

Achieving Permanent Water Security to Colorado River Basin is a Dream, Without Transbasin Diversion from Mississippi River

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Abstract

The existing water management pathways in Colorado River basin are unable to sustain water security in similar droughts continuing since 2012. Even sharing of water by Colorado River Compact 1922, wastewater management and desalination are unable to sustain water resources development in drought years to this basin. To sustain water security, Nevada State needs 271.184MCM, Colorado State 145.612MCM- 777.42MCM per year, California State 4.15maf/5.12km³ in 2050 and Colorado River basin 3.2maf/3.95km³ by 2060. Since the existing water security pathways are not sustaining water resources development to this basin, the permanent option would be transbasin water diversion from Mississippi River.

Key words: Water scarcity, Megadrought, Water miseries, Water security, Action Plan, Transbasin water diversion, sustainable water resources development

1. Introduction

The Colorado River basin states are practicing water management pathways to bridge its water supply demand gap. However, more attention is paid to the intra basin water sharing of the Colorado River, desalination and wastewater management.

The 1922 Colorado River Compact allocates 15million acre feet(maf)/18.50km³ of water to the basin states. As per this agreement, water is being shared thus: Colorado 3.86maf, New Mexico 0.84maf, Utah 1.71maf, Nevada 0.30maf, Arizona 2.85maf, Wyoming 1.04maf and California 4.40maf. In addition to the 4.4maf to California, the agreement has allotted half of all surplus water when available in this river to this state. Further, a major amendment to a 1944 treaty grants Mexico 1.5maf of river water each year – enough to supply about 3million homes – making it the lifeblood of Tijuana and other cities in northwest Mexico. Mexican President Felipe Calderon achieved this.

All these states are treating and recycling the wastewater for appropriate uses, the coastal states desalinate seawater and use it for appropriate purposes including for drinking in some regions. However, these major approaches are unable to sustain water resources development to these basin sates due to the periodical droughts similar to the present continuing since 2012. Hence, the Nevada, Colorado and California states, as well the Seven Colorado River Basin States and the Bureau of Reclamation are proposing water demand to the above states and the basin.

2. Materials and methods

After seeing the water miseries of the California State due to the present extreme drought since 2012, the first author being the regular visitor to California State is very much interested to utilize his and other authors' experience to arrest the water miseries of the Colorado River basin permanently.

The authors do not have access to none of the water managers of this basin, and hence they have collected data like population, water resources, quantity of water shared in the Colorado River among the seven basins states, flood flow from Mississippi River etc., from the public domain.

Since the Southern Colorado River basin is located in the 10,000–11,000 years old Great Basin and Mojave Deserts, it is impossible to bridge the water supply demand gap beyond to a certain extent possible by the existing water management pathways, including the most effective practice of intra basin

transfer of water among the Colorado River basin seven states.

The authors with their long experience in the field of water resources are explaining the benefits of inter basin water transfer and the economic loss of the unutilized water let into the Gulf of Mexico from the Mississippi River in this paper.

They are now suggesting the inter basin transfer of water from Mississippi River to the water scarcity Colorado River basin, the permanent option to bridge the water supply demand gap now and beyond 2050.

3. Colorado River basin water miseries

This basin has been experiencing the impacts on water resources, hydropower, recreation, and ecologic services because of the periodical droughts. Further, the basin has experienced its lowest 16-year period of inflow in over 100years, and reservoir storage in the Colorado River system has declined from nearly full to about half of capacity. As per US-Davis Centre for Water Science/USA, the farmers left 400,000acres in 2014 and 560,000acres in 2015, unplanted in California alone due to drought. Since Colorado River basin is located in the arid Western/USA, similar water woes are likely to intensify in future and cause even bigger miseries, because of anthropogenic climate change.

The severely drought affected California State, costs a crop revenue loss of \$810million, additional pumping loss of \$454million and livestock and dairy revenue loss \$203million. The total direct losses were \$1.5 billion, the total economic cost was \$2.2 billion and the total job losses 17,100 due to farmers left 400,000 acres as follow in 2014, or 6% of the State's annual irrigated cropland unplanted (Richard Howitt, et al., 2014). Richard Howitt et al., also assessed the drought economics of this state for 2015 and 2016 as follows. In the 2015 California drought, the surface water loss was 8.7maf, drought related idle land 54,000acres, crop revenue losses \$900million, total economics cost \$2.7billion and the total job loss 21,000. In the 2016 drought surface water loss was 2.6maf, drought related idle land 78,780acres, crop revenue losses \$247million, total economics influences \$603million and the total job loss 4,700. Because of the land kept idle in the drought, many farm workers have lost their livelihood security. ***This pathetic situation of the food providers of this state worries the first author much, being the son of a farmer from Tamil Nadu State, India.***

4. Water demand to Colorado River basin

The Southern Nevada Water Authority (SNWA), in 2004, proposed a project to convey via a 306 miles pipeline 176,000 acre feet (acft)/217.09MCM per year, from aquifers underlying several valleys in northern Nevada. This quantity is equal to half of the amount of water allocated to Nevada from the Colorado River by the Colorado River Compact of 1922.

A Colorado rancher and engineer, Gary Hausler, after reading a 2004 report finding that Colorado State needed over 118,000acft/145.55MCM to 630,000acft/777.09MCM of water per year to meet the future demand, proposed to build a two story tall, 1200mile, pipeline from the Mississippi River to Colorado. According to his estimate, this would cost \$22.5billion.

Pat Mulroy, the general manager of the Southern Nevada Water Authority is suggesting the same idea of Gary Hausler on building a pipeline to divert Mississippi River floodwaters to alleviate the water stress of the Western States of Colorado River system (Guest Blog by Michael Clark, September 6, 2011).

The first author of this paper has carried out an independent study for California State and found that it could be possible to additionally generate/save about 21.94maf/27.06km³ of water (Table 1) and even then, there will be water supply demand gap of 4.15maf/5.12km³ in 2050. He suggests practicing 26 water security pathways along with transbasin water diversion from Mississippi River, to arrest the water miseries to this state permanently, beyond 2050 in his unpublished "**Policy Paper**" sent to Mr. Donald J. Trump, President of USA (Natarajan, Dr. P.M, 2016).

Drought proof water management pathways to generate/save additional water resources in California State- Table 1				
	Drought proof water management pathways	Water generation saving		Remarks
		maf	Km ³	

1	Sewage treatment and recycling	7.12	8.79	Additional water generation
2	Enhancing desalination of water	1.38	1.71	Additional water generation
3	Reducing domestic water supply at WHO standard	2.2	2.74	Water saving
4	Restricting the environmental water flows	3	3.7	Additional water generation
5	Rotation of crop cultivation	3.42	4.2	Water saving
6	Bringing down the irrigation water use to the national level	0.876	1.081	Water saving
7	Maintaining the almonds crop area without further increase in the irri potential	0.042	0.053	Water saving
8	Arresting seawater ingress	1	1.23	Water saving
9	Using smart energy for in thermoelectric power generation	1.58	1.949	Water saving
10	Arresting leakages	0.87	1.07	Water saving
11	Practicing vegetarian diet	0.44	0.54	Water saving
12	Transbasin water diversion from Mississippi River to Colorado	-	-	To bridge the water supply demand gap
	Total	21.94	27.06	

More recently, the Seven Colorado River Basin States and the Bureau of Reclamation jointly projected the water demand to the Colorado River basin by 2060 based on a study, carried out by the Governor's Representatives on Colorado River Operations States of Arizona, California, Colorado, Nevada, New Mexico, Utah, and Wyoming in 2012. This study has quantified the future water demand of the 7 Western States of Colorado River basin by six different demand scenarios that include varied assumptions about future economic conditions, population growth, and water needs for agricultural, municipal and industrial, energy, minerals, and fish, wildlife, and recreation purposes. This study estimated the Colorado River Basin imbalance of approximately 3.2maf/3.95km³ of water per year by 2060. Moreover, the greatest increases in demand are projected to occur in the Lower Basin. The Basin Study also illustrates that because of the magnitude and distribution of the imbalances, no single solution will be adequate to meet all future water demand of the Colorado River basin and supply imbalances (Governor's Representatives on Colorado River Operations States... 2012). This study also suggests Mississippi River water sharing.

From the above details, it is seen that the water demand of Nevada, Colorado and California States as well as for the Colorado River basin has been already estimated.

The proposed approach of augmenting groundwater supply to the Nevada State from the aquifers within this State suggested by the SNWA is likely to cause huge decline of groundwater level, land subsidence and arrest the perennial effluent seepage that supplies water to streams and hence it is not environmentally sound. However, by effective artificial groundwater recharge it is possible to tap groundwater. However, to recharge the aquifer it is difficult to get almost 777.09MCM quantity of fresh water now proposed to tap from the Nevada aquifers, from the drought prone Colorado River

basin. Therefore, it is better to transfer the excess water from the Mississippi River system to the Colorado River basin States and permanently arrest the water miseries.

5. Water let into the Gulf of Mexico from Mississippi River

As per Brenda Moraska Lafrancois, David L. Vana-Miller and Steven P. Johnson 2006 the Mississippi River enters the Gulf of Mexico with a mean annual discharge of $640,000\text{ft}^3/18,123\text{m}^3$ of water per second ($1,565.83\text{MCM}/1.57\text{km}^3$ per day and annual flow $571,526.93\text{MCM}/571.53\text{km}^3$) about 161 km downstream of New Orleans through a $26,159\text{km}^2$ delta.

Based on drainage area and mean annual discharge, the Mississippi River is the largest river in U.S (Iseri and Langbein 1974), via annual discharge the Mississippi is the sixth largest river in the world (Berner and Berner, 1996).

6. Economics of unutilized water let into the Gulf of Mexico

If the excess water let into the Gulf of Mexico from Mississippi River is used for irrigation, it can irrigate about 140million acres of rice crop at 37inches of water per acre and produce about 431.20million tons of rice at the California state's average production at 6,847pounds ($3081.15\text{kilogram}/3.08\text{tons}$)/acre and the value of rice is $\$862,208.36\text{million}/\862.21billion per annum at $\$44.99$ per 50pund/22.5kg of a bag.

At the per capita consumption of 500gram per day, this rice could feed about 2,367.74million people per annum. At 50 farm laborers per acre of land for agricultural operation per crop season, the 140million acres need about 7,000million person-days and at $\$80$ per person-day as wage, these farm workers are likely to earn about $\$560,000\text{million}$ per crop season. Due to the huge environmental loss of water from Mississippi River, the farm work force loses a huge income. By the proposed inter basin transfer of water to Colorado River basin from Mississippi River in this paper, no farmland will be kept idle and hence the farm workforces of the Colorado River basin need not lose farm income in future. By this exercise, the thirst of millions of people would be arrested permanently.

7. Mississippi river flood water resource

As per the National Weather Service Weather Forecast Office, since 1543 to 2011 there were 39 floods in the Mississippi River. However, there were 32 frequent floods in the 18th and 19th century. In the 21st century, there were three floods in 2002, 2008 and 2011. Three major floods occurred in 2011, 2027 and 2937. The flood of 2011 set a new record stage at Vicksburg and Natchez. The peak stream flow at Vicksburg was, 2,310,000ft³/65,000m³/second (5,616MCM/5.62km³ per day) exceeded both the estimated peak stream flow of the Great Mississippi flood of 1927, 2,278,000ft³/64,500m³/second (5,572.8MCM/5.57km³ per day), and the measured peak stream flow of the 1937 flood, 2,080,000ft³/59,000m³/second, (5,097.6MCM/5.098km³ per day) [Wikipedia].

Since there is frequent floods in this river basin, the floodwater can be harvested and harnessed within this basin in future, or diverted to other water deficit basins like Colorado. In the Anthropogenic Epoch, an intensive flood in this river basin is likely to be a regular event (The intensified 2005 hurricane Catherina weather event is an example of the impact of climate change in the eastern USA).

8. Arresting flood damage and bridging the water supply demand gap of Colorado River basin by sharing the Mississippi River environmental and floodwater resources

The maximum floodwater in the Mississippi River in 1937, 1927 and 2011 are 5,097.6MCM, 5,572.8MCM, and 5,616MCM respectively. There were frequent floods in 35 years in this river since the 18th century to 2011. Even the flood flow is sufficient to the water requirement of Colorado River basin.

The mean annual discharge of water from this river in the downstream of New Orleans is 1,565.83MCM/1.57km³ per day and the annual flow is 571.53km³. The EPA has estimated the average per day flow at 1,467.94MCM into the Gulf of Mexico from the Mississippi River (annual flow is 535,798.10MCM/535.798km³). This flow is more than 136 times (13,567%) of the per day water demand of the Colorado River basin States. The Mississippi River basin annual flow to the sea is about 15.31times of Lake Mead.

The above mean annual discharge let into the Gulf of Mexico could supply to the July, 2014 USA 318.90million people at the World Health Organization norm of domestic water supply at 135litres per capita per day (lpcd) for 34 years. And for one

year to the nation as per the Falkenmark Water Stress Indicator standard at 1700m^3 per capita per annum almost. For the 59.34million people in July 2014 of Colorado River basin, the unutilized water could supply domestic water at 135lpcd for 183.24years and at 1700m^3 per capita per annum for 5.3years.

According to the state Farm Bureau, the damage from the Mississippi River flood of 2011 was \$4billion and the summer 1993 Upper Mississippi and Midwest flooding was \$30.2billion. Losses in Arkansas are estimated at more than \$500million. In Memphis, where the river crested, damage was estimated at \$320million. Agricultural losses in Mississippi, including grain and catfish farms, could hit \$800million, says Riley, a commodities specialist at Mississippi State University (Gary Strauss and Marisol Bello, USA TODAY, 5/12/2011) and Dr. Jeff Masters, 2011). In this way, there were flood damages in the remaining 37 Mississippi River basin floods in the past. By harvesting and sharing the flood, damage could be arrested.

The above data shows, that the Mississippi River basin's environmental flow and flood discharge are huge and it is being let into the Gulf of Mexico without harnessing it for human benefits, while there are water miseries in many parts of USA. Hence, it is very sad to state that with so much surplus water facility in the Mississippi River basin, the Western Colorado River basin States 'within the same nation' is put under extreme hardship.

In addition to the above two sources of water, about 40millionacft/49,339MCM/49.34km³ of water stored in over 3,000 reservoirs in the Mississippi River basin can be also used in Colorado River basin. Therefore, there may not be a problem to supply water to the Colorado River basin States by the three sources on daily basis by supplying at 10.82MCM.

In case of no flood in Mississippi River, even then, the mean annual discharge of water from the Mississippi River let into the Gulf of Mexico and the water stored in the existing reservoirs could individually supply and sustain Colorado basin water demand. However, the future floodwater, similar in 1937, 1927 and 2011 has to be harvested in suitable locations in Mississippi River basin and used there, or transferred to Colorado River basin, or to other water scarcity regions in USA.

Hence, first, let the unutilized Mississippi River water, flow to the Colorado River basin and quench the thirst of the people. This approach is likely to arrest the water miseries of the Colorado River basin permanently beyond 2050.

9. Economic implications of water loss to the Colorado River basin

An estimated total economic impact of Colorado River water loss to the Colorado River basin States per annum is \$1,298.02billion and in this amount, the GDP of the Southern California State for 7 counties alone is \$657.45billion. The contribution of the Colorado River for the annual Gross State Product (GSP) [of each Upper Basin State (Colorado, New Mexico, Utah, and Wyoming)] is estimated to range from approximately \$22billion to \$189billion based on 2014 US dollar. The contribution of the Colorado River for the annual GSP of each Lower Basin State (Arizona, Nevada, and the Southern California 7 counties) is estimated to range from \$115billion to over \$657billion based on 2014 US dollar.

Total estimated economic losses of GSP due to the impact of Colorado River water loss is \$1,434.12billion (Direct Losses \$694.78bn, indirect losses \$231.12bn and induced losses \$508.22bn as per the 2014 US dollar). Employment loss is 16,000,996 (Direct losses 7,859,245, indirect losses 2,361,250 and induced losses 5,780,501). The Labor income loss is \$871.45Billion (Direct losses \$434.29bn, indirect losses \$139.35bn and induced losses \$297.81bn).

Approximately 64.4% of the Colorado River Basin Region's annual GSP could be lost if the Colorado River water is no longer available to residents, businesses, industry, and agriculture. ***The annual losses to GSP resulting from the non-availability of Colorado River water range from 49.5% to 87.4%, dependent on the geography of this basin.***

Over 16million, public and private sector jobs in the Colorado River basin region rely on the availability of Colorado River water each year, and \$871billion (as 2014 US dollar) labor income (Tim James et al., 2014, The L. William Seidman Research Institute).

Due to the present drought since 2012 in the California State, 400,000 farm workforces have lost their livelihood security,

because of keeping 542,000 acres of fertile agricultural lands kept barren. ***Therefore, if the Federal and the Colorado River basin States do not take immediate action to arrest the water scarcity of the Colorado River basin, the water stress alone is likely to collapse the economy of the world's richest nation, the USA. Hence, USA needs a "New Treaty" to arrest the water miseries.***

10. USA needs one more Treaty similar to the Colorado River Compact 1922

In the present context of water scarcity in the Colorado River basin, there are two main approaches to arrest the water supply and demand gap 1. Desalination of seawater and 2. Inter-basin water transfer from the Mississippi River system to Colorado River basin. Among the two, inter-basin water transfer from the Mississippi River system seems to be better since the desalination brings many environmental problems and the cost will be very high to meet all human needs of water. Further, it may be difficult to transfer desalinated water to all the Western States located far away from the coast, though it is possible to a certain extent to use in California State located on the eastern coast of the Pacific Ocean in 840 miles length.

The USA has already showed the way to the world to share and arrest the water miseries in the Colorado River basin by the 1922 Colorado Compact. This nation is capable of bringing one more innovative example by sharing the Mississippi River water and show the world to share the water from all the 286 transboundary river basins flowing in 145 nations, covering 40% of the global population in nearly half of the Earth's land surface accounting for an estimated 60% of global freshwater resources.

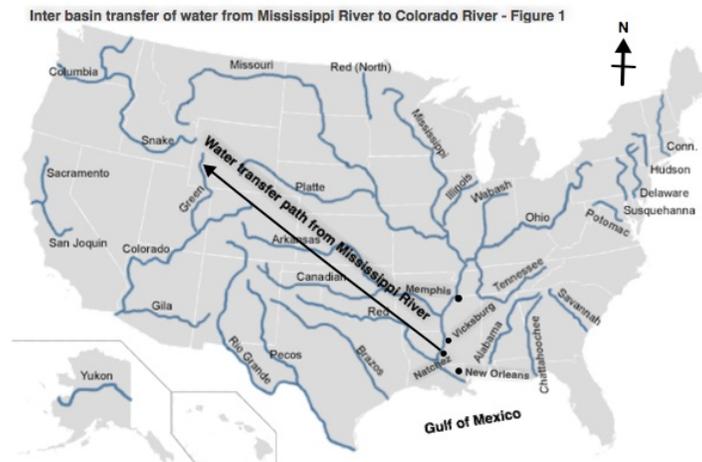
This new Treaty would also show a bright path to other big and small river basins located in every nation/State, to share the water similar to the 1922 Colorado River Compact. The climatologists' predicts that the climate change is likely to reduce the water resources of the Colorado River basin to the extent of 10% to 20% in the coming decades since it is located in the arid climate, and hence it is pertinent to plan for transbasin water diversion to Colorado River basin suggested in this paper. ***If the climate change decreases the water resources of this basin, it is highly doubtful to sustain water resources development to the present extent with the existing water management pathways.***

11. Transbasin water diversion path

The floodwater and the perennial environmental flow let into the sea from the Mississippi River can be transferred from Vicksburg/Natchez point, preferably near Natchez (both are located south of Memphis one below the other on the eastern bank of Mississippi River) to the Colorado River basin-Figure 1.

This is the first time a favorable location to transfer water to Colorado River basin from Mississippi River has been identified.

By this approach, both the water scarcity in Colorado River basin and flood damage in Mississippi River basin could be arrested. Therefore, USA needs one more Compact similar to the 1922, and this is the need of the hour in the present context of water miseries.



12. Cost of transbasin water diversion

As per the Colorado Rancher and engineer, Gary Hausler, inter basin transfer of water from Mississippi River to Colorado would cost about \$22billion. Though by desalination it could be possible, the exorbitant cost in production of freshwater from this source and the extra investment for transportation to homes, industries and agricultural fields etc., this costly option make us to think several times before we march towards this direction.

Per day water demand for Colorado basin is 10,824.087MLD. Each plant at 190MLD, 57 plants are required to produce

3.2maf of desalinated water per annum The estimate at \$one billion (David Garrick, January 7, 2014)[9], each plant similar to the Carlsbad, San Diego, California State, the capital cost of the plants works out to \$57billion. Roughly, \$14billion at \$0.25billion for each plant is necessary to bring the desalinated water to the residence, farms etc. The annual maintenance cost of these plants works out to \$969million at \$17million per plant (Source: Kiewit Infrastructure West Co. and J.F. Shea Construction Company and IDE America). The total cost of the exercise works out to \$72billion. To run these plants huge uninterrupted energy is necessary and to tackle the environmental problem of this exercise additional fund is necessary. **Hence, comparing \$22billion for interbasin transfer of water, the cost of desalination is more than three times.**

13. Arresting hunger and poverty in USA by Transbasin water diversion

In USA, there is not only water stress but also water related socioeconomic divides like loss of livelihood security to farmers, hunger and poverty. The financial and economic crisis that erupted in 2008 caused a significant increase in hunger in the United States. One in 7 people struggle to get enough to eat in USA. In 2013, 14.3% of households (17.5million households, approximately one in seven), were food insecure (Coleman-Jensen 2014b, p. 1). In 2013, there were 45.3million people in poverty. This is up from 37.3million in 2007. Over 19.9million Americans live in extreme poverty. This means their family's cash income is less than half of the poverty line, or about \$10,000 a year for a family of four. They represented 6.3% of all people and 43.8% of those in poverty (Alisha Coleman-Jensen et al., 2015 and World Hunger Education Service (WHES) Associates and Contributors (2014-15).

In USA, 48.1million Americans lived in food insecure households, including 32.8million adults and 15.3million children and 46.7million people (14.8%) were in poverty in 2014. Fourteen states exhibited statistically higher household food insecurity rates than the U.S. national average of 14.3% between 2012 and 2014 (Feeding America website, 2014).

It is also possible to supply the Mississippi River water for domestic and industrial uses as well as for agriculture, below Southwest, Midwest and Deep Southeast of southern USA,

where there is water stress, located along the path of the proposed inter basin transfer to Colorado River basin. In the Great Lakes also, in the total 22,684km³ of water (EPA, May 25, 2011), there is a balance of about 22,511.05km³ of water. Hence, it is possible to grow more food and generate agriculture based employment potential in the water stressed regions and arrest hunger and poverty in USA by sharing the excess water both in the Mississippi River and Great Lakes.

14. Conclusions and recommendations

Because of water scarcity, there are water miseries in the Colorado River basin, even practicing many water management pathways. Almost in every year, a huge quantity of water 535.798km³ to 571.53km³ has been let into the Gulf of Mexico from the Mississippi River without using for human benefits.

Hence, out of the total annual environmental flow to the sea from the Mississippi River basin, at least about 50% to 75% of water should be reserved for the drought prone areas for human uses. Since the huge environmental flow coupled with flood will cause removal of earth in the riverbed, banks and in the breaches by erosion and deposition of the sediments in sea, it is better to minimize the environmental flow in stages in the flood prone Mississippi River basin. An “**Action Plan**” is necessary to utilize the water let into the sea from the Mississippi River basin step by step.

Along with the transbasin water diversion and the ongoing water management practices like desalination of sea water, artificial groundwater recharge, wastewater management, rainwater harvesting, increasing irrigation efficiency, adopting micro irrigation practices, switching over to crops which require less water, bottled water, sharing Colorado River water, carbon emission reduction etc., are to be continued in the Colorado River basin as usual. Whichever are the new approaches, the policy makers plan and propose to sustain water resources development in the Colorado River basin, they may not achieve sustainable water resources beyond a certain limit without Mississippi River water sharing.

Hence, transbasin water diversion from the Mississippi River system to Colorado River basin is need of the hour to arrest all the water miseries of this basin permanently. ***Unless the water from the Mississippi River reaches the Colorado***

River basin, proposed by the authors and others in this paper, achieving sustainable water resources development in Colorado River basin would be a utopia.

The proposed alignment of the water diversion from the Mississippi River to Colorado River needs further study. To finalize location of water transfer from the Mississippi River to Colorado River basin and for cost estimation, the authors need field check and deliberations with the policy makers, hydrologists and hydrogeologists of both river basins.

As the regular visitor and now the resident of USA, the first author is willing to utilize his experience for this good cause with the support of the policy makers of Government of USA.

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