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Analysis of Pan Evaporation Data in Peninsular Malaysia

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Abstract: This paper attempts to highlight the findings of the direct method of measurement for evaporation on the daily manual pan evaporation data collection and availability analysis from the pan evaporation data provided by the Department of Irrigation and Drainage (DID) Malaysia using the U.S. Class 'A' evaporation pan stations located in Peninsular Malaysia. It also aims to review and analyse the average daily pan evaporation at 14 evaporation stations for the year 2015, monthly and annual pan evaporation data at five evaporation stations for the years 2011 to 2015 in Peninsular Malaysia with the data provided by DID Malaysia through a 5-year trend analysis and will discuss on the current issues pertaining to the pan evaporation data collection practices. The findings will later identify, propose and recommend on the best approach to improve the pan evaporation data information standards with reference to the latest World Meteorological Organization (WMO) guidelines and practices as well as the local standards and technology available in the market.

Keywords: Evaporation , World Meteorological Organization (WMO)

1. Introduction

Evaporation is simply defined as water lost to the atmosphere (DID Malaysia, 2009). It is one of the most important parameters in the hydrological cycle and it is a process whereby liquid changes to the gaseous state which then enters through the atmosphere as water vapor. Evaporation is an important weather variable that has numerous applications related to decision making in agriculture, forestry, ecology, hydrology and other fields (Bruton, Hoogenboom, & McClendon, 2000; Fu, Charles, & Yu, 2009).

The rate of evaporation is the amount of water evaporated from a unit surface area per unit of time. The unit of time is normally a day and the amount of evaporation should be read in millimetres (WMO, 2018). Therefore, the unit measurement for evaporation is in mm/day. Depending on the type of instruments used in measuring the rate of evaporation, the usual measuring accuracy is between

0.1 to 0.01 mm. According to DID Manual (2009), the measuring accuracy for evaporation using the

U.S Class 'A' pan of the evaporation pan stations for DID Malaysia is 0.1 mm.

Pan evaporation has been relatively widely observed because of its simplicity in design (Tebakari, Yosgitani, & Suvapimoi, 2005). Reasonable accurate method of measurement from the pans can be achieved satisfactorily and it is least expensive, easy to maintain and will provide good estimates of annual evaporation (WMO, 2018).

2. Objectives

The main objectives of this paper are:

- To apply data observation analysis on daily pan evaporation data acquired from DID Malaysia at 14 numbers of evaporation pan stations in Peninsular Malaysia for the year 2015;
- To apply a 5-year trend analysis on monthly and annual pan evaporation data at five numbers of evaporation pan stations in Peninsular Malaysia for the years 2011 to 2015;
- To propose recommendations on the best management practices to improve the data collection and processing practice with reference to the latest WMO guidelines and practices as well as the local standards and technology available in the market.

3. Literature Review

Literature reviews for past studies includes a desk top research with reference to the WMO standards and guidelines, as well as local standards and technology available in the market. The evaporation estimation that is widely practiced around the world can be obtained by direct measurement and indirect measurement (WMO, 2018). Direct measurement involves the construction physical structures for example the evaporation pans. Among the various types of evaporation pans that are widely used for direct measurement are the U.S Class 'A' Evaporation Pan, Russian GGI-3000 pan, Russian 20 m2 tank, Colorado sunken pan and USGS Lake floating Evaporation pan. In contrast, the measurement of evaporation

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using indirect method involves application of empirical equations and formulae and instrumentations for example the calculation and application of equations on the water budget, energy budget and aerodynamic method or mass transfer method.

However, the U.S Class 'A' evaporation pan is one of the most widely used instruments for evaporation measurement and it has been used by many researchers around the world (Benzaghta M. , Mohammed, Ghazali, & Amin, 2012; Linsley, Kohler, & Paulhus, 1982). Furthermore, evaporation pans installed above the ground are inexpensive and easy to install and easy to maintain (WMO, 2018).

As an example, Australia has installed more than 300 U.S Class 'A' evaporation pans for measurement of daily evaporation as one of the components in their automatic weather stations (BOM Australia, 2020). A study was made at a weather station in Darwin Airport (Northern Territory of Australia which is located nearest to the equatorial belt) with the latest evaporation data for the month of April to June 2020 where the evaporation data was extracted from the Internet address of www.bom.gov. au. The result of the observation evaporation data is as shown in Figure 2. From the graph, the total evaporation from April to June 2020 was 603.9 mm (for 91 days) and the average daily evaporation for Darwin Airport area was 6.67 mm/day with the data performance of 100%.

Figure 2 Daily Evaporation Data at Darwin Airport, Northern Territory, Australia.

Another example is from Indonesia where pan evaporation measurement in Indonesia routinely uses Standardised U.S. Class 'A' pan by some agencies (Wati, Sopahcluwakan, & Fatkhuroyan, 2018). A team of researchers has evaluated the variability of the daily pan evaporation observational data during 2003 through 2012 (10 years data) from 30 meteorological stations in Java and Bali Island, Indonesia and compared it to the Actual (E) and Potential Evaporation (Ep) of a Netherlands software in the same period with statistical method. The end result was that they both produced good performance in the daily and monthly data analysis. The average daily evaporation for Java and Bali Island in Indonesia, which ranges from 2.9 to 5.5 mm/day, was 4.2 mm/day.

In Singapore, a commercial company introduced a commercially-available product which was used successfully in the United States, Australia and other countries to reduce the surface water evaporation and was trialled to a Singapore Bedok reservoir (Babu, Eikass, Price, & Verlee, 2010). In evaluating the efficiency and potential use of the product in reduction of evaporative losses under tropical conditions, three months of evaporation data were collected using four U.S. Class 'A' Evaporation Pans which served as positive and negative controls. The commercial product was applied to the two pans while two other pans served as experimental controls. The data analysis from the pan evaporation study shows more than 30% mean total reduction of reduction by the use of this product. The average daily evaporation for the Bedok Reservoir and other reservoirs in Singapore, which ranges from 5.0 to 6.0 mm/day, was 5.5 mm/day.

Elsewhere, Djaman, Koudahe and Ganyo (2017) reported performing a long-term trend analysis in Togo for the measurement and estimation of annual and monthly pan evaporation at four (4) meteorological stations during 1976 to 2011 namely at Lome, Tabligbo, Atakpame and Sokode. They obtained the results of varied annual pan evaporation of 1803 to 2081 mm at Lome, from 1294 to 1496 mm at Tabligbo, from 1605 to 1974 mm at Atakpame and from 1839 to 1990 at Sokode. Monthy pan evaporation varied from 137 to 197 mm at Lome, 89 to 149 mm at Tabligbo, 137 to 214 mm at Atakpame and 137 to 190 mm at Sokode. The average overall daily evaporation for the four evaporation stations was 4.97 mm/day.

In Malaysia, the most widely practiced method for the measurement of evaporation by government agencies was done by installing the U.S. Class 'A' evaporation pan. DID Malaysia has adopted the Hydrological Procedure (HP) No. 21 (1981) which is in accordance with the WMO standards and guidelines. Before the evaporation data was analysed, data screening and processing was executed through all the pan evaporation data to determine the data availability and performance (Department of Irrigation and Drainage Malaysia, 1982).

The observed data would be rejected if:

1. The daily rainfall exceeded 40 mm/day;
2. the observed evaporation was less than 1.0 mm/day whether rainfall occurred or not;
3. the observed evaporation was greater than 10.0 mm/day, if rainfall occurred; and
4. the observed evaporation was greater than 15.0 mm/day, if rainfall did not occur.

However, the observed evaporation data of greater than 15.0 mm/day (rainfall did not occur) was adopted to ensure that the data were free from splashing of rainwater into the pan, overflowing and other effects. The data that has not been recorded or missing, showing the question marks (?) sign, will be also considered non-performance and excluded for observation.

It should be noted that, as a general guide, the average daily evaporation in Malaysia is generally within the range of 4.0 mm/day to 5.0 mm/day (Malaysia Meteorological Department, 2017). The DID Malaysia gives an average daily evaporation of 5.0 mm/day (DID Malaysia, 2009).

4. Methodology

DID Malaysia has adopted the U.S. Class 'A' evaporation pan in their daily evaporation data collection at evaporation stations located throughout Peninsular Malaysia

(DID Malaysia, 1981). Daily pan evaporation data was recorded manually by observers as early as 8.00 a.m. in the morning and the data was sent, stored, retrieved, processed and published by DID Malaysia.

For the purpose of this study, the following methodology was carried out in obtaining the results:

1.Acquire daily manual pan evaporation data at all available evaporation pan stations in Peninsular Malaysia from DID Malaysia;
2.Conduct an observation analysis on daily pan evaporation data for the year 2015 at a selected 14 numbers of evaporation pan stations in Peninsular Malaysia for data availability and performance;
3.Conduct trend analysis of average monthly and annual pan evaporation data at five selected numbers of evaporation pan stations in Peninsular Malaysia for the years 2011 through 2015 (5- year trend analysis);
4.Review, study and recommend the best engineering and management practices on evaporation data collection system with reference to WMO, HP, Water Resource Publications (WRP), technical studies and various technical manufacturers' information available in the market.

4.1 Data Acquisition

Daily manual pan evaporation data at all available evaporation stations in Peninsular Malaysia was acquired from DID Malaysia. The pan evaporation data was made available in two (2) sources, namely the NIWA Tideda database which listed a total of 48 numbers of evaporation pan stations and the DID Hydrological book (Evaporation) 2000-2015 which listed a total of 16 numbers of evaporation pan stations.

4.2 Daily Manual Pan Evaporation Data Observation Analysis

An observation analysis was carried out in a desktop study to investigate the availability and performance of manual daily pan evaporation data from the evaporation stations throughout Peninsular Malaysia. Since there is a huge amount of data to be analysed, it was suggested that the analysis be limited to a one-year data analysis namely 2015 and 14 out of 16 evaporation pan stations from the DID Hydrological Book (Evaporation) was analysed as two evaporation stations produced some missing data. Table 3 shows the list of the 14 numbers of evaporation pan stations for analysis. Figure 3 shows the map with the location of evaporation pan stations in Peninsular Malaysia for the observation analysis.

NO.	STATION NO.	STATION NAME	YEAR OPENED	YEAR CLOSED
JOHOR DARUL TAKZIM (DT)				
1.	0430341EP	Loji Air @ Sg. Layang	1987	2017
2.	0320471EP	Pintu Kawalan Tg. Agas @ Muar	1976	2017
3.	0500151EP	Stor JPS @ Endau	1962	20170228
KEDAH DARUL AMAN (DA)				
4.	1900031EP	JPS Padang Mat Sirat @ Langkawi	1963	2017
PERAK DARUL RIDWAN (DR)				
5.	0110041EP	Stn. Petak Ujian @ Tg. Piandang	1960	20151231
SELANGOR DARUL EHSAN (DE)				
6.	0190381EP	Tanjung Karang	1981	2018
7.	0210321EP	Loji Air Kuala Kubu @ K.K. Baru	1972	2018
N. SEMBILAN DARUL KHUSUS (DK)				
8.	0270121EP	Stor JPS Sikamat @ Seremban	1963	2017
PERLIS INDERA KAYANGAN				
9.	0010261EP	Padang Katong @ Kangar	1974	2017
PAHANG DARUL MAKMUR (DM)				
10.	0550931EP	Rumah Pam Pahang Tua @ Pekan	1962	2017
TERENGGANU DARUL IMAN(DI)				
11.	0620031EP	Sek. Men. Sultan Omar @ Dungun	1966	2018
12.	0700021EP	SMK Pengkalan Nyireh @ Besut	1970	2018
KELANTAN DARUL NAIM (DN)				
13.	0740151EP	Pej. Pertanian Batang Merbau	1982	20150831
14.	0710101EP	Serdang Gunung Barat @ Bachok	1983	2019

Table 3 - List of selected evaporation pan stations in peninsular Malaysia for average daily evaporation (NIWA Tideda, DID, 2020).

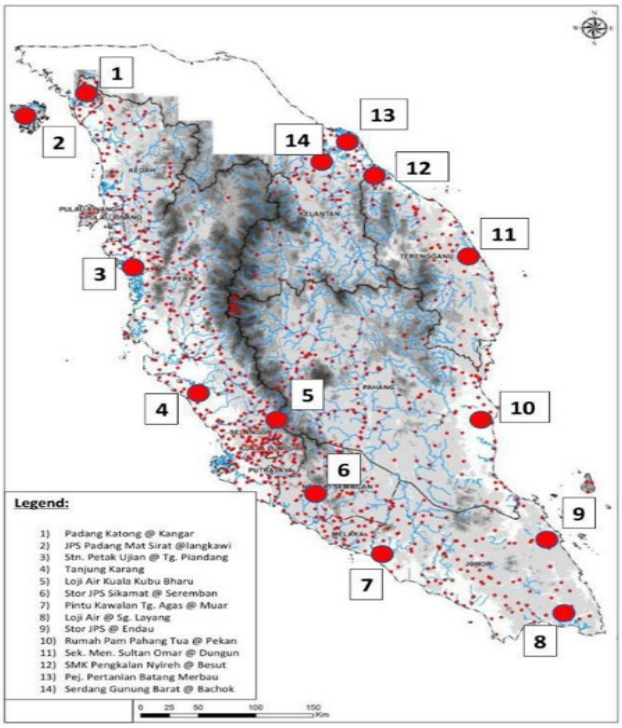

Figure 3 Location map of evaporation pan stations in Peninsular Malaysia for the daily observation analysis

Trend Analysis for Average Monthly Pan Evaporation
A 5-year trend analysis was also carried out in the desktop study to investigate the average monthly pan evaporation data from the year 2011 through 2015 or a 5-year trend analysis. Pan evaporation data for all the 14 numbers of evaporation pan

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stations were scrutinised and screened for the data availability and data performance for these. Only five out of 14 numbers of evaporation pan stations were selected for the trend analysis as the other nine evaporation stations produced some missing or unnecessary data information. They are:

1. Serdang Gunung Barat at Kelantan DN (Station No. 0710101EP);
2. JPS Padang Mat Sirat,Langkawi at Kedah DA (Station No. 1900031EP);
3. Loji Air Kuala Kubu Bharu at Selangor DE (Station No. 0210321EP);
4. Stor JPS Sikamat,Seremban at Negeri Sembilan DK (Stn No. 0270121EP); and
5. Rumah Pam Pahang Tua at Pekan, Pahang DM (Station No. 0550931EP).

A trend analysis was also carried out in the desktop study to investigate the annual pan evaporation data from the year 2011 to 2015 at the same five numbers of evaporation pan stations as stated above.

4.3 Data Review

The desktop study also includes the literature reviews and proposal of the best approach in improving the existing evaporation data collection system and information standards with reference to the latest WMO guidelines and practices as well as the local standards and latest technology available in the market.

5. Results and Discussion

The results, findings and discussion of the average daily, monthly and annual pan evaporation analysis is as shown below.

5.1 Observation Analysis of Daily Manual Pan Evaporation Data

An observation analysis was conducted at the 14 numbers of evaporation pan stations in Peninsular Malaysia for the year 2015. Daily pan evaporation data for every station was screened and analysed using the average method. Table 4 shows the data performance analysis for the 14 numbers of evaporation pan stations average daily evaporation in Peninsular Malaysia for 2015.

The following results were found:

- The overall average daily manual evaporation was 4.57 mm/day;
- The overall data availability and performance was 85.9%;
- The maximum average daily evaporation was 6.03 mm/day at Pej. Pertanian Batang Merbau, Kelantan DN with the data performance of 99.6%;
- The minimum average daily evaporation was 2.8 mm/day at Tanjung Karang, Selangor DE with the data performance of 73.7%;
- The highest data performance of 99.6% was at Pej. Pertanian Batang Merbau, Kelantan DN; and
- The lowest data performance of 72.3% was at Pintu Kawalan Tg. Agas @ Muar, Johor DT and Rumah Pam Pahang Tua, Pekan, Pahang DM.

The initial findings and results show that the results range from the highest 99.6% to lowest 72.3% of the data performance. The result also showed that ten (10) out of the 14 numbers of evaporation pan stations shows excellence performance (above 80%) and four (4) numbers of evaporation pan stations show average performance (50% - 79%). Generally, the overall average data performance of DID Malaysia's evaporation stations is in the excellent condition of 85.9 % with the overall average daily evaporation of 4.57 mm/day.

In comparing with other countries from the literature review, Java and Bali Island in Indonesia showed an overall average daily evaporation of 4.2 mm/day (Wati, Sopahcluwakan, & Fatkhuroyan, 2018) while Bedok Reservoir and the other reservoirs in Singapore showed the overall average daily evaporation of 5.5 mm/day (Babu, Eikass, Price, & Verlee, 2010). Elsewhere, Djaman, Koudahe and Ganyo (2017) obtained the result of the overall average daily evaporation for the four evaporation stations in Togo at 4.97 mm/day.

Table 4 Data Performance Analysis for Evaporation in Peninsular Malaysia For the Year 2015(Source: The DID Hydrological Handbook (Evaporation) from 2000 to 2015)

Station No.	Station Name	State	DID Publication Average Evaporation (mm/day)	DID Publication Data Performance (%)
0190381EP	Tanjung Karang	Selangor DE	2.89	73.7
0430341EP	Loji Air Sg. Layang	Johor DT	3.55	91.5
0320471EP	Pintu Kawalan Tg. Agas @ Muar	Johor DT	4.21	72.3
0620031EP	SM Sultan Omar @ Dungun	Terengganu DI	4.31	86.6
0010261EP	Padang Katong@ Kangar	Perlis IK	4.00	77.5
0270121EP	Stor JPS Sikamat Seremban	N. Sembilan DK	4.06	86.3
0210321EP	Loji Air Kuala Kubu Bharu	Selangor DE	4.37	83.6
0110041EP	Stesen Petak Ujian @Tanjung Piandang	Perak DR	4.87	93.4
1900031EP	JPS Padang Matsirat, Langkawi	Kedah DA	4.91	95.9
0550931EP	Rumah Pam Pahang Tua, Pekan	Pahang DM	4.18	72.3
0500151EP	Stor JPS Endau	Johor DT	5.50	91.5
0700021EP	SMK Pengkalan Nyireh, Besut	Terengganu DI	5.69	83.0
0710101EP	Serdang Gunong Barat	Kelantan DN	5.38	95.3
0740151EP	Pej. Pert. Batang Merbau (stn. closed 31/8/15)	Kelantan DN	6.03	99.6
		Total average	**4.57**	**85.9**

From the above results, several factors which affects the performance of the data collection practices might occur from:

1. Human integrity for example human errors in recording the daily data manually or lack of understanding during the filling-in of observation data using specific forms;
2. Provision of quality control document as in accordance to the WMO or local agency standards and procedures during or after site visit or observations not complied;

3. he maintenance period not as scheduled and replacement of the instruments or equipment that are obsolete and need to be replaced,
4. evaporation pans not properly levelled or maintained for a period of time;
5. no proper training for observers and seniors in maintaining the station.

These conditions could be further improved with a carefully planned and coordinated effort program such as, among others:

1. Upgrading the present manual evaporation stations to the automatic evaporation stations;
2. Improving and upskilling the knowledge level of the observers and officers to be well-trained in the IT technology with the installation and operation of the automatic system;
3. Conducting regular training workshops, seminars, symposiums etc. to the observers and officers involved in the data collection and data processing of the evaporation parameter; and
4. Upgrading the documentation of the data collection and data processing filing system so that all the evaporation data will be kept in a proper and well-coordinated condition.

5.2 Trend Analysis for Average Monthly Pan Evaporation in Peninsular Malaysia from 2011 to 2015 (5-Year Analysis)

A 5-year trend analysis was carried out in the desktop study to investigate the data availability and performance of average monthly pan evaporation in Peninsular Malaysia from the year 2011 to 2015 (5-year trend analysis). All the 14 pan evaporation data were scrutinised for the data availability and data performance. Only five out of the 14 evaporation stations were selected, after performing data screening, as the other nine stations produced some missing or rejected data information.

The five selected evaporation pan stations are:

1. Serdang, Gunung Barat Bachok at Kelantan (Station No. 0710101EP);
2. JPS Padang Mat Sirat at Kedah (Station No. 1900031EP);
3. Loji Air K. Kubu Bahru at Selangor Darul Ehsan (Station No. 0210321EP);
4. Setor JPS Sikamat at Seremban, Negeri Sembilan (Station No. 0270121EP);
5. Rumah Pam Pahang Tua at Pekan, Pahang Darul Makmur (Station No. 0550931EP).

Table 4-2 shows the trend analysis for average monthly pan evaporation (mm) in Peninsular Malaysia from 2011 to 2015 for the five evaporation stations. From the Table 4.2, the following results were found:

1. The average monthly pan evaporation ranges from the maximum of 169 mm/month for the month of April at Serdang Gunung Barat, Kelantan DN to the minimum of 56 mm/month for the month of December at Rumah Pam Pahang Tua at Pekan, Pahang DM;
2. Data availability and performance of the average monthly pan evaporation of the five evaporation stations ranges from the highest 100% to the lowest 93%;
3. Three evaporation pan stations showed the highest data performance of 100% namely at Serdang Gunung Barat, Kelantan DN, JPS Padang Mat Sirat at Langkawi, Kedah DA and Stor JPS Sikamat at Seremban, Negeri Sembilan DK;
4. Two evaporation pan stations that showed the data performance of 93% are at Tanjung Karang at Selangor DE and Rumah Pam Pahang Tua at Pekan, Pahang DM;
5. The average monthly evaporation for Peninsular Malaysia was 124 mm/month with the overall average data performance of 97.2 %.

The subsequent Table 4-3 shows the summary of results and a brief description of the trend analysis of the average monthly pan evaporation (mm) in Peninsular Malaysia for each of the five evaporation stations.

Elsewhere, Djaman, Koudahe and Ganyo (2017) reported performing a long-term trend analysis in Togo for the measurement and estimation of annual and monthly pan evaporation at four (4) meteorological stations during 1976 to 2011 namely at Lome, Tabligbo, Atakpame and Sokode. They obtained the results of varied annual pan evaporation of 1803 to 2081 mm at Lome, from 1294 to 1496 mm at Tabligbo, from 1605 to 1974mm at Atakpame and from 1839 to 1990 at Sokode. Monthly pan evaporation varied from 137 to 197 mm at Lome, 89 to149 mm at Tabligbo, 137 to 214 mm at Atakpame and 137 to 190 mm at Sokode. The average overall daily evaporation for the four evaporation stations was 4.97 mm/day.

Table 4-3 Summary of Discussion for Trend Analysis of Average Monthly Pan Evaporation (mm) for Peninsular Malaysia

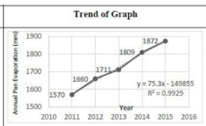
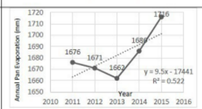
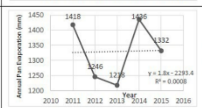
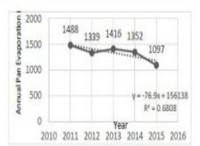
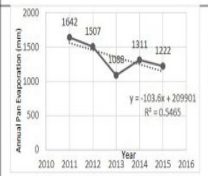
Station No.	Station Name	Trend of Graph	Brief Description
0710101EP	Serdang Gunung Barat, Kelantan DN		Pan evaporation data for Gunung Serdang Barat from 2011 to 2015 shows that the annual evaporation ranges from the maximum total evaporation of 1872 mm for the year 2015 to the minimum of 1570 mm for the year 2011 with the average annual evaporation of 1724 mm/year. The graph shows a significantly increasing trend in annual evaporation.
1900031EP	JPS Padang Mat Sirat, Langkawi, Kedah DA		Pan evaporation data for 2011 through 2015 shows that the annual evaporation ranges from the maximum total evaporation of 1716 mm for the year 2015 to the minimum of 1662 mm for the year 2013 with the average annual evaporation of 1682 mm/year. The graph shows a significantly increasing trend in annual evaporation which is similar to Serdang Gunung Barat, Kelantan DN.
0210321EP	Loji Air Kuala Kubu Baru, Selangor DE		Pan evaporation data for Loji Air Kuala Kubu Baru from 2011 through 2015 shows that the annual evaporation ranges from the maximum total evaporation of 1436 mm for the year 2014 to the minimum of 1218 mm for the year 2013 with the average annual evaporation of 1330 mm/year. The graph shows a very slight increasing trend in annual evaporation.
0270121EP	Stor JPS Sikamat, Seremban, Negeri Sembilan DK		Pan evaporation data for Stor JPS Sikamat, Seremban, Negeri Sembilan DK from 2011 to 2015 shows that the annual evaporation ranges from the maximum total evaporation of 1488 mm for the year 2011 to the minimum of 1097 mm for the year 2015 with the average annual evaporation of 1339 mm/year. The graph shows a decreasing trend in annual evaporation.
0550931EP	Rumah Pam Pahang Tua at Pekan, Pahang DM		Pan evaporation data for Rumah Pam Pahang Tua at Pekan from 2011 through 2015 shows that the annual evaporation ranges from the maximum total evaporation of 1642 mm for the year 2011 to the minimum of 1088 mm for the year 2013 with the average annual evaporation of 1354 mm/year. The graph shows a significantly decreasing trend in annual evaporation.

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Table 4-3 Summary of Discussion for Trend Analysis of Average Monthly Pan Evaporation (mm) for Peninsular

From the trend analysis, the following findings for the five evaporation stations were observed:

1.the maximum pan evaporation of 169 mm/month for the month of April at Serdang Gunung Barat, Kelantan DN is associated with the driest month;
2.the minimum pan evaporation of 56 mm/month for the month of December at Rumah Pam Pahang Tua at Pekan, Pahang DM is associated with the wettest month;
3.there was a slight increasing trend of evaporation at JPS Padang Mat Sirat, Langkawi, Kedah DA;
4.there was a decreasing trend of evaporation at four evaporation stations namely at Serdang Gunung Barat, Kelantan DN, Loji Air Kuala Kubu Baru at Selangor DE, Stor JPS Sikamat at Seremban, Negeri Sembilan DK and Rumah Pam Pahang Tua at Pekan, Pahang DM.

In general, the increasing trend from the above two stations at namely Serdang Gunung Barat, Kelantan DN and JPS Padang Mat Sirat, Langkawi, Kedah DA implied that higher evaporation rates were experienced during the months of May to September. Generally, the result for evaporation strongly suggest that the downward trend of the average monthly evaporation is impacted by the monsoon seasons particularly the Northeast Monsoon during the periods of November to February, the Southwest monsoon during the periods of May to August and the inter-monsoon during the periods of March to April and September to October (Yusuf, Foo, Suhaila, & Kong, 2012).

5.3 Trend Analysis for Annual Evaporation in Peninsular Malaysia from 2011 To 2015 (5-Year Analysis)

Another 5-year trend analysis was also carried out in the desktop study to investigate the data availability and performance of annual pan evaporation in Peninsular Malaysia for the five evaporation stations from 2011 to 2015. Table 4-4 displays the trend analysis of the stations. From the table, the following results were found:

1. the maximum total annual pan evaporation was 1872 mm/year for Serdang Gunung Barat,
Kelantan DN for the year 2015;
2. the minimum total annual pan evaporation was 1088 mm/year at Stor JPS at Sikamat, Seremban Negeri Sembilan DK for the year 2015;
3. the overall average annual pan evaporation for Peninsular Malaysia 1486 mm/year.

The subsequent Table 4-5 shows the summary of results and brief discussion for the trend analysis of the annual pan evaporation (mm) in Peninsular Malaysia for each of the five evaporation stations.

Station Name / Year	Serdang Gunung Barat at Kelantan DN	JPS Padang Mat Sirat at Langkawi, Kedah DA	Kuala Kubu Baru at Selangor DE	Stor JPS Sikamat at Seremban, Negeri Sembilan DK	Rumah Pam Pahang Tua at Pekan, Pahang DM
2011	1570	1676	1418	1488	1642
2012	1660	1671	1246	1339	1507
2013	1711	1662	1218	1418	1088
2014	1809	1686	1436	1352	1311
2015	1872	1716	1332	1097	1222
Average Annual	**1724**	**1682**	**1330**	**1339**	**1354**

Table 4-4 Trend Analysis for Annual Pan Evaporation in Peninsular Malaysia

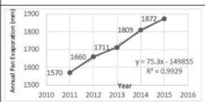
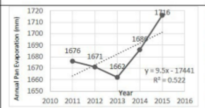
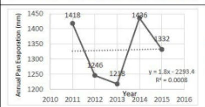
Station No.	Station Name	Trend of Graph	Brief Description
0710101EP	Serdang Gunung Barat, Kelantan DN		Pan evaporation data for Gunung Serdang Barat from 2011 to 2015 shows that the annual evaporation ranges from the maximum total evaporation of 1872 mm for the year 2015 to the minimum of 1570 mm for the year 2011 with the average annual evaporation of 1724 mm/year. The graph shows a significantly increasing trend in annual evaporation.
1900031EP	JPS Padang Mat Sirat, Langkawi, Kedah DA		Pan evaporation data for 2011 through 2015 shows that the annual evaporation ranges from the maximum total evaporation of 1716 mm for the year 2015 to the minimum of 1662 mm for the year 2013 with the average annual evaporation of 1682 mm/year. The graph shows a significantly increasing trend in annual evaporation which is similar to Serdang Gunung Barat, Kelantan DN.
0210321EP	Loji Air Kuala Kubu Baru, Selangor DE		Pan evaporation data for Loji Air Kuala Kubu Baru from 2011 through 2015 shows that the annual evaporation ranges from the maximum total evaporation of 1436 mm for the year 2014 to the minimum of 1218 mm for the year 2013 with the average annual evaporation of 1330 mm/year. The graph shows a very slight increasing trend in annual evaporation.

Table 4-5 Summary of discussion for trend analysis of annual pan evaporation (mm) for peninsular Malaysia

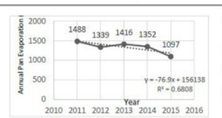
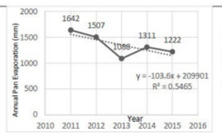
Station No.	Station Name	Trend of Graph	Brief Description
0270121EP	Stor JPS Sikamat, Seremban, Negeri Sembilan DK		Pan evaporation data for Stor JPS Sikamat, Seremban, Negeri Sembilan DK from 2011 to 2015 shows that the annual evaporation ranges from the maximum total evaporation of 1488 mm for the year 2011 to the minimum of 1097 mm for the year 2015 with the average annual evaporation of 1339 mm/year. The graph shows a decreasing trend in annual evaporation.
0550931EP	Rumah Pam Pahang Tua at Pekan, Pahang DM		Pan evaporation data for Rumah Pam Pahang Tua at Pekan from 2011 through 2015 shows that the annual evaporation ranges from the maximum total evaporation of 1642 mm for the year 2011 to the minimum of 1088 mm for the year 2013 with the average annual evaporation of 1354 mm/year. The graph shows a significantly decreasing trend in annual evaporation.

Table 4-5 Summary of discussion for trend analysis of annual pan evaporation (mm) for peninsular Malaysia

From the trend analysis, it was observed that the following findings for the five evaporation stations are:

1. There was an increasing trend in evaporation at two evaporation stations namely at Serdang Gunung Barat, Kelantan DN and JPS Padang Mat Sirat, Langkawi, Kedah DA;
2. There was a decreasing trend in evaporation at five evaporation stations namely at Loji Air Kuala Kubu Baru at Selangor DE, Stor JPS Sikamat at Seremban, Negeri Sembilan DK and Rumah Pam Pahang Tua at Pekan, Pahang DM.

Generally, the result of annual evaporation strongly suggests there is similarity to the findings of average monthly evaporation, except for Serdang Gunung Barat at Kelantan DN. This indicate that the downward trend of annual evaporation is also affected by the monsoon seasons, especially the Northeast Monsoon during the period of November to February, the Southwest Monsoon during the period of May to August and the inter-monsoon during the period of March to April and September to October (Yusuf, Foo, Suhaila, & Kong, 2012).

In comparison, Djaman, Koudahe and Ganyo (2017) reported performing a long-term trend analysis in Togo for the measurement and estimation of annual and monthly pan evaporation at four (4) meteorological stations during 1976 to 2011 namely at Lome, Tabligbo, Atakpame and Sokode. They obtained the results of varied annual pan evaporation of from 1803 to 2081 mm at Lome, from 1294 to 1496 mm at Tabligbo, from 1605 to 1974mm at Atakpame and from 1839 to 1990 at Sokode. The overall average annual pan evaporation in Togo was 1769 mm/year which is higher than the Peninsular Malaysia overall annual pan evaporation of 1486 mm/year.

5.4 Review, Study and Recommend the Best Engineering and Management Practices for Evaporation Data Collection System

The existing manual pan evaporation data collection system has been practiced for decades by DID Malaysia, adopting the HP 21 (1981) which is in accordance with the WMO standards and guidelines. However, it was considered to be very old, as some of the details found in the procedure must be further checked, strengthened and revised in order to conform with the current technology requirements and practice.

As indicated in paragraph 4.1 on the findings of daily pan evaporation data, some of the related issues that affect the output of manual data are human errors during data recording, incorrect data submission formats, a maintenance schedule that is not properly followed and the instruments or equipment that are outdated and need to be replaced.

However, these problems need to be resolved and in reviewing and researching the evaporation data collection practices of DID Malaysia, it is recommended that the present manual evaporation pan system be improved and upgraded to the automatic system, taking into consideration the concept and recommended designs to be kept as simple and economical as possible. An example of an automatic evaporation pan station with the design concept of the components and the wiring diagram of the evaporation pan with the rainfall gauge of the system installed at site is as shown in Figure 4-1.

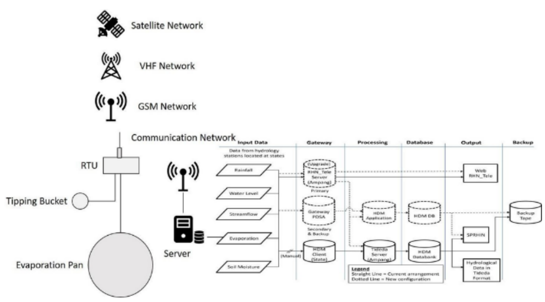


Figure 4-1 Design concept of an automatic evaporation pan station (Diagram courtesy of DID Malaysia).

For further improvement of the evaporation data collection system, a carefully planned and coordinated effort program amongst all parties involved should be implemented such as, among others:

1. Improving and increasing the knowledge level of the observers and officers to be well-trained in the IT technology with the introduction of the automatic system;
2. Conducting regular training workshops, seminars, symposiums and conventions to the observers and officers involved in the data collection and data processing system of the evaporation parameter; and
3. Upgrading or standardizing the documentation for the data collection and data processing filing system so that all the evaporation data will be kept in a proper and well-coordinated condition for a longer period of time.

In general, to upgrade and maintain the quality of the measurement of evaporation, the maintenance of these stations should be executed by observers who are trainable, conscientious and reliable.

6. Conclusion

From the data observation and trend analysis of the desktop study, the following information can be concluded:

1. The evaporation dataset provided by DID Malaysia and the results obtained from the observation analysis, although the data performance was 85.7% after performing data screening, showed that it can be satisfactorily applied for further analysis either by applying the evaporation data directly or by incorporating with other mathematical models for evaporation estimate such as Penman- Monteith equation and Blainey-Criddle equation.
2. The results of the average monthly and annual evaporation 5-year trend analysis conducted at the five evaporation pan stations which resulted a 97.2% data performance are very satisfactory. The trend analysis indicates that the evaporation effects in the regions of Peninsular Malaysia were dominated by a significant downward evaporation trend due to the monsoon patterns of Peninsular Malaysia especially during the months of November through February.
3. This paper is limited to analyzing only the average daily, monthly and annual manual pan evaporation in Peninsular Malaysia. A more rigorous analysis may consider the inclusion of other variables, such as the application of empirical equations and formulas for the water budget, the energy budget, the aerodynamic method or the mass transfer method.
4. To upgrade and maintain the quality of the measurement of evaporation, the maintenance of these stations should be executed by observers who are trainable, conscientious and reliable.
5. The automation system with proper monitoring will increase the efficiency of data collection.

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