Journal of Oceanography & Marine Environmental System 4 (1): 14-28, 2020
ISSN 2222-1395

DOI: 10.5829/idosi.jomes.2020.14.28

Study of Thermo Model for Discharge Water from Electrical Power Station, Case Study: Sidi Krir Power Plant 3 & 4

[1]Ayman A. El-Gamal, [1]Ahmed Eladawy, [2]Ahmed Khalifa and [2]Walid Elsayed

[1]Marine Geology Department, Coastal Research Institute,
National Water Research Centre, Alexandria, Egypt
[2]Coastal Engineering Department, Coastal Research Institute,
National Water Research Centre, Alexandria, Egypt

Abstract: Thermal pollution of coastal water is one of the consequences of the discharge of hot cooling water of the electrical power stations to the coastal area. Sidi Krir Electrical Power Plant 3&4 use Mediterranean seawater for the cooling and condensation of steam through the condensers. This leads to increase the temperature of this water that discharged back to the sea through intermediate checkpoint at seal well and two separated pips (d1 and d2) with total distance 880 m. Actually, due to the high rate of flow (22,000 m^3/hr) of the discharged water, they do not have the ability to measure the water temperature at the mixing zone off shore. They always check the outer water temperature from sensor located at the seal well, which is not represented accurately the real seawater temperature at the mixed point offshore. The aim of this work is to estimate the water temperature at the mixed zone and compare it with temperature in seal well in order to comply with the legal values as in the Environmental law. Water temperature distribution model was established based on hydrographic model for the area under investigation using Delft 3D. The investigation of the water quality model, in particular water temperature, revealed that the ΔT between the two sits during fully and partially load at d1 and d2 was = - 5.3497 than the water temperature measured by sensor at seal well. This value was confirmed by field measurements of water temperature at the same sites.

Key words: Marine Temperature · Coastal Water Quality · Modelling · Electrical Power Plant · Cooling Water Discharge

INTRODUCTION

Egyptian environmental agency affair (EEAA) put some guidelines to control the criteria of any discharging water to the coastal water such as water temperature to prevent thermal pollution and to minimizing any change of the coastal environment [1]. According to the Egyptian Environmental Law 4/1994 [2], the coastal water temperature is not allowed to raise 10°C and the discharged water has to be less than 38°C [3]. All companies have to comply with these criteria of water temperature. Sidi Krir power plant 3&4 works diligently to comply with all the laws and regulations governing the work in the energy production and environmental conservation system. The seawater in the area in front of the power plant has affected from the thermal increase from the discharge of the hot cooling water to the coastal water. Actually, they do not have the ability to measure the water temperature at the mixing zone by placing permanent measuring devices, so, this work is to do the necessary study to calculate the expected temperature of the cooling water at the point of mixing with seawater. The company is looking to comply with the EEAA guidelines of water temperature of cooling water discharged to the sea especially during the full capacity work of the power plant.

Problem status: The complex operation of the electrical power plant can be considered in compliance with the regulatory requirement all the time and under the operating conditions. However, the available seawater outlet temperature measurement point at the seal well can

Corresponding Author: Ayman A. El-Gamal, Coastal Research Institute, Dead Sea road, Abu Qir, Alexandria, Egypt. Tel: +201005296027.

exceed the allowable limit of 38 degrees during some periods of the year (during the full load period in summer days of extremely hot weather). Actual temperature measurements of the seawater outlet at the discharge point and adjacent sides to the sea in the offshore side during the maximum load expected to comply with the legal requirement.

The Aim of the work: This study was carried out in order to comply with the guidelines of EEAA about two conditions. The first is the difference between seawater temperature get in and discharged out the plant has to be less than 10°C. The second condition is the maximum discharging water temperature to the coastal water has to be less than 38°C at any time. The aim of this work is to study the thermal distribution in the seawater under the impact of the hot cooling water discharging to the coastal water offshore. Fieldwork activities implemented to investigate the actual distribution of the water temperature during the normal operation of the electrical power plant and during the full load. Finally station need to determine the temperature difference between the available reading in seal well point and at the mixing zone to be a factor use for correction the temperature out signal sending to national environmental network.

MATERIALS AND METHODS

Site and Circulating Water System Description: Sidi Krir Power plant 3&4 is a conventional steam power plant located on the Mediterranean Sea in Sidi Krir, Alexandria. Sidi Krir plant uses seawater taken from the Mediterranean Sea for the cooling and condensation of steam through the condensers. The power plant is equipped with a Circulating Water (CW) System whose function to remove the waste heat from the steam by supplying the Mediterranean seawater as cooling water to the steam condensers and discharging it back to the sea. The sea water is supplied from two off-shore Circulating Water Intake Structures each connected to the on-shore Common Intake Pit by a 2.5 m diameter concrete-lined pipe buried under the seabed. The length of each of the two 2.5 m diameter concrete-line pipe is about 550 m form the intake structure to the intake suction pit where 340 meters of each line extend under the seawater.

Two seawater outlet lines from the condenser water box merge into one line till discharging into the seal well. The main function of the seal well is to discharge the outlet cooling seawater into the sea. The seal well structure is embedded in the ground, with total area of 176.64 m^2 and height varying from 8.30 and 9.30 m among those only 2.50 m lies above the ground level. The seal well structure is divided into two equal parts through a separation wall; each part contains a weir. The seawater is discharged from the seal well into the sea through two 2.25 meters diameter pipes with total length of 880 meters (out of which almost 550 meters are after the shoreline). The vertical distance is 500 m as Environmental Low 4/1994 requirements. The Intake and Discharge piping site plan are illustrated in Fig. 1.

The station have 5 water temperature sensors for each unit, 2 at the condenser inlet (one for each half), 2 at the condenser outlet (one for each half) and the fifth one located at the head of the seal well

Plan of the Study: In order to achieve the objectives as mentioned, CoRI gather all the requested data as these steps:

- Review the current existing temperature measurement point at the seal well outlet and define whether this point can be used to judge the compliance of the plant to the environmental law or not.
- Conduct actual measurements for the seawater temperature at the offshore point of discharge during the partial and full loads conditions and compare it to the corresponding temperature reading at the seal well.
- Evaluate the temperature drop between the current point of measurement of the seawater discharge temperature at the seal well and the point of mixing of the discharge water with the offshore marine water.
- Define any impact to the seawater inlet temperature at the offshore side as result of the operation of the neighbouring power plant.
- Create a mathematical model to evaluate the actual seawater discharge temperature at the offshore point from the available temperature reading at the seal well temperature measurement point.
- The outcome of the study can be used to the EEAA for approval and agreement in case of online monitoring to the discharge seawater temperature.

Methodology and Equipment: Gathering data of hydrological and geological parameters with the sea levels and wind speed with its direction. All these information were used to build the hydrodynamic model and then the water quality model to indicate the dispersion of water temperature at the power plant site.

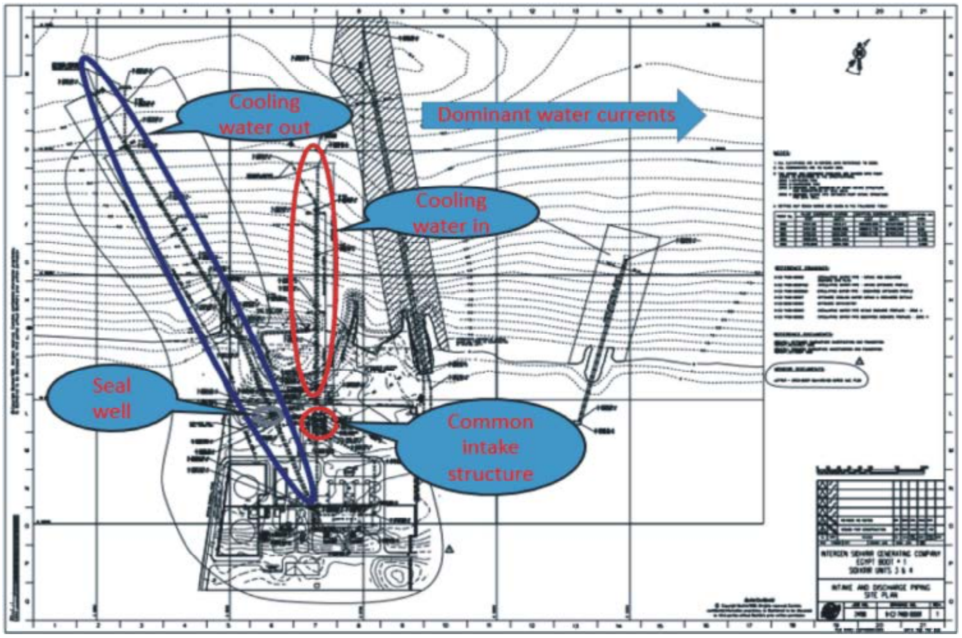

Fig. 1: Schematic diagram of the common intake structure and the seal well.

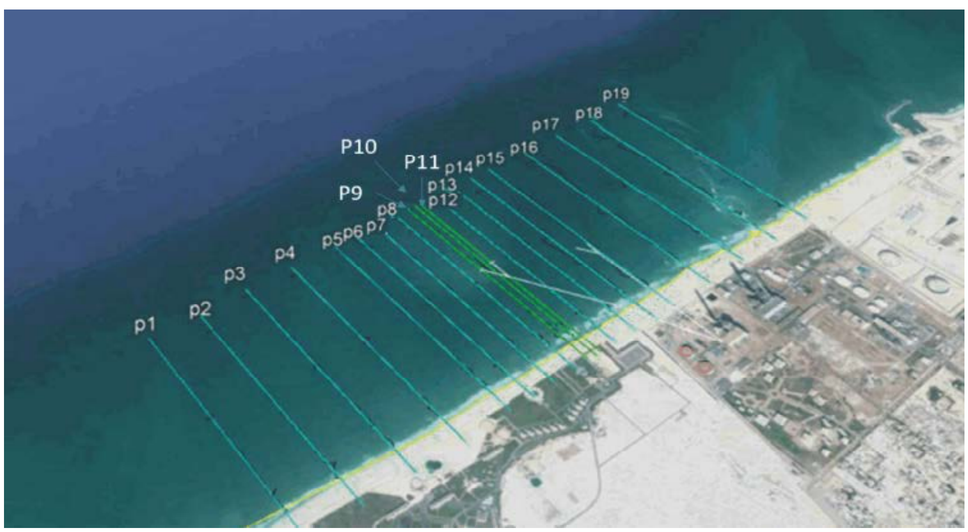

Fig. 2: Profiles under investigation of the study area.

Shoreline Survey: Shoreline survey was carried out using DGPS Hemisphere R131 with accuracy less than 1m for horizontal coordinate connected with Marine Laptop model Tetra Note-EX using Navigation and hydrographic survey software (C-Navigator). The data will be transferred to North, East UTM coordinate zoon 36 and drawn in Autocad format.

Bathymetric Survey (Sea Bottom Survey): Hydrographic survey was carried out along cross sections nearly perpendicular to the shoreline with space distance range 100 m between each two consecutive cross section up to a distance 1000 m seaward from shoreline of the study area. Sounding is taking every 1.0 sec. along the cross-shore profiles. The survey was carried out using Echo-Sounder SYQWEST Bathy 500 MF Multi frequencies - survey Echo Sounder with 0.1 m accuracy together with the same system used for shoreline survey. The bathymetric survey for the area under investigation was done for 19 profiles as shown in Fig. 2 with coordination listed in Table 1. Surfer model was used to draw the contour map and the contour map was transferred to Autocad format.

Table 1: Water temperature profiles coordination

Ser.	profile name	start X	start Y	end X	end Y
1	p1	752334.7604	3436512.957	751619.404	3437344.965
2	p2	752486.4128	3436643.347	751771.0564	3437475.355
3	p3	752638.0651	3436773.737	751922.7087	3437605.745
4	p4	752789.7175	3436904.127	752074.3611	3437736.135
5	p5	752941.3699	3437034.517	752226.0135	3437866.525
6	p6	753017.196	3437099.712	752301.8396	3437931.72
7	p7	753093.0222	3437164.907	752377.6658	3437996.915
8	p8	753168.8484	3437230.102	752453.492	3438062.11
9	p9	753215.8871	3437276.105	752500.5307	3438108.113
10	p10	753244.6746	3437295.297	752529.3182	3438127.305
11	p11	753259.8388	3437315.316	752544.4824	3438147.323
12	p12	753320.5008	3437360.492	752605.1444	3438192.5
13	p13	753396.327	3437425.687	752680.9706	3438257.695
14	p14	753472.1531	3437490.882	752756.7967	3438322.89
15	p15	753547.9793	3437556.077	752832.6229	3438388.085
16	p16	753699.6317	3437686.467	752984.2753	3438518.475
17	p17	753851.2841	3437816.857	753135.9277	3438648.865
18	p18	754002.9364	3437947.247	753287.58	3438779.255
19	p19	754154.5888	3438077.637	753439.2324	3438909.645

Water Temperature Measurements: Water temperature of the coastal water in front of the power plant was measured using CTD model Aquaread in vertical profiles from surface to bottom in selected sites along horizontal profiles cross to the shoreline. Three sites per profile were checked for vertical variation of water temperature during the normal load and maximum 7 sites per profile were checked during heavy load. All the data were exported as excel sheet. The starting profile is located over the main discharging tube of cooling water to the coastal area. The horizontal profiles extend till 1000 m distance seaward from shoreline. Repeated profiles east and west of the main profile perpendicular to the shoreline with space distance range from 100 to 200 m between each two consecutive cross section. The interval 100 m is for the first 250 m east and west and 200 m interval at distances more than 250 m.

Seawater Currents: Water currents of the coastal water in front of the power plant were measured using AANDERAA current profiler in some locations just for model calibration.

Grain Size Analysis: In order to characterize the sediment, mechanical analysis has been performed [4]. Four sediment samples were collected by Grap sampler from each one of six profiles (P1, P4, P8, P12, P12 and P19). The locations of the samples were shown in Fig. 2. The sediment samples were collected from beach, surf zone and two samples from offshore. The collected samples were washed by distilled water to remove soluble salts and then dried. Grain-size analysis was conducted directly by sieve analysis according to the methods described by Folk and Ward [5]. The used sieves have meshes comprise whole phi scale (ϕ), which are: -1, 0, 1, 2, 3 and 4 correspond to 2.0, 1.0, 0.5, 0.25, 0.125 and 0.063 mm. Statistical evaluation of the collected sediment samples has been executed using a computer program (GSSTAT). This analysis was carried out to determine the mean grain size and the sorting (standard deviation) according to the equations of Folk & Wards [5].

Modelling: Hydrodynamic modelling was set in order to build the water quality dispersion model. Dispersion modelling was carried out using Delft 3D to estimate the contour lines of seawater temperature (isotherm) in the coastal water in front of the power plant.

Delft 3D-WAQ is a three-dimensional water quality model framework. It solves the advection-diffusion- reaction equation on a predefined computational grid for a wide range of modelled substances. Delft 3D-WAQ allows great flexibility in the substances to be modelled, as well as in the processes to be considered. Hydrodynamic modelling usually requires a more detailed schematization or grid than water quality modelling. Therefore, it is generally allowed to reduce the number of computational cells in water quality modelling via aggregation in both the horizontal and vertical directions. The results calculated in the Delft 3 D- FLOW module (such as velocities, water elevations, density, salinity, vertical eddy viscosity and vertical eddy diffusivity) are used as inputs for Delft 3 D-WAQ via a coupling process.

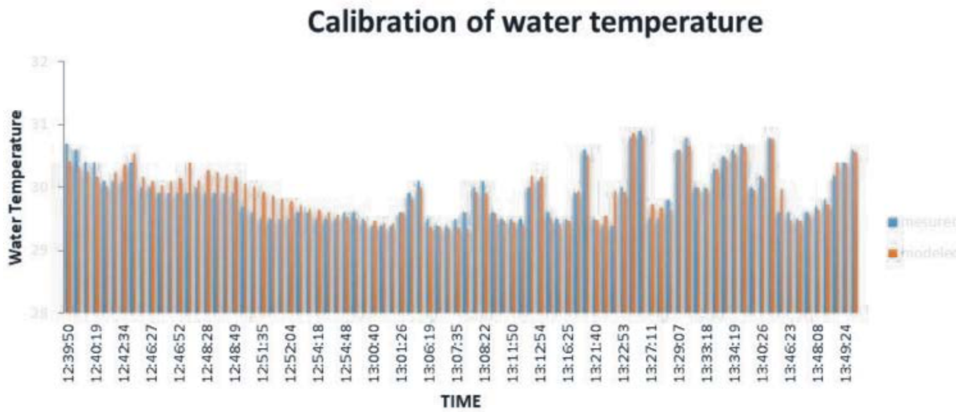

Fig. 3: Calibration of water temperature.

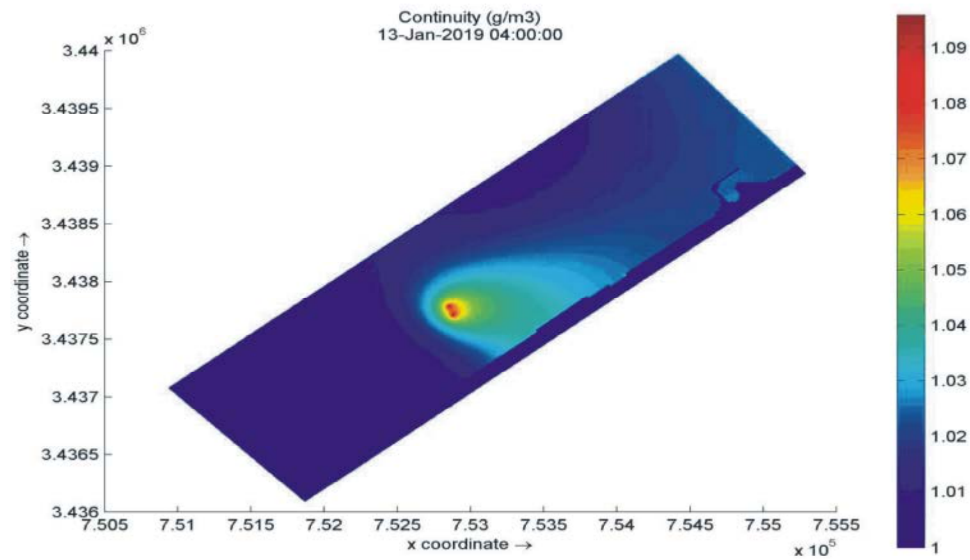

Fig. 4: The result of continuity.

Delft3D-WAQ solves the equations for transport and physical, chemical and biological processes in the marine environment. Delft3D-WAQ reproduces the mass balance of the selected state variables for each computational cell. Boundary conditions were used for the Delft3D-WAQ Model. Water temperature values of the two situations; full load and partial load outlets were set as values of 38 and 33ºC, respectively. For the open boundary, the water temperature at the outlets set as 30ºC in full load and 28ºC in the partially load. For the continuity of all parameters (outlet, open boundary) are set as 1 g/m^3 for the calibration of the model. With time step in flow and wave model 1minute and for water quality model for 30 minute for 24 months begin from 1/1/2019 to 31/12/2020. Fig. 3 shows the results of water temperature values and the estimated values

Model Calibration by Continuity: Measured data sets for water quality model were used for the calibration and validation of the model in order to accurately simulate the water quality in the study area. All constants were calibrated by trial and error, based on these data sets, thereafter, the model was calibrated using Continuity technique, which is a special conservative tracer that is used to check the accuracy and stability of the simulation. The discharge in the model is set to have a continuous concentration of 1 g/m^3 and the open boundaries also have a similar continuity constant. Any deviation from the value of 1 g/m^3 at any monitoring station indicates numerical error during simulation. As shown in Fig. 4, which indicate the stability of the model during the whole run.

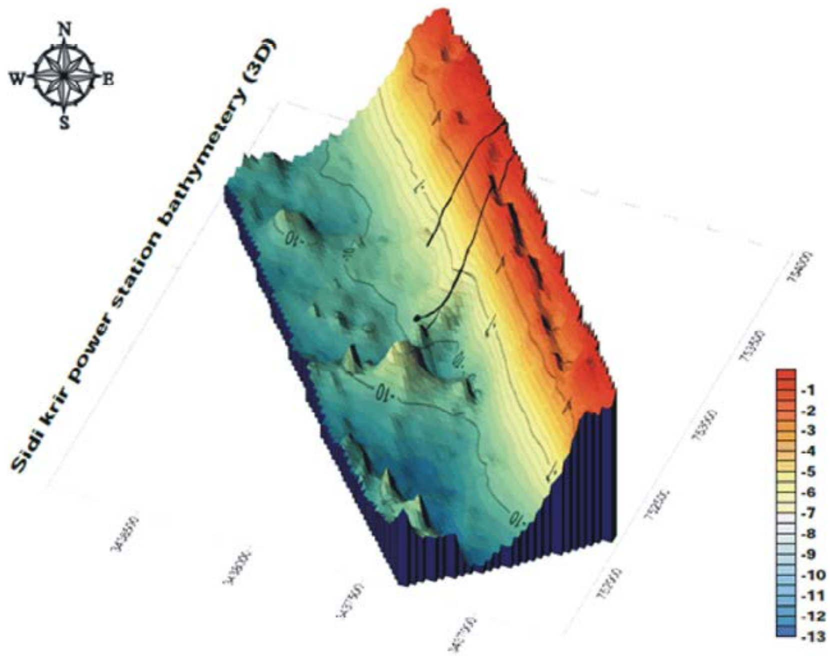

Fig. 5: 3D bathymetrical map for the area under investigation during 2019.

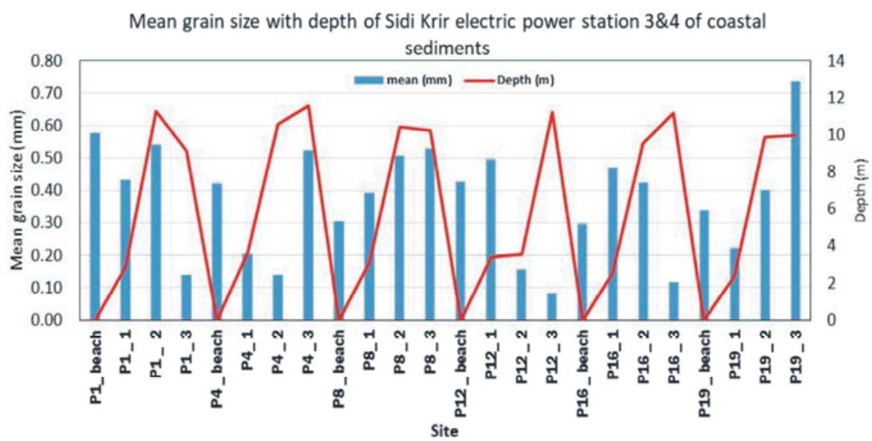

Fig. 6: Mean grain size (mm) with depth (m) of sediments collected from the shore area of electrical power station of Sidi Krir 3&4 during 2019.

RESULTS AND DISCUSSION

Bathymetry: Bathymetrical maps were drown as two dimension map and as three dimension map as in Fig. 5. The contour lines of depths -4, -7 and -10 m were recognized as shown in the maps. The bathymetrical map indicated the irregularity of the contour line of 10 m. This is due to presence of submarine seamounts west of the discharging tube of cooling water.

Grain Size Analysis: The coastal sediments of Sidi Krir electrical power station 3&4 area is nominated generally as sand with percentages from 95.12% to 100%. One offshore sediment sample at profile 12 recognized as silty sand with percentage of silt as 49.92% and 50.08% sand. No gravel and clay were detected in the sediments under investigation. All of beach sediments samples have 100% sand except at profile 8, which has 99.34% sand. Identification of the mean grain size and sorting of the sediments under investigation was presented in Table 2 and shown in Fig. 6 with variation of depth.

Table 2 list the main characters of the sediments collected from the site under investigation. Mean grain size is ranged from 0.05 mm to 0.4 mm with description from coarse silt to medium sand, respectively. In general,

Table 2: Mean grain size and sorting with depth of Sidi Krir 3&4 coastal sediments

Sample_id	Mean grain size (mm)	Sediment class	Sorting (mm)	Sorting description
P1_ BEACH	0.58	Coarse Sand	0.45	Poorly Sorted
P1 _ 1	0.43	Medium Sand	0.56	Moderately Sorted
P1 _ 2	0.54	Coarse Sand	0.63	Moderately Well Sorted
P1 _ 3	0.14	Fine Sand	0.62	Moderately Well Sorted
P4 _ BEACH	0.42	Medium Sand	0.55	Moderately Sorted
P4_ 1	0.20	Fine Sand	0.66	Moderately Well Sorted
P4 _ 2	0.14	Fine Sand	0.61	Moderately Well Sorted
P4 _ 3	0.52	Coarse Sand	0.62	Moderately Well Sorted
P8 _ BEACH	0.30	Medium Sand	0.56	Moderately Sorted
P8_ 1	0.39	Medium Sand	0.51	Moderately Sorted
P8 _ 2	0.51	Coarse Sand	0.54	Moderately Sorted
P8 _ 3	0.53	Coarse Sand	0.41	Poorly Sorted
P12 _ BEACH	0.43	Medium Sand	0.55	Moderately Sorted
P12_ 1	0.50	Coarse Sand	0.52	Moderately Sorted
P12 _ 2	0.16	Fine Sand	0.66	Moderately Well Sorted
P12 _ 3	0.08	Very Fine Sand	0.44	Poorly Sorted
P16 _ BEACH	0.30	Medium Sand	0.60	Moderately Sorted
P16_ 1	0.47	Medium Sand	0.48	Poorly Sorted
P16 _ 2	0.42	Medium Sand	0.59	Moderately Sorted
P16 _ 3	0.12	Very Fine Sand	0.67	Moderately Well Sorted
P19 _ BEACH	0.34	Medium Sand	0.58	Moderately Sorted
P19_ 1	0.22	Fine Sand	0.57	Moderately Sorted
P19 _ 2	0.40	Medium Sand	0.56	Moderately Sorted
P19 _ 3	0.74	Coarse Sand	0.58	Moderately Sorted

all the tested sediments samples of the backshore, shoreline and at surf zone were medium and fine sand. While the offshore sediment samples were fine and very fine sand except coarse silt sediment, which collected from offshore at depth 11.42 m in the fourth profile as shown in Fig. 6.

Sorting is indication of purity (well sorted) or mixing the sand with another transferred from other sites (poor sorted). The standard deviation is to measure the sorting of the sediments, representing the fluctuations in the kinetic energy or velocity conditions of the depositional agent [6].

Table 2 list the sorting values and its descriptions. The sorting of the backshore (land) samples were deviated from moderately sorting, moderately well sorting and well sorting. The same behaviour was observed in the shoreline samples. This indicated that the sediment samples of land and shoreline were indigenous sediments. On the other hand, the offshore zone sediment samples were differentiated as moderately sorted and poorly sorted. Certainly, the moderately sorted sites have a mixing between indigenous and allochthonous sands. This differentiation will increase in the case of poor sorting, which indicated of receive sediments from the other zones.

Water level calibration: The actual water level was compared with the estimated water level as shown in Fig. 7. Compatibility was observed between the actual and the estimated water levels.

Actual measurements results: Water temperature was measured in the field using CTD during partial and full load of the power plant. Figs. 8 a, b and c has the water temperature distribution of the profiles in front of the company. These measurements were done during three different days. The summary was listed in Table 3. Fig. 8a represents to the western profiles, which its water did not affected from the hot cooling water discharged to the sea and they show relatively lower values compared with other measured values. Fig. 8b, represents the middle profiles, which has the output cooling water indicate the clearly difference between the measurements and the reading of the seal well. Fig. 8c, which represents the eastern profiles, showed the relatively higher water temperature due to the neighbour eastern power plant.

The variation is clear within the vertical profiles of the outer horizontal profiles east and west compared with the middle profiles as shown in Fig. 9. The water temperature in the western profile are the lowest water temperature compared with the relatively higher in the eastern profiles

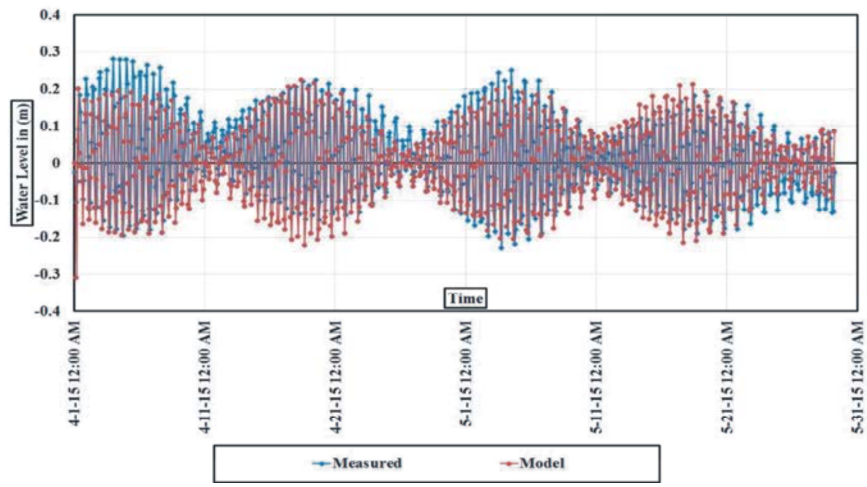

Fig. 7: Water level calibration.

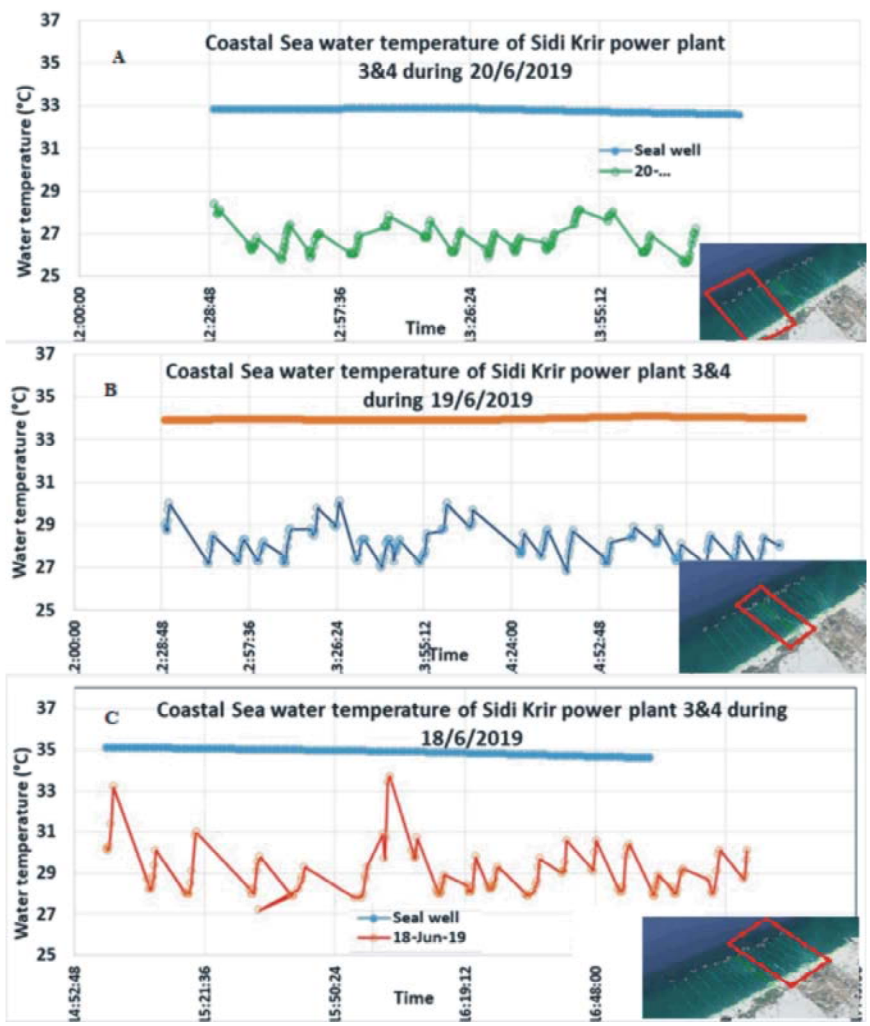

Fig. 8: Distribution of water temperature measured in profiles off the Sidi Krir power plant 3&4 during three successive days.

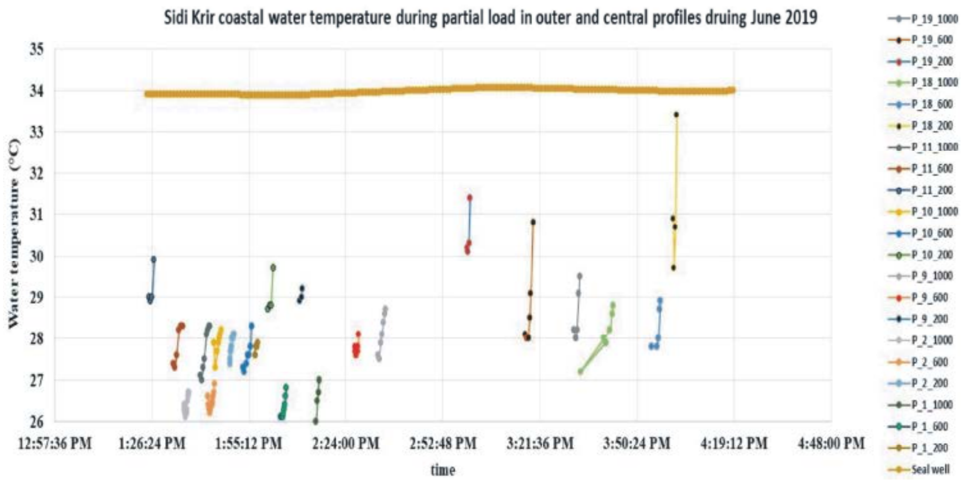

Fig. 9: Distribution of vertical profiles of water temperature in the central and outer horizontal profiles.

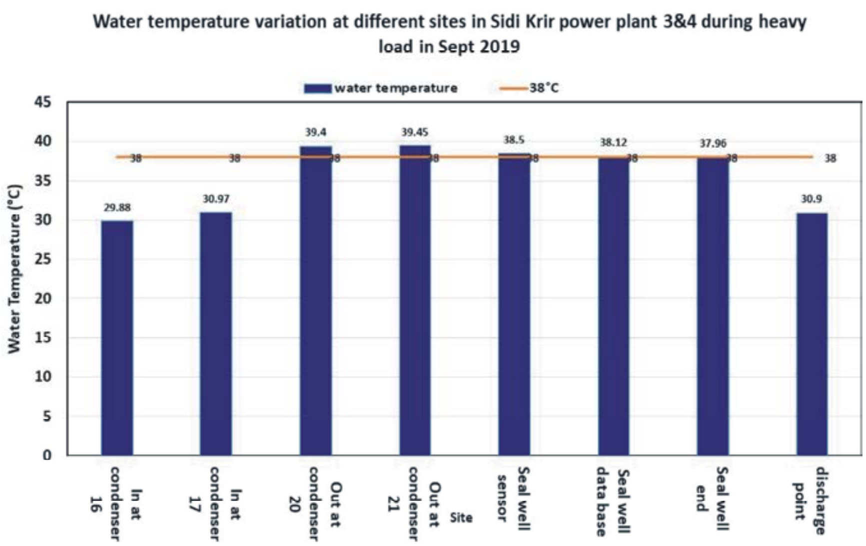

Fig. 10: Water temperature differences in water cycle of the company during heavy load.

Table 3: Average, minimum and maximum of water temperature of coastal profiles in Sidi Krir power station 3&4.

	Actual measurements	Seal well sensor reading
Profiles 1 - 5 20/6/2019		
Average	26.69±0.65 °C	34.01±0.04 °C
Minimum	25.6 °C	33.96 °C
Maximum	28.4 °C	34.09 °C
Profiles 6 - 13 19/6/2019		
Average	28.04±0.7 °C	33.94±0.06 °C
Minimum	26.8 °C	33.88 °C
Maximum	30.1 °C	34.07 °C
Profiles 14 - 19 18/6/2019		
Average	28.96±1.13 °C	34.89±0.15 °C
Minimum	27.2 °C	34.61 °C
Maximum	33.7 °C	35.11 °C

due to the neighbor plant. The 200m distances vertical profiles measurements looks higher than the more distance profiles such as 600 and 1000m. This is may be due to the shallowness of the water in 200m.

Fig. 10 shows the variation of water temperature during heavy load in the water in the company and out of the condenser followed by the seal well reading and the actual water temperature in the exchange zone off shore. It shows the seal well sensor reading more than 38°C but when this discharged water travel firstly by falling in the seal well to about 9 m depth with speed 22000 m/hr and transfer out the power plant through tubes with 550 m in the sea. This travel of the water play an important role to decrease its temperature.

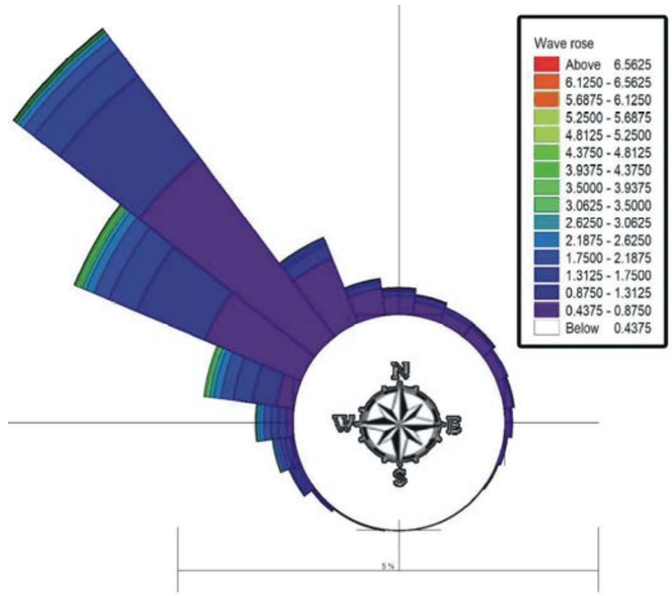

Fig. 11:Wave Rose in the area under investigation.

Fig. 12: Wave distribution according to wave height 1.15m & Time period 6sec & Northern west direction

Modelling Results: In order to measure, the water temperature gradients and the dispersion model for water temperature in the area under investigation, hydrographical model was constructed first to use as basic information to build the water quality model.

Hydrographic Model Output: Under the average wave with 1.15m height and 6sec wave period the longshore current velocity ranging from 0.30 m/s to 0.15 m/s. The current near the pipeline outlets is ranging from 0.10m/s to 0.05 m/s (Figs. 12 and 13). Under the maximum wave with 4.5m height and 12 sec wave period the longshore current velocity ranging from 0.60 m/s to 1.0 m/s. The current near the pipeline outlets is ranging from 0.30 m/s to 0.50m/s (Figs. 14 and 15).

The Water Quality Modelling: The thermal plume dispersion from the Sidi Krir power station discharges has been successfully characterized by numerical modelling. In order to analyse the difference in temperature (ΔT) between the water in seal well and discharged water through the outlet tubes, which located 800 m seaward offshore.

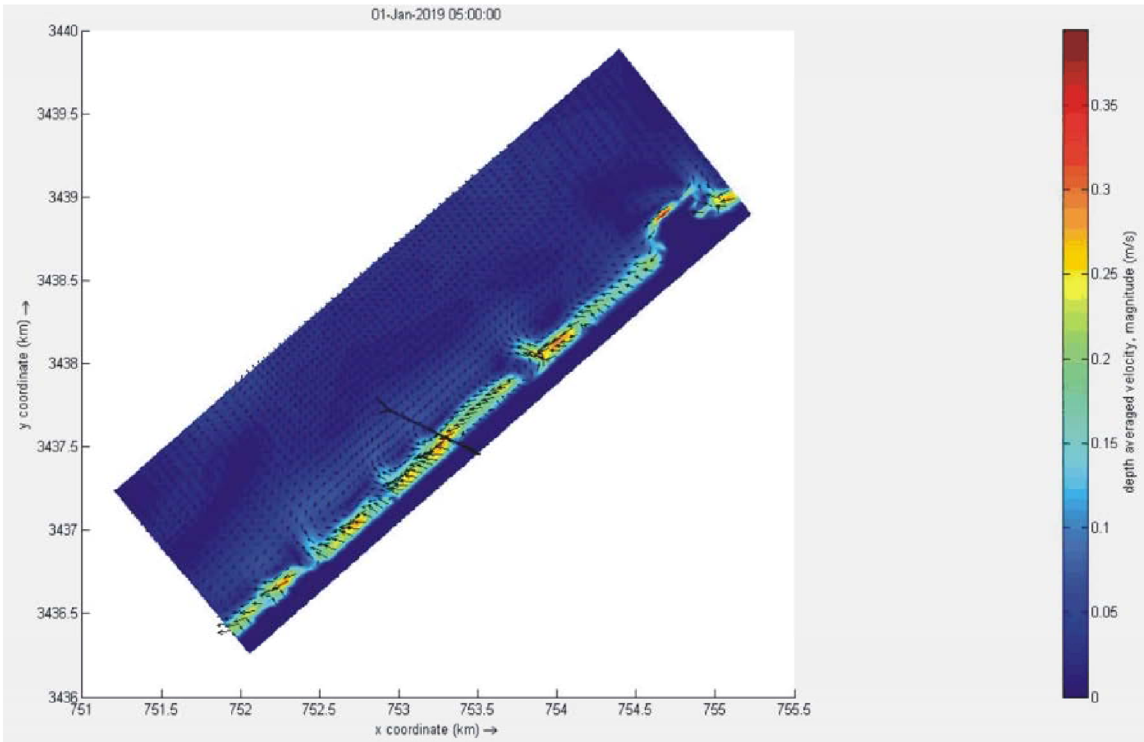

Fig. 13: Current due to wave distribution according to wave height 1.15m & Time period 6sec & Northern west direction

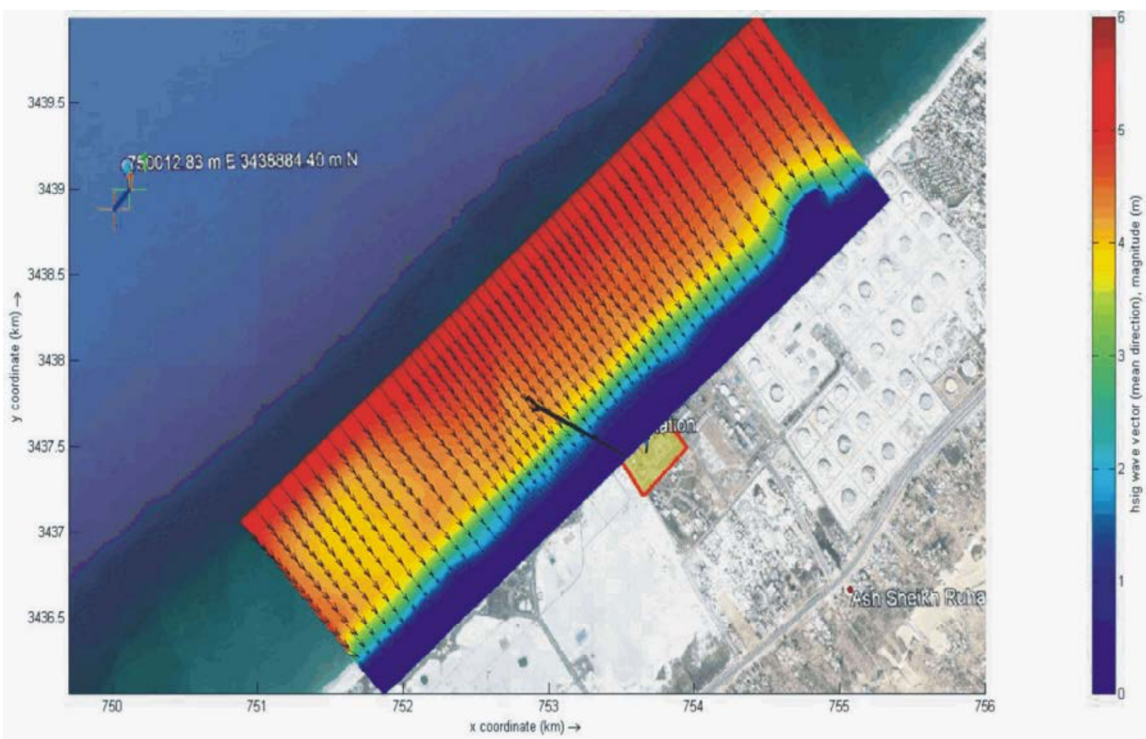

Fig. 14: Wave distribution according to wave height 4.5m & Time period 12sec & Northern west direction

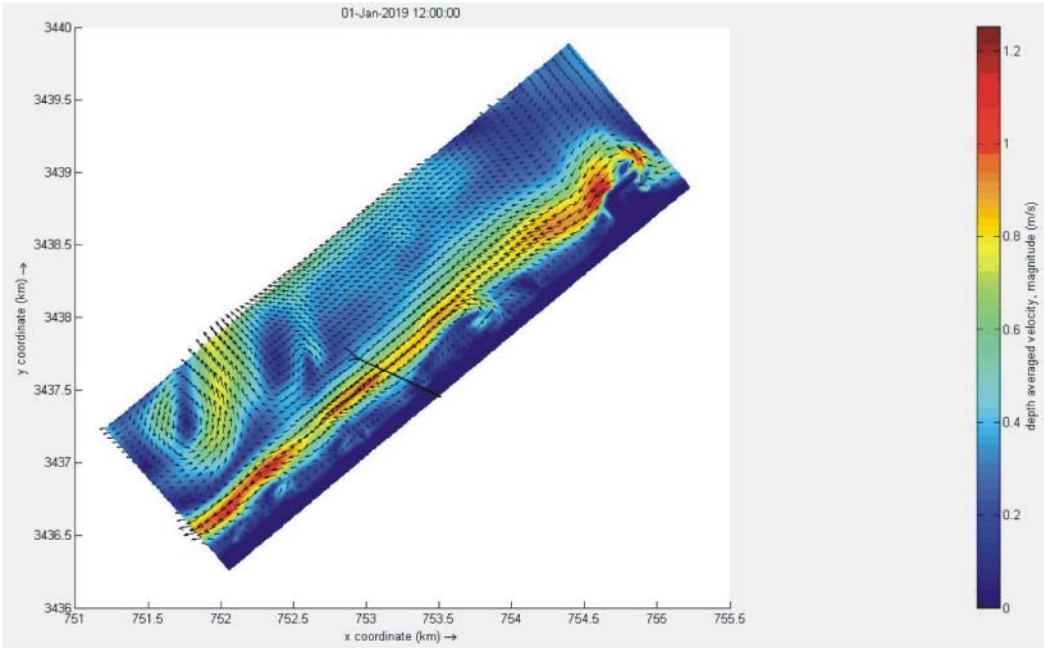

Fig. 15: Current due to wave distribution according to wave height 4.5m & Time period 12sec & Northern west direction

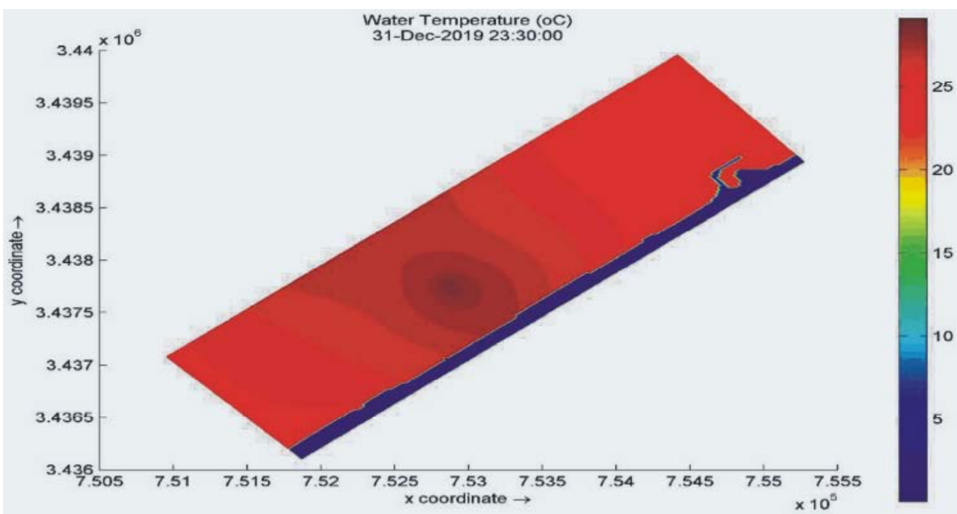

Fig. 16: The distribution of heat energy at d1 at Sidi Krir power station at partially load

Scenario of Partially Load: In this situation the ambient temperature for the water was 28.06°C and temperature at seal well was 33.03°C and the maximum average temperature form the model at the two tubes d1 and d2 were 28.51 and 28.95°C, respectively. In this case the difference of water temperature (ΔT) is equal to **4.51**. During the partial load, the distribution of the heat energy at the first line (d1) of condenser at Sidi Krir power station 3&4 is presented in Fig. 16. The modelled temperature at observation point near to d1 at partially load is presented in Fig. 17. At the second line (d2) the distribution of the heat energy is presented in Fig. 18. The modelled temperature at observation point near to d2 at partial load is presented in Fig. 19.

Scenario of Full Load: In this situation the ambient temperature for the water was 30.16°C and temperature at seal well was 38.25°C and the maximum average temperature form the model at d1 and d2 was 32.90 and 30.95°C, respectively. In this case the difference of water

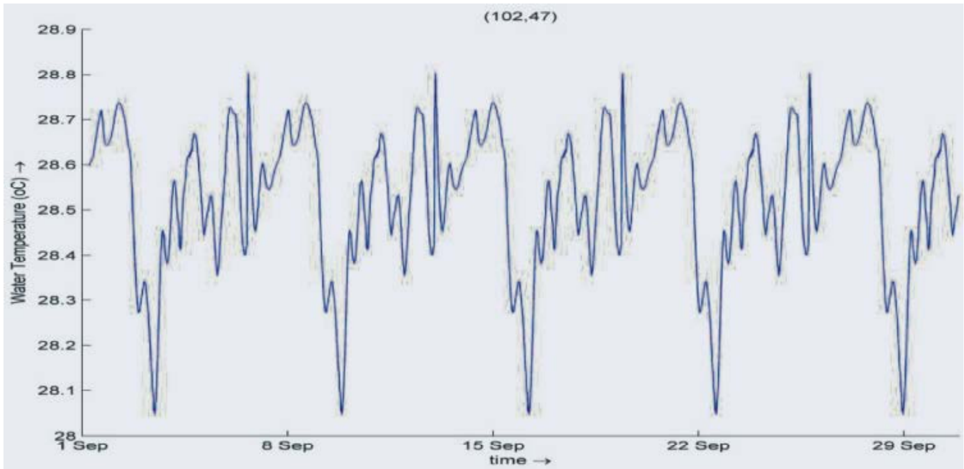

Fig. 17: The modelled temperature at observation point near to d1 at partially load.

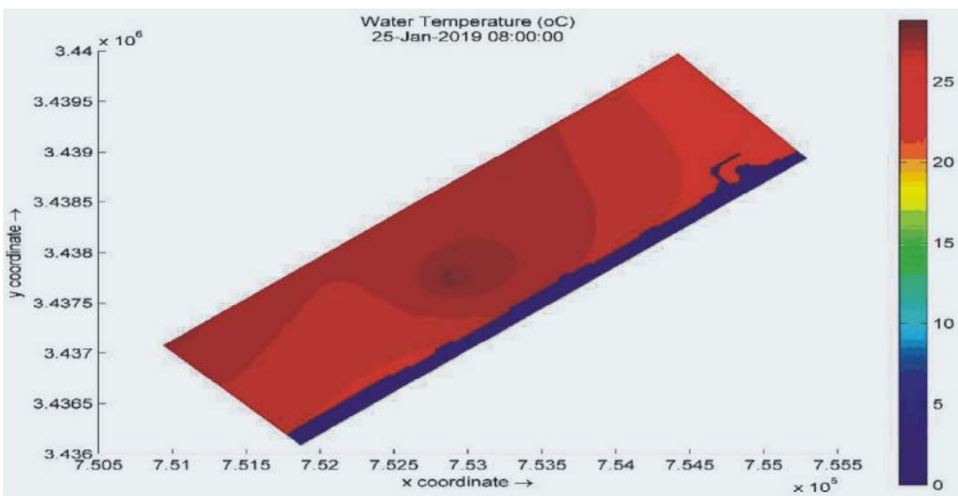

Fig. 18: The distribution of heat energy at d2 at Sidi Krir power station at partially load.

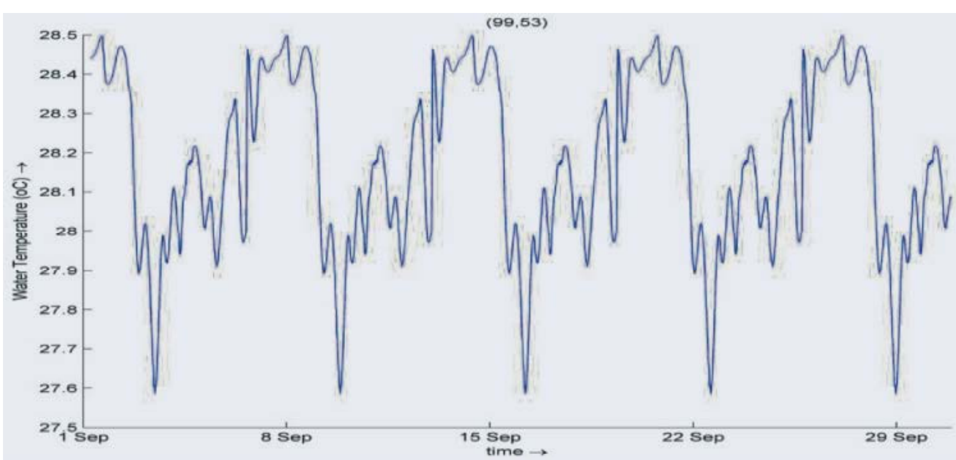

Fig. 19: The modelled temperature at observation point near to d2 at partially load

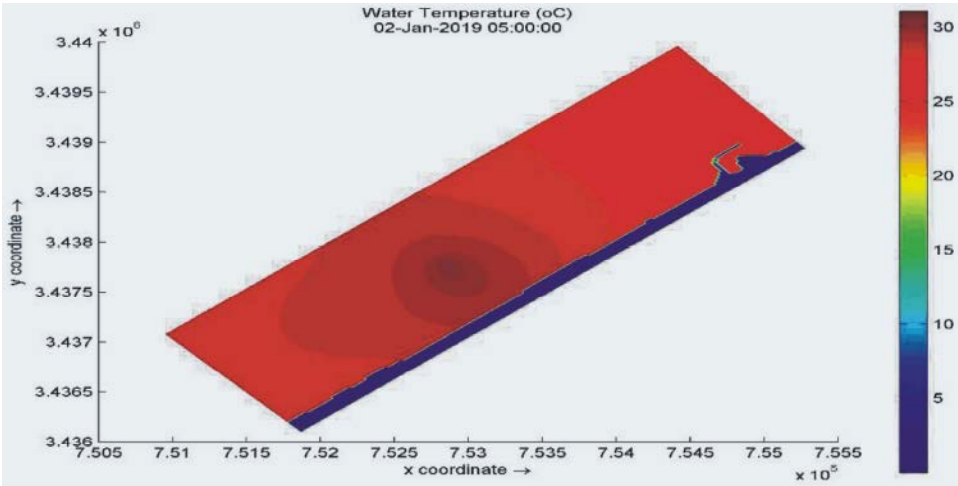

Fig. 20: The distribution of heat energy at d1 at Sidi Krir power station at heavy load

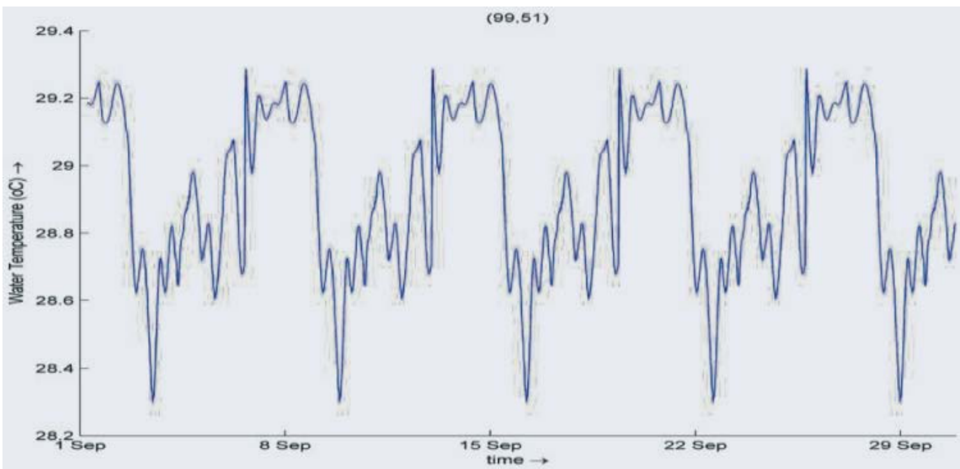

Fig. 21: The modelled temperature at observation point near to d1 at heavy load

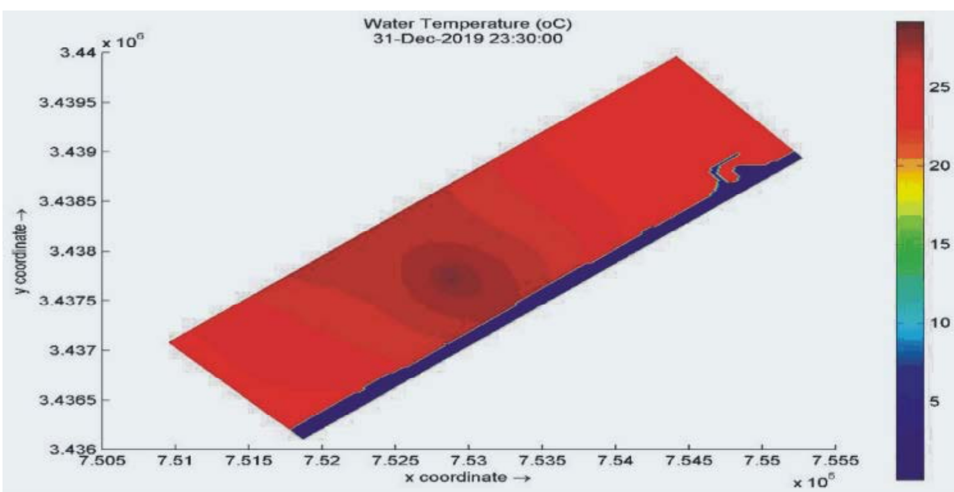

Fig. 22: The distribution of heat energy at d2 at Sidi Krir power station at heavy load

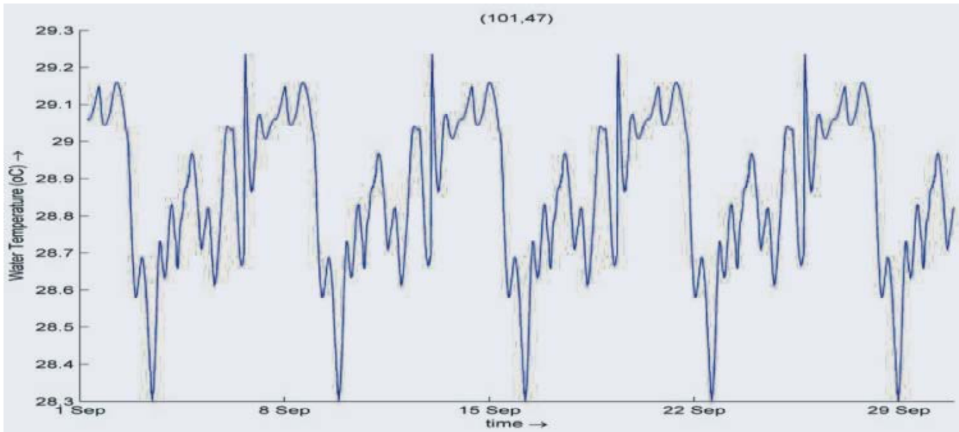

Fig. 23: The modelled temperature at observation point near to d2 at heavy load

temperature (ΔT) is equal to **5.35**. During the full load, the distribution of the heat energy at the first line (d1) of condenser at Sidi Krir power station 3&4 is presented in Fig. 20. The modelled temperature at observation point near to d1 at full load is presented in Fig. 21. At the second line (d2) the distribution of the heat energy is presented in Fig. 22. The modelled temperature at observation point near to d2 at full load is presented in Fig. 23.

CONCLUSION

There is difference between the two locations of dumping the cooling water for Sidi Krir power station 3&4, at seal well and at the discharging sites d1 and d2 in their temperature.. After calibration and validation of the model, the ΔT in two situations at fully and partially load at d1 and d2 was = **- 5.35** against the temperature measured by sensor at seal well.

ACKNOWLEDGMENTS

The authors would like to thank the maritime team of Rosetta Station and Marine Geology staff, Coastal Research Institute for their support during the fieldwork and the lab work. Also, the authors acknowledge Eng. Magdy Sanad and his team of Sidi Krir Power Station 3&4 for their support during this work.

REFERENCES

1. McGlenn, M., 2019. What is regulatory compliance?, Absolute blog. https://blogs.absolute.com/what-is-regulatory-compliance/
2. EEA, A., 2009. The environment law, Law number 4 of 1994, promulgating, amended by law no. 9 for 2009, Ministry of State for Environmental Affairs. http:// www.eeaa.gov.eg/ en-us/laws/envlaw.aspx
3. EEAA, 2015. Prime minister order 964/2015, Official Magazine, 66R(A) 19 April 2015.
4. Friedman, G.M., 1979. Differences in size distributions of populations of particles among sands of various origins. Sedimentology, 26: 3-32.
5. Folk, R.L. and W.C. Ward, 1957. Brazos River Bar: A study in the significance of grain size parameters. Journal of Sedimentary Petrology, 27: 3-26.
6. Vijayakumar, V., S. Vasudevan and T. Pruthiviraj, 2011. Sedimentological characteristics of Perumal lake Cuddalore District, Tamilnadu, South India. International Journal of Environmental Science, 1: 2019-2027.