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FLOOD MODELING IN THE MAHAWELI RIVER REACH FROM KOTMALE TO POLGOLLA

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ABSTRACT

The occurrence of floods and inundation of the low lands adjacent to the Mahaweli River reach from Gampola to Polgolla were very frequent prior to the Kotmale reservoir project in mid 1980s. However, during last two decades with the construction of the Kotmale dam, the regulation of flow by the reservoir has reduced the inundation risk of these lands, which were vulnerable to frequent flooding. As a result, these lands are developed at an increasing rate and more people have started to live in them. This fact gives an alarming signal to the authorities, as the damage that might be caused due to an extreme flood event could be significant. It is therefore of paramount importance that comprehensive flood modeling and inundation analysis of the Mahaweli River reach between Kotmale and Polgolla is carried out.

This paper presents the flood modeling and inundation analysis in the Mahaweli river reach from the Kotmale dam to Polgolla barrage using the HECRAS model. The HECRAS model was set up for the river reach using the river cross-sections at 200 m intervals from Kotmale dam to Polgolla barrage. The model was applied to estimate the water stages along the river reach for the floods of different return periods. Though the Kotmale reservoir acts as a flood control reservoir for floods of medium return periods, it becomes ineffective to reduce the flood levels in the downstream flood plains due to floods of high return periods when it has to release high discharge. Inundation areas in the downstream of the dam due to several flood discharges are presented.

1 INTRODUCTION

Mahaweli River; the longest river in Sri Lanka is flowing over more than 335 km and it has several major branches. More than 40% of the demand for the electric power in the country depends on this river while it provides irrigation water for a large area.

Many structures such as dams, weirs, etc., are built along the river to harness its hydroelectric and irrigation potential. Kotmale dam and Polgolla barrages are such constructed structures for generating hydropower and diverting water, respectively.

Kotmale project is one of five major head works projects being undertaken under the Mahaweli Development Scheme. It is the most upstream of these projects and develops the hydro potential of a major right bank tributary of the Mahaweli River, the Kotmale Oya. The development consists essentially of regulating reservoir on the Kotmale Oya formed by Kotmale dam at a point about 6.5 km upstream of its confluence with the Mahaweli River. The dam is a rock fill dam, is about 87 meters height and covers an area of 6.70 square kilometers.

Polgolla barrage is a weir constructed to divert the Mahaweli river water mainly for irrigation purposes. Sudu Ganga carries the diverted water to the North Central Province. Water flowing along the Mahaweli River passes through Victoria, Randenigala and Rantembe dams generating of electricity.

After the construction of the Kotmale dam the floods to downstream were decreased. Therefore it can be ensured that the reservoir acts as a flood-controlling reservoir itself. People use the downstream flood plain for development processes and for domestic purposes. However with the high discharges from the Kotmale reservoir, the downstream flood plain would be at a risk. The analysis presents inundation levels and areas along the Mahaweli River from the Kotmale dam to the Polgolla barrage.

Figure 1.1 shows the details of the catchments for Kotmale dam and Polgolla barrage. The areas are given in Table 1.1.

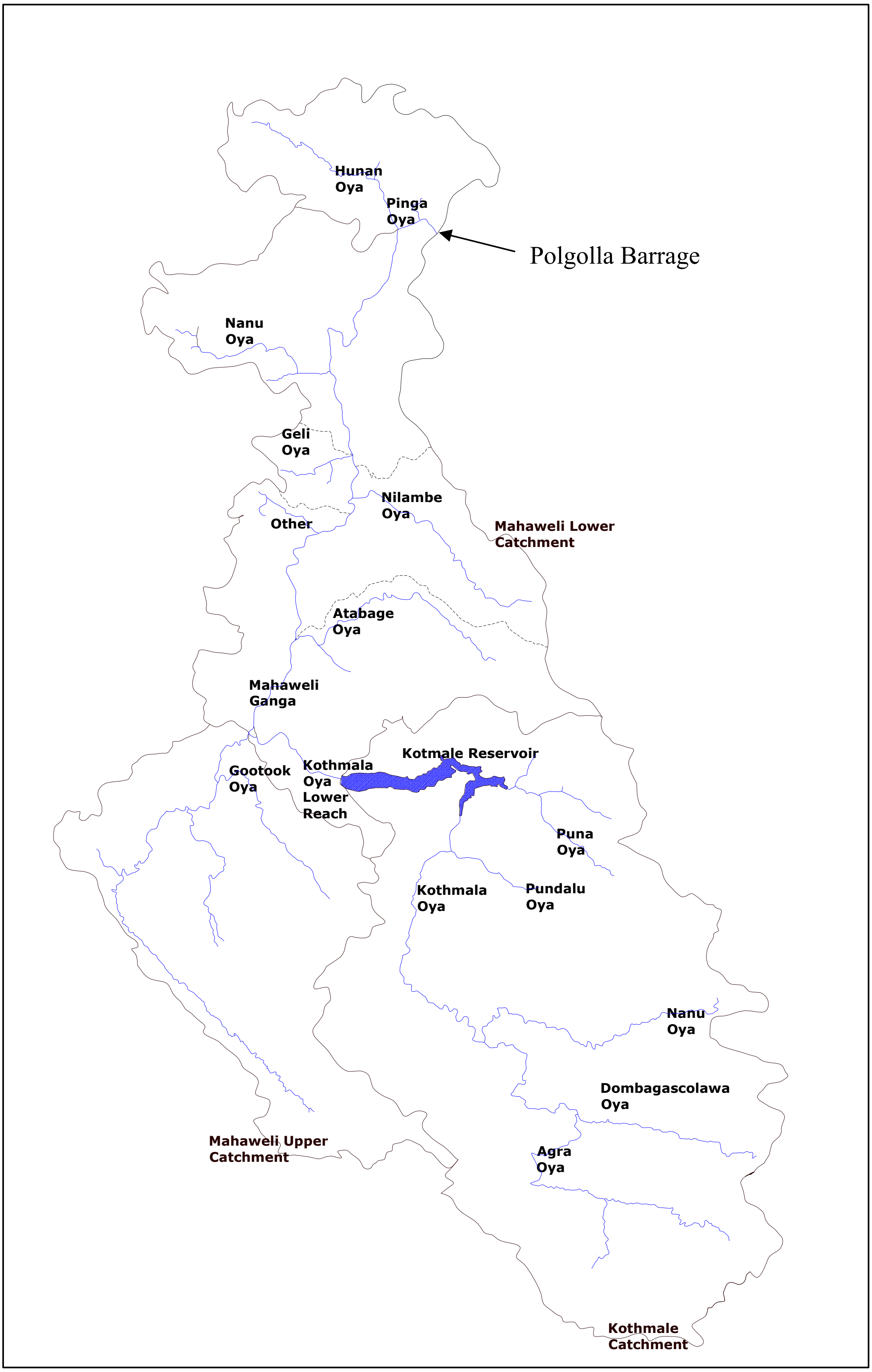

Figure 1.1 The Mahaweli basin above Polgolla barrage

Table 1.1. Details of the sub basins

No	Sub basin name	Area / (km^2)
1	Atabage Oya	94.35
2	Nilambe Oya	71.27
3	Geli oya	15.88
4	Nanu Oya	81.66
5	Hunan/Pinga Oya	75.22
6	Mahaweli Lower	434.62
7	Mahaweli Upper	215.00
8	Kothmala Oya	535.21
9	Other	49.77

2. THEORETICAL BACKGROUND FOR THE MODEL APPLICATION

HEC-RAS (version 3.1.1)[1] is capable of performing one-dimensional water surface profile calculations for steady gradually varied flow in natural or constructed channels. Sub critical, supercritical, and mixed flow regime water surface profiles can be calculated.

Water surface profiles are computed from one cross section to the next by solving the Energy equation with an iterative procedure called the standard step method. The Energy equation is written as follows and Figure 2.1 describes the notations.

$$Y_2 + Z_2 + (\alpha_2 V_2^2 / 2g) = Y_1 + Z_1 + (\alpha_1 V_1^2 / 2g) + h_e \quad (1)$$

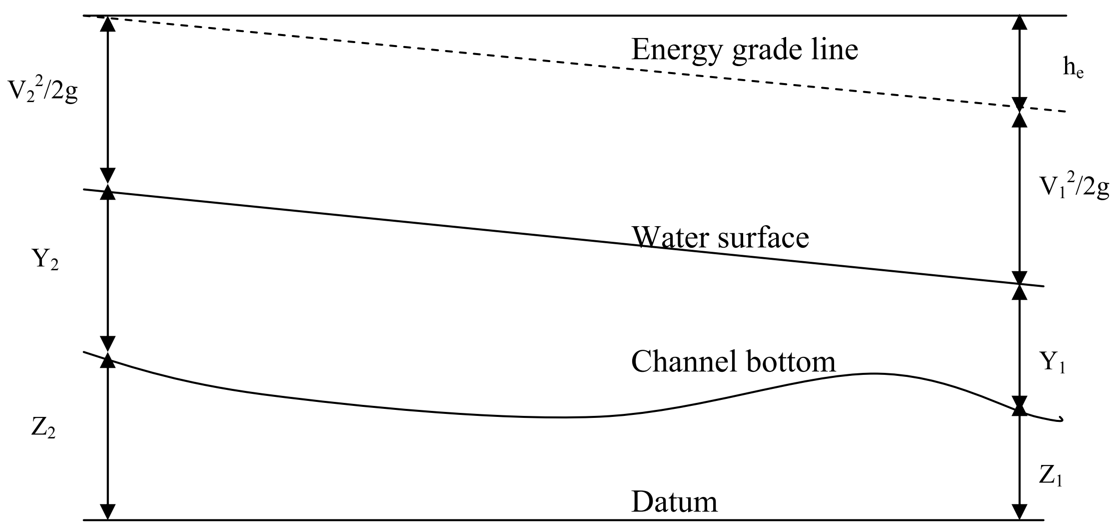

Figure 2.1 Representation of terms in the energy equation

The energy head loss (h_e) between two cross sections is comprised of friction losses and contraction or expansion losses. The equation for the energy head loss is as follows.

$$h_e = LS_f + C((\alpha_2 V_2^2 / 2g) - (\alpha_1 V_1^2 / 2g)) \quad (2)$$

The distance weighted reach length, L is calculated as follows.

$$L = (L_{lob}Q_{lob} + L_{ch}Q_{ch} + L_{rob}Q_{rob}) / (Q_{lob} + Q_{ch} + Q_{rob}) \quad (3)$$

3. METHODOLOGY

3.1 Analysis of the discharge

Daily rainfall data at 15 gauging stations over the catchments are available and were used in the study.

Annual maximum daily rainfall over a period of 23 years at the Sandringham Estate, were observed to be fitting into the Gumbels distribution [(3)]. Based on that distribution, rainfall having a 200-year return period is obtained as 175 mm per day.

Rainfall for the catchments at a low time resolution of at least hourly maximum rainfall is required normally in flood flow analysis. Therefore, in the absence of hourly rainfall information at this stage, 9 rainfall scenarios events with different hourly intensities were considered. Peak flows were then calculated using SCS Dimensionless Triangular Unit Hydrograph Method for each of these events. (Table 2.2).

Table 2.2. Difference rainfall scenarios considered

No	Rainfalls	Total Flow at Polgolla /(m^3/s)
1	87.5 mm/hr of rainfall in 1 hour	8291
2	43.75 mm/hr of rainfall in 2 hours	7833
3	29.17 mm/hr of rainfall in 3 hours	7519
4	105 mm/hr of rainfall in 1 hour	8840
5	52.5 mm/hr of rainfall in 2 hours	8290
6	35 mm/hr of rainfall 3 in hours	7912
7	122.5 mm/hr of rainfall 1 in hour	9388
8	61.25 mm/hr of rainfall 2 in hours	8746
9	40.83 mm/hr of rainfall 3 in hours	8306

3.2 HEC RAS model application

The HEC-RAS model has been set up for the Mahaweli River from the downstream of the Kotmale dam up to the Polgolla barrage. The Upper Mahaweli River joins the river at several kilometers downstream of the Kotmale dam. There are also several small tributaries joining the river as shown in Figure 1.1. The model requires the river geometry to be defined with cross sections with riverbed elevations. The one-dimensional cross-sectional averaged computation requires the roughness values at the banks and the river.

The river cross sections were read from 1:10000 scale maps produced by the Survey Department, Sri Lanka. The cross sections along the river were used at 200 m intervals throughout the river reaches. The HEC-RAS program was run for 9 cases as described in Table 2 and the inundation levels were found.

3.3 Boundary conditions

The boundary conditions should be defined according to flow analysis. The model was run in mixed flow situations, so that two boundary conditions were required in upstream and downstream in order to get the inundations. Upstream boundary condition was set up to be the normal slope condition and the downstream boundary condition was set up to a known elevation using the weir formula [(2)].

3.4 Inundation analysis for different discharges.

The analysis was carried out for nine different discharges as given in the Table 2.2. In each case the boundary conditions were given as describes above. The inundation levels and the inundation areas were plotted in the HEC-RAS software and the most vulnerable places were identified.

4. RESULTS

4.1 Verification

The flood occurred in 1978 is the latest recorded of high magnitude. According to the estimates of the Irrigation Department, the maximum discharge is 3050 m^3/s at Peradeniya. The water level rose up to the railway bridge across the Mahaweli River at Peradeniya, which are about 15m above the riverbed. In the absence of any other data for model verifications, the model was applied to simulate this condition. Runoff generated by a rainfall of 29.2 mm/hr for a period of 3 hrs from the basin except the sub basin above Kotmale dam was taken. To match the discharge of 3050 m^3/s at Peradeniya an outflow of 1338 m^3/s from the Kotmale reservoir was considered. The water stage at Peradeniya Railway Bridge due to 1978 flood is computed as 14.6 m above the riverbed.

4.2 Identification of Critical locations

From the nine discharges, three different were selected to plot the inundation width and the Figure 4.1 gives it. According to that figure 12 critical locations were identified along the river and the Table 4.1 gives the inundation widths of those critical locations in nine scenarios. The length of the river was measured from the Polgolla barrage to Kotmale dam.

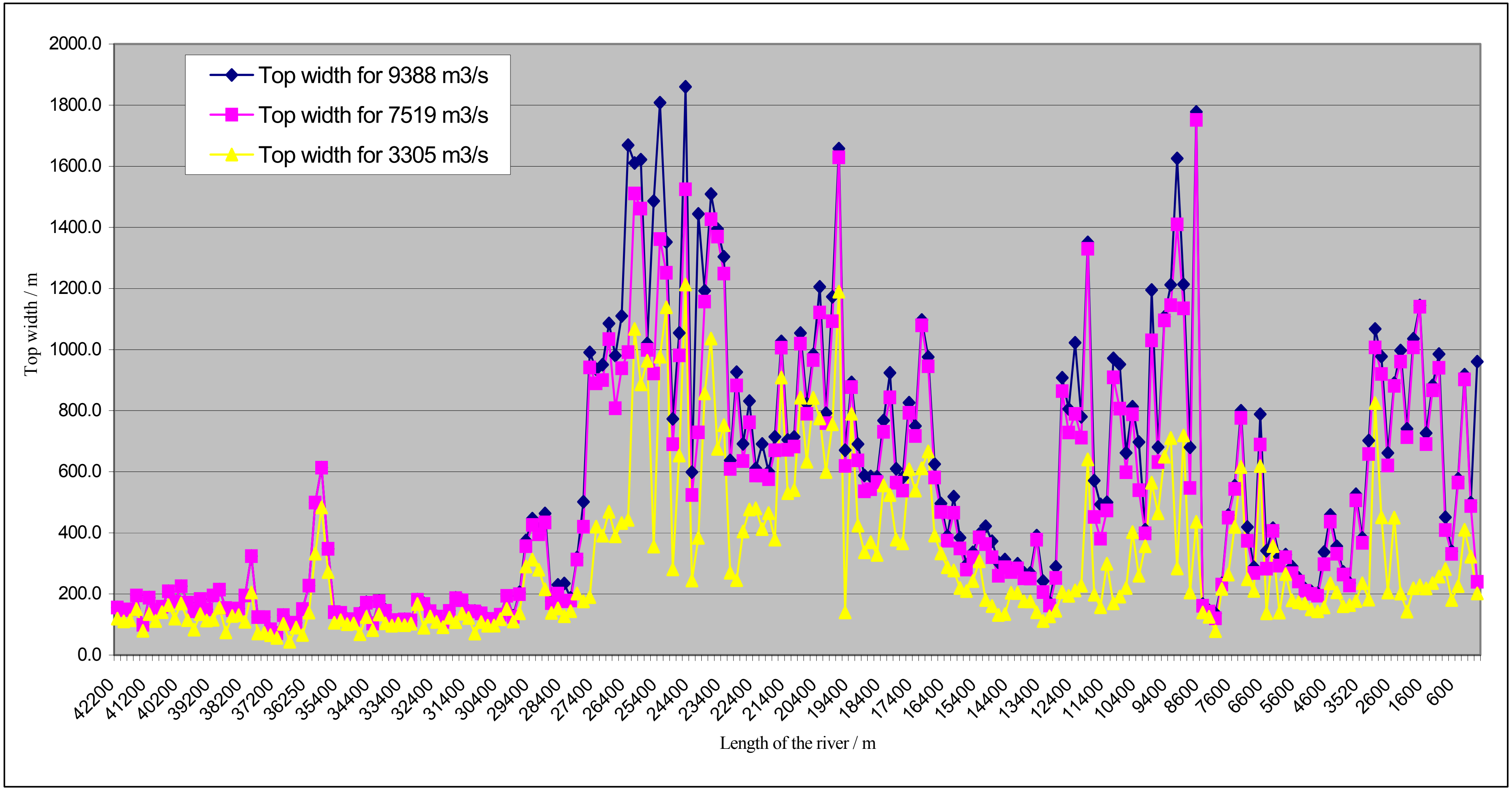

Figure 4.1 Inundation top widths for three different discharges

Table 4.1 Inundation top widths (by meters) at critical locations

	Flows / m3/s								
Lengths / m	**9388**	**8840**	**8746**	**8306**	**8291**	**7912**	**7833**	**7519.0**	**3305**
26400	1669.1	1644.0	1638.9	1618.7	1619.3	1598.0	1594.6	991.5	442.6
26200	1610.7	1600.3	1598.2	1589.9	1590.0	1581.4	1579.9	1510.9	1067.3
26000	1621.7	1608.9	1606.2	1595.9	1596.1	1585.3	1583.6	1461.1	886.2
25600	1486.3	1483.5	1482.9	1480.6	1480.7	1126.4	1091.0	921.5	354.7
25400	1808.3	1805.0	1804.3	1801.7	1801.8	1384.0	1380.0	1361.3	976.8
24600	1860.0	1860.0	1860.0	1562.8	1563.9	1543.9	1540.6	1524.7	1212.8
24200	1444.3	802.8	796.3	772.1	773.5	750.9	747.2	729.0	383.7
23800	1509.1	1499.4	1493.0	1469.0	1470.4	1448.0	1444.3	1426.3	1035.9
23600	1394.4	1388.7	1387.0	1380.7	1381.1	1375.2	1374.3	1369.6	675.3
19800	1657.8	1650.0	1648.1	1641.4	1641.8	1635.5	1634.5	1629.4	1189.4
9200	1625.9	1565.6	1553.1	1501.9	1503.3	1456.8	1448.2	1409.6	283.7
8800	1777.8	1770.5	1768.9	1762.7	1762.9	1757.3	1756.2	1751.6	436.2

5. DISCUSSION AND CONCLUSIONS

According to the figures 4.1 it can be clearly seen that the inundation width at the following locations are higher than the rest of the area.

I. 0 m to 3200 m
II. 5400 m to 7600 m
III. 8000 m to 11200 m
IV. 15800 m to 17200 m
V. 18400 m to 20800 m
VI. 22000 m to 26800 m

Sometimes these top widths are higher than one kilometer with the high discharges. However, people in the above mentioned locations should not be cleared, because the analysis was shown the critical situations with the highest possible outflow from the Kotmale reservoir.

The analysis was carried out on the basis of geometric data from 1:10000 maps. For a detailed analysis, it is better to input the cross sections using GIS maps and for the hydrological analysis the actual flows can be used.

8. REFERENCES

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