Integrated Urban Regeneration and Water Transport System (IURWTS), Kochi
Kochi Metro Rail Limited

An Expanded Version of Notes Submitted Earlier (Final)

Agenda Item No.117.01. File No: 159/A1/2021/KCZMA, Nov. 8, 2021

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Contents

List of Abbreviations

CLG	:	Canal Lock Gate
CRZ	:	Coastal Regulation Zone
CWPRS	:	Central Water and Power Research Station
DEM	:	Digital Elevation Model
DPR	:	Detailed Project Report
EBS	:	Marine Ecology Survey and Biodiversity Impact Assessment Study (IURWTS project)
GKR	:	Greater Kochi Region
GoK	:	Government of Kerala
HAT	:	Highest Astronomic Tide
HHFP	:	Hydrologic, Hydraulic and Flood Plain
IURWTS	:	Integrated Urban Regeneration and Water Transport System
KBS	:	Kochi Backwater System
KCZMA	:	Kerala Coastal Zone Management Authority
KES	:	Kochi Estuarine System
KFVZ	:	Kochi Corporation's Flood Vulnerable Zone
KMRL	:	Kochi Metro Rail Limited
KP3T	:	Kochi Corporation Plus Three municipalities (Kalamassery, Thrikkakkara, and Thripunithura)
KSDMA	:	Kerala State Disaster Management Authority
LiDAR	:	Light Detection and Ranging
LTS	:	Large Tenasillahe Slough
OBT	:	Operation Break Through
PP	:	Project Proponent

1 Background

Kochi Metro Rail Limited (KMRL), hereafter project proponent (PP), has made several submissions – documents, reports, clarifications, and presentations – related to the CRZ clearance application for the project. PP has submitted additional documents in response to the queries raised earlier and subsequent to seeking technical opinion in the matter from Principal Secretary, S&TD, GoK as per decision 115th KCZMA Meeting of Aug. 12, 2021.

Some of the documents submitted initially by PP to KCZMA for CRZ clearance such as the following were shared with KCZMA members at different times from February 2021 to August 2021.

- A.1. CRZ Application (Form-1)
- A.2. Final DPR to KIIFB
- A.3. EIA report
- A.4. HTL-LTL Report
- A.5. CRZ Maps
- A.6. Clearance issued by the state wetland authority (SWAK)
- A.7. Disaster Management Plan
- A.8. Consent to Establish by KSPCB
- A.9. Hydraulic Modelling and Flood Plain (provided in Aug 2021)
- A.10. Biodiversity Report – prepared by CUSAT (provided in Aug 2021)
- A.11. KMRL-IURWTS-287-2021 KCZMA (covering letter, Aug. 9, 2021)
- A.12. CRZ clarifications final 02.07.202 (2 versions, Aug 2021)

The agenda for the KCZMA/Meeting-117 mentions also the following:

- A.13. Ground Water study
- A.14. Storm water management plan
- A.15. Weed management plan
- A.16. Sewerage and Sanitation management plan

The Agenda for KCZMA Meeting-117 mentions that after discussion with Principal Secretary S&TD, KCZMA asked the PP to submit further clarifications incorporating the following aspects:

- K.1. The Hydraulic/ Flood simulation modelling for the two scenarios:
    - a. With Canal Lock Gate (CLG)
    - b. Without Canal Lock Gate (CLG)
- K.2. The characteristics of biodiversity and aquaculture covering the following:
    - a. Pre-Project
    - b. Project Implementation and
    - c. Post Project Stages

K.3. The runoff estimation should consider the changes in land use pattern

The PP has submitted the following documents in response to the clarifications sought:

B.1. Technical Report No.5945, August, 2021, Review of Hydrologic, Hydraulic and Flood Plain Model of Canal System for Kochi IURWTS – reviewed and vetted by Central Water and Power Research Station (CWPRS)

B.2. Clarifications on comments received from KCZMA in meeting dated 02.07.2021 (date: 12.10.2021)

The two additional documents submitted (B.1 and B.2) are also meant to address some of the queries and comments (including specifically that in the note prepared by Dr C. P. Geevan, Member KCZMA). KCZMA raised these comments, queries, and concern after detailed examination of the project proposal and post two presentations by the PP. Item B.1 is a is a reviewed and vetted copy of the Hydrologic, Hydraulic and Flood Plain (HHFP) Model revised as per suggestions of CWPRS. Item B.2 is partially an updated version of A.12 and partly a response to the additional clarifications (K.1 to K.3) sought by KCZMA.

2 General Remarks

Item B.1 is the HHFP Model of the PP vetted and reviewed by CWPRS. It mentions that the PP revised their original simulations as per suggestions given by CWPRS. However, report does not give any indication of either the suggestions of CWPRS or the consequential changes in the model outputs arising from those suggestions. Having said that, henceforth we will be considering B.1 as the final and authenticated version of the HHFP Model in which *CLGs are not present*. We will hereafter use this as the reference document for all further discussions related to HHFP.

Unlike B.1, item B.2 consists of numerous unauthenticated claims, innuendos, misrepresentations, misinterpretations and unseemly attempts to change the meanings of the queries I have raised in the note circulated within KCZMA and shared with the PP. The tenor and tone of the response to queries raised are uncalled for and appears to be an attempt to either browbeat the member or make it appear as if the concerns expressed are based on inadequate understanding of the proposal. The PP cannot or is unwilling to understand that the concerns expressed are genuinely constructive to ensure proper ecological management of a complex project proposal and are fully consistent with the responsibilities of the member. Raising certain concerns do not constitute questioning the very rationale of the project or the concept.

The PP's response (B.2), unfortunately, is of a peculiar nature, forcing me to point out that such responses are unwarranted from any applicant – big or small; public or private. Given the nature of statements in B.2 submitted by PP, let me make a few general remarks:

1) No member of KCZMA has questioned the concept of reviving the waterways or the relevance of restoring the canal network, be it for waterways or improving the stormwater drainage.
2) The claim of the PP that the IURWTS is primarily for flood control project is totally unconvincing and no document placed on record so far supports that claim including B.1 and B.2. The canal

restoration does not cover the drainage network linked to the restored canals or desilting of the degraded backwater lagoons associated with the canal network. The PP should note that desilting here does not in any sense mean indiscriminate dredging.

3) We recognise that the revival of the waterways by the restoration of a few canals will surely have some collateral benefit of reducing the inundation in a very small portion of Kochi corporation and adjacent areas where the stormwater drainage has been blocked or reduced by various factors including the damage done by illegal activities such as that in and around the Chilavanoor lagoon taken note of by the Hon’ble High Court of Kerala (see Fig.1). The KCZMA members are aware of the need for canal restoration and do not need lessons from the PP.
4) Revival of waterways (i.e., canal restoration) can potentially be incorporated into a larger flood management plan – both of urban flooding due to heavy rains and flooding caused by excessive flows in the rivers draining into the Kochi Estuarine System (equivalently the Kochi Backwater System, KES or KBS). We recognise that any controls on the free water movement though canals by deploying flow controls must be carefully integrated into the larger flood management arrangements for the whole region rather than by individual canal-specific approach.
5) The KBS is basically an estuarine system having essentially estuarine ecology and estuaries are among the most productive environments on earth. Quite contrary to the misleading assertion made in B.2 that the EIA has “established that the canals are largely freshwater dominated” (B.2 page 28), they are an intrinsic part of the KES as the EBS itself notes which is based on sampling carried out in September when the estuarine system is dominated by freshwater which is characteristic seasonal feature of KES.
6) We do have a huge concern that any development in the Kochi Estuarine System including the operation of flow controls using CLGs must include a sufficiently robust ecological management or mitigation plan to address all the likely major impacts.

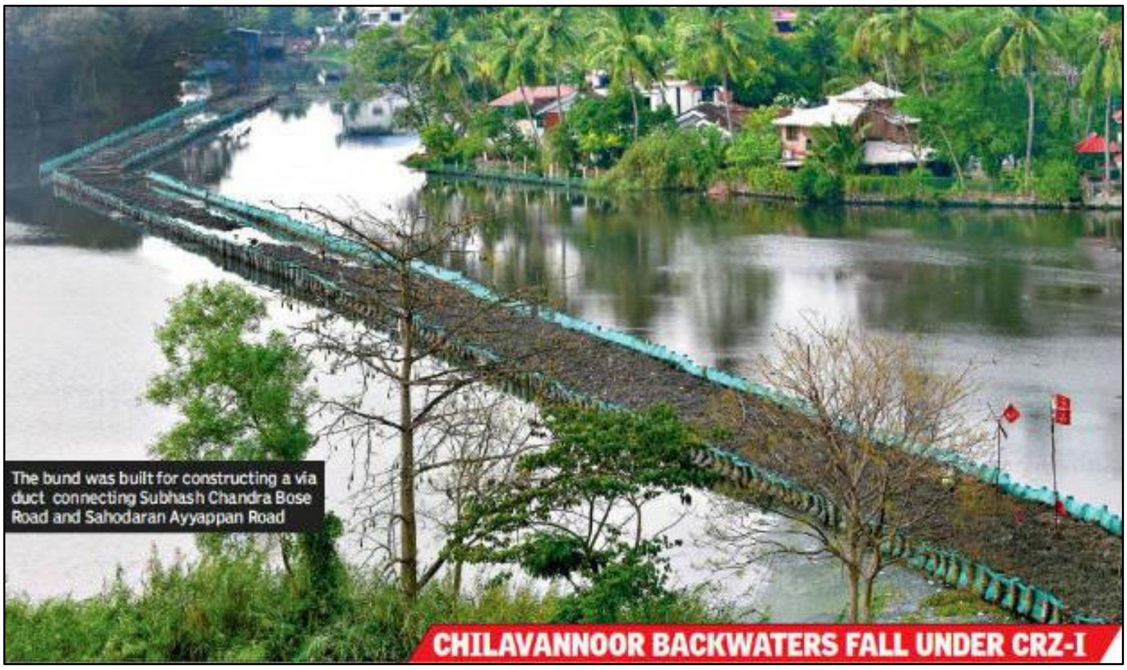


Figure 1: Obstruction of water movement in the Chilavanoor Lagoon within CRZ-I by illegal construction for a walkway not approved by KCZMA

3 Recap of the Concerns Raised Previously

For the reasons stated earlier, and for completeness, it is necessary to restate the points raised in the note circulated by me on July 9, 2021 (hereafter, my note). The two key aspects of the proposed project affecting the hydrological characteristics of parts of the KES are:

a) Restoration of 5 canals of total length 34.33 km by desilting, deepening, and widening where required
b) Employing Canal Lock Gates (CLG) to maintain a constant water depth for navigation (i.e., 1.4m to 1.9m).

There is no doubt that the restoration of 34.33 km of canals will have a marginal beneficial effect in reducing the waterlogging during heavy rainfall in the urban catchment areas of the canals. However, when the CLGs are in place, as envisaged in the project, when the CLGs are closed they impede the natural inflows and outflows. This raises concerns about the integration of the opening and closing of CLGs as a synchronised activity within the framework of a larger flood management plan for the Greater Kochi Region (GKR). Since there is no discussion on these aspects, only a detailed independent study can decide how the authorities concerned can implement such an integration of the CLGs with requisite synchronisation.

A detailed discussion on the flood management plan for GKR is far beyond the scope of this note. While it need not be central to the present discussion, it will surely be so if the primary goal of the project is presented as that of flood control rather than revival of historically existing waterways. Contrary to the assertions by the PP, the reduction in inundation along 125 metres on each side of the 5 canals accounts for less than 5 percent of the flood vulnerable zone of Kochi Corporation. The expected reduction in areas inundated after rainfall in the catchments of the canals does not make the project one of major flood control. We shall discuss this in detail later mainly because the inaccurate assertions made by PP in B.2 require to be corrected and rejected forthwith.

One of our main concern relates to the implications of the CLGs on the canal ecosystem. Discussions on this aspect are conspicuously absent in all the documents. As per DPR of the project, the minimum depth of canals must be maintained between 1.4m to 1.9m at all times for the operation of the proposed water transport system. Since there are inflows and outflows in the canals, the desired depth will be ensured by “locking the water inside during low tides as well as by opening them for high tides.” (DPR, Page 4A-28). While the DPR mentions 5 CLGs, the final design has 6 CLGs as per clarifications by the PP and shown on the maps.

Unfortunately, the EIA study has not considered the longer-term impacts of the CLGs on the hydrology and ecology of the 34.33 km long canal system. The DPR, EIA and various technical studies cited in the EIA clearly recognise their hydrological and ecological importance despite their current degraded condition. The literature cited also recognises the key role of the tidal influx in the Kochi Backwater System (KBS) or the Kochi Lagoon as per nomenclature used by the PP.

The Marine Ecology Survey and Biodiversity Impact Assessment Study (EBS) prepared for the project states,

> *"The canals should be considered as an ecosystem having its own life structure and wetland character. So, they are to be protected and considered under the National and State wetland conservation and coastal regulation rules."* (EBS, page 175)

The EBS also points out the importance of regular water exchange in the canals. The EBS states that regular water exchange is needed to keep the canal in the healthy state (page 175). Having highlighted these important aspects regarding the ecology of the 34.33 km long canal ecosystem, the EIA does not include any discussion on the impacts of the CLGs. Besides the general significance of the water flow regulation, the controlling of flows by CLGs has its implications for the salinity profile of the associated waterbodies. These aspects are of direct relevance within the framework of coastal ecosystems and CRZ.

4 Critical Overview of the Context, Data and Projections

There are certain essential features of the area covered by the 5 canals totalling 34.33 km that span parts of Kochi Corporation and three municipalities (Kalamassery, Thrikkakkara, and Thripunithura) adjoining it, which will be referred to henceforth as Kochi Plus 3 Towns (KP3T). The covering note by CPWRS that vetted the hydrological and hydraulic studies by the PP provides a brief description of the area. As per that, most of the Kochi is a lowland region having average land elevation above MSL of 7.5m towards the eastern parts and less than 1.0m towards the west. Approximately, 40% of the surface area consists of water formed by the rivers, canals, and lagoons of the Kochi Estuary (CPWPRS, page 2, document B.1).

The hydrological analysis employing HEC-HMS for delineation of the sub-basins of the urban catchments of the three canals uses the ALOS PALSAR DEM (CWPRS page 5, document B.1) in which elevation is in 12.5m intervals. When the elevations are less than 10m above MSL, use of DEM data of 10m or more cannot be particularly useful. The hydrologic modelling, therefore, employs DEM on a 0.5m grid obtained by merging data from Light Detection and Ranging (LiDAR) survey along the canals covering 125m on either side of the canal banks (document B.1, pages 10,11 of 87), topographic surveys and channel bathymetries. In short, the hydrologic modelling is limited to 125m on either side of the canal based on rain in the catchments of the canals. The HHFP studies do not extend beyond the DEM data for the 125m on either sides of the canals or the catchments other than that of the canals.

The HHFP modelling study estimates the total runoff from the catchments of three main canals out of the five. The two smaller canals, Thevara Canal (1.41 km) and Market Canal (0.66 km) are artificial extensions into land from Kochi lagoon. They do not have own natural catchments and hence the hydrologic studies do not include them. Three major canals – Edappally Canal, Chilavanoor Canal and combined catchment of Thevara + Thevara-Perandoor Canals – are the focus of the study. They run roughly north-south through Kochi corporation plus three towns. The IURWTS canal water levels are influenced by the tides, conditions of the sea, flows from the adjoining rivers draining into the lagoon to the north and south of the catchment and by local stormwater flows into the canals (CWPRS - page-2, document B.1). The total area of the canal catchments is less than 40 sq.km.

As per document B.2, the data used consists of hourly rainfall data from the Kochi Naval Base covering the period from 1993-2015 and 0.25° X 0.25° (i.e., 15’ X 15’) gridded daily rainfall dataset for Kochi station (9°57'36''N, 76°16'12''E) from the India Meteorological Department for the period 1975-2013, 2018 and 2019 data collected from Southern Railway, Ernakulam (CWPRS, page 5). For the geographical location of Kochi, the 0.25° X 0.25° grid is equivalent to nearly 27.35 km by 27.75 km (i.e., each cell of the grid being about 760 sq.km). It is unclear how such a gridded data is useful to model rainfall in sub-basins of the canals when the area of canal-wise catchments is less than 16 sq.km (maximum is 15.21 sq.km for Edappally Canal).

An important aspect we must consider in flood management is the contribution from the rivers draining into KES. CWPRS has merely vetted the HHFP modelling due to rainfall in the canal catchments and not gone to any other aspect which is beyond those catchments, and this is a larger question when it comes to flood management for the district and GKR. Since CWPRS was only examining the HHFP model of the rains in the canal catchments, the larger aspects were not within the purview of the vetting carried out by CWPRS.

Document B.1 states that data is not available on the inflows flows from rivers into KES. The HHFP report (document B.1) states, “effect of river flows on tide levels at the canal boundaries cannot be quantified as there are no concurrent tide and flow records” (p 40 of 87, document B.1). Undoubtedly, high inflows from the flooded rivers aggravate the urban flooding caused by rainfall in the catchments of the canals. The HHFP study confined to rain in the canal catchments alone cannot account for these scenarios explicitly or adequately using indirect methods. In the model, the effect of elevated water levels further to the north of the CLGs on the northern ends of the canals is approximated by imposing certain boundary conditions. These boundary conditions make certain allowance for the higher flood levels at the northern ends of the canals influenced by riverine flows.

An important aspect we must not overlook is that both the extent of inundation before and after restoration are the outputs of the HHFP based on the model parameters and boundary conditions. We do not have detailed data on the inundation along the canals in their existing condition or when they were in a better shape decades ago. Perhaps due to paucity of data, the model results have not been compared to actual data on urban flooding due to the combinations of river flood, urban flood due to heavy rain in canal catchments, and storm surges from the sea concurrently with high tide.

The HHFP document notes that “extreme river flood events that inundate the city cannot be accommodated in the design of the canals which are focused on ensuring adequate stormwater drainage from the local city catchments under a range of “normal” or “moderate flood” river conditions.” (HHFP page 38 of 87, document B.1). The HHFP also does not explicitly account for the effect of river flows on the local tide levels. Therefore, the design imposes boundary conditions with higher than-normal tide levels as a way of incorporating these conditions.

The inferences from the above discussion are:

a) The HHFP modelling does not explicitly account for the extreme river discharge into the Kochi Estuary.
b) The HHFP model is restricted to the rainfall in the catchments of the canals with the effects of tides and river discharge approximated using certain boundary conditions which are inadequate to represent the effects on extreme riverine flood events realistically.
c) The HHFP does not consider the flooding on northern part of the canals beyond the CLGs on the northern ends of the canals even though the closure of CLGs will aggravate the flooding in that part of the Ernakulam district.
d) The inundation before restoration are also model outputs and there is no comparison to any actual data of a single pre-restoration scenario.

5 Inundation Along the Sides of the Canals

The modelling study provided in the HHFP Model and authenticated by CWPRS covers four scenarios (EX-1 to EX-4). The four scenarios used in the modelling work are summarised in Table-1 below:

Table 1: Four scenarios used in the HHFP Model simulations

Scenario Name	Storm Event Return Period	Boundary Conditions Used
EX-1	50	Normal mean sea level at 0.8m CD and at high tide 1.1m CD
EX-2	25	high tide (MHHW) condition of 1.1m CD.
EX-3	25	Highest astronomic tide (HAT) level of 1.4m CD.
EX-4	25	River flood condition of 1.6m CD (north) 1.45m CD (south) for Edappally canal, Chilavanoor canal north: 1.4m CD and south: 1.1m CD, and Thevara – Perandoor north: 1.25m CD and south 1.1m CD.

The inundation due to rains in the urban catchment areas of the canals under different scenarios as per hydrological studies are summarised in Table-2. Here, the area inundated in different scenarios is compared to Kochi Corporation's Flood Vulnerable Zone (KFVZ) and the total geographic area of Kochi Corporation (95 sq.km.) plus three municipalities – Kalamassery (27 sq.km.), Thrikkakkara (28 sq.km.) and Thripunithura (29 sq.km.). The five canals are located within Kochi and three towns. The Index Map of Kochi IURWTS Project provided by the PP shows the catchments of the canals it is reproduced here (Fig. 1). While there are studies giving estimates of the flood vulnerability area of Kochi Corporation, we do not have such information on the three towns.

Table 2: Summary of Hydrologic Studies Presented in Document B.2

Flooded Area (FA) sq.km					Comparison of FA-BR	
Scenario	Before Restoration (FA-BR)	After Restoration (FA-AR)	Difference FA-BR less FA-AR	Decrease	Kochi Flood Zone (%)	Total Area of Kochi + 3 Towns (%)
EX1	2.30	1.33	0.97	42%	3.1	1.3
EX2	2.52	1.59	0.93	37%	3.4	1.4
EX3	3.41	2.60	0.81	24%	4.5	1.9
EX4	2.78	2.09	0.70	25%	3.7	1.6

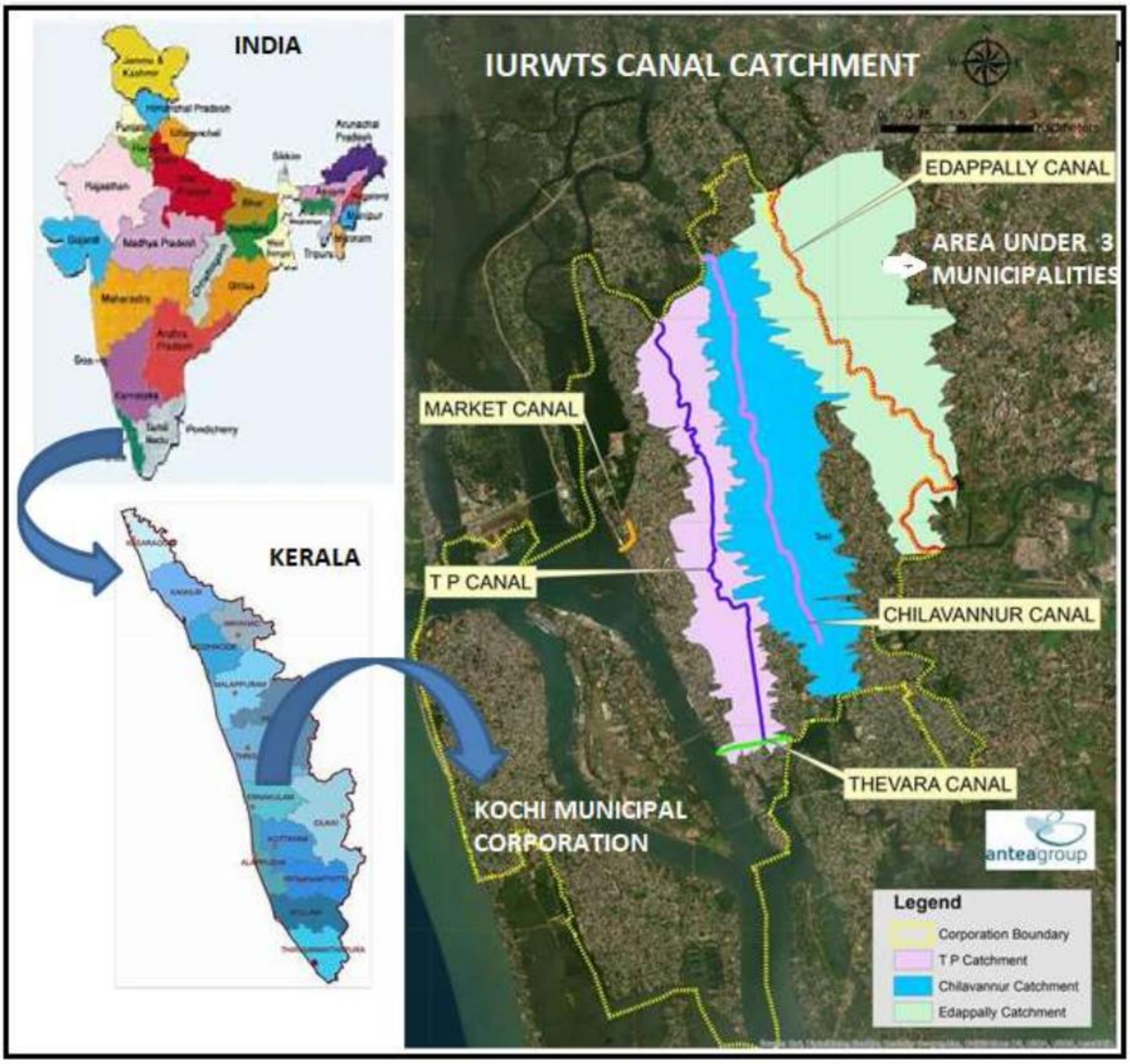


Figure 2: Index Map of Kochi IURWTS Project (source: document B.1)

A more detailed response will be needed to carefully scrutinise all these claims. Suffice to mention here a couple of essential points:

a) The total area 125m on both sides of the five canals considered in the hydrological study account for less than two percent of the total area of Kochi corporation plus three municipalities.

b) The flooded area before restoration envisaged in the modelling study is less than five percent of the area of Kochi Corporation's Flood Vulnerable Zone.

c) We must note that the Kochi corporation's Operation Break Through (OBT) project after the 2018 flood did not include all these five canals.

d) Only an insignificant part of the area adjoining the five canals is in the high flood risk zone as we can see from available studies on urban flood in Kochi Corporation.

e) Undoubtedly, there will be some reduction of the area inundated on either side of the canals after canal restoration (deepening, desilting, etc.)

6 Hydrologic Models – Without and With CLG

One of the additional clarifications sought by KCZMA (K.1) is the HHFP models without CLG and with CLG. All the hydrological and hydraulic modelling studies authenticated by CWPRS (document B.1) represent the Without-CLGs case.

The canal bed level is designed to 0.9m below CD. The simulations reported in B.1 assume that the CLGs do not exist. The study notes that once CLGs are installed, pumping may be required to evacuate stormwater runoff entering the canals. The top shutter level is proposed to be 1.65m above MSL which is 0.25m above the current HAT and approximately the same as the land levels adjacent to the shutters (B.1, page 38 of 87).

While the maximum reduction of 50 percent inundated area after restoration is seen for Edappally for EX-1 (B.1, page 61 of 87), the least reduction of 18 percent is also for this canal. Document B.1 presents the reduction in inundation canal-wise without including a summary of the combined reduction. When the best cases of reduction in inundated area under the four scenarios (EX-1 to EX-4) after restoration for the canals are combined, it is only 25 percent for EX-4. To repeat, *note that all these simulations are Without-CLG.*

The With-CLG case requires somewhat elaborate discussion since the PP has confined all the HHFP studies to the inundation on the sides of the canal due to rainfall in the urban catchments of the canals. The very purpose of CLGs is to control inflows and outflows. Closure of CLGs on the northern ends blocks the inflow from the sub-basin outlets of catchments outside that of the canals. The closure of CLGs have considerable implications for those areas facing heavy rainfall and flows from flooded rivers. A look at Kerala State Disaster Management Authority's (KSDMA) flood risk map for the Ernakulam district will clearly show that while the areas covered by IURWTS are at low flood risk, the areas further north of the CLG on the northern ends of the canals are at exceptionally elevated risk. These will be apparent from a map of the region on which KSDMA's flood risk zonation and the location of CLGs are superimposed (Fig. 3).

It is obvious that the areas to the north adjoining the CLGs (northern ends) are at exceptionally high flood risk compared to the area covered by IURWTS. A closer look the map shows that the three major canals are important in easing the flooding from rivers on the northern areas (Fig. 4). Historically, all these canals were in a much better shape than they are today and could carry large amount of river discharges from the north to KE. It is these northern areas that are most affected by the flooding of the rivers not the areas covered by IURWTS. The extensive wetlands and drainage network to the south of the high flood risk areas are now degraded compared to the condition several decades ago due to draining of wetlands and loss of drainage network by rapid urbanisation. Flood management in the district requires an integrated approach in which all the major canals, the drainage network connected to them, and the remaining wetlands needs restoration.

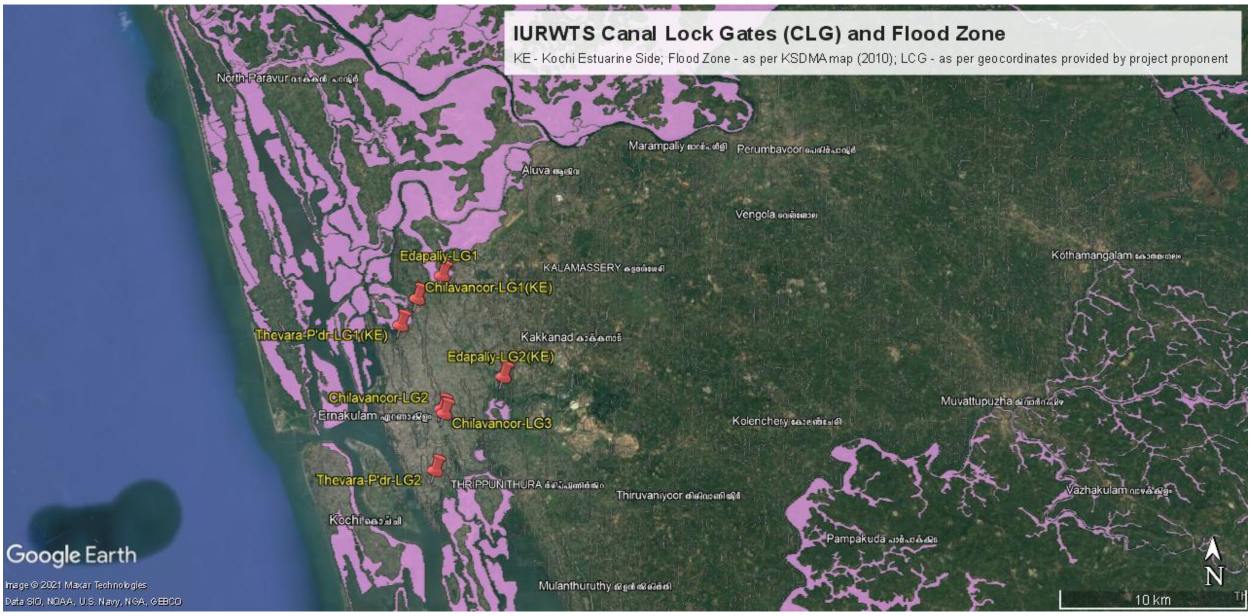


Figure 3: IURWTS Canal Lock Gates (CLG) and Flood Risk Mapping of 2010 by KSDMA (shaded areas)

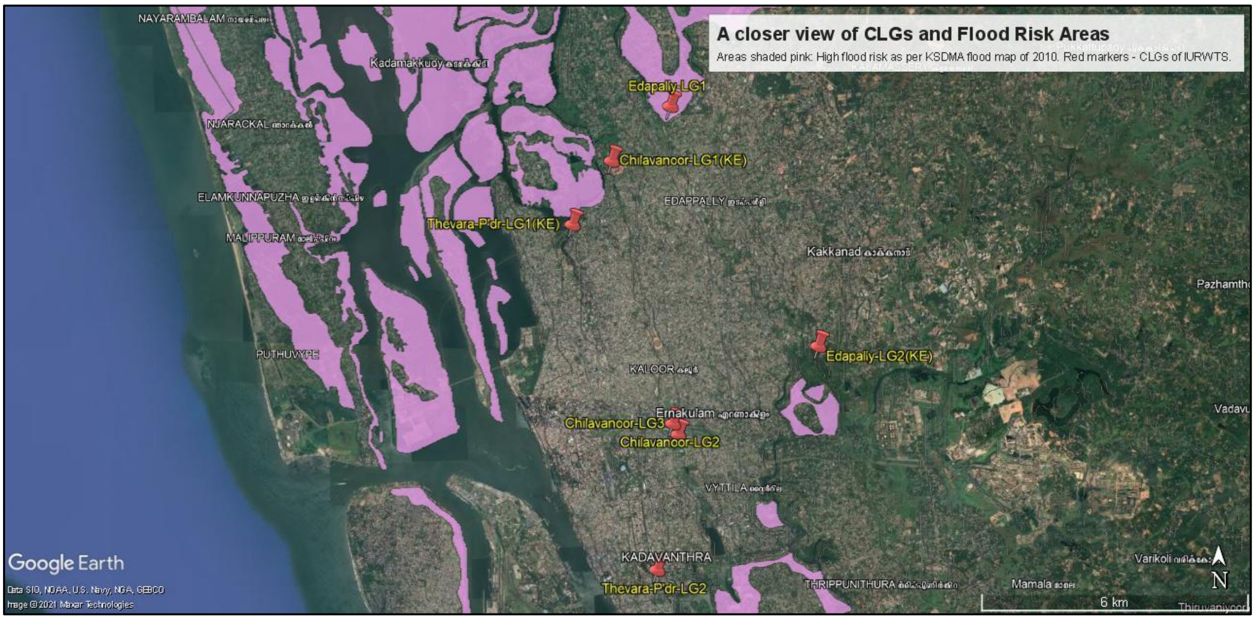


Figure 4: Closer look at the CLGs and High Flood-Risk Areas, Ernakulam district (shaded areas)

The above discussion shows that more than the water logging from rainfall in the urban catchments of the canals, flood management in the Ernakulam district must ensure that modifications in the drainage system anywhere do not aggravate the flooding in the northern parts where risk from river flooding is exceptionally high. Clearly operation of the CLGs have considerable impact on managing the flooding north of the CLGs of the three canals shown in the figures 3 and 4. The situation will be clearer if we consider the Edappally canal and its CLGs (Fig. 5, 6).

Figure 5: Edappally Canal and CLG-1 on the northern side near River Muttar

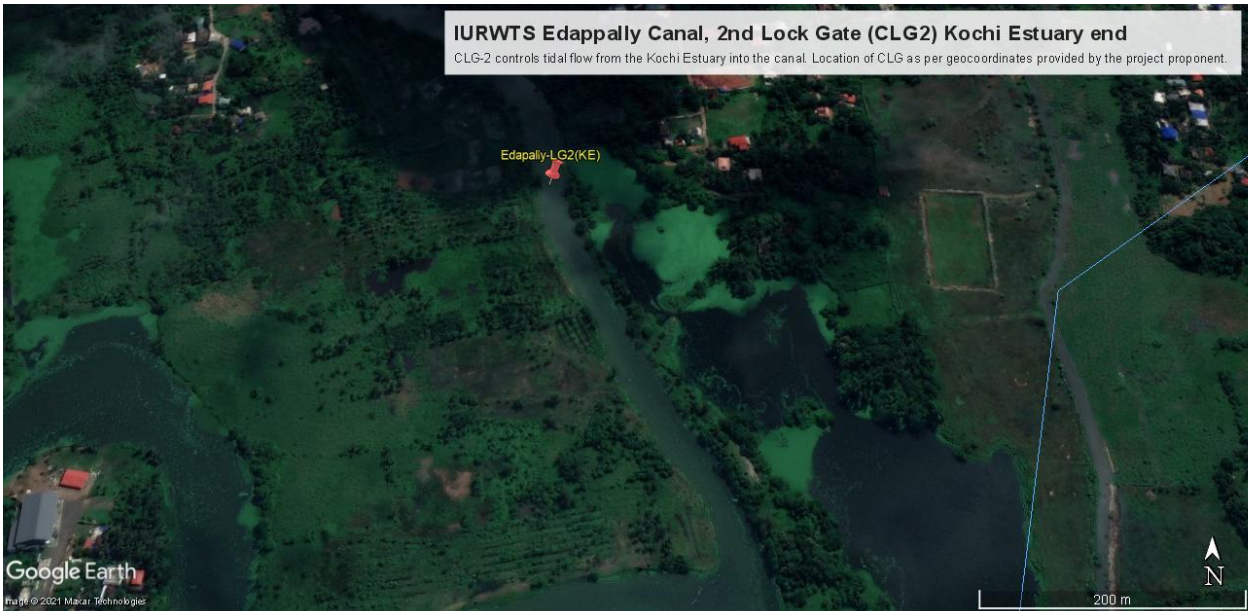


Figure 6: Edappally Canal and CLG-1 on the Kochi Estuary end

7 With-CLG Scenarios

B.2 includes a short discussion on With-CLGs of the HHFP simulations for the scenario EX-4. CWPRS has not reviewed or vetted these claims. Nor does B.2 give a clear description of the CLG closure(s). It does not mention details of the CLG closed state (i.e., one or more closed). Many statements in B.2 are assertions by the PP that should require proper validation. It is an open question what boundary conditions are appropriate for simulating the case of With-CLG closed. It must be kept in mind that the With-CLG Closed and Without-CLG are not as simple as it may appear prima facie. We must ask what indeed With-CLG (i.e., all or a few closed and when) really means. To be useful for the present discussion it must include the actual operational arrangements when the gates are open during a certain duration of the rising tide as mentioned in the DPR and closed during other times. It must also provide the consequences of closing the CLGs at the northern ends of the canals on the area to the north of the CLGs which faces flooding from rivers.

In B.2 a new assertion has been made about the CLGs that control tidal flow into the canals, which is different from what is stated in the DPR. This assertion which does not appear in any of the authentic documents such as DPR is inconsistent with the very reasoning used for deploying CLGs. This assertion states that the seaward side CLGs will be kept open for 14 hours every day from 6 pm to 8 am next day. On one hand the DPR says the CLG will be kept open during rising tide and will remain closed during ebbing tides. Tides do not have a cyclic pattern based on 24-hour clock. Instead, tidal pattern depends on Earth-Moon-Sun alignment which varies daily based on the rotation of Earth and of Moon around it in elliptical orbits. Other astronomic movements (Earth around the Sun, etc.) also affect the tide. Since tides do not have the same pattern from 8am to 6pm (or any such window) in a 24-hour period each day, the new assertion is inconsistent with the design criteria for employing the CLGs on the estuary side. Therefore, we can consider as authentic only what is stated in the DPR which clearly mentions that the CLGs will be kept open on the estuary side only during rising tide when the tide is +0.5 m and closed at all other times. Alternately, the new assertion should be subject to a robust verification mechanism and included in the project's environmental compliance reports.

Due to reasons stated above, the claims given in B.2 regarding modelling effects of CLG closure requires independent validation by CPWRS with regard to all the assertions made and also regarding how the boundary conditions appropriate to these asserts can be framed. More importantly, the effects of closure are significant to areas outside the catchments of the canals to the north of the CLGs of the three major canals. At the risk of repetition, let me summarise the arguments:

While the Without-CLG condition is straightforward case of having no CLGs or any such structures that affect the movement of water in any manner in the restored canals, that of With-CLG is not. The following conditions must be considered and appropriate boundary conditions imposed in the simulations:

1) CLGs are fully closed all the time, i.e., not open during the entire simulation
2) CLGs are opened and closed on seaward ends according to tides as mentioned in the DPR – open only when the tide is rising and above +0.5m, with drawdown of water level from +0.7 m to +0.5 m (i.e., 20 cms) but closed at other times. This is different from the unauthenticated assertion in B.2, which says CLGs are open for 14 hours each day from 6pm to 8am.
3) CLGs are opened and closed on the landward side according to excess flow from rivers tides as mentioned in the DPR – closed during such events combined
4) All unique combinations of CLGs as per (b) and (c) above, i.e., open or closed on landward end as per river flows and open or closed as per tidal condition on seaward ends.
5) CLGs closed as per assertion in B.2, i.e., closed from 8am to 6pm (10 hours) and open from 6pm to 8am next day (14 hours) on seaward ends irrespective of all other conditions
6) CLGs closed on landward ends as per river flow and in combination with condition (e), i.e.8am to 6pm closed (10 hours) on seaward ends and closed on landward ends all the time to simulate river excess flow conditions.

These conditions must be applied to the four scenarios EX-1 to EX-4 to complete the With-CLG and Without-CLG case simulations. Some of the simulations that must be carried out with CLGs closed are summarised below (Table-3):

Table 3: Indicative list of simulations that must be carried out with CLGs closed for each of the four scenarios (EX-1 to EX-4)

Condition	**CLG Status Landward End**	**CLG Status Seaward End**
1	Closed Always	Closed Always
2	Open Always	Open & Closed as per DPR (see #2 above)
3	Closed Always	Open & Closed as per DPR (see #2 above)
4	Closed/ Open as per river flow	Open & Closed as per DPR (see #2 above)
5	Open	Closed for 14 hours (6pm to 8am next day) Open for 10 hours (8am to 6pm)
6	Closed	Closed for 14 hours (6pm to 8am next day) Open for 10 hours (8am to 6pm)
7	Closed/ Open as per river flow	Closed for 14 hours (6pm to 8am next day) Open for 10 hours (8am to 6pm)

Based on the above arguments, I have no choice but to reject the assertions made about the impacts of With-CLGs closed given in B.2 because it does not consider impacts outside the catchments of the canals where there is high flood risk. Study based exclusively on the rainfall in the catchments of the canal cannot address the impact of the closed CLGs to certain areas from which flood water drains into these canals. The claim of CLGs being open from 6pm to 8am daily is not consistent with the rationale described in the DPR for deploying the CLGs on estuary side. As per DPR, the CLGs can be kept open only during a certain short phase of the rising tide.

8 Ecological and Hydrologic Concerns about CLGs

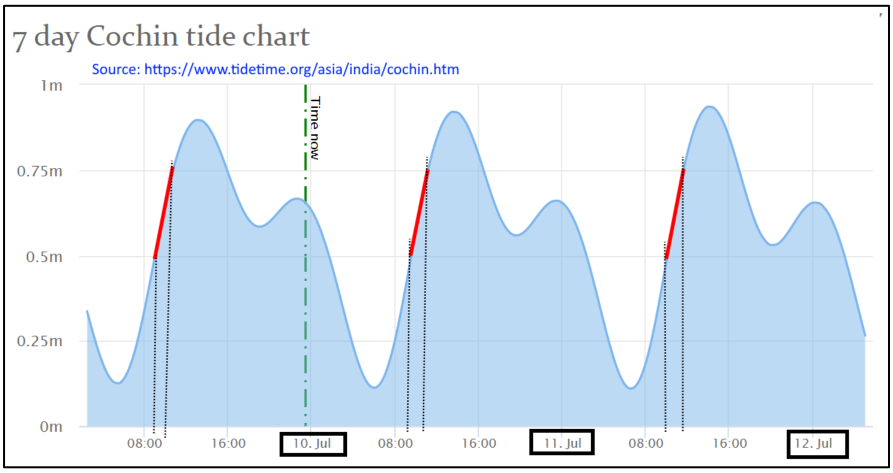
The DPR claims that the operation of CLGs is such that it will ensure “stagnant water in the canal” to flow out into the sea. I have argued in the note circulated earlier that this is neither proven nor possible. Therefore, the concern expressed in the DPR itself, which is a core concern whenever and wherever CLGs are used anywhere in the world, is not addressed in any of the documents submitted by the PP. Instead, a completely irrelevant comparison of the water volumes in the 34.33 km length of canal and that of the KES has been made. Even in that PP has made calculation mistakes pointing to the unseemly eagerness to portray the question raised as incorrect.

The concern about the canal ecology is related to the clear recognition in the DPR itself; that stagnation is an issue. It is a widely understood problem when such flow controls are used. This was already clearly explained in my previous note, but I am forced to repeat in the face of a misleading response by the PP. Inexplicably, the PP has made a bizarre comparison of the canal water volume to that of the Kochi Estuary itself (with calculation mistakes). Just because there is a discussion on water exchange between canal and sea or estuary does not mean one has to make a strange comparison of the canal volume with that of the sea or estuary. Question relates to water quality in the canal under conditions with flow control using CLGs, keeping them closed to maintain a constant depth of 1.4m to 1.9m at all times for the operation of the proposed water transport system. That does not call for either any kind of comparison of the canal volume with that of Kochi Estuary or the Arabian Sea.

According to section 3A.1.1.3 of the DPR, the regulatory mechanism “helps the navigation in the canal with a clear draft of 1.6 m in the canal (-0.9 m MSL Bottom level of canal to +0.7 m MSL)” (DPR, Page 3A-16). Per section 4A.4.7 of DPR, water depth is kept between 1.4 m to 1.9 m. The CLG shutters are kept closed so as to maintain canal water level at +0.70 m MSL. The DPR claims that during high tide, after the water level reaches + 0.5 m MSL the shutters are brought down to +0.5 m MSL and due to that “the stagnant water in the canal starts flowing out.” The water exchange between canal and estuary has to be quantified and the turnover time of each canal without CLG and with CLGs as per operating norms must be carried out.

Tidal rise is a continuous process and not controlled as with the opening and shutting of the CLG. As per design, only a small portion of the volume of water in the canal equivalent to the 0.2m deep layer in the canals has the likelihood of being exchanged with the estuary. When the tide is rising, only a small fraction can flow out in the short period when there can be outflow. The extent to which a portion of the water from the canal can flow out against rising tide needs to be quantified and compared against the normal tidal pattern that has diurnal, seasonal, annual and long-term variations. Obviously, if the rate of tidal influx is significantly more than the outflow from the canal, which is often the case, there will be hardly any outflow. In effect, the rate of mixing or flushing would be extremely low as the CLGs will drastically reduce the mixing compared to the situation without the CLGs.

The proposal claims that merely by opening the CLG on the estuary side during rising tide when the tide is +0.5 m, a drawdown from water level at +0.7 m to +0.5 m (i.e., 20 cms), will cause “stagnant water in the canal” to flow out. Question is how much that would be. A large outflow is not realistic because the effective outflow during the rising tide will depend on the difference in the outflow from the canal and the powerful tidal influx. The duration of rising tide above +0.5 m is short. From the



tide charts (see figure), we can see that usually in a day, the duration of flood tide from +0.5 m to +0.75 m is about 90 minutes. There will be outflow only if the net outflow (out flow from canal less tidal inflow) is positive in this short portion of the flood tide. While the quantitative estimates of the volume of exchange under different scenarios of tidal action must be computed, it is obvious that the effective outflow in such a short period would be a tiny fraction of the total volume of water in the canals maintained at a minimum depth of about 1.6 m.

9 Canal Lock Gates and the Need for Mitigation Options

The canal lock gates are essential to keep the desired minimum water depth and the CLGs inevitably alter the tidal flushing and the water residence time in the waterbodies associated with these canals. The challenge here is to identify sound mitigation options to ensure periodic turnover of the water or ensure that on an average over a period determined in the EMP, the residence time is kept nearly same as it will be without the CLGs controlling the inflows and outflows. This should not be a difficult proposition after the details are adequately studied, quantified, and model simulations carried out to find workable solutions.

Interestingly, the document B.2 makes the questionable claim, attributed to anonymous experts from CUSAT (i.e., without mentioning any names), given below (B.2, page 18):

> *CUSAT studies reveal from reference reports that the installation of lock gates have had beneficial effects on the environment and resources in the Broughton Creek, Australia (Winberg and Health, 2010) and Columbia River estuary (Sara Ennis, 2009) facing similar situation as seen in the Kochi canals.*

We would like the experts from CUSAT who have stated this to come before KCZMA and authenticate what has been ascribed to them or provide a report under the seal of CUSAT with names of authors clearly mentioned. We cannot have anonymous attributions claiming to be that of experts. We would like these experts to enlighten us how the conditions discussed here (i.e., of canal restoration) are like that in Broughton Creek, Australia or Columbia River Estuary on the Pacific Coast of the United States. For unknown reasons, after quoting certain studies the document B.2 refrains from giving the complete bibliographic information. We cannot see the similarity of the kind claimed by the PP between the subject of studies cited by the PP and the Kochi Estuary or the canals discussed here. Having noted that the similarity claimed in B.2 is grossly misleading, I would like to quote from some of the known publications of the authors referred to in B.2 in an attempt by the PP to suggest a false equivalence between Kochi Estuary and certain ecosystems on a) the West Coast of USA and b) New South Wales, Australia.

First, excerpts from the abstract and executive summary of a study on Broughton Creek, Australia by Winberg and Health, (2010):

> *Floodgates and drainage networks, in addition to natural channels and tributaries, have been developed extensively throughout agricultural lands on the estuarine floodplains of NSW for drainage of agricultural fields and pastures. A characteristic and unfortunate consequence of draining and exposing previously waterlogged floodplains to oxygen, is the oxidation of reduced pyritic soils to produce sulfuric acid.* ***<u>Mass fish kills and poor water quality are dramatic and well documented effects of floodgate</u>*** *and drain management of floodplains in northern NSW, following intensive rain and high flush events that release stored reservoirs of acidic water from upstream of floodgates.*

- ***Floodgates have severe impacts on species diversity and abundance*** *across the full range of macro fish and invertebrates sampled, primarily as a result of highly acidic and high metal content water quality conditions*
- ***Important commercial species such as prawns are strongly impacted by both flood and smart gate structures,*** *with a potential loss of 1400 prawns for every ML of water upstream of floodgates,*
- *Leaky gate structures (smart gates) that provide some tidal buffering of upstream water provide significant improvement of water quality and increases in diversity and abundance of fish and invertebrates.*

(emphasis added)

Next, from a study on Columbia River Estuary, USA by Sara Ennis (2009):

> ***Results from this study and the literature indicate that increased tidal inflow*** *serve to increase salmon passage and tidal circulation, causing a corresponding reduction in temperature,* ***all of which are desirable conditions for productive rearing habitat.*** *Flow dynamics in LTS should be modeled to determine an acceptable rate of inflow so that one or more of the fish orifices can be left open on a long term basis. Two years of additional data collection with the orifices open would provide an indication of the effect of increased tidal inflow on temperature and a balanced comparison for the data from the two years prior to replacement. Because tide gate replacement is minimally effective relative to dike removal as a restoration strategy, it is critical to optimize the potential of the outcome.* ***Once in place, tide gate operations should simulate a natural slough to the extent possible within the limitations of the site.***

(emphasis added)

To conclude, let me also mention here that there are any number of peer reviewed research papers on the problems arising from the use of flow controls and canal gates. Incidentally, the work of Winberg and Health (2010) is a report while that of Sara Ennis (2009) is a master's degree project. That aside, both the studies underscore the ecological problems caused by the use of flow control systems such as dikes, canal gates or tidal barriers.

Limited or disrupted connectivity of the estuary with sea can significantly affect in an adverse manner the community composition and water quality (Souder et al 2018). The operation of the tide gates and seasons influence the composition of the aquatic biota including species, their distribution and abundance (Scott et al. 2016). The differences on either side of the gates tend to aggravate when the gates are opened less frequently (Seifert and Moore 2017). The water quality of streams with and without tide gates differs which would degrade the aquatic habitat quality and rearing capacity (Bass 2010; Gordon et al. 2015; Weybright and Giannico 2017). The dikes and tide gates installed to control the free flow of water under the influence of rising tides disrupts the movement of the "front" of the estuary, modifying the saltwater wedge and associated water circulation pattern (Giannico and Souder 2005). The tide gates alter the pulsed nature of upstream habitats in several ways such as change in water mixing, turbulence, freshwater levels, and so on (Bates 1999; Coats et al. 1989; Khaleel and Othman 1997; Odum 1970; Middleton 1999; Odum et al. 1995; Portnoy 1991; Scalisi 2001). The characteristics of salinity mixing, and the extent of the freshwater tongue, is related to the type and size of gate, the amount of freshwater pooled upstream, and the relative difference in salinity between fresh and brackish water in the area (Jay and Kukulka 2003). In the case of Kerala there are studies on the adverse effects of the tidal regulator at Thanneermukkom (e.g., Thampatti & Padmakumar 1999; Haldar et al 2019) and the hydrological impacts of tidal regulator at Pozhikkara in Kollam (Shaji 2009). A study on Kochi Estuary shows that poor flushing and longer residence time retain effluents and pollutants longer, resulting in eutrophication, deterioration of water quality, and biodiversity loss (John et al 2020).

Although the ecosystems – Kochi Estuary, Columbia River Estuary (USA), and Broughton Creek, Australia are not comparable in the way the PP wrongly claims, it is important that the PP takes note of the concerns expressed in these studies which are not vastly different from those raised earlier. Therefore, without further arguments, I insist that the PP consider the concerns expressed by the two studies they themselves have quoted in document B.2 (Winberg and Health 2010; Sara Ennis 2009).

There are many implications of drastic reduction in the flushing, significantly decreased tidal mixing and a nearly stagnant waterbody. We expect EIA for such a project to thoroughly examine all these aspects such as changes in the aquatic system (e.g., change in estuarine features, eutrophication, invasive growth of aquatic macrophytes, algal bloom, multiplication of parasites, etc.) which may also have significant public health ramifications. While in the short-term the proposed project can provide some improvements to water quality, situation can change in the medium to long-term unless proper mitigation measures are implemented, and adequate caution is exercised. The EIA and EMP ought to have addressed all these concerns. The project proponent must examine all these and present a satisfactory mitigation plan to minimise the impacts of deploying several canal gates to control the inflows and outflows, from rivers and tide driven flows.

s/d

Nov. 13, 2021 *C. P. Geevan*
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References

Bass, A.L. 2010. Juvenile coho salmon movement and migration through tide gates. M.S. Thesis, Department of Fisheries and Wildlife, Oregon State University, Corvallis, OR. 124 pp.

Bates, K. 1999. Flap gates. Pages 13-1–13-4 in Fishway design guidelines for Pacific salmon. Notes from fish passageways and diversion studies. USFWS, Keaneysville, West Virginia.

Coats, R., M. Swanson, and P. Williams. 1989. Hydrologic analysis for coastal wetland restoration. Environmental Management 13(6):715–727.

Ennis, S. (2009). Effects of Tide Gate Replacement on Water Temperature in a Freshwater Slough in the Columbia River Estuary.

Giannico, G. and Souder, J.A. 2005. Tide Gates in the Pacific Northwest: Operation, Types and Environmental Effects. Oregon Sea Grant, Oregon State University, 32 p.

Giannico, G., & Souder, J. A. (2005). Tide gates in the Pacific Northwest: operation, types, and environmental effects.

Gordon, J., M. Arbeider, D. Scott, S. Wilson and J. Moore. 2015. When the Tides Don't Turn: Floodgates and Hypoxic Zones in the Lower Fraser River, British Columbia, Canada. Estuaries and Coasts 38: 2337 -2344.

Haldar, R., Khosa, R., & Gosain, A. K. (2019). Impact of anthropogenic interventions on the vembanad lake system. In Water Resources and Environmental Engineering (pp. 9-29). Springer, Singapore.
Jay, D. A., and T. Kukulka. 2003. Revising the paradigm of tidal analysis—the uses of non-stationary data. Ocean Dynamics 42:1–16.
John, S., Muraleedharan, K. R., Revichandran, C., Azeez, S. A., Seena, G., & Cazenave, P. W. (2020). What controls the flushing efficiency and particle transport pathways in a tropical estuary? Cochin estuary, southwest coast of India. Water, 12(3), 908.
Khaleel, M. S., and K. I. Othman. 1997. Degradation down-stream from a sluice gate; variation of bed and sediment characteristics with time and discharge. Journal of Hydrol-ogy 191:349–363.
Middleton, B. 1999. Wetland restoration, flood pulsing, and distribution dynamics. John Wiley & Sons, New York
Odum, W. E. 1970. Insidious alteration of the estuarine environment. Transactions of the American Fisheries Society 99(4):836–847.
Odum, W. E., E. P. Odum, and H. T. Odum. 1995. Nature's pulsing paradigm. Estuaries 18(4):547–555.
Portnoy, J. W. (1991). Summer oxygen depletion in a diked New England estuary. Estuaries 14(2):122–129.
Scalisi, M. 2001. Larson Slough tide gate study: an investigation of the hydrodynamics across the Larson Slough inlet and water quality of Larson Slough. Second draft report to the Coss Watershed Association, 18.
Scott, D.C., M. Arbeider, J. Gordon and J.W. Moore. 2016. Flood control structures in tidal creeks associated with reduction in nursery potential for native fishes and creation of hotspots for invasive species. Canadian Journal of Fisheries and Aquatic Sciences 73(7): 1138-1148.
Seifert, R.E. and J.W. Moore. 2017. Floodgate Operations and fish communities in tidal creeks of the lower Fraser River (British Columbia, Canada). Estuaries and Coasts. https://doi.org/10.1007/s12237-107-0313-3.
Shaji, E. (2009). Hydrological Impact of a Tidal Regulator on Land and on Water in a Tropical Estuary of Kerala, India. Nature Environment and Pollution Technology, 8(4), 627-634.
Souder, J.A., L.M. Tomaro, G.R. Giannico and J.R. Behan. 2018. Ecological Effects of Tide Gate Upgrade or Removal: A Literature Review and Knowledge Synthesis. Report to Oregon Watershed Enhancement Board. Institute for Natural Resources, Oregon State University. Corvallis, OR. 136 pp.
Thampatti, K.C.M. and Padmakumar, K.G. 1999. Rice bowl in turmoil: The Kuttanad wetland ecosystem. Resonance, pp. 62-70.
Weybright, A.D., and G.R. Giannico. 2017. Juvenile coho salmon movement, growth and survival in a coastal basin of southern Oregon. Ecology of Freshwater Fish. 2017:1–14.
Winberg, Pia C. and Heath, Tom. (2010) "Ecological Impacts of Floodgates on Estuarine Faunal Assemblages", Report by the University of Wollongong Shoalhaven Marine & Freshwater Centre, Nowra, for the Southern Rivers Catchment Management Authority.

1. KCZMA agree with the analysis that shows the project cannot be considered as primarily a flood control project. It cannot be a major flood control project just because it improves the storm water drainage along the sides of the canals restored in the project for use as waterways round the year. The note correctly recognizes the need to integrate canal-wise controls on water movement, especially the use of Canal Lock Gates (CLGs) to control the water flows, into the larger flood management plan for Ernakulam district. Therefore, during flood events the operation of the CLGs must necessarily be carried out subject to approval and supervision of the District Collector and not exclusively by the project proponent on these canals. These canals running through Kochi Municipal Corporation and three other towns have always been a public asset. It should continue to be under the overall supervision of the district authorities and the monitoring by the District Level Coastal Zone Management Committee.

2. The note raises certain concerns about the ecological impacts of establishing the CLGs and controlling both freshwater and estuarine water flows into the 34.33 km long canal system. Dr Geevan's note points out that the biodiversity study by CUSAT has noted clearly that the canals constitute an ecosystem that needs proper care and attention. We agree that the concern raised is important and must be addressed. The project proponent has made certain assertions regarding the operation of the CLGs, i.e. when they will be open and closed. However, there is not enough clarity regarding the operation of the CLGs on the northern end. There is some inconsistency in the assertion now made by the project proponent regarding the operation of the estuarine side CLGs and the operational requirements stated in the DPR. In view of these, the project proponent must provide a declaration giving proper schedule of the opening and closing of each gate in different seasons: a) CLG operating schedule for each canal for each month for the CLG on the northern ends and b) the daily schedule for CLGs on the estuary end.

3. There should be a permanent monitoring and regulatory institution with adequate powers to ensure compliance which can be the District level Coastal Zone Management Committee or a dedicated body. The study by CUSAT, "Marine Ecology Survey and Biodiversity Impact Assessment Study for EIA & CRZ Studies for Integrated Urban Regeneration and Water Transport System (IURWTS) Project in Cochin" carried out for the project and submitted by the project proponent has given a framework for monitoring in the chapter "Management Strategies and Action Plan'' (pages 175 – 183). The report proposes that a nodal agency "with adequate resources and authority be set up to ensure the environmental health of selected canals under IURWTS project." We recognise that any controls on the free water movement though canals by deploying 6 canal lock gates will have adverse effect on the ecosystem and biodiversity. The concerns expressed by Dr Geevan should be included within this and the operation of the gates subject to regular monitoring.

4. All these can be included in the environmental compliance requirements of the project.