that can perform both the governance and management functions directly. Politically, such WUCs are said to be stronger compared to WUAs. It is believed that WUAs often function weakly in the face of strong public bureaucracies and powerful village governments compared to WUCs. Further, WUCs can by themselves explore the possibility of external donor funded assistance.

275. If one look at the status of farmers' cooperative in Nepal, they seem to be successful mainly for production industries like dairy cooperative, vegetable cooperative and so on. Irrigation being service industry, success of such cooperative in service sector is yet to be documented. This plan suggests that irrigation cooperatives should not only look at irrigation management, it should rather have much broader responsibilities to handle and manage crop production, coordination of the use of fertilizers, marketing, transport of agricultural goods and selling to consumer. Such situation however may dilute the function of irrigation services. Further, success stories of such multi-objectives cooperative in Nepal is also yet to be documented.

276. As irrigation management transfer to WUCs is a new approach for Nepal, it may be implemented in a trial basis in a couple of medium scale irrigation systems, also on mechanised irrigation like hill pumping schemes. Further, management transfer to WUCs will be supported by modernization of irrigation system, OFWM, and institutional capacity building of WUCs.

Irrigation management transfer to DoWRI-WUA joint management

277. Most large scaled AMISs in Nepal are operating under the joint management model. In this 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 to be monitored by WUA.

22 The draft Irrigation Act (2015) was prepared and approved by the then Ministry of Irrigation and was placed before Parliament for its assent. This has not been enacted as of now and seemingly has become out of date in the context of new federated structure of governance in Nepal.

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

279. Unlike the irrigation management transfer to the first three organizational entities noted above,[23] the DoWRI-WUA joint management mode of irrigation is considered to be very appropriate for managing large-scaled 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 influencing performance of irrigation management by WUA at lower level. As a result, sustainability of DoWRI-WUA joint management model is being questioned.

280. Despite the situation depicted above, 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.

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

Formation and strengthening of WUAs for irrigation management transfer

282. Irrespective of the organizational entities selected for management transfer of the main system as outlined by the foregoing sections, management of lower level of distribution system (usually a block of 100 ha or below irrigated by a tertiary canal), will invariably be continued by the concerned WUA (or WUG). In this sense, as usual, formation and strengthening of WUA will receive adequate attention. WUA is a community organization that brings together farmers for the purpose of managing a common irrigation system. In Nepal, they are formed under society registration act, and they can be registered with the government either at the office of Chief District Officer (CDO) or at concerned irrigation division.

283. 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 WUA also exist. the formation of WUA should start from the lowest level to allow adequate representation of farmers at their higher level organization.

284. 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 project:

285. WUG will be responsible for all water management activities on its own within the block. Some of these activities include water allocation, water distribution, canal maintenance, collection of ISF, resources mobilization for maintenance, and other organization activities. The WUG in turn is supposed to receive irrigation water in agreed schedule and quantum at the respective terminal points by the upper level service provided.

286. 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

23 Local government, water users cooperative, and private operator

management activities; (d) liaison with farmers; and (‘e) maintain closer linkage between irrigation and agricultural development and value enhancement

Performance of WUAs

287. 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, an irrigation act was drafted in 2015, which was approved by the then Ministry of Irrigation and was placed before Parliament for its assent. However, due to changed political context (federated structure of governance), this act now needs reformulations and amendment.

The master plan proposes following strategies for enhancing performance of WUA and its subsidiary units:

- Empower WUA (WUG) legally: WUG should be the focal institution for exercising legal authority. For this, WUGs may be registered with the local government for governance support. Accordingly, local government should 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

288. On Farm Water Management (OFWM) refers to management of water within a tertiary command24 with an objective of enhancing its irrigation efficiency therein, and subsequently uplift livelihood of rural community. 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’s interest. Thus, OFWM is shaped by both the collective and individual actions and includes multiple activities.

289. 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) several organizational activities within tertiary command (decision-making, resources mobilization, dispute resolution etc).

290. 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 should 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.

291. 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 should be started with diagnostic

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

assessment[25] 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
- Improve 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
- Improve O&M of tertiary canals and essential infrastructure

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
- Design water distribution schedule and operationalize it within the tertiary command
- Proposal to monitor actual operation of water distribution within tertiary command
- Proposal for maintenance of tertiary canal and resources mobilization

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
- Flow measuring structure at the tertiary inlet where calibration of existing structure is not feasible

3.2.5.4 Improving ISF Collection

292. Table 26 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 26: 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 transferred described through Chapter 8.2 Transparent and well-publicized regime of setting tariffs and charges which are linked to the level of irrigation service Agreed mechanisms, involving WUAs, DoWRI and local government, for monitoring irrigation service performance

25 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.

	Local implementation (of nationally agreed formulas) to ensure local conditions reflected in irrigation fees Ensure equitable water distribution to encourage all WUA members to pay
Lack of legal authorization to WUA for enforcing rules of irrigation management and ISF collection	Register WUAs with local government for governance support Establish bye-laws and other supporting legislation/rules to preserve principles of payment for irrigation service, and support WUAs in institutionalizing irrigation rules and concept of “service – for – fee”
Inadequate capacity of WUAs (or WUGs)	Enhance capacity of WUAs (or WUGs) for 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 should be in place to oblige payments Legal action to collect arrears
Lack of incentive to pay ISF	Increase the incentive to pay by ensuring adequate levels of service provision At the farm level, have clear agreement about the set of exceptional circumstances under which ISF may be waved or reduced
Current system of fee collection involves high cost and low collection efficiency	Involve WUAs, with local knowledge and presence, 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

293. 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%.

294. 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 to procure a couple of laser land leveller by the government 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 set of guidelines to be developed in coming days.

295. Farmers commonly own two, there or more adjoining plots, but not at same levels. In such a situation, as in the case of laser land levelling, adequate support needs to be provided to individual farmers at subsidized rate for consolidating their lands into one larger plot for enabling them using farm machinery for efficient uses of water. This activity also helps in increasing overall agricultural production. As in the case of land levelling, certain level of subsidy needs to be provided for land consolidation

3.2.7 Infrastructure support for water augmentation

296. 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 this gap that benefit to individual farmers. Certain subsidy mechanism needs to be established for their utilization at larger scale. Some such technologies to be supported under IMP are:

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

3.2.8 Maintenance of major hydraulic structures

297. Irrigation infrastructure like barrage, major weirs, tunnels, pump house, big siphons etc will be categorized as major hydraulic structures and their maintenance will be planned separately. Technically, these are complicated structure and thorough understanding of their hydraulics is essential for their maintenance. As a result, their maintenance requires 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 maintenance26 in coordination with the project office, and document success and failure stories of maintenance. The concerned project office will however undertake their regular maintenance27 following the guidelines provided by the major hydraulic maintenance unit at federal level.

298. 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

299. 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 following a systematic maintenance planning process. Paragraph below presents its concept.

300. Maintenance planning (or asset management plan): Maintenance planning is a process that starts from defect identification to pre-maintenance task. In recent year, aspects related maintenance

26 By definition, periodic maintenance works are those works which are not required to be done regularly, but needs to be undertaken in a cyclic manner in an estimated schedule. Periodic maintenance encompasses those large and medium repair works that requires greater resources. Thus, this type of works usually requires detail planning, engineering design, drawings, detail cost estimates, and close supervision of maintenance execution. Some of the periodic maintenance works are: major repair of structures; replacement and addition of structures; replacement of steel gate plates, spindle, and bushes.

27 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 of the maintenance activities, since small repairs identified and carried out at early stages would prevent occurrence of major problems.

planning of an irrigation system has grown into a thematic area of “asset management plan28 (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.
- To minimize deterioration of structures, canals, and their movable mechanical parts to the extent that they last for their economic life.

Table 25: 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, higher should be the maintenance priority. The higher the probability of structural failure due to lack of maintenance, the higher should 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
Maintenance execution	Carrying out the maintenance / modernization activities
M&E and technical audit	This is an important task. Maintenance categorization, prioritization, and budgeting will be monitored and evaluated; Likewise, their technical audit will be conducted following a procedures to be developed by DoWRI

301. 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

28 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

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 established and made mandatory.

3.2.10 River Basin Planning

302. Irrigation should be planned, operated and managed in a river basin context – that is, one that considers the hydrological boundaries as the most appropriate planning unit. 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.

303. It is important to note that modern strategic river-basin planning needs to address increasingly complex water challenges, which nowadays also include climate change adaptation and disaster risk management. Hence, river basin plans need to recognize national water resource policies and, at the same time, inform and incorporate local and state/provincial plans and policies to the possible extent. Furthermore, river basin planning takes place in the context of a range of broader socio-economic and environmental planning processes and therefore needs to consider them, in addition to the technical aspects of water planning.

304. Since Nepal has been undergoing a phase of economic development, a substantial number of water resources projects are being planned, constructed and executed. Unfortunately, it continues to take a conventional sectoral project-by-project approach to development, which has limitations and deficiencies. With a river basin approach, many sectors/ sub-sectors like hydrology, climate, ecosystem, floods and droughts, erosion and sedimentation, hydropower production, irrigation, and upstream and downstream linkages, among others, can be considered in their totality.

305. As the GoN explicitly states in its existing policies proper harnessing of available water resources through a river basin planning and management approach could increase agricultural and hydropower productivity and improve the economic status of the country. For such an approach to work, there is a need for 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 understood. If the basin's future state can be projected to a reasonable degree of confidence, the drivers of such changes can be identified and manipulated to bring about positive changes in the present development process.

3.2.11 Capacity Development

306. The need for capacity development in the irrigation sector does not need over-emphasis. There is a general consensus among policy-makers in the developing world and aid agencies that a lack of required institutional capacity is constraining the development and improvement of irrigated agriculture as a means of alleviating poverty, increasing food security and improving livelihoods among both rural and urban populations. The need for capacity development in the irrigation sector is particularly obvious where irrigation management is transferred (IMT) to the users. Without due consideration to raising the required capacity, the transfer will be a major threat to its success with the desired reform. However, IMT should not mean an abandonment of the irrigation sector by government, but the creation of a "new partnership" between farmers, government and the private sector in the regulation, provision, financing and utilization of irrigation services. Building the capacity of the central (MoEWRI, WECS and DoWRI), the state governments, local municipalities and WUAs and possibly also farmer cooperatives (FCs) through on-the job training and formal training package on irrigation service development and management will be absolutely crucial to ensure the sustainability of the investments made under this master plan. At the WUA level, capacity development should connote that the WUAs are capable of managing irrigation infrastructure under their responsibility technically, financially and institutionally.

307. The main purpose of capacity development as suggested under this IMP is to build capacity for irrigation development and management and ensure the sustainability of its management and operation. This should represent a more holistic approach to the sector, which will result in irrigation services being more sustainable and cost-efficient. The focus has to be shifted towards such capacity development which involves more than enhancing the knowledge and skills of individuals and also focuses crucially on the quality of organizations - meaning that operations of particular organizations are influenced by the enabling environment, the power structure, relationship management and the institutions in which they are embedded. It is important to acknowledge that capacity development efforts generally have four main problematic areas: most capacity development support remains fragmented and not harmonized; sector-specific capacity development strategies need strengthening; tools and instruments are not effectively and fully utilized, and quality assurance is inadequate.

308. Accordingly, future capacity development initiatives must incorporate those concepts and approaches that are pursued by the IMP, including: (i) development of implementation capacities for irrigation infrastructure at the most appropriate level; (ii) education and training on MOM of irrigation infrastructures; (iii) disaster risk management (planning, response, and recovery) to better prepare for and react to such climate change impacts; (iv) mainstreaming of climate change directly into irrigation development initiatives; and (v) consolidate the irrigation results by empowering users through training on business literacy, entrepreneurship and enterprise creation and possible formation of farmers' cooperative to enhance their profit from irrigated agriculture.

309. This implies that future capacity-building initiatives under IMP should focus on MoEWRI and DoWRI at federal level, MoPID at state level, local governments and WUAs at local level. These should also include other sectoral agencies related agriculture, environment, forestry, and watershed and soil conservation at national, state and local level.

3.2.11.1 Federal level

310. There is a significant challenge to synchronize the river basin planning and management concepts with the newly-implemented federated administrative arrangements. WECS, as the lead agency for IWRM and river basin planning and management in Nepal, has an important role to play in bringing all concerned units of the three tiers of government to accept the basic principles of integrated approach to water resource sector development and to have RBOs in place as initial step in this direction. It is most probable that WECS goes through a complete restructuring, with increased number of specialists and regrouping of its divisions and sections. The capacity development of WECS and other relevant agencies should include: (i) sector-wide capacity building in river basin planning and management in line with IWRM principles; (ii) designing and implementing social, environmental and safeguards; (iii) understanding and responding to the impacts of climate change and disaster risk management; (iv) driving policy reforms to implement river basin plans; and (v) compiling and maintaining a comprehensive database with a wide range of relevant data at state level.

3.2.11.2 Provincial level

311. The provinces are likely to take a some time to gain expertise in (i) river basin planning based on the IWRM principles; (ii) social, environmental and safeguard management; (iii) responding to the impacts of climate change and disaster risk management. This knowledge is essential for cohesion and harmonization with river basin approach and overall national water resource planning and development process.

312. Two provinces sharing a given river basin need both to have a full understanding of the benefits of shared planning and management of the water within a given basin and harmful effects in the absence of such understanding and excessive competition for the use of water. It becomes the responsibility of the provincial government to ensure that human resources having such understanding and competencies are available.

313. Since the investments made in irrigation infrastructures by the GoN so far focused primarily on cost planning and construction with limited or no consideration to maintenance need and replacement requirement, there is a capacity decline of a system to deliver water, requiring huge cost for major repair and total replacement. Capacity at provincial level needs to be build-up for improvement of the management of irrigation systems in terms of efficient and effective water delivery service through improvements in both infrastructure and operational aspects and farm production and returns. State ministry needs to have an assessment of required HR competencies in line with its set priority of programs and projects. Some of the critical technical skills which may be required on an intermittent basis need to be availed from the central agencies on deputation basis, without having a permanent cadre at state level.

314. The provincial level Ministry of Physical Infrastructure Development is yet to have meaningful functional linkages with central agencies like MoEWRI, DoWRI and WECS. The proposed RBOs under WECS need to play a technical back-up role for the concerned State ministry for having something like 'regional water plan' by providing necessary data and knowledge related to a particular river basin.

3.2.11.3 Local government level

315. As observed during the field visit, there is a substantial void of capacities at local levels to plan and perform their defined roles and responsibilities relating to services from systems. Since the deputed staff in the local governments (LGs) need to cover several technical areas (roads, water supply, agriculture, irrigation, etc.), it is difficult to expect irrigation related in-depth knowledge and skill on their part. For planning and financing of irrigation within boundaries of local municipality the LG staff should possess the ability to: (i) oversee the management of existing systems; (ii) plan for effective and efficient rehabilitation, expansion and implementation of new systems; and (iii) more importantly, ensure sustainability through efficient and effective cost recovery for management, operation and maintenance.

316. Basically, staffs at municipality level need to have the capacity to facilitate and mobilize farmers at distribution canal level. They need to have proper oversight of irrigation systems ensuring efficiency and effectiveness in water delivery within their boundaries and, if need be, train staff and members of WUAs in different technical and managerial aspect of system O&M. They also need to be able to assist to prepare action plans of WUAs for equitable distribution of water and proper maintenance of channels, with minimum irrigation service fees.

317. LGs needs to play an important role to encourage and facilitate private sector service providers to acquire necessary knowledge and skills required for O&M of irrigation systems and increase in farmers' production and returns from irrigated agriculture. The increased demand for such services from farmers can encourage them to remain in these professions profitably.

3.2.11.4 WUA Level

318. It is essential that WUAs/WUGs are trained 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. One of the weakest parts in the O&M of farmer-managed irrigation systems and agency- managed irrigation systems in Nepal is the lack of effective irrigation asset management planning, resulting in a cycle of neglect of proper O&M and consequently, replacement at a high cost.

319. Disputes in irrigation systems in Nepal generally arise due to water use activities, resource mobilization and the dominance of influential members over economically and socially disadvantaged members. Other major causes of disputes include the shifting of an upstream intake closer to a

downstream one, claiming the share of water, allowing water leakages from a diversion weir of an upstream system and also some users' reluctance to participate in maintenance and repair works, together with some member defaulting on the irrigation service fee payments. Of late, over politicization of WUA/WUG members due to their over enthusiastic affiliation with respective political parties is posing a major threat to the very existence of association itself and is becoming a major source of disputes. These are areas where conflict management capacity of WUAs/WUGS needs to be significantly improved.

320. Taking cognizance of fact that prevailing practices on financial management at WUA level is poor, the key members and staffs of WUG/WUA also need comprehensive trainings, including ToT, on basic bookkeeping, basic financial management measures, planning and budgeting for small specific projects, internal control, audit requirement, etc.

321. A supportive policy and legal environment is crucial to the sustainability of WUAs. Government's policies for administrative and financial decentralization have provided the impetus for many management transfer programmes which diminish the role of the state and expand the role of WUAs, but these policies remain to be well reflected in the policies and laws to be developed by governments at state and local levels too.

3.2.12 Prioritized Research and Development Areas

322. Research and development, including technology adaptation, should form an integral part of IMP. This needs to be a prime function of federal government, i.e., MoEWRI, DoWRI and other think tank institutes like WECS. This enables to design and revise policy, legal and organizational framework, along with suitable standards for designing, constructing, operating and maintaining irrigation projects, which can be equally worth considering at state and local levels. The knowledge created through research will also need to be fed to capacity-building initiatives to be taken at all levels of the government.

323. The following are considered the four priority areas for research for improving irrigation and agriculture practices in line with the demands of integrated water resource management, agricultural development strategy and climate change adaptation. Each of these priority areas consists of a number of sub-themes and problems or issues that are worth examining.

<u>Irrigation and agriculture practices</u>

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, as is well recognized and established in many other countries. This has become more pertinent in the context of federal mode of governance. A pilot intervention in a system with close integration of all above sectors together and obtaining better result will establish a basis for this to be replicated and up- scaled in similar settings in future.

Index-based crop insurance coverage: Crop failure has become one of the prominent socio-economic and political problems in developing economies like Nepal, which is often attributed to man-made and natural disasters, exacerbated by climate change impacts. More frequently than ever, farmers from many parts of the country are made to suffer due to these reasons, resulting in their inability to pay back loans and falling into "debt trap" over the years. A study can look into the possibility of institutionalizing a mechanism by which the financing and administration of this insurance scheme can be tested in some selected places.

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 appropriate fertilizer, improved seeds and other agricultural inputs are essential. The testing of soils and recommending specific crop/seed, fertilizer and proper mix are not common in most of the irrigated agriculture areas in Nepal. Experimental research on such an issue is necessary at various levels to articulate appropriate policies and encourage farmers to derive better income from their irrigated agriculture.

Management of Irrigation

Pilot on functional "tar" irrigation system to benefit upland areas. 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. Provision of irrigation water in these pocket areas in hills can substantially improve food security situation and enhance the socio-economic status of farmers in these areas. There could be some piloting exercise for improving water efficiency and having better agricultural practices. These, if proved successful, could be taken as role model for other existing "tar" irrigation system for replication and also for new projects of similar nature to come in future.

Quality assurance and harmonization of irrigation system development and MOM: Quality assurance in development and/or during construction of irrigation schemes is probably the weakest part in the management of the entire project cycle in Nepal, in addition to inappropriate design in some cases. The experiences show that a user group's involvement from the early stage of the project cycle tends to help mitigate some of these shortcomings. Establishment of community-based QA teams can also be experimented in different settings.

Irrigation service fee system in irrigation 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 and it is even not sufficient for funding regular MOM of the system in most cases. As the fiscal situation of governments (at all levels) is getting tighter, the use of the taxpayers' money for subsidizing irrigation will become harder to justify. For the sustainability of irrigation services, irrigation service fees need to be reviewed periodically and properly applied, potentially with development of a model irrigation service fee system.

Practical modality of sustainable MOM of irrigation systems: Most of the irrigation systems in Nepal are built by the government through funds mobilized internally or through external sources, and most often MOM is being carried out and paid for by the government. It is true even in the case of some transferred systems. Piloting of a successfully sustaining MOM and possible full ownership of assets will pave the way to replicate it in an extended manner and relieve the financial burden of governments at each level.

Exploring potential for private sector participation: As the governments are increasingly seeking to address the complex issue of targeting investments and improving irrigation services for agriculture to achieve growth and rural development, it is necessary to attract private sector participation in irrigation sector by combining public and private sector expertise in order to improve sector management and delivery of required irrigation services. Experimental research on certain PPP-based irrigation projects can be value-adding exercises.

Social development in irrigation

Effective participation of women and other disadvantaged users in MOM: The social status of women and disadvantaged segments of population still needs a lot of positive discriminatory actions to improve the situation to a desired level. Intending 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 work in this area will help generate new knowledge and validate the existing one which can be fed to the future policy reform initiatives at all levels.

Maximization of returns from irrigated agriculture: For the irrigation sector to contribute towards improved livelihoods and overall socio-economic development in Nepal, the farmers and other water users need to enhance the income levels from irrigated agriculture. It will also enhance the possibility of farmers bearing the responsibility of financing O&M of irrigation systems to a larger extent. Transforming WUAs to water user cooperatives may help farmers to explore various ways for improving agricultural practices through crop diversification, cropping intensity, better seeds and fertilizers, better harvesting, storage techniques and swift 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

Rejuvenating irrigation: Nepal's irrigation sector does not seem to have changed its basic 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, whether this is financially sound/viable or not. It is felt that it is not too late to re-think this general approach and consider possible other and smarter options, in line with the concept of river basin planning with much broader participation of all stakeholders in planning and decision process. Research on different possible modes of irrigation is needed that can help change the stereotyped approach of policy makers as well as irrigation practices in Nepal.

Healthy watersheds: In Nepal, as in most countries, watersheds are being threatened by haphazard urbanization of settlement, unplanned set-up of industrial and processing activities, deforestation and through other issues emanating from climate change. At present, the development of irrigation systems and its interaction with watershed management is rather weak. It is time to develop some pilot projects where these two interdependent sectors are closely interlinked and good results of which could be replicated in other existing and future water resource projects in general, and irrigation projects in particular.

Mainstreaming climate change adaptation in irrigation planning and management: The rapidly retreating glaciers, rapid rise in temperature, erratic rainfalls and increase in incidence 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. Nepal must prepare itself 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 as a priority through undertaking various research studies.

Sustainable storage development in the Greater Himalayan Region: It is possible to utilise the potential of water storage capacity in the Greater Himalayan region for adaptation to climate change. It may be possible to harness the natural systems in the biosphere through initiatives such as wetlands conservation and improved watershed management in the hills and mountains, as well as groundwater aquifer recharge in the foothills. Small ponds and tanks for rainwater harvesting could also be built on hill farms and around hill communities. The construction of large dammed reservoirs on the downstream plains is a further option and has been carefully considered in this Irrigation Master Plan. The knowledge gap concerning such sustainable water storage will have to be addressed through fresh research studies.

Water needs to protect the environment and bio-diversity: Water erosion and silting have a major impact in the river basin, not only for downstream flows and the maintenance of biological balances and natural ecosystems, but also for 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 certain research studies.

3.3 Sub-national Plans

324. Each province expressed the desire to have their own irrigation master plan. This is very understandable since each province is now responsible for their development. Subsequently, the project has been extended to allow the preparation of independent provincial master plans, cutting up the relevant information by province, and presenting this to each province. This is one major step in getting the plan out to the provinces, and allowing them to have a say in their development.

3.4 Consultation and Conflict Resolution

325. As the implementation progresses there is a need to deepen the interaction between provinces, particularly when inter—boundary transfer or projects are concerned. Provinces that are a source of water or hydro-power will want a share of the benefits when irrigation projects benefit from these and the source province does not. This is the case in the Sunkoshi-Marin diversion project, from province 3 to province 2. Also the case for the Kaligandaki-Tinau diversion, from province 4 to province 5, and to some extent province 6 to province 7 for Karnali diversion. These type of inter-province interactions will have to be solved in the coming years as the federal system evolves.

4. Section IV: Financing Irrigation Master Plan 2019

4.1 Prioritised Large-scale Projects

326. Based on economic analysis and ranking of all projects, 7 large-scale projects (6 MPPs and 1 Barrage Project) have been identified for financing priority. The implementation plan lays out the timeline for the roll-out of these projects.

327. The ongoing project of Bheri-Babai will continue until 2024. The Sunkoshi MPP involving the Sunkoshi 3 hydropower storage dam with 2 transfer tunnels, to Marin and Kamala is the next priority project. 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.

Table 27: Major Prioritized Projects

SN	No.	Project Name	Total hydro, 2018 Financial cost (NPR m)	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	104.10
2	E4	Sunkoshi Marin & Sunkoshi Kamala with Sunkoshi 3 Dam,	154,172	58,114	212,285	310,574	2,677	352,264	19.94	12.52	32.46	16	519.37
3	C2	Kaligandaki-Tinau transfer for full irrigation in Rupandehi Andhi Kkhola Dam, MPP	125,460	8,109	133,569	195,411	1,685	41,953	16.22	1.75	17.97	1	17.97
4	W6	Naumure Dam, Rapti Kapilbastu Diversion, MPP	130,647	9,046	139,694	204,372	1,762	51,256	16.89	1.95	18.84	10	188.44
5	W4	Karnali Transfer to Kailali Irrigation, MPP	37,726	9,818	47,545	69,558	600	40,628	4.88	2.12	6.99	9	62.95
6	W2	Bheri-Babai Transfer + Nalsingad Dam, MPP	27,623	9,721	37,344	54,634	471	45,111	3.57	2.10	5.67	21	119.01
7	E8	Chatara Barrage	7,861	12,805	20,666	30,234	261	66,482		2.76	2.76	15	41.40
		Total cost	**647,585**	**129,906**	**777,492**	**1,137,470**	**9,806**	**711,437**					**1,053.22**

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 of 341,389 ha
4. W2 Bheri-Babai will develop 51,000 ha, which includes about 10,000 ha from Sikta IP.

328. The schedule of implementation is itemised below:

Sunkoshi MPP	2020-2030
Bheri-Babai MPP	2019-2024
Chatara Barrage	2024-2029
Naumure Dam MPP	2027-2034
Karnali Transfer MPP	2029-2036
Tamor Morang MPP	2033-2040
Kaligandaki Tinau MPP	2037-2043

329. The total capital investment for these major priority projects is $9,806 million over the 25-year period.

4.2 Groundwater Projects

330. 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	2020-2023
Jhapa-(Morang)	2021-2024, and 2029-2033
Parsa-Chitwan	2023-2026
Dang	2032-2035

331. Those supplementing MPP projects are:

Kapilbastu, Nawalparasi,	2024-2028
Sunsari, Mahottari, Dhanusha, Siraha, Bara	2022-2033
Nawalparasi	2028-2033
Banke, Kailali	2031-2034

332. The total capital for a total of 358,000 ha of groundwater projects is $997 million over 25 years.

4.3 Hills and Mountain Projects

333. 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.

334. 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 pumping were identified during this process. Finally, in Category 2, are the remaining classified pumping suitability is left for future verification and design. The area to identify is 454,500 ha.

Table 28: Capital Costs of Hills and Mountains Category Projects

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

335. The total cost of this program is $1,583.1 million over the 25-year period.

4.4 Irrigation Management, Modernisation, and Rehabilitation

336. The DoWRI has two projects which can be either merged of rebranded under an umbrella of Modernisation, Rehabilitation and MOM. These are CMIASP-AF and IWRMP. The rebranding would be the inclusion of IMT, combined with ISF collection. The irrigation management transfer has basically been a failure because the farmers have no confidence in the ability to draw water when needed. This is because the management is not sufficiently enhanced to provide the adequate service, and the system is not physically capable of supplying due to poor construction or lack of maintenance. Therefore, the systems firstly need to be modernised or rehabilitated before the next steps can be achieved. While completing this task, managers and farmers need to be trained in operating and maintaining the system at all levels. A key component of this program will be concentration on improving efficiencies, at all levels.

337. The program will continue for the whole 25 years, at an annual cost of $4.5 million with a total of $1,069 million.

4.5 Priority Flood Risk Management Projects

338. Some basins have no physical interventions, like East Rapti, with only installed FFEWS in the basin. These consist of automatic rain gauge with telemetry and discharge measurement stations. Some basins required a reduction of physical interventions to make the project economical. The following table lists the lengths of embankments, revetments and spurs, the costs of physical interventions and the FFEWS. The EIRR is also given.

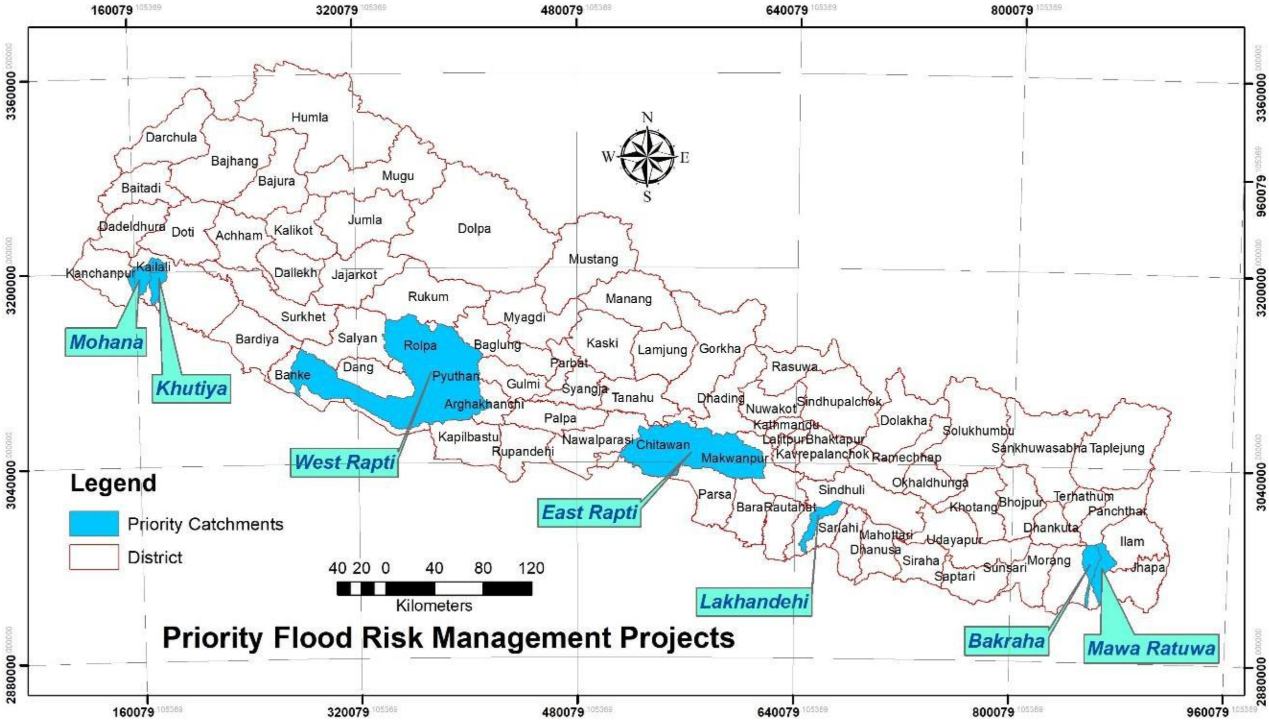
339. The total allocation for this activity is USD 48 million.

Table 29: Details of Priority Flood Risk management Projects

SN	Project Basin	District	Embankment Length	Revetment Length	Spur Number	Physical Works Cost	FFEWS Costs	Total Costs	EIRR
			(m)	(m)	(No.)	US$	US$	US$	%
1	West Rapti	Banke, Dang, Pyuthan, Rolpa, Arghakhaanchi	13,580	13,580	44	15.545	1.2108	16.755	10.8
2	Mawa Ratuwa	Jhapp, Ilam	11,985	13,315	213	10.198	1.619	11.817	16.2
3	Larhadehi	Sirlahi	1,600	2,760	27	1.147	1.267	2.414	11.1
4	Bakraha	Morang	4,365	4,365	42	3.603	1.066	4.669	9.9
5	East Rapti	Chitawan, Makawanpur	-	-	0	0.000	1.367	1.367	
6	Mohaha and Khutiya	Kailali	13,530	12,650	177	8.744	2.188	10.932	19.9
		Project total	**45,060**	**46,670**	**503**	**39.237**	**8.718**	**48**	

Source: Project Feasibility Reports, 12 July 2019 Mott MacDonald

Figure 8: Location of Priority Flood Risk Management Projects



Source: Project Feasibility Reports, 12 July 2019 Mott MacDonald

4.6 IMP Implementation Plan and Costs

340. The investment framework cost is shown in Figure 11. The total outlay is USD 14,447 million. There are three peaks of investment: 2024 for USD 830.4 million, in 2037 for USD 691.4 million and 2039 for USD 727.7 million.

341. Not included in this framework is the annual MOM costs of each project once they become operational. However, the rate, years of operation, and cost of each major priority project is given Table.

342. To assist in the implementation of this plan, dissemination is required to all provinces. Previously, all provinces were visited and consulted, and all requested their own plan. This IMP is being split into each proving component according the 4 categories mentioned above.

343. Also, as part of the implementation must be a M&E program to keep track of progress, review status and success of each program and recommend the way forward based on lessons learnt.

4.7 Targets for Year-Round Irrigation

344. There are two main national policies that are important to the IMP, which is the ADS (2015) and the NWP (2005), both of which have given targets for water use, productivity, cropping intensities and year-round irrigation. The IMP has considered these targets with a view to meeting them and incorporating them into the plan, and also to be an essential part of the M&E plan.

345. 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 proposed to increase from the present of 132% to 182% by 2025, 205% in 2030 and finally reach 230% in 2045. The NWP target for CI is 193% in 2027, which fits between the IMP proposed targets.

346. Year round (YR) irrigation is one of the main thrust 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 55% by 2025, 66% by 2030 and 100% by 2045.

Table 30: National Policy Targets

Policy Target	ADS 2015		NWP 2005		IMP-2018	
	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%

347. The proposed program for the MPP, groundwater and hills and mountain developments is given in Figure 10. 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 9, and shows that by the end of the project, 2045, 100 % YR irrigation will be achieved in the Terai and 74% in hills and mountains. By the short term, 2025, YR will have reached 56%, by medium term 2030 the percentage will be 80 %. The above targets can be achieved if the plan is followed.

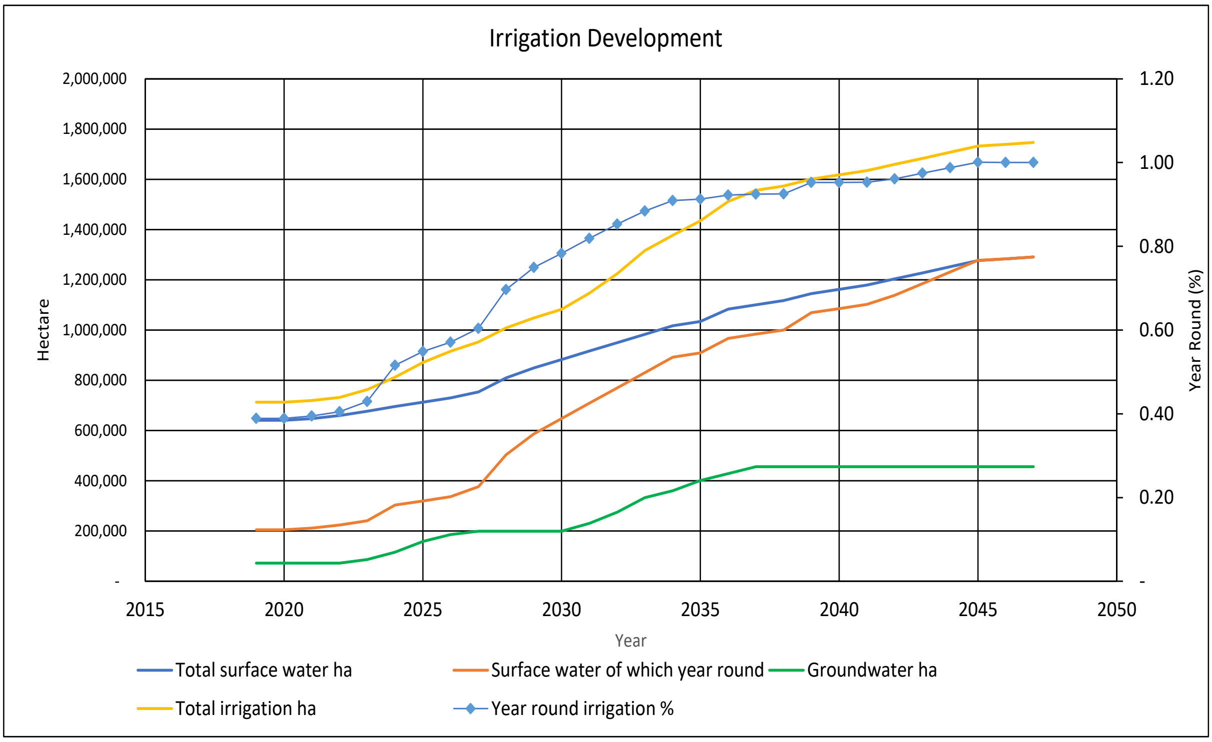


Figure 9: Irrigation Development Progress in IMP-2018

4.8 Private Sector Participation and PPP Options

348. Government of Nepal has enacted PPP Act 2019 to provide a framework of PPP in infrastructure structure 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. However, there might be substantial legal challenges to be overcome, when project initiatives are taken.

349. 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 (details in Annex E).[29] 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 often brings certainty to the stable demand for irrigation services.

350. Various types or categories 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 financing of some large, medium and special types of project is to involve a mix of funding through government, donor, NGO, cooperatives and farmers and hence is open up for adopting some 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 31.

Table 31: PPP options for the irrigation schemes to be included in the IMP

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

[29] Annex E: Institutions, Policy, Public Private Partnership, River Basin Planning, Financing Irrigation, Capacity Development, Research, Roles and Responsibilities Report

Table 32: Timeframe periods, Development Areas and Costs ($ million)

Scenario	Projects	Short Term 2019-2024 Area (ha)	Short Term 2019-2024 Cost (US$ Mil)	Medium Term 2025-2029 Area (ha)	Medium Term 2025-2029 Cost (US$ Mil)	Long Term 2030-2044 Area (ha)	Long Term 2030-2044 Cost (US$ Mil)
E.6	Tamor Morang with Tamor HPP					114,000	2,350.0
E.4	Sunkoshi Marin and Sunkoshi Kamala with Sunkoshi 3 HPP	170,000	674.0				
E.4	Sunkoshi Marin and Sunkoshi Kamala with Sunkoshi 3 HPP			182,000	2,022.0		
C.2	Kaligandaki Tinau transfer. Rupandehi Irrigation and Andikhola Dam					42,000	1,684.0
W.6	Naumure Dam, Regulation Dam, Rapti Kapilbastu Tunnel, Powerhouse and Irrigation Area					51,000	1,762.0
W.4	Karnali Diversion Tunnel Project					41,000	600.0
W.2	Bheri-Babai transfer and Nalsingad Dam	45,000	471.0				
E.8	Chatara Barrage			66,500	260.0		
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
	Hills Gravity and Pumping - Category #1 and #2	157,000	997.0				

	Hills Gravity and Pumping - Category #3					409,000	1,561.0
	Irrigation management Modernisation and Rehabilitation	152,000	222.7	152,000	222.7	152,000	623.5
	Term Total	**604,000**	**2,613**	**538,500**	**2,848**	**949,000**	**8,986**

Selected Project	Scenario	Project	Score	Economic IRR (re-schedule)	Economic NPV, 9%, NPR m, reschedu	New Irrig Area (ha)	Rehab Irrg Areas (ha)	Total Development	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 Andikhola Dam	88.2	14.0%	85,477		41,953	41,953	6	2037	2043
4	W.6	Naumure Dam, Regulation Dam, Rapti Kapilbastu Tunnel, Powerhouse and Irrigation Area	59.3	11.4%	36,778	10,407	40,849	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, Rupundehi		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	2033
14	7	GroundWater: Jhapa, Phase 2		8.1%	-1,636			35,000	4	2029	2032
15	8	GroundWater: Banke, Kailali		6.7%	-3,001			22,000	3	2031	2034
16	9	GroundWater: Dang		11.3%	2,166			15,000	3	2032	2035
17		Hills Gravity and Pumping Category #1		11.3%	2,166			111,500	7	2020	2026
18		Hills Gravity and Pumping Category #2		11.3%	2,166			454,500	18	2027	2035
19		Irrigation management Modernisation and Rehabilitation		11.3%	2,166			511,500	25	2020	2045

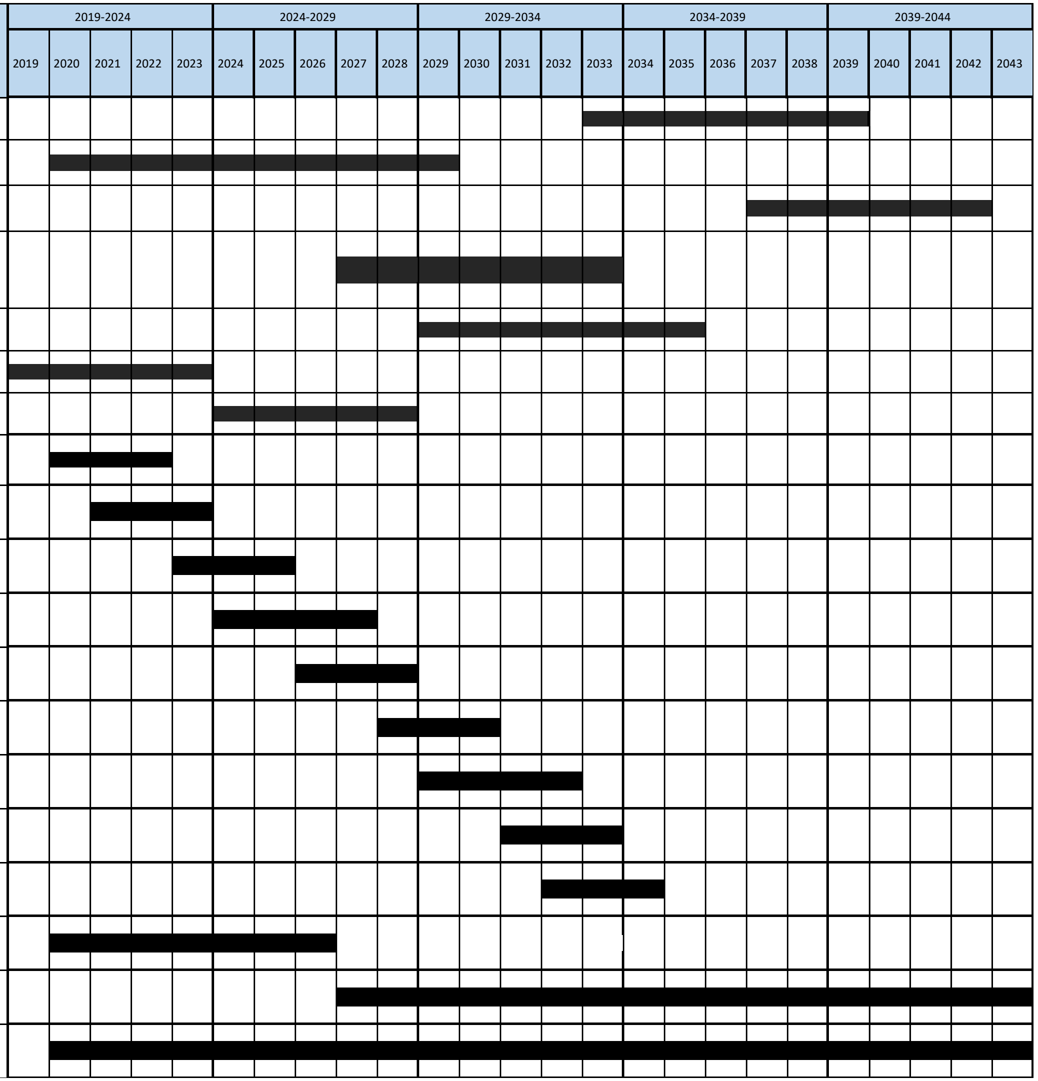
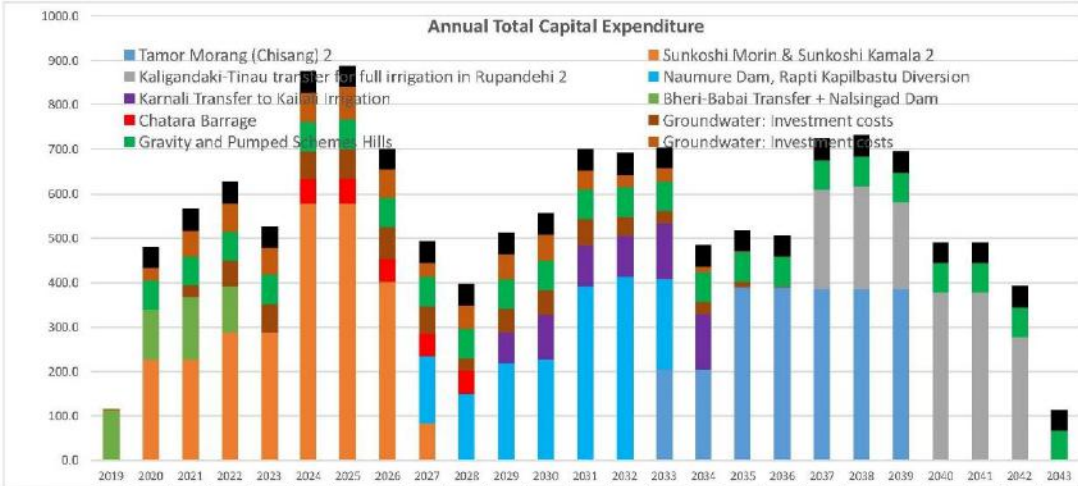


Figure 10: Proposed Implementation Plan



MPP and Koshi Barrage: Investment and Operating Costs, USD m current 2018 prices	Total Cost $ m		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	2,350.75																	203.8	203.8	391.7	391.7	386.6	386.6	386.6				
Sunkoshi Morin & Sunkoshi Kamala 2	2,677.36				227.0	227.0	288.2	288.2	579.1	579.1	404.3	84.4																
Kaligandaki-Tinau transfer for full irrigation in Rupandehi 2	1,684.58																					224.0	231.5	195.4	377.2	377.2	279.2	
Naumure Dam, Rapti Kapilbastu Diversion	1,761.83											151.6	151.6	219.6	227.5	393.3	414.0	204.3										
Karnali Transfer to Kailali Irrigation	599.64													68.6	99.2	90.5	90.5	125.4	125.4									
Bheri-Babai Transfer + Nalsingad Dam	470.98			113.2	113.2	141.0	103.6																					
Chatara Barrage	260.64								56.4	56.4	49.2	49.2	49.2															
NB Construction periods as recommended by Consultant Engineer	9,806	Total		113.2	340.2	368.1	391.8	288.2	635.5	635.5	453.6	285.2	200.8	288.2	326.7	483.8	504.5	533.5	329.2	391.7	391.7	610.6	618.1	582	377.2	377.2	279.2	
					0.147	26.42	57.85	63.49	60.81	66.62	72.16	63.24	29.35	54.19	55.69	59.47	43.58	28.34	29.31	12.61	0.48							

Groundwater: Investment costs		Total Cost $ m	Start	End		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, Sialahi	Package 8	91.0	2020	2023		0.1	26.3	31.6	31.8	1.3																			
Jhapa, Phase 1	Package 9	91.0	2021	2024			0.1	26.3	31.6	31.8	1.3																		
Parsa, Chitwan	Package 10	95.6	2023	2026					0.2	27.6	33.2	33.3	1.3																
Kapilbastu, Rupundehi	Package 11	111.5	2024	2028						0.2	32.2	38.7	38.9	1.6															
Sunsari, Mahottari, Bara, Dhanusha, Siraha	Package 12	79.7	2026	2029								0.1	23.0	27.6	27.8	1.1													
Nawalparasi	Package 13	91.0	2028	2033										0.1	26.3	31.6	31.8	1.3											
Jhapa, Phase 2	Package 14	79.7	2029	2032											0.1	23.0	27.6	27.8	1.1										
Banke, Kailali	Package 15	50.1	2031	2034													0.1	14.5	17.4	17.5	0.7								
Dang	Package 16	34.1	2,032	2,035														0.1	9.9	11.8	11.9	0.5							
Groundwater: Investment costs	Total	724				0.1	26.4	57.9	63.5	60.8	66.6	72.2	63.2	29.3	54.2	55.7	59.5	43.6	28.3	29.3	12.6	0.5							
Gravity and Pumped Schemes Hills	Total	1,583				66.0	66.0	66.0	66.0	66.0	66.0	66.0	66.0	66.0	66.0	66.0	66.0	66.0	66.0	66.0	66.0	66.0	66.0	66.0	66.0	66.0	66.0	66.0	66.0
Irrigation management Modernisation and Rehabilitation	Total	1,138				47.4	47.4	47.4	47.4	47.4	47.4	47.4	47.4	47.4	47.4	47.4	47.4	47.4	47.4	47.4	47.4	47.4	47.4	47.4	47.4	47.4	47.4	47.4	47.4

Figure 11: Investment Costs and Time Frame

5. SECTION V: MONITORING AND EVALUATION PLAN

351. This irrigation master plan covers a 25-year span with multiple national projects costing billions of dollars. In order to maximise the benefits of this plan, a comprehensive M&E plan is required to keep 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 should 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.

352. The existing development projects need to be monitored on an annual basis, and reported in the annual year book. This annual year book is an excellent location for reporting on the master plan implementation progress. There are five transfer projects proposed in the plan, which should be monitored in the three time steps. Ground water development and hills and mountains gravity and pumping schemes should be monitored annually and reported in the year book. In addition, the inventory needs to be updated annually as well.

353. Finally, there are performance indicators such as the following: modernisation area, efficiency, cropping intensity, equity, productivity, crop water productivity and O&M funding should also be reported in the annual year book. All these O&M tasks are shown in Table 6.

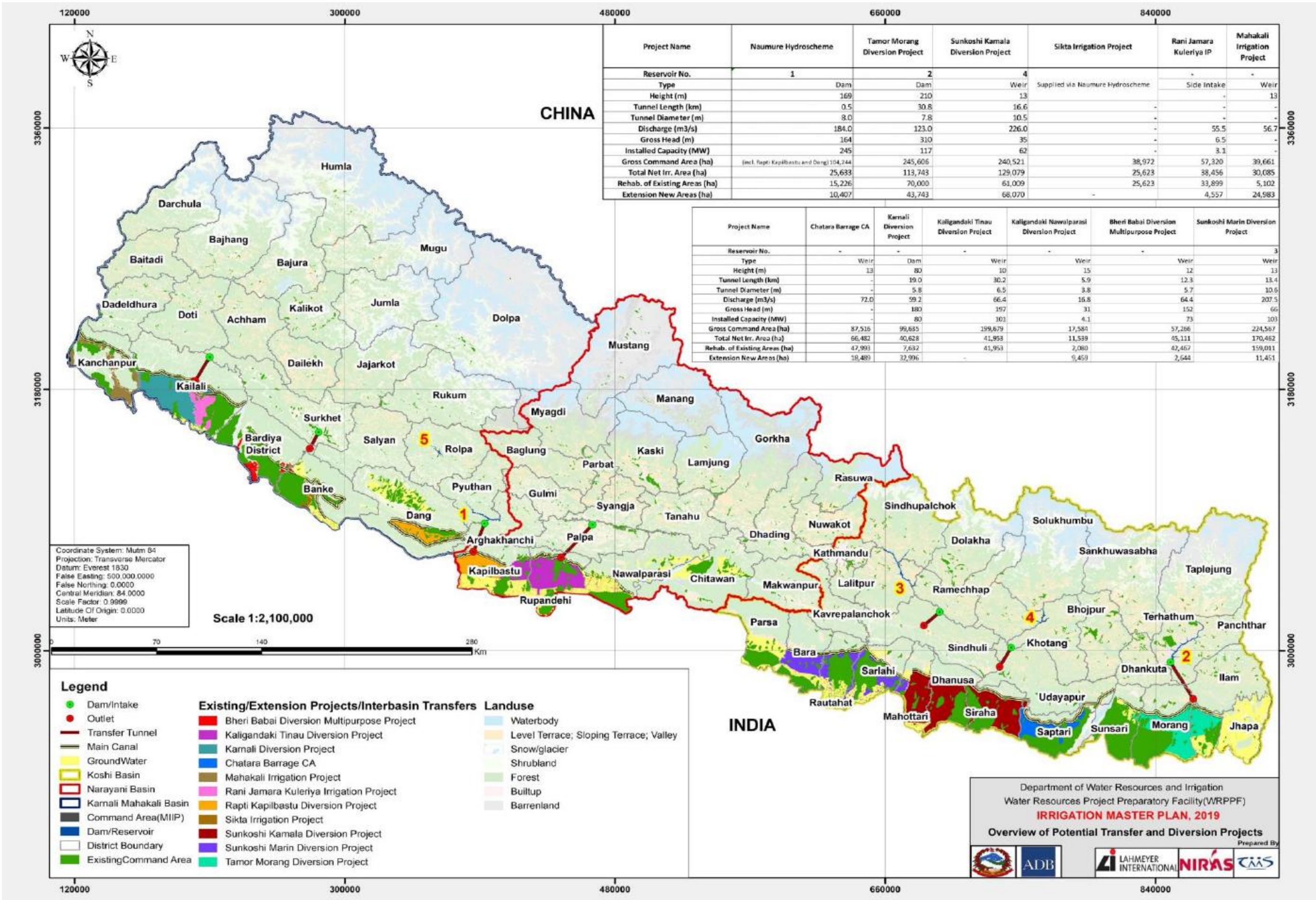
Table 33: Monitoring and Evaluation Plan

2020-2045

Goal	Indicator	Definition How Measured	Current Baseline	Target	Frequency When Measured	Responsible Reporting How?
ADS (2013)	Year Round Irrigation	Percentage	18% (2013)	2018, 2023, 2033 30% 60% 80%		
NWP (2005)			30% (2005)	2007, 2017, 2027 49% 64% 69%		
IMP (2019)			39% (2019)	2025, 2030, 2045 60% 80% 100%	2025, 2030, 2045	Annual year book
Completion of Construction Schemes	Bheri-Babai	Ha constructed	33,000 ha	40,000 constructed	5 years 2025	Annual year book
	Rani Jamara		10,000	30,000 ha	5 years 2025	Annual year book
	Mahakali III		5,000 ha	25,000 ha	5 years 2025	Annual year book
New Scheme Transfer	Sunkoshi Marin	Ha constructed	0	122,000 ha	2020 to 2029	5, 10 and 25 year review
	Naumure Dam, Kapilbastu transfer	Dam, Transfer tunnel, CAD	0	42,000 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	70,000 ha new	2024 to 2028	5, 10 and 25 year review
Groundwater	MIIP Sarlahi and Rautahat	Ha constructed	0	40,000 ha	2020 to 2025	Annual year book
	Other GW schemes	Ha constructed	0	280,000 ha	2020 to 2025	Annual year book
Hills and Mountains Hills and Mountains	Gravity and Pumped, Identified	Ha Constructed	0	160,000 ha	2020 to 2026	Annual year book
	Gravity and Pumped, Classified	Ha Constructed	0	360,000 ha	2027 to 2045	Annual year book
Inventory	Ha irrigated	Ha under YR and MS irrigation	1,454,000 ha	Annual update of surface an GW irrigation	Annual	Annual year book

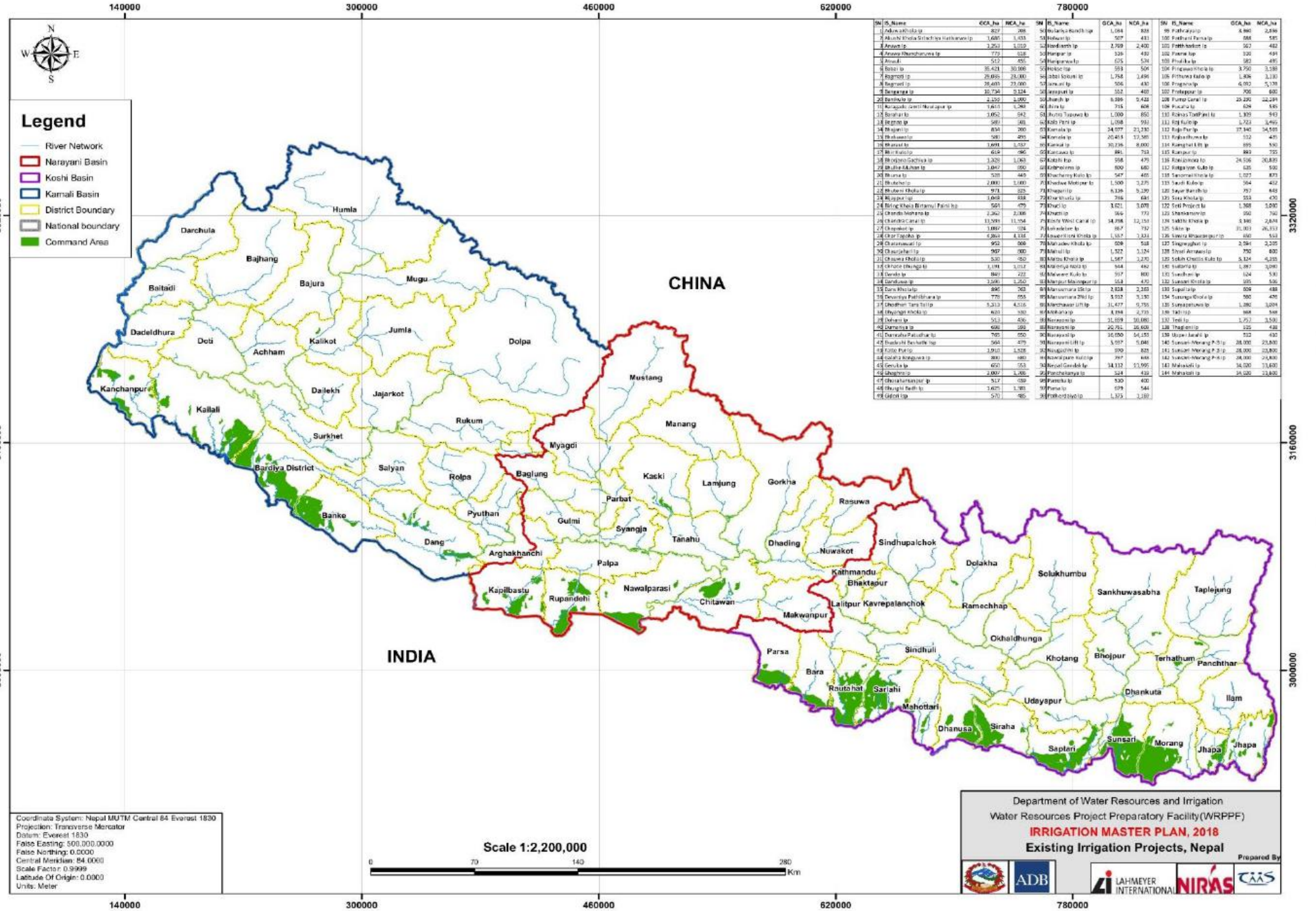
Goal	Indicator	Definition How Measured	Current Baseline	Target	Frequency When Measured	Responsible Reporting How?
Management and Efficiency	Modernisation	Ha modernised	0	Surface 165,000 ha GW 400,000 ha	Annual	Annual year book
	Efficiency	Percentage	About 25%	2025, 2030, 2045 29% 35% 40%	Annual	Annual 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
	Crop Water Productivity	$WP = \frac{Y_c(kg)}{V_a(m^3)}$	Yield kg / water volume m^3		Annual	Annual year book
	O&M fraction	$O\&M = \frac{C_{o\&m}}{I_S}$	Cost of O&M/ Budget for sustainable MOM	80%		

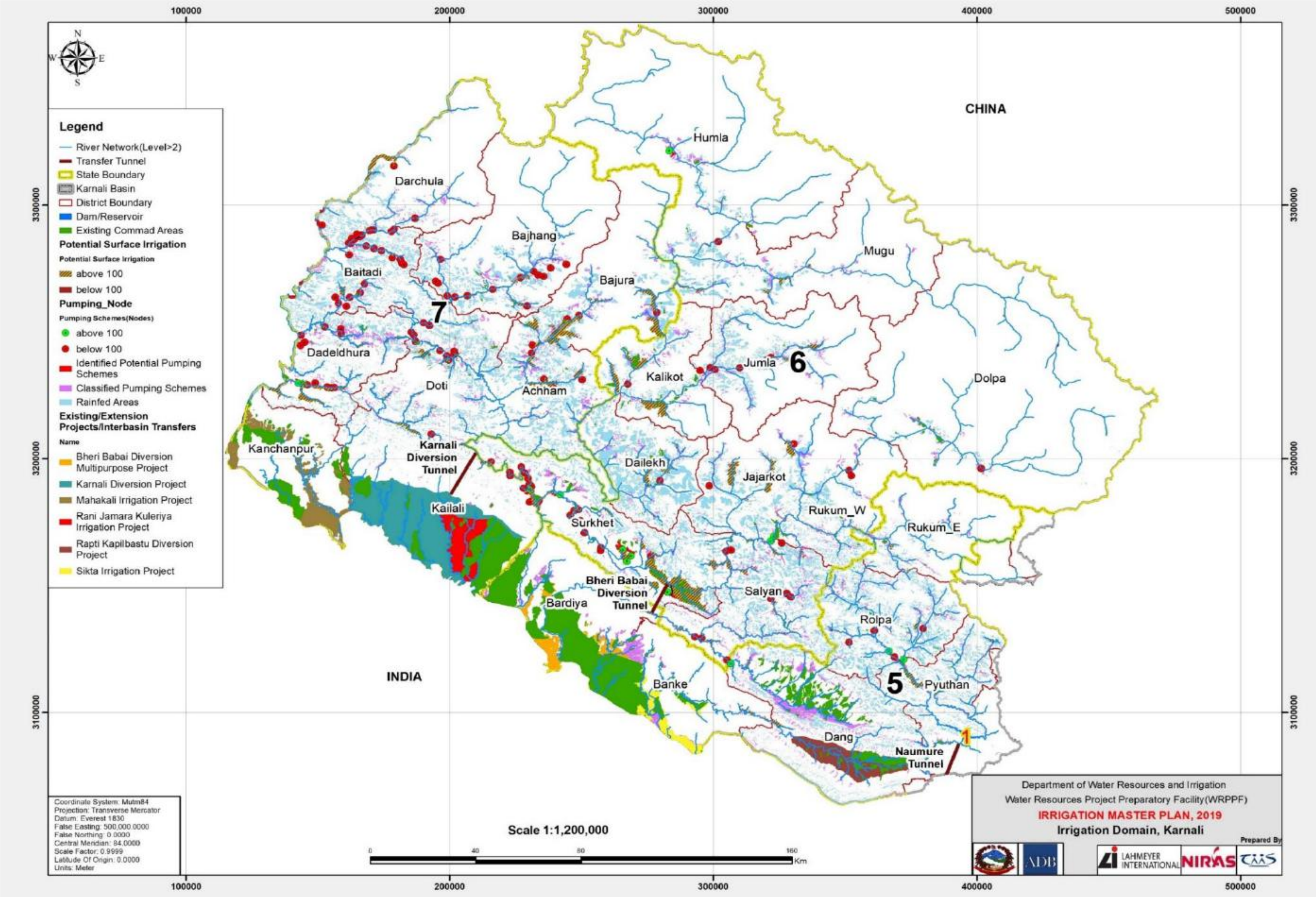
LARGE FORMAT MAPS LIST

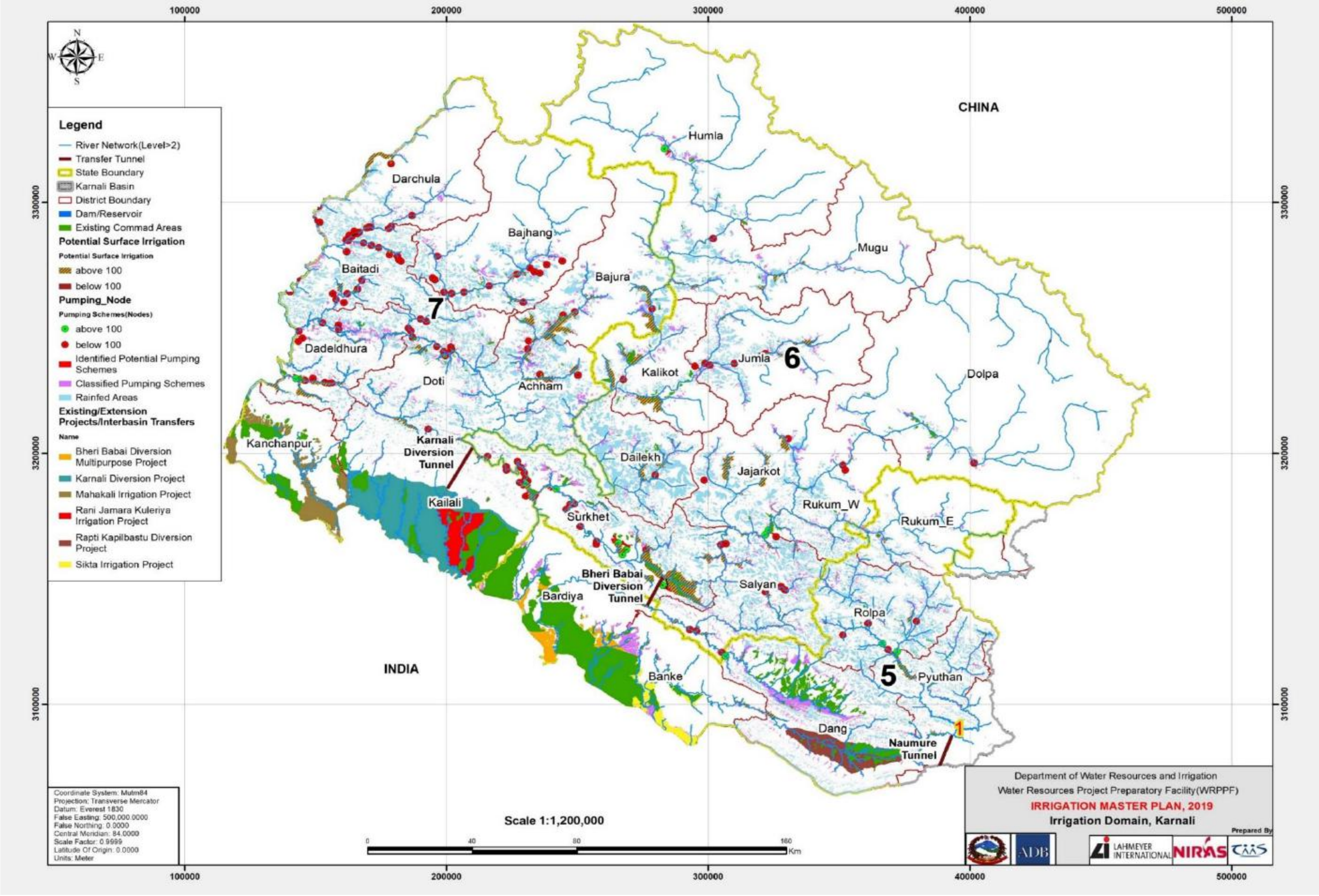


Project Name	Naumure Hydroscheme	Tamor Morang Diversion Project	Sunkoshi Kamala Diversion Project	Sikta Irrigation Project	Rani Jamara Kuleriya IP	Mahakali Irrigation Project
Reservoir No.	1	2	4	Supplied via Naumure Hydroscheme	-	-
Type	Dam	Dam	Weir		Side Intake	Weir
Height (m)	169	210	13		-	13
Tunnel Length (km)	0.5	30.8	16.6	-	-	-
Tunnel Diameter (m)	8.0	7.8	10.5	-	-	-
Discharge (m3/s)	184.0	123.0	226.0	-	55.5	56.7
Gross Head (m)	164	310	35	-	6.5	-
Installed Capacity (MW)	245	117	62	-	3.1	-
Gross Command Area (ha)	(incl. Rapti Kapilbastu and Dang) 104,244	245,606	240,521	38,972	57,320	39,661
Total Net Irr. Area (ha)	25,633	113,743	129,079	25,623	38,456	30,085
Rehab. of Existing Areas (ha)	15,226	70,000	61,009	25,623	33,899	5,102
Extension New Areas (ha)	10,407	43,743	68,070	-	4,557	24,983

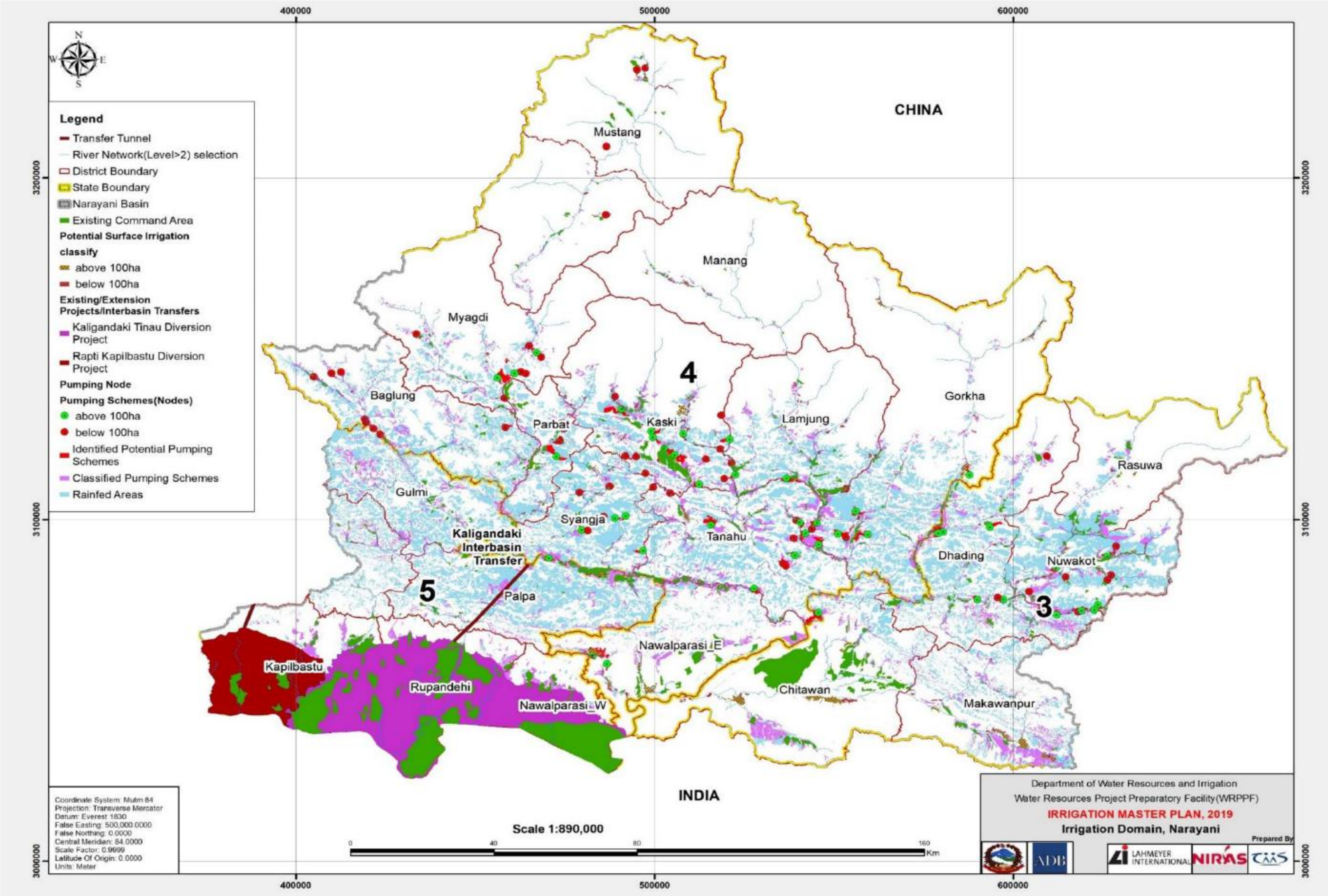
Project Name	Chatara Barrage CA	Karnali Diversion Project	Kaligandaki Tinau Diversion Project	Kaligandaki Nawalparasi Diversion Project	Bheri Babai Diversion Multipurpose Project	Sunkoshi Marin Diversion Project
Reservoir No.	-	-	-	-	-	3
Type	Weir	Dam	Weir	Weir	Weir	Weir
Height (m)	13	80	10	15	12	13
Tunnel Length (km)	-	19.0	30.2	5.9	12.3	13.4
Tunnel Diameter (m)	-	5.8	6.5	3.8	5.7	10.6
Discharge (m3/s)	72.0	59.2	66.4	16.8	64.4	207.5
Gross Head (m)	-	180	197	31	152	66
Installed Capacity (MW)	-	80	101	4.1	73	103
Gross Command Area (ha)	87,516	99,635	199,679	17,584	57,266	224,567
Total Net Irr. Area (ha)	66,482	40,628	41,953	11,539	45,111	170,462
Rehab. of Existing Areas (ha)	47,993	7,632	41,953	2,080	42,467	159,011
Extension New Areas (ha)	18,489	32,996	-	9,459	2,644	11,451

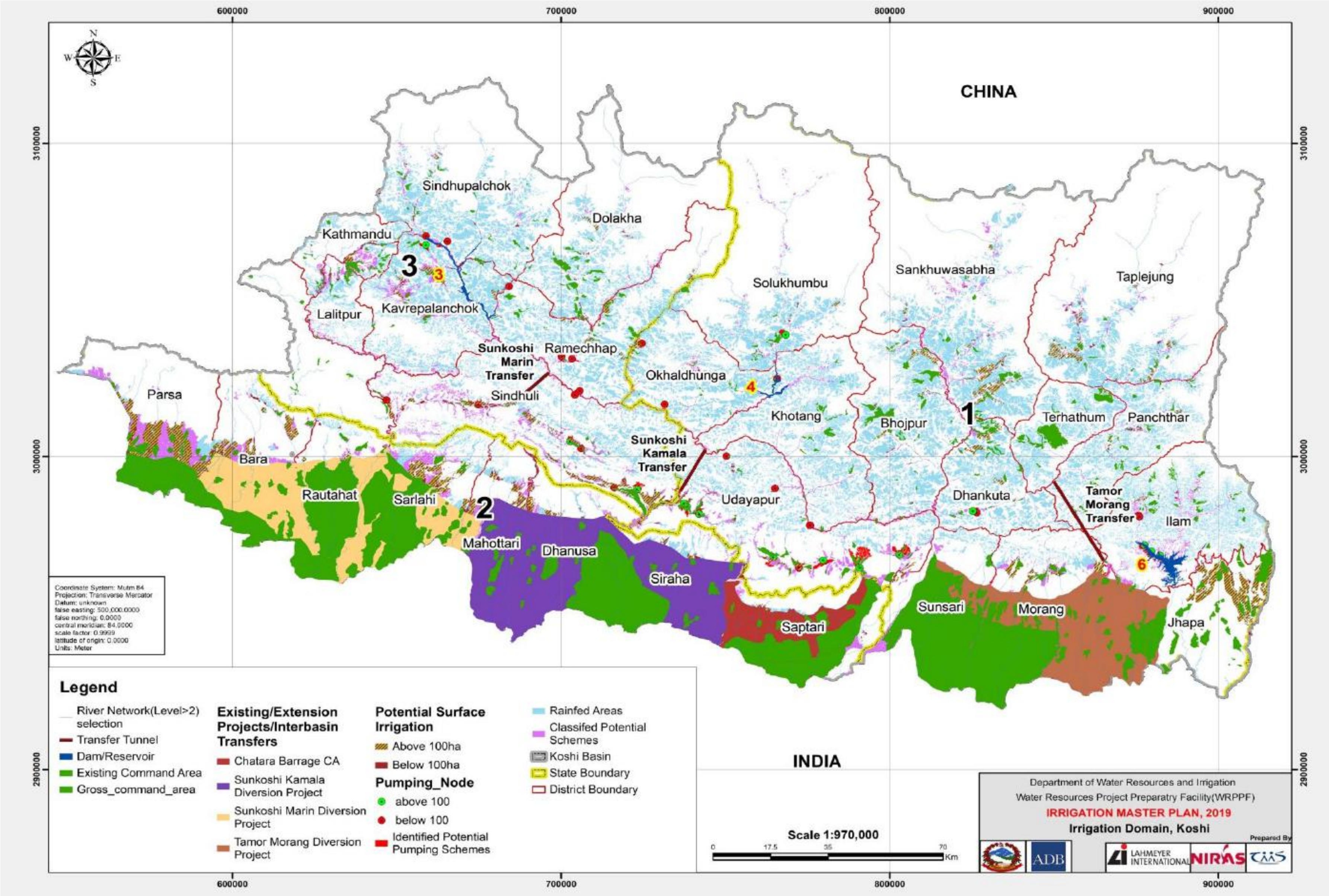

140000
300000
460000
620000
780000
3320000
3160000
3000000
Legend
River Network
Narayani Basin
Koshi Basin
Karnali Basin
District Boundary
National boundary
Command Area
CHINA
INDIA
Humla
Darchula
Bajhang
Mugu
Bajura
Baitadi
Dadeldhura
Doti
Achham
Kalikot
Jumla
Dolpa
Kanchanpur
Kailali
Dailekh
Jajarkot
Mustang
Manang
Rukum
Surkhet
Bardiya District
Salyan
Myagdi
Rolpa
Baglung
Kaski
Lamjung
Gorkha
Rasuwa
Banke
Pyuthan
Parbat
Gulmi
Syangja
Tanahu
Dhading
Nuwakot
Sindhupalchok
Dang
Arghakhanchi
Palpa
Dolakha
Kathmandu
Bhaktapur
Solukhumbu
Kapilbastu
Rupandehi
Nawalparasi
Chitawan
Lalitpur Kavrepalanchok
Ramechhap
Sankhuwasabha
Taplejung
Makwanpur
Okhaldhunga
Parsa
Sindhuli
Khotang
Bhojpur
Terhathum
Panchthar
Bara
Rautahat
Sarlahi
Dhankuta
Ilam
Mahottari
Udayapur
Dhanusa
Siraha
Saptari
Sunsari
Morang
Jhapa
Coordinate System: Nepal MUTM Central 84 Everest 1830
Projection: Transverse Mercator
Datum: Everest 1830
False Easting: 500,000.0000
False Northing: 0.0000
Central Meridian: 84.0000
Scale Factor: 0.9999
Latitude Of Origin: 0.0000
Units: Meter
Scale 1:2,200,000
0
70
140
280
Km
Department of Water Resources and Irrigation
Water Resources Project Preparatory Facility (WRPPF)
IRRIGATION MASTER PLAN, 2018
Existing Irrigation Projects, Nepal
Prepared By
ADB
LAHMEYER INTERNATIONAL
NIRAS

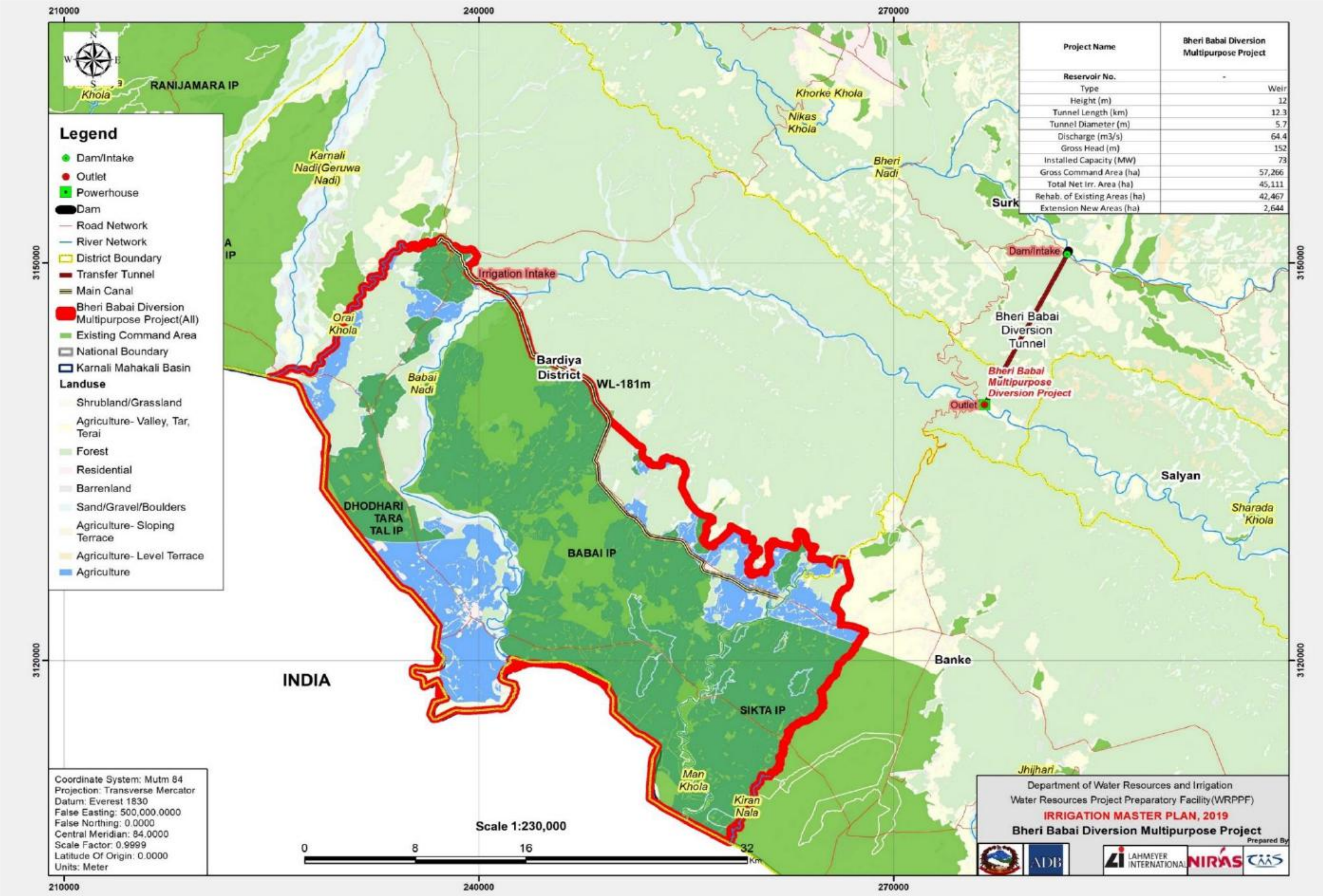

Legend
River Network(Level>2)
Transfer Tunnel
State Boundary
Karnali Basin
District Boundary
Dam/Reservoir
Existing Commad Areas
Potential Surface Irrigation
above 100
below 100
Pumping_Node
above 100
below 100
Identified Potential Pumping Schemes
Classified Pumping Schemes
Rainfed Areas
Existing/Extension Projects/Interbasin Transfers
Bheri Babai Diversion Multipurpose Project
Karnali Diversion Project
Mahakali Irrigation Project
Rani Jamara Kuleriya Irrigation Project
Rapti Kapilbastu Diversion Project
Sikta Irrigation Project
CHINA
INDIA
Humla
Darchula
Bajhang
Mugu
Bajura
Baitadi
7
Dadeldhura
Jumla
6
Kalikot
Doti
Achham
Dolpa
Kanchanpur
Karnali Diversion Tunnel
Dailekh
Jajarkot
Kailali
Surkhet
Rukum_W
Rukum_E
Bheri Babai Diversion Tunnel
Bardiya
Salyan
Rolpa
5
Pyuthan
Banke
Dang
Naumure Tunnel
Scale 1:1,200,000
Department of Water Resources and Irrigation
Water Resources Project Preparatory Facility(WRPPF)
IRRIGATION MASTER PLAN, 2019
Irrigation Domain, Karnali
Prepared By
ADB
LAHMEYER INTERNATIONAL
NIRAS

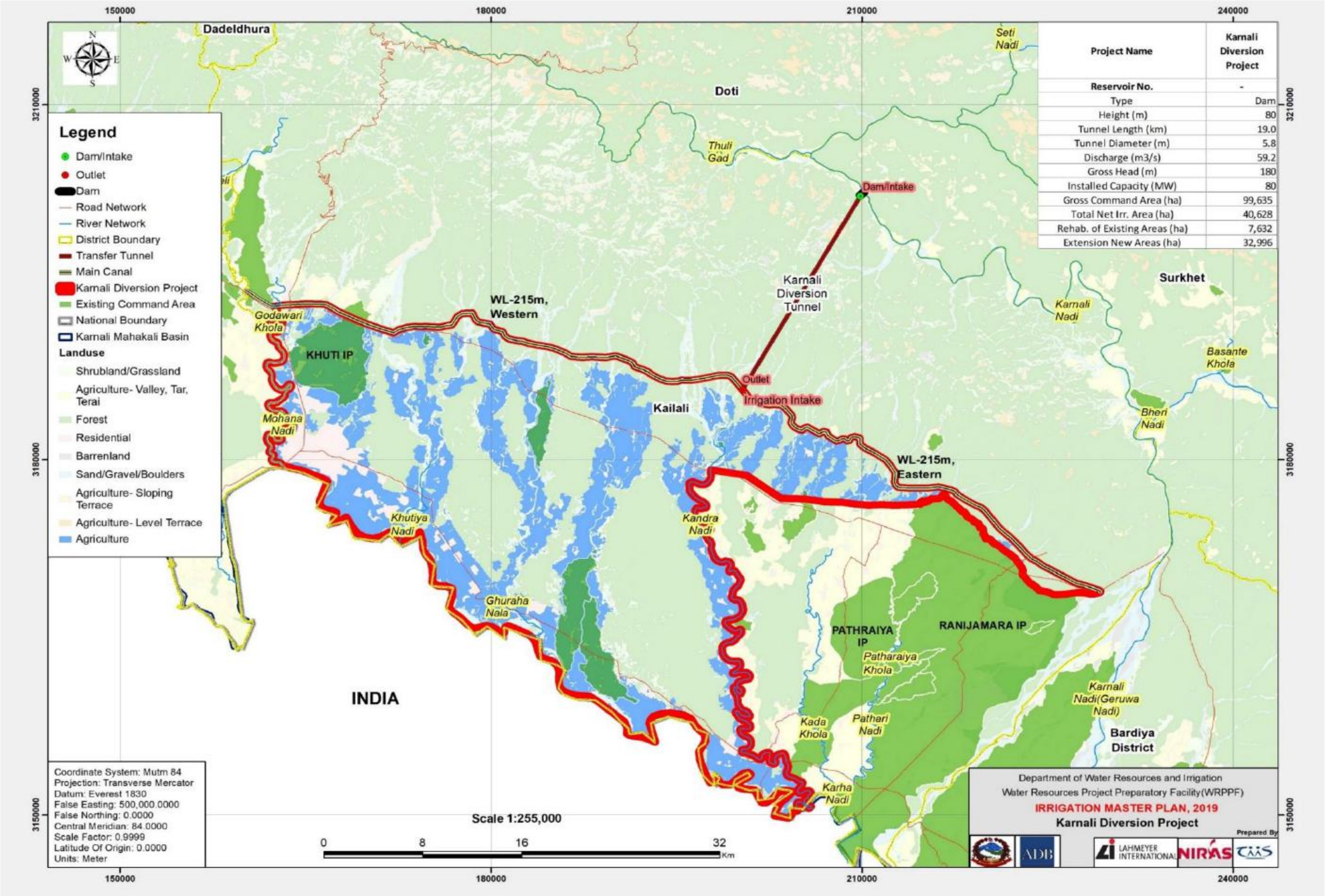


Legend
River Network(Level>2)
Transfer Tunnel
State Boundary
Karnali Basin
District Boundary
Dam/Reservoir
Existing Commad Areas
Potential Surface Irrigation
above 100
below 100
Pumping_Node
Pumping Schemes(Nodes)
above 100
below 100
Identified Potential Pumping Schemes
Classified Pumping Schemes
Rainfed Areas
Existing/Extension Projects/Interbasin Transfers
Bheri Babai Diversion Multipurpose Project
Karnali Diversion Project
Mahakali Irrigation Project
Rani Jamara Kuleriya Irrigation Project
Rapti Kapilbastu Diversion Project
Sikta Irrigation Project
CHINA
INDIA
Humla
Darchula
Bajhang
Mugu
Bajura
Baitadi
7
Jumla
6
Dadeldhura
Kalikot
Dolpa
Doti
Achham
Kanchanpur
Karnali Diversion Tunnel
Dailekh
Jajarkot
Kailali
Rukum_W
Rukum_E
Surkhet
Bheri Babai Diversion Tunnel
Salyan
Bardiya
Rolpa
5
Pyuthan
Banke
Dang
Naumure Tunnel
Scale 1:1,200,000
Department of Water Resources and Irrigation
Water Resources Project Preparatory Facility(WRPPF)
IRRIGATION MASTER PLAN, 2019
Irrigation Domain, Karnali
Prepared By

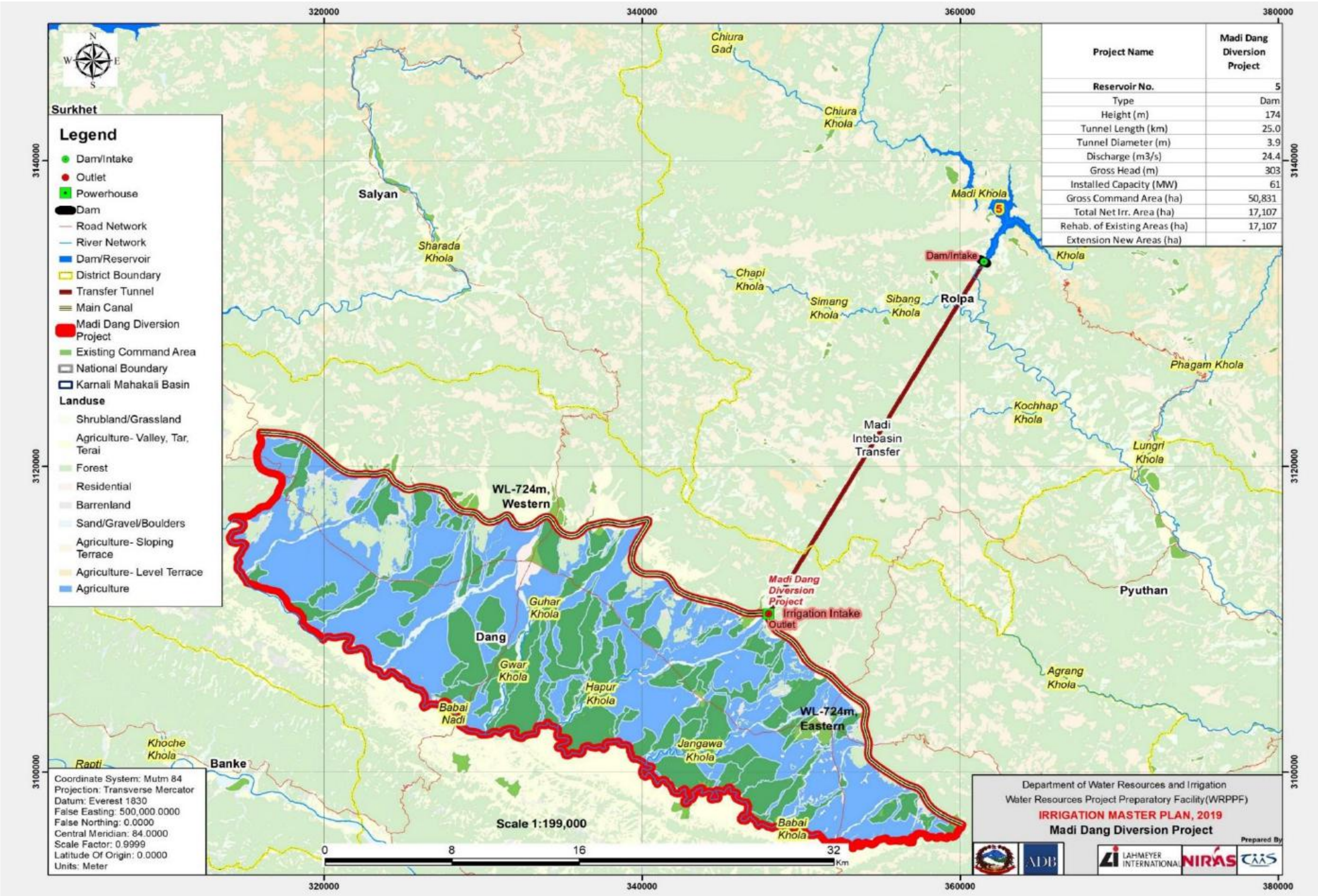

Legend
Transfer Tunnel
River Network(Level>2) selection
District Boundary
State Boundary
Narayani Basin
Existing Command Area
Potential Surface Irrigation
classify
above 100ha
below 100ha
Existing/Extension Projects/Interbasin Transfers
Kaligandaki Tinau Diversion Project
Rapti Kapilbastu Diversion Project
Pumping Node
Pumping Schemes(Nodes)
above 100ha
below 100ha
Identified Potential Pumping Schemes
Classified Pumping Schemes
Rainfed Areas
CHINA
INDIA
Mustang
Manang
Myagdi
Baglung
Parbat
Kaski
Lamjung
Gorkha
Rasuwa
Gulmi
Syangja
Tanahu
Dhading
Nuwakot
Kaligandaki Interbasin Transfer
Palpa
Nawalparasi_E
Kapilbastu
Rupandehi
Nawalparasi_W
Chitawan
Makawanpur
4
5
3
Scale 1:890,000
Department of Water Resources and Irrigation
Water Resources Project Preparatory Facility(WRPPF)
IRRIGATION MASTER PLAN, 2019
Irrigation Domain, Narayani
Prepared By

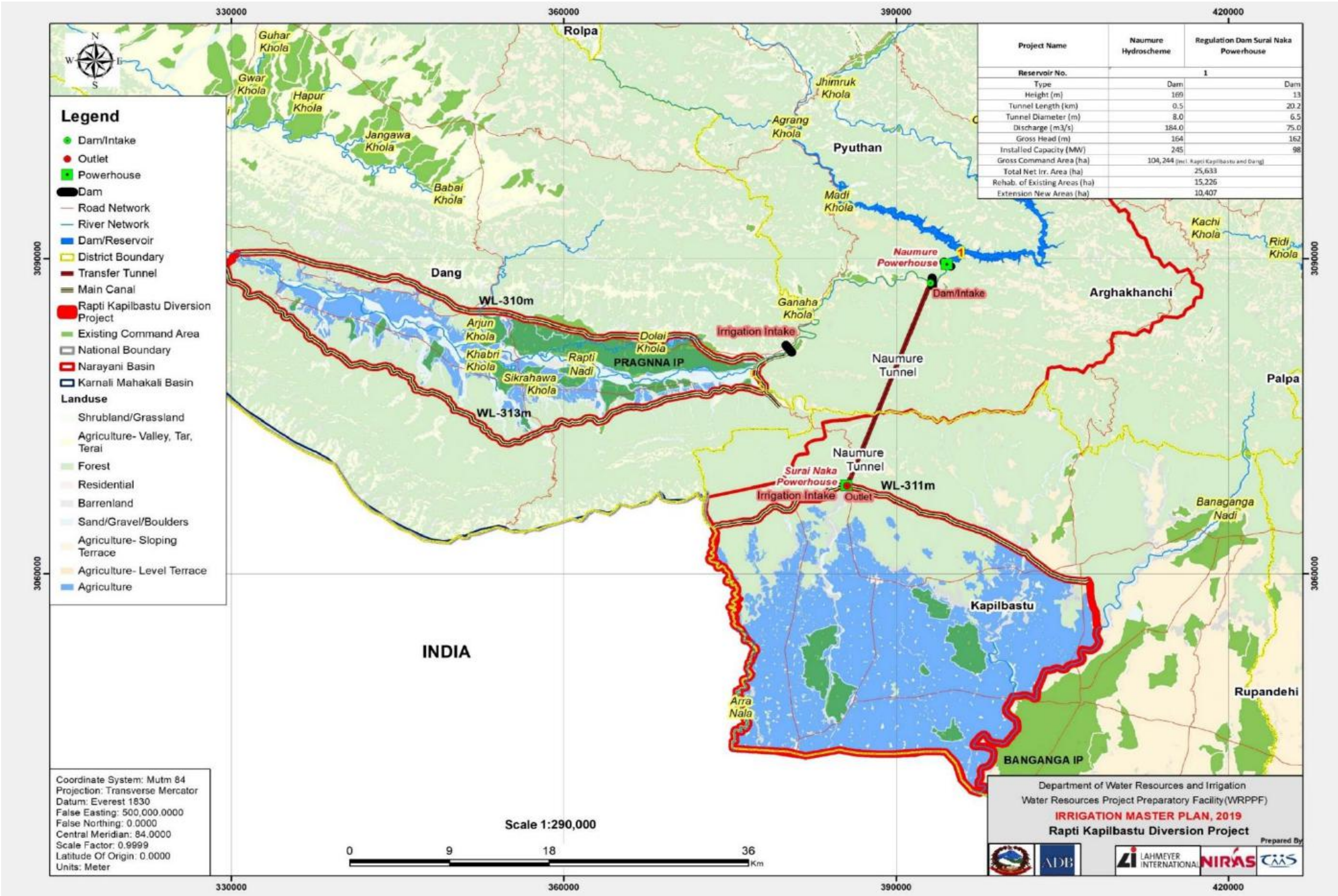

CHINA
INDIA
Sindhupalchok
Dolakha
Kathmandu
Solukhumbu
Sankhuwasabha
Taplejung
Lalitpur
Kavrepalanchok
Sunkoshi Marin Transfer
Ramechhap
Okhaldhunga
Parsa
Sindhuli
Khotang
Bhojpur
Terhathum
Panchthar
Sunkoshi Kamala Transfer
Bara
Rautahat
Sarlahi
Udayapur
Dhankuta
Tamor Morang Transfer
Ilam
Mahottari
Dhanusa
Siraha
Saptari
Sunsari
Morang
Jhapa
Legend
River Network(Level>2) selection
Transfer Tunnel
Dam/Reservoir
Existing Command Area
Gross_command_area
Existing/Extension Projects/Interbasin Transfers
Chatara Barrage CA
Sunkoshi Kamala Diversion Project
Sunkoshi Marin Diversion Project
Tamor Morang Diversion Project
Potential Surface Irrigation
Above 100ha
Below 100ha
Pumping_Node
above 100
below 100
Identified Potential Pumping Schemes
Rainfed Areas
Classifed Potential Schemes
Koshi Basin
State Boundary
District Boundary
Scale 1:970,000
Department of Water Resources and Irrigation
Water Resources Project Preparatry Facility(WRPPF)
IRRIGATION MASTER PLAN, 2019
Irrigation Domain, Koshi
Prepared By
ADB
NIRAS


210000
240000
270000
3150000
3120000
Legend
Dam/Intake
Outlet
Powerhouse
Dam
Road Network
River Network
District Boundary
Transfer Tunnel
Main Canal
Bheri Babai Diversion Multipurpose Project(All)
Existing Command Area
National Boundary
Karnali Mahakali Basin
Landuse
Shrubland/Grassland
Agriculture- Valley, Tar, Terai
Forest
Residential
Barrenland
Sand/Gravel/Boulders
Agriculture- Sloping Terrace
Agriculture- Level Terrace
Agriculture
Project Name | Bheri Babai Diversion Multipurpose Project
Reservoir No. | -
Type | Weir
Height (m) | 12
Tunnel Length (km) | 12.3
Tunnel Diameter (m) | 5.7
Discharge (m3/s) | 64.4
Gross Head (m) | 152
Installed Capacity (MW) | 73
Gross Command Area (ha) | 57,266
Total Net Irr. Area (ha) | 45,111
Rehab. of Existing Areas (ha) | 42,467
Extension New Areas (ha) | 2,644
RANIJAMARA IP
Khola
Karnali Nadi(Geruwa Nadi)
Khorke Khola
Nikas Khola
Bheri Nadi
Surk
Dam/Intake
Irrigation Intake
Orai Khola
Babai Nadi
Bardiya District
WL-181m
Bheri Babai Diversion Tunnel
Bheri Babai Multipurpose Diversion Project
Outlet
Salyan
Sharada Khola
DHODHARI TARA TAL IP
BABAI IP
Banke
INDIA
SIKTA IP
Man Khola
Kiran Nala
Jhijhari
Coordinate System: Mutm 84
Projection: Transverse Mercator
Datum: Everest 1830
False Easting: 500,000.0000
False Northing: 0.0000
Central Meridian: 84.0000
Scale Factor: 0.9999
Latitude Of Origin: 0.0000
Units: Meter
Scale 1:230,000
0 8 16 32
Km
Department of Water Resources and Irrigation
Water Resources Project Preparatory Facility(WRPPF)
IRRIGATION MASTER PLAN, 2019
Bheri Babai Diversion Multipurpose Project
Prepared By
ADB
LAHMEYER INTERNATIONAL
NIRAS

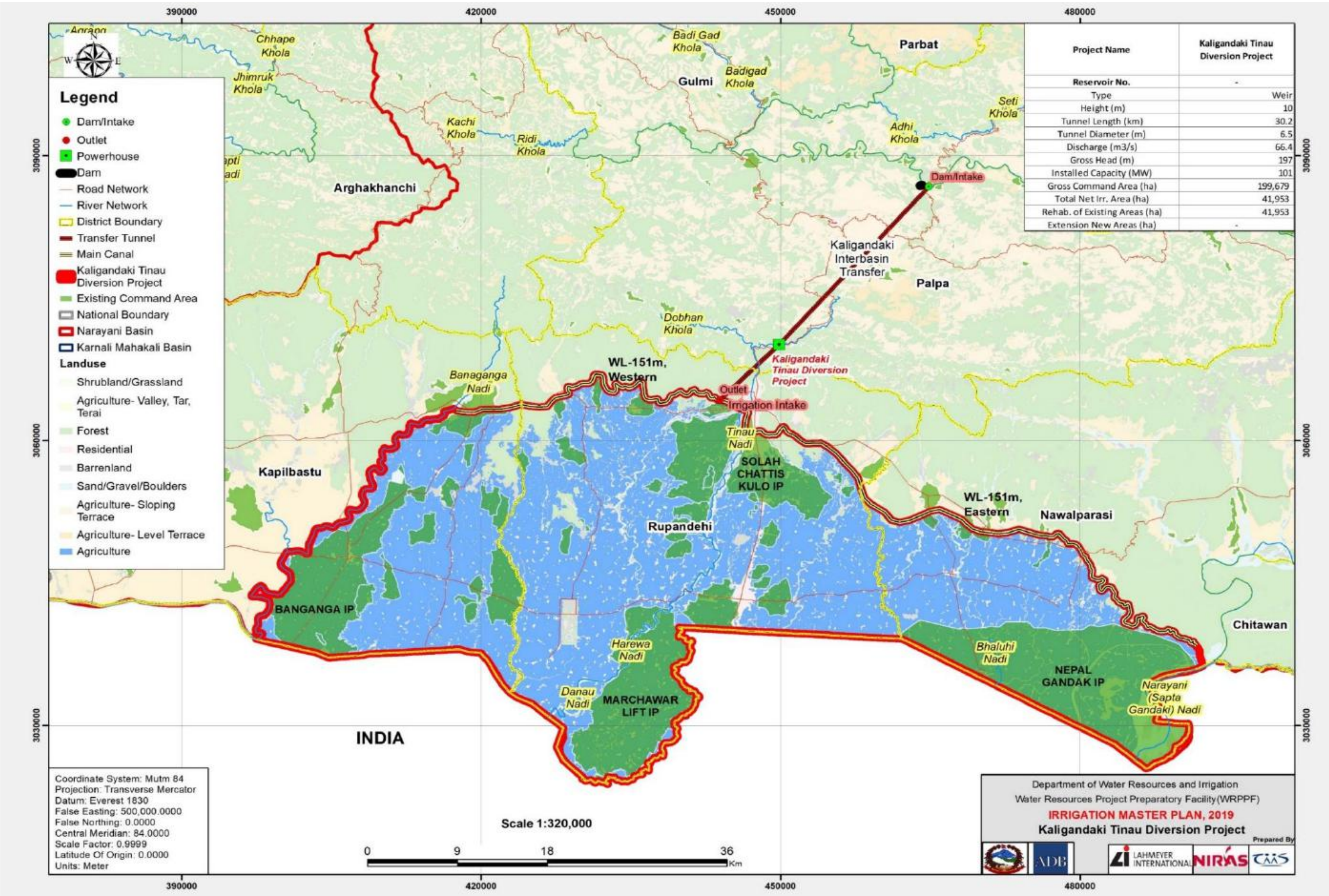


Project Name
Karnali Diversion Project
Reservoir No.
Type
Dam
Height (m)
80
Tunnel Length (km)
19.0
Tunnel Diameter (m)
5.8
Discharge (m3/s)
59.2
Gross Head (m)
180
Installed Capacity (MW)
80
Gross Command Area (ha)
99,635
Total Net Irr. Area (ha)
40,628
Rehab. of Existing Areas (ha)
7,632
Extension New Areas (ha)
32,996
Legend
Dam/Intake
Outlet
Dam
Road Network
River Network
District Boundary
Transfer Tunnel
Main Canal
Karnali Diversion Project
Existing Command Area
National Boundary
Karnali Mahakali Basin
Landuse
Shrubland/Grassland
Agriculture- Valley, Tar, Terai
Forest
Residential
Barrenland
Sand/Gravel/Boulders
Agriculture- Sloping Terrace
Agriculture- Level Terrace
Agriculture
Dadeldhura
Doti
Kailali
Surkhet
INDIA
Bardiya District
Karnali Diversion Tunnel
WL-215m, Western
WL-215m, Eastern
Outlet
Irrigation Intake
Dam/Intake
KHUTI IP
PATHRAIYA IP
RANIJAMARA IP
Coordinate System: Mutm 84
Projection: Transverse Mercator
Datum: Everest 1830
False Easting: 500,000.0000
False Northing: 0.0000
Central Meridian: 84.0000
Scale Factor: 0.9999
Latitude Of Origin: 0.0000
Units: Meter
Scale 1:255,000
Department of Water Resources and Irrigation
Water Resources Project Preparatory Facility(WRPPF)
IRRIGATION MASTER PLAN, 2019
Karnali Diversion Project

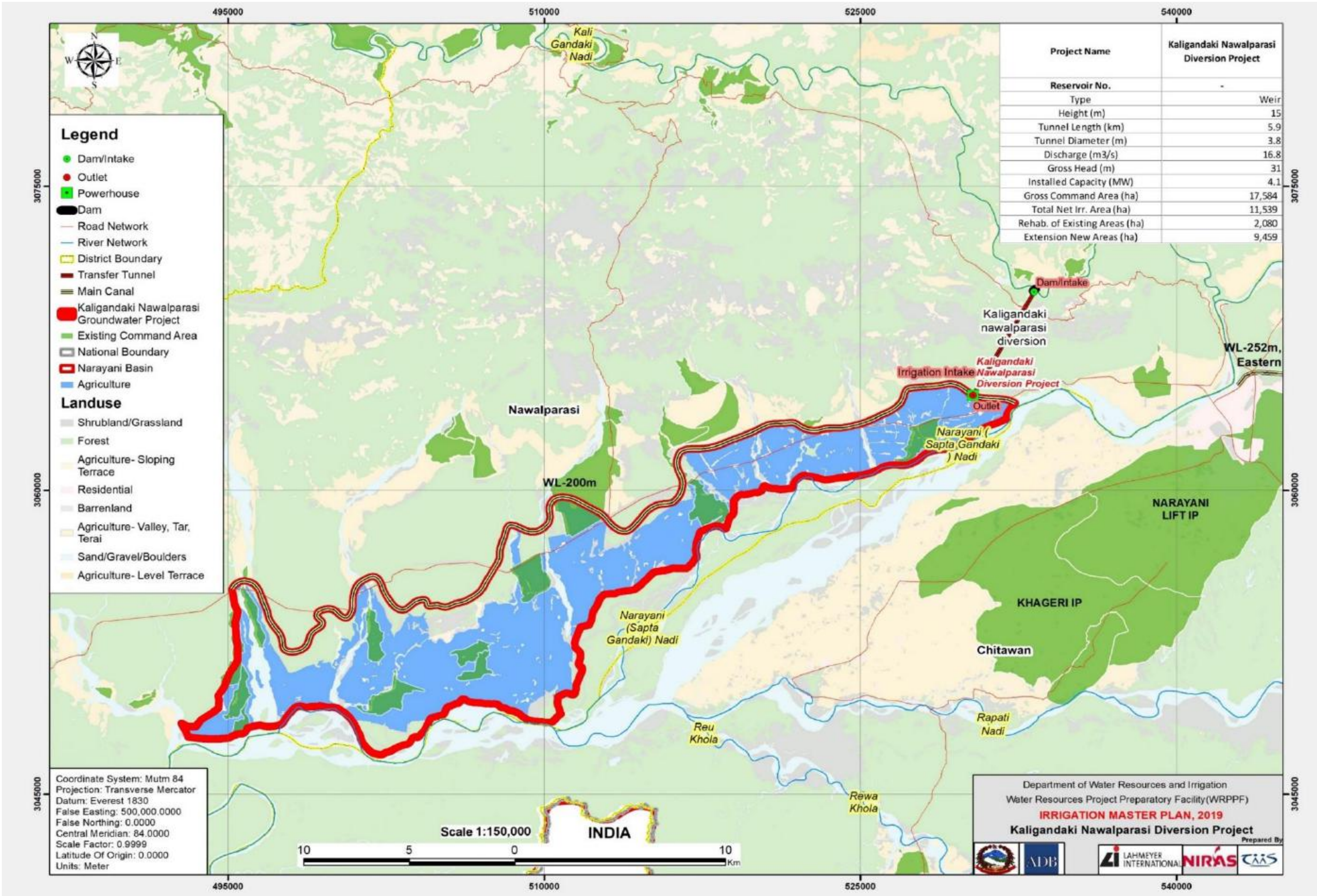

Project Name: Madi Dang Diversion Project
Reservoir No.: 5
Type: Dam
Height (m): 174
Tunnel Length (km): 25.0
Tunnel Diameter (m): 3.9
Discharge (m3/s): 24.4
Gross Head (m): 303
Installed Capacity (MW): 61
Gross Command Area (ha): 50,831
Total Net Irr. Area (ha): 17,107
Rehab. of Existing Areas (ha): 17,107
Extension New Areas (ha): -
Legend
Dam/Intake
Outlet
Powerhouse
Dam
Road Network
River Network
Dam/Reservoir
District Boundary
Transfer Tunnel
Main Canal
Madi Dang Diversion Project
Existing Command Area
National Boundary
Karnali Mahakali Basin
Landuse
Shrubland/Grassland
Agriculture- Valley, Tar, Terai
Forest
Residential
Barrenland
Sand/Gravel/Boulders
Agriculture- Sloping Terrace
Agriculture- Level Terrace
Agriculture
Surkhet
Salyan
Rolpa
Pyuthan
Dang
Banke
Chiura Gad
Chiura Khola
Madi Khola
Sharada Khola
Chapi Khola
Simang Khola
Sibang Khola
Phagam Khola
Kochhap Khola
Lungri Khola
Agrang Khola
Guhar Khola
Gwar Khola
Hapur Khola
Jangawa Khola
Babai Nadi
Babai Khola
Khoche Khola
Rapti
Dam/Intake
Madi Intebasin Transfer
WL-724m, Western
WL-724m, Eastern
Madi Dang Diversion Project
Irrigation Intake
Outlet
Scale 1:199,000
0 8 16 32 Km
Coordinate System: Mutm 84
Projection: Transverse Mercator
Datum: Everest 1830
False Easting: 500,000.0000
False Northing: 0.0000
Central Meridian: 84.0000
Scale Factor: 0.9999
Latitude Of Origin: 0.0000
Units: Meter
Department of Water Resources and Irrigation
Water Resources Project Preparatory Facility(WRPPF)
IRRIGATION MASTER PLAN, 2019
Madi Dang Diversion Project
Prepared By
ADB
LAHMEYER INTERNATIONAL
NIRAS

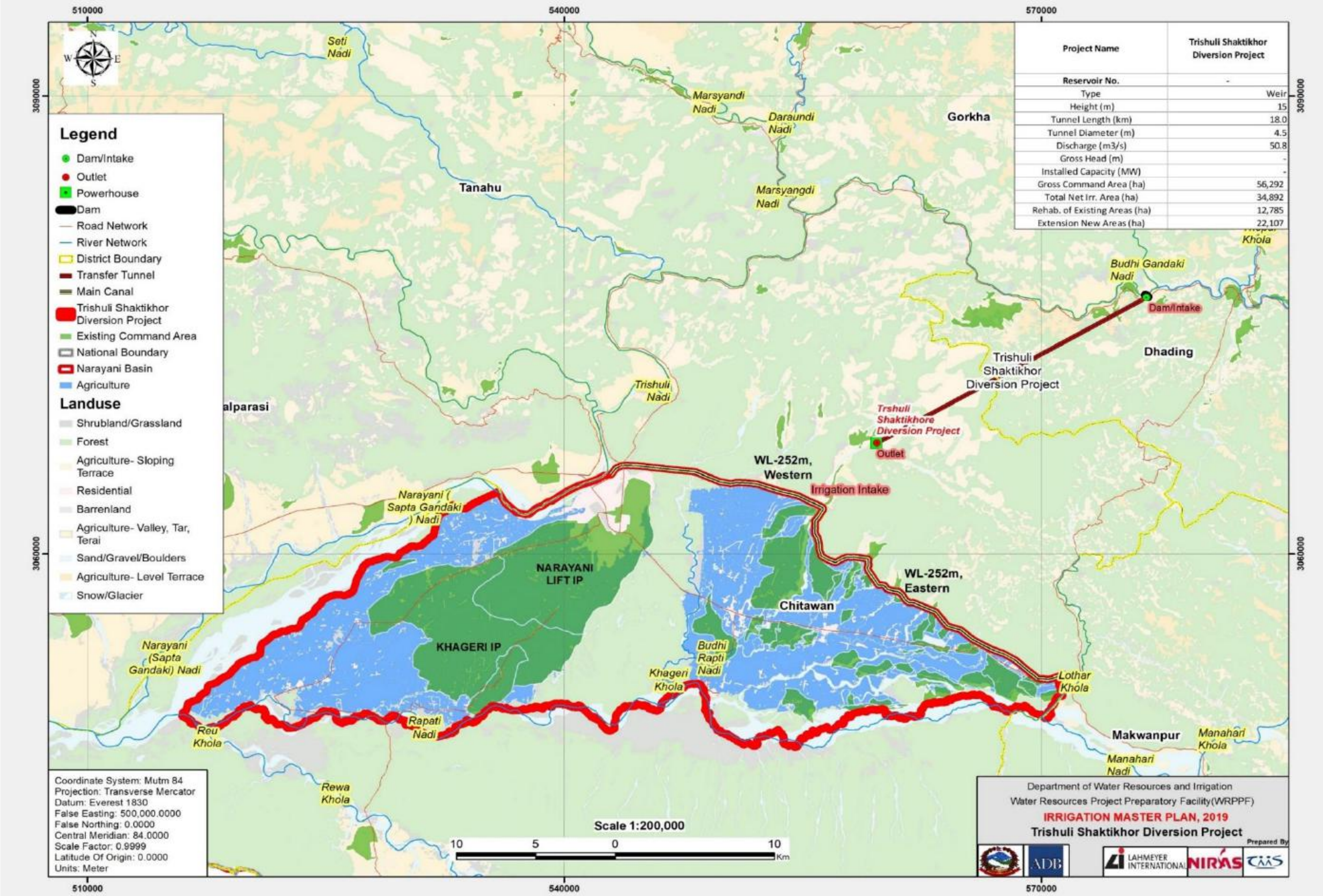


Project Name	Naumure Hydroscheme	Regulation Dam Surai Naka Powerhouse
Reservoir No.	1	
Type	Dam	Dam
Height (m)	169	13
Tunnel Length (km)	0.5	20.2
Tunnel Diameter (m)	8.0	6.5
Discharge (m3/s)	184.0	75.0
Gross Head (m)	164	162
Installed Capacity (MW)	245	98
Gross Command Area (ha)	104,244 (incl. Rapti Kapilbastu and Dang)	
Total Net Irr. Area (ha)	25,633	
Rehab. of Existing Areas (ha)	15,226	
Extension New Areas (ha)	10,407	



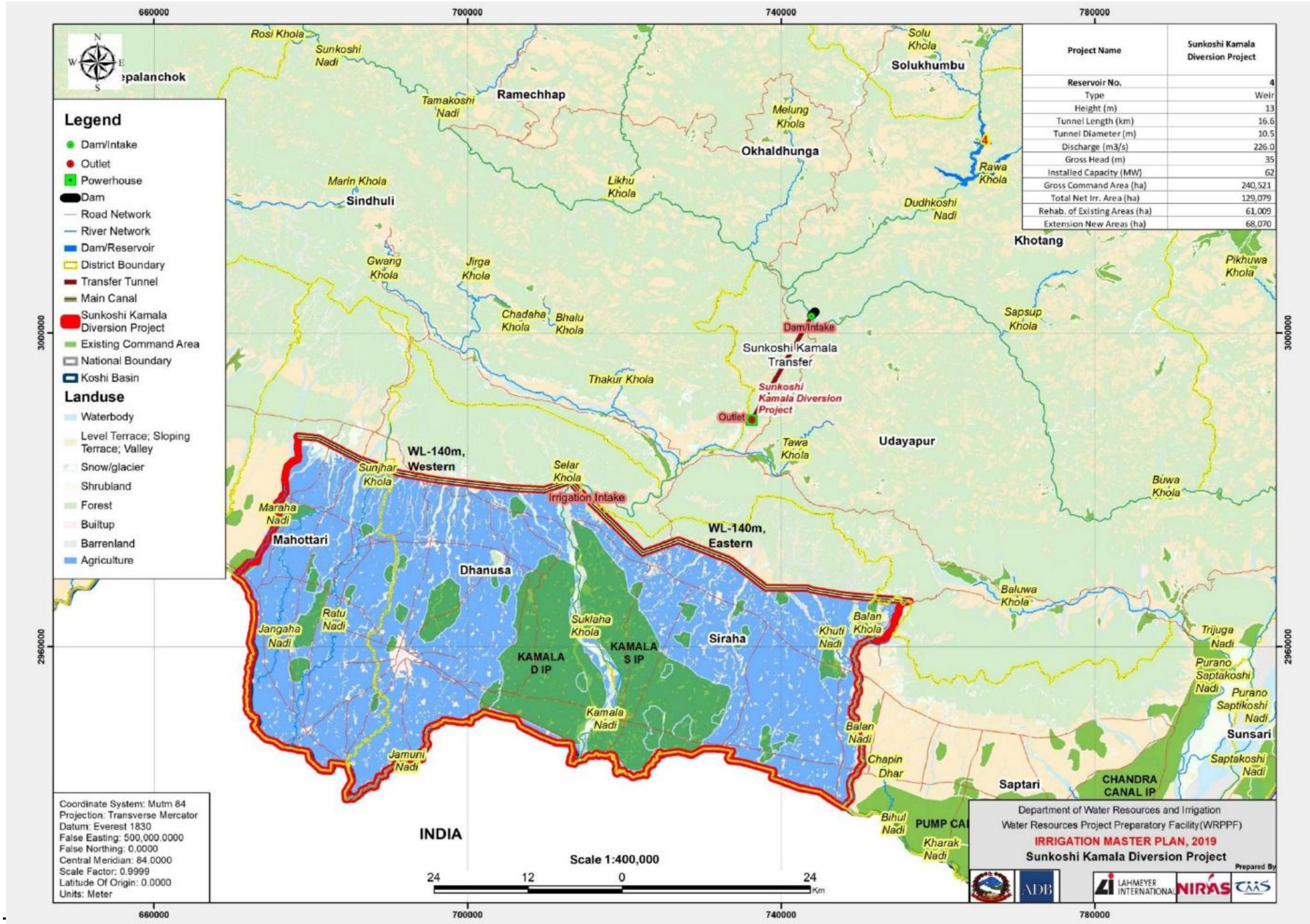
Legend
Dam/Intake
Outlet
Powerhouse
Dam
Road Network
River Network
District Boundary
Transfer Tunnel
Main Canal
Kaligandaki Tinau Diversion Project
Existing Command Area
National Boundary
Narayani Basin
Karnali Mahakali Basin
Landuse
Shrubland/Grassland
Agriculture- Valley, Tar, Terai
Forest
Residential
Barrenland
Sand/Gravel/Boulders
Agriculture- Sloping Terrace
Agriculture- Level Terrace
Agriculture
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) | -
Chhape Khola
Jhimruk Khola
Kachi Khola
Ridi Khola
Badi Gad Khola
Badigad Khola
Gulmi
Parbat
Seti Khola
Adhi Khola
Dam/Intake
Arghakhanchi
Kaligandaki Interbasin Transfer
Palpa
Dobhan Khola
Banaganga Nadi
WL-151m, Western
Kaligandaki Tinau Diversion Project
Outlet
Irrigation Intake
Tinau Nadi
SOLAH CHATTIS KULO IP
Kapilbastu
WL-151m, Eastern
Nawalparasi
Rupandehi
BANGANGA IP
Chitawan
Harewa Nadi
Bhaluhi Nadi
NEPAL GANDAK IP
Narayani (Sapta Gandaki) Nadi
Danau Nadi
MARCHAWAR LIFT IP
INDIA
Coordinate System: Mutm 84
Projection: Transverse Mercator
Datum: Everest 1830
False Easting: 500,000.0000
False Northing: 0.0000
Central Meridian: 84.0000
Scale Factor: 0.9999
Latitude Of Origin: 0.0000
Units: Meter
Scale 1:320,000
0 9 18 36 Km
390000
420000
450000
480000
3090000
3060000
3030000
Department of Water Resources and Irrigation
Water Resources Project Preparatory Facility (WRPPF)
IRRIGATION MASTER PLAN, 2019
Kaligandaki Tinau Diversion Project
Prepared By
ADB
LAHMEYER INTERNATIONAL
NIRAS


Project Name
Kaligandaki Nawalparasi Diversion Project
Reservoir No.
-
Type
Weir
Height (m)
15
Tunnel Length (km)
5.9
Tunnel Diameter (m)
3.8
Discharge (m3/s)
16.8
Gross Head (m)
31
Installed Capacity (MW)
4.1
Gross Command Area (ha)
17,584
Total Net Irr. Area (ha)
11,539
Rehab. of Existing Areas (ha)
2,080
Extension New Areas (ha)
9,459
Legend
Dam/Intake
Outlet
Powerhouse
Dam
Road Network
River Network
District Boundary
Transfer Tunnel
Main Canal
Kaligandaki Nawalparasi Groundwater Project
Existing Command Area
National Boundary
Narayani Basin
Agriculture
Landuse
Shrubland/Grassland
Forest
Agriculture- Sloping Terrace
Residential
Barrenland
Agriculture- Valley, Tar, Terai
Sand/Gravel/Boulders
Agriculture- Level Terrace
Kali Gandaki Nadi
Dam/Intake
Kaligandaki nawalparasi diversion
Irrigation Intake
Kaligandaki Nawalparasi Diversion Project
Outlet
WL-252m, Eastern
Nawalparasi
Narayani (Sapta Gandaki) Nadi
WL-200m
NARAYANI LIFT IP
KHAGERI IP
Chitawan
Rapati Nadi
Reu Khola
Rewa Khola
INDIA
Scale 1:150,000
Coordinate System: Mutm 84
Projection: Transverse Mercator
Datum: Everest 1830
False Easting: 500,000.0000
False Northing: 0.0000
Central Meridian: 84.0000
Scale Factor: 0.9999
Latitude Of Origin: 0.0000
Units: Meter
Department of Water Resources and Irrigation
Water Resources Project Preparatory Facility(WRPPF)
IRRIGATION MASTER PLAN, 2019
Kaligandaki Nawalparasi Diversion Project
Prepared By
ADB
LAHMEYER INTERNATIONAL
NIRAS
495000
510000
525000
540000
3075000
3060000
3045000

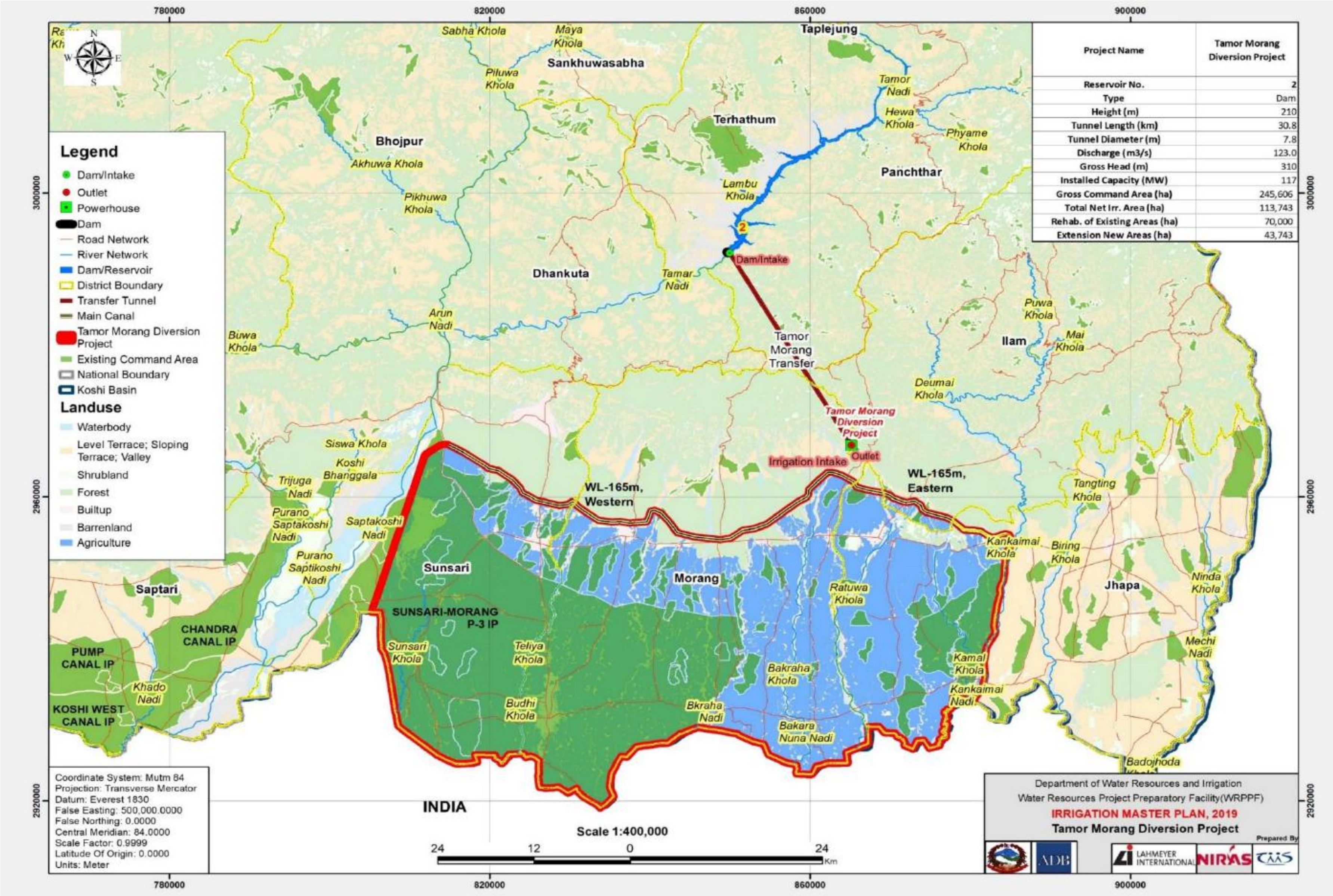


Project Name
Trishuli Shaktikhor Diversion Project
Reservoir No. -
Type Weir
Height (m) 15
Tunnel Length (km) 18.0
Tunnel Diameter (m) 4.5
Discharge (m3/s) 50.8
Gross Head (m) -
Installed Capacity (MW) -
Gross Command Area (ha) 56,292
Total Net Irr. Area (ha) 34,892
Rehab. of Existing Areas (ha) 12,785
Extension New Areas (ha) 22,107
Legend
Dam/Intake
Outlet
Powerhouse
Dam
Road Network
River Network
District Boundary
Transfer Tunnel
Main Canal
Trishuli Shaktikhor Diversion Project
Existing Command Area
National Boundary
Narayani Basin
Agriculture
Landuse
Shrubland/Grassland
Forest
Agriculture- Sloping Terrace
Residential
Barrenland
Agriculture- Valley, Tar, Terai
Sand/Gravel/Boulders
Agriculture- Level Terrace
Snow/Glacier
Gorkha
Tanahu
Dhading
Chitawan
Makwanpur
NARAYANI LIFT IP
KHAGERI IP
WL-252m, Western
WL-252m, Eastern
Irrigation Intake
Trishuli Shaktikhor Diversion Project
Trshuli Shaktikhore Diversion Project
Outlet
Dam/Intake
Seti Nadi
Marsyandi Nadi
Daraundi Nadi
Marsyangdi Nadi
Budhi Gandaki Nadi
Trishuli Nadi
Narayani (Sapta Gandaki) Nadi
Budhi Rapti Nadi
Khageri Khola
Rapati Nadi
Reu Khola
Rewa Khola
Lothar Khola
Manahari Khola
Manahari Nadi
Coordinate System: Mutm 84
Projection: Transverse Mercator
Datum: Everest 1830
False Easting: 500,000.0000
False Northing: 0.0000
Central Meridian: 84.0000
Scale Factor: 0.9999
Latitude Of Origin: 0.0000
Units: Meter
Scale 1:200,000
10 5 0 10 Km
Department of Water Resources and Irrigation
Water Resources Project Preparatory Facility(WRPPF)
IRRIGATION MASTER PLAN, 2019
Trishuli Shaktikhor Diversion Project
Prepared By
ADB
LAHMEYER INTERNATIONAL
NIRAS
510000
540000
570000
3090000
3060000

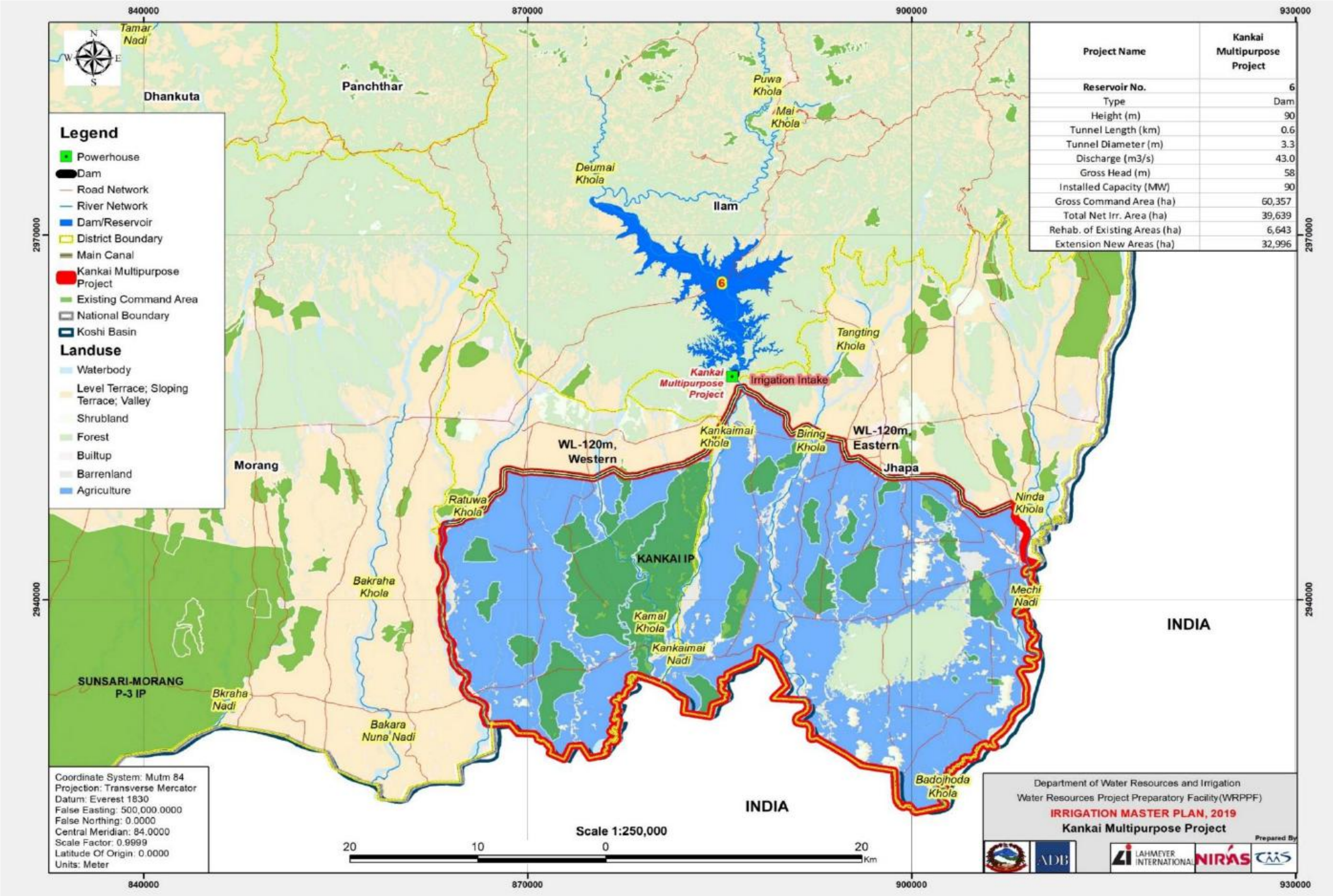
Project Name
Sunkoshi Marin Diversion Project
Reservoir No. 3
Type Weir
Height (m) 13
Tunnel Length (km) 13.4
Tunnel Diameter (m) 10.6
Discharge (m3/s) 207.5
Gross Head (m) 66
Installed Capacity (MW) 103
Gross Command Area (ha) 224,567
Total Net Irr. Area (ha) 170,462
Rehab. of Existing Areas (ha) 159,011
Extension New Areas (ha) 11,451
Legend
Dam/Intake
Outlet
Powerhouse
Dam
Road Network
River Network
Command Area(MIIP)
Dam/Reservoir
District Boundary
Transfer Tunnel
Main Canal
Sunkoshi Marin Diversion Project
Existing Command Area
National Boundary
Narayani Basin
Koshi Basin
Landuse
Waterbody
Level Terrace; Sloping Terrace; Valley
Snow/glacier
Shrubland
Forest
Builtup
Barrenland
Agriculture
Gorkha
Nuwakot
Dhading
Kathmandu
Bhaktapur
Lalitpur
Makwanpur
Kavrepalanchok
Sindhupalchok
Ramechhap
Okhaldhunga
Sindhuli
Bara
Rautahat
Sarlahi
Mahottari
Dhanusa
Udayapur
INDIA
Dam/Intake
Sunkoshi Marin Diversion Project
Outlet
Irrigation Intake
WL-130m, Western
WL-130m, Eastern
BAGMATI S IP
BAGMATI R IP
NARAYANI B IP
NARAYANI R IP
Coordinate System: Mutm 84
Projection: Transverse Mercator
Datum: Everest 1830
False Easting: 500,000.0000
False Northing: 0.0000
Central Meridian: 84.0000
Scale Factor: 0.9999
Latitude Of Origin: 0.0000
Units: Meter
Scale 1:450,000
Department of Water Resources and Irrigation
Water Resources Project Preparatory Facility(WRPPF)
IRRIGATION MASTER PLAN, 2019
Sunkoshi Marin Diversion Project
Prepared By

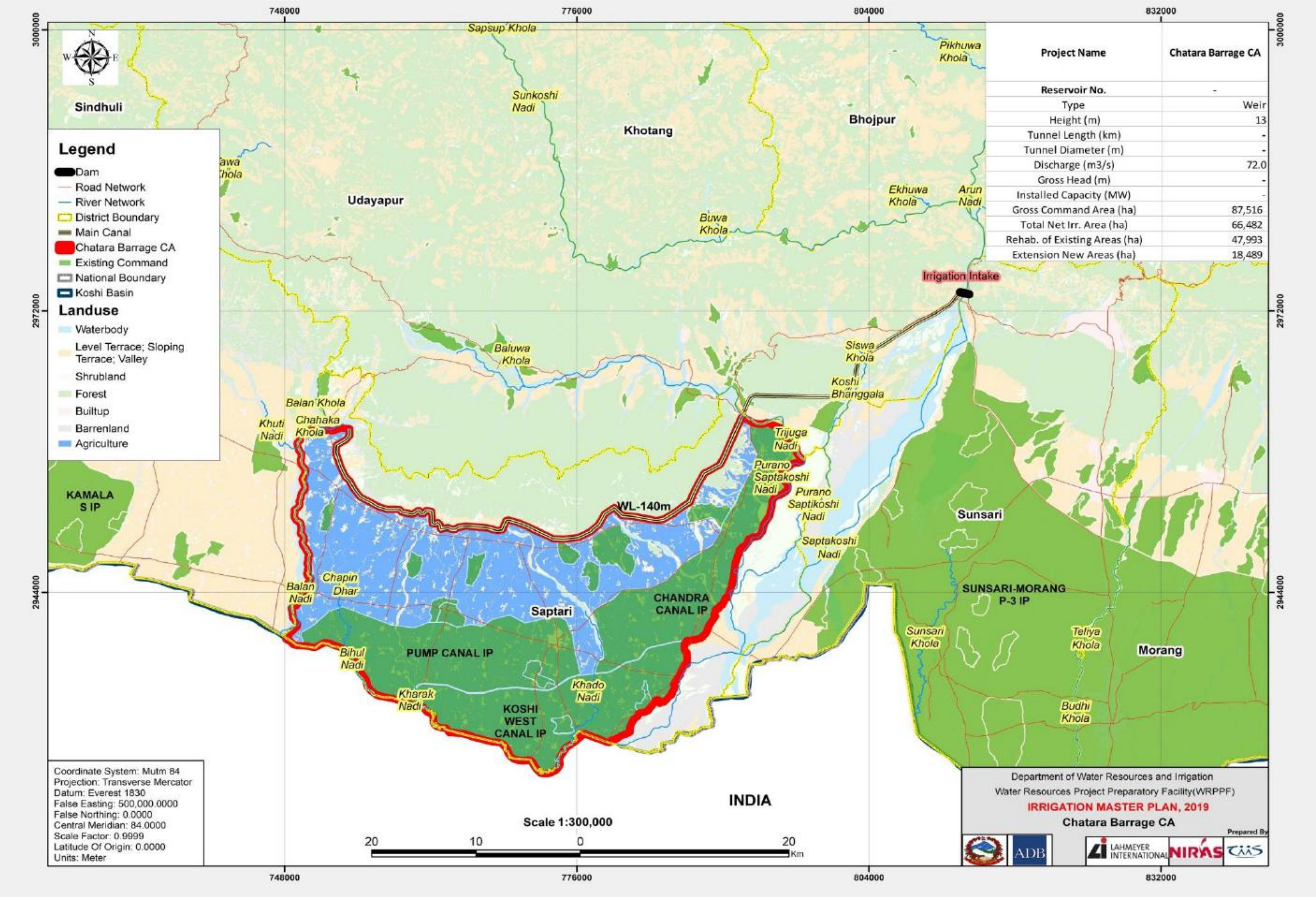


Project Name
Sunkoshi Kamala Diversion Project
Reservoir No. 4
Type Weir
Height (m) 13
Tunnel Length (km) 16.6
Tunnel Diameter (m) 10.5
Discharge (m3/s) 226.0
Gross Head (m) 35
Installed Capacity (MW) 62
Gross Command Area (ha) 240,521
Total Net Irr. Area (ha) 129,079
Rehab. of Existing Areas (ha) 61,009
Extension New Areas (ha) 68,070
Legend
Dam/Intake
Outlet
Powerhouse
Dam
Road Network
River Network
Dam/Reservoir
District Boundary
Transfer Tunnel
Main Canal
Sunkoshi Kamala Diversion Project
Existing Command Area
National Boundary
Koshi Basin
Landuse
Waterbody
Level Terrace; Sloping Terrace; Valley
Snow/glacier
Shrubland
Forest
Builtup
Barrenland
Agriculture
Ramechhap
Okhaldhunga
Solukhumbu
Sindhuli
Khotang
Udayapur
Mahottari
Dhanusa
Siraha
Saptari
Sunsari
INDIA
Dam/Intake
Sunkoshi Kamala Transfer
Sunkoshi Kamala Diversion Project
Outlet
Irrigation Intake
WL-140m, Western
WL-140m, Eastern
KAMALA D IP
KAMALA S IP
CHANDRA CANAL IP
Coordinate System: Mutm 84
Projection: Transverse Mercator
Datum: Everest 1830
False Easting: 500,000.0000
False Northing: 0.0000
Central Meridian: 84.0000
Scale Factor: 0.9999
Latitude Of Origin: 0.0000
Units: Meter
Scale 1:400,000
Department of Water Resources and Irrigation
Water Resources Project Preparatory Facility(WRPPF)
IRRIGATION MASTER PLAN, 2019
Sunkoshi Kamala Diversion Project
Prepared By

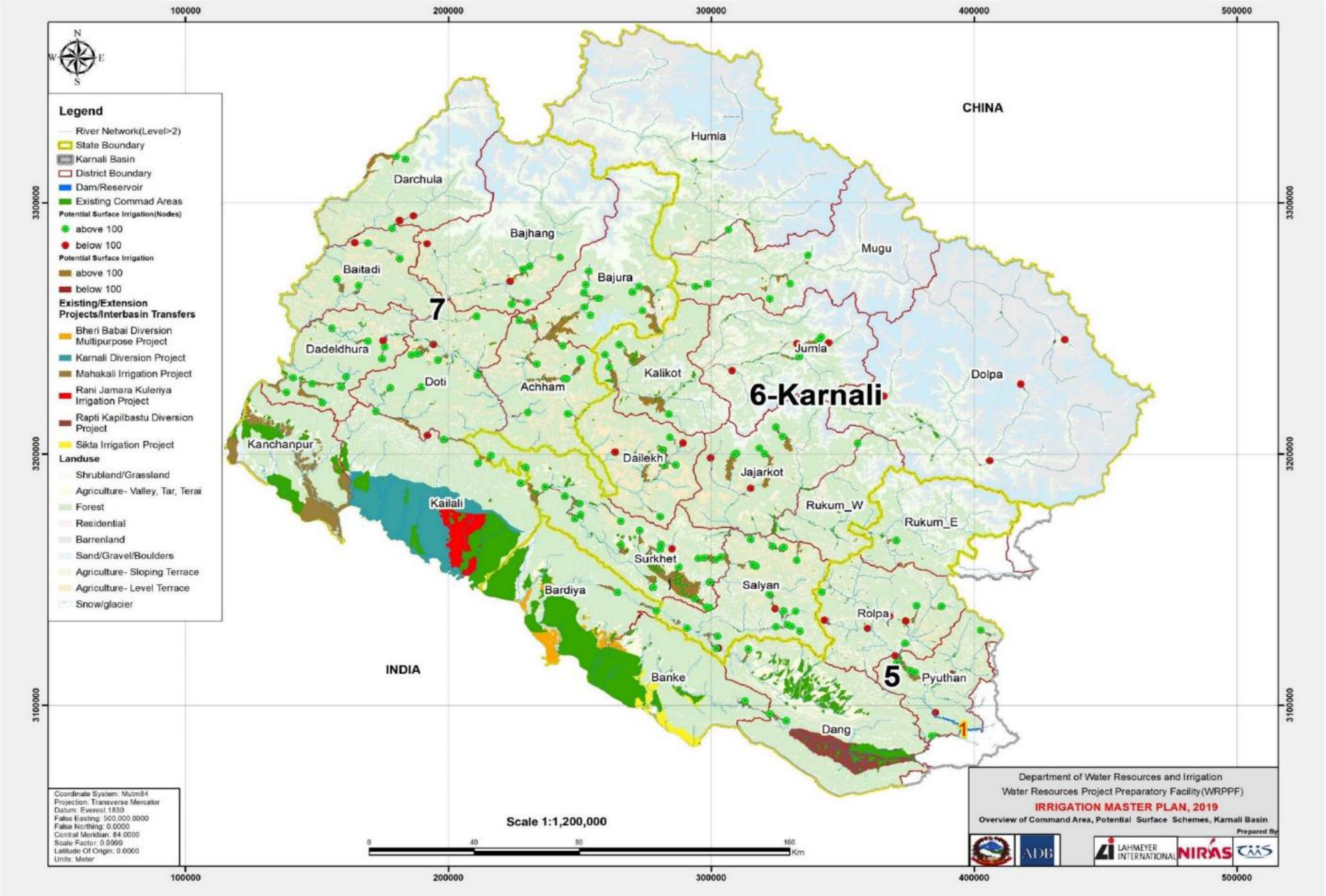


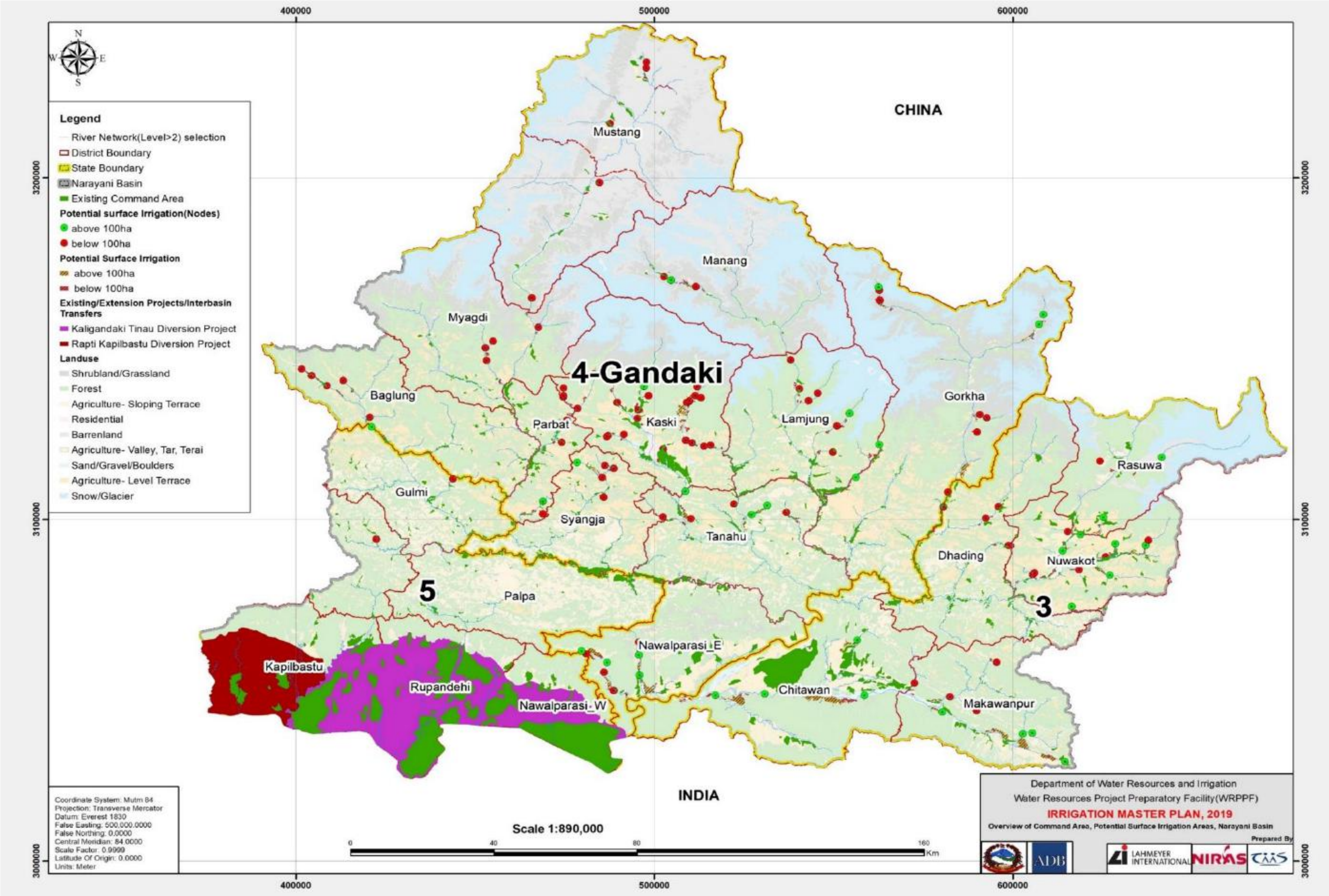
Legend
Dam/Intake
Outlet
Powerhouse
Dam
Road Network
River Network
Dam/Reservoir
District Boundary
Transfer Tunnel
Main Canal
Tamor Morang Diversion Project
Existing Command Area
National Boundary
Koshi Basin
Landuse
Waterbody
Level Terrace; Sloping Terrace; Valley
Shrubland
Forest
Builtup
Barrenland
Agriculture
Project Name | Tamor Morang Diversion Project
Reservoir No. | 2
Type | Dam
Height (m) | 210
Tunnel Length (km) | 30.8
Tunnel Diameter (m) | 7.8
Discharge (m3/s) | 123.0
Gross Head (m) | 310
Installed Capacity (MW) | 117
Gross Command Area (ha) | 245,606
Total Net Irr. Area (ha) | 113,743
Rehab. of Existing Areas (ha) | 70,000
Extension New Areas (ha) | 43,743
Taplejung
Sankhuwasabha
Terhathum
Bhojpur
Panchthar
Dhankuta
Ilam
Sunsari
Morang
Jhapa
Saptari
Dam/Intake
Tamor Morang Transfer
Tamor Morang Diversion Project
Irrigation Intake
Outlet
WL-165m, Western
WL-165m, Eastern
SUNSARI-MORANG P-3 IP
CHANDRA CANAL IP
PUMP CANAL IP
KOSHI WEST CANAL IP
INDIA
Coordinate System: Mutm 84
Projection: Transverse Mercator
Datum: Everest 1830
False Easting: 500,000.0000
False Northing: 0.0000
Central Meridian: 84.0000
Scale Factor: 0.9999
Latitude Of Origin: 0.0000
Units: Meter
Scale 1:400,000
Department of Water Resources and Irrigation
Water Resources Project Preparatory Facility(WRPPF)
IRRIGATION MASTER PLAN, 2019
Tamor Morang Diversion Project
Prepared By


Project Name
Kankai Multipurpose Project
Reservoir No. 6
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
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
Legend
Powerhouse
Dam
Road Network
River Network
Dam/Reservoir
District Boundary
Main Canal
Kankai Multipurpose Project
Existing Command Area
National Boundary
Koshi Basin
Landuse
Waterbody
Level Terrace; Sloping Terrace; Valley
Shrubland
Forest
Builtup
Barrenland
Agriculture
Dhankuta
Panchthar
Ilam
Morang
Jhapa
Tamar Nadi
Puwa Khola
Mai Khola
Deumai Khola
Tangting Khola
Kankai Multipurpose Project
Irrigation Intake
Kankaimai Khola
Biring Khola
WL-120m, Western
WL-120m, Eastern
Ratuwa Khola
Ninda Khola
KANKAI IP
Bakraha Khola
Mechi Nadi
Kamal Khola
Kankaimai Nadi
SUNSARI-MORANG P-3 IP
Bkraha Nadi
Bakara Nuna Nadi
Badojhoda Khola
INDIA
INDIA
Coordinate System: Mutm 84
Projection: Transverse Mercator
Datum: Everest 1830
False Easting: 500,000.0000
False Northing: 0.0000
Central Meridian: 84.0000
Scale Factor: 0.9999
Latitude Of Origin: 0.0000
Units: Meter
Scale 1:250,000
20 10 0 20 Km
840000
870000
900000
930000
2970000
2940000
Department of Water Resources and Irrigation
Water Resources Project Preparatory Facility(WRPPF)
IRRIGATION MASTER PLAN, 2019
Kankai Multipurpose Project
Prepared By
ADB
LAHMEYER INTERNATIONAL
NIRAS

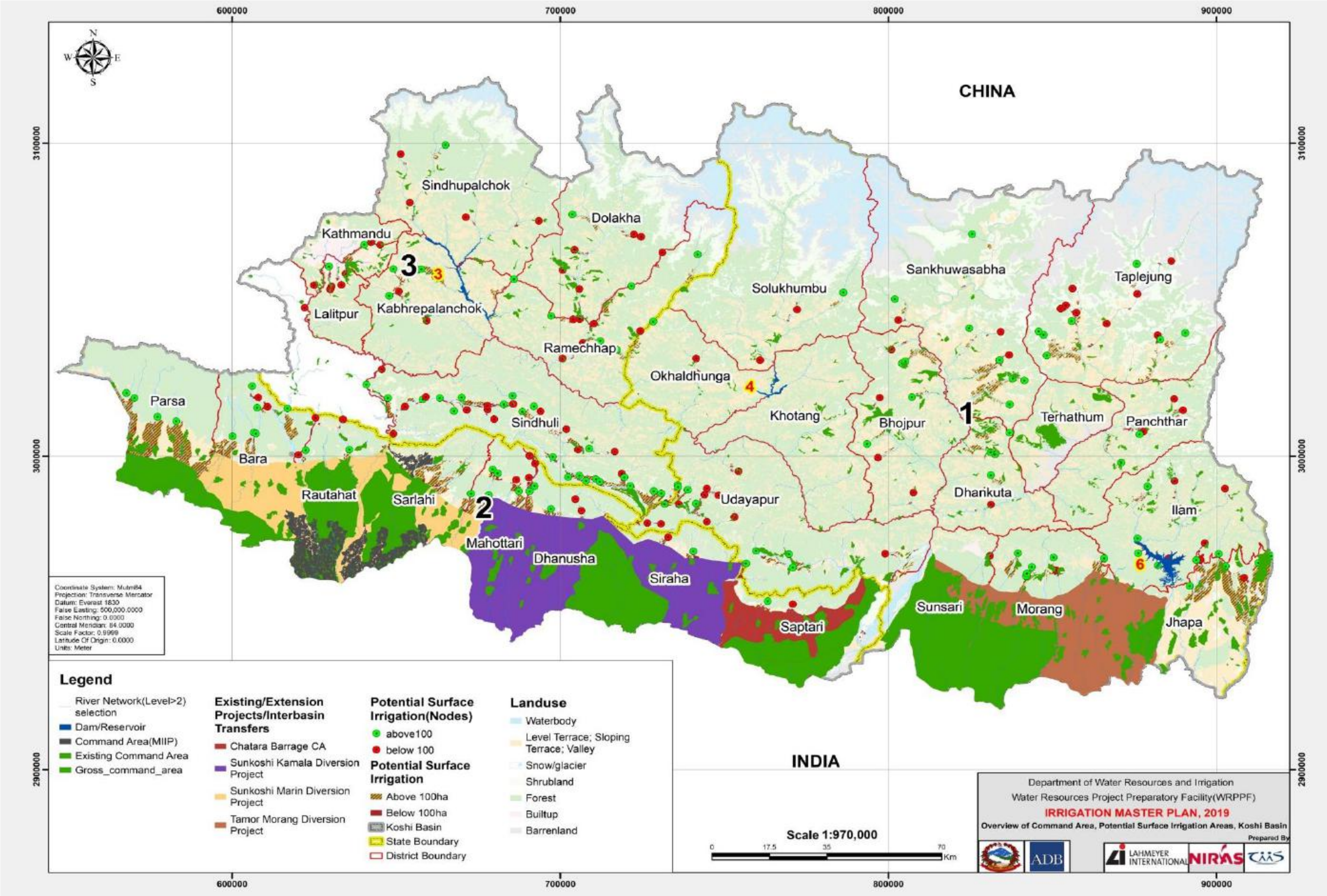


Project Name
Chatara Barrage CA
Reservoir No. -
Type Weir
Height (m) 13
Tunnel Length (km) -
Tunnel Diameter (m) -
Discharge (m3/s) 72.0
Gross Head (m) -
Installed Capacity (MW) -
Gross Command Area (ha) 87,516
Total Net Irr. Area (ha) 66,482
Rehab. of Existing Areas (ha) 47,993
Extension New Areas (ha) 18,489
Legend
Dam
Road Network
River Network
District Boundary
Main Canal
Chatara Barrage CA
Existing Command
National Boundary
Koshi Basin
Landuse
Waterbody
Level Terrace; Sloping Terrace; Valley
Shrubland
Forest
Builtup
Barrenland
Agriculture
Sindhuli
Udayapur
Khotang
Bhojpur
Sunsari
Morang
Saptari
INDIA
Irrigation Intake
WL-140m
KAMALA S IP
PUMP CANAL IP
KOSHI WEST CANAL IP
CHANDRA CANAL IP
SUNSARI-MORANG P-3 IP
Sapsup Khola
Sunkoshi Nadi
Pikhuwa Khola
Ekhuwa Khola
Arun Nadi
Buwa Khola
Baluwa Khola
Siswa Khola
Koshi Bhanggala
Balan Khola
Chahaka Khola
Khuti Nadi
Trijuga Nadi
Purano Saptakoshi Nadi
Purano Saptikoshi Nadi
Saptakoshi Nadi
Chapin Dhar
Balan Nadi
Bihul Nadi
Kharak Nadi
Khado Nadi
Sunsari Khola
Tefiya Khola
Budhi Khola
748000
776000
804000
832000
3000000
2972000
2944000
Coordinate System: Mutm 84
Projection: Transverse Mercator
Datum: Everest 1830
False Easting: 500,000.0000
False Northing: 0.0000
Central Meridian: 84.0000
Scale Factor: 0.9999
Latitude Of Origin: 0.0000
Units: Meter
Scale 1:300,000
20 10 0 20 Km
Department of Water Resources and Irrigation
Water Resources Project Preparatory Facility(WRPPF)
IRRIGATION MASTER PLAN, 2019
Chatara Barrage CA
Prepared By


Legend
River Network(Level>2)
State Boundary
Karnali Basin
District Boundary
Dam/Reservoir
Existing Commad Areas
Potential Surface Irrigation(Nodes)
above 100
below 100
Potential Surface Irrigation
above 100
below 100
Existing/Extension Projects/Interbasin Transfers
Bheri Babai Diversion Multipurpose Project
Karnali Diversion Project
Mahakali Irrigation Project
Rani Jamara Kuleriya Irrigation Project
Rapti Kapilbastu Diversion Project
Sikta Irrigation Project
Landuse
Shrubland/Grassland
Agriculture- Valley, Tar, Terai
Forest
Residential
Barrenland
Sand/Gravel/Boulders
Agriculture- Sloping Terrace
Agriculture- Level Terrace
Snow/glacier
CHINA
INDIA
Humla
Darchula
Bajhang
Mugu
Baitadi
Bajura
7
Dadeldhura
Jumla
Kalikot
Dolpa
Doti
Achham
6-Karnali
Kanchanpur
Dailekh
Jajarkot
Kailali
Rukum_W
Rukum_E
Surkhet
Salyan
Bardiya
Rolpa
5
Pyuthan
Banke
Dang
Scale 1:1,200,000
Department of Water Resources and Irrigation
Water Resources Project Preparatory Facility (WRPPF)
IRRIGATION MASTER PLAN, 2019
Overview of Command Area, Potential Surface Schemes, Karnali Basin
Prepared By



CHINA
INDIA
Legend
River Network(Level>2) selection
District Boundary
State Boundary
Narayani Basin
Existing Command Area
Potential surface Irrigation(Nodes)
above 100ha
below 100ha
Potential Surface Irrigation
above 100ha
below 100ha
Existing/Extension Projects/Interbasin Transfers
Kaligandaki Tinau Diversion Project
Rapti Kapilbastu Diversion Project
Landuse
Shrubland/Grassland
Forest
Agriculture- Sloping Terrace
Residential
Barrenland
Agriculture- Valley, Tar, Terai
Sand/Gravel/Boulders
Agriculture- Level Terrace
Snow/Glacier
4-Gandaki
5
3
Mustang
Manang
Myagdi
Baglung
Parbat
Kaski
Lamjung
Gorkha
Rasuwa
Gulmi
Syangja
Tanahu
Dhading
Nuwakot
Palpa
Nawalparasi_E
Kapilbastu
Rupandehi
Nawalparasi_W
Chitawan
Makawanpur
Scale 1:890,000
Department of Water Resources and Irrigation
Water Resources Project Preparatory Facility(WRPPF)
IRRIGATION MASTER PLAN, 2019
Overview of Command Area, Potential Surface Irrigation Areas, Narayani Basin
Prepared By



CHINA
INDIA
Sindhupalchok
Dolakha
Kathmandu
Lalitpur
Kabhrepalanchok
Ramechhap
Solukhumbu
Sankhuwasabha
Taplejung
Okhaldhunga
Khotang
Bhojpur
Terhathum
Panchthar
Parsa
Bara
Rautahat
Sarlahi
Sindhuli
Udayapur
Dhankuta
Ilam
Mahottari
Dhanusha
Siraha
Saptari
Sunsari
Morang
Jhapa
1
2
3
3
4
6
600000
700000
800000
900000
3100000
3000000
2900000
Coordinate System: Mutm84
Projection: Transverse Mercator
Datum: Everest 1830
False Easting: 500,000.0000
False Northing: 0.0000
Central Meridian: 84.0000
Scale Factor: 0.9999
Latitude Of Origin: 0.0000
Units: Meter
Legend
River Network(Level>2) selection
Dam/Reservoir
Command Area(MIIP)
Existing Command Area
Gross_command_area
Existing/Extension Projects/Interbasin Transfers
Chatara Barrage CA
Sunkoshi Kamala Diversion Project
Sunkoshi Marin Diversion Project
Tamor Morang Diversion Project
Potential Surface Irrigation(Nodes)
above100
below 100
Potential Surface Irrigation
Above 100ha
Below 100ha
Koshi Basin
State Boundary
District Boundary
Landuse
Waterbody
Level Terrace; Sloping Terrace; Valley
Snow/glacier
Shrubland
Forest
Builtup
Barrenland
Scale 1:970,000
0 17.5 35 70 Km
Department of Water Resources and Irrigation
Water Resources Project Preparatory Facility(WRPPF)
IRRIGATION MASTER PLAN, 2019
Overview of Command Area, Potential Surface Irrigation Areas, Koshi Basin
Prepared By