Draft Final Report
On
Main Irrigation Canal Operation Plan
For
Crops
In
Kankai Irrigation System

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ACRONYMS

AF	:	Additional Fund
AMIS	:	Agency Managed Irrigation System
AO	:	Association Organisor
CR	:	Cross Regulator
DB	:	Division Box
DOI	:	Department of Irrigation
DTO	:	Direct Tertiary Outlet
FAO	:	Food and Agriculture Organisation
FC	:	Field Channel
FGD	:	Focus Group Discussion
GO	:	Gate Operator
HR	:	Head Regulator
IMD	:	Irrigation Managent Division
IMT	:	Irrigation Management Transfer
ISF	:	Irrigation Service Fee
IWR	:	Irrigation Water Requirement
IWRMP	:	Irrigation and Water Resources Management Project
KIS	:	Kankai Irrigation System
MIC	:	Main Irrigation Canal
NARC	:	Nepal Agriculture Research Council
SE	:	Sub-engineer
SIC	:	Secondary Irrigation Canal
SMU	:	Sub project Management Unit
TIC	:	Tertiary Irrigation Canal
TS	:	Terminal Structure
VDC	:	Village Development Committee
WMU	:	Water Management Unit
WUA	:	Water Users Association
WUG	:	Water Users Group

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1 INTRODUCTION

1.1 Project Background

The World Bank has had a long-standing role in the development of Nepal's irrigation and water resources sector. In order to continue this role, the World Bank and The Government of Nepal have signed the agreement of Irrigation and Water Resources Management Project (IWRMP) on the 31st January, 2008. The first phase of the agreement ended on June 30, 2013 and extension of one year till June 30, 2014 was done. In December 2012, the GoN requested to the World Bank to provide an additional financing of US$50 million in order to complete the original commitment of rehabilitation and internalize, institutionalize and replicate the gains made so far in both irrigation water management and agricultural practices. As a result, Additional Financing (AF) of the project signed with the start date of July 2014 and a closing date of June 30, 2018, with a credit support of US$ 30 million and Grant support of US$ 20 million. The IWRMP consists of four components as follows:

(A) Irrigation Infrastructure Development and Improvement
(B) Irrigation Management Transfer
(C) Institution and Policy Support for Improved Water Management
(D) Integrated Crop and Water Management

Among above components, the overall objective of Component B is to improve irrigation service performance and service delivery to selected irrigation systems in the Terai through the completion and consolidation of Irrigation Management Transfer (IMT) to the relevant Water Users Association (WUAs).

The management transfer to the WUAs would mean turning over the governance, management, and maintenance responsibilities in agreed upon parts of an irrigation system for sustainable use by them.

The principal outputs of Component B are envisaged as:

- Efficient and equitable irrigation service delivery by financially and institutionally sustainable WUAs;
- Improved physical performance of the selected irrigation schemes;
- Reliable bulk water service delivery by Department of Irrigation (DOI) in line with the Transfer Agreement, and
- Formation and strengthening of WUAs to become self-governing, self –financing, and self-regulating organization;

Component B is presently supporting 4 legally empowered WUAs which are responsible for the operation and maintenance of 4 existing sub-systems within 4 Agency Managed

Irrigation Systems (AMIS). These four sub-projects are Kankai Irrigation System (7,000 ha), Sunsari Morang Irrigation System Sitagunj Branch (8,000 ha), Narayani Irrigation System (Block-8) 3000 ha and Mahakali Irrigation System First Phase (5100 ha). Activities planned to achieve the goal of sustainable irrigation management concept is focused on infrastructure development, water management, institutional development and mitigation measures for social and environmental impacts on the irrigation system. The water management and WUA development works of these project supported sites is continued in the Additional Financing (AF) period of the project. With the new agreement of AF, DOI is going to implement the second phase of IMT program in Ramgunj (7800 ha) branch of Sunsari Morang Irrigation Project, Block-2 (3000 ha) of Narayani Irrigation Project and Phase-II (5700 ha) of Mahakali Irrigation Project.

This report is prepared in an attempt to part of **Stage 3: Institutional Strengthening for IMT** action plan for the implementation of IMT in Project Implementation Manual of IWRMP, and to part of TOR for TA-B under IWRMP.

1.2 Objective

The principal objective of this work is to prepare Main and Branch Canal Operation Plan of Kankai Irrigation System for all irrigation seasons such that Irrigation Management Division (IMD) of Department of Irrigation for Kankai Irrigation System (KIS) and WUA of KIS is able to share water entitlement in accordance with IMT agreement for sustainable use in all irrigation season.

1.3 Scope of Works

Present works have been confined to preparation of Main Canal Operation Plan of KIS for all Irrigation Seasons that include Monsoon, Winter and Spring crops.

2 SUB PROJECT DESCRIPTION

2.1 Historical Development

Kankai Irrigation System (KIS) was initiated in year 1970 with a loan assistance of Asian Development Bank (ADB). The construction works was implemented in two phases. The first phase was started in year 1971 to provide irrigation facilities in 5000 ha, which was completed in 1981. The second phase was started in 1980 to extend irrigation facilities to another 3000 ha; but the irrigation facilities was extended up to 2000 ha only by year 1991. Remaining 1000 ha has very limited infrastructure development up to hydraulic layer of tertiary canal. Thus total command area developed so far is 7000 ha in KIS.

2.2 Physiography

Kankai Irrigation System (KIS), lies in the eastern terai (plain) of Nepal, between the latitudes of 26 to 27 degree North and longitude of 87 to 88 degree East. The elevation of the system varies from 120 m in North to 75 m in the South. The command area of the system is surrounded by India in the South, Kankai River in the east, Krishna River in the west, and Main canal in the north. Kankai River is the source of water of the system and is of perennial type. The catchment area of the Kankai River at headworks site is 1190 sq. km. The river originates from Mahabharat Mountain Range flows down through terai plain and crosses the Indo Nepal Boarder and finally merges into River Ganges in India. The general Layout of KIS is presented in Figure 2-1 as below.

2.3 Location and accessibility

Kankai Irrigation System lies between the latitudes of 26 to 27 degree North and longitude of 87 to 88 degree East. The command area is covered by Satashidham, Shivgunj, Paanchgachhi, Mahabhara, Dharampur, Topgachhi and Baigundhura Village Development Committee (VDC) of Jhapa district. The main canal crosses E-W Highway at its head reach. The KIS is connected with gravel road throughout the command area. The head reach of command area is located within nearest city Damak and Birtamod. Nearest airport is located at Bhadrapur, some 50 km east of command area.

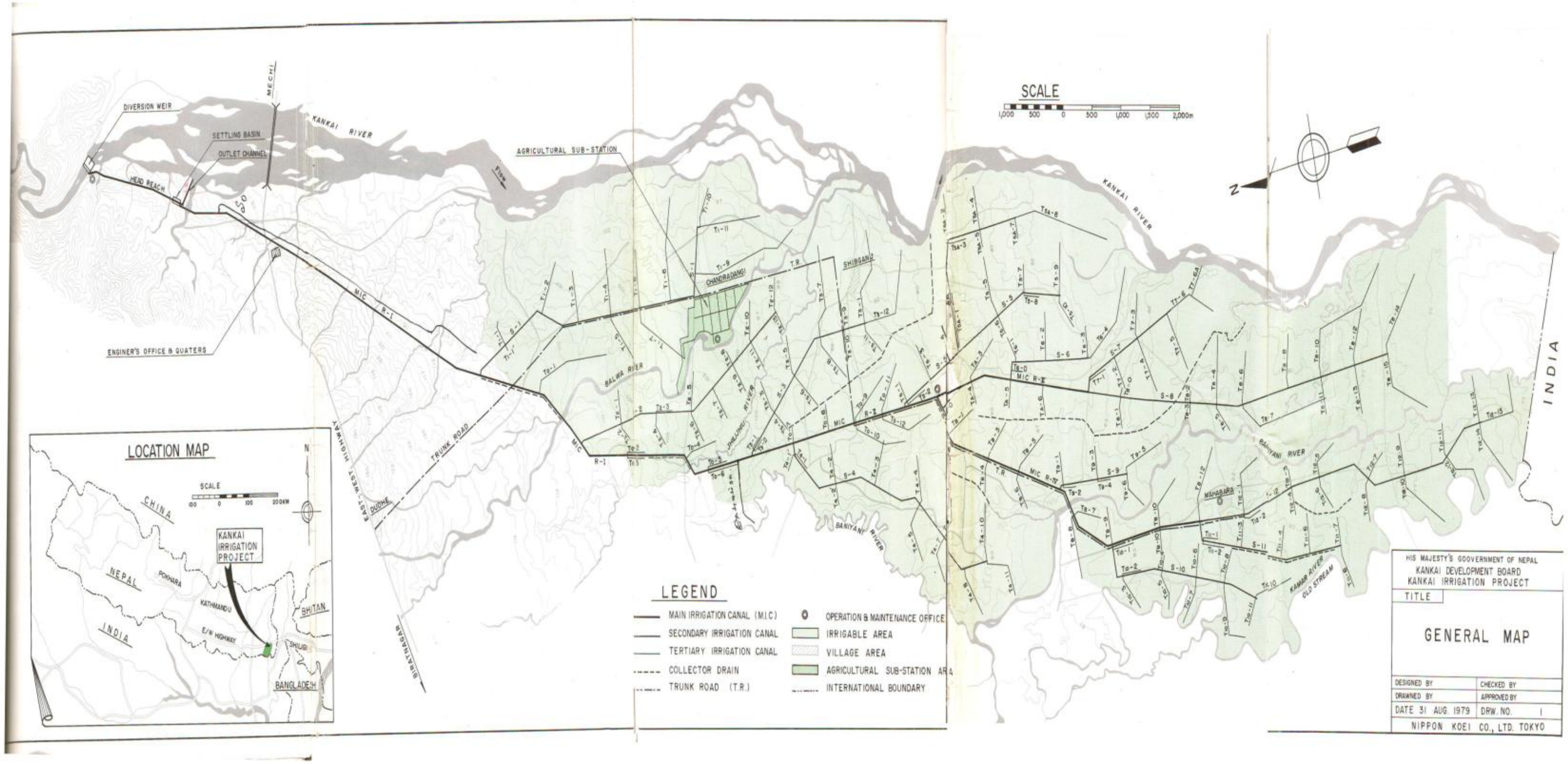


Figure 2-1: General Layout of KIS (Reach-I to Reach-IV)

2.4 Headworks and Irrigation Facility

Kankai Irrigation System (KIS) has fixed weir type headworks designed across Kankai River at Domukha (an historical place of religious importance) of Jhapa District. The weir is located around 3 km upstream of East-West Highway (Kakai) Bridge over Kankai River. The length and height of weir in place is 126 m and 1.84 m respectively. The undersluice located to the right bank of Kankai River along headworks axis is designed to pass upto 600 cumces discharge downstream. Main canal offtaking upstream of undersluice has idle length of 1570 m until the location of Sardare Escape structure comes along its flow course.

KIS has named main canal as Main Irrigation Canal (MIC), secondary canals offtaking from MIC as Secondary Irrigation Canal (SIC) and tertiary canals offtaking from SIC as Tertiary Irrigation Canal (TIC). The TIC is also named for Direct Tertiary Outlets (DTO) from MIC. Please refer Figure 2-2.

Kankai Irrigation System has developed its MIC into five reaches over its two phases of development. The canal network in Reach-I through Reach-IV has been developed in its first phase down up to tertiary canal level. Reach-V in KIS is extension part developed only partly in second phase. The idle length and Reach-I of MIC is concrete lined in KIS, whereas other four reaches are unlined. The design features of MIC including groups of SICs and DTOs in a given Reach of MIC is presented in Table 2-1.

The idle length in the head reach of MIC is although designed for 10.6 cumecs, the canal siphon in place at the head reach is however designed only for 10.15 cumecs. Therefore, designed discharge at the head of Reach-I, starting at Sardare Escape structure, is 10.15 cumecs for its total length of 11.5 km. The designed discharge in MIC at the head of Reach-II is 4.55 cumecs, whereas Reach-III and Reach-IV bifurcates at the same location in MIC with designed discharge of 1.95 cumecs each. The Reach-V bifurcates at chainage 9+886 in Reach-I of MIC have designed capacity of 7.225 cumecs as per report.

Table 2-1: MIC Design Features with offtaking SICs and DTOs

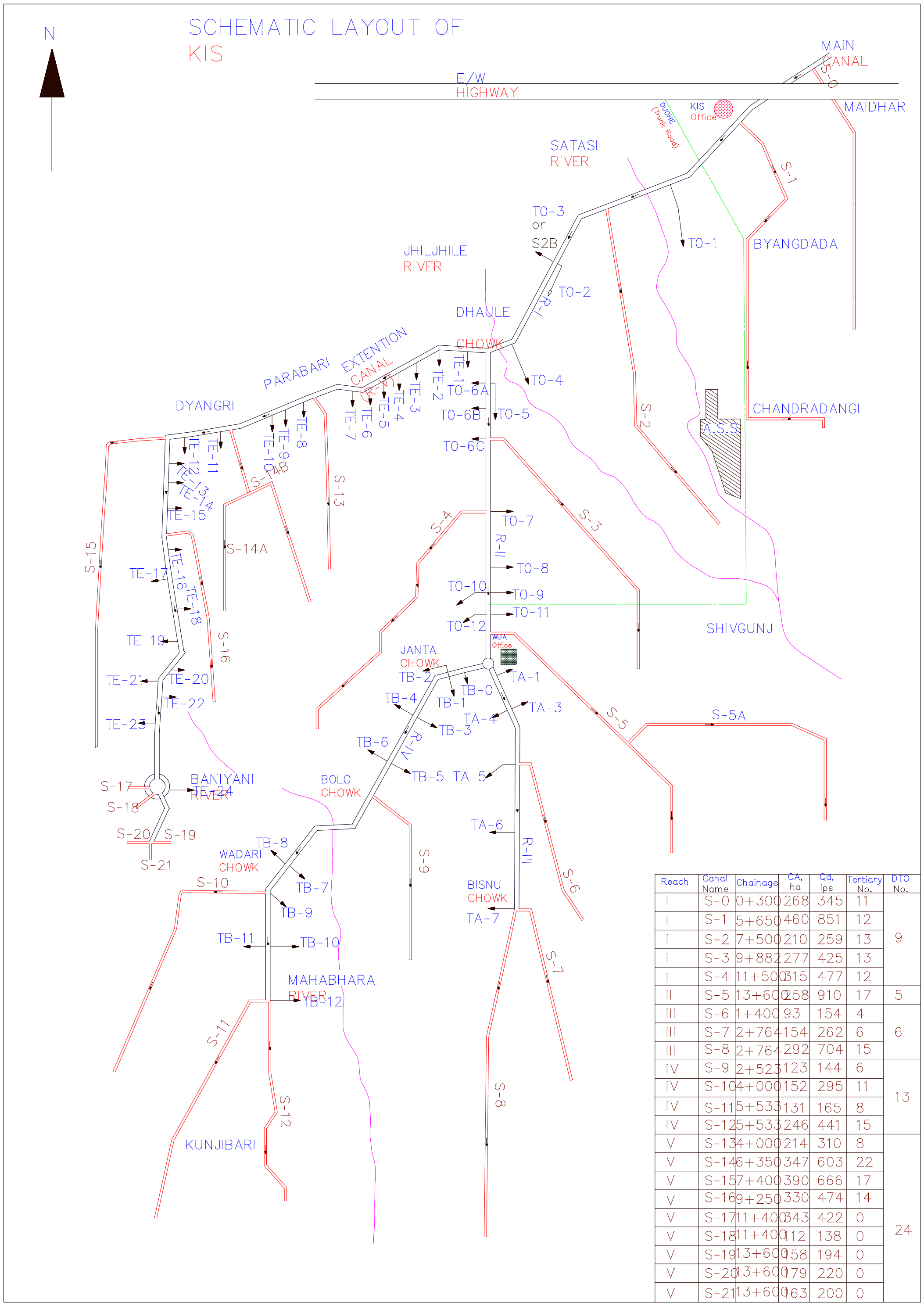
MIC Reach	Chainage in MIC	Canal Type	Length (m)	Long. Slope, m/m	Designed Discharge, m^3/sec	Name of offtaking SICs	Name of offtaking DTOs
Head Reach (Idle Length)		Concrete Lined	1570				
Reach-I	0+000	Concrete Lined	11500	1 : 1000	10.15	S0, S1, S2, S3 and S4 (5 nos)	T01 to T07 (7 nos)
Reach-II		Unlined	2600	1 : 1850	4.55	S5 (1 nos)	T08 to T012 (5 nos)
Reach-III		Unlined	2767	1 : 1540	1.95	S6, S7 and S8 (3 nos)	TA1 to TA6 (6 nos)
Reach-IV		Unlined	5533	1 : 1540	1.95	S9, S10, S11 and S12 (4 nos)	TB0 to TB12 (12 nos)
Reach-V	9+886	Unlined	11600		7.225	S13, S14,	TE1 to TE23

(Extension Canal)						S15 and S16 (4 nos)	(23 nos)
Reach-V (Undeveloped Length 2.2 Km)						S17, S18, S19, S20 and S21 (5 nos)	
		Reach Total	**34000**				

*Source: Project Completion Report and SMU

There area 22 SICs and 287 TICs (including 54 DTOs) in KIS. Out of which, there are 13 SICs (S0 to S12) and 31 DTOs branching off from MIC covering Reach-I to Reach-IV. Reach-V has therefore 9 SICs (S13 to S21) and 23 DTOs branching off from MIC. The design features of MIC including groups of SICs and DTOs in respective reach of MIC are categorized in Table 2-1 for reference.

Further, TICs offtaking from SIC are designed to space at an average interval of 600 m. Moreover, the Field Channel (FC), also known as supply ditch, offtaking from TIC is provisioned with precast Division Boxes (DB) at an average interval of 100m along TIC length. The command area to be covered by FC assumed in design is 10 ha. However, at most of the places the DB is found non-existing with lack of FC in majority of places. Consequently, localized breach of TICs and field to field irrigation in absence of FC are in practice in KIS even in winter and spring irrigation seasons.



Reach	Canal Name	Chainage	CA, ha	Qd, lps	Tertiary No.	DTO No.
I	S-0	0+300	268	345	11	9
I	S-1	5+650	460	851	12	
I	S-2	7+500	210	259	13	
I	S-3	9+882	277	425	13	
I	S-4	11+500	315	477	12	
II	S-5	13+600	258	910	17	5
III	S-6	1+400	93	154	4	6
III	S-7	2+764	154	262	6	
III	S-8	2+764	292	704	15	
IV	S-9	2+523	123	144	6	13
IV	S-10	4+000	152	295	11	
IV	S-11	5+533	131	165	8	
IV	S-12	5+533	246	441	15	
V	S-13	4+000	214	310	8	24
V	S-14	6+350	347	603	22	
V	S-15	7+400	390	666	17	
V	S-16	9+250	330	474	14	
V	S-17	11+400	343	422	0	
V	S-18	11+400	112	138	0	
V	S-19	13+600	158	194	0	
V	S-20	13+600	179	220	0	
V	S-21	13+600	163	200	0	

Figure 2-2: Schematic Layout of KIS showing SICs and DTOs with MIC reach bifurcation

2.5 Command Area

The KIS has although developed irrigation command of 5000 ha in its first phase and 2000 ha in second phase, the SMU/IWRMP in Phase-I has revised (during F/Y 2012/13) command area with WUA of KIS while preparing for parcellary map of respective offtaking canals from MIC. The details of originally designed and revised command area of respective offtake from MIC is obtained from Sub-project Management Unit (SMU) of KIS and presented in Table 2-2 for reference.

Table 2-2: Details of Command Area and Head Duty of Offtaking Canals from MIC

Reach	Chainage in MIC	Canal Name	Designed Canal Length	Designed Command area	Revised Command area	Designed Discharge	Designed Canal Head Duty	Existing Canal Head Duty	Remarks
			Km	Ha	Ha	l/s	l/s/ha	l/s/ha	
I	0+300	S0	4.65		268	345		1.29	
I	5+650	S1	5.8	736.1	460	851	1.16	1.85	
I	6+619	T0-1		72.7	63	83	1.14	1.32	
I	7+590	S2	3.9	226.6	210	259	1.14	1.23	
I	8+397	S2B		24.8	114	150		1.32	
I	8+397	T0-2		16.6	15	19	1.14	1.27	
I	9+535	T0-4		27.8	25	32	1.15	1.28	
I	10+782	S3	3.4	372	277	425	1.14	1.53	
I	11+500	T0-7		16.6	19	19	1.14	1.00	
II	0+648	T0-8		17.7	14	20	1.13	1.43	
II	1+110	T0-9		45.5	20	52	1.14	2.60	
II	1+600	T0-11		33.8	12	39	1.15	3.25	
I	11+500	S4	4.6	417.5	315	477	1.14	1.51	
I	9+897	T0-5		10.1	8	12	1.19	1.50	
I	9+897	T0-6		37.2	21	45	1.21	2.14	
II	12+610	T0-10		22.4	31	26	1.16	0.84	
II	1+600	T0-12		27.6	53	31	1.12	0.58	
IV	0+490	TB-2		23	6	26	1.13	4.33	
IV	1+250	TB-4		28.4	10	32	1.13	3.20	
IV	1+850	TB-6		19.2	24	22	1.15	0.92	
II	2+100	S5	6.6	798	258	910	1.14	3.53	
III	1+400	S6	2.15	136.1	93	154	1.13	1.66	
III	0+050	TA-1			20	25		1.25	
III	0+700	TA-3		25.8	17	29	1.12	1.71	
III	2+764	S7	8.7	230.2	154	262	1.14	1.70	
III	2+767	S8			292	704		2.41	
IV	2+523	S9	1.2	126.5	123	144	1.14	1.17	
III	0+700	TA-4		21.7	25	24	1.11	0.96	
III	1+400	TA-5		19	18	22	1.16	1.22	
III	2+716	TA-6		22.1	20	25	1.13	1.25	
III	2+764	TA-7			27	33		1.22	
IV	0+150	TB-0		20.3	13	23	1.13	1.77	
IV	0+490	TB-1		29.3	26	33	1.13	1.27	

IV	1+250	TB-3		32.9	31	38	1.16	1.23	
IV	1+850	TB-5		33.5	51	38	1.13	0.75	
IV	2+900	TB-7		24.3	21	28	1.15	1.33	
IV	4+000	TB-9		19.6	11	22	1.12	2.00	
IV	4+850	TB-10		67.1	37	74	1.10	2.00	
IV	4+000	S10	3.23	259.3	152	295	1.14	1.94	
IV	2+900	TB-8		21.9	34	25	1.14	0.74	
IV	5+530	S11	3.2	144.4	131	165	1.14	1.26	
IV	4+850	TB-11		14.8	26	17	1.15	0.65	
IV	5+533	S12	1.11		246	441		1.79	
IV	5+533	TB-12		45.8	19	52	1.14	2.74	
V	4+000	S13			214	310		1.45	
V	0+350	TE-1			50	84		1.68	
V		TE-2			5	7		1.40	
V		TE-3			10	18		1.80	
V		TE-4			65	98		1.51	
V		TE-5			57	90		1.58	
V		TE-6			131	200		1.53	
V		TE-7			98	150		1.53	
V		TE-8			58	90		1.55	
V		TE-9			23	39		1.70	
V	6+350	S14			347	603		1.74	
V		TE-10			70	119		1.70	
V	7+400	S15			390	666		1.71	
V		TE-14			15	22		1.47	
V		TE-15			21	33		1.57	
V		TE-16			16	30		1.88	
V		TE-19			21	32		1.52	
V		TE-21			29	47		1.62	
V	9+250	S16			330	474		1.44	
V		TE-11			60	87		1.45	
V		TE-12			10	10		1.00	
V		TE-13			23	27		1.17	
V		TE-17			22	33		1.50	
V		TE-18			41	49		1.20	
V		TE-20			35	51		1.46	
V		TE-22			14	20		1.43	
V		TE-23			30	54		1.80	
V	11+400	S17			343	422		1.23	
V	11+400	S18			112	138		1.23	
V	13+600	S19			158	194		1.23	
V	13+600	S20			179	220		1.23	
V	13+600	S21			163	200		1.23	
	Total	**MIC**	**34**	**7000**	**6950**	**10150**	**1.43**	**1.44**	

* Source: SMU_KIS and Project Completion Report

It is also reported by SMU of KIS that DTO, T0-0 is renamed as S2B upon extension of command area. Also command area of DTO, T0-3 is merged to S2B SIC command in the revision works. Further, from Table 2-2 it may be noted from the pattern of boarder shedding that DTOs have been considered operating as grouped to respective SIC in order to irrigate area bounded by common topography and hydrology. Therefore, grouping of DTOs exactly do not follow individual Reach of MIC. The Table 2-2 above also reflects that duty at the head of SICs and TIC of DTOs offtaking from MIC is originally designed at 1.14 lps/ha. The duty at the head of Reach-I in MIC for 7000 ha is observed to be 1.45 lps/ha. Moreover, the duty designed at the head of TICs offtaking from respective SIC is 1.0 lps/ha as per reports.

2.6 Irrigation Efficiencies

There is no clear documentation on assumed efficiencies of MIC, SIC and TIC in KIS. It is however learnt from report that there is continuous flow of water from MIC to its respective offtakes. Therefore, irrigation efficiency of MIC for its full development of 8000 ha in KIS is assumed 90% as tabulated below in Table 2-3. Further, considering current development of 7000 ha, the MIC efficiency is calculated as 80%.

Table 2-3: MIC Efficiency

Design Discharge at Sardare Intake, 10150 lps
Command area, 7000 ha (Phase-I and II developed area)
Command area, 8000 ha (Phase-I and II developed area including 1000 ha undeveloped area)

Duty at Sardare Escape	Duty at head of Sec/DTO	Efficiency of MIC	Remarks
lps/ha	lps/ha		
I	II	=1-{(I-II)/I}	
1.45	1.14	0.80	Phase-I and II developed area
1.25	1.14	0.91	Phase-I and II developed area including 1000 ha undeveloped area

*Source: SMU_KIS and Project Completion Report

As we know, the Reach-I is lined upto 11.5 km (11.5/34*100 = 34%) out of 34 km length of MIC Reaches. The remaining 66% length of main canal in unlined. The irrigation efficiencies of lined canal fairly maintained is however about 95%. The irrigation efficiency of unlined canal fairly maintained and flowing continuously is no less than 80%. Therefore, MIC efficiency, to conservative side, is considered as 85% for further use in this report.

Further, efficiency of SIC in KIS is assumed to be 85% as well as combined efficiency of TIC and Field Channel (FC) is assumed to be 80% for further use in this report. Field application efficiency of paddy crop and dry foot crop is assumed to be respectively 90% and 70% based on experience of similar irrigation system in Terai area of Eastern Nepal.

2.7 Flow control structure

As we know, the performance of water delivery through control structures in distribution system managed by Water Users Association (WUA) is as essential as main system managed by agency, apart from on-farm water management by farmer. In this line, flow control structure helps to solve the problem as to how water can be distributed in a more transparent and spatially equitable manner in order to fill the institutional vacuum at the on-farm system level. It gives the water users the following benefits as:

- The time spent by water users for getting their turns for irrigation decreases several times, resulting in considerable time savings;
- Actual per unit of area water supply by layers of canal becomes more balanced and uniform showing more spatial equity among hierarchy of canals, especially for those in tail reaches;
- Crop yields increase in most TIC, especially those in middle and tail reach;
- Net income of the tail enders increase; and
- The overall number of dispute about irrigation turns declines; though dispute about water volumes increase due to fewer privileges in irrigation water supply enjoyed by the upstream water users.
- Irrigation Service Fee (ISF) collection improves due to a greater satisfaction by water users, especially those in middle and tail reach.

The inflow to MIC Reach-I in KIS is equipped with manually operated vertical sliding gates at Sardare Escape location called Sardare Intake. There are series of manually operated vertical sliding gates as Cross Regulators (CRs) suitably placed along MIC to set target water level for discharge into respective SICs and DTOs located upstream of it. The CRs are also installed at the bifurcation of Reach-III, IV and V in MIC. Along SIC, series of CRs are also in place to control water level upstream of it in order to have desired discharge to respective lower order TIC.

There are provision of manually operated vertical sliding Head Regulators (HRs) at the intake of respective SIC and DTOs to regulate discharge through it in KIS. Further, discharge measuring structures located downstream of HR at the head of respective SIC and DTO is equipped with Parshell Flume in Reach-I to Reach-IV, except for S0 in Reach-I, of MIC. In Reach-V of MIC, only SICs starting from S14 to S16 have facility of Parshell Flumes. The S13 and S17 through S21 including DTOs starting from TE1 through TE23 have only HRs regulates and measures desired/intended discharge.

There are escape structures in place along Reaches of MIC to safely dispose off not wanted irrigation water either due to sudden heavy precipitation in command area or due to maintenance that may otherwise be required at downstream reach of canal network.

There are also provisions of Terminal Structures (TS) placed suitably at the end of TIC offtaking at tail end of SIC. However, on account of lack of proper internal drainage system in place has led to breach and disruption of full or part of TIC in KIS command area over course of time. Further, there is no documentation of TSs as reported by SMU of KIS. Table 2-4 below shows list of principal flow control structures along Reaches of

MIC for reference. List of hydraulic structures along MIC is tabulated in Annex-A for reference.

Table 2-4: Principal flow control structures in MIC

Reach	Chainage	Structure	Gate (WxH)	Designed Discharge, m^3/s	Canal length (Km)	Full Supply Depth (m)	Remarks
R-I (11.5 Km)	0+000	HR for MIC	1.55x1.8@2	10.15			
	0+016	Syphon-1	1.9x1.9x194.5	10.15			
	0+300	HR for S0	1.3x1.15	0.345	4.65		
	0+743	CR	1.5x1.8@2				
	1+239	Syphon-2	1.9x1.9x52	10.15			
	5+240	Spillway		2.5			Overflow spillway No.1 (with gate)
	5+650	**HR for S1**	**1.2x1.1**	**0.851**	**5.8**		
	5+653	CR-1	1.65x1.8@2	9.2		1.598	S1 Check
	7+039	Spillway		2.5			No.1 Spillway
	7+055	Syphon-3	1.9x1.8x183	9.11			
	7+590	HR for S2	0.7x0.9	0.259	3.9		
	7+593	CR-2	1.65x1.8@2	8.77		1.47	S2 Check
	8+397	Oulet for S2B		0.15			No HR
	9+222	Spillway		3.5			No.1 bifurcation spillway (with gate)
	9+637	Syphon-4	1.9x1.8x85	8.67			
	9+886	HR Left					
	9+882	HR Right	1.65x1.8@2	10			**R-V offtake (Bifurcation)**
	10+782	**HR for S3**	**1.0x0.8**	**0.425**	**3.4**		
	10+785	CR-3	1.65x1.5@2	5.7		1.415	S3 Check; With Drop
	9+897	**T06**	**0.4x0.6**	**0.045**			
	11+500	**HR for S4**	**1.0x0.8**	**0.477**	**4.6**		**With Bridge (BR)**
R-II (2.6 Km)							
	13+600	**HR for S5**	**1.0x1.1**	**0.91**	**6.6**		
	13+530	CR-5	1.65x1.4@2	3.62		1.374	S5 Check
	14+060	Spillway		3.2			Overflow
	2+600	HR Left					
	14+083	HR Right	1.028x1.15@2	3.62		1.252	
R-III (2.8 Km)							
	1+400	HR for S6	0.4x0.9	0.154	2.15		
	1+430	CR-6	1.5x1.1@2	1.34		0.92	S6 Check; With Drop
	2+764	HR for S7	0.7x0.9	0.262			

	2+767	CR/HR for S8	1.2x1.1@1	0.704	8.7		**S7 Check; With Drop (Bifurcation)**
R-IV (5.5 Km)							
	2+523	HR for S9	0.6x0.7	0.144	1.2		
	2+526	CR-9	1.5x1.1@1	1.69			S9 Check; With Drop
	2+720	Spillway		1.6			No.2 Spillway (With Gate)
	2+737	Syphon-4	1.1x1.1x108.5	1.95			
	4+000	HR for S10	0.7x0.9	0.295	3.23		
	4+030	CR-10	1.2x1.15@1	1.51			S10 Check; With Drop
	5+530	HR for S11	0.7x0.9	0.165	3.2		
	5+533	HR for S12	1.2x1.1@1	0.441	1.11	0.765	**S11 Check; CR-10 (Bifurcation)**
R-V (11.4 Km)	4+000	HR for S13					
		CR				0.688	
	6+350	HR for S14					
		CR				0.575	
	7+400	HR for S15		0.666			
		CR					
	9+250	HR for S16		0.474			
		CR					
	11+400	HR for S17		0.422			
		HR for S18		0.138			
BP of Extension undeveloped area		CR					EP of R-V
	13+600	HR for S19		0.194			
	13+600	HR for S20		0.22			
	13+600	HR for S21		0.2			

*Source: Project Completion Report

In apropos, methods to control flow mainly depend upon sufficiency/deficiency of available water to meet peak/off-peak demand at offtakes of TIC. Depending upon availability of water and demand (i.e., peak/off-peak) sought from agricultural plants; flow can be continuous, intermittent and rotational.

Intermittent flow in canals shares desired discharge along its hierarchical/hydraulic level that is opened at the same time. Whereas, rotational flow shares discharge and time along a (group of) canal level that is opened at different time. The flow in an irrigation system can be rotated in duration and/or frequency contributing to volume of water supplied and/or desired.

Existing flow controls of irrigation canals in KIS is presented in Table 2-5 and Table 2-6 for reference. It can be observed from Table 2-5 that discharge monitoring and measuring structure, Parshell Flume located downstream side of Head Regulator (HR) is placed at the head of respective SICs and DTOs. There is however no Parshell Flume in DTOs along Reach-V of MIC. Similarly, there is no Parshell Flume in place at the head of S0 and S17 to S21 of SIC in Reach-I and Reach-V respectively of MIC. Therefore, discharge is controlled solely by HR in place at the head of respective offtakes in Reach-I and V of MIC.

Table 2-5: Type of discharge control by canal level in KIS

MIC Reaches	Hydraulic level of canal head	Type of Discharge control					Remarks
		Gated	Flow Type	Operation Type	Ungated	Flow Type	
	MIC	Adjustable sliding gate	Orifice flow	Maually operated			
Reach-I to Reach-V	SIC	Do	Do	Do	Parshell Flume	Overflow	From S0 to S16
Reach-V		Do	Do	Do			From S17 to S21
Reach-I to Reach-IV	DTO of TIC	Do	Do	Do	Parshell Flume	Overflow	
Reach-V		Do	Do	Do			From TE1 to TE23
Reach-I to Reach-IV	TIC	Do	Do	Do	Parshell Flume	Overflow	
Reach-V		Do	Do	Do			

*Source: Site Verification

Also, flow through control structure is adjusted based on scarcity of water for use and on off-peak demand. The adjustable (continuous) flow needs variable settings of water level for discharge to pass with specified start time and end time during an irrigation season. Adjustable (continuous) flow in parent canal shows, in general, rotational flow over respective child canals. The rotational flow in higher order canal generally indicates intermittent flow in respective lower order canal/s if number of hydraulic level of canals is more than two. Table 2-6 below shows water level control existing in KIS. It can be observed that there is no water level control along DTOs and TICs in KIS.

Table 2-6: Type of water level control by canal level in KIS

MIC Reaches	Hydraulic level of canal	Type of Water level control	Remarks

		Gated	Flow Type	Operation Type	
	MIC	Adjustable sliding gate	Orifice flow	Maually operated	
Reach-I to Reach-V	SIC	Do	Do	Do	
Reach-I to Reach-V	DTO of TIC				No control
Reach-I to Reach-V	TIC				No control

*Source: Site Verification

Given the flow control structures in KIS, the type of operational flow possible along hierarchy of irrigation canal levels depending on water availability and crop demand is presented in Table 2-7 as below.

Table 2-7: Types of operational flow possible in KIS

MIC Reaches	Hydraulic level of canal	Type of possible flow	Remarks
	MIC	Adjustable continuous flow	
Reach-I to Reach-V	SIC	Adjustable continuous/rotational flow	
Reach-I to Reach-V	DTO of TIC	Adjustable continuous/rotational flow	
Reach-I to Reach-V	TIC	Adjustable rotational/intermittent flow	
	FC	Rotational flow	

*Source: Site Verification

Further, possible methods to control flow through hydraulic levels of canal network in KIS that covers design assumption, operation practice and theoretical possibility is presented in Figure 2-3 for reference.

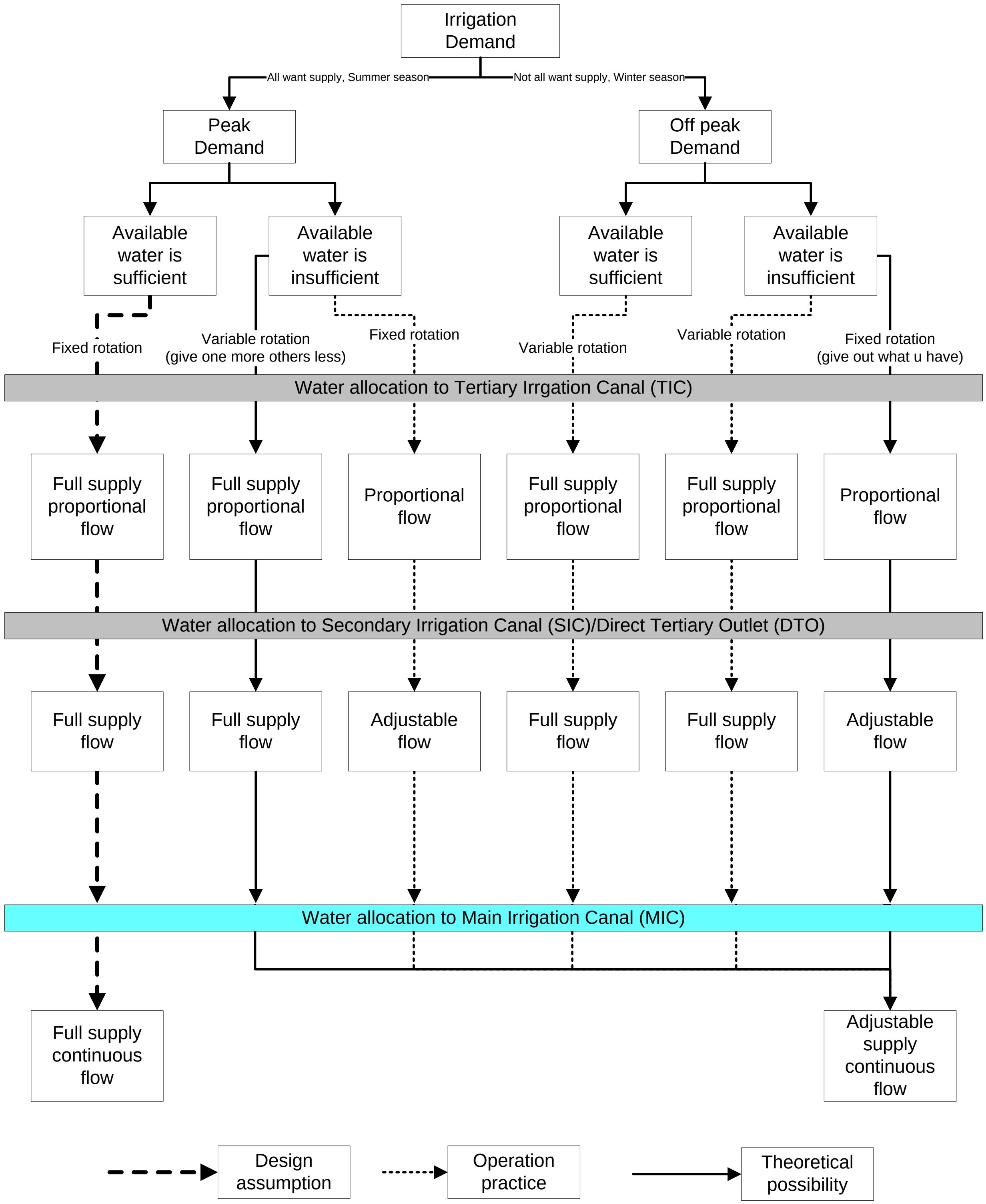


Figure 2-3: Methods to control flow along hydraulic levels of KIS

2.8 Soil Types

There is no documentation on available agricultural soil types in KIS. However, observations through field visit of KIS command shows that silty clay to silty loam soil exist in majority of command area, which has moderate to low soil drainage capacity from agricultural view point.

2.9 Agro-meteorology

Nearest meteorological station considered representative to command area of KIS is at Chandragadhi, the altitude of which is 120 m. The location of Station is latitude 26.56^0 N and longitude 88.05^0 E. The climatological data as in Table 2-8 is derived from software ClimWat for CROPWAT freely available through Food and Agriculture Organisation (FAO) website. The effective rainfall is derived from CROPWAT software using USDA Soil Conservation Method.

Table 2-8: Monthly Agro-climatological data set of Chandragadhi for KIS

Month	Rainfall, mm	Eff. Rainfall, mm	Min. Temp., ^{0}C	Max. Temp., ^{0}C	Humidity, %	Wind, km/day	Sun, hours	Radiation, MJ/m²/day	ET_{ref}, mm/day
January	6	5.9	10.5	23.4	66	86	7.9	14.6	2.26
February	18	17.5	11.9	26.3	63	104	8.4	17.3	3.02
March	19	18.4	15.9	32	56	121	8.8	20.4	4.38
April	62	55.8	20.2	34.8	37	147	8.8	22.3	5.92
May	188	131.4	23.1	34	67	147	8.1	22.1	5.38
June	390	164	25.1	33	77	130	5.3	18.1	4.38
July	730	198	25.3	32.2	82	121	4.2	16.3	3.86
August	406	165.6	24.9	32.3	84	104	4.6	16.3	3.74
September	456	170.6	24	31.7	86	95	5.7	16.6	3.62
October	111	91.3	21.7	31.4	74	86	7.1	16.3	3.52
November	9	8.9	15.4	29.8	69	78	8.1	15.2	2.93
December	8	7.9	10.9	24.7	76	78	7.8	13.7	2.16
Total	**2403**	**1035.3**							
Average			**19.1**	**30.5**	**70**	**108.1**	**7.1**	**17.4**	**3.8**

*Source: CROPWAT output

It can be observed from Table 2-8 that total amount of normal rainfall starting from month November to month March covering winter irrigation season is only 60 mm (2.5%) out of total rainfall of 2403 mm over normal year. Whereas, reference evapo-transpiration for the same period of months during winter irrigation season is about 450 mm. Further, normal rainfall from months April to June (spring irrigation season) is 640 mm (26.7%) and from months July to October (monsoon irrigation season) is 1703 mm (70.8%) of total in an year. Moreover, reference evapotranspiration for spring irrigation season is about 476 mm and monsoon irrigation season is about 453 mm.

3 MAIN CANAL OPERATION

3.1. Cropping Pattern

Yearly cropping pattern in practice is collected from WUA of respective SIC starting from S0 to S21 through Focus Group Discussion (FGD) held at WUA office using specified format. The data were further verified and fine tuned by collecting cropping pattern database from WUAs at TIC level branching from respective SIC. It has been observed from Table 3-1 that major crops being followed in winter season are maize, wheat, mustard, vegetable and potato. The cropping intensity in winter season is 35%. Further, cropping intensity of spring crops is 41% and of monsoon crop is 92%.

Table 3-1: Existing cropping pattern in KIS

Total command area	6950	ha	SIC Command area for S1 to S12		3542	ha	
Season	**Crop**	**cropped area, ha**	**cropped %**	**First Planting**	**First Harvesting**	**Last Planting**	**Last Harvesting**
Monsoon	Rice	6394	92	25-Jun	28-Oct	20-Jul	22-Nov
	Sub Total	**6394**	**92**				
Winter	Wheat	339	5	15-Nov	15-Mar	31-Dec	30-Apr
	Maize	898	13	15-Nov	18-Mar	28-Feb	7-Jul
	Potato	385	6	15-Oct	1-Feb	31-Dec	21-Apr
	Mustard	466	7	7-Oct	25-Jan	31-Dec	20-Apr
	Vegetable	217	3	1-Oct	7-Jan	14-Jan	21-Apr
	Pulses	68	1	15-Oct	1-Feb	15-Nov	5-Mar
	Onions	55	1	15-Dec	4-May	15-Jan	3-Jun
	Sub Total	**2428**	**35**				
Spring	Spring Rice (S-1 to S-12)	1383	39	7-Mar	7-Jun	31-Mar	30-Jun
	Maize	78	2	15-Feb	24-Jun	7-Mar	15-Jul
	Sub Total	**1461**	**41**				
	Total (cropping intensity)		**168**				

*Source: WUAs FGD at individual TIC level offtaking from SIC

Considering existing cropping pattern total cropping intensity being practiced by water users in KIS is 168%. This is rather low value. Further, spring crops in KIS is cultivated covering command area starting from S0 to S12 (Reach-I to Reach-IV) and S13 to S21 (Reach-V) in alternate years. Given the low cropping intensity, moderation in crop area with consultation from SMU and WUA of KIS as in Table 3-2 is proposed for use in future that amounts cropping intensity to 199% considering an year when S0 to S12 SIC covers with spring crops.

Table 3-2: Proposed cropping pattern in KIS

Total command area	6950	ha		Total command S0 to S12	3810	ha	
Irrigation Season	**Crop**	**cropped area, ha**	**cropped %**	**First Planting**	**First Harvesting**	**Last Planting**	**Last Harvesting**
Monsoon	Rice	6354	91	25-Jun	28-Oct	20-Jul	22-Nov
	Sub Total		**91**				
Winter	Wheat	844	12	12-Nov	12-Mar	31-Dec	30-Apr
	Maize	1103	16	15-Nov	20-Mar	31-Jan	4-Jun
	Potato	539	8	20-Oct	7-Feb	21-Dec	10-Apr
	Mustard	647	9	1-Oct	19-Jan	21-Dec	10-Apr
	Vegetable	396	6	15-Oct	18-Jan	30-Jan	4-May
	Pulses	126	2	15-Oct	2-Feb	20-Dec	9-Apr
	Sub Total		**53**				
Spring	Spring Rice	2025	53	7-Mar	5-Jun	27-Mar	25-Jun
	Sp Maize	67	2	15-Feb	19-Jun	7-Mar	10-Jul
	Sub Total		**55**				
	Total (cropping intensity)		**199**				

*Source: Discussion with SMU and WUA

The existing and proposed cropping pattern of winter, spring and monsoon crops in respective SICs command is tabulated in **Annex-A** of this report for reference. The proposed cropping pattern of individual SIC command is modeled in CROPWAT software to estimate monthly irrigation requirements. It may be noted that CROPWAT models percentage of individual cropped area in a SIC command. Although the data on existing cropping pattern have been collected from WUA for SICs only, the cropped area of DTOs is considered conjoined with respective SICs to estimate amount of cropped area in a SIC to be modeled in CROPWAT with proposed cropping pattern. The output of CROPWAT model is presented in **Annex-B** of this report.

3.2. Crop Coefficient

In the absence of data from eastern regional office of Nepal Agriculture Research Council (NARC) stationed at Tarhara on crop coefficients (K_C) for different crops being grown in KIS, the value of K_C is derived from FAO CROPWAT software model. The growth stages of crop have been slightly modified to suit site condition based on WUA experience learnt from FGD. Table 3-3 presents K_C values and period of growth stage for crops in KIS.

Table 3-3: Period of growth stages and coefficient of different crops in KIS

Growth Period, days			Growth Stages					
Crop Coefficient, KC	Land preparation	Puddling	Initial	Development	Mid season	Late Sesaon	Total	Remarks
Monsson Paddy	25	5	20	45	30	30	125	
	1.05		1.10		1.20	1.05		
Wheat			30	25	40	20	115	
			0.3		1.15	0.3		
Winter Maize			20	35	40	30	125	
			0.3		1.2	0.35		
Mustard			20	30	40	20	110	
			0.35		1.15	0.35		
Potato			25	25	40	20	110	
			0.5		1.15	0.75		
Pulses			20	30	40	20	110	
			0.4		1.15	0.35		
Small Veg			20	30	30	15	95	
			0.7		1.05	0.9		
Spring Paddy	10	5	20	30	25	15	90	
	1.05		1.1		1.2	1.05		
Spring Maize			20	35	40	30	125	
			1.1		1.2	1.05		

Use of above data is made in CROPWAT model to derive at monthly water requirements of individual crop and combination of crops in a SIC and consequently MIC of KIS.

3.3. Cropped Area

The individual cropped area in percentage of respective SICs command has been modeled in staggered manner in CROPWAT software in order to match sowing in real situation. The accumulated cropped area of SICs command over the month, as output of CROPWAT is presented in Table 3-4 as below.

Table 3-4: Command area and pattern of cropped area over months by group of SIC command

Canal (group) Name*	**Group of Revised Command area, ha**	**Months of Year with Cropped Area (Ha)**											
		Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
MIC	**6950**	**3662**	**3658**	**4882**	**3495**	**2280**	**6649**	**6383**	**6357**	**6357**	**6406**	**6917**	**3449**
S0	268	196	236	268	142	102	233	228	201	201	201	241	174
S1, T0-1	523	429	429	481	235	157	523	131	465	465	465	523	403
S2, S2B,T0-	364	142	142	364	342	317	364	109	328	328	328	364	138

2,T0-4													
S3, T0-7,8,9,11	343	127	127	343	305	278	343	120	309	309	309	343	123
S4, T0-5,6,10,12 ,TB-2,4,6	467	70	70	467	453	425	467	140	434	434	434	462	65
S5	258	111	111	258	237	194	258	77	245	245	245	258	106
S6, TA-1,3	130	62	62	130	124	109	130	91	124	124	124	130	53
S7	154	43	40	132	120	92	154	105	143	143	146	154	43
S8	292	131	131	152	85	44	292	204	277	277	277	292	128
S9, TA-4,5,6,7 TB-0,1,3,5,7, 9,10	403	149	149	351	306	222	403	383	383	383	383	403	149
S10, TB-8	186	69	69	167	153	112	186	173	173	173	173	186	69
S11, TB-11	158	92	92	142	103	55	158	150	150	150	150	158	92
S12, TB-12	264	195	195	248	145	66	264	251	251	251	251	264	195
S13, TE-1,2,3,4,5, 6,7,8,9	711	533	526	434	171	0	640	213	640	640	647	711	533
S14 (S14A&B), TE-10	417	392	392	271	154	0	375	104	375	375	375	417	392
S15, TE-14,15,16, 19,21	492	177	177	113	89	0	467	148	467	467	467	492	177
S16, TE-11,12,13, 17,18,20, 22,23	565	164	164	124	79	17	537	170	537	537	537	565	119
S17	343	230	230	192	127	51	326	223	326	326	326	343	178
S18	112	41	39	28	6	0	106	73	106	106	109	112	41
S19	158	58	47	38	17	5	123	85	123	123	139	156	54
S20	179	111	107	91	38	11	168	115	168	168	174	179	100
S21	163	139	122	86	65	24	130	90	130	130	147	163	114

*Canal group indicates SIC and DTOs offtakes from MIC irrigating part of area towards respective SIC command

It can be observed from above table that cropped area of KIS starting from months June to November is more than 90%, with highest (6917 ha) in the month of November when monsoon paddy is harvested and wither crops being sown. In the months of December to May, highest crop coverage is in the month of March (4882 ha), about 50% crop coverage, when winter crop is being harvest and spring crop is being replaced with. The lowest crop coverage is in the month of May (2280 ha) when spring crop is being harvested in S0 to S12 command area.

3.4. Irrigation Water Requirements

Crop water requirements of SIC command interplayed with effective rainfall in CROPWAT model results in precipitation deficit net Irrigation Water Requirements (IWRs) on daily basis spread uniformly over month. Similarly, monthly IWR of all SICs are combined to form monthly IWR at the head of KIS as demand to be supplied during summer, winter and spring seasons. The efficiency of off-farm canal network and on-farm to arrive at gross IWR is considered in accordance with Table 3-5 as below.

Table 3-5: Efficiency of off-farm unit and on-farm unit in KIS

Efficiency	From	To	Value, %	Remarks
MIC	intake of MIC	offtake of SIC/DTO	85	
SIC	intake of SIC	offtake of TIC	85	
TIC	TIC and FC	Farm head	80	
Field application, dry foot and paddy crop	Farm head	crop root zone	70 and 90	

Further, precipitation deficit continuous flow discharge required at Sardare Intake located at the head of MIC over months for irrigation seasons is obviously very less as in Table 3-6 against its designed capacity and duty of 10150 lps and 1.45 lps/ha respectively. It can also be observed that crop water requirements in the month of August and September is governed by rainfall alone, hence no irrigation requirements.

Table 3-6: Average duty and depth required at the head of MIC for continuous flow over months

Particulars	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Remarks
Cropped Area, ha	**3662**	**3658**	**4882**	**3495**	**2280**	**6649**	**6383**	**6357**	**6357**	**6406**	**6917**	**3449**	
Discharge, lps	794	979	4951	1760	512	4167	1180			966	1148	341	
Average Duty, lps/ha	0.22	0.27	1.02	0.50	0.23	0.62	0.19			0.15	0.17	0.10	
Average Depth, mm/d	1.9	2.3	8.8	4.3	1.98	5.4	1.6			1.3	1.5	0.9	

Moreover, existing winter, spring and summer irrigation practices by water users in KIS command directs to irrigating standing crops at an average interval not exceeding 20 days for winter crops and 7 days for other crops under normal precipitation and climatic conditions, as learnt from WUA during FGD while collecting cropping patterns for respective SIC. In apropos, given desiliting consideration at Sardare Intake, operation of

MIC over average months in year is only 5.5 day (Sunday 6:00 am to Friday 6:00 pm) a week. This entails, supply of daily demand through MIC over periodic months should be factorized by ratio of Irrigation Interval (II) and MIC operation days in a week to derive at period discharge in terms of gross IWR at Sardare Intake.

3.5. Dependable Discharge at Sardare Intake

There is no historical documentation on availability and reliability of Kankai River flow at headworks site of KIS as per report from SMU. However, recourse has been made to understand pattern of documented irrigation water supply to MIC at Sardare Intake over about 10 years. The Sardare Intake operates only 5.5 days a week. Remaining 1.5 days are used to flush sediment deposit upstream of Intake. Usually Friday 6:00 PM to Sunday next 6:00 AM is closure time of Sardare Intake to MIC. There is historical practice of recording water gauge and thus rated discharge three times a day at Sardare Intake. The daily discharge is tabulated as in Table 3-7 over all years of record to reckon average monthly discharge flowing through Sardare Intake every year of available record.

Table 3-7: Average monthly discharge record at Sardare Intake

S.N.	Year	April	May	June	July	August	September	October	November	December	January	February	March
1	2005/06	**1.02**	**3.19**	**3.94**	**4.31**	**4.93**	**5.13**	**5.40**	**0.00**	**3.72**	**4.03**	**1.54**	**3.36**
2	2006/07	**3.96**	**4.46**	**4.07**	**6.19**	**7.16**	**5.69**	**3.10**	**5.11**	**3.63**	**3.27**	**1.61**	**4.19**
3	2007/08	**5.09**	**5.33**	**4.37**	**6.90**	**5.31**	**4.54**	**3.80**	**0.83**	**1.54**	**2.56**	**1.68**	**3.28**
4	2008/09	**4.66**	**5.46**	**4.23**	**6.90**	**5.19**	**4.66**	**3.49**	**0.83**	**1.54**	**2.51**	**1.66**	**2.63**
5	2009/10	**3.16**	**0.00**	**0.00**	**5.95**	**5.45**	**5.02**	**5.22**	**1.73**	**2.36**	**3.51**	**2.92**	**3.74**
6	2010/11	**4.35**	**4.19**	**4.14**	**4.59**	**5.31**	**4.66**	**3.67**	**0.83**	**1.54**	**2.56**	**1.68**	**2.63**
7	2011/12	**4.18**	**5.46**	**4.34**	**5.40**	**3.37**	**4.87**	**4.48**	**0.00**	**0.20**	**0.94**	**0.20**	**0.75**
8	2012/13	**0.26**	**1.16**	**2.73**	**4.56**	**5.72**	**5.34**	**2.50**	**0.00**	**0.32**	**0.62**	**0.44**	**1.28**
9	2013/14	**1.73**	**1.72**	**3.75**	**3.21**	**3.81**	**3.92**	**3.46**	**0.00**	**0.28**	**1.89**	**1.99**	**3.62**
10	2014/15	**4.16**	**0.00**	**0.00**	**6.01**	**5.86**	**4.70**	**4.43**	**0.00**	**0.29**	**1.35**	**3.10**	**3.43**

The historical record of average monthly discharge is modeled in Rainbow software for frequency analysis to reckon reliable flow at level of 20% (wet year), 50% (normal year) and 80% (dry year) as in Table 3-8.

Table 3-8: Reliable flow at Sardare Intake

Month	Reliable Mean Flow at Sardare Intake		
	20%	50%	80%
April	4.51	3.62	2.42
May	5.17	4.18	2.88
June	4.26	3.96	3.56
July	6.37	5.40	4.44
August	6.04	5.26	4.34
September	5.24	4.87	4.48
October	4.73	4.09	3.18

November	2.77	1.51	0.71
December	2.42	1.14	0.42
January	3.22	2.32	1.43
February	2.41	1.68	0.96
March	3.71	3.07	2.27

The normal flow corresponding to 50% reliability has been considered for use in water balancing with gross IWR.

3.6. Irrigation Interval and Water Balance

A shortest irrigation interval based on field soil moisture balance and precipitation deficit net IWR on daily basis for given crops growth stage is more accurate method to schedule field irrigation for small scale command area. However, for large scale command area an irrigation interval to match supply with water demand of standing crops at given growth stage is contingent on water availability at Sardare Intake and water users experience is considered superior over any other methods.

Table 3-9: Irrigation interval and water balance at Sardare Intake of KIS

Particulars	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Assumed Irrigation supply Interval at field, days (multiple of SIC delivery days)	**22**	**14**	**7**	**7**	**7**	**7**	**7**	**7**	**7**	**7**	**14**	**22**
MIC delivery operation in a week), days	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5
Gross Scheme (MIC) discharge required for **all SICs in a delivery period, l/s**	**3131**	**2542**	**6305**	**2240**	**647**	**5289**	**1492**	**0**	**0**	**1209**	**2898**	**1356**
50% Dependable (normal) supply at Sardare Intake (MIC head), l/s	2320	1680	3070	3620	4180	3960	5400	5260	4870	4090	1510	1140
Surplus/Deficit supply, l/s	-811	-825	-3235	1380	3533	-1329	3908			2881	-1379	-216

In order to supply whole SICs with irrigation water at a time when MIC operates 5.5 days in a week, from Table 3-9 it is obvious that there is deficit of 50% dependable supply over crop demand in months November to March and in the month of June. The deficit is acute particularly in month of March when part of winter mid development stage crop is standing and spring crop is being planted. Also, in the month of November and March the deficit is about 50% of required amount. In the month of November and March there is, however, standing mid development stage monsoon paddy crop and land preparation stage of spring paddy crop (as in S0 to S12) in about 50% of command area of KIS. This may be observed as in Table 3-4. Hence, given the dependable supply of water at Sardare Intake it is suggested to ration irrigation supply to groups of SICs on rotational basis while matching field water demand with assumed irrigation interval as in Table 3-9 above and Table 3-10 as below. Therefore, rotational supply between groups of SIC is imperative in order to balance dependable supply at Sardare Intake of MIC.

3.7. Mode of SIC and DTO Operation

It can be observed in Table 3-9 that SICs will be operated with bulk water delivery for at most 5.5 days a week to accomplish a dose of field crop irrigation interval. Considering facts of previous section and gross discharge requirements at Sardare Intake as in Table 3-9, mode of equal group of SICs operation for a delivery period has been worked out to be 2 with 50% as much reduction in flow requirement at Sardare Intake. Therefore, period of main canal operation will be doubled as two equal groups of SIC is proposed to be rotated.

Table 3-10: Mode of SIC operation and delivery period of MIC for winter crops

Particulars	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Mode of equal groups of SICs Operation for a delivery period	2	2	2	1	1	2	1	-	-	1	2	2
Delivery Period of MIC (Interval of groups of SICs operation to match irrigation supply interval at field), days	11	7	4	7	7	4	7	-	-	7	7	11
Flow required at MIC head for a group of SICs over a delivery period, l/s	**1565**	**1271**	**3152**	**2240**	**647**	**2644**	**1492**	**-**	**-**	**1209**	**1449**	**678**
50% Dependable (normal) supply at Sardare Intake (MIC head), l/s	2320	1680	3070	3620	4180	3960	5400	5260	4870	4090	1510	1140
Surplus/Deficit wrt requirement, l/s	**755**	**409**	**-82**	**1380**	**3533**	**1316**	**3908**	**-**	**-**	**2881**	**61**	**462**

It can also be observed from above Table 3-10 that MIC operation would be continuous for the month of November, February through July. This is on account of balancing irrigation requirement with available reliable irrigation supply at Sardare Intake. In the month of August and September, rainfall would require no supplement of irrigation water through canal network. However, database as above is derived based on output of

CROPWAT under normal agro-climatic condition. Deviation of agro-climatic condition over month would require alteration (about 15 days ahead or behind) of MIC and SIC operation. It can also be observed from Table 3-10 that month of March is critical over any other month in terms of water requirement and dependable flow availability. The obvious reason being part of command area covered with winter mid development stage crop, and part with (S0 to S1) land preparation for spring paddy crop.

3.8. MIC Operation Plan

The principal reason for developing an operation plan is to improve water delivery in terms of reliability, adequacy and timing to water users without compromising the hydraulic control of the conveyance and distribution system. The secondary reason include collection of field data on the system and establishing a basis for record keeping of intended and actual water delivery during each irrigation season.

An operation plan for water delivery in a canal system involves the determination of required discharges at key locations in the system, the required structure settings at those locations. The operation plan in our case is in terms of controlling canal structures with the primary intent of controlling discharges, and the secondary purpose of controlling water levels in the canals.

Devising MIC operation plan by scheduling MIC operation for spring, summer and winter crop is aimed to deliver bulk water to respective SIC under jurisdiction of WUA such that readily measurable discharge in each irrigation cycle for proposed crops can be realized by use of Parshell Flume located at the downstream of HR at the head of SIC in KIS.

Considering discussions in previous sections, a water delivery schedule with clear start and end of irrigation doses over irrigation seasons at Sardare Intake including respective SIC is tabulated in **Annex D** of this report. The details of scheduling MIC at Sardare Intake for proposed winter crops is presented in Table 3-11 as below for reference.

Table 3-11: MIC operational schedule at Sardare Intake for winter crops in KIS

Parent canal	Sardare Intake	Command Area, Ha	6950
Chainage	0+000	Cropped Area, Ha	3764
Name of canal offtake	Main Irrigation Canal, MIC	Irrigated Area, Ha	3764
Name of Chairperson	Suryanarayan Singh Tajpuriya	Operational Group	
Name of Gateoperator	Santa Lawati	Design Discharge, l/s	10150

Start of Irrigation Dose		**End of Irrigation Dose**		**Dose Period**	**Discharge per dose**	**U/S head underflow**	**SIC Groups**
Date	**Day**	**Date**	**Day**	**Days**	**l/s**	**cm**	
2015/12/06 6:00 AM	Sunday	2015/12/11 6:00 PM	Friday	5.50	586.5	32	S0 to S12

2015/12/11 6:00 PM	Friday	2015/12/13 6:00 AM	Sunday	1.50			
2015/12/13 6:00 AM	Sunday	2015/12/18 6:00 PM	Friday	5.50	769.9	38	S13 to S21
2015/12/18 6:00 PM	Friday	2015/12/27 6:00 AM	Sunday	8.50			
2015/12/27 6:00 AM	Sunday	2016/01/01 6:00 PM	Friday	5.50	586.5	32	S0 to S12
2016/01/01 6:00 PM	Friday	2016/01/03 6:00 AM	Sunday	1.50			
2016/01/03 6:00 AM	Sunday	2016/01/08 6:00 PM	Friday	5.50	769.9	38	S13 to S21
2016/01/08 6:00 PM	Friday	2016/01/17 6:00 AM	Sunday	8.50			
2016/01/17 6:00 AM	Sunday	2016/01/22 6:00 PM	Friday	5.50	1456.2	56	S0 to S12
2016/01/22 6:00 PM	Friday	2016/01/24 6:00 AM	Sunday	1.50			
2016/01/24 6:00 AM	Sunday	2016/01/29 6:00 PM	Friday	5.50	1674.6	61	S13 to S21
2016/01/29 6:00 PM	Friday	2016/02/07 6:00 AM	Sunday	8.50			
2016/02/07 6:00 AM	Sunday	2016/02/12 6:00 PM	Friday	5.50	1456.2	56	S0 to S12
2016/02/12 6:00 PM	Friday	2016/02/14 6:00 AM	Sunday	1.50			
2016/02/14 6:00 AM	Sunday	2016/02/19 6:00 PM	Friday	5.50	1674.6	61	S13 to S21
2016/02/19 6:00 PM	Friday	2016/02/21 6:00 AM	Sunday	1.50			
2016/02/21 6:00 AM	Sunday	2016/02/26 6:00 PM	Friday	5.50	1156.9	49	S0 to S12
2016/02/26 6:00 PM	Friday	2016/02/28 6:00 AM	Sunday	1.50			
2016/02/28 6:00 AM	Sunday	2016/03/04 6:00 PM	Friday	5.50	1348.5	54	S13 to S21
2016/03/04 6:00 PM	Friday	2016/03/06 6:00 AM	Sunday	1.50			
2016/03/06 6:00 AM	Sunday	2016/03/09 6:00 PM	Wednesday	3.50	1156.9	49	S0 to S12
2016/03/09 6:00 PM	Wednesday	2016/03/11 6:00 PM	Friday	2.00	1348.5	54	S13 to S21
2016/03/11 6:00 PM	Friday	2016/03/13 6:00 AM	Sunday	1.50			
2016/03/13 6:00 AM	Sunday	2016/03/16 6:00 PM	Wednesday	3.50	3313.1	93	S0 to S4
2016/03/16 6:00 PM	Wednesday	2016/03/18 6:00 PM	Friday	2.00	2935.3	86	S5 to S21
2016/03/18 6:00 PM	Friday	2016/03/20 6:00 AM	Sunday	1.50			
2016/03/20 6:00 AM	Sunday	2016/03/23 6:00 PM	Wednesday	3.50	3313.1	93	S0 to S4
2016/03/23 6:00 PM	Wednesday	2016/03/25 6:00 PM	Friday	2.00	2935.3	86	S5 to S21
2016/03/25	Friday	2016/03/27	Sunday	1.50			

6:00 PM		6:00 AM					
2016/03/27 6:00 AM	Sunday	2016/03/30 6:00 PM	Wednesday	3.50	3313.1	93	S0 to S4
2016/03/30 6:00 PM	Wednesday	2016/04/01 6:00 PM	Friday	2.00	2935.3	86	S5 to S21
2016/04/01 6:00 PM	Friday	2016/04/03 6:00 AM	Sunday	1.50			
2016/04/03 6:00 AM	Sunday	2016/04/08 6:00 PM	Friday	5.50	3313.1	93	S0 to S4
2016/04/08 6:00 PM	Friday	2016/04/10 6:00 AM	Sunday	1.50			

3.9. Discharge Measurement

Rating equation for operational discharge measurement at Sardare Intake is in hand as presented in Table 3-11 for reference.

From WUA confidence on system operation point of view, there should always be provision of such hydraulic structure at the head of offtakes from MIC that readily discharge measurement is possible in order to realize transparent communication of bulk water delivery to respective SICs by both IMD and WUA. This has been made possible by development of rating table through calibration and listing incremental relationship between upstream head measured by water gauge mark and discharge through Parshell Flume structures in place in Reach-I to Reach-IV of KIS. There is however Parshell Flume existing at the head of S14 to S16 in Reach-V of KIS. No Parshell Flume in S0 of Reach-I, S8 of Reach-III, S13 and S17 through S21 in Reach-V of KIS existence. Further is no Parshell Flume in DTOs (23 nos) in Reach-V of KIS.

Detail of rating tables for calibrated hydraulic structures at the head of SIC is presented in **Annex E**. A sample of calibrated rating table for S1 SIC is presented in Table 3-12 for reference.

Table 3-12: Rating table of Parshell Flume at the head of S1 SIC

Head over flume crest	Discharge	Remarks
cm	lps	
1	2	
2	5	
3	9	
4	14	
5	20	
6	27	
7	34	
8	42	
9	50	
10	59	

11	69	
12	79	
13	89	
14	100	
15	112	
16	124	
17	136	
18	149	
19	162	
20	176	
21	190	
22	204	
23	219	
24	234	
25	249	
26	265	
27	281	
28	298	
29	314	
30	331	
31	349	
32	367	
33	385	
34	403	
35	422	
36	441	
37	460	
38	480	
39	500	
40	520	
41	541	
42	561	
43	582	
44	604	
45	625	
46	647	
47	670	
48	692	
49	715	
50	738	
51	761	

52	784	
53	808	
54	832	
55	**856**	
56	881	
57	906	
58	931	
59	956	
60	981	
61	1007	
62	1033	
63	1059	
64	1086	
65	1112	
66	1139	
67	1167	
68	1194	
69	1221	
70	1249	
71	1277	
72	1306	
73	1334	
74	1363	
75	1392	
76	1421	
77	1450	
78	1480	
79	1510	
80	1540	

3.10. Water Level Control

During winter and spring seasons the desired flow requirements through head of SICs and DTOs in KIS for standing crop in field is obviously less than peak water requirements for paddy crops, for which the canal capacity is designed and implemented.

Therefore in order to meet off-peak water requirements through head of SICs and DTOs, supply regulation of target water level upstream of CR in places along MIC is imperative. However, there is lack of documentation on principal dimensions and elevations of flow control structures existing along MIC in KIS as reported by SMU. Consequently, as a primitive measure, it is assumed that Gate Operators would make use of series of real time operational trials in CR regulation and gain experience in setting target water level upstream of it.

Alternatively, I it suggested to obtain principal dimensions and levels of flow control structures including L-profile and X-profile in MIC by implementing engineering survey works. The data thus obtained would be modeled in suitable Hydrodynamic software to simulate real time water level variations through CRs in MIC and discharge variations through HRs in offtaking canal for different operational parameters in KIS.

3.11. Canal Operation Policy

In order for smooth realization of MIC and SICs operation schedule in winter, spring and summer seasons, as discussed in previous sections, a policy on canal operation is to be inevitably enabled as follows:

- Flow through Sardare Intake for MIC will run as per Scheduled program.
- There are two groups of SICs offtaking from MIC will be rotated over equal volumetric supply (discharge and time) basis. During operation of Group-A, SICs of Group-B will be closed and vice versa.
- The bulk water delivery period for a Group of SICs is proposed to be at most 5.5 days each, depending on monthly water requirements.
- From first week of December to first week of March, Group-A of SICs comprises S0 to S12 offtaking from Reach-I to Reach-IV of MIC and Group-A of SICs consists of S13 to S21 SICs offtaking from Reach-V of MIC.
- From second week of March to first week of April, Group-A of SICs comprises S0 to S4 offtaking from Reach-I of MIC and Group-II of SICs consists of S5 to S12 SICs offtaking from Reach-II to Reach-V of MIC.
- The volume (discharge and time) flow through each Group will be almost equal such that minimum regulation of Sardare Intake gate and CRs is sought for between changes of proposed operation Group.
- In an operating Group, the target water level upstream of CRs in MIC and opening of HRs for intended discharge in SICs and DTOs are once set through trial gate regulations will be maintained by the Gate Operator over each irrigation dose/cycle.
- During full supply level flow, all CRs must be open or only partially closed as much as is required to just make required discharge flow into offtaking canals upstream of it.
- Calibrated Parshell Flume at the head of SIC provisions readily discharge measurements for monitoring of water allocation to respective Group of SICs.
- Irrigation agency is responsible for MIC operation and allocation of water to respective Group of SICs as per scheduled program.
- WUA is responsible for monitoring supply to respective SIC as per scheduled program
- WUA is responsible for distribution of water from SIC through TIC to Field Channels covering standing crop once intended discharge is allocated to respective SIC as per scheduled program.

- WUA is responsible to irrigate farm using Field Channel and refrain from field to field irrigation as per schedule.
- No water users and WUA should attempt to tamper with gate settings during and after operation schedule programmed for Groups of SICs.
- Any alteration in discharge requirements by WUA of SIC would be moderated through Gate Operators working for irrigation agency.
- WUA should use request slip to irrigation agency in prescribed format for desired discharge alteration in SIC.
- Agency and WUA are responsible to identify and minimize unauthorized offtakes being malpractised by water users along MIC.
- WUA is responsible to identify and minimize unauthorized offtakes being mal-practiced by water users within canal network in respective SICs and DTOs.
- At the end of irrigation season both WUA and Agency would jointly evaluate performance of canal operation on primitive basis, and lessons are learnt to modify operation schedule to be programmed for next year.
- WUA would estimate data on crop area and cropping pattern at each TIC and accumulate those data for each SIC in order for Agency to plan main canal operation at least one month in advance of irrigation season.

4 CANAL OPERATION TASK DESCRIPTION

4.1 Role of Irrigation Management Division

The Water Management Unit (WMU) of Irrigation Management Division (IMD) is responsible for operation, maintenance and management of MIC and its associated hydraulic structures. The O&M unit is assumed to be headed by Division Chief and assisted by Engineer, Sub-engineers (SE), Supervisors and Gate Operators (GO) in order of their hierarchy.

Division Chief

The WMU is responsible for implementing water management over MIC with participation of WUA. The responsibility of WMU includes monitoring of the operation and water management and evaluating the performance of the MIC and the participation of the WUA.

The specific responsibilities of Dvision Chief include:

- Review and/or establish water users organization structure to match with irrigation system planning
- Plan and implement training for farmers based on adult learning process to provide adequate knowledge and skill of operation and water management to enable them to take over the responsibility of the management of canal system.
- Plan and implement training for the WMU staff in the principals and procedures of canal operation and water management.
- Prepare the operation program in crop season.
- Supervise the implementation of operation and water management by both WMU staff and the water users.
- Plan and implement the collection of relevant data for the preparation of operation program, the evaluation of System performance, and the evaluation of WUA participation.
- Supervise the Engineers and the activities of other field staff under Engineers in WMU.
- Supervise the recording of canal flows and rainfall.
- Conduct surveys of cropping pattern, crop areas and crop yields
- Implement surveys pertaining to monitoring of silt deposition in the MIC.
- Implement the operation of MIC according to program
- Establish coordination with WUA in water management activities.
- Suggest and implement modification in MIC operation program in response to rainfall.
- Get reports prepared on operation and water management in each crop season.

Engineer

The engineer is the principal technical officer responsible for implementing all the activities related to operation and water management in the system. He is assisted by SEs, Supervisors, GOs, Association Organisors (AOs). The specific responsibilities follow as;

- Operate the MIC in accordance with the operational program prepared by WMU.
- Ensure that canals are operated at the specified level and in specified mode of operation.
- Ensure that flows in the canals are recorded at specified time and at the time of water level fluctuation in MIC as per prescribed format.
- Ensure opening and closure of canal or a group of canals on schedule and record the operation group of canal in the specified format.
- Prepare the records of canal flows at the end of each irrigation cycle, and that of rainfall and others on weekly basis to the WMU for analysis.
- Monitor the flow in respective SICs and DTOs and motivate the concerned WUA to implement any maintenance action, if required.
- Inspect the canals during operation on a daily basis and implement the routine and seasonal maintenance actions, as required.
- Demarcate the area irrigated in each crop season.
- Implement surveys of cropping pattern, crop areas and crop yields with AOs and WUA
- Supervise the preparation of Irrigation Area Boundary Maps (IABM)
- Guide respective WUA and water users in implementing water management related activities and provide them with on-the-job training in operation and maintenance action.
- Supervise the AOs in guiding and assisting the WUGs to practice irrigation by supply the whole discharge of TIC to one farmer at a time by practicing rotation among Field Outlet from TIC.
- Hold meetings with WUA to evaluate the water delivery response of water users.
- Motivate the WUA in constructing Field Channels (FCs) and mainataing the whole on-farm system.
- Implement the routine and seasonal maintenance.
- Report on weekly basis to Division Chief about the situation of operation and maintenance.
- Monitor the progress of overall operation and water management program and identify the dalay to be reported to Division Chief.
- Conduct surveys of L- sections of canals to monitor the silt and sand deposit in different canal.
- Report and prepare inventory of maintenance need in specified format.
- Supervise the SEs and the activities of GOs and AOs.

Sub-engineer

The Sub-engineer (SE) is the technical assistant to an Engineer. He is fully responsible for implementing any O&M action. Specified responsibilities of SE are as below:

- Supervise and ensure the operation of a canal in accordance with the operational program prepared by WMU.
- Ensure that the water gauges at relevant locations of flow measurements are marked and in proper condition.
- Record the flow in a canal at specified times and at the time of any fluctuations on a daily basis.
- Record the operational groups of canals in the specified format.
- Submit the record of flows and the operational group of canals at the end of each irrigation cycle.
- Assist the Water Users Groups (WUGs) in technical matters.
- Inspect daily the canal in his jurisdiction and report the situation in specified Inspection Form.
- Implement the surveys on L- section and X- section of canals at the end of each crop season.
- Demarcate the area irrigated in each crop season
- Implement surveys of cropping pattern, crop areas and crop yields with AO and WUA
- With AO motivate water users through WUA to plant same crop in respective TICs that makes easy water management activities on-farm and off-farm.
- Prepare the inventory of maintenance needs for periodical maintenance actions.
- Supervise the GOs in realizing operation and casual labour forces in realizing maintenance activities.
- Get assistance from supervisors whose main function is to supervise implementation of routine and seasonal maintenance being realized by labour forces.

4.2 Role of Gate Operator

The specific responsibilities of Gate Operators (GO) are as follows:

- Regulate the gate in such a way that the supply in the canal is maintained nearly at the level or discharge specified in operation program.
- Record the flow at the specified time and at the time of any fluctuation.
- Keep the area immediately around and in the vicinity of gates and Parshell Flume free of weeds and any floating trash. Keep the area always clean.
- Coordinate with WUA in supply of water demand as per operation program.
- Report in time to WMU through engineers on supply of water demand by WUA, if departed from original operational program.
- Regularly maintain the smooth operation of gate by greasing and oiling its components.
- Regularly clean water gauge marks at the end of irrigation cycle and report for obliteration, if apparent to WMU through engineers

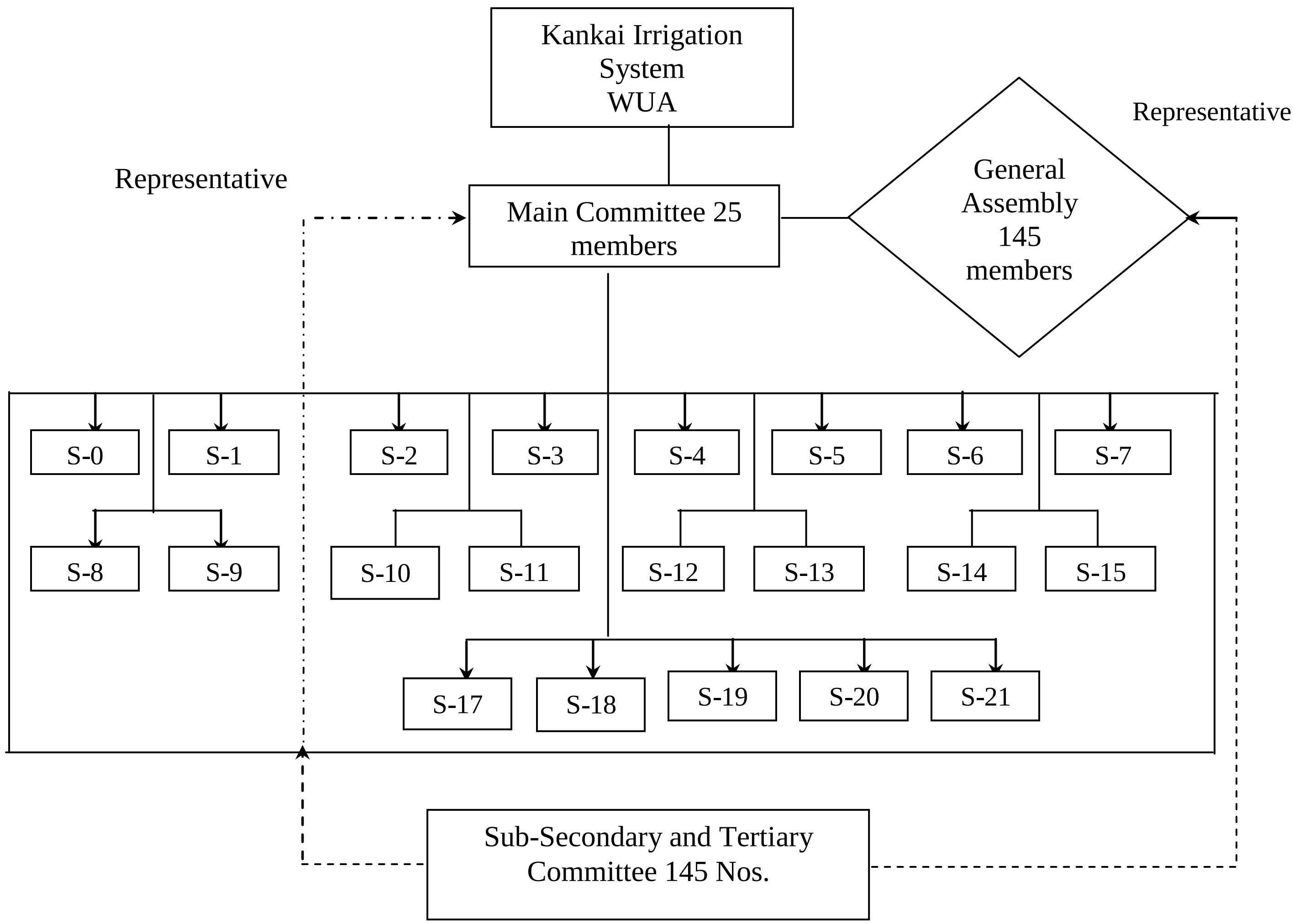
- Watch for correct operation or report defect in operation of gate, for example leakage of water through gate or malfunctioning of gate closure.
- Watch for, prevent or report any unauthorized abstraction of water from canals.
- Carefully watch and report to WMU, without delay, any such defect in the canal reach and hydraulic structures in place that can otherwise endanger the safety of canal or cause undue loss of water.

4.3 Role of Water Users Association

The specific responsibilities of Water Users Association (WUA) are as follows:

1 For each crop season, prepare estimate of crop area in respective TICs and DTOs of KIS at least a month advance and submit to WMU for MIC operation program preparation.
2 Distribute among TICs of allocated water to SICs and DTOs as per operational program in an equitable manner.
3 Daily monitor on availability of water as per operational program using work force in association with WMU.
4 Request on alternation in water demand for respective SICs in a specified format to WMU
5 Prepare and maintain the record of flows and the operational group of TICs at the end of each irrigation cycle.
6 Daily maintain the record of flow in respective SICs, and DTOs at specified times and at the time of any fluctuations.
7 Demarcate the area irrigated by TICs and DTOs in each crop season
8 Implement surveys of cropping pattern, crop areas and crop yields with AO of KIS
9 Daily monitor, record and prepare inventory of the maintenance condition of respective SIC, DTOs and TIC canal.
10 Watch for correct operation or report defect in operation of the SIC and DTO gates to WMU.
11 Keep the area immediately around and in the vicinity of regulating gates and Parshell Flume free of weeds and any floating trash. Keep the area always clean.
12 Regularly clean water gauge marks in cooperation with GO at the end of irrigation cycle and report for obliteration, if apparent to WMU
13 Report, without delay, any such defect in the canal and hydraulic structures that might endanger the safety of canal or cause undue loss of water to WMU.

5 WATER USERS ORGANISATION



Secondary Canal Committee:

Secondary	S-0	S-1	S-2	S-3	S-4	S-5	S-6	S-7	S-8	S-9	S-10	S-11
Members	7	11	6	9	16	6	5	5	7	10	8	5

Secondary	S-12	S-13	S-14	S-15	S-16	S-17	S-18	S-19	S-20	S-21
Member	7	11	12	8	11	2	2	2	2	2

Figure 5-1: Organisation Chart of WUA in KIS