Farmer Organization's Potential for Reducing Waterlogging and Salinity Through Improved Equity and Reliability of Irrigation Water: Evidence from Hakra 4-R Distributary in Southern Punjab

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ABSTRACT

The state managed surface irrigation in Pakistan has been supplying unreliable and inequitable irrigation water to farmers, forcing farmers to irrigate sub-optimally, especially in areas where groundwater is brackish. Farmers having excess or unreliable water tend to over-irrigate and cause drainage. Those having less water tend to under-irrigate, which causes salinity. Improving reliability and equity in water supplies will, therefore, not only save drainage production, but also may lead to more efficient use of water and agricultural productivity, and conserving environment.

Through institutional reforms in the irrigation and drainage sectors, the secondary level management of the system is being handed over to the FOs (Farmers Organizations). The FOs are expected to provide water to the member farmers more reliably and in an equitable manner. However, there are concerns about farmer's ability to manage the system properly. The paper addresses the question if the FOs are able to distribute water equitable and reliably by taking Hakra 4-R FO as a case. The FO took-over the system management during May, 2000. IIMI (International Irrigation Management Institute) staff has been monitoring the irrigation system before and after the change in management with respect to reliability and equity. Previous data showed that there had been huge variations in respect of equity among various outlets. The monitoring data is analyzed to compare the situation of equity and reliability during the state and farmers' management. Analyzing the initial performance of the FO, the paper argues that the FO has brought considerable improvements in equity and reliability of irrigation water.

1. INTRODUCTION

The efficiency from the canal head to root zone of the canal irrigation system in Pakistan due to age, over use, and poor maintenance is around 35-40%, which is extremely low and causes water loss, especially within the watercourse commands. Such a huge loss of extremely precious natural resource reduces available water for crops, and contributes to waterlogging and salinity [1]. The situation is further aggravated in areas where the groundwater can not be used for irrigation due to poor quality, because the lost water not only is not reusable, but also leads to raising water table.

The original design considerations were based on supplying a limited but equitable volume of water to various watercourses and farm units. However, due to political pressure, rent seeking and physical system deterioration, water supplies are no more equitable among watercourses as well as among distributaries. Besides, the main and branch canals' operational practices and fluctuations make water supplies unreliable for farmers. The unreliable and inequitable supplies of irrigation water force farmers to irrigate sub-optimally, especially in areas where groundwater is brackish. Farmers having excess or unreliable water tend

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to over-irrigate and cause drainage [2]. Those having less water tend to under-irrigate, which causes salinity. Improving reliability and equity in water supplies will, therefore, not only save drainage production, but also may lead to more efficient use of water and agricultural productivity, and conserving environment. Besides, the chances of conflicts within and among watercourses regarding inequity will reduce.

Pakistan through its provincial governments [3] has embarked upon the institutional reforms in irrigation and drainage sector with broad objectives of streamlining the Irrigation and Drainage Systems, replacing the existing administrative set up and procedures with more responsive, efficient and transparent arrangements, achieving economical and effective operation and maintenance of the irrigation, drainage and flood control system in the Province, making the irrigation and drainage network sustainable on a long term basis; and introducing participation of beneficiaries in the operation and management of irrigation and drainage systems.

The search for solutions to the irrigation and drainage problems has resulted in 1997 in the passage of the PIDA (Provincial Irrigation and Drainage Authority) Acts in the Punjab, Sindh, Baluchistan and Northwest Frontier Provinces. Under these acts, the present Provincial Irrigation Departments would become financially autonomous PIDAs. The authorities would be responsible for the policy level decisions and water acquisition and allocation at the provincial levels. Farmers would be organized into Farmer FOs to take over operation and maintenance of watercourses, minor canals, distributaries and the lower level drainage infrastructure. FOs would be responsible for equitably distributing the available water to their members and levying charges for irrigation and drainage services, with the proceeds divided among the PIDAs, AWBs and FOs to reflect costs at each level. A new institution - the AWB (Area Water Board) would be the intermediary between these two levels, receiving water from the PIDAs and equitably distributing water among the FOs.

The success of these reforms depends greatly on FO's hydraulic and financial performance. If FOs are able to deliver better service, in terms of reliability and equity, farmers would be willing to pay for the system O&M. The paper uses data from Hakra 4-R Distributary and evaluates the potential of the FO in supplying reliable and equitable water to its members.

2. BACKGROUND

2.1 Site Characterization

The Hakra 4-R Distributary along the Hakra Branch Canal of the Fordwah Eastern Sadiqia irrigation system has a total discharge of 197 cusecs, and a total of 124 irrigation outlets serving a command area of nearly 18,000 hectares. This distributary system has two minors, i.e., 1-RA Labsingh and 1-R Badruwala, each discharging 22 and 43 cusecs, respectively and with 16 and 33 watercourses, respectively. Both the minors and the distributary below Rd 72+000 are lined. The average annual rainfall ranges from 125 mm to 250 mm. A hot and dry climate, low rainfall and unfit groundwater necessitate the ensured, and regular, surface irrigation water supplies. The distributary system supplies water to 4690 warabandi shareholders. The banks of the distributary are now deteriorating in some places due to frequent use as livestock routes. The freeboard of the distributary has almost disappeared in the head and middle reach due to continuous deposition of sediment, especially in the head reach. For the Kharif season, cotton, sugarcane and rice are the most popular cash crops. Recent years of drought have limited rice and sugarcane in the head reach only, where lands are relatively waterlogged. Sorghum, millet, and maize are sown as fodder. Occasionally, vegetables are also sown, but usually for domestic consumption. During winter, or the Rabi season, wheat is the most popular crop, while clovers are the main fodder crops generally sown to feed domestic livestock. Some of the farmers also cultivate vegetables and oilseeds, and on a few farms, orchards, especially of the citrus family, can also be seen. The cropping intensity was 122 percent, higher at the head reaches (147%) compared to the tail reaches (97%). The average farm income was Rs. 78,963 for an average operated area of 13.25 acres, as reported by the respondents [4].

Groundwater in this area is generally considered unfit for irrigation. However, due to a shortage of canal water, and inequity and unreliability of canal water supplies, farmers have been compelled to look for groundwater. About 237 shallow tubewells are located along the distributary. The baseline socio-economic survey [4] conducted during July-August 1995, on a sample of 367 respondents selected randomly from 13 watercourse commands of the distributary, provided some information about the socio-economic features of the pilot site. The majority of farmers (56%) owned up to

5 acres of land along the Hakra 4-R Distributary, whereas 6 percent owned land of 25 acres, or above. A majority of the respondents (62%) had no formal literacy. About 45 percent of respondents reported water inequity among distributaries, of which 23% attributed the problem to the "influentials". About 80% referred to inequity within the distributary, and this number ranged from 67% in the head reaches to 84% in the tail reaches; most respondents attributed the problem to big landlords and irrigation officials. None reported inequity within the watercourse. Over 90% of the sampled farmers along the Hakra 4-R Distributary were of the view that they missed their water turns due to distributary rotation. Almost 50% of these farmers missed more than 10 irrigation turns during 1994-95.

2.2 Background Situation

The IIMI had organized the farmers of Hakra 4-R Distributary into a FO during 1995-97 through a slow and stepwise social organization methodology. The FO negotiated an IMT (Irrigation Management Turnover) with the PIDA between 1997 and 2000, and finally took over the management of the distributary system on May 10, 2000. Since then the FO has employed its own staff and is managing the distributary system. In the original organizational design, the FO had 5 subsystem level sub-organizations representing the 5 hydraulic subsystems, where farmers could measure water [5]. In 2000, when PIDA conducted elections, the subsystems became irrelevant as the PIDA rules do not recognize any subsystem organization. However, the subsystems reflect the distinct socio-technical characteristics, which are important for water distribution. Subsystem 1 is the head reach (RD 0-46), subsystem 2 is the middle reach (RD 46-72), subsystem 3 is the tail reach of the distributary (RD 72-Tail). Minor 1RA is the fourth and Minor 1R is the fifth subsystem. The FO still refers to the subsystems and manages water according to the subsystems.

During the 1999-2000 closure period, the Pakistan Army and the PIDA staff had remodeled most of outlets to foster equity. The expectation was that the outlets would draw proportionate discharges afterwards. However, due to the lining of the reaches below RD 72 of Hakra 4-R (Subsystem 3) and minor 1R (Subsystem 5), these subsystems can not receive more than 120% of the design discharge. Due to a design fault in minor 1R, the water used to accumulate in the middle reach (Subsystem 2), and the water could not be delivered equitably among various outlets. In the IMT Agreement, PIDA agreed to remodel outlets in such a way that proportionate water reaches to the tail subsystems. In practice, the remodeling undertaken in April 2000 reversed inequities and water rushed to tails. Due to sowing season, farmers were dissatisfied and the FO had to immediately remodel outlets to distribute water more equitably. These three re-modeling efforts offered a good opportunity to study potential of the FO in distributing water equitably.

3. METHODOLOGY

IIMI staff had conducted inflow-outflow tests during 1995, 1999 and 2000.The staff has also been monitoring the distributary inflows and 15 sample outlets along the distributary during 2000. Based on 1999 inflow outflow results, three sample outlets were selected from each of the 5 subsystems in such a way that the outlets drawing more, less and proportionate shares were equally represented. Besides, the tail outlets and the water levels at the subsystem intake are also being monitored. The questions that need to be answered are a) is water supply at the head more reliable after the FO's takeover? And b) After FO's takeover, is water supply more equitable among subsystems and among outlets?

The reliability has two dimensions, i.e. continuity, and steadiness. Estimating the CV (Coefficient of variation) of the delivery performance ratio for the inflow at the head can capture both these variables. Dividing the actual discharge with the design discharge produces DPR and CV can be obtained as a ratio of standard deviation of DPR to the average DPR at the head, as suggested by Modlen and Gates, [6]. Thus, the performance indicator for reliability (P_R) can be defined as equation 1.

$$PR = CV\,(Q_{act} / Q_{des}) \qquad (1)$$

Where Q_{act} is the actual discharge into the channel and Q_{des} is the design discharge. In a perfectly reliable water supply situation, the value of P_R should be zero. Ideally, if the water supply is equitable, each structure on the distributary should receive water with the same proportion, as that of the head of the distributary. The proportionate share can be computed through DRP (Delivery Performance Ratio) of various structures. Mathematically, DPR is defined as equation (2).

$$DPR = Qact / Qdes \qquad (2)$$

The ratio of DPRs of various structures (subsystem heads and outlet heads) to that of the head regulator, or relative DPR, estimates the level of equity among the subsystems and outlets. Thus for a structure, equation (3) estimates relative DPR.

$$DPR_R = (DPR_S/DPR_H) \qquad (3)$$

Where DPR_R is the relative DPR of the structure, DPR_S is the DPR of the structure, and DPR_H is the DPR at the head of the channel or section/ subsystem. Following Hypothesis are tested in this paper.

- The temporal CV of the supplies at the head of the distributary during the FO management is lower compared to the same period last year;
- The relative DPRs of the subsystem are lower during FO period than before; and
- DPRs of outlets are closer to those at the subsystem intakes during FO period than before.

4. RESULTS AND DISCUSSIONS

This section presents and discusses the results of the hypothesis testing.

4.1 Reliability of Water Supply

Table 1 presents the average DPR at the head of the distributary, its standard deviation and temporal coefficient of variation for the period after the FO took-over the management, and also for the same period for the last year. The table shows that the delivery performance has improved during the year 2000 compared to the same period during 1999. The standard deviation has declined showing a more consistent water supply. The value of coefficient of variation has dropped to half, indicating a considerable improvement in the reliability of water supplies at the head of the distributary. More reliable supplies at the head have paid dividends for various reaches also. Table 2 presents the situation of reliability in various reaches for the period before and after IMT during 2000. Except for the minor 1R, the reliability seems to improve by a factor of over 4 for all other subsystems. For 1R minor, the improvement is double due to a structural fault in the lining that prohibits proportionate withdrawal at lower or higher flow.

To supplement this information, the hydrograph of the two years is presented at Figure 1, which shows much more fluctuations in 1999 compared to the year 2000. The higher reliability of discharges is the outcome of FO's efforts to force PIDA staff to stop rotation of distributaries when ample water is available in the branch canal. The value of the DPR suggests that compared to last year, the average amount of water is also more. Improved reliability of water means a guaranteed water supply for farmers, and therefore, they will not tend to over- or under-irrigate their crops as much as possible.

Improved reliability has important implications for water use and crop productivity. In an uncertain situation, farmers tend to flood their fields with the expectation of high risk that they will miss their next water turn, so they need to apply as much water as possible. This leads to over irrigation, leading to accumulation of water in the root zone and subsoil, leaching of nutrients, and damage to the crop roots. If there is a clay layer in the subsoil and water can not go down, the result is waterlogging. However, when water becomes more reliable, and the farmer predicts, from the past behavior of the canal, that he can irrigate his fields every week, he only applies such volume of water to field, which is enough to save crop from wilting till next irrigation. Thus, he then tends to conserve water

TABLE 1. DELIVERY PERFORMANCE RATIO OF HAKRA 4-R DISTRIBUTARY HEAD (10 MAY TO 15 JULY)

Parameter	1999	2000
Mean DPR	1.04	1.09
Standard Deviation of DPR	0.55	0.32
Temporal CV of DPR	0.53	0.29

TABLE 2. TEMPORAL COEFFICIENT OF VARIATION OF RELATIVE DPR$_S$ FOR DIFFERENT REACHES OF HAKRA 4-R DISTRIBUTARY FOR YEAR 2000

Period	Reach RDs				
	0-46	1RA Minor	46-72	72-Tail Main	1R Minor
Before IMT	0.41	0.21	0.58	0.26	0.20
After IMT	0.11	0.06	0.11	0.06	0.12

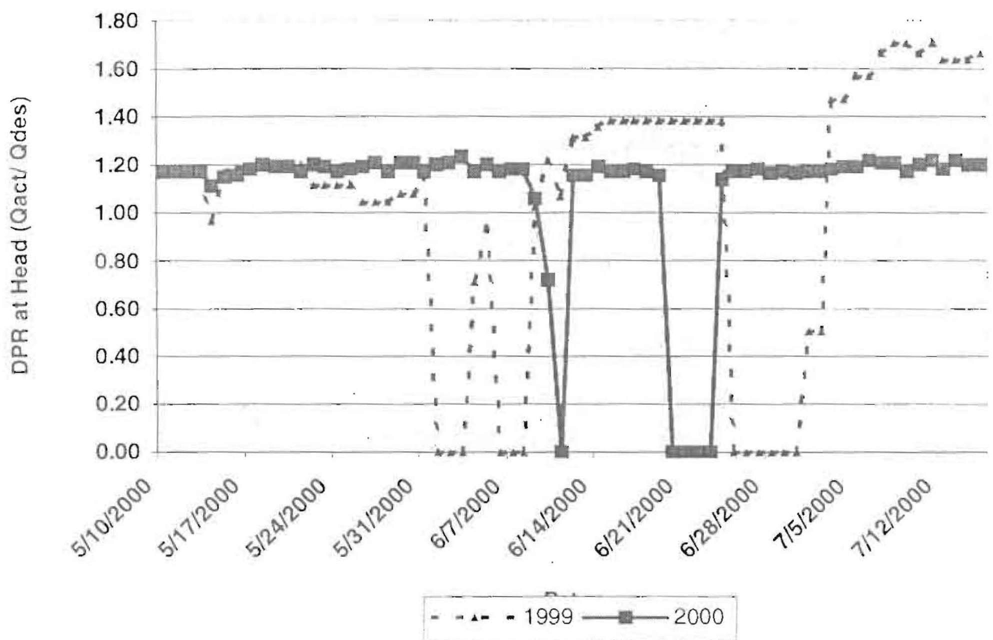

FIG. 1. RELIABILITY OF SUPPLIES AT THE HEAD OF HAKRA 4-R FOR MAY, 1999 TO JULY, 2000

4.2 Equity Among Subsystems

Figure 2 shows the relative DPRs of subsystems with respect to the head of the distributary. The graph shows that after the army and PIDA remodeled the outlets, there had been considerable differences among subsystems. The relative DPRs varied between 0.7-2.5. The head and middle reach had suffered most of the times. Just before the IMT, when PIDA had revised the longitudinal section of the middle reach according to the provisions of the agreement, the inequities narrowed down, but the relative DPR remained within the range of 0.5-1.5, indicating 50% of proportionate supplies to 150% of supplies to some subsystems. The FO took-over the distributary management during first half of May and started remodeling outlets. As a result, during late June and onwards, the range of relative DPRs became within ± 30% of the head supplies. This shows improvements in equity among subsystems. However, the FO still has to remodel a few more outlets in lined sections to abridge the gap further.

4.3 Equity Among Outlets

If there is equity among various outlets, an outlet should draw water in the same proportion as that of the subsystem head. Thus, the ratio of these two DPRs (Relative DPR) should be ideally 1.

Since the outlets are yet being repaired in the two minors and tail portion of the distributary, the outlets from the head and middle reaches only are analyzed. Table 3 presents the equity situation of the sample outlets in the head and middle reaches, as well as that at the tail clusters of the distributary and its two minors.

At the time when the FO formation process was initiated, the average relative DPR of outlets was off by 5% than the ideal value of 1. However, the value of CV suggested that there had been considerable variations among outlets. In 1999, or earlier part of the year 2000, the inequities had increased. The value of CV in 1999 was around 0.7, which dropped to around 0.3 after the revision of the longitudinal section. The FO's repair efforts brought more equity and pulled the CV down to 0.2. The value of relative DPR is also close to 1.

During the closure period of 1999-2000, Pakistan Army and the PIDA staff repaired the defective outlets. Most of the effort was to install the outlets with accurate dimensions, without any reference to the water level or bed level, which had changed overtime due to sedimentation and scouring. Therefore, as an effect the outlets in the head and middle reaches started drawing less than proportionate discharges, and water rushed to the tails. The trend-lines in Figure 3 show that during 1999 the line is highest for the head reach and gradually falls below the proportionate share in the tail. After the

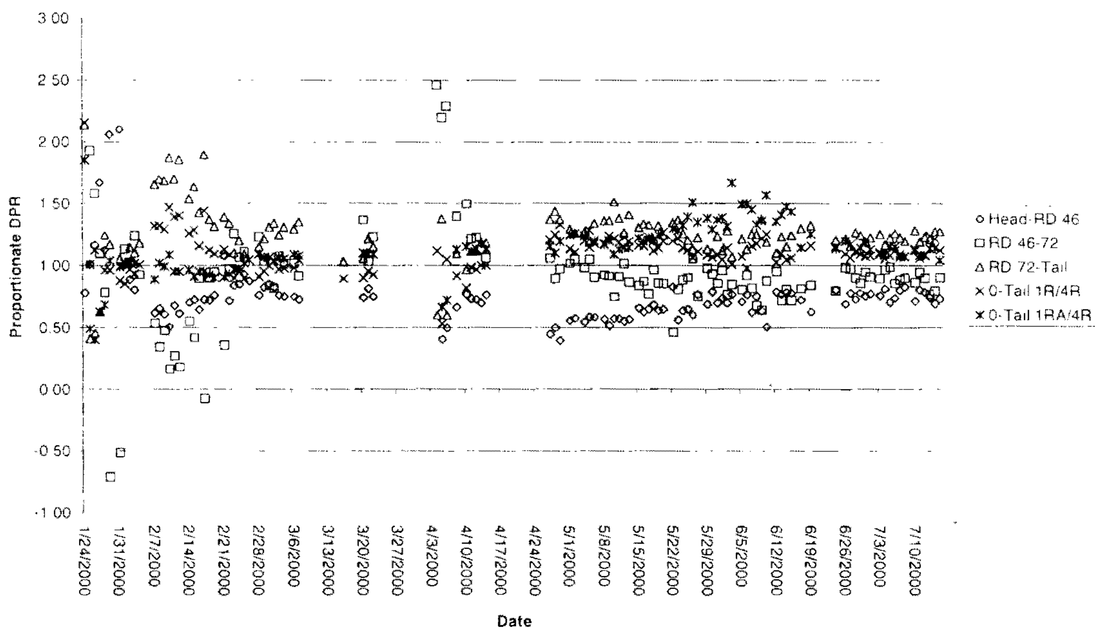

FIG. 2. WATER SUPPLY TO SUBSYSTEMS RELATIVE TO HEAD SUPPLIES DURING YEAR 2000 AT 4-R DISTRIBUTARY

TABLE 3. RELATIVE DELIVERY PERFORMANCE RATIO OF SAMPLE OUTLETS TO HAKRA 4-R DISTRIBUTARY HEAD FOR SELECTED PERIODS

Parameter	October 95	August 99	April 2000	July 2000
Mean Relative DPR to Subsystem Head	1.05	1.65	1.22	0.97
Standard Deviation	0.25	1.19	0.27	0.19
Spatial CV	0.24	0.72	0.29	0.20

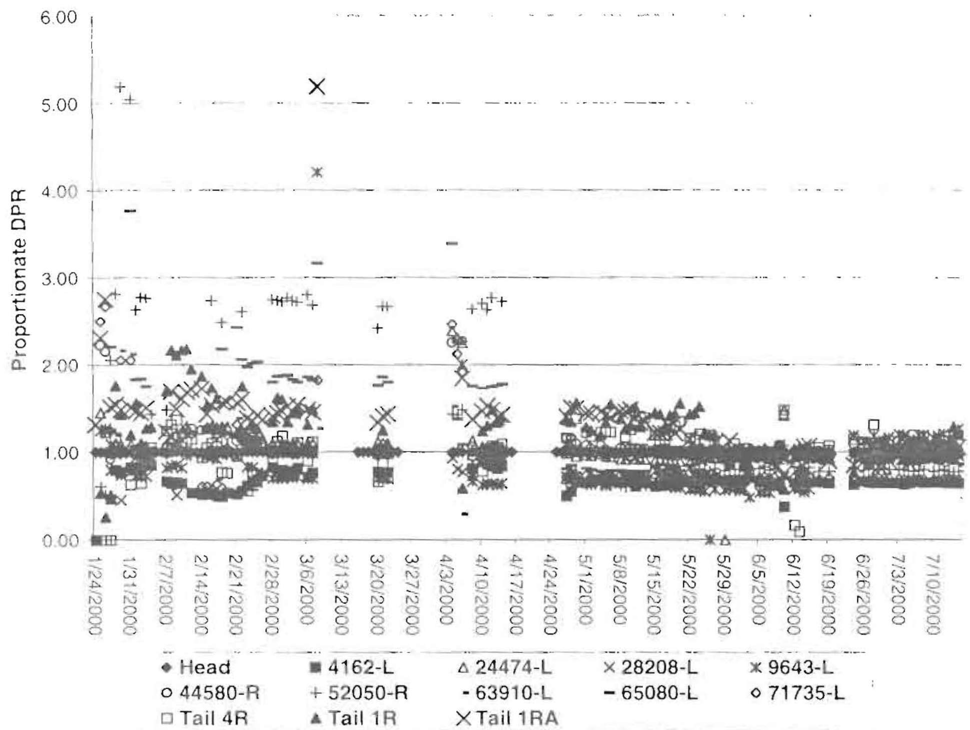

FIG. 3 WATER SUPPLY TO SAMPLE OUTLETS RELATIVE TO SUBSYSTEM HEAD DURING YEAR 2000 AT 4-R DISTRIBUTARY

remodeling by Army, the situation became reverse. The outlets towards the end started drawing much more than those at the head. After the FO took-over and repaired the outlets, the inequities narrowed down. This shows a gradual improvement in water distribution among outlets. After a complete repair of the remaining outlets, the situation may improve further.

5. CONCLUSIONS

The IMT at the Hakra 4-R Distributary has demonstrated the potential for bringing improvements in reliability and equity of water distribution among watercourses as well as among subsystems. Reliability has a very special link to the drainage production. The canal management procedures followed by PIDA staff, therefore, need to be analyzed in terms of the constraints and problems in delivering a quality service to farmers. There are important lessons and implications for the surface irrigation and drainage management in Pakistan, as well as for the ongoing institutional reforms.

The effort, which has gone into the social mobilization of farmers has paid dividends in terms of leadership development and improving farmer's skills for negotiating reliable water supplies and understanding of the importance of equitable distribution. The future efforts to form and mobilize FOs should focus on creating proper understanding about the need to distribute water equitably. The concept of subsystems that was introduced as a social organization strategy to maximize participation is also important for water management and distribution. While the PIDA rules should be general to cover the entire province, the organizational designs should be flexible enough to reflect the diversity of the irrigation systems and communities. The present FOs should be carefully and objectively monitored instead of monitoring the paper work of the FOs. The old performance indicators should therefore be revised in such a way that these provide objective evaluation of the reforms performance at various levels of hierarchy of the system.

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