MELAMCHI WATER SUPPLY DEVELOPMENT BOARD

MELAMCHI DIVERSION SCHEME

IRRIGATION WATER USES IN MELAMCHI VALLEY

June, 2002

MELAMCHI WATER SUPPLY DEVELOPMENT BOARD

MELAMCHI DIVERSION SCHEME

IRRIGATION WATER USES IN MELAMCHI VALLEY

June, 2002

Date of issue	: 10.06.02
Prepared by	: Gregor Perzyna
Checked by	: Mandira Shrestha / Willem Peletier
Approved by	: Ove Rusten

TABLE OF CONTENTS

LIST OF ABBREVIATIONS/ACRONYMS

a.s.l.	above sea level
DIO	District Irrigation Office
DHM	Department of Hydrology and Meteorology
FAO	Food and Agriculture Organization of the United Nations
GIS	Geographical Information System
GTZ	German Technical Cooperation
MDS	Melamchi Diversion Scheme
MWSP	Melamchi Water Supply Project

1 BACKGROUND

The Melamchi Water Supply Project (MWSP) is designed to solve a major water supply shortage in the Kathmandu Valley. During the dry season period, the planned scheme will highly affect the hydrological regime of the Melamchi River downstream of the intake. This report aims to clarify some issues related to the present and the future allocation of the Melamchi streamflow for irrigation uses.

Hydrological data

The accurate assessment of the water resources in the Melamchi basin have been in the past and to some degree is still constrained by a limited hydrological and water uses database. During 1999, NORPLAN has initiated the hydrological measurement campaign in the Melamchi basin. This campaign continues and aims specially to collect additional information related to the dry season streamflow and irrigation water uses. The activities carried out by NORPLAN includes:

In order to secure the consistency of the existing hydrological data base:

- Regular measurements at the Helambu DMH gauging station which is located upstream of the proposed intake site.
- Low flow measurements of Yangri and Larke Rivers.

In order to improve the knowledge about flow variation along the Melamchi River, flow conditions during irrigation season, water uses and necessary riparian flows:

- Regular dry season, streamflow measurements along the Melamchi River from the gauging station down to Melamchi Pul Bazaar.
- Discharge measurements of major tributaries contributing flow to the Melamchi River
- Measurements of the diverted flow in irrigation canals below the intake site
- Mapping of irrigation system

Results of these measurements are crucial for the understanding of the Melamchi basin water resources system and the accurate estimation of hydrological variables.

Present report has been prepared based on data available by the end of April 2002. This year NORPLAN's measurement campaign continues. Therefore, in the near future this report will be updated to include the recently collected data and field findings.

2 THE MELAMCHI BASIN

The headwaters of the Melamchi River are situated on the south slopes of the Jungal Himal Range in the Langtang National Park, at an elevation exceeding 5000 m above sea level (a.s.l.). Down to the intake and further to its confluence with the Indrawati River at Melamchi Pul Bazar, the river flows in south direction. The total basin area of the Melamchi River is approximately 327 km^2. The proposed intake site of the Melamchi Diversion Scheme is located at an elevation of about 1425 m a.s.l., approximately 4.9 km downstream of the Department of Hydrology and Meteorology (DHM) gauging station 627.5.

Mountainous river

The upper part of the Melamchi basin, upstream from the Melamchi gauging station has characteristics of a high-altitude, mountainous catchment. In this part of the basin, the river valley is deep and the average slope of river bed per 1 km of channel length has a very high value of more than 18%. Upstream of the gauging station the basin has no permanent human habitation or agricultural development.

Lower basin

The lower part of the Melamchi basin from the Melamchi gauging station down to the confluence with the Indrawati River has a flatter river gradient. Downstream of Timbu village the agricultural use of the river valley increases. Water from the Melamchi main stream is used for irrigation of fields located within the valley bed. The terraced fields located on the steep slopes of the Melamchi valley are irrigated by water from the Melamchi tributaries.

2.1 Climate

During the summer, from June to September, the basin climate is influenced by the southeast monsoon. The winter precipitation is related to synoptic-scale cyclonic activity with its origin in the Mediterranean region. On the local scale the areal distribution of both monsoon and winter precipitation will vary dependent on local topography and small-scale orographic effects

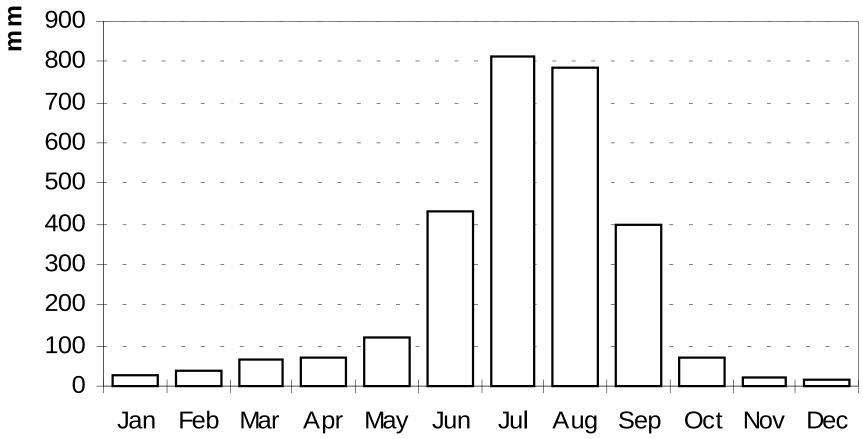
Areal rainfall

The distribution of the average annual precipitation within the Melamchi basin shows a strong gradient dependent on altitude. The annual rainfall varies from more than 4500 mm in the most upper part of the basin to 2500 mm (Nawalpur), in the lower part of the basin..

Seasonal distribution

The seasonal distribution of rainfall is unimodal and reflects a single, monsoon season lasting from the middle of June until September (see Fig. 2.1). On average about 80% of the annual precipitation falls during this period. The months of maximum precipitation are July and August with the average precipitation close to 800 mm. A prolonged dry season lasts from November until March. During this period, the recorded monthly precipitation generally does not exceed 50 mm. Part of winter precipitation falls as snow. The position of the snow line varies from less than 3500 m a.s.l. in January to more than 4500 m a.s.l. in July.

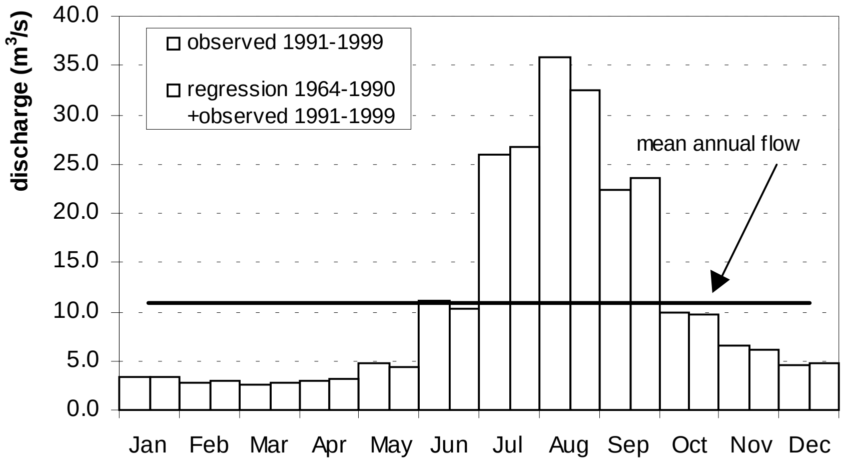
Figure 2.1 Distribution of average monthly precipitation at the Tarke Ghyang. The rainfall station is located in vicinity of the intake site (mm).



2.2 Hydrological conditions

The long term mean annual flow at the MDS intake site is about 11 m^3/s. There is a large difference between magnitude of flows during dry and wet season. The high flow season lasts from July to October. The dry season extends from January until May. The months of minimum flow at the intake site are February and March.

Figure 2.2 Mean monthly discharge at the Melamchi intake site.



Magnitude of flows

The magnitude of the dry season flows of Melamchi is stable and varies little from year to year. During the extremely dry years, low flows decrease by no more than 30 % below a long-term mean flow value. This mean flow value, calculated for the four months period from January to April, is equal to 2.9 m^3/s (1991-2000). The month of minimum flow is March with an average discharge value of 2.6 m^3/s.

Seasonal distribution

The seasonal distribution of Melamchi flows at the intake site indicates that during much of the year the River will have a surplus of flow compared to the total water demand within the basin. The water stress period is restricted to a dry season from January to April. In the future, during this period, the Melamchi streamflow will have to cover the minimum demand of the Diversion Scheme as well as the environmental, irrigation and other demand downstream of the intake site.

Low flow phenomenon

There were no detailed studies on the low flow phenomenon in the Melamchi basin. It is generally accepted however, that the dry season flows are groundwater fed with contribution from snowpack melting during the end of the season. The occurrence of years with extremely low flows could not be linked to the amount of monsoon precipitation during the preceding year. It is a tentative opinion of the Consultant that the magnitude of the Melamchi low flows may rather depend on the relative contribution to the total flow from snow melting. The extreme low flows would then occur during years with a high position of the snowline and little snow magazine.

Diurnal variation

The contribution from snow melting introduces diurnal streamflow variation. Recent April 2002 field investigations have shown that the Melamchi dry season streamflow may notably vary on diurnal scale. Streamflow gauging at the intake site at late afternoon on April 12 has showed discharge nearly 1 m^3/s higher than at the morning of the following day (respectively 3.1 m^3/s and 2.2 m^3/s).

Low flow frequency

The Weibull distribution yields for the minimum monthly flow with magnitude 2 m^3/s a return period T= 20 years. This indicates that on average, once within 21 years the minimum monthly flow of Melamchi at the intake site can be lower than 2 m^3/s. That does not mean that such flows can not occur more often or can occur during several consecutive years.

3 IRRIGATION WATER USES – PRESENT SITUATION

Presently, the Melamchi River acts as a source for two main water uses. Firstly, irrigation of the terraced rice fields is the single major consumptive use and supply of water to water mills is the major non-consumptive use. Secondly, Melamchi water is used for domestic supplies, micro-hydropower and a paper mill.

Rice irrigation

Rice irrigation is a traditional practice among farmers in the Melamchi Valley. On suitable slopes of the valley, terraces (level basins) have been constructed. These terraces are irrigated gravitationally, by the cascade method i.e. irrigation water is supplied from the main canal to the highest terrace, and then allowed to flow to a lower terrace and so on. Generally the size of individual basins is small and does not increase 100–150 m^2 with smaller basins being located on the steeper slopes. The cultivation of rice fields is done by hand but during preparation of the soil animal powered tillage is used. The small size of terraced basins makes them easy to level and efficient irrigation can be attained with relatively small canal flow.

Cascade irrigation

The cascade practice of irrigation allowing the water to flow from higher to lower terraces contributes to trapping the sediments coming from upper slopes. Farmers normally carry out conservation measures on a yearly basis, especially after the rainy season. Thus, the Melamchi basin behaves somewhat as a close system, retaining in-situ a large proportion of the sediments.

The water diverted from the Melamchi tributaries irrigates the higher elevated slopes of the Melamchi Valley. The water from the Melamchi River is used to irrigate the terraces located close to the bottom of the valley and fields located within the Melamchi alluvial channel. Within the Melamchi basin, the irrigated rice is cultivated from Ambathan down to Melamchi Pul Bazaar.

In the lower parts of the basin the irrigated rice-cropping season lasts normally from April to July. This season starts approximately 2 weeks later in the upper part of the basin.

3.1 The Melamchi River irrigation system

Irrigation canals

The latest field inventory carried out by NORPLAN during April 2002 has located 32 irrigation canals supplied by Melamchi River. The basic information about the Melamchi River irrigation canals is summarised in Table 3.1. Figures 1 and 2, Appendix 1 contain the schematic layout of the Melamchi irrigation canals separately for the left and the right bank of the river.

The bulk of the Melamchi irrigation system consists of short and medium length open earthen canals with temporary intake structures that have to be rehabilitated after each flood season. Three long canals, which have been constructed with assistance of the District Irrigation Office (DIO) and GTZ, are lined, have permanent intake structures and flow regulation facilities. The Melamchi farmers are used to direct participation and cooperation on the irrigation system maintenance and development. Therefore, this system may be considered as having a relatively high level of performance over a long period.

Table 3.1 Information on irrigation canals diverting water from the Melamchi River.

Total number of irrigation canals	32
Number of canals serving the river left bank fields	15
Number of canals serving river right bank fields	17
Number of canals serving exclusively irrigation	18
Number of canals serving both irrigation and water mills	14
Total canal length (km)	39
Number of canals with length within the range 0 m – 250 m	7
Number of canals with length within the range 250 m – 500 m	4
Number of canals with length within the range 500 m – 1000m	5
Number of canals with length within the range 1000 m – 2000 m	12
Number of canals with length within the range 2000 m – 4000 m	2
Number of canals with length within the range 4000 m – 5000 m	1
Irrigated area on the river left bank (ha)	144
Irrigated area on the river right bank (ha)	145
Total irrigated area (ha)	289

Inspection of the graphs indicates that on both the left and the right banks of the Melamchi River irrigation canals constitute a quite complicate system. Particularly:

⇒ many canals having their intake in the Melamchi River are crossing triburaries to the Melamchi River and additional water is supplied to the canals from these tributaries.

⇒ frequently several canals overlap each other and water from higher elevated canals leaks or is conveyed to lower elevated canals.

⇒ the same paddy fields may be irrigated by water from different canals. Usually, a longest canal, with an upper most intake, serves the higher elevated terraces. As an example, consider in Figure 1, the system of canals IL16, IL19, IL19.1 and IL22. Canal IL16 serves the higher elevated terraces down to Bhattarphat Khet (Talamarang). On this distance, the lower elevated terraces may be irrigated by both water from IL16 and by canals IL19, IL19.1 and IL22.

⇒ The Melamchi irrigation system is a dynamic one and changes occur in time. Last years field findings show that construction of new canals (IL 16 and IR30) encouraged farmers to abandon many old earthen canals. As a result the total intake of water diminished and Melamchi water is used more efficiently.

Primary canals

The intake to the first major canal (IR3) is located in Chesgaun. This irrigation canal has a permanent intake and had been constructed by DIO. Canal IR3 ends close to left bank of the Gohore Besi and has length of nearly 4 km. The other two longest canals are IL16 and IR30 with lengths of 4.5 km and 3.6 km respectively. The intake of IL16 is located on left bank of the Melamchi in Chanaute. This is an important canal made by DIO. It has a temporary weir and permanent intake. The intake to canal IR30 is located approximately 50 m upstream from the confluence the Nuhar Khola. The permanent weir and intake have been build by DOI. The canal is lined. Canal IR30 continues down to Melamchitar.

3.2 Distribution of irrigated land along the Melamchi River

The spatial distribution of the irrigated paddy fields along the Melamchi River depends mostly on the local topography and particularly, on the location of the slopes with gradients allowing for the terraced agriculture. Most of the feasible slopes are already cultivated and perspectives for the future extension of the irrigated fields are limited.

Spatial distribution

Figures 3 and 4, Appendix 1 summarise the information on the distribution of the irrigated area along the Melamchi River. For a generalisation purpose, on the distance between the intake and the Melamchi confluence with the Indrawati River, the Melamchi basin has been divided into 9 segments. For the each segment two characteristic values have been estimated:

- Total area of the land irrigated by the Melamchi River within the basin segment (Fig.3)
- Total area of the land irrigated by the canals having their intake structure within the segment (Fig.4)

Characteristic values

The first value is directly indicative for the distribution of the irrigated land along the Melamchi River. The second value is significant in relation to the amount of irrigation water to be diverted from the Melamchi River within the segment. It has to be noted that both values may differ because some canals having intake in particular segment crosses the segment boundary and irrigate the fields in the downstream segment.

The respective estimates of the irrigated areas have been obtained from the maps created in a GIS – ArcView environment. The necessary basic data has been collected in the field by NORPLAN's Topography and Hydrology teams. The estimates of the irrigated area are preliminary and may be somehow biased. The estimation error should not be however larger than 10%. The summary of information on the area irrigated by the Melamchi water is presented in Table 3.2.

Table 3.2 Information on the total area of irrigated land within the segments and the total area of land irrigated by canals with intakes located within the segments.

Basin segment section	Total irrigated area within the segment (ha)	Total area of irrigated land by water diverted from the Melamchi main stream within the segment (ha)
Intake		
Ambathan	0	0
Timbu	0.3	0.3
Chesgaun	8	8
Kiulpati	16	78
Tar	96	34
Sera	24	70
Talamarang	65	21
Nuhar Khola	28	26
Melamchi Pul	52	52
Sum Basin	289	289

Analysis of the presented data indicates that the largest irrigated areas are located within the Kiulpati–Tar (96 ha) and the Sera–Talamarang (65 ha), segments. On the distance from the Intake to Kiulpati, the total area of irrigated land is small and does not exceed 25 ha. It has to be noted however, that within the same distance, intake structures are located that divert water for irrigation of nearly 90 ha, with a prevailing part of the water being diverted within the segment Chesgaun-Kiulpati. This indicates that the demand for irrigation water is shifted upstream with respect to location of the irrigated fields.

3.3 Calculation of the rice irrigation water demand for the Melamchi basin conditions.

The deep dry season flow lasts in the Melamchi basin from January until May with March and April being the months of the minimum flow. Farmers for land preparation by puddling normally use the last two weeks of March. During this period water is mainly used for saturating of the soil layer and the rice plant nursery. The irrigation season along the Melamchi River is on its maximum during the month of April. During May, the streamflow of the Melamchi rises and the effective precipitation improves the water balance. The calculation results of rice irrigation water requirements are presented below.

Method

The calculation of the irrigation water need for paddy rice has been performed in the following steps according to the FAO procedure:

1. The reference crop evapotranspiration: Et_o has been calculated by the FAO Penman-Monteith method. Due to the lack of more suitable data, the climatic variables from the Kathmandu Airport have been used. The temperature series has been adjusted by $+3^0C$ in order to compensate for lower elevation of the downstream part of the Melamchi basin (900 m a.s.l)

2. The rice crop factor K_c has been fixed to 1.15, which is a rather high value for a tillering period.

3. Calculation of the crop water need: $ET_{crop} = ET_0 \times K_c$

4. Determination of the amount of water needed (SAT) to saturate the soil for land preparation by puddling. It was assumed that during the April month the soil is already saturated and SAT equals 0mm.

5. Determination of the amount of percolation and seepage losses. In spite of lack of the measured infiltration data the high value of 7mm a day for sandy soils has been adopted

6. Determination of the amount of water needed to establish a water layer WL. This amount has been estimated for 100 mm

7. Calculation of the effective rainfall P_e. Effective rainfall has been conservatively assumed to be 0mm during April month.

8. Calculation of the irrigation water need:
   $IN = ET_{crop} + SAT + PERC + WL - P_e$

The results of calculation for the month of April are presented in Table 3.3.

Table 3.3 Details of the calculation of paddy rice irrigation water needs.

ET_0	(mm/day)	4.4
K_C		1.15
Rice water need Et_{rice}	(mm/month)	152
Water for soil saturation (SAT)	(mm/month)	0
Percolation (PE)	(mm/month)	210
Water layer (WL)	(mm/month)	100
Effective rainfall (Pe)	(mm/month)	0
Rice irrigation water needs (mm/month)	(mm/month)	462
Rice irrigation water needs (mm/day)	(mm/day)	15.4
Rice irrigation water need (l/sha)	(l/sha)	1.78
Conveyance efficiency	%	75
Application efficiency	%	60
Irrigation scheme efficiency	%	45
Gross irrigation water need (l/sha)	(l/sha)	3.96

The obtained value of daily paddy rice irrigation needs of **15.4 mm** for the Melamchi Valley conditions is high compared to values referred in the literature.

Gross needs

The calculated value of irrigation water needs is a net demand of rice crop at the terraced basin site. Additional losses are experienced during transport of water due to the infiltration and the seepage from the canals and during the process of water application in the field. For the Melamchi conditions with relatively short canals and the cascade mode of water application, the scheme irrigation efficiency has been conservatively assumed as 45%. Applying this value to the earlier estimated rice irrigation water needs, we can calculate the gross irrigation water demand per hectare of the rice field. This value for the Melamchi Valley has been estimated for approximately **4 l/sha.**

It should be noted that for the Melamchi irrigation schemes, the water losses due to the leakage from the canals and lateral seepage from the terraces are mostly recovered. This water partly flows back to the River or to the lower elevated terraces. Therefore, at present situation the improvements in local efficiency would result rather only in theoretical savings. The situation may change after commission of the MDS. With considerably less water in the Melamchi mainstream, some measures to improve the schemes' efficiency could be necessary. Especially improving the main distribution systems by construction of lined canals and installing permanent weirs allowing for flow regulation may considerably help with water scheduling and in consequence reduce the water stress.

3.4 Distribution of present water irrigation demand along the Melamchi River

For the purpose of estimation of the present water irrigation needs, we have used the calculated value of the gross irrigation water demand per hectare of the rice field increased by 5% i.e. the value of **4.2 l/sha.** This higher value has been used in order to secure the conservative mode of calculation and to prevent underestimation of the irrigation water demand.

Segment needs

The gross irrigation needs along the Melamchi have been calculated on a segment basis. For each segment, two different values have been estimated. The segment irrigation water needs and the segment intake water needs.

Irrigation needs

The segment irrigation water needs have been calculated by multiplication of the April value of 4.2 l/sha by the total area of irrigated land within the segment.

Intake needs

To obtain the present intake water needs for each segment, the April value of 4.2 l/sha has been applied to the total area of the land irrigated by the canals having the intake structure within the segment.

The results of calculations are presented in Table 3.4 and illustrated in Figures 5 and 6, Appendix 1.

The present irrigation water needs within the segments vary within the range 0 l/s to 403 l/s. The segments intake water needs vary between 0 l/s and 327 l/s. Both irrigation needs and intake needs are negligible on the distance from the planned intake of the MDS down to Chesgaun. The largest intake needs characterises the segment bordered by Chesgaun and Kiulpati. Most of the water diverted within this segment is used to irrigate the rice fields located within the downstream segment Kiulpati–Tar. At present, this is the segment with the largest irrigation water needs within the Melamchi basin.

Inspection of Table 3.4 shows that in the upper part of the Basin due to location of the intake structures, the demand for irrigation water is shifted upstream with respect to location of the rice fields. Such a situation is rather unfortunate considering the future impact of the MDS uses.

Table 3.4 Information on gross irrigation water intake demand within the segments

Basin segment section	Gross segment irrigation water needs (l/s)	Gross segment irrigation water intake during April (l/s)
Intake		
Ambathan	0	0
Timbu	1.2	1.2
Chesgaun	32	32
Kiulpati	68	327
Tar	403	143
Sera	101	292
Talamarang	273	90
Nuhar Khola	116	110
Melamchi Pul	220	220
Sum Basin	1214	1214

The calculated theoretical April value of the total basin irrigation needs (**1214 l/s**) corresponds in fact well to the accumulated flow measured during April 2002 in the irrigation canals. The last value equals to approximately 980 l/s. During 2002 April, the irrigation season in the upper parts of the Melamchi river has been delayed what may explain the 20% difference.

3.5 Impact of the irrigation uses on the dry season flows

In March 1999, NORPLAN has initiated comprehensive hydrological measurements campaign in the Melamchi basin. This campaign continues until today and a special emphasis is given to the measurements of the dry season Melamchi flow downstream of the planned MDS intake. There are 8 standard measurement sites within the reach between the proposed intake site and Melamchi Pul Bazaar.

The improvement of the knowledge about the reliability of the dry season flows, the seasonal flow variation patterns and the expected flow magnitude during the low flow season at different sites downstream of the intake is crucial. This information is and will be a basis for scheduling of the Melamchi streamflow in order to ensure the irrigation and ecological water needs and at the same time, possibly the most effective performance of the planned MDS. Therefore, NORPLAN plans to go ahead with the campaign during the coming years.

Dry season flow

In the Melamchi basin the beginning of the irrigation season coincides with the last six weeks of dry season flows, the second part of March and April. During the month of May, the water balance of the Melamchi River is considerably improved by contribution from snowmelt and effective rainfall.

Net flow

In fact, for the Melamchi River the magnitude of the natural flow i.e. flow in a stream as it would occur under natural conditions is unknown. Lack of necessary, local scale, meteorological and ground water data prohibits at present the possibility of reliable natural runoff modelling within the basin. The streamflow measured during dry season is a net flow, being the portion of flow left in the river after net intake for different water uses:

$Q_{NET} = Q_{NATURAL} – Q_{NET\ WATER\ USES}$

Where Q_{NET} measured flow at the site
$Q_{NATURAL}$ natural river flow at the site
$Q_{NET\ WATER\ USES}$ net water uses upstream of the site

A summary of the measured flows along the Melamchi River since March 1999 is presented in Table 3.5. Direct comparison of the values is somewhat constrained by:

- Different timing of measurements within the month
- Variable water use downstream of the proposed intake. The water use changes seasonally as well as on a year to year basis.
- Varying weather conditions within the period of measurement campaigns - occurrence of short rain showers.

Table 3.5 Summary of the Measured Flows Along the Melamchi River since 1999.

	1999	2000				2001			2002	
Location of gauging site along the River	Mar (end)	Jan (end)	Feb (end)	Mar (end)	Apr (mid)	Apr (beg)	Apr (mid)	May (mid)	March (mid)	April (mid)
Gauging Station 627.5	2.0	3.4	2.4	2.1	2.5	1.8	-	-	-	-
Proposed Intake site	-	-	-	-	-	2.2	2.4	-	2.5	2.4
Ambathan	2.6	4.0	2.7	2.4	3.1	2.3	2.5	4.1	2.6	2.5
Chesgaun	2.7	4.2	3.3	2.7	3.4	2.4	2.8	4.2	2.7	2.6
Kiul	2.9	5.1	3.4	3.1	3.4	2.5	2.9	4.3	2.8	3.4
Chanaute	3.6	6.3	4.2	3.6	4.2	3.3	3.6	5.3	3.3	3.9
Talamarang	3.9	7.0	4.9	4.1	4.4	4.0	3.7	5.8	4.0	4.0
Nuhar Khola	3.7	7.0	5.2	4.2	4.5	3.5	4.0	6.1	4.5	4.2
Melamchi Pul	3.8	6.8	5.6	4.2	4.2	3.7	3.8	6.5	4.5	5.0

Low flow scenario

To quantify an approximate impact of the irrigation uses on dry season streamflow, we constructed an extreme low flow scenario based on the streamflow values gauged during beginning of April 2001 and estimated data on gross irrigation water intake within the segments of the Melamchi basin. The 95% dry season flow duration value derived from the daily flow duration curve at the intake site (1999-2000) equals to 2.1 m^3/s. This value was decided to be used as an initial scenario discharge at the intake site. Therefore, the lowest gauged April 2001 streamflow data, have been proportionally adjusted by (–

0.1 m^3/s). Additionally, the Melamchi discharge at Talamarang has been corrected down by 0.6 m^3/s in order to eliminate the influence of a local rain shower that occurred hours prior to measurement.

Irrigation is the single largest consumptive water use in the Melamchi basin and in fact, the impact of other uses on the Melamchi stream-flow may be neglected.

Return flow

Observations in the field have shown that a considerable amount of water transported in the irrigation canals leaks back to the Melamchi River. Also, a portion of water applied to the fields returns back to Melamchi both by the surface and by lateral seepage. The exact quantification of the irrigation return flow at this stage of the project is not possible due to the lack of necessary data. As an approximation, in a conservative manner, we assumed that 40% of the irrigation water, diverted to cover the conveyance and field application losses, returns back to Melamchi. For the earlier estimated irrigation scheme efficiency of 45% and water needs 4.2 l/sha, it means that on average approximately 0.9 l/sha returns back to the Melamchi River.

Natural flow

Finally, the approximate value of the natural flow at each of the gauging sites along the Melamchi mainstream has been calculated as:

$$Q_{NATURAL} = Q_{NET} + Q_{NETIRRIG}$$

$$Q_{NETIRRIG} = Q_{IRRIG} - Q_{IRETURN}$$

Where Q_{NET} measured flow at the site (scenario)
$Q_{NATURAL}$ natural river flow at the site
$Q_{NETIRRIG}$ net irrigation water use upstream of the site
Q_{IRRIG} irrigation water intake upstream of the site
$Q_{IRETURN}$ irrigation water return flow upstream of the site

The outcome of calculations is summarised in the Table 3.6.

Net irrigation uses

Inspection of the Table 3.6 indicates that for the constructed scenario of minimum flow, during April, the consumptive irrigation use upstream of Melamchi Pul Bazaar is approximately **1 m^3/s.** At this location, the value of natural flow i.e. the hypothetical flow for an assumption of no irrigation intake from the Melamchi River would be **4.6 m^3/s.** At present situation, the irrigation uses account for **21%** of the natural flow. The net flow measured in the River accounts for **79%** of the natural flow.

The irrigation uses are negligible upstream of Chesgaun. The intensive use of water for irrigation starts on the distance between Chesgaun and Tar. The total irrigation use upstream of Tar is approximately **0.4 m^3/s** and accounts for **14%** of the natural flow at the site.

Table 3.6 Summary of information on distribution of natural, net flow and irrigation uses along the Melamchi River

Gauging site	Q_{NET}) (l/s)	Q_{IRRIG} (l/s)	$Q_{IRETURN}$ (l/s)	$Q_{NETIR-RIG}$ ($m^{3/}s$)	$Q_{NATU-RAL}$ (m^3/s)	Irrigation uses as percentage of natural flow (%)	Net flow as percentage of natural flow (%)
Proposed Intake site	2100	0	0	0.0	2.1	0	100
Ambathan	2200	0	0	0.0	2.2	0	100
Chesgaun	2300	33	7	0.03	2.3	1	99
Tar	2400	503	111	0.4	2.8	14	86
Chanaute	3200	794	175	0.6	3.8	16	84
Talamarang	3400	884	194	0.7	4.1	17	83
Nuhar Khola	3400	994	218	0.8	4.2	19	81
Melamchi Pul	3600	1214	251	1.0	4.6	21	79

Figure 7, Appendix 1 shows for the different cross-sections, the net flow of the Melamchi River and the upstream irrigation use as a percentage of the natural flow at the site. Respectively for the same locations, Figure 8, Appendix 1 illustrates the magnitudes in m^3/s of the net streamflow and the upstream irrigation use.

The results of analysis reveals that for the actual level of the water uses, there is an adequate amount of water in the Melamchi River in order to meet requirements of all water users.

4 WATER USES IN THE FUTURE SITUATION

MDS uses

After commissioning, the planned Melamchi Diversion Scheme will be the single largest water user in the basin. During the dry season, the MDS will have a notable impact on the magnitude of Melamchi streamflow downstream of the intake site. At the same time, it is important that the volume of Melamchi flow downstream of the intake will meet the ecological, sanitary and the water use requirements.

Kathmandu water distribution system has only a limited water storage capacity (for approximately 24 hours). Therefore, a riparian release of 0.4 - 0.5 m^3/s, with some volume reduction of expected supply, may probably be sanctioned as the maximum reasonable magnitude of bypass flow that does not affect the Scheme's reliability in a significant manner.

Ecological needs

The Supplementary Environmental Assessment study conducted by METCON (January 2001) concluded that the amount of water available at Timbu after diversion and riparian release of 0.4 to 0.5 m^3/sec is adequate to sustain aquatic life. The question remains if a bypass flow of this magnitude will be enough to meet irrigation demands.

Low flow scenario

To study the Melamchi dry season flow and situation of irrigation uses subject to MDS water diversion, the Consultant has used the minimum flow scenario for the month of April created in the previous chapter. During analysis we used following assumptions:

- constant riparian release of 0.5 m^3/s or for the established flow conditions constant use of 1.6 m^3/s
- present spatial distribution and area of irrigated land, and current magnitude of net irrigation uses (see Table 3.6)

Future net flow

With the above assumptions we have calculated, the approximate value of the future net flow at each of the gauging sites along the Melamchi mainstream as:

$$Q_{NET} = Q_{NATURAL} - Q_{NETIRRIG} - Q_{MDS}$$

Where Q_{NET}	measured flow at the site with operational MDS (scenario)
$Q_{NATURAL}$	natural river flow at the site
Q_{MDS}	Melamchi Diversion Scheme water use (intake)

The results of calculations are summarised in Table 4.1. Inspection of this Table indicates that for the actual level of the irrigation uses and the MDS use with a riparian flow of 0.5 m^3/s the demand of both uses could be met at each point along the Melamchi River, even during periods with extreme low flow. For the established low flow scenario the consumptive uses (MDS + irrigation) upstream of Melamchi Pul Bazaar would account for some **2.6 m^3/s** or **56 %** of natural flow**.** Assuming the present level of irrigation uses the expected value of net streamflow at this location would be some **2 m^3/s**.

After commission of the MDS the largest water stress will be faced on the stretch between the intake and Tar. It may be expected that during periods of extreme low flow the net flow within this reach will not exceed **30%** of the natural flow or **0.8 m^3/s**. This forecasted low value of streamflow indicates that there is a very little or no room for further expansion of irrigated area upstream of Tar without an extensive improvement of the field management methods and irrigation procedures. After Tar, the Melamchi tributaries Gohare and Gori Khola significantly contribute to streamflow and reduce the water stress.

Table 4.1 Summary of information on future net flow and uses along the Melamchi River

Gauging site	$Q_{NATURAL}$ (m^3/s)	$Q_{NETIRRIG}$ (m^3/s)	Q_{IMDS} (m^3/s)	Q_{NET} (l/s)	Irrigation uses as percentage of natural flow (%)	MDS uses as percentage of natural flow (%)	Net flow as percentage of natural flow (%)
Proposed Intake site	2.1	0.0	1.6	0.5	0	76	24
Ambathan	2.2	0.0	1.6	0.6	0	73	27
Chesgaun	2.3	0.03	1.6	0.7	1	69	30
Tar	2.8	0.4	1.6	0.8	14	57	29
Chanaute	3.8	0.6	1.6	1.6	16	42	42
Talamarang	4.1	0.7	1.6	1.8	17	39	44
Nuhar Khola	4.2	0.8	1.6	1.8	19	38	43
Melamchi Pul	4.6	1.0	1.6	2.0	21	35	44

Figure 9, Appendix1, shows a comparison of the net flow magnitude along the Melamchi River for the present and future (including MDS uses), extreme minimum flow scenarios. Figure 10, illustrates the portion of the net flow, irrigation uses and MDS uses as the percentage of natural flow. Figure 11, Appendix 1, illustrates the magnitudes in m^3/s of the forecasted future net streamflow and the upstream irrigation use.

5 CONCLUSIONS

The seasonal distribution of Melamchi flows at the intake site indicates that during much of the year the River will have a surplus of flow compared to the total water demand within the basin. The water stress period is restricted to the dry season from January to April. In the Melamchi basin, the beginning of the irrigation season coincides with the last six weeks of the dry season flows, the second part of March and April. During the month of May, the water balance of the Melamchi River is considerably improved by contribution from snowmelt and effective rainfall.

Presently, the Melamchi River acts as a source for two main water uses. Firstly, irrigation of the terraced rice fields is the single major consumptive use and supply of water to water mills is the major non-consumptive use. Secondly, Melamchi water is used for domestic supplies, micro-hydropower and a paper mill. After commission, the planned Melamchi Diversion Scheme will be the single largest water user in the basin.

For the purpose of present study the demands of ecological flow and the two largest consumptive uses i.e. irrigation and MDS have been considered. It was assumed that the demand of water mills would cease after electrification of the Melamchi Valley. The demand of other uses is relatively small and has been neglected.

The spatial distribution of the irrigated paddy fields along the Melamchi River depends mostly on the local topography and particularly, on the location of the slopes with gradients allowing for the terraced agriculture. Most of the feasible slopes are already cultivated and perspectives for the future extension of the irrigated fields are limited. A total area irrigated by water from the Melamchi River has been estimated for nearly **290 ha.** The largest irrigated areas are located on the distance between Kiulpati -Tar (96 ha) and the Sera–Talamarang (65 ha).

The irrigation season along the Melamchi River is on its maximum during the month of April. During May, the streamflow of the Melamchi rises and the effective precipitation improves the water balance. The estimation of the April month irrigation water needs for paddy rice has been performed according to the FAO procedure.

The calculations yielded the value of **15.4 mm** as daily paddy rice irrigation needs for the Melamchi Valley conditions. This is relatively high value compared to values referred in the literature. The gross irrigation water demand per hectare of the rice field, including conveyance and field application losses, has been estimated for approximately **4 l/sha.**

For the purpose of estimation of the basin irrigation water needs, the calculated value of the gross irrigation water demand per hectare of the rice field has been increased by 5% to the value of **4.2 l/sha.** This higher value has been used in order to secure the conservative mode of computation. The theoretical April value of the total Melamchi basin irrigation needs has been estimated for nearly **1215 l/s**. This value corresponds in fact well to the accumulated flow measured during April 2002 in the irrigation canals. The last value equals to approximately 980 l/s.

An extreme low flow scenario has been used to quantify present impact of the irrigation uses on dry season streamflow. This scenario has been based on streamflow values gauged along the Melamchi River during beginning of April 2001 and the estimated data on gross irrigation water intake within the segments of the Melamchi basin.

For the April scenario of minimum flow, the consumptive irrigation use upstream of Melamchi Pul Bazaar has been estimated for some **1 m^3/s.** At present situation, the irrigation uses account for some **21%** of the natural flow. The net flow measured in the River accounts for **79%** of the natural flow. The irrigation uses are negligible upstream of Chesgaun. The intensive use of water for irrigation starts on the distance between Chesgaun and Tar. The total irrigation use upstream of Tar is approximately **0.4 m^3/s** and accounts for **14%** of the natural flow at the site. The results of analysis reveals that for the actual level of the water uses, there is an adequate amount of water in the Melamchi River in order to meet requirements of all water users.

In the upper part of the Basin, the demand for irrigation water is shifted upstream with respect to location of the rice fields due to the location of the intake structures. Such a situation is rather unfortunate considering the future impact of the MDS uses.

The same extreme low flow scenario has been used to study future conditions of the Melamchi dry season flow and situation of irrigation uses subject to MDS water diversion. During analysis following assumptions has been used:

- constant riparian release of 0.5 m3/s or for the established flow conditions constant use of 1.6 m^3/s
- present spatial distribution and area of irrigated land, and current magnitude of net irrigation uses

The results of analysis indicates that for the actual level of the irrigation uses and the MDS use with a riparian flow of 0.5 m^3/s the demand of both uses could be met at each point along the Melamchi River, even during periods with extreme low flow.

For the established low flow scenario the consumptive uses (MDS + irrigation) upstream of Melamchi Pul Bazaar would account for some **2.6 m^3/s** or **56 %** of natural flow**.** Assuming the present level of irrigation uses the expected value of net streamflow at this location would be some **2 m^3/s**. After commission of the MDS the largest water stress will be faced on the distance between intake and Tar. It may be expected that during periods of extreme low flow the net flow within this reach will not exceed **30%** of the natural flow or **0.8 m^3/s**. This forecasted low value of streamflow indicates that there is a very little or no room for further expansion of irrigated area upstream of Tar without an extensive improvement of the field management methods and irrigation procedures. After Tar, the Melamchi tributaries Gohare and Gori Khola significantly contribute to streamflow and reduce the water stress.

APPENDIX 1

Figures 1-11

Figure 1. Irrigation canal system - left bank

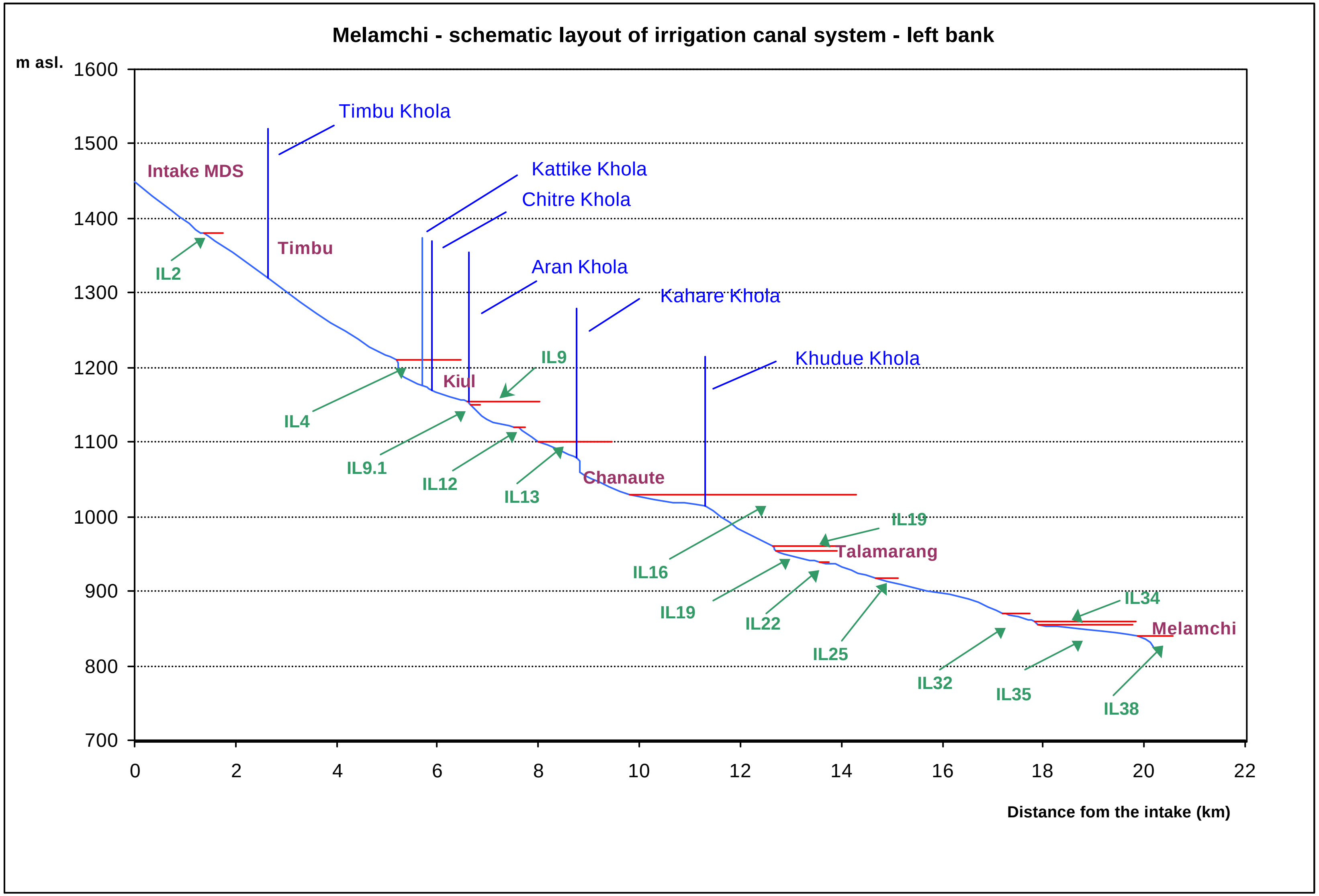


Figure 2. Irrigation canal system - right bank

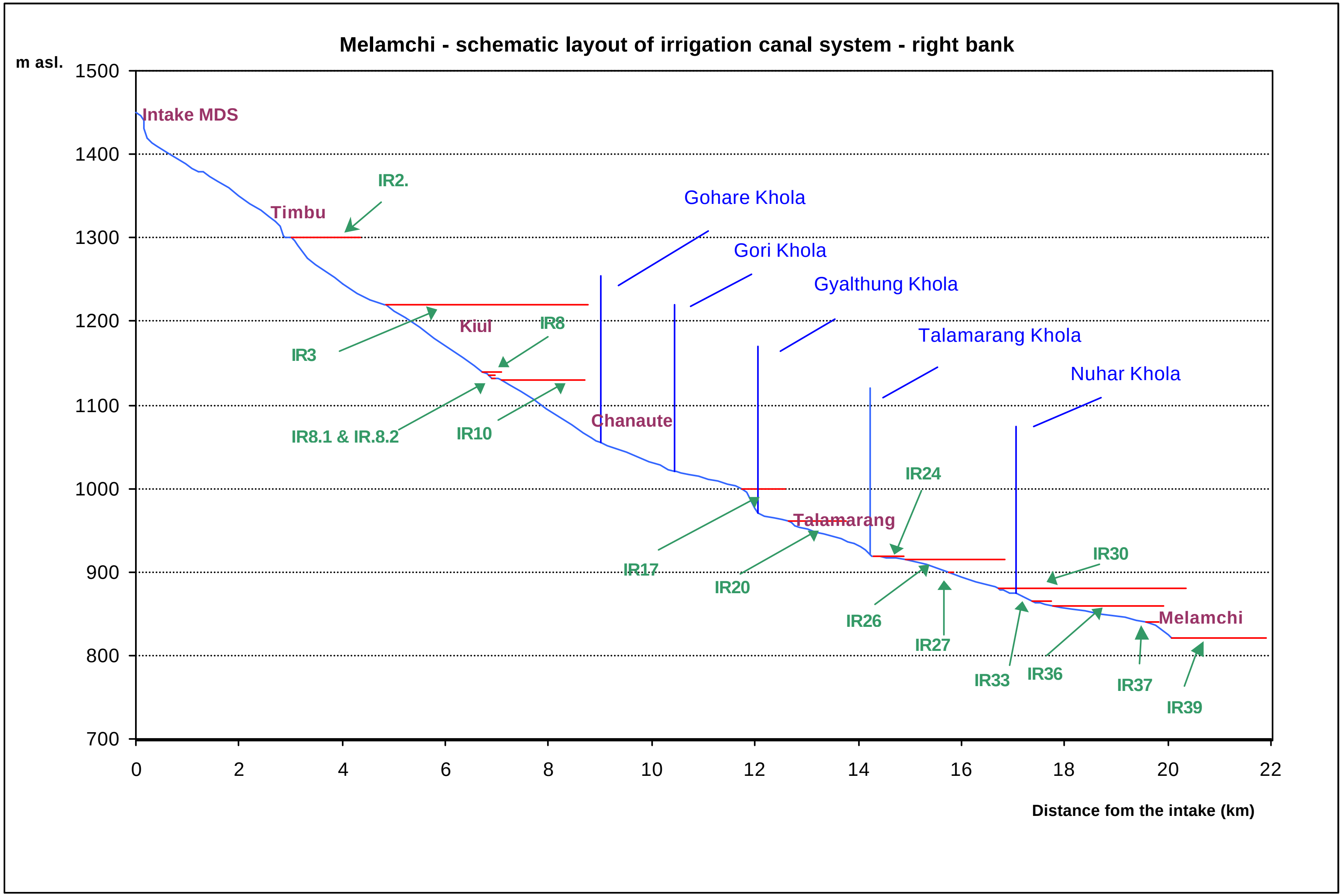


Figure 3. Data on rice crop area irrigated within the segments of the Basin

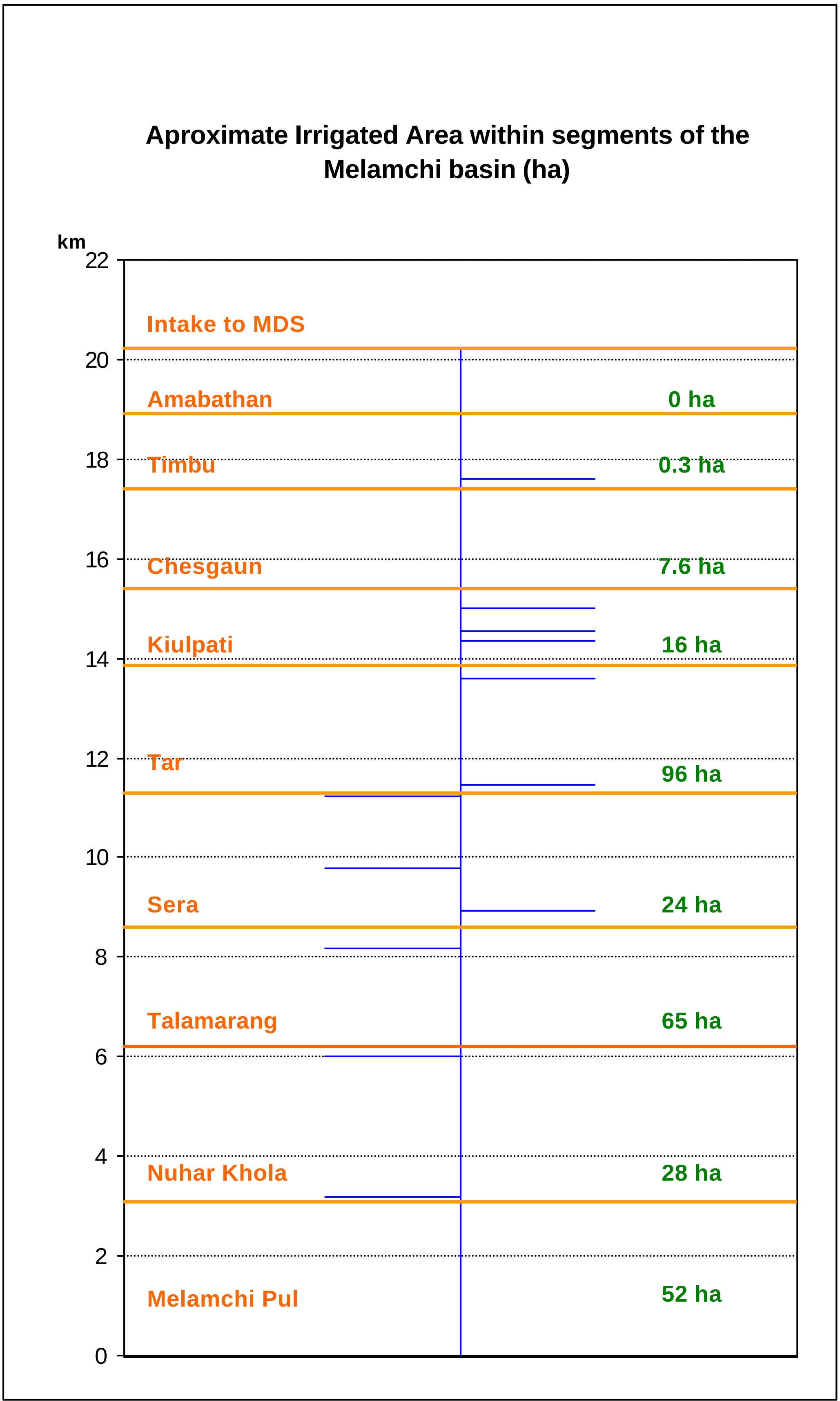


Figure 4. Data on rice crop area irrigated within the segments of the Basin

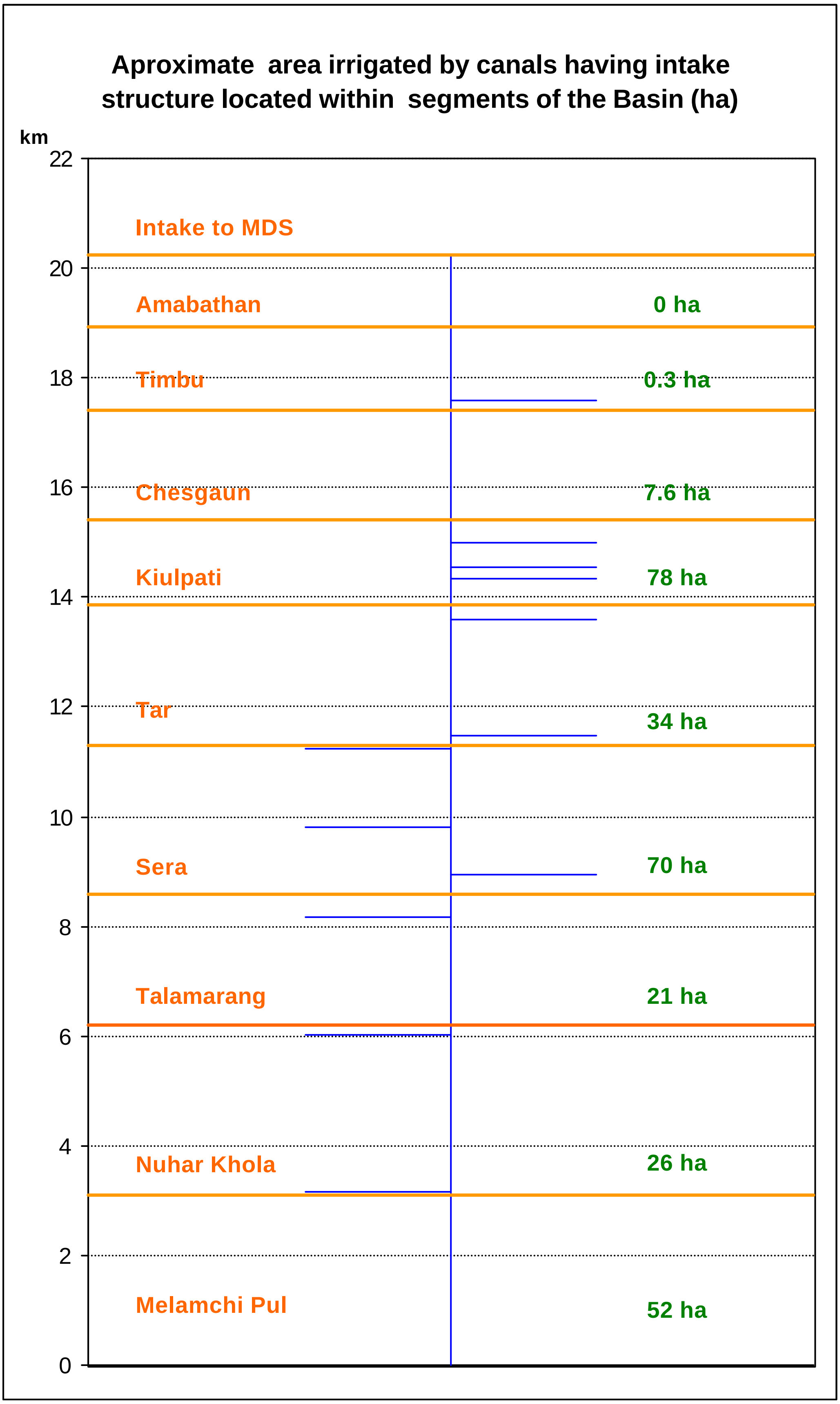


Fig 5. Irrigation water needs within segments if the Melamchi Baasin

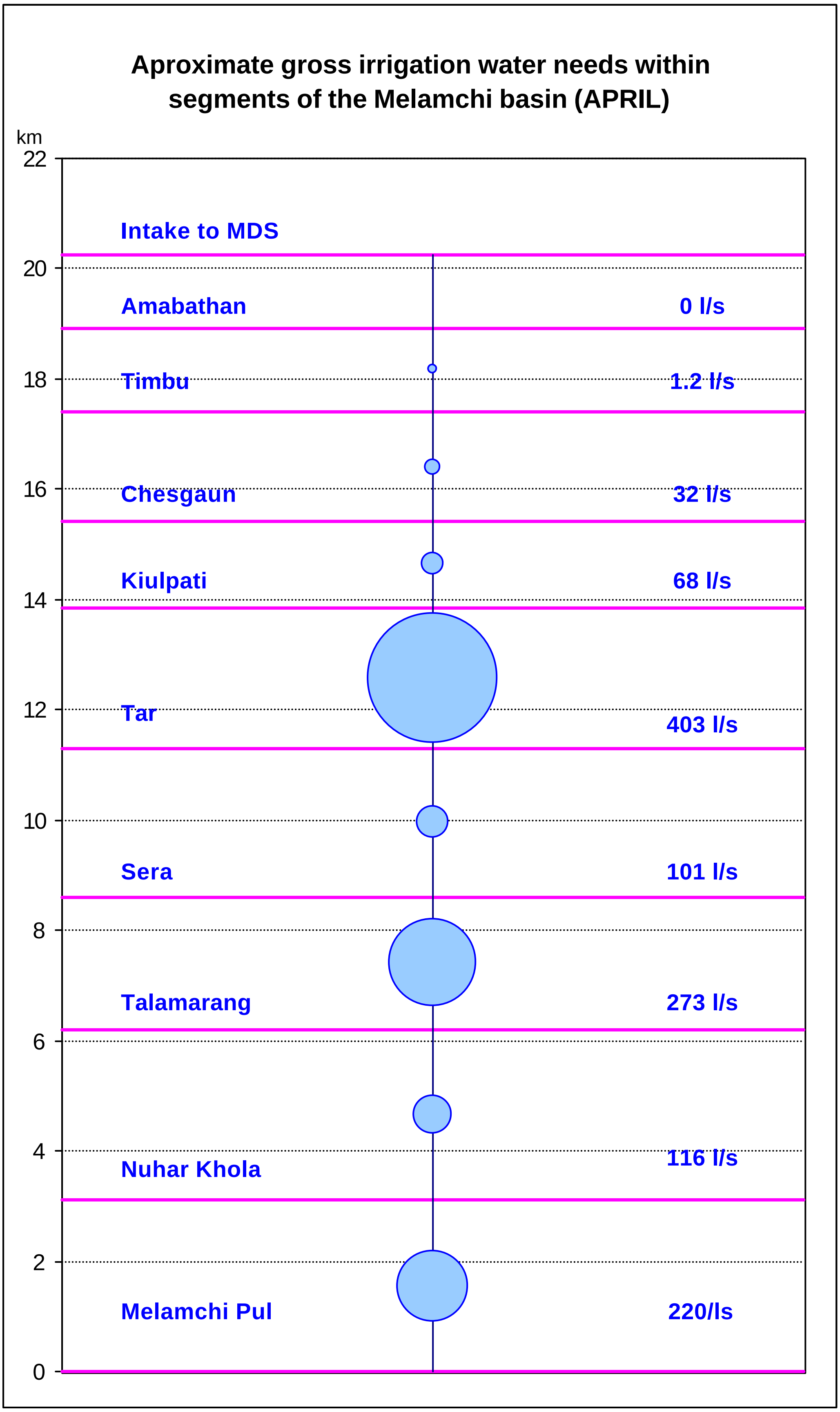


Fig 6. Irrigation water intake needs within segments if the Melamchi Baasin

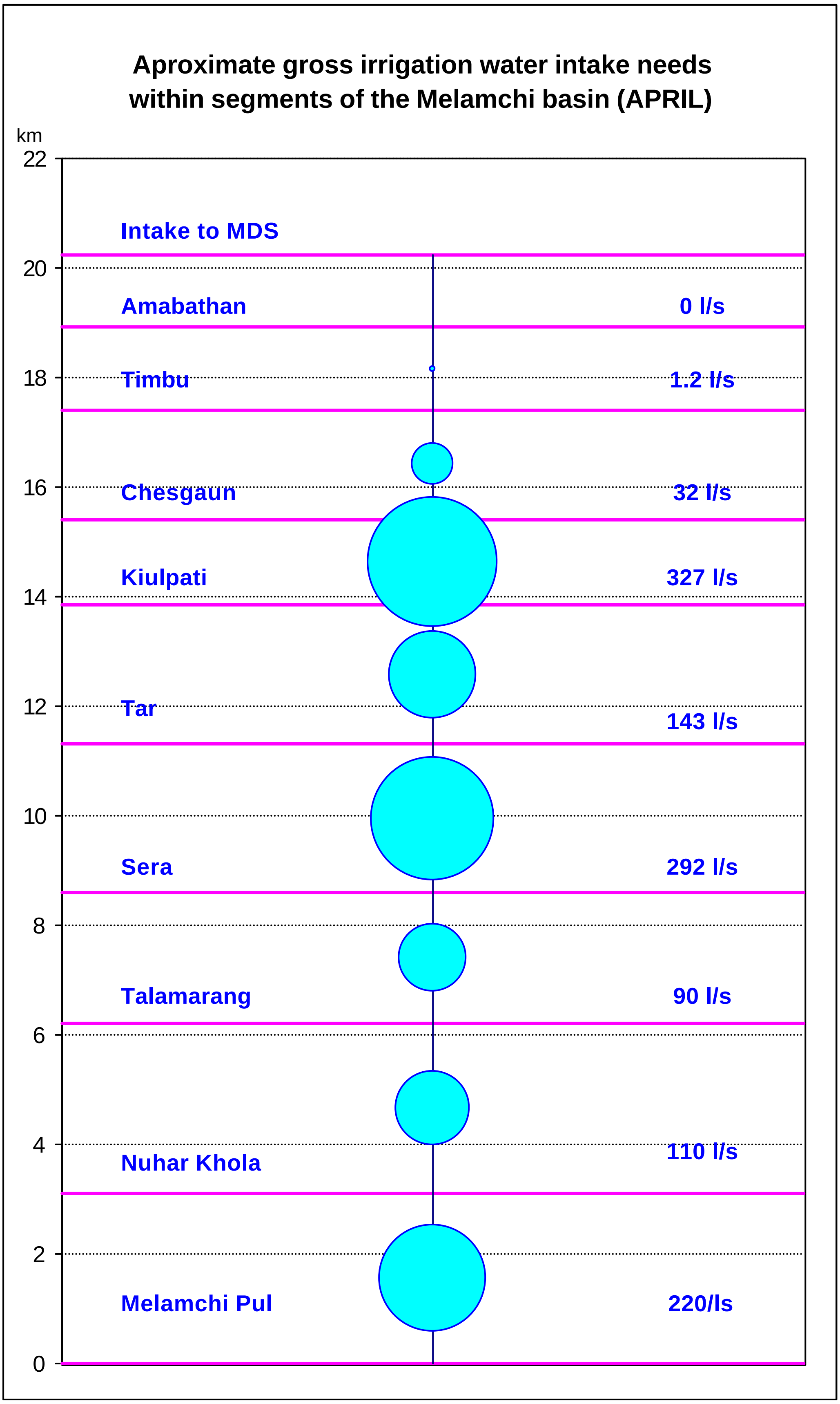


Fig 7. Irrigation uses upstream of the site as percentage of natural flow
Present level of uses - minimum flow scenario (APRIL)

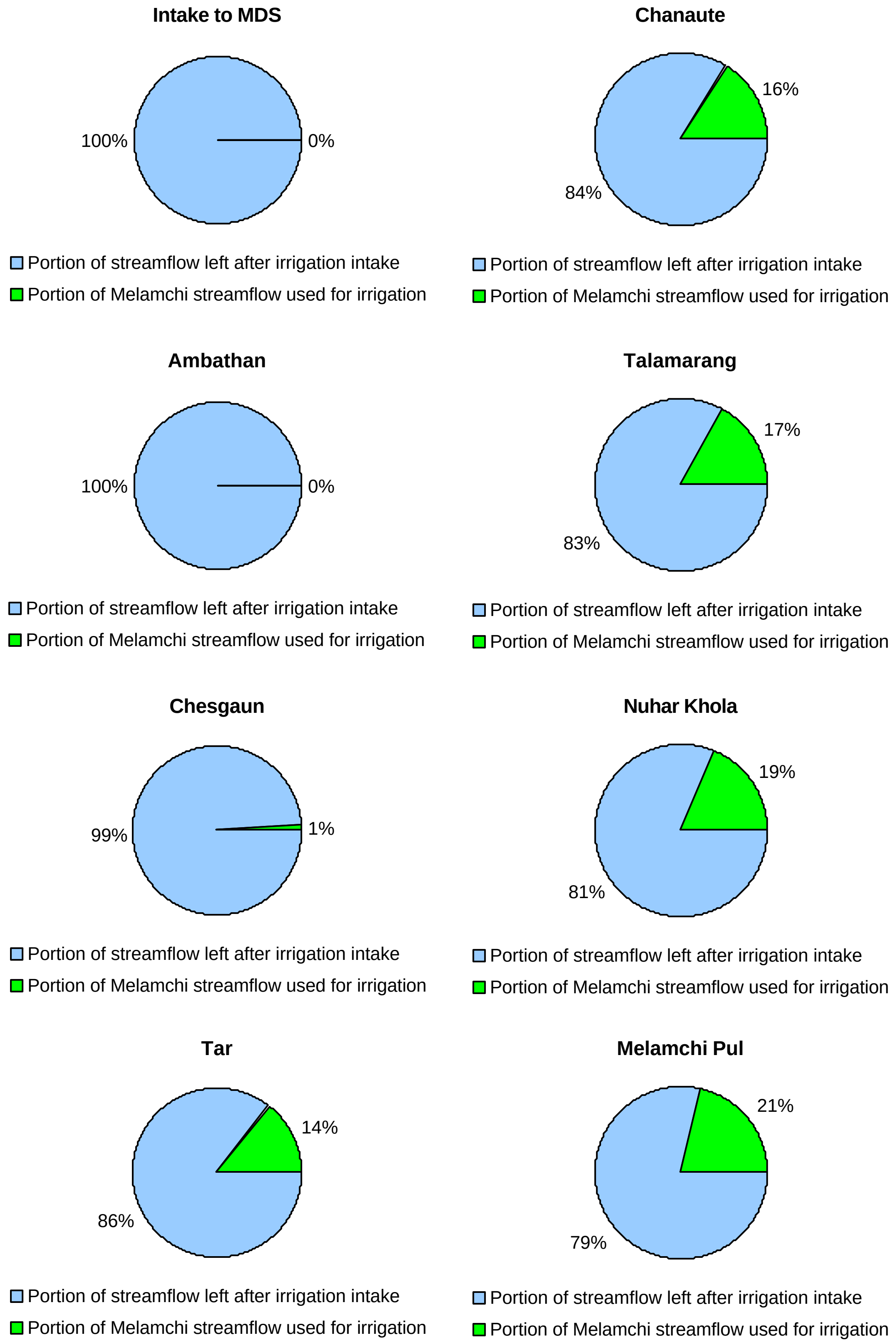


Fig 8. Irrigation uses upstream of the site and net flow at the site
Present level of uses - minimum flow scenario (APRIL)

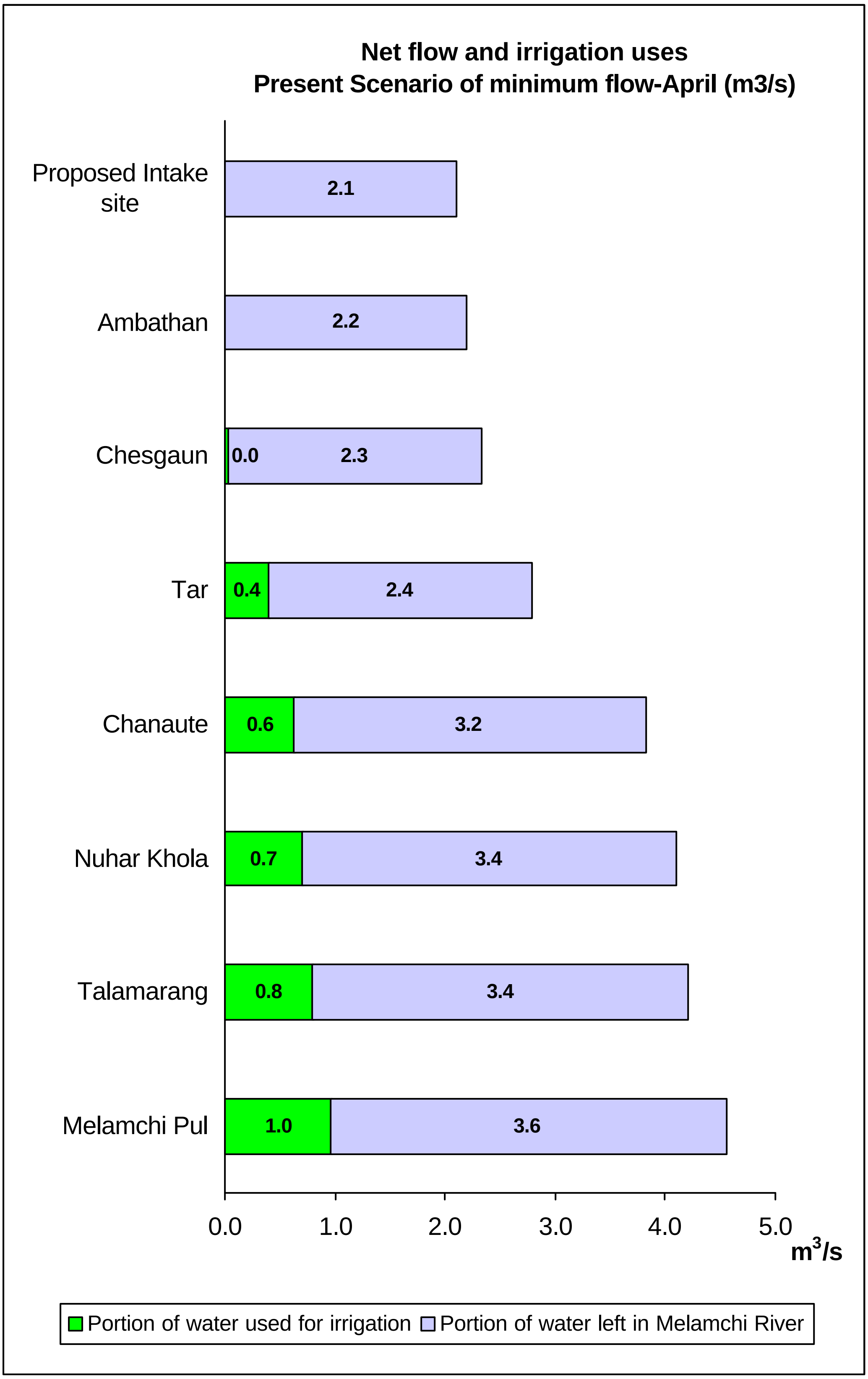


Fig 9. Net flow at present and with an operational MDS
Riparian flow - 0.5 m^3/s. Minimum flow scenario (APRIL)

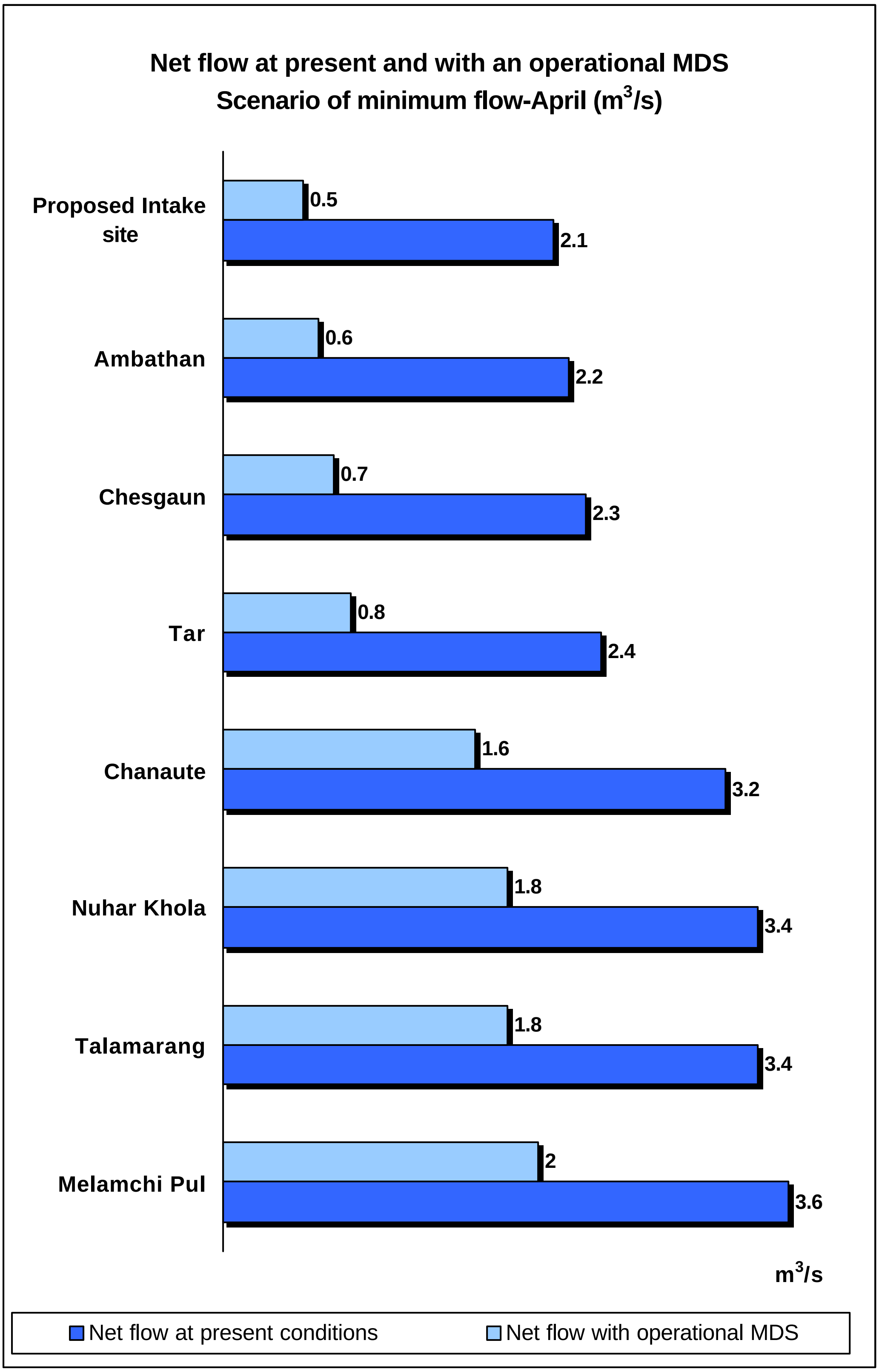


Fig 10. Irrigation and MDS uses upstream of the site as percentage of natural flow
Future level of uses - minimum flow scenario (APRIL)

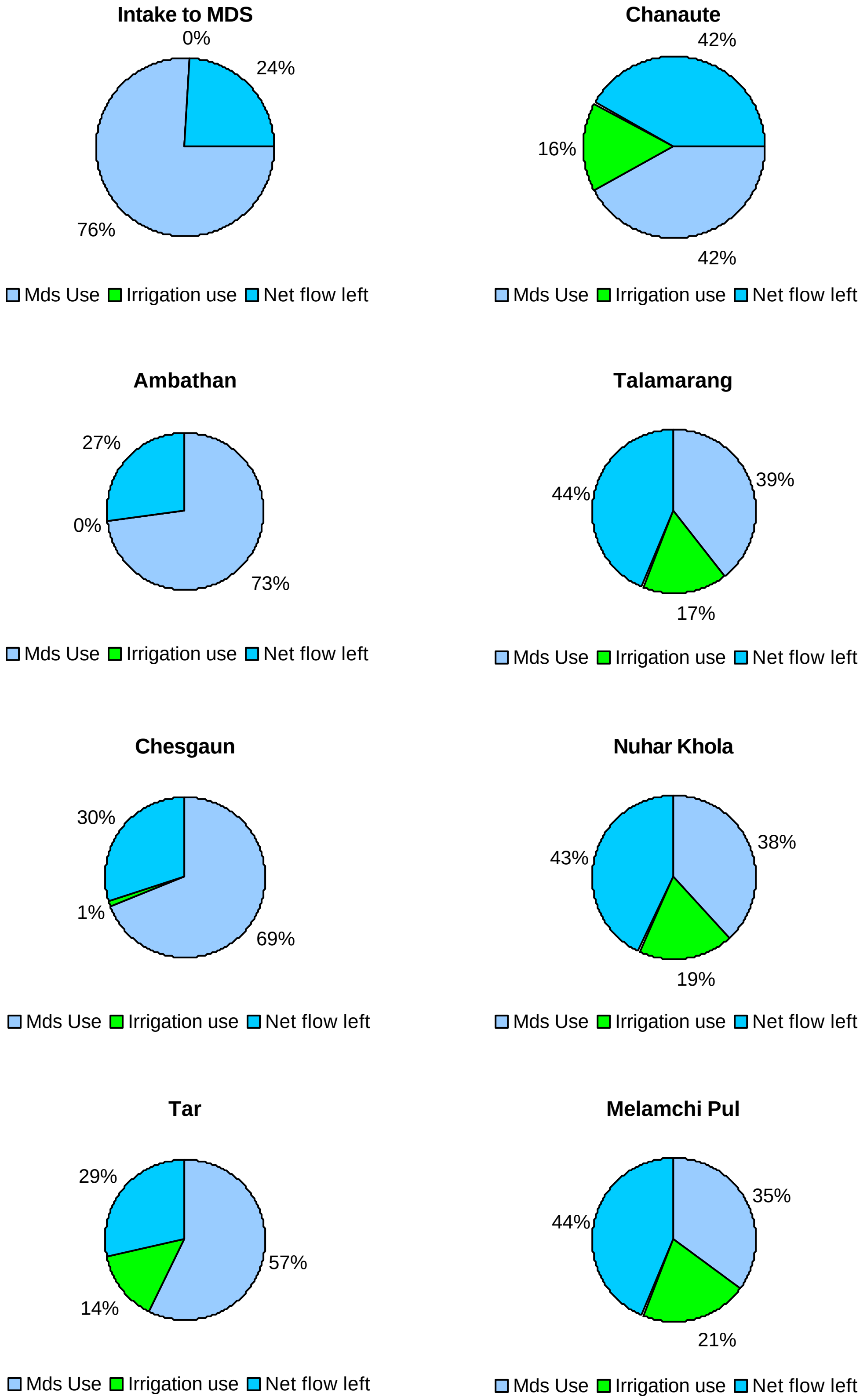


Fig 11. Irrigation uses upstream of the site and net flow at the site
Operational MDS -riparian flow of 0.5 m^3/s - minimum flow scenario (APRIL)