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OVERCOMING SALINE INTRUSION IN WATER SUPPLY AT MUAR, JOHOR

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Abstract

Muar River Basin is the major source of raw water supply for three states in the South of Peninsular Malaysia namely Johor, Negeri Sembilan and Melaka. For Johor, Muar River is the main source for almost all water treatment plants in Muar and Segamat districts. El Nino 2014 phenomenon has affected almost entire states of Johor where the situation has never happened before, and its impact amongst others is the intrusion of salt water into Gersik water treatment plant located at 85km from the river estuary. Water Safety Plan (WSP) team of Ranhill SAJ SDN BHD (SAJ) has acted promptly on consumer complaints following the salty water supply in Muar district on March 11, 2014. SAJ WSP team has conducted Total Dissolved Solution (TDS), Salinity and Conductivity tests at all water intakes. From the observation, pH reading of 6.7 to 6.8 at normal trend but TDS reading reads over 2000ppm from the safe standard level of 1500ppm and Chloride readings at above 900ppm levels from a safe level of 250ppm. The reading showed the increasing trends during high tides that push the salt water flow further upstream of the river. The issue of saline intrusion was reported to the relevant agencies, namely Badan Kawalselia Air Johor (BAKAJ), Ministry of Health Malaysia (MOH) and Suruhanjaya Perkhidmatan Air Negara (SPAN) for immediate control because high chloride contamination in water supply could risk the health of consumers and may caused damage as well to the safety of hospital and factory equipments. This paper is prepared to share the experience of the mitigation measures taken by SAJ in facing dry weather impact of El Nino's phenomenon that struck in March 2014 that had affected treated water supply to nearly 118,000 user accounts.

Keywords: SAJ; Muar river; Water supply; saline; release.

1.0 INTRODUCTION

The Muar River Basin is located within four state of peninsular Malaysia, namely Johor, Negeri Sembilan, Melaka and Pahang. The catchment area is approximately 6560 km^2. About 61% of the basin is located in Johor Darul Takzim. The upstream catchment of Muar River started in Negeri Sembilan and Pahang before it flows through Johor and finally discharges into Strait of Malacca. The basin is located at the north-western part of Johor state between Kesang River basin to the north and Batu Pahat River basin to the south. Most of the basin areas have relatively low elevation and relief except in the north-west area at the headwaters of Sg. Muar. The main tributaries are Gemencheh River in the north-west, Palong River in the north east and Segamat River in the east of the basin. Figure 1 shows the main river and the catchment area of the Muar River Basin.

At present, the raw-water abstractions from Muar River for potable water are from 18 numbers of water treatment plant that operated by Ranhill SAJ Sdn. Bhd. (SAJ). Locations of the intakes are shown in Figure 2. From National Water Resource Study 2000-2050 (NWRS) and Johor Water Resource Study 2010-2060 (JWRS), it has been found that the water resource demand in the Muar River Basin is adequate to satisfy Johor (Muar and Segamat) up to year 2060 with total production about 242 Million Litre Day

(Mld). JWRS has indicated that 50-year ARI design drought yield balance of 30 Mld for future needed after deduction of 350 MLD that should be made available at Panchor intake to limit or 'flush' saline intrusion. But the weather at the early 2014 has shown unpredictable dry season with long numbers of recorded days without rain.

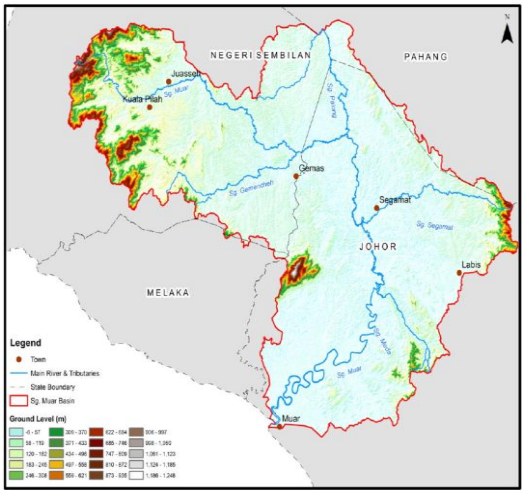

Figure 1 : Main River & Catchment Area of the Muar River Basin

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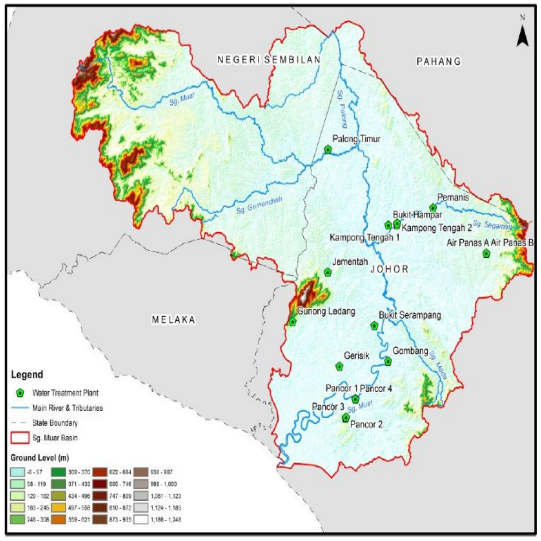

Figure 2 : Location of WTPs in Muar River Catchment, under State of Johor

Monthly Bulletin January 2014 by the Department of Meteorology Malaysia recorded the weather conditions in Peninsular of Malaysia in the mid-phase of Northeast Monsoon and most places have experiencing dry and cold weather conditions. This weather is influenced by the wind from the northeast which brought cold air from China Mainland which at that time experienced winter. Rainfall surveys recorded mainly in Peninsular Malaysia, Northern Kedah, Negeri Sembilan, Malacca, Johor and South Pahang experiencing a reduction of rainfall up to 60% below the average level with less rainfall 100mm per month. The monitoring of rain station at Juaseh Dam under SAJ operations has also shown a very low rainfall record in January and February 2014 compared to the previous year as Table 1 below.

Table 1: Rainfall Records at Juaseh Dam, Segamat, Johor

Month	Yearly Rainfall (mm)							
	2007	2008	2009	2010	2011	2012	2013	2014
Jan	288	316.5	141	100.5	1328.5	37	251.6	30
Feb	55	98	106	28.5	62	176	354.5	1
Mar	315.5	518	301	136	206	162	82.5	252.5
Apr	308	195	209	156	111.5	228	165.5	135.5
May	277	103	43	243	217	144.3	141.5	313.3
Jun	235.5	162	69	116	82.5	64.5	55	64
Jul	228.5	297	26	226	14.5	176.5	82.5	185.5
Aug	209	103	147	121	135.5	144.5	183	302
Sept	150	174	135	266	260.5	122.5	202.5	116
Oct	217	335	201	221	317.9	194	287.5	208
Nov	203	213	237.7	295	178	342.8	158.6	205
Dec	888	107	185	140	484.5	326.5	511.2	177
Total	3374.5	2621.5	1800.7	2049	3398.4	2118.6	2475.9	1989.8

The impact of less rainfall from January to early March 2014 has caused most of the rivers and some dam levels declined significantly in northern and eastern part of Johor. This includes what happened to the Upper Muar River at Palong Timur Water Treatment Plant (WTP) intake which located between Johor and Negeri Sembilan state boundary. Figure 3 shows the condition of the upstream Muar River at Palong Timur intake that is almost dry.

SAJ Water Safety Plan Team (WSP) regularly conducted river monitoring along Muar River to ensure the safety of a drinking water supply. They conducted selected standards water quality parameters index included pH, Total Dissolved Solids (TDS) and Chloride. Parit Jarom Jetty monitoring station (about 60 km from Sungai Muar river mouth as shown in Figure 4) showed the signs of presence of sea water with salinity readings of 2210 ppm and TDS readings of 2720 ppm on 3 March 2014, but readings recorded at Panchor Intake is below 50ppm for TDS and below 20ppm for Chloride. This salinity survey confirms that the movement of saline water is still far from the most downstream water intake of Panchor 1 which is 16 km ahead from Parit Jarom monitoring station.

Figure 3: Photo of Sungai Muar in upstream of Palong Timur WTP, Segamat during dry weather early 2014

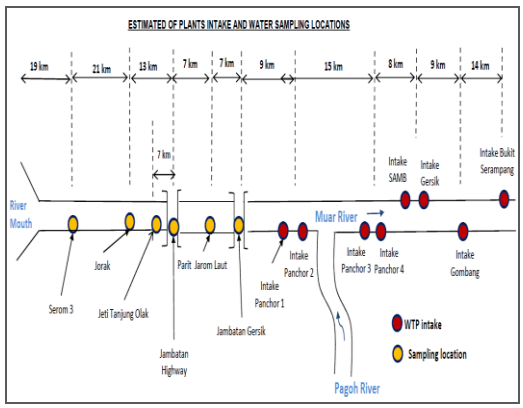

Figure 4: Location Of Plant Intakes and Water Sampling Points

On 11 March 2014, SAJ Customer Information Center (SAJIC) has received many complaints from consumers in the Muar district about the salty clean water supply. WSP SAJ team have acted promptly on consumer complaints with salinity water sampling survey along Muar River and all WTP intakes. The results have confirmed the presence of saline water at Panchor intake. From the observation, pH reading of 6.7 to 6.8 at normal trend but TDS reading reads over 2000ppm from the safe standard level of 1500ppm and Chloride readings at above 900ppm levels from a safe level of 250ppm. The salinity reading showed the signs of increase when the river level at the tide between noon and midnight. The issue of saline intrusion to water intakes urgently informed to the relevant agencies, especially to BAKAJ, KKM and SPAN for early notification of abnormal scenario. SAJ was preparing the notice of water supply disruption and remedial action because the contaminated water to the distribution system could create dangers to the health of consumers as well as the safety of hospital and factory equipments.

Dry weather and saline water intrusion at water intake give a heavy challenge to SAJ in committing safe water supply to his customers. This means that the closure of all five major water plants in Muar District which supplied almost 150 Million liter daily will affect almost all day-to-day and economy activities. SAJ has set not to shut down water plants operation but notifies that the supplied water is for hygienic use only and not suitable for drinking, especially to consumers with health problems.

2.0 METHOD

The SAJ has taken emergency measures to address increased complaints from consumers including monitoring every 2 hours of raw water quality and studying the possibility of raw water release from the Juaseh Dam which located at most upstream of Segamat River, tributary of Muar River. The BAKAJ office also helped to investigate if any third-party raw water abstractions along Sungai Muar include Melaka Raw Water Transfer at Gersik intake and Kg. Sawah paddy scheme that may beyond the authorized limit. The issue of salty water entering the intake of water plants is a serious matter and has never been happen before. For the quick fix remedial action, SAJ had to revise the Juaseh Dam Operation Manual. The dam with active storage 30 Million Cubic Meter (MCM) was built purposely to regulate all water intakes along Sungai Juaseh at Segamat District and did not specified for discharging to Muar River for saline control. Juaseh Dam is regulating reservoir for the intakes at Segamat with minimum maintenance flow of 80 Mld. The normal procedure for the Juaseh Dam release was based on several key criteria such as dropping water level at plant intake, decreasing in raw water quality below the MOH standard, pollution and sudden increase during heavy rain season.

Johor Water Resource Study 2010-2060 (JWRS) recently completed on 2013 by BAKAJ also included salinity study on all major river basin in Johor. For Muar River, Basin, simulation result under extreme conditions with various river flow discharges ranging 1 m3/s to 30m3/s and the highest astronomial tide (HAT), the saline limit is estimated to reach up to approximately 68.3km from the river mouth of Muar River. The saline intrusion limit finding is about 4km downstream of the Panchor intake under JWRS Study. The saline intrusion at Panchor intake beyond to Gersik intake which is about 100km from river mouth was far away from calculated yield 1 in 50-year design return period.

Juaseh Dam Emergency Plan urgently revised and setup by the SAJ Planning Division. The purpose is to optimize the use of raw water resources from Juaseh Dam in reducing the level of salinity of Muar River at Panchor intake, which is about 130km away. Reconstruction of emergency operation rule was utilised any available information from existing Juaseh Dam Operation & Manual dated 1992, JWRS & NWRS study and JPS reports. River data included cross section, distance and profile were obtained using information from Google Earth, JWRS study and topo maps. Some of the information from the original O & M is incomplete and outdated, the calculation of the water flow at the dam spillway outlet must be measured at site. Estimation of expected river travel time from Juaseh Dam to water intake at Segamat River (38km) and from Segamat River to Panchor Intake (76km) was calculated by Bernoulli's Equation principles for rectangular weir and v-notch weir (Figure 5). The equations used as express below:

$$Q = \frac{2}{3}(2g)^{0.5} \cdot b \cdot H^{1.5} C_d$$

$$Q = \frac{8}{15}\tan\theta \cdot (2g)^{0.5} \cdot H^{2.5} C_d$$

where:

g	=	gravitational acceleration, 9.81m/s
θ	=	angle of v notch (45 degree)
H	=	height of flow over notch
b	=	width of the weir, meter
C_d	=	discharge coefficient , 0.525 (flat top rec.. weir) and 0.62 (v-notch)

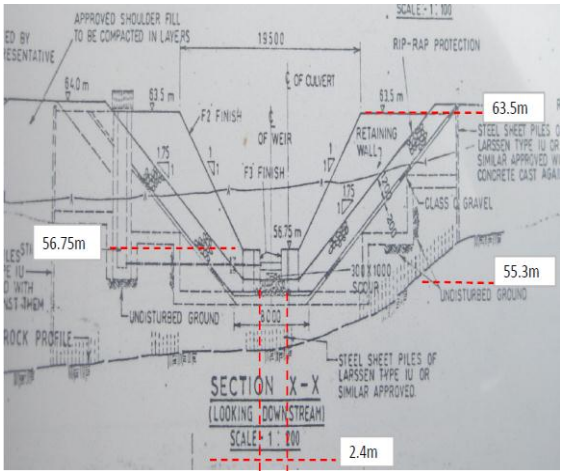

Figure 5: 45 Degree V-Notch and Rectangular Weir of Juaseh Dam Spillway Outlet

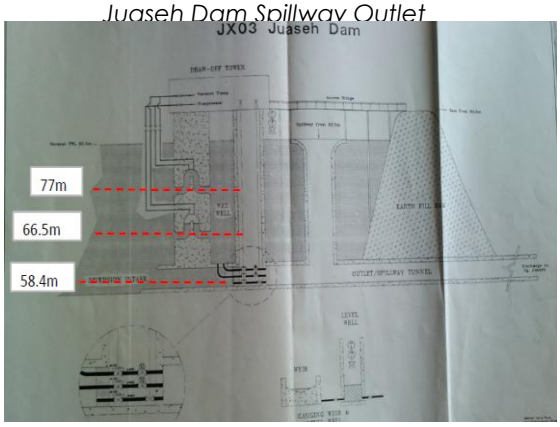

Figure 6: Cross Section of Juaseh Dam Outlet System

The structural parameter of the weir (crest height, 45 degree notch angle, weir width) was abstracted form as-built drawing. Compound rectangular crested v-notch weir is the most commonly used devise in channels and water structure for flow measurement and flow regulation due to its simplicity. Discharge coefficient for flat top contracted rectangular weir is taken as 0.525 and 0.62 for v-notch weir. A spreadsheet of the weir flow calculations has been setup and the maximum release rate from the dam outlet through scour pipe sizing 900mm diameter is estimated about 880 Mld. Figure 7 shows the flow through weir when the scour valve fully open.

Figure 7: Flow over a Sharp Cress Weir of Juaseh Dam

The discharge of a stream is calculated by using simple equation of velocity (length of travel per unit of time as cumec/second) times estimated area of river (meter^2) times length of river (km). Estimated time of arrival of release water and discharge rate is as shown in Table 2. Therefore, the optimum release of 880 Mld is needed immediately to overcome the intrusion of saline water at Panchor intake.

Estimated With Different Flow Regime

Q Discharge From Juaseh Dam		Travel time Juaseh Dam to Kg. Tengah Intake (day)	Travel time Kg. Tengah Intake To Panchor Intake (day)	Total days water arrive at Panchor (day)
MLD	m^3/s			
50	0.58	35.4	69.9	105.3
100	1.16	17.7	35.0	52.7
200	2.31	8.9	17.5	26.3
300	3.47	5.9	11.7	17.6
400	4.63	4.4	8.7	13.2
500	5.79	3.5	7.0	10.5
600	6.94	3.0	5.8	8.8
700	8.10	2.5	5.0	7.5
800	9.26	2.2	4.4	6.6
880	10.19	2.0	4.0	6.0
900	10.42	2.0	3.9	5.9

Table 2: Estimated Travel Time with Different Flow Regimes

However, the release of 880 MLD from Juaseh Dam as opposed from the original operation manual which only limited between 80Mld to 200 MLD and would be a huge risk during the current drought. With emergency release of 880 ML daily from the current full supply level only can withstand for 34 days if there is no rain. The SAJ has decided to release 880 mld of water on 14 March 2014 with valve openings gradually increase from 25% to fully 100% fully open on 18 March. The valve openings and water storage levels of the Juaseh Dam are closely monitored by the SAJ operations teams to prevent water storage in the dam to be empty. The intake levels and saline readings at Panchor intake were also monitored by SAJ WSP for every hour, day and night for ensure the recovery from the water crisis.

3.0 RESULTS AND DISCUSSION

Based on estimated flow time travel from Juaseh Dam to Kg. Tengah Intake is about 2 days. Observation on intake level at Kg Tengah Intake showed a sharp rise in the river level on 16 March 2014, which is equivalent to estimated calculations (Figure 8).

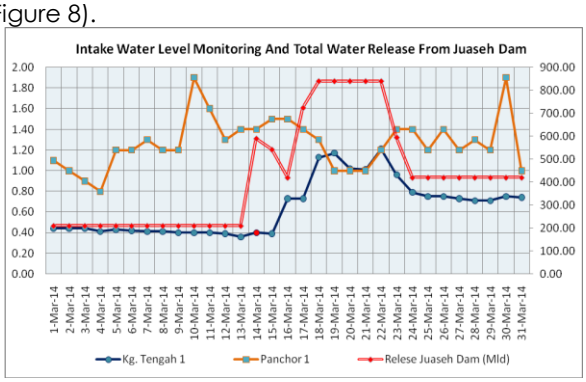

Figure 8: Recorded Intake Level at Kg. Tengah & Panchor Intake

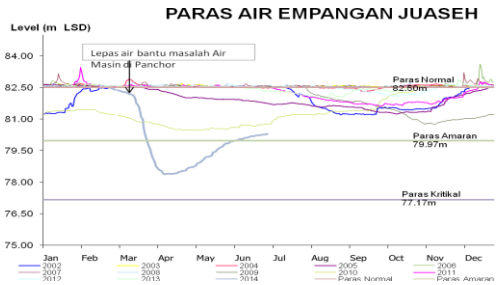

Figure 9: Recorded Dam Level for Juaseh Dam, Segamat

Juaseh Dam Emergency Plan finally bringing results to the saline intrusion problem when the trend of chloride levels in raw water at Panchor's intake shows a decline from the 1000ppm level to below 500ppm on the sixth day of dam release. The level of chloride continued to fall below 250ppm on the seventh day with the help of the rainfall on 16 March. The rain station in Juaseh Dam recorded 73mm rainfall on Sunday, 16 March after 65 days of without rain started from 10

4.0 CONCLUSION

The extreme heat phenomena and long days without rain have hit several countries and Malaysia is no exception from experiencing it. El-Nino can be considered as global treat. The high temperatures of up to 38.1 degree Celsius not only affect the ecosystem but also affected the source of human life "water". In Johor, this EL-Nino phenomenon has affected the reduction river and dam level of several

main water catchments, including the issue of saline water. This led to the "disruption" source and water supply to the public and it became worse as "water crisis". Besides triggering water rationing to the public, implementation contingency plan such as water release from Juaseh Dam is the best solution alternative to tackle the saline intrusion in Muar River

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