Sethusamudram Ship Canal Project: oceanographic/geological and ecological impact on marine life in the Gulf of Mannar and Palk Bay, southeastern coast of India

Sethusamudram Ship Canal Project (SSCP) will link the Gulf of Mannar and Palk Bay in the southeastern coast of India. This economically and environmentally crucial mega project to change the face of regional shipping has been initiated after being cleared by the Environment Ministry and Cabinet Committee. This 360 km long and 300 m wide shipping canal will provide a continuous navigable route cut through Adam's Bridge, a natural chain of shoals to avoid circumnavigating Sri Lanka.

Ecological balance during and after completion of the project: On completion, the canal will save 20 h of ship journey and considerable amount of fuel. But a busy continuous navigation in this region will offset and trigger devastating ecological imbalance, affecting the lives of millions of fishermen and many endangered organisms (fishes, coral reefs, sea horses, algae and other marine plants) of the subtropical, shallow Gulf of Mannar. The Gulf of Mannar and Palk Bay support a delicate ecosystem, with the second highest marine biodiversity on the earth. The Palk Bay is already on the verge of '*Jivânikhâtanam*' (a process that will entomb/endanger marine organisms).

Is our pre-SSCP assessment of environmental impact adequate and correct? The scheme should have been put through after a well-informed and many-sided debate, a common rule of developmental prudence. The United States Environmental Protection Agency (USEPA) has developed useful guidelines[1] for evaluating ecological indicators that include conceptual relevance of ecosystem function, feasibility of implementation, response variability in time and space, and ability to convey information on ecological condition that is meaningful for resource management. Instead, the National Environmental Engineering Research Institute (NEERI), Nagpur has approved the project after a rapid Environmental Impact Assessment (EIA).

Evaluation of the environmental/ecological impact of a maritime project is based on a detailed study of geological, biological, physical and chemical oceanographic parameters. These factors play an important and collective role. If any one of these factors is stressed beyond the manageable and threshold limit, the system gets affected adversely beyond repair. Turbidity (suspension of clay and mud in water column) is one such factor. This could be fatal to an ecosystem. Unfortunately, according to an estimate, SSCP dredging may displace around 9.7 million m^3 bulk of rock, shoal and sediments, making the water column highly turbid till the project is completed. The operation will displace/release a few hundred thousand tons of clay-size particles (dumping of this is another major issue).

The stressed turbidity causes imbalance in O_2–CO_2 ratio, imperative for life and health of phytoplanktons, which are the lowest in the marine 'food chain'. Moreover, if this kind of turbidity continues for a long duration (till completion SSCP), penetration of sunlight below 2–3 m depth will be blurred. This will check the photoinhibitation and lower the pH of water (more acidic) as CO_2 supply will continue due to respiration of animals, while release of O_2 will diminish amidst the slow pace of photosynthesis. This process will encourage abundant growth of anaerobic organisms and may worsen the health of other organisms.

Are coral reef stressed? Coral reefs, the land-bridging platforms and lungs of the shallow oceans, are at decline worldwide due to anthropogenic impact/activity. Coral reefs are bioherms that favour high biodiversity *vis-à-vis* supporting standing crop of phytoplanktons. Like tropical rainforests, coral reefs have evolved complex interdependent community structures[2,3] despite or more likely, because of paucity of nutrient resources in their environments[4,5]. The turbid conditions that SSCP is likely to cause will harm and destroy corals within a short span of time (Table 1).

Table 1. Expected natural stresses on environment, including those amplified by human activities (based on Hallock *et al.*[5]) during/after the SSCP

Natural processes that can induce stress
Physical damage to natural barrier (shoals of Adams Bridge), high sea tide and surf
High sedimentation, reduced salinity and reduced nutrition
Currents (tidal currents and upwelling causing change in water temperature)
Change in currents may bring pollutants in the region/to the shore
Oxidative stress, insufficient oxygen
Temperature (hot and cold stresses)
Photoinhibitation, shading
Biotic interaction (predation, competition, bioerosion, parasitism, disease)
Chemical stress (naturally occurring trace metals and hydrocarbons)
Natural stresses that can be amplified by anthropogenic activities
Physical damage (ship grounding, anchor damage, dredging, transfer of sediments to maintain depth of the channel)
Biotic interaction (invasive species from Gulf of Mannar to Palk Bay and vice versa)
Increase in anaerobes

In a way, the whole environment in the Gulf of Mannar and Palk Bay is at stake and life from micro- to macro-levels, like fishes, corals, sea horses, sea cows and many species of marine plants is endangered, including those living around Shingle Island and Van Tivu Island, both of which are situated within the Gulf of Mannar Marine National Park, widely known for its biodiversity. The proposed canal will pass 20 km away from the Shingle Island and 6 km from the Van Tivu Island.

What needs to be carried out? A multilevel approach to monitor the marine ecosystem and evaluate the risk assessment of the region needs to be carried out. Risk assessment data should be collected from satellite imageries to molecules. Environmentalists must evaluate the measures required to protect the two important warm, subtropical marine ecosystems of the Bay of Bengal and the Indian Ocean.

The data collected will provide the environment managers with affordable procedures to minimize the impact of the Sethusamudaram project on the regional environment and also safeguard the biodiversity of the region to the extent possible. Furthermore, the area is vulnerable to tsunamis. The project needs to be evaluated for post-disaster management. The project has been initiated in July 2005.

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Imprint of 26 December 2004 Sumatra earthquake in aquifers of Hyderabad granite pluton

There have been many reports of earthquake-induced groundwater anomalies[1]. A convincing explanation arrived on earthquake-induced hydrological changes is that they are caused by changes in hydrostatic pressure due to earthquake-induced changes in crustal volumetric strain[2,3]. Any quantitatively measurable change in an environmental parameter that occurs before the main shock is thought to be linked to the preparation process of the main shock and is regarded as a precursor[4]. Change in water level in deep wells is recognized by the IASPEI (International Association of Seismology and Physics of Earth's Interior) as a precursor in earthquake studies. This explanation has been offered over several decades and there have been reports of quantitative analysis of earthquake-induced groundwater anomalies and crustal volumetric strain changes. One of the recent devastating events in the history of mankind and near the Indian subcontinent was the Sumatra earthquake of 26 December 2004 and the consequent tsunami, which had caused mass destruction and property damage all along the east coast of the Indian subcontinent. The effects before and after the Sumatra earthquake were clearly registered in hydrographs of wells located over Hyderabad granite pluton. Here we present the micro-level impressions registered in hydrograph of a deep bore-well located in the National Geophysical Research Institute (NGRI) campus, Hyderabad, supported with records of other bore-wells located more than ~100 km away from the NGRI well site.

A battery-powered pressure transducer [*IN-SITU*, Minitroll Water Logger, USA], was installed at 20 m depth in a bore-well (~80 m deep) located in the NGRI campus, for monitoring the aquifer response to precipitation and ground motion due to earthquakes since December 2003. Geophysical logging of the well has shown a fractured aquifer zone under confined conditions at 55–60 m. Electrical logging with the lithologue of the bore-well is shown in Figure 1. The pressure transducer was subjected to different sampling time intervals (from few seconds to 1 h) for optimization of sampling with less extraneous noise influence on the hydrograph. The effect of semi-diurnal tides[5,6], is seen prominently at every six hourly interval on water levels.

Daily hydrograph records were analysed with seismograph records (Seismometer KS-2000M) of NGRI seismic observatory to understand the behaviour of water level during seismically active time periods. Response of water level in wells to earthquake is found to be influenced by factors such as magnitude, focal depth, distance from epicentre, depth of well and aquifer condition (confined or unconfined), hydrologic environment, etc.

The observational site on the southern Indian shield (Eastern Dharwar Craton) is characterized by sheared and deformed lithosphere[7]. Basically, these K-granite plutons are thought to be emplaced as isolated bodies over the Dharwar Craton. A multi-parametric geological, geophysical and GPS study over Eastern Dharwar Craton has brought out a differential upliftment of Hyderabad granite pluton and Bangalore geotectonic block between Late Archaean and Early Proterozoic periods[8]. Morpho-tectonic studies, surface and lake sediments, radioactivity, heat flow pattern and tremors indicated persistence of neotectonic activities in the study region[9]. The morpho-tectonic map of the area with study sites is also shown in Figure 1.

The world's most powerful earthquake of magnitude 9.3 had struck on 26 December 2004, near the west coast of northern Sumatra Island at 00:58:53 UTC or 06:28:53 IST. The cause was attributed to be thrust faulting on the boundary of the Indian–Burmese plates. The accumulated stress due to ongoing subduction of the Indian plate beneath the overriding Burma micro-plate and release of strain was the cause of the Sumatra earthquake[10]. The fault displacement analysis implies that fault rupture propagated to the northwest from the epicentre. The Sumatra earthquake generated a giant wave (tsunami) which propagated across the Indian Ocean. The tsunami struck the Indian coast at around 8:50 h IST in Chennai and 9:10 h IST in Visakhapatnam[11]. The tsunami caused severe destruction along the east coast and parts of west coast of India, killing thousands of people and causing heavy loss of property.

The daily hydrograph records for the months of December 2004 and January 2005 were subjected to wavelet-spectral analysis for removal of tidal effects. December being a non-monsoon month, the water level had surprisingly shown a gradual rise from the early hours of 25 December 2004, which persisted till 2 January 2005. Micro-analysis of hydrograph data of 26 December 2004 has shown a 4 mm amplitude of sudden variation in water level at 6:42:40 IST or 01:14:40