Storing river runoff in the Gulf of Khambhat: A critique of the 'Kalpasar' concept

A scheme of dam construction across the Gulf of Khambhat (Cambay) for storage of runoff water of several rivers draining into the Gulf has been proposed by Kane[1]. The proposed dam will connect Gundi near Bhavnagar on the west (Saurashtra side) and Hansot near Bharuch on the east (South Gujarat side) and is expected to create a 2900 km^2 freshwater lake. The total length of the dam is estimated to be 56.4 km and the cost approximately Rs 3000–4000 crores (~US$ 1000 million). The proposed lake has been named 'Kalpasar' (taken from a Sanskrit word meaning a lake which can give one whatever one wishes standing on its bank). The annual river inflow into the Kalpasar lake has been estimated to be about 14,000 million m^3 after the proposed Narmada dam and other irrigation schemes on the rivers Sabarmati, Mahi and other minor rivers have been completed.

M/s Haskoning, a Dutch firm, was retained by the Government of Gujarat and a reconnaissance report on this project was submitted in 1989. The proposal of Kane[1] is based on the report of Haskoning[2]. The scheme has also been advocated by Patel[3] as part of a larger strategy to develop water resources in the State of Gujarat.

While we generally endorse the concept of creating a freshwater lake in the Gulf of Khambhat, we suggest an innovative modification of the dam structure that may help to store more fresh water and additionally lead to considerable saving in the cost through reduction in both length and thickness of the dam structure. The proposed modification is based on the basic hydrological principle, namely, the significant density difference between the sea water and the river runoff, that should allow the lighter river water (density ~1.0 g/cc) to float on the denser sea water (density 1.025 g/cc). Employing this principle, if the dam structure is so designed that it is open from the bottom allowing hydraulic continuity on north and south of the dam, one should expect the incoming lighter river water to push the denser sea water out to the open ocean through the open bottom of the dam. The modification may also obviate some of the difficulties that we anticipate in the scheme as described by Kane[1], without affecting the possible benefits.

In the scheme proposed by Kane[1] an earth fill dam is to be constructed across the Gulf along a suitably selected contour so that the maximum depth of the water column does not exceed 30 m. At the time of the lowest tide level, sea water from the northern (landward) portion of the dam is to be drained out to the southern (seaward) side, to the extent possible through sluice gates. Subsequently, when the fresh water in the monsoon starts flowing into the northern portion through the rivers, this portion is expected to be converted into a freshwater lake through mixing and dilution of the remaining sea water with the in-flowing river water. In this manner after a period of a few (3–5) years the reservoir is expected to be washed off of all the residual sea water. In this scheme, the maximum water that can be stored in the Kalpasar without flooding any additional coastal areas is between the highest and the lowest tide levels. With an average of 14,000 million m^3 of water per annum, estimated to be available in the 2900 km^2 area of the lake, the maximum estimated thickness of freshwater column at the dam site is expected to be in excess of 6 m, which is of the same order as the tidal range (about 8 m) in the Gulf of Khambhat. Thus, even though a very large volume of reservoir will be created (up to 30 m depth at the dam site), the volume actually available for storage of fresh water would be smaller than the estimated freshwater inflow in several years of above-average rainfall. Therefore, the excess river water runoff would have to be either stored on land above the high tide level or would have to be let out into the open sea.

There is also some concern regarding mixing and dilution being able to wash off the residual sea water in 3–5 years time as envisaged by Haskoning[2] and Kane[1]. Simple calculations assuming the water body to be wedge-shaped between the northernmost section of the Gulf (~100 km from the dam) and the dam site, where the depth will be ~30 m, give a residence time of water in the lake (ratio of the total storage volume to the annual average inflow) of about 5 years. But for salt concentration to reduce from the sea water value of ~35,000 ppm to ~500 ppm (suitable for irrigation and drinking), the time required will be much longer even if perfect mixing and no evaporation (about 2 m water column) are assumed Mixing and dilution, therefore, may not result in Kalpasar becoming a freshwater lake in a reasonable period after construction of the dam.

However, if we could construct the dam in such a way that the bottom 10 m or more is open over a fairly large length of the dam, say where the water column is more than 20 m, we may be able to obviate the above difficulty without compromising in any way the expected benefits. With the bottom of the dam open, there is no need to have gates to empty the reservoir. Also there is no need for having any spillway for draining off the excess river inflow out of the reservoir into the sea. Both these functions, namely (i) the draining of the sea water and (ii) any excess river inflow, will automatically be accomplished through the lower open end of the dam wall due to the transfer of the underlying sea water, governed by the hydrostatic balance on the two sides across the dam. The maximum height of the dam above the mean sea level in our scheme needs to be just enough to prevent the ingress of sea water overflowing the dam resulting from tide/wave-induced changes in the sea level

The density contrast between the river runoff and the sea water is envisaged to maintain a reasonably well-defined interface at a depth of about 6 m or more to enable exploitation of the stored fresh water in a meaningful manner. This interface is, however, not static but moves up and down in response to hydrostatic changes induced (i) on the seaward side by the tides and waves and (ii) on the reservoir side by the inflow/consumptive use of the runoff water. Therefore, it may not be unreasonable to apprehend that due to mixing the interface may not be well defined, thereby defeating the very purpose of creating the reservoir at a huge expense. This is an aspect which

needs careful investigation employing both mathematical and physical models. However, a positive aspect of our scheme is that all inflows of fresh water into the reservoir not consumptively utilized will cumulatively depress the interface on the reservoir side and increase freshwater storage. Such inputs of fresh water to the Kalpasar lake also include rain (about 0.7 m) falling directly on to the lake and inflows from the minor rivulets, streams, creeks and channels and ground water discharge not accounted for in the 14,000 million m^3 of runoff from major rivers after the proposed dams on the Narmada and other rivers have been completed. We, therefore, intuitively anticipate that this effect involving cumulative lowering of the interface (with no spillage) will more than compensate for the possible mixing of saline and fresh water due to vertical movement of the interface induced by tides/waves. We expect that pressure changes due to the tides and waves can be expected to be communicated from the open sea side to the reservoir side, through the open bottom, rather gently in a piston-flow-like manner due to the damping of the disturbance with depth in the 20 m or more water column on either side of the dam. The dam itself will prevent the transfer of the wave/tide-induced turbulence at the surface from the open sea to the reservoir side.

The other factors influencing the position and thickness as well as movement of the fresh-water–sea-water interface in the reservoir, such as evaporation, consumptive use of water, wind-induced waves in the reservoir itself and the tidal effects within the body of the water stored in the reservoir, are common to both the schemes and, therefore, are not being discussed here. In our view, mixing is an area of major concern that needs a detailed investigation through mathematical models of currents and mixing processes likely to operate in the Kalpasar lake and the extent to which they may affect adversely the quality of water stored in the lake.

1. Kane, A. S., 'Kalpasar', the only permanent solution of the perennial water problem of Gujarat, Paper presented at the seminar on The Water Problems of Gujarat: Approaches to Solution, organized by the Centre for Research and Training in Rural Development (CERITA) and Gujarat Science Academy (GSA), 7 January 1995, PRL, Ahmedabad
2. Haskoning, Khambhat gulf development reconnaissance report, Govt. of Gujarat, Water Resources Department, 1989.
3. Patel, V. J, Total water resources management in Gujarat for those who care for balanced growth, Paper presented at the seminar on The Water Problems of Gujarat: Approaches to Solution, organized by the Centre for Research and Training in Rural Development (CERITA) and Gujarat Science Academy (GSA), 7 January 1995, PRL, Ahmedabad.

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In situ preserved *Vertebraria* axes in Ib River Coalfield, Orissa

The Permian Gondwana form genus *Vertebraria Royle*[1] occurring from Post-glacial time through Late Permian is characterized by elongate, flattened, segmented, cylindrical casts which are simple or branched, often bearing root-like organs at the transverse ridges. In transverse section the *Vertebraria* axes show wedge-like sectors radiating from the centre[2]. According to Mussa[3] *Vertebraria* is a complex form consisting of several genera. Specimens of *Vertebraria* are found preserved in positions both parallel and perpendicular to the bedding plane and the actual nature of these axes was quite controversial for some time[3–9]. Most of the specimens assigned to *Vertebraria* are generally impressions or compressions and very rarely petrified specimens with anatomical details. It consists of a central region of exarch primary xylem with four to seven radiating arms of secondary xylem. The distinct growth rings with septate arrangement is surrounded by a cylindrical periderm with a well-developed cork, leaving spaces between the xylem arms. In longitudinal section the secondary xylem arms are connected at varying intervals by transverse platforms, also composed of secondary xylem tracheids, but generally containing a root trace.

Several specimens of *Vertebraria indica* Royle were collected from the Barakar beds exposed in a nala near Ganga Nagar village near Brijraj Nagar town, District Sambalpur, Orissa. No other element of Glossopteris flora is preserved in this bed. Some 50 specimens were found preserved as casts in the fine-grained, light pink, hard shales in an area of 2–3 m. The surface view showed 5–6 wedges 0.5–2 0 cm in diameter, with very little pith in the centre. The maximum length of these axes was 8 4 cm, lying diagonally along the bedding plane. Growth directions of these axes in the sediment indicate that *Vertebraria* was an underground root system of some plant. The actual plant which bore these underground axes was perhaps drifted to another site. Diagonal and vertical axes (Figure 1 *a*, *b*), preserved in a small area of 2–3 m, probably belonged to a single plant and represent *in situ* preservation. Total absence of horizontal axes and any other plant parts led us to believe this. The presence of such axes in various coal fields[10–14] indicates that some of the species of *Glossopteris* had arborescent habit supported by a well-developed strong root system. Wherever such vertical and diagonal axes were found, other plant organs like leaves were not found in nearby areas. Though horizontal axes along with other plant parts are commonly found in most coalfields, indicating autochthonous nature of coal, in no way are such vertical and diagonal *Vertebraria* axes indicative of autochthonous nature of coal as believed by some. Enormous quantity of vegetal matter which might