EFFECT OF HYDROPHYTES ON THE PERFORMANCE OF SECONDARY CANAL; YAR HUSSAIN MINOR, SWABI- KHYBER PAKHTUNKHWA, PAKISTAN

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ABSTRACT

Hydrophytes effect directly canal performance by reducing water flow, enhancing sedimentation, raising water level and reduce canal cross section area. The free-floating hydrophytes trapped in the outlets and culverts dipping its flow. In this apprehension a research study was conducted to investigate the effects of hydrophytes on canal capacity and at the outlets on the performance of the secondary canal known as Yar Hussain Minor (YHM) of Maira branch canal; part of the upper Swat canal irrigation system in Khyber Pakhtunkhwa (KP) province of Pakistan. Maira branch canal and its secondary canals were designed for crop based irrigation operation (CBIO), which could supply irrigation water for maximum cropping intensity (180%) even during peak periods of irrigation requirements. The existing water allowance was 0.67 Ls^{-1} ha^{-1} (6.6 mm day^{-1}), which was based on the maximum crop water requirements. The challenges faced by YHM are physical barriers like hydrophytes and the turbid water received from river Swat producing eutrophication, sedimentation and encourage further growth of hydrophytes. Moreover to control the flow of water for the outlets triangular profile crump's weirs have been used in all secondary canals including YHM for comparative division to the tertiary outlets. Hydrophytes growth was observed in head reaches of canal. Five types of aquatic weeds were found. The hydrophytes growth in canal head reaches directly reduces the cross section by more than 50%. Indirectly the free-floating hydrophytes got stuck in the outlets and affected its flow. Therefore, daily discharges were measured with and without detached hydrophytes at each outlet from staff gauging. Frequency was based on days hydrophytes blockage observed divided by total time. It is concluded that the presence of hydrophytes decreased the performance of secondary canal, the hydrophytes and users' interventions (like putting stones to affect flow) influenced the outlets performance by 80%. Furthermore trifurcators type outlets were more prone to influence by hydrophytes followed by bifurcators outlet.

Keywords: Hydrophytes, performance of secondary canal; Yar Hussain Minor

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INTRODUCTION

Hydrophytes are aquatic plants that grow and reproduce in an aquatic environment (Lawrence, 1966). The presence of hydrophytes in canal reduces water flow, enhances water level and increase the chances of sedimentation, which reduces canal capacity (Green, 2006). Likewise the free-floating and detached hydrophytes after mechanical control hangs along walls of crump weir causing outlets obstruction and affect the outlet performance. The performance of irrigation canals is influenced by several factors such as the design, physical environment and management. Performance of irrigation canals has been studied in the past by a number of researchers in terms of their design and the physical environment (Unal *et al*., 2004; Ghumman *et al.,* 2006; Tariq, 2010; Mangrio *et al*., 2014). These studies were conducted in both protective and crop based systems. The performance has been found to be below par in either case. In the protective supply based there were inconsistencies in flow received by the farmers in the head reaches and tail reaches (Ahmad *et al.,* 2007; Tariq and Kakar, 2010). With the head receiving more than their allocation as compared to tail of the canal.

This study was conducted in a secondary canal Yar Hussain minor of the Maira branch canal. Maira branch is part of the upper Swat canal irrigation system in KP, Pakistan. The irrigation system was remodeled in 1993, in which water allowance was increased from 0.34 Ls^{-1} ha^{-1} to 0.67 Ls^{-1} ha^{-1} (Munir, 2011) and crump weir outlets were also introduced. After remodeling irrigation water to Maira branch and its secondary canals came from river Swat and river Indus (Tarbela reservoir).

The water from river Swat is turbid in the summer, while that coming from Tarbela reservoir remains clear all year with low turbidity. High turbidity brings sediments, while clear waters can induce growth of hydrophytes. In the YHM secondary canal, sedimentation and growth of hydrophytes were observed, which at the same time, affected of secondary canal flows at the tertiary outlets, through blockage. Aquatic weeds stuck within bifurcation wall of weirs and raise water level in the canal. Therefore, daily water levels were measured with and without aquatic weeds at each outlet for measuring daily discharges.

The hydrophytes in the head canal reach also pertain characteristics of command areas of tertiary and water courses. Hydrophytes are generally found stick on the crump weirs walls. These physical factors have influenced the canal and outlets performance and capacity and this was not studied before. The present study was carried out with the aim to investigate the effects of hydrophytes on canal capacity and at the outlets on the performance of the secondary canal known as Yar Hussain minor of Maira branch canal; part of the upper Swat canal irrigation system in KP, Pakistan.

MATERIALS AND METHODS

Description of the irrigation system and research site

The research study was conducted on a secondary canal known Yar Hussain Minor of Maira branch of upper Swat canal (Fig. 1). The head regulator of YHM is situated at 34° 9'10.39"N, 72°22'48.80"E at Maira branch canal. The Maira branch obtains water from two water sources, the Swat river and the Tarbela dam built on Indus river. Water from river Swat reaches Maira branch through Machai branch of USC while from Tarbela reservoir, in Pehur High Level Canal (PHLC). The irrigation system was remodeled in 1993, in which water allowance was increased from 0.34 Ls^{-1} ha^{-1} to0.67 Ls^{-1} ha^{-1}(Munir, 2011). The YHM takes-off from Maira branch at RD 3325-Right, has total length of 6.83 Km, with a design discharge of 0.72 cumecs which is 6.6 mmd^{-1} and corresponds to the maximum daily irrigation requirements. It has 11 tertiary outlets (Moghas) with 938 ha of CCA. All of the outlets were triangular profile (crump) weirs with the main difference being the presence of partition walls for proportionality. Based on the presence of partition walls the crump weirs were classified as single bifurcator (SB), double bifurcator (DB) and trifurcator (TF) (Fig. 2). The canal sections have a range of slopes, velocities and dimensions, causing sedimentation and submerged hydrophytes in the head reaches.

The study was conducted from 1 January to 30 December 2014, covering both summer and winter seasons. The total length of the canal was 6832 m, with a CCA of 938 ha. There are 11 crump weir outlets on YHM. Data was collected on selected single bifurcator, double bifurcator and trifurcator outlets.

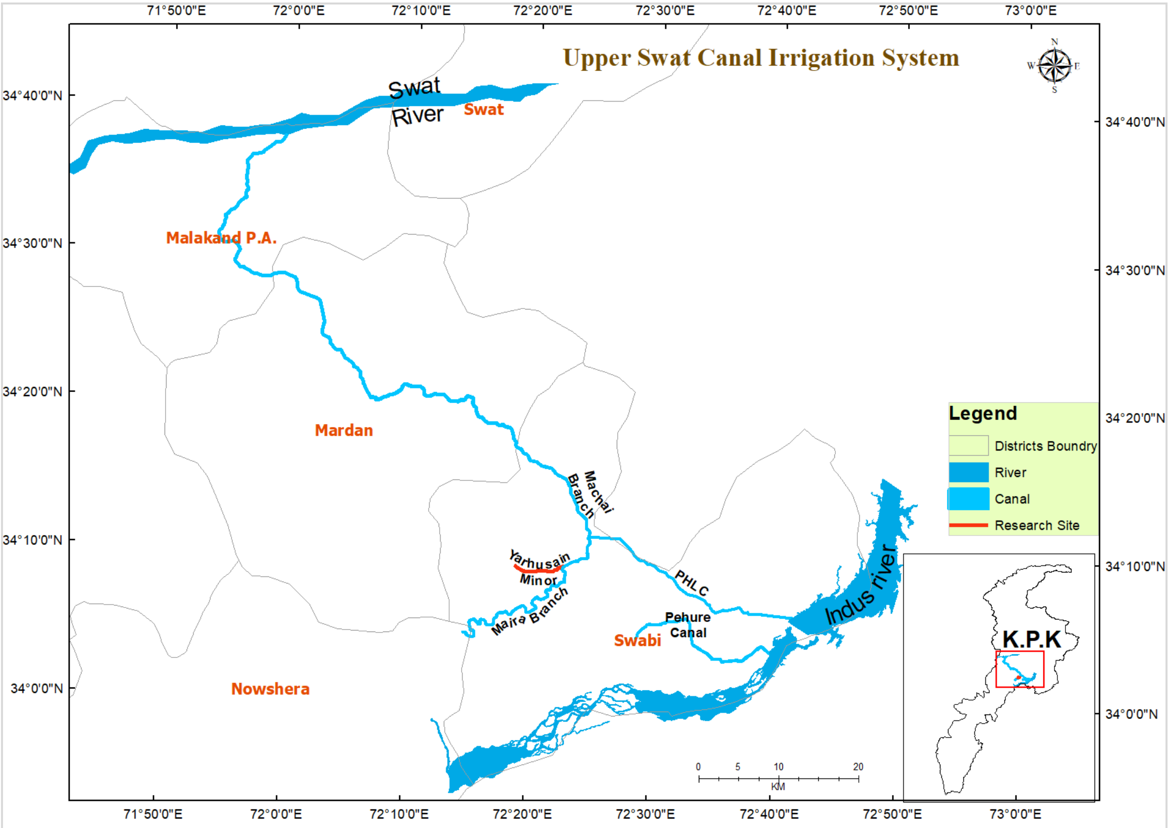


Fig. 1: The map of irrigation system under study of YHM

Single Bifurcator (SB) Double Bifurcator (DB) Trifurcator (TF)

Fig. 2: Types of crump weir

Hydrophytes effect on canal performance

As mentioned earlier that hydrophytes growth in different reaches of canal directly affect canal performance, while indirectly hydrophytes detaching from their point of growth and getting stuck to the walls of crump weirs and affected outlet performance (Fig. 3).

Direct effect of hydrophytes on canal

Generally, the weeds and sediments block the irrigation system and reduce the cross section. The following formula was used to compute the blocked area for certain cross section at an interval of 50 m. The blockage factor for a single cross section has been defined as (Green, 2005):

$$Bs = \frac{Av}{A} x100 \quad (1)$$

Where, Bs is cross-sectional blockage factor in proportion or percentage; Av is area of wetted cross sectional blocked area by sediments (m^2), and A is wetted cross sectional area (m^2).

Indirect effect of hydrophytes

Indirectly these hydrophytes detached and stuck with bifurcation wall of weirs and reduced width of outlets. Therefore, daily discharges were determined with and without detached hydrophytes present at each outlet. The outlet width blocked by detached hydrophytes was measured daily by measuring tape and this width was subtracted from total outlet width. On daily basis the detached hydrophytes were observed and frequency of their presence was calculated on daily, monthly and annual basis. Frequency was based on days hydrophytes blockage observed divided by total time.

Basic performance assessment/Delivery performance ratio (DPR)

Delivery performance ratio is used to determine the performance of canal under normal condition without any interference. DPR is the ratio of actual discharges to the design discharges (Boss *et al.,* 1994):

$$DPR = \frac{Qa}{Qd} \quad (2)$$

Where, *Qa* = Actual discharges ($m^3 s^{-1}$)
Qd = Design or authorized discharges ($m^3 s^{-1}$)

The criterion set by KP provincial irrigation department, was used to determine the performance of the canal outlets. If the outlets drew within ± 10% of their design discharge, it's considered as satisfactory (Govt. of KP, 1992). Additional performance value ± 30 % were used by (Murray-Rust and Snellen, 1998), below this the performance of an outlet is considered to be un-satisfactory.


(a) Hydrophytes in canal (Direct impact)


(b) Detached hydrophytes stuck at outlet

Fig. 3: Hydrophytes in the secondary canal and the outlet

Flow data collection and analysis

Discharges at YHM outlets were measured by using a current meter and to develop a relationship between the heads measured and the flow rates. The head discharge relations for the secondary canal head, drop structures and all outlets to determine the daily discharges by using following equation.

$$Q = C * B * H^{1.5} \quad (3.1)$$

Where,

Q =Flow Discharge of hydraulic structure in $m^3 s^{-1}$ (cumecs) and
B =Width of the weir crest (m)
H = Depth of water above the crest of weir (m) and
C = Coefficient

The theoretical value of C for Crump weir is 1.98, however it changes with field conditions (weir height, upstream, downstream slopes etc.).

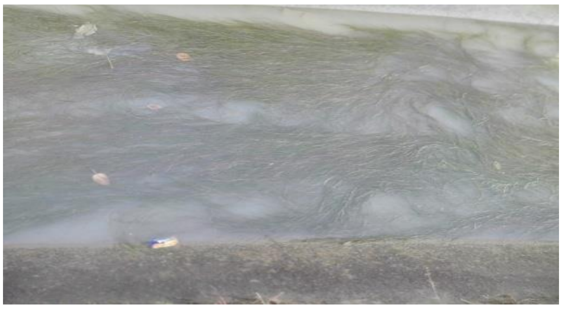
Table 1: Procedure to collect physical data on canal and its outlets along with frequencies and magnitude

Parameter	Methodology	Frequency	Magnitude
Cross Section Area Blockage	Canal profile survey	4 times (May, June, August and December)	At each 25 m interval along canal Head Section
Types of Hydrophytes	Samples collected and identified	Once	Head section
Discharges with/without Detached Hydrophytes in Outlets	Field Observations (Tape measurements)	Once daily at 3 different selected outlets	Selected outlets
	Water level measurement from reference mark	Once daily at 3 different selected outlets	
Frequency of Detached Hydrophytes	Field Observations	Once daily at 3 different selected outlets	Selected outlets

Results and Discussions

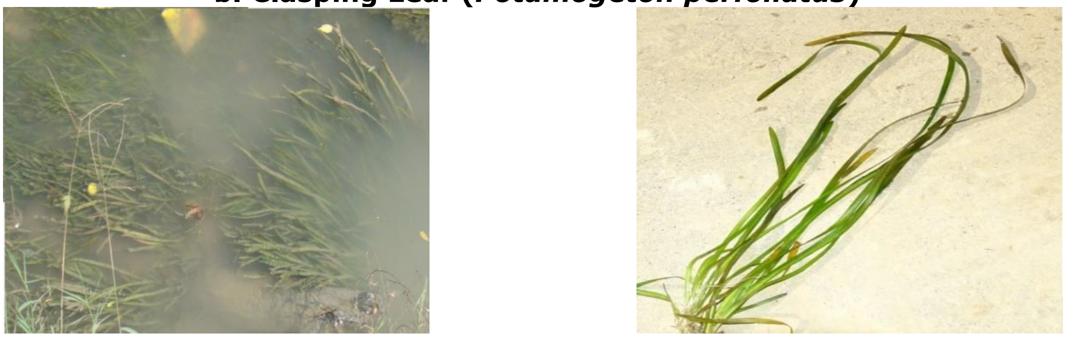
Types of hydrophytes

In the YHM, the hydrophytes growing can be termed as aquatic weeds, which can be broadly defined as "undesirable plants growing in aquatic environment (Lawrence, 1966). The hydrophytes growth in canal can reduce velocity, raise water level, cause deposition of sediments (Fig. 3a) and when detached stuck in the weirs, affecting canal performance (Fig. 3b). Hydrophytes samples were collected and identified in Department of Weed Sciences and Botany, The University of Agriculture Peshawar. Five different species were found in the YHM (Fig. 4 a-e). The earlier studies also reported hydrophytes in water bodies of the same area (Fawad *et al.,* 2013)



a. Sago Pondweed (*StuckeniaPectinata*)

b. Clasping Leaf (*Potamogeton perfoliatus*)



c. Tape Grass (*Vallisneria americana*)

d. *Hydrilla verticillata*

e. String Algae

Fig. 4: Hydrophytes species found in YHM

Direct effect of physical factors on canal capacity

As mentioned earlier (Figurs-4.3 and 4.4) lower than design slopes and velocities were observed between RD 160-1750 (Head reaches) of YHM. Major sediment deposition also occurred in the same head reach of the canal and consequently hydrophytes growth was also observed reducing the cross-section area for the flow. Fig. 4 showed maximum blockage at RD 350 (52% of the cross-section area blocked), consequently 38%, 41%, 50% and 52% reduction occurred in canal performance in May, June, August and December, respectively. Similar findings were reported by Munir (2011) and Choi and Kang (2006). As a result of these findings, the free board of canal was raised by provincial irrigation department (PID) to protect against overtopping and inundations.

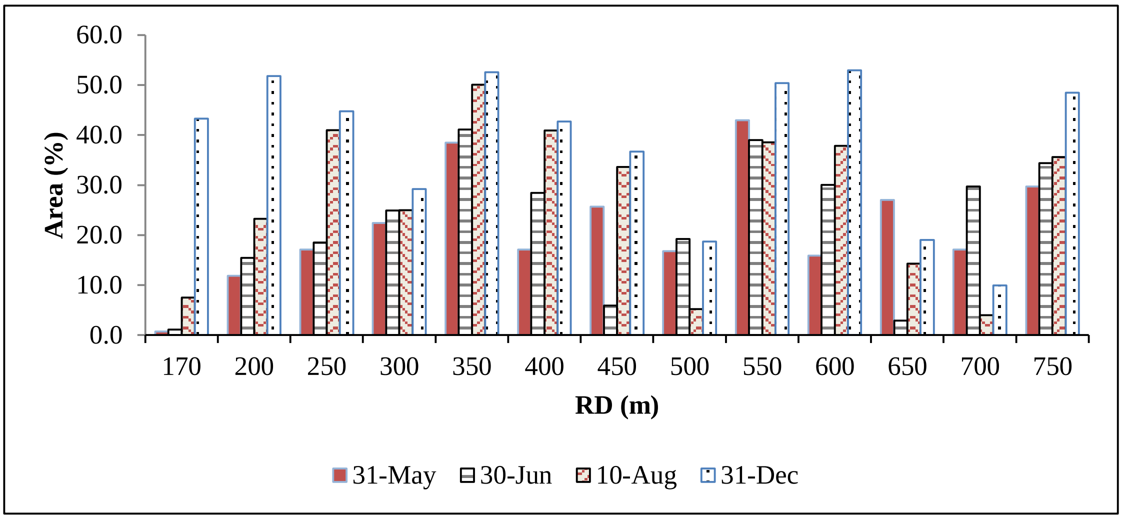


Fig. 1: Cross section area of YHM blocked by sediments

Indirect effect of hydrophytes on canal outlets performance

Hydrophytes also had indirect effect on flow pattern in the canal. Hydrophytes detached from their roots at the point of growth and travelled downstream to get stuck in the outlets.

Effect aquatic weeds on single bifurcator outlet (1190-R)

The DPR through single bifurcator of YHM (Fig. 6) showed the effects of weeds from the start March 2014 till end May 2014. Major presence of detached hydrophytes was observed in November and December (Fig. 7). Hydrophytes reduced the flow in the outlet during October by 11%, November by 27% and December by 73%, respectively. On the average 12% of the time detached hydrophytes was observed which affected the DPR. As shown in figure below that after May weeds grew up in canal and affected the outlet performance. Maximum blockage by weeds occurred from the mid November till the end of December 2014. In December about 75% of the time (blockage frequency) weeds blocked outlet partially. Throughout the study period the average discharge with and without weeds were 0.056 and 0.059, respectively. This affected the DPR. The weeds DPR values was 102.7, which increased to 107% after the removal of weeds, the difference of 4.3% of the design. In June only three-time (Jun 2, 3 and 11, 2014) weeds blocked outlet. This affected the DPR only 5.1% of the design. The weeds blocked maximum width of 0.19 m (80%) of this outlet (December 23, 2014). It reduced the discharge to 0.0117 instead of 0.0462 cumecs. This also reduced the DPR (21%), while after weeds the DPR was 81% of the design. Earlier studies have shown that construction defects were responsible for poor performance of irrigation canals (Murrey-Rust and Halseema, 1998; Mangrio *et al.,* 2014).

The possible reasons of the weed blockage were that after the mid of October the weed grew in length and increased the chance of stucking with bifurcation of outlet. Also, there was no peak demand of water, therefore farmers did not remove these weeds from the outlets. While before that time no such weeds observed in-tangled in the outlet because the length was not enough to stuck in to the outlet. Moreover farmers also practiced to remove debris and weeds from the mogas due peak demand of water in summer season.

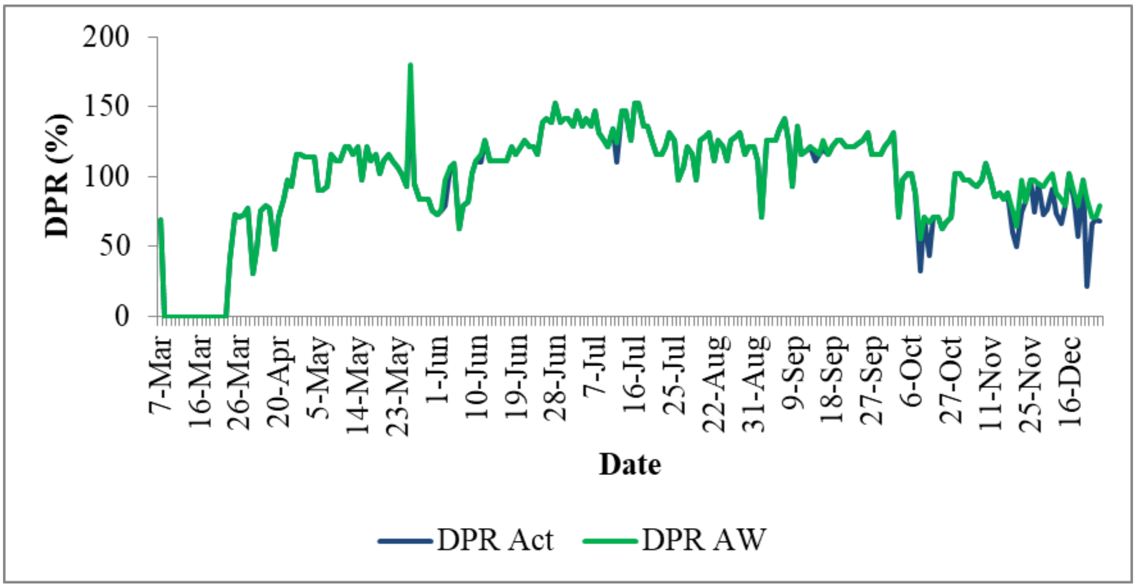


Fig. 6: DPR with and without hydrophytes of single bifurcator outlet ((1190-R)

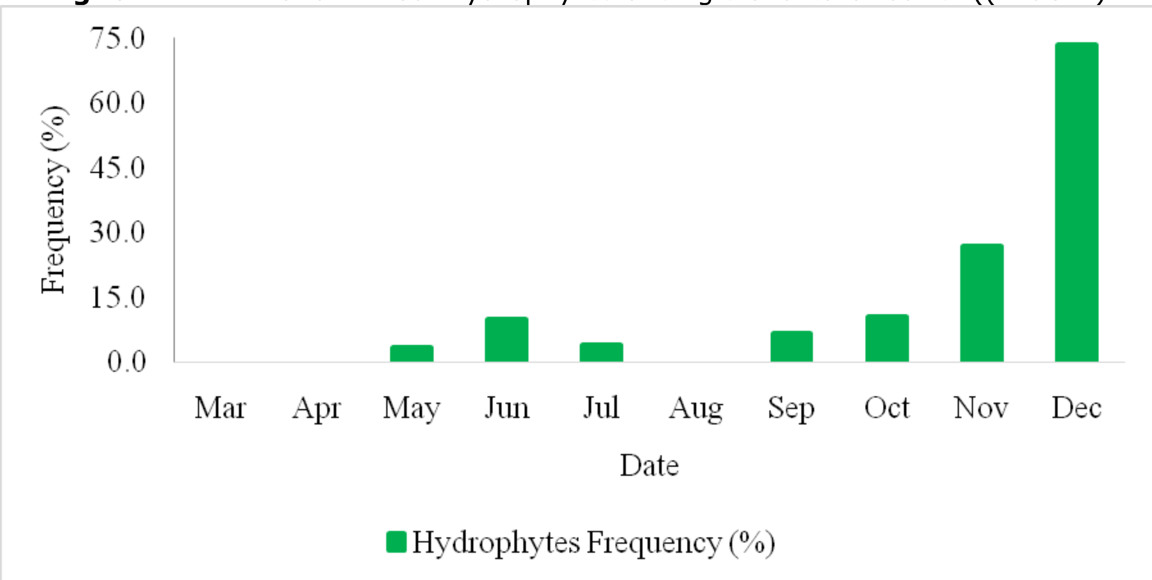


Fig. 7: Hydrophytes blockage frequency of outlet (1190-R)

Effect of weeds on double bifurcator (DB) outlet (1670-L)

Outlet 1670-L was a double bifurcator type. The water supply was highly variable to this outlet of YHM (Fig. 10). The detached hydrophytes blockages was also observed in last two months of Nov and Dec (73%), on average 18% of the time blockage was observed (Fig. 11). Figure below shows the weeds effect on fourth outlet performance from March 2014 till end December 2014. As indicated from the mentioned Figures that after the month of May, weeds generally grew-up and affected outlet performance. It was observed that maximum outlet blockage due to weeds growth occurred as 31% in October and 73% in November/December. While during the months of March, April and June no weeds hang-up in outlet, while the average discharge with and without weeds were 0.054 and 0.057. This weed affected DPR values of 135% and increasing up-to 142% after the removal of weeds, showing that weeds reduced the DPR value to 6.7% of the design. In the month of November, the weed affected the outlet performance. The average discharges in this month with and without weeds were 0.39 and 0.44 cumsecs. The weed reduced the average outlet discharge to 0.006 cumsecs and reduced the DPR values from 111% to 96.5% of design.

The possible reasons after mid of October relates to weeds length, which creates blockages and easily stuck-up at outlet bifurcations. Also, there was no peak demand of water and stone were placed, therefore farmers did not removed weeds. Before this no weeds were observed stuck in to the outlets because of smaller lengths of individual weeds and farmers vigilance for proper removal of debris from the outlets due to high water demand due to hot weather.

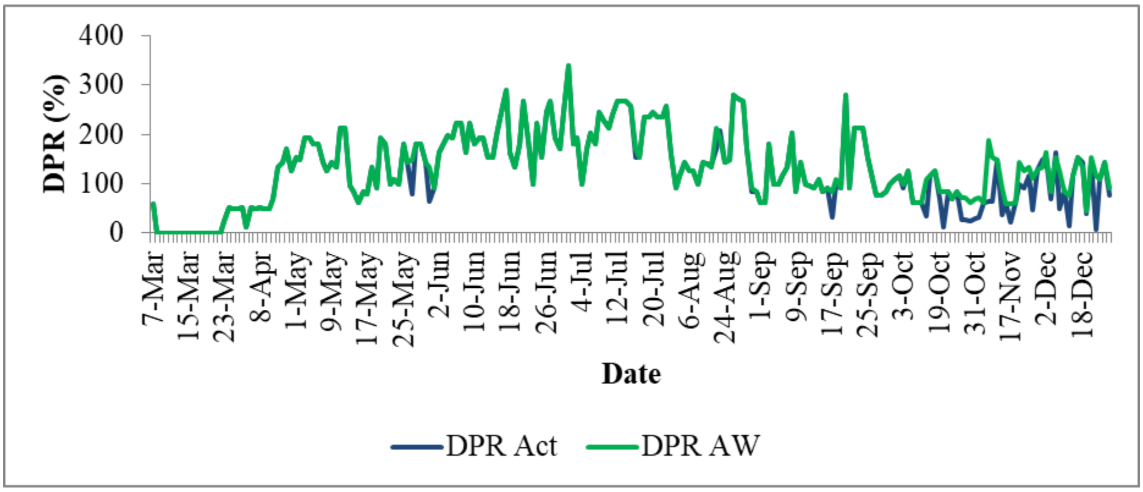


Fig. 8: DPR with and without weeds of outlet 1670-L

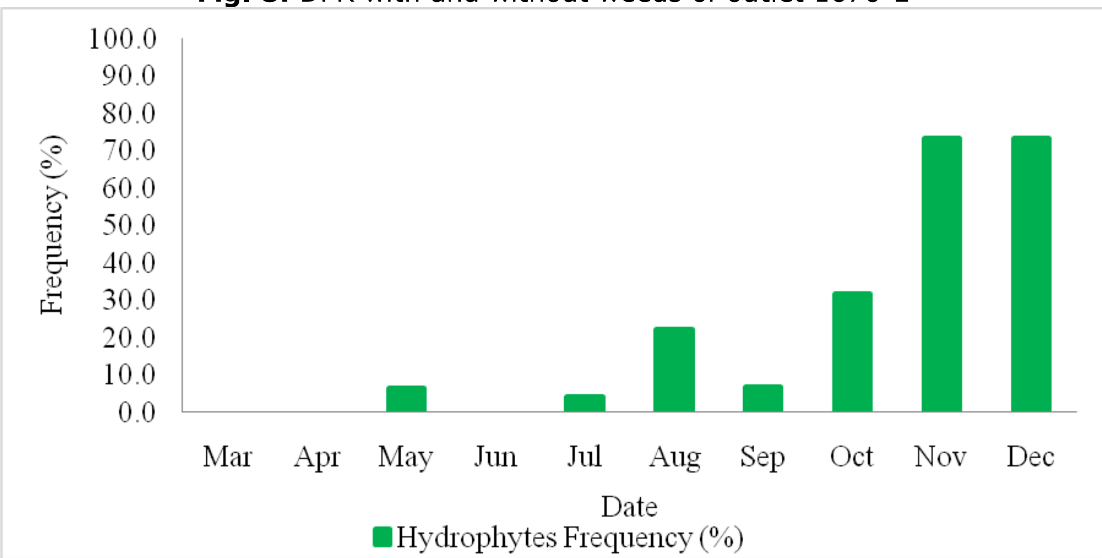


Fig. 9: Stone and hydrophytes blockage frequency of outlet 1670-L

The weeds problem starts from end of August and continuously affects the outlet performance, because the weeds growing from April attain enough length/ height and intensity till mid of October to stuck-up at outlet bifurcation structures. The increased length and branching during August, also increases the effect of pressure of water on the weed biomass and as a result enhances detachment and uprooting of the plants. The uprooted weeds hung-up at bifurcation wall and affects its performance.

Effect of weeds on trifurcator (TF) Outlet (4500-R)

The outlet 4510-R was a trifurcator type and more sensitive to be blocked by detached hydrophytes. Therefore highly variable water supply was observed (Fig. 12). The supply was more than the design requirements during July, August and September

(Monsoon season). In other months the average supply was generally less than the design requirements. The possible reasons were the presence of more detached hydrophytes. Below figure shows the weeds effect on outlet performances from March 2014 till end December 2014. As shown that from of second week of May till the research end (give date), weeds affected the outlet performance. On overage 23% of the time detached hydrophytes blockage was observed. The blockage intensities from May to December were 19.4, 30, 12, 16.7, 6.7, 47.4, 53.3 and 60.0%, respectively. It shows that the maximum effects were observed in the month of December in which weeds blocked outlet 60% of the time, while in the first two months no severe weeds effect was observed that is in Rabi seasons weed effect was negligible. Throughout the study period the average discharge with and without weeds were 0.036 and 0.037, affecting with weeds DPR values was 119.5% which increased to 123.7 % of the design after the removal of weeds. It means that weed reduced the DPR value by 4.24% of the design and weeds affected the outlet performance in November. The average discharges with and without weeds were 0.031 and 0.035 cumecs that reduced the DPR values from 115.7 to 104.3% of the design.

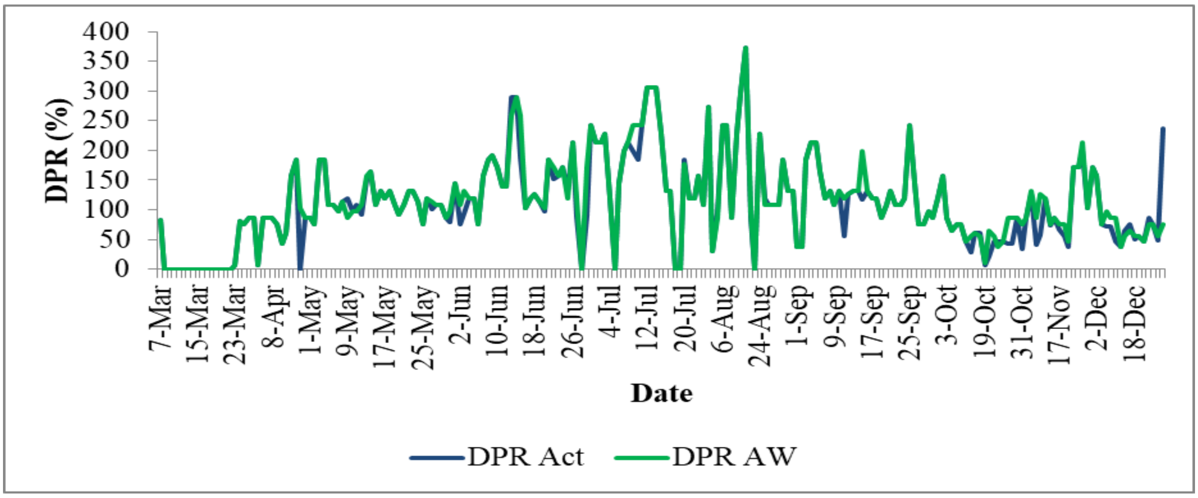


Fig. 10: DPR with and without weeds of outlet 4505-L

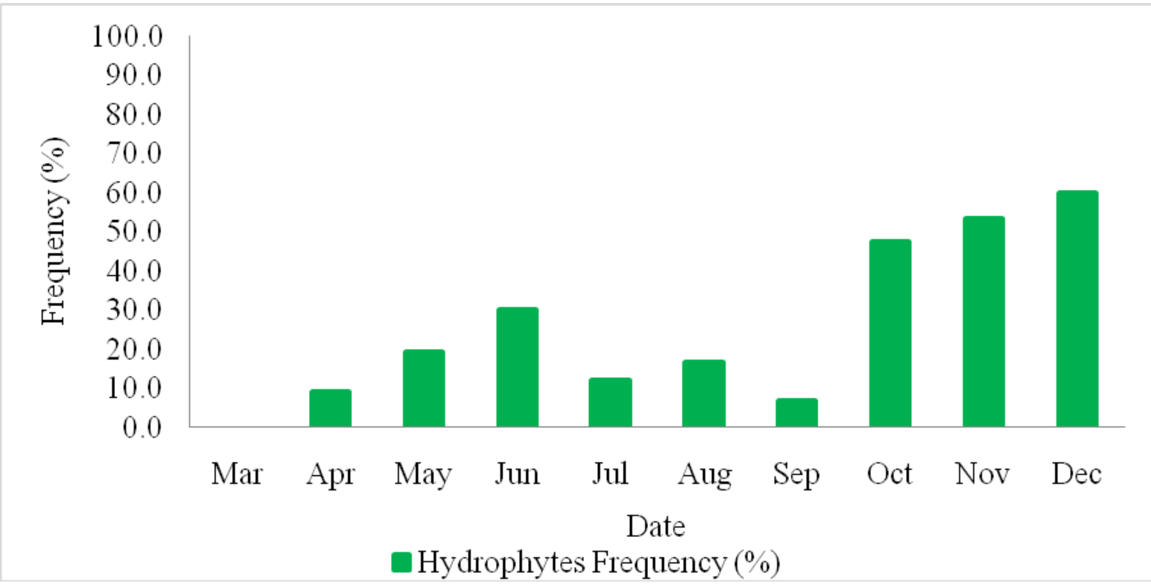


Fig. 11: Stone and hydrophytes blockage frequency of outlet 4510-L

Indirect Effect of Physical factors on Canal

The data in Fig. 12 shows the frequency of hydrophytes found in the different outlet types. It shows that all the three types of structures i.e. bifurcators, double bifurcators and trifurcators. Maximum blockages were observed at trifurcators, followed by double bifurcators. It can be concluded that trifurcators and double bifurcators were slightly more prone to hydrophytes than single partition wall bifurcators and that trifurcators types of outlets were most inclined to catch and collect the detached aquatic weeds and be blocked by the detached hydrophytes.

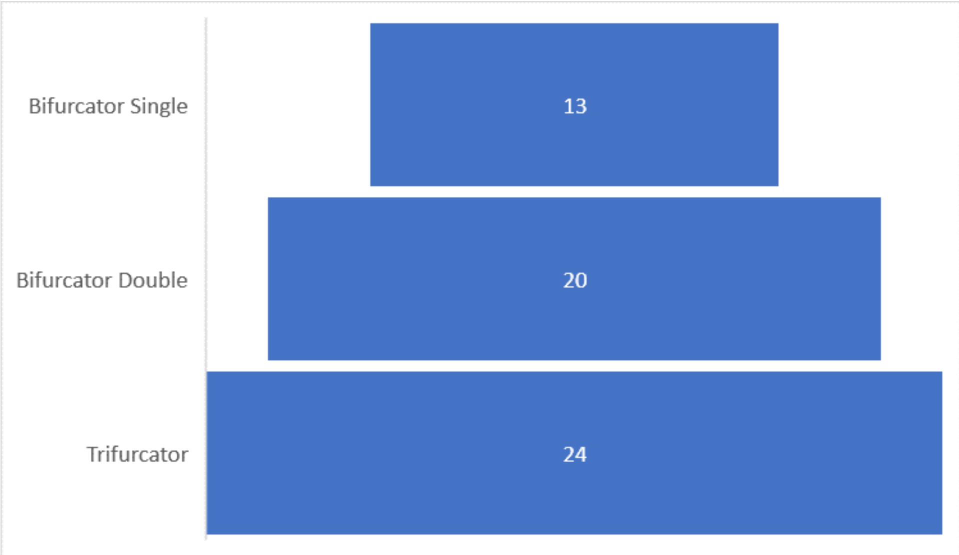


Fig. 12: Outlet type and frequency of detached hydrophytes

Conclusions

It is concluded that hydrophytes affected secondary canal performance and reduced canal cross section by more than 50% which resulted overtopping and losses of water. The design of flow division structures created opportunities for flow manipulation at the canal outlets. Trifurcators type outlets were more prone to influence by hydrophytes. The detached hydrophytes in the canal stuck in the outlets, which affected performance of 80% outlets of the canal. Hydrophytes management is required to improve the performance of the canal. It is recommended that trifurcates outlets should be avoided in future.

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