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ARTICLE

# DETERMINATION OF SUSTAINABILITY THRESHOLDS FOR RIVER YAMUNA AND ITS FLOODPLAINS DUE TO THE CONSTRUCTION ACTIVITIES IN DELHI

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## ABSTRACT

*Nature has a limited capacity to provide resources and absorb pollutants with time. Thus it's important to identify environmental threshold values, since it's important to know about the critical zones before actual tipping points in the system are reached. These Environmental Thresholds can be defined as a point or zone where there is a dramatic change in the state of matter or a system. In a threshold response, a minor change in the independent variable results in a dramatic change in the dependent variable.This research paper focuses on the determination of threshold levels for the river Yamuna and its floodplains with reference to the construction and operation of the Metro link between Nizamuddin Railway station and Yamuna Bank Metro Station in Delhi which would transect the River Yamuna through an elevated track. The study aims to identify the environmental thresholds with respect to the ecology of the river and its floodplains through identification of specific indicators which could be used to monitor the change which could lead to a further breakdown of an already stressed environment. It also seeks to quantify these thresholds so that they could monitored more effectively through indicators.*

**KEY WORDS**
*Sustainability; Threshold; Indicators*

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## INTRODUCTION

The floodplains and the Yamuna riverbed are considered to be one of the sensitive locations due to their vital role in maintaining the groundwater levels in the vicinity of Delhi. The construction of the third phase of the Delhi metro rail link at the flood plain near Hazrat Nizamuddin will further affect the flood plain of the river Yamuna which is already stressed due to the existing structures and bridges. The third phase of Delhi Metro's master plan proposes to connect the Nizamuddin railway station to the Yamuna bank metro station which involves the construction of a bridge across the river Yamuna and a maintenance depot on the right bank. In addition to this, a bund shall also be constructed along the east bank. The proposed metro line along with the tentative location of the depot is shown in the [Fig.1]. The study has been done through the following stages:

i. Identify threshold areas: The identification of areas, along/ in the river and its floodplains where there is likelihood of occurrence of environmental issues pertaining to air, water, land use and noise will exceed the threshold limits
ii. Selection of thresholds and establishment indicators: From the chosen threshold areas, a set of indicators will be established, which are susceptible to change and have crossed the permissible limits. The major and minor thresholds would influence the identification of major and minor indicators.
iii. Explore inter-relationship between indicators: Creation of sets and subsets to explore the inter-relationship between the indicators, in order to determine those indicators which are most susceptible to change. The thresholds can be directly linked to environmental resources, pressure/stress on the environment and underlying driving force . Measurement of threshold levels: Quantification of threshold levels for determining the critical points for environmental sustainability. The detailed methodology has been shown in the [Fig. 2].

## MATERIALS AND METHODS

### Construction methods adopted by Delhi Metro

The Delhi metro uses the following methods for construction of the Metro Link. The construction involves the building of the piers and the laying of the over head track. During the construction of the piers on the wetland, the position of the pillars is first identified on the ground and marked. After this, a special technique called "well sinking" is employed to construct the pillars. At a later stage, when the track is constructed, a special technique known as Incremental Launching is used. The technique involves the construction of the bridge in segments, as opposed to constructing it in irregular parts. The entire segment is first cast on a casting bed and then pulled over the pillars of the bridge by jacking. The construction technique is ideal for busy cities because it allows construction without any major disruption of traffic.[3]

### Determination of the state of the Eco-system

The domain area shown in the figure 1 is bounded by NH24 on the north and DND flyover towards the south and Sarai kale khan bus station in the west and Noida in the east. Within the enclosed domain a wide varaiety of species were present. It has been reported that Typha angustata, Eichhornia crassipes and Sachharum munja were distributed all along the fringes of the river in this area. The largest areas were occupied by Typha angustata (1.72 sq. km.) and Eichhornia crassipes (0.26 sq. km.). Smaller areas were occupied by Nympheae stellata (0.95 sq. km.), Sachharum munja (0.03 sq. km.), Carex fedia (0.03sq. km.) and Polygonum glabrum (0.03 sq. km.) Over the entire river stretch, Typha angustata was the most common semi-aquatic plant and reached thehighest abundance in this area.

### Impact assessment of the structures over the Yamuna

[Fig. 3] shows the impacts of the construction of structures over the river (Babbar, 2001). Many primary and secondary effects have been noticed in and around the near bed due to the construction activities. The construction of bridges has resulted in a change in the surface water profiles which significantly affect the aquatic systems. Further, the river experiences complex patterns of scouring in the vicinity. Moreover, this has found to have significant effect on the biodiversity and soil in the surrounding areas. It has also been observed that in the long run, the niose and air pollution in the surroundings increased due to increased flow of traffic. Hence the construction of every structure on the river causes many indirect and direct impacts.

## RESULTS

### Determination of the state of the ecosystem and calculation of the stresses

The method for determining the additional stress is as shown in the [Fig. 4]. The methodology includes the determination of stresses due to water quality, air quality, noise, and biodiversity and land degradation.

### Water quality

The discharge from 22 drains joining river Yamuna at NCT – Delhi was 49.57 m3/sec in 2000 which reduced to 42.65 m3/sec in 2005. Correspondingly there was reduction of about 25% in BOD load contributed by these drains. From the description above and the graphs it is clear that the stretch under consideration is the most polluted with the DO levels approximately close to zero. Hence we can conclude that the health of the river is under severe stress.

Since the water quality parameters have already exceeded the permissible value, it is difficult to estimate the stresses based on the changes in those parameters. Hence, the water quality index can be calculated as follows:

Water Quality Index = (a/A) x W (1)
Where,
a = area of water body affected (m2), A= Total area (m2)
W= Weightage factor = (Stress factor x Fraction of species affected)/ Maximum stress factor
Where the maximum value of the Stress factor is 2.25 (justification of this value) times the number of species since the total value from each species cannot exceed 2.25. The value is obtained as 23 x 2.25 =51.75 for the total species present. From the above formula, the weightage factor is obtained as (23x40)/ (42 x 51.75)* (14.27/100) = 0.0602

### Air pollution

Table 1 shows the predominant pollutant concentrations at the ITO intersection which is the nearest measuring station for the selected domain.
The Air quality index has been calculated by using the following formula
AQI = [SOx/ SOxStd] + [NOx/ NOxStd] + [Particulates /Particulatesstd]+ [CO/ COstd] (2)
The air quality index for the average pollutant concentrations during the years 1989-97 and for the years 2000-06 has been obtained as 6.17 and 5.20 respectively. Assuming that the pollutant concentrations will not exceed three times the permissible concentration, the total factor will not exceed a value of 12. For this case the average value of the index is 5.68.

### Noise pollution

The main sources of noise from the operation of trains includes: engine noise, cooling fan noise, noise due wheel rail interaction, electric generator and miscellaneous noise like passenger's chatting. The roughness of the contact surfaces of rail and wheel and train speed are the factors, which influence the magnitude of rail wheel noise. The vibration of concrete structures also emits noise. Hence total noise level would be about 80.4dB (A). The permissible standards for a silence zone is 50dB where as the site will be exposed to a value very much greater than the permissible value. Hence the value of one is considered as a factor that should be multiplied with the noise impact.

### Land use in the flood plain

The land use pattern in the river bed in the stretch under consideration has been shown in the [Table 1]. The east bank is occupied by the unauthorized colonies and agriculture in many zones. The west bank is more diverse with archeological structures, landfills and recreational facilities. Due to the proposed metro line and the construction of bund, the land use pattern is expected to change. [2]

The approximate change in the area has been calculated by making the following considerations.

The reduction in the river bed area is equal to the number of piers times the diameter of each pier. The area of each pier and the number of piers are assumed to be same as that of the existing Delhi metro bridge that has been constructed near the Yamuna bank metro station
The area of the bund is calculated as 16 hectares.
The area of the metro depot proposed is considered to be equal to that of the built up area because the existing two depots have an areas of 39 hectares and 72 hectares. Hence a value closer to the average value has been chosen.
The total area of the metro track has been calculated based on the total width of the metro tracks in the existing alignments. The value is obtained as six hectares. The change in the land use pattern has been shown in the [Table 2].
Determination of the land use Index is given as
Landuse Index= $\sum$ (change in area /100) * factor for land use = 0.1522

## Biodiversity

Among the four different zones listed, the effect of the construction activities on the aquatic and terrestrial species has been quantified. It has been estimated that there are forty two aquatic species and thirty two terrestrial species present in the riverbed (Babbar, 2001). Out of those, twenty three aquatic species and eighteen terrestrial species are located in the zone where the construction activities are going to take place. For each species present in the zone III, a factor has been multiplied to calculate the effect of the activities on the particular species. The factors are calculated as follows

If the species is located only in zone III and absent in all other zones, a factor of 2 is considered

If the species is present in more than one zone, then a factor of 1 is used. The effect on the same species present in the adjacent zone becomes half of the original value.

The total effect is calculated as the product of the fraction of the species present in the zone to the total weightage obtained.
For the case of terrestrial species, the effect will be confined only to the immediate zones. The species if absent in the adjacent zone will not carry any effect on to the zone ahead.

**Table 1:** Pollutant concentration at the ITO intersection (Source: www.envforc.nic.in)

| Year (Permissible concentrations) | SOx(μg/m3) (80) | NOx(μg/m3) (80) | Particulates (μg/m3) (100) | CO(μg/m3) (2000) |
|---|---|---|---|---|
| 1989 | 8.7 | 18.5 | 373 | 2905 |
| 1990 | 10.2 | 22.5 | 338 | 2688 |
| 1991 | 13.3 | 27.2 | 317 | 3464 |
| 1992 | 18.4 | 30.4 | 377 | 3259 |
| 1993 | 18.5 | 33.2 | 372 | 4628 |
| 1994 | 19.5 | 33.0 | 377 | 3343 |
| 1995 | 19.0 | 34.1 | 407 | 3916 |
| 1996 | 19.0 | 33.7 | 387 | 5587 |
| 1997 | 16.2 | 33.0 | 370 | 4847 |
| 2000-2006 | 10.9 | 80 | 234 | 3450 |

**Table 2:** Change in the land use pattern due to the proposed construction activities

| | Area (Hectares) | % of Area | Area (Hectares) | % of Area | % change in Area |
|---|---|---|---|---|---|
| River | 150.63 | 14.28 | 150.63-0.0854=150.5436 | 14.27 | -0.01 |
| Agriculture | 775.71 | 73.55 | 722.01-16=706.01-6= 700.01 | 66.37 | -7.18 |
| Built up area | 53.70 | 5.09 | 2(53.70)+6=113.4 | 10.75 | +5.64 |
| DND | 47.14 | 4.47 | 47.14 | 4.47 | +0.00 |
| Protection structures | 17.79 | 1.69 | 17.79+16=33.79 | 3.2 | +2.39 |
| Hindon cut | 9.63 | 0.91 | 9.63 | 0.91 | +0.00 |
| | 1054.60 | | 1054.60 | | |

The weightage factor is calculated using the formula described below.
Weightage factor = (Stress factor x Fraction of species affected)/ Maximum Stress Factor (3)
Where the maximum value of the Stress factor is 2.25 times the number of species since the total value from each species cannot exceed 2.25. The value is obtained as 40.50 for the total species present.

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From the above formula, the weightage factor is obtained as (31.50x18)/(32 x 40.50) = 0.437. The total land in the domain is 1054.60 and the area occupied by species which is directly affected is 700.01hectares. Thus we get the, Biodiversity Index value as 0.29. Since and and water have the maximum impact on the sustainability threshold of the ecosystem under study five scenarios emerged which may be undertaken for analysis as shown below [Table 3].

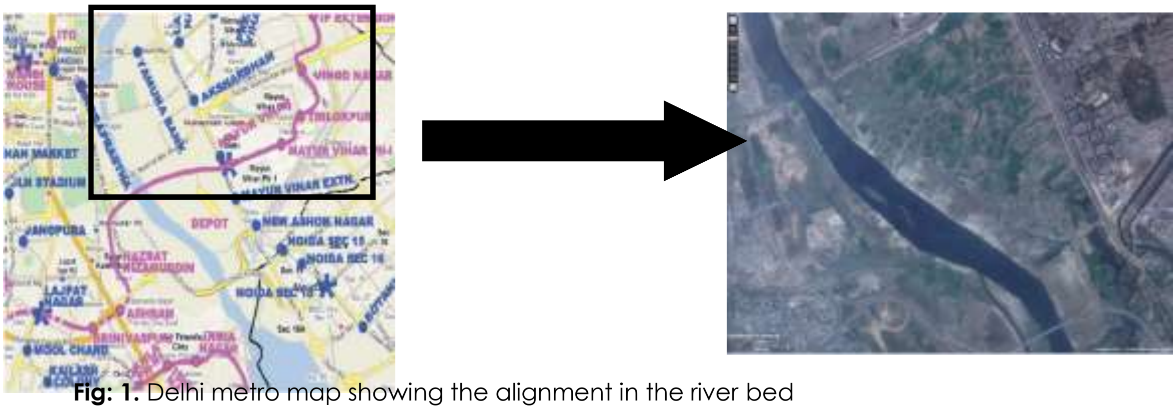

**Fig: 1.** Delhi metro map showing the alignment in the river bed

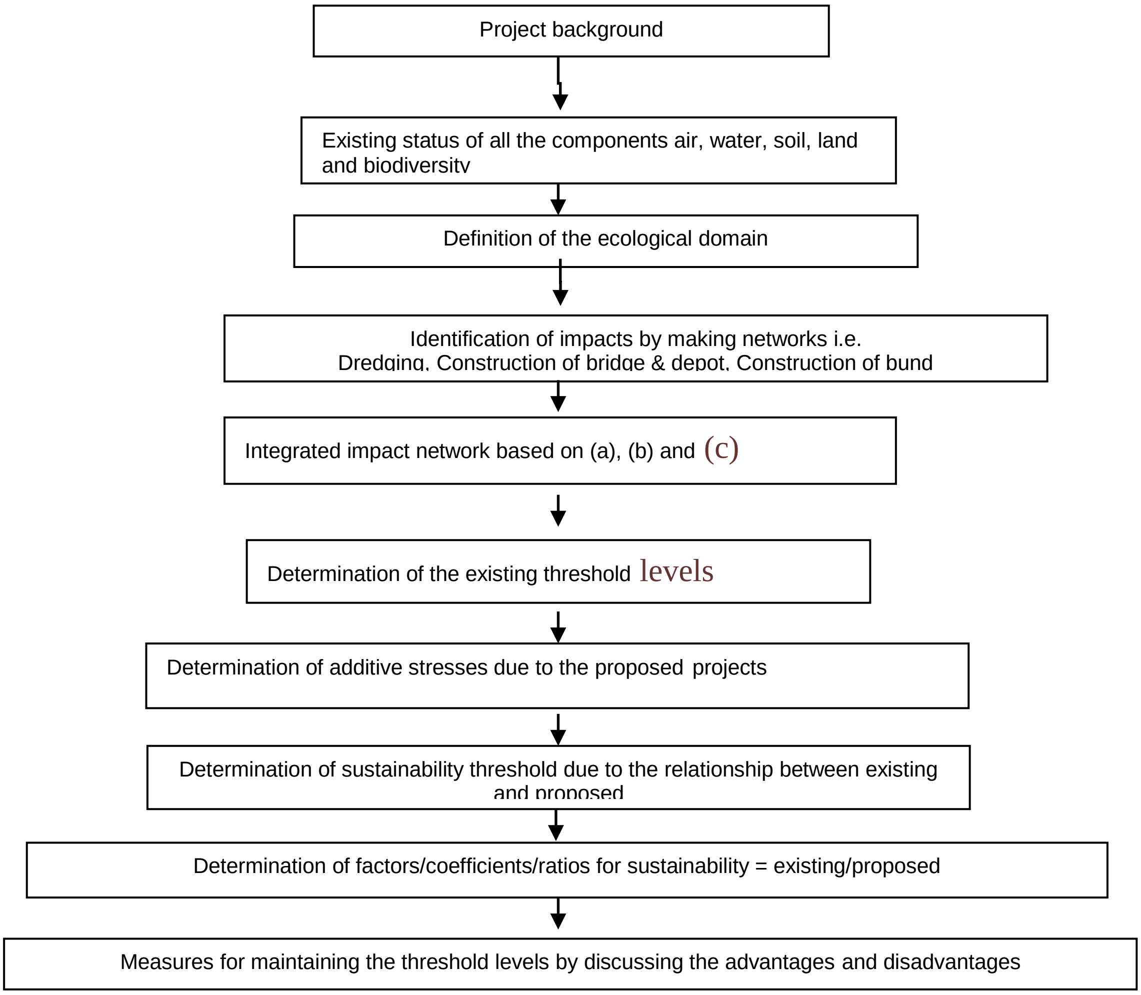


**Fig: 2.** Methodology for quantifying the sustainability threshold for the domain

**Table 3:** Possible Scenarios for the analysis of threshold levels for the current site

| Sl no | Component | Scenario-I (Max-Max) | Scenario-II (Mid-Mid) | Scenario-III (Min- Max) | Scenario-IV (Min-Min) | Scenario-V (Max-Min) |
|---|---|---|---|---|---|---|
| 1 | Air | 0.4 | 0.3 | 0.2 | 0.1 | 0.4 |
| 2 | Water | 0.4 | 0.3 | 0.4 | 0.1 | 0.4 |
| 3 | Land | 0.2 | 0.2 | 0.2 | 0.05 | 0.1 |
| 4 | Biodiversity | 0.2 | 0.2 | 0.1 | 0.1 | 0.1 |
| 5 | Noise | 0.2 | 0.1 | 0.1 | 0.1 | 0.05 |

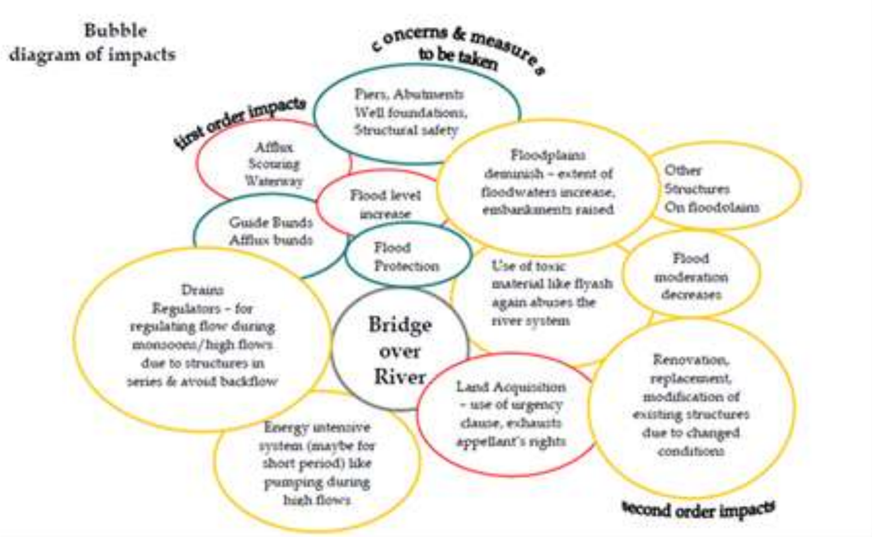


**Fig: 3.** Conceptual Diagram showing the effect of structures on the river [1]

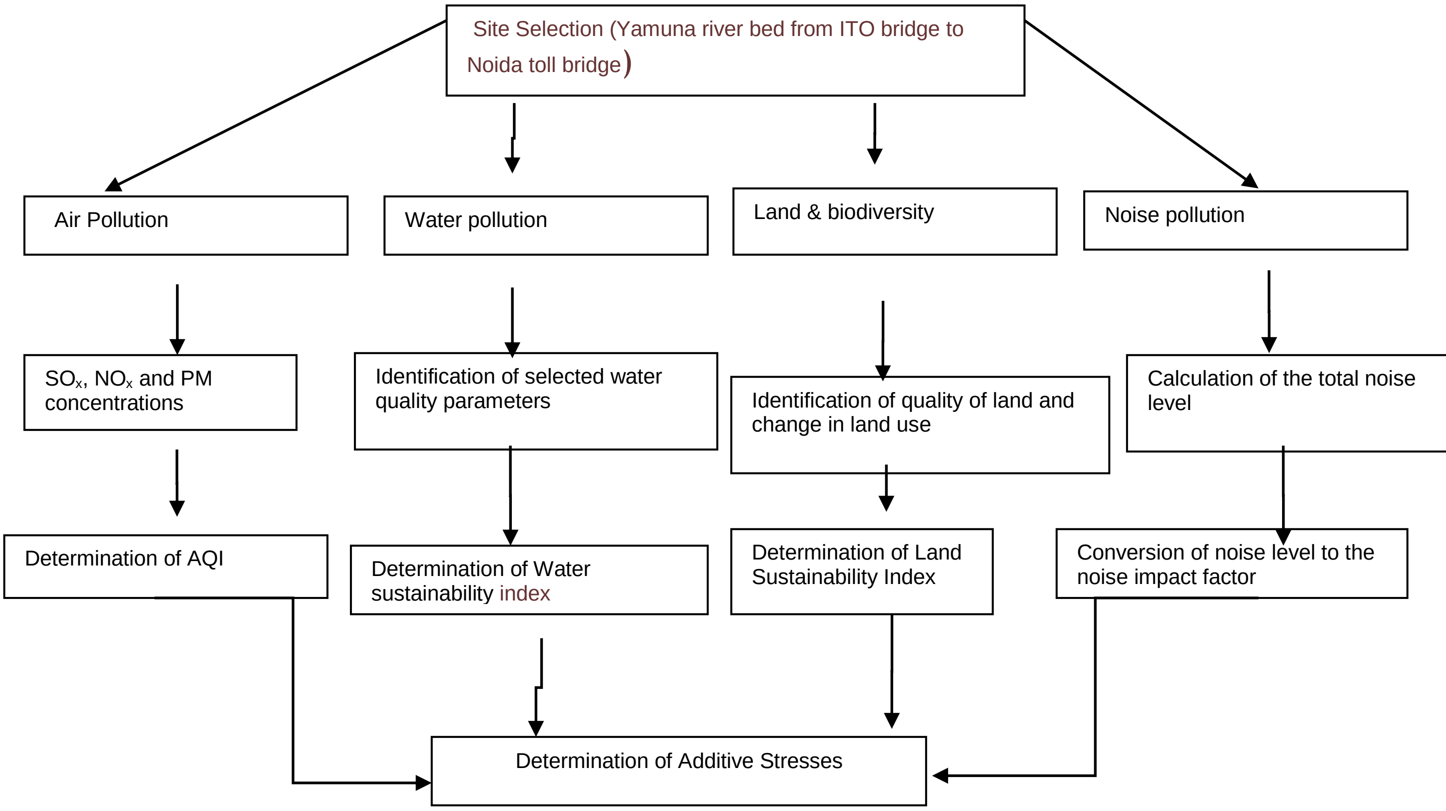


**Fig.4:** Methodology for determination of additive stresses

## DISCUSSION

1. **Pressure indicators**

In this case the pressure indicators identified are the large scale human interference which would be further enhanced through the construction of the Delhi Metro.

2. **State indicators**

According to the state of the ecosystem it can be safely concluded that most of the components including soil and water have already crossed the acceptable concentrations of their sustainability. Any further intervention especially on the flood banks or the wetland zone would not only threaten the state of the air and soil but also cause long term impacts to the biodiversity and water.

3. **Threshold indicators**

These indicators relate pressure and state indicators. They are “distance-to-target” type of indicators.

## CONCLUSION

The threshold indicators can be summarised thus:

Total Stress on the Ecosystem (The total index) = Ax AQI + B x WQI + Cx LQI + DxNQI

In our case the actual Stress on the eco-system,

S= 5.68+0.0602+1.608+0.1522+0.437= 7.92

The Maximum Stress on the Eco-System=12+1+3+1+1=18

Therefore the Sustainability Threshold Index is,

Sustainability Threshold Index= 7.92/18=0.44

The tipping points for the Sustainability of each identified component can be calculated as;

Threshold index=Actual Stress/ Maximum permissible Stress

1. Air= 5.68/12= 0.4733
2. Water= 0.0602/1= 0.0602
3. Noise=1.608/3=0.536
4. Land=0.1522/1= 0.1522
5. Biodiversity= 0.437/1=0.437

Hence the tipping point would be close to the 1/3rd of the maximum value. This value is assumed on the basis of the ability to regenerate without a change in state of the renewable and non-renewable sources, in order to enable them to withstand stress conditions.

### CONFLICT OF INTEREST

There is no conflict of interest.

### ACKNOWLEDGEMENTS

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### FINANCIAL DISCLOSURE

None

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