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Drought Management Practices and Plans For Khadakwasla Reservoir

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ABSTRACT: During drought, a keyaim of water-resource management is to prepare the realistic reservoir operating policies for water allocation, especially in a river system involved with flood-control reservoirs. Hence it is very much necessary to plan for the drought situations and the mitigation measure suggestions of the same.The paper herewith discuss about the optimization model for the Khadakwasla Reservoir operations based on the data of draught occurred in the 2009.Even during the drought situations there are demands of water downstream and the maximum flow to the reservoir is assumed during the drought situations to develop a draught allocation model.. During the drought situations the available waters tends to concentrate in a small area of reservoir and it leads to the maximum loss of water through evaporation and seepages. Considering the above allocation model has some limits to distribute the available water to the demand sources.

KEYWORDS: Drought; Reservoir Management; Reservoir Operation, Khadakwasla Complex

I. INTRODUCTION

Droughts, resulting from natural variability in supply and from increased demand due to urbanization, have severe economic implications on local and regional water supply systems. In the context of short-term; monthly to seasonalwater management, predicting these supply variations well in advance are essential in advocating appropriate conservation measures before the onset of drought(Golembesky et al. 2009).

Occurrence of the drought is an obvious situation which most of the time occurs due to the gap between the demand and supply of the water from the reservoir. The drought situation occurs mainly because of the improper planning of the release of the water from the reservoir. However when there are more than one reservoir is supply the water to the different sources the demand can be easily identified throughout the year.ans water is stored into the dams in such a way that there are very less evaporation or seepage loss due to the less amount of water in the reservoir. The forecasting of the weather mostly the rainfall helps to distribute the water throughout the year to the demand sources by proper planning of the water distribution each month to avoid the drought situation in non monsoon or in monsoon months as well.

The Drought Manual brought out in 2009 by the Union Agriculture Ministry describes the efficient use of reservoirs and groundwater in reducing the impact of drought. But, there is no effective mechanism in place to ensure that reservoir operations and groundwater use are regulated in anticipation of drought. The latest institute to have been set up in this context is the National Rainfed Area Authority set up in 2006 by the Govt of India with the purpose of mitigating miseries of drought prone rainfed areas. Out of Net Cultivable Area (NCA) of around 141 Million Hectares (MH) in India, about 81 MH is rainfed, according to Ministry of Agriculture, Government of India. Out of around 60 MH of irrigated NCA, about 37-38 MH is irrigated by groundwater. Remaining it has to be from surface water sources.

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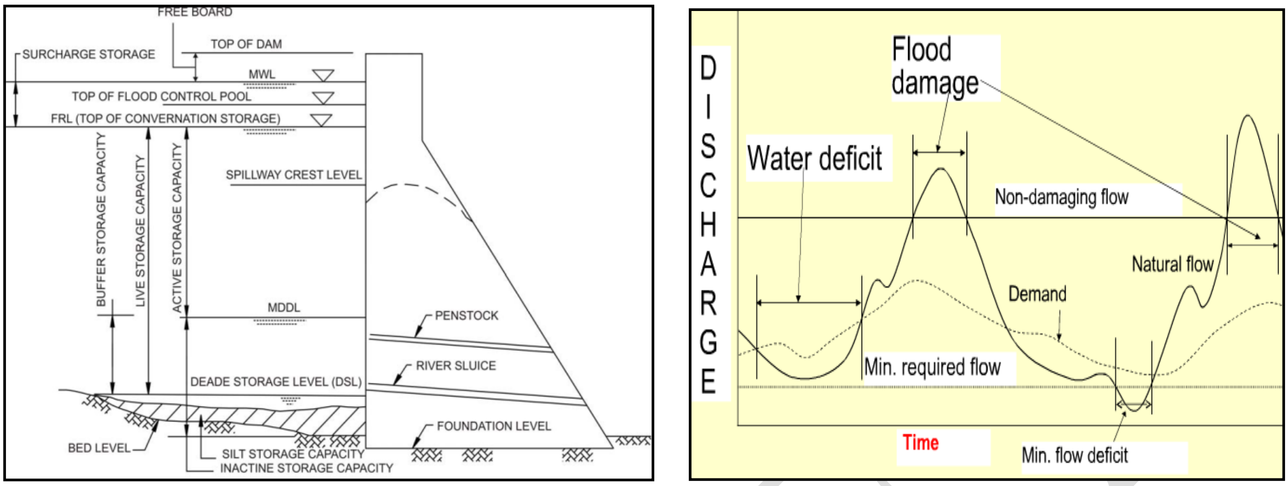

Fig. 1 Concepts of Storage Zoning for flow deficit

To develop a practical reservoir operation model during drought periods, and an idea about the reservoir operation during drought condition, the zones of a reservoir concepts need to be clear, which is depicted in the Figure 1.

II. MATERIAL AND METHODOLOGY

Generally, hydrologic indicators used to define triggers are physical measures of a system, such as reservoir storage, stream flow levels, or groundwater supply. Reservoir storage is useful because it is relatively easy to determine. However, it can underestimate drought severity for several reasons: reservoir levels may not reflect increased demands associated with dry periods, it may be inappropriate for small reservoirs, and many reservoirs are operated on a rule curve which may disguise early drought indications (S fisher).

There are various indicators of the drought which can predict the drought situations. The meteorological indicators are the most important indicators to predict the drought situation. These meteorological indicators include the precipitation details, climatological responses, air temperature, evaporation rates, etc. Stream flow level can also indicate the droughts if they are closely monitor for their level in various seasons. However there is problem associated with the identification of drought with stream monitoring as small streams may react quickly to the shot dry periods and large streams may take time to respond the dry periods. Ground water can also be a source of the water in various areas where the draught situations can be easily identified by monitoring the water level in the aquifer stratigraphy and the aquifer recharge rates.

Hence among the various indicators of the drought the major indicator prove to be a rainfall and the pattern of rainfall along with the factors associated with the rainfall volume.

Agricultural indicators typically consider soil water and crop parameters, such as soil moisture in the top 100 cm of soil, crop yields, or cumulative precipitation and temperature since the beginning of spring. Perhaps the best known of these indices is the Palmer Index, which refers to either the ***Palmer Drought Severity Index*** (*PDSI*) or the ***Palmer Hydrologic Drought Index (****PHDI*). The PDSI attempts to track weather patterns and the PHDI tracks hydrologic factors such as soil moisture, lake level, or stream flow. Although precipitation is widely used in agricultural regions as a measure of drought severity (Alley 1985), it is an empirical method with several of the Palmer index limitations. All of the indices described may provide a partial description of drought, but none define it completely. Attempts to correlate an indicator with a particular level of drought severity observed in a region have resulted in several multiple-parameter indicators. Some proposed composite indicators are the method of truncation (Chang and Kleopa 1991), the Water Availability Index (Davis and Holler 1987), and the Surface Water Supply Index (Dezman et al. 1982).

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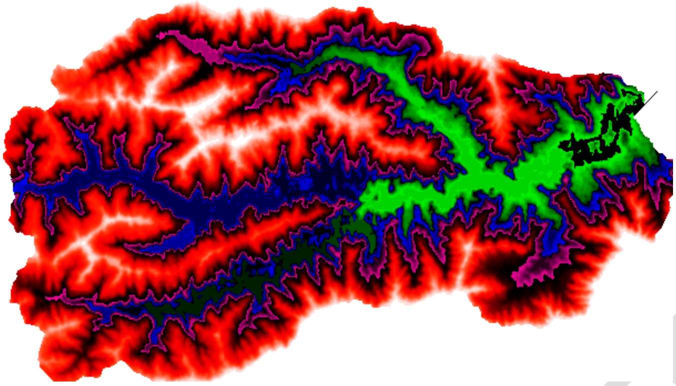

Fig. 2 TheKhadakwasla reservoir

III. WATER AVAILABILITY INDEX AND RESERVOIR LOSSES CALCULATION

The water availability index (WAI) relates current water availability to historical availability during periods of drought by measuring the deviation-from-normal rainfall over the prior four months (Davis and Holler, 1987). The WAI is multiplied by a constant to make the index fall between 0 and 10, with zero representing normal conditions and ten a severe drought. In its most common form it now includes just two variables: forecast stream flow and current reservoir storage. Hoke (1989) included a factor for minimum and maximum desirable reservoir pool elevation, and Raney (1991) included volume and drainage area factors to account for multiple reservoirs within one watershed. By calculating the WAI one can manage the distribution of the water throughout the year from the reservoir by adjusting the minimum/maximum inflow to the reservoir by analysing the data of the inflow and demand. The stream flow in the present paper is reservoir inflow data. Monthly data, January through December is also processed in the same manner. A monthly WAI are calculated by ranking the individual monthly values from the lowest to the highest and then a non-exceedance value is calculated by the by the following equation:

(1-(Rank/n+1))

Where the rank is the numerical position of the individual data point and n equals total number of years analysed. This non-exceedance value can be further processed by the following formula:

(((non-exceedance probability X 100)-50)/12).

Where fifty is subtracted from the non-exceedance probability to centre the value around zero. Dividing by twelve scales the values from +4.1 to -4.1 and which follows the Palmer Drought Index (PDI). This latter calculation is completely optional as the non-exceedance value conveys all the relevant information necessary to interpret the index in a much simpler context. The non-exceedance value is the preferred method.

RESERVOIR LOSSES DURING A DROUGHT

The major losses of water from a reservoir during a drought are evaporation to the atmosphere and seepage to groundwater. These losses can be estimated for a reservoir in a valley with a very regular geometry, having valley side slopes of a and a longitudinal valley slope of b (Fig.below). Here, H, deepest depth of water in the reservoir at the dam; W, half width of the triangular water surface at the dam, and L, longitudinal length of the water surface. While no single reservoir will ever have these characteristics, this shape is similar to that of many surface reservoirs. The surface area of this reservoir is A=LW, and its storage volume S=1/3LWH. We later compare this reservoir shape with those of several actual reservoirs.

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Evaporation

Evaporative losses from a reservoir are generally taken to be proportional to the surface area of the reservoir,E=eA.By substitution, Eq.(1)is the evaporative loss from a reservoir with storage S. The evaporation loss for the reservoir is of the order of -0.45-1.8 MCM for the year, 2009.

Seepage

Many seepage "losses" are eventually regained downstream in the form of stream flows or groundwater. However, during a drought, seepage is a loss of water available during a critical time. Seepage losses from the reservoir will need to flow under the dam or hillsides, and should be proportional to the **head** on the dam by Darcy's law.

Concave loss-storage relationships

The above losses relationship is reservoir surface area and see page head increase with storage, they increase at adiminishing marginal rate(2^{nd} derivative is negative). Surface area(and evaporation) and head on the reservoirs are therefore concave functions of storage. Reservoir losses generally tend to be concave functions of storage.

Flow continuity equation of a reservoir

Based on the principle of conservation of mass, the continuity equation for the reservoir operation is given by

$$S_{t+1} = S_t + I_t - (R_t + SP_t) - EL_t \quad (4)$$

$$S_{min} \leq S_t \leq S_{max} \quad (5)$$

Where

St= Current available reservoir storage at the start of the period, t
S_{t+1}= Reservoir storage at the end of the period, t
I_t= Inflow during the period, t
R_t= Release during the period, t
EL_t= Evaporation loss in the reservoir during the period, t
SP_t= Spill during the period, t
S_{min}= Minimum storage and S_{max}= Maximum storage

The total release of water from Khadakwasla reservoir (Rt) needs to be made according to the priorities. The priorities may be taken as i) Drinking water Supply for Pune city, & NDA water supply) for Irrigation supply

$$R_t = RD_t + \sum R_{i,t} \quad (6)$$

Where

RD_t= Supply to the drinking water demand of the Pune city during the period, t
$R1,_t$= Release to the irrigation during the period, t
$R2,_t$= Release to the irrigated Daundduring the period, t
$R3,_t$= Release to the Baramatiagricultural area during the period, t.

Month	St	It	Rt	EL_t	S_{t+1}
Jan	50.49	57.77	85.44	0.30	22.51
Feb	48.56	90.02	97.32	0.30	40.97
Mar	45.25	90.03	106.29	0.60	28.39
Apr	36.25	92.05	110.85	1.70	15.75
May	45.91	102.35	116.66	1.73	29.87
June	56.32	75.24	64.66	1.50	65.39
July	85.01	16.35	130.25	1.50	-30.40
Aug	51.96	27.17	108.96	1.20	-31.03
Sep	59.07	0.41	56.39	0.60	2.49
Oct	60.40	0.00	49.34	0.70	10.36
Nov	64.02	0.51	85.10	0.60	-21.16
Dec	60.71	59.51	91.84	0.50	27.89

Table 1: Flow continuity equation calculations for Khadakwasla reservoir

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IV. WATER AVAILABILITY INDEX FOR THE KHADAKWASLA RESERVOIR

To calculate the WAI for the khadakwasla reservoir we have considered the storage and inflow data of the reservoir for the year 2009. The year 2009 is considered in the study because it is the latest year of draught for the Khadakwasla Complex. Table 1 describes the application of flow continuity equation and table 2 describes the water availability index for the Khadakwasla watershed.

Sl. No.	Year 2009	End of Monthly Reservoir storage(Mcum)	Inflow to reservoir(Mcum)	Storage + Inflow(Mcum)	Rank	Probability	Water Availability Index (WAI)
1	Jan	50.488	57.76	108.255	7	46.15	0.32
2	Feb	48.563	90.02	138.583	12	7.69	3.53
3	Mar	45.25	90.02	113.699	8	38.46	0.96
4	Apr	36.245	92.05	128.297	10	23.08	2.24
5	May	45.907	102.35	129.072	11	15.38	2.88
6	June	56.321	75.23	92.518	5	61.54	-0.96
7	July	85.006	16.34	101.352	6	53.85	-0.32
8	Aug	51.961	27.16	79.128	4	69.23	-1.60
9	Sep	59.068	0.41	59.480	1	92.31	-3.53
10	Oct	60.399	0	60.399	2	84.62	-2.88
11	Nov	64.024	0.51	64.535	3	76.92	-2.24
12	Dec	60.711	59.51	120.225	9	30.77	1.60

Table 2: Water Availability Index (WAI) of Khadakwasla reservoir

THE DAYS OF SUPPLY REMAINING INDEX (DSR)

As per the data collected from the Khadakwasla, Panshet, Varasgaonand Temghardams, the following was revealed. The inflows values considered here are including the evaporation loss from total inflow to the reservoir. The demands from the various sources which are fulfilled by the water from the khadakwasla reservoir are as follows

Sl. No.	Year 2009	Beginning storage volume (Mcum)	Inflow volume (Mcum)	Total Storage (Mcum)	Demand volume (Mcum)	Ending storage volume(Mcum)	Demand met?	DSR days
1	Jan	50.488	57.76	108.255	85.444	22.51	Yes	0.26
2	Feb	48.563	90.02	138.584	97.315	40.97	Yes	0.42
3	Mar	45.25	90.02	135.275	106.285	28.39	Yes	0.27
4	Apr	36.245	92.05	128.297	110.849	15.75	Yes	0.14
5	May	45.907	102.35	148.257	116.656	29.87	Yes	0.26
6	June	56.321	75.23	131.556	64.662	65.39	Yes	1.01
7	July	85.006	16.34	101.352	130.251	-30.40	No	-0.23
8	Aug	51.961	27.16	79.128	108.963	-31.03	No	-0.28
9	Sep	59.068	0.41	59.479	56.385	2.49	Yes	0.04
10	Oct	60.399	0	60.399	49.341	10.36	Yes	0.21
11	Nov	64.024	0.51	64.536	85.10	-21.16	No	-0.25
12	Dec	60.711	59.51	120.225	91.839	27.89	Yes	0.30

Table 3: Demands of water

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The ***Days of Supply Remaining*** (DSR) index includes current reservoir storage, inflows from precipitation and the Panshet,Varasgaon and Temghar dam and predicted demands for drinking water and irrigation supply.DSR is calculated by predicting future inflows and demands and determining when the inflows and existing supply will no longer be adequate to meet demands (Fisher and Palmer, 1997). The DSR values are calculated at the beginning of each time step, which here we have calculated it for the each month. At that time, forecasts are made of the subsequent month's inflows and demands. Inflows are added and demands subtracted for each successive month. Table 3 describes the water supply details if the dam.
From the result Table 3it is observed that there is no inflow from the reservoir during the month of July, Aug and November. Where the draught situations in the July and August are due to the late start of monsoon season and hence because of no rainfall there is depletion of the average resources of water and hence the draught situation occurs whereas for the drought in the month of November there is increased demand of agriculture for the same reason of less rainfall is occurred and thereby a drought situation is faced.

V. OBSERVED DETAILS/RESULTS

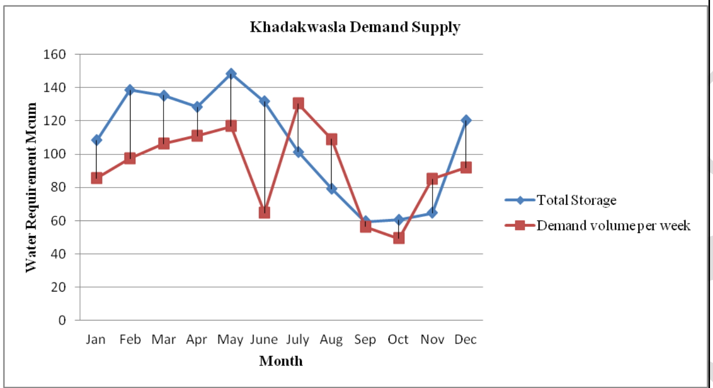

Fig. 3. Khadakwasla Demand Supply graphical representation

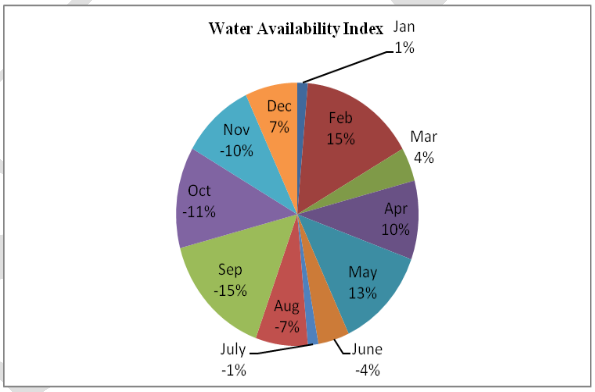

Fig.4 WAI of the Khadakwasla reservoir

Application of hedging rule for Khadakwasla reservoir for uncertain inflow
Figure 3 and shows the distribution of water and availability index for the khadakwasla dam along with the dry spell period.

Hedging rule policies for reservoir operations accept small deficits in current supply to reduce the probability of a severe water shortage later (Jiing-Yun You 2008). The most common reservoir operation policy implemented in practice is a Standard Operating Policy (SOP). SOP releases water as closely as possible to the demand target, saving only surplus water for future demand. During the periods of operation, when the inflow is plentiful, SOP is practical. However in the later period of operation, SOP does not consider the potential shortage vulnerability. Hedging rules curtail releases over some range of water supply to retain water in storage for use in later periods. Thus, some water is stored, rather than released, even when there is enough water for full release requirement in the present period. If the reservoir has low refill potentials or uncertain inflows, then hedging provides insurance for the most valued water uses. The intent of hedging is to reduce the water shortage and cost of large shortage at the drought period, by way of sacrificing more frequent small shortage.

In 1-point hedging, the release begins at the origin and increase linearly at a slope <1until intersecting with the target level of release and in 2-point hedging, a linear hedging rule begins from a first point at somewhere up from the origin on the shortage portion of the SOP rule to a 2ndpoint occurring where the hedging slope <1 intersects the target release. In 3-point or multipoint hedging, where intermediate points are specified in the above rule, introducing 2 or multi-linear portions to the hedging portion of the overall release rule and in zone-based hedging, where hedging quantities are discrete proportions of release targets for different zonal levels of water availability. Continuous hedging, the slope

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of the hedging portion of the rule can vary continuously. But, a linear 2-point hedging policy may be near optimal for a wide range of circumstances. Si, Ii, d_m, A and E are storage, inflow, demand, water availability and evaporation respectively.

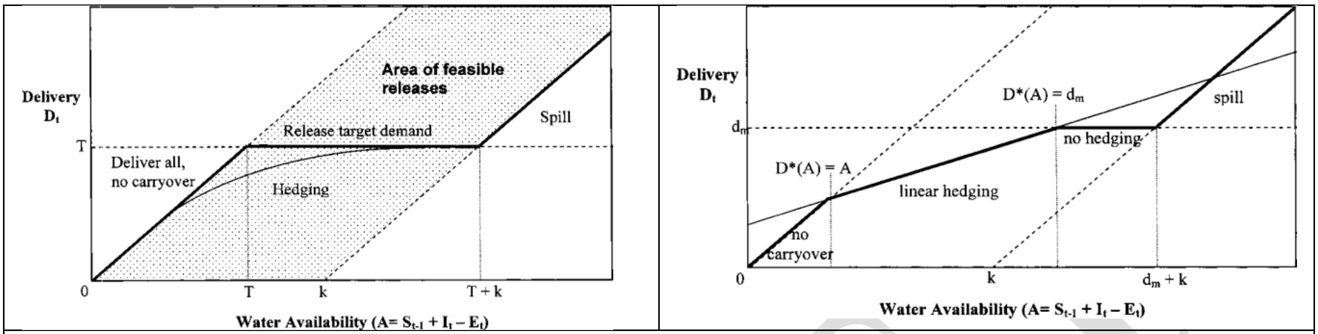

Fig.5 Different hedging against SOP (Lund, ASCE, 2004)

Theoptimization of hedging only applies when water available is less than maximum demand plus storage capacity ($A>d_m+k$). If $A>d_m+k$, hedging is irrelevant since ample water exists to supply all demands, fill the reservoir, and spill, as with the SOP rule. The equation (6) represents the total release of water from the reservoir during the period ***t*** with priority preference. The primary demand (I priority) is achieved by adopting hedging rule for other demands viz., irrigation demands for Duand and Baramati irrigation. The simulation is formulated in such a way that the release is made as per the priority order. That is, release to the III priority is possible only after fulfilling the second priority (release to irrigation demand). The fourth priority (Baramati agricultural demand) is fulfilled only after fulfilling the requirements of I, II and III priorities as showin in Figure 5.

Drought storage rule and implication

Since marginal losses from Additionals storage generally decreasewithincreasingstorage,losseswillbeminimizedif,totheextentpracticable water is stored in one reservoir, rather than distributed among many. Here the khadakwasla reservoir is chosen for concentrating storage as it is having the least loss potential. Balancing storage among reservoirs, a common practice where each reservoir is filled to a similar percentage of its overall capacity, does not minimize water losses. Indeed, if all reservoirs in a system had the same loss-storage relationship, balancing storage among reservoirs would maximize water losses during a drought.

In the present study it is observed that due to improper distribution of the water available the drought like situation needs to be faced. However if the water is distributed by considering the following level of water distribution the drought like situation may not be there. Following are the different level of management of water to reduce the occurrence of the drought. Even if there is no drought like situation currently water managers must take appropriate action to reduce future losses and not increase them by imposing unnecessary restrictions when they are not needed (Wright et al., 1986).This help to reduce the consumption among the public and helps to bring the awareness of water use.

Level	Activity
1	Monitor stream flow, storage, forecast rainfall, forecast climate situations *Normal Reservoir operations*
2	Reduce release to base, increase flow measurements, evaluate gate leakage and reservoir facilities, notify concession operators *Actively Augmenting Releases/ reduce the water supplied to the agriculture at Daund*
3	Further reduction of release, evaluate storage for emergency water needs *Reduce the water supplied to the agriculture at Baramati*
4	Further reduction of release, allocate water for emergency needs, **Water Supply Release for drinking Only*

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VI. CONCLUSIONS

From the above study the regular demand of water is almost fix throughout the year hence if the situations like drought are avoid then there should be some triggers which will help the distributor of water to reduce the water demand and supply the water only for the necessary activities. For Khadakwasla dam this triggers should be applied during the summer to avoid the drought like situations due to late monsoon period. and needs to be monitor this triggers till the monsoon ends as there are drought like situations due to small periods monsoons which creates a great loos of agricultural fields and drought like situations needs to be faced.Being prepared for droughts can help to mitigate some of those costs and damages. It costs money to plan, but planning to be prepared for droughts in advance of when they occur saves much more that it costs. Drought plans help to prepare a consistent framework and respond to drought events. Thus the Khadakwasla complex drought management plan should include the indicator monitoring like rainfall, streamflow, evaporation then it should have the triggers for the reduction of water supply and responses for the same will definitely help to reduce the drought situations in the area.

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