A HYDROLOGICAL INVESTIGATION OF THE SOUTHERN DEVELOPMENT AREA

by

Palitha Manchanayake

Abstract

This paper deals with a hydrological investigation carried out for the Southern Development Area. It discusses the rainfall variability, the evaporation, potential evapo-transpiration, and the runoff of the locality. As the annual lake evaporation has been identified to be higher than the observed annual rainfall at Hambantota, certain possible remedial measures such as the applying of a thin, non toxic cetyl alcohol film on the proposed reservoir surfaces as an evaporation inhibitor has been suggested, in order to safe guard the available limited water resource.

1.0 Introduction

The Southern Development Authority is launching a massive program to develop the neglected areas of southern Sri Lanka. This development consists of different components such as the 'Ruhunupura Project', Diversion of Menik Ganga and Uma Oya to the development area, Construction of an International Airport, Construction of an Express Highway connecting the new 'Ruhunupura' city with Colombo etc. The 'Ruhunupura Project' involves the development of the natural harbour at Hambantota into one of Asia's top ports which would service the 200 odd ships that now bypass Sri Lanka daily on their long voyage between Aden and Singapore by the provision of bunkering and other services. Another aspect is the development of the so called "eco-friendly nature city"- 'Ruhunupura', which is surrounded by renowned wildlife parks and sanctuaries such as Yala, Bundala, Kirindi Oya, Handapanagala and Walawe attracting worldwide tourists.

In the context of the possible diversion of Menik Ganga and the Uma Oya into this development area, it was intended to investigate some of the hydrological characteristics of the area. It should be mentioned that the author carried out the study with the data available to him, and the conclusions arrived at, may have to be viewed in that perspective. The rainfall records available were for 80 years from 1896 to 1975. The riverflow records were for 30 years from 1944 to 1973.

2.0 Rainfall Variability

Of the area covered by Southern Development Program, the two districts of Hambantota and Moneragala are generally experiencing severe water shortages. As such, it was decided to investigate the rainfall variability in these two districts, individually and jointly. Even though the catchment wise analysis of rainfall seems more appropriate, and because the surface runoff from a river basin depends on so many hydrological factors such as the topography, geology, soil types, vegetation, stream network and the catchment slope etc. , it was intended to look at the mere rainfall variability on a district basis, in this investigation. Thus, in order to get an independent view point of the rainfall variability, it was thought to evaluate the district rainfalls on a seasonal basis, and the data published by Harihara Ayyar (1977) was used for this study. The Probabilities of occurrence of large scale deficiencies of rainfall, their recurrence intervals and the periodicity of the chances of deficient rainfall in one crop season being followed by a deficient rainfall in the immediate next crop season etc. are generally needed for long term planning of agricultural and irrigation purposes.

Harihara Ayyar (1977) has tried to use different criteria such as using the mean deviation, one and a half times the mean deviation, twice the mean deviation, and the standard deviation etc., and they were found to be not that satisfactory. However, a departure of 25% of the long term mean as the limiting value of the possible variation around the mean, has been found by Harihara Ayyar (1977) to be a more suitable criterion for agricultural meteorology. It could also be mentioned that there is no universally accepted criterion for designating the rainfall as 'deficient' or 'excess', as it varies according to the purpose in view,

Eng. Palitha Manchanayake BSc.Eng (Hons), M.Eng.Sc (NSW), CPEng, FIE (SL), Hydrologist, Flood Forecasting Centre, Commonwealth Bureau of Meteorology, Sydney, Australia.

whether it is for agriculture, irrigation, reservoir storage or any other usage. For the present study too, a variation of 25% of the long term mean has been accepted, and thereby the values of rainfalls below 75% of the long term mean have been identified as 'droughts' (or deficient rainfalls), and the values of rainfalls above 125% of the long term mean have been identified as the 'floods' (or excess rainfalls), and were studied on a district basis.

The word 'drought' could be referred to as a relative term, as it has different meanings at different parts of the world. Hudson & Hazon (1964) point out that in Bali (of Indonesia) a period of six days without rain is considered a 'drought'; and in certain parts of Libya 'droughts' are recognised only after 2 years without rain, while in Egypt any year the River Nile does not flood is considered a 'drought' regardless of its rainfall.

The data published by Harihara Ayyar (1977) covering the 22 districts of Sri Lanka, is for a period of 80 years starting from 1896 to 1975. The 'droughts' (deficient rainfalls) and the 'floods' (excess rainfalls) during the individual Yala and Maha seasons for the two districts namely Hambantota and Moneragala were extracted and their frequencies of recurrence were calculated. The recurrence frequencies of droughts are given in Table 1, and the recurrence frequencies of droughts in succession are given in Table 2, for Hambantota and Moneragala districts for both Yala and Maha seasons. Similarly the recurrence frequencies of floods, and the recurrence frequencies of floods in succession are given in Tables 4 & 5 respectively. The Table 3 gives the recurrence frequencies of droughts in any adjoining Yala & Maha seasons for Hambantota and Moneragala districts.

3.0 Evaporation

The estimation of evaporation is of importance in many hydrologic problems associated with planning and operation of reservoirs andirrigation systems. In an arid zone like Hambantota, this estimation is particularly important to conserve the scarce water resource. However, the exact measurement of evaporation from a large body of water is a difficult task to perform. It is usually being measured by using the Standard U.S. Weather Bureau open pan

Table 1. Recurrence Frequency of Droughts

District	Yala Season	Maha Season
1. Hambantota	1 in 4.2 years	1 in 5 years
2. Moneragala	1 in 4.7 years	1 in 5 years
3. Both Districts (taken together)	1 in 11.4 years	1 in 8 years

Table 2. Recurrence Frequency of Droughts in Succession

District	Yala Season	Maha Season
1. Hambantota	1 in 13.3 years	1 in 40 years
2. Moneragala	1 in 11.4 years	1 in 11.4 years
3. Both Districts (taken together)	1 in 80 years	1 in 40 years

Table 3. Recurrence Frequency of Droughts in any Adjoining Yala & Maha Seasons

District	Any Two Adjoining Yala or Maha Seasons
1. Hambantota	1 in 17.7 years
2. Moneragala	1 in 11.4 years

Table 4. Recurrence Frequency of Floods

District	Yala Season	Maha Season
1. Hambantota	1 in 4.4 years	1 in 7.3 years
2. Moneragala	1 in 4.4 years	1 in 6.7 years
3. Both Districts (taken together)	1 in 16 years	1 in 20 years

Table 5. Recurrence Frequency of Floods in Succession

District Yala Season Maha Season		
1. Hambantota	1 in 20 years	—
2. Moneragala	1 in 11.4 years	1 in 40 years
3.Both Districts (taken together)	1 in 80 years	—

Table 6. Average Monthly and Annual Evaporation

	Average Monthly and Annual Evaporation (in millimetres)												
Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Ridiyagama Pan Evaporation = (Row 1)	134	140	156	137	161	161	166	187	163	148	108	127	1788
Ridiyagama LakeEvaporation=(Row1) x 0.7	94	98	109	96	113	113	116	131	114	104	76	89	1253
Tissamaharama Pan Evaporation = (Row 2)	136	133	148	149	157	165	168	170	157	147	118	123	1771
Tissamaharama Lake Evaporation=(Row 2)x 0.7	95	93	104	104	110	116	118	119	110	103	83	86	1241
Hambantota Pan Evaporation calculated using Penman,1948 = (Row 3)	189	193	205	183	180	192	205	205	192	174	153	158	2229
Hambantota Lake Evaporation=(Row 3)x 0.7	132	135	144	128	126	134	144	144	134	122	107	116	1566

Table 7. Observed Rainfall & Calculated Lake Evaporation for Hambantota

	Average Monthly and Annual Lake Evaporation & Rainfall (mm)												
Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Hambantota Lake Evaporation calculated using Kohler et el,1955	112	118	136	129	124	123	136	136	132	121	105	96	1468
Hambantota Observed Average Rainfall	101	58	66	109	121	55	43	42	46	126	188	121	1076

evaporimeters. The pancoefficient which is the ratio of annual lake evaporation to pan evaporation has been observed to be quite consistent for most of the countries around the world, and for a Standard U.S. Weather Bureau Class A Pan, a value around 0.70 has been widely accepted (Linsley, Kohler and Paulhus, 1983). The pan evaporation observations of Ridiyagama and Tissamaharama are given in Table 6. Their corresponding lake evaporation figures arrived at, by multiplying the pan evaporation data by 0.7, are also given in Table 6. However, it has been noted that the data collected for Tissamaharama was not from a U.S. Weather Bureau Class A Pan. But the figures for annual lake evaporation for Ridiyagama and Tissamaharama are much comparable being 1253 mm and 1241 mm respectively.

It is also possible to compute pan evaporation using easily available or derivable meteorological parameterslike radiation, sunshine, cloud cover, wind, vapour pressure and the air temperature. Arulananthan (1978) has computed pan evaporation using parameters such as total solar radiation received, mean dry bulb & dew point temperatures of the air and the total wind run at pan level, following the method suggested by Penman (1948), and the monthly values of pan evaporation calculated for Hambantota are also given in Table 6. Using these figures, their corresponding monthly lake evaporations were arrived at, by the use of the same 0.7 multiplication factor. The annual lake evaporation (calculated by using Penman, 1948) for Hambantota totals close to 1566 mm.

4.0 Potential Evapo-Transpiration

Transpiration is the process by which water leaves the body of a living plant and reaches the atmosphere as water vapour. The water is taken up by the plant-root system and escapes through the leaves. The factors that affect the transpiration would be the atmosphreric pressure, temperature, wind, light intensity and characteristics of the plant. The transpiration is essentially confined to daylight hours and the rate of transpiration depends upon the growth periods of the plant, while the evaporation continues all through the day and night although the rates are different. While transpiration takes place from plants, the land area in which plants stand also loses moisture by the evaporation of water from soil and water bodies. The quantity of water consumed by a cropped field through transpiration by the crops and by evaporation from the soil, is referred to as the evapo-transpi-

Table 8. Specific Yields & Runoff / Rainfall Ratios

River Basin and Location	Catchment Area (sq.km)	Average Rainfall (mm)	Average Runoff (mcm)	Specific Yield (mcm/sq.km/yr)	Runoff / RainfallRatio
Kirindi Oya at Wellawaya	157	2298	99.2	0.62	0.27
Kirindi Oya at Lunugamwehera	902	1829	385.6	0.43	0.23
Menik Ganga at Kataragama	778	1708	243.9	0.31	0.18
Urubokke Oya at Julampitiya	140	2506	139.2	1.00	0.40
Uma Oya at Welimada	177	2008	173.8	0.98	0.49
Walawe Ganga at Embilipitiya	1562	2193	1377.2	0.88	0.40

ration or the consumptive use. As it could be expected, the consumptive use of a crop will depend upon the kind of crops grown, the stage of growth of the crops, and the prevalent weather conditions. When water is not a limiting factor and the cropped field is under saturated soil moisture conditions, the evapo-transpiration taking place is termed the 'potential evapo-transpiration', which is practically the 'lake evaporation'. Water usage by the crops are generally being calculated by multiplying the potential evapotranspiration by the crop coefficients which specifically represent a particular type of crop and its stage of growth.

Arulananthan (1978) has computed the lake evaporation using the co-axial graphical technique (given in Kohler, Nordensen & Fox, 1955) utilising the parameters such as mean air temperature, dew point temperature, solar radiation and the pan level wind. The values of lake evaporation thus calculated for Hambantota are given in Table 7, and Arulananthan (1978) arrives at an annual total of 1468 mm. The average monthly rainfalls observed at Hambantota amounts only to an annual total of 1076 mm, and they are given in Table 7. In arriving at an average figure for lake evaporation for the area, whether we take the 1253 mm of Ridiyagama, or 1241 mm of Tissamaharama, or 1566 mm of Hambantota (calculated using Penman,1948), or 1468 mm of Hambantota (calculated using co-axial graphical techniques) is a question to be answered by the water-planners, depending on what they intend using in their calculations. But the basic fact to be noticed is that all those figures of lake evaporations are higher than the average annual observed rainfall at Hambantota by at least 165 mm considering the annual totals, and that the monthly evaporation is greater than the monthly rainfall of Hambantota during nine months of the year. This suggests the necessity to conserve water during the wet season in order to use it during the dry spell.

5.0 Runoff

The runoff or yield characteristics of some of the available locations in and around the "Southern Development Area" were studied, and the results are given in Table 8. The specific yields, or the average runoff per square kilometre of catchment per year, were calculated for Kirindi Oya at Wellawaya, Kirindi Oya at Lunugamwehera, Menik Ganga at Kataragama, Urubokke Oya at Julampitiya, Walawe Ganga at Embilipitiya and for Uma Oya at Welimada. The values of specific yields varied from 0.31 at Kataragama, and 0.43 at Lunugamwehera to 0.98 at Welimada and 1.00 at Julampitiya. The runoff/rainfall ratios varied from 0.18 at Kataragama and 0.23 at Lunugamwehera to 0.40 at Julampitiya, 0.40 at Embilipitiya and 0.49 at Welimada. It is noticed that the lowest specific yield and the lowest runoff/rainfall ratio were corresponding to Menik Ganga at Kataragama, which implies that it has only a slim chance of a trans-basin diversion from it when compared to other basins. At the same time, Uma Oya at Welimada shows the highest specific yield and the highest runoff/rainfall ratio of the nearby catchments, indicating a more favourable option in the context of water availability for trans-basin diversions.

These results were arrived at, using the riverflow records for the 30 years from 1944 to 1973. The changes, if at all, in the last two decades by way of irrigation developments, land and water use patterns have not been encountered in the study.

6.0 Conclusions

It is quite evident that the rainfall in the area is really scarce and the recurrence of the 'droughts' (worked out on the rainfalls alone) for Hambantota and Moneragala are quite frequent, namely 1 in 4.2 years, and 1 in 4.7 years respectively for the Yala season; and 1 in 5 years for the Maha season.

The annual lake evaporation of Ridiyagama and Tissamaharama have been found to be 1253 mm and 1241 mm respectively. The annual lake evaporation calculated for Hambantota using the method suggested by Penman (1948) was 1566 mm. The lake evaporation calculated for Hambantota using Kohler, Nordensen & Fox (1955) was 1488 mm annually. The observed average annual rainfall at Hambantota was found to be 1076 mm. Thus, the lake evaporation has been higher than the average annual observed rainfall by at least 165 mm, considering the annual totals. Also, it is noticed in Table 7, that the monthly lake evaporation has been greater than the monthly rainfall at Hambantota during nine months of the year. This suggests the necessity to conserve water during the three wet months of the year in order to use it during the dry spell.

The study revealed that the lowest specific yield and the lowest runoff/rainfall ratio was for Menik Ganga at Kataragama, while the highest specific yield and the highest runoff/rainfall ratio was for Uma Oya at Welimada. This demonstrates a lesser viability of a trans-basin diversion from Menik Ganga, while it illustrates Uma Oya as a more favourable option in the context of water availability. The water planners designing the new system will have to go into details and decide on it.

7.0 Some Suggestions for consideration

(1) Whether the trans-basin diversions are done or not, it will be a very important aspect to safe guard the precious available water from the natural evaporation of the locality. As the volume of water lost by evaporation is directly proportional to the surface area of the water body, the reduction of surface area wherever possible and feasible, reduces the evaporation losses. Different measures such as avoiding shallow water storages, and opting for deeper reservoirs with smaller water spreads, wherever possible, in designing of the system, would be an aspect to be considered. Again, this will be at the hands of the water planners.

(2) From the Table 7, it is evident that the annual lake evaporation of Hambantota is much greater than the observed average rainfall of the area. So in order to make use of the available rainfall, one solution would be to take steps to reduce the evaporation from the reservoirs by applying a thin chemical film on the water surface.

Certain chemicals such as cetyl alcohol (hexadeconal) and stearyl alcohol (octadeconal) form monomolecular layers on a water surface. These layers act as evaporation inhibitors by preventing the water molecules to escape past them. The thin film formed has the following desirable features:

1. The film is strong and flexible and does not break easily due to wave action.

2. If punctured due to impact of raindrops or by birds, insects etc., the film closes back soon after.

3. It is pervious to oxygen and carbon dioxide; the water quality is therefore not affected by its presence.

4. It is colourless, odourless and non-toxic.

Cetyl alcohol has been found to be the most suitable chemical for use as an evaporation inhibitor. It is a white, waxy crystalline solid and is available as lumps, flakes or powder. It can be applied to the water surface in the form of powder or emulsion. Its specific gravity is 0.85 and has a melting point between 40 to 50 degrees Centigrade. The monomolecular film formed by cetyl alcohol on water surfaces is only about 0.015 micron in thickness.

It has been shown that water treated with cetyl alcohol is safe for human consumption and for fish and other aquatic life. On the basis of experiments conducted at Umberumberka and Corella lakes in Australia for town water supplies in dry and arid parts of the country, it is stated that for winds of upto 8 km/hr, the evaporation savings have been 40 % or more; and when the wind velocity exceeds 24 km/hr, no savings could be affected (Varshney,1986).

However, the public response and the general acceptance of this non-toxic cetyl alcohol film on the water bodies of rural Sri Lanka will have to be tested. Also, the long term bio-degradability of cetyl alcohol in the environment will have to be found out.

(3) The author carried out this study with the data available to him, and the conclusions arrived at, may have to be viewed in that perspective. As such, a study on the same lines with more recent rainfall and river flow data is suggested.

(4) Another aspect to investigate would be to utilize effective and economically feasible irrigation systems such as sprinkler-irrigation and/ or drip-irrigation schemes. It comes to my mind a certain drip irrigation system for an orange cultivation at Eluvankulama, north of Puttalam,which has a similar climate to Hambantota area. The success or failure of these cultivations, and the lessons for improvements from them are to be investigated.

8.0 References

1. Arulananthan J.T. (1978), Evaporation and potential evapotranspiration in Sri Lanka, Department of Meteorology, Colombo 7.

2. Harihara Ayyar P.S. (1977), The behaviour of the Yala and Maha season rainfall in Sri Lanka, Department of Meteorology, Colombo 7.

3. Harihara Ayyar P.S. (1977), Water requirement of crops in Sri Lanka, Department of Meteorology, Colombo 7.

4. Hudson H.E. & Hazon R. (1964), Droughts and low streamflow, in Hand Book of Applied Hydrology Edited by Ven Te Chow, Mc. Graw Hill, U.S.A.

5. Hydrology Division (1974), Annual Rainfall and Surface Runoff, Irrigation Department, Colombo 7.

6. Kohler M.A., Nordensen J.J., & Fox W.W. (1955), Evaporation from Pans and Lakes, U.S. Weather Bureau Research Paper 38.

7. Linsley R.K., Kohler M.A., Paulhus J.L.H. (1983), Hydrology for Engineers, McGraw-Hill International Book Company, Tokyo.

8. Penman H.L. (1948), Natural Evaporation from Open Water, Bare Soil and Grass, Proceedings of Royal Society, London.

9. Sirinanda K. U. (1985) , Droughts in Sri Lanka, in Some Aspects of Water Resources of Sri Lanka With Special Reference To Hydrology, National Committee of Sri Lanka for the International Hydrological Programme, Irrigation Department , Colombo 7.

10. Subramanya K . (1984) , Engineering Hydrology , Tata McGraw - Hill Publishing Company Limited., New Delhi.

11. Varshney R. S.(1986), Engineering Hydrology, Nem Chand & Bros, Roorkee (U. P.).