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RESEARCH ARTICLE

Laser Measurement Systems for Water Levels in River of Shatt Al -Hilla, Iraq

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Abstract

This paper introduces a kind of measurement method of the displacement for the water levels in river by the use of the laser distance measurement .The monitoring of water levels in river provides information about changes in water levels can support flood forecasting systems. Based on the principle of the laser reflection and fixed parameters of river bed, thus to obtain the actual data of the height of water levels. The empirical results for the weather and water properties it limited the wavelength of laser type used in this laser system by using three laser wavelengths 530,632.8 and 810nm. The study has been focused on the area located around the city of Hilla at shatt AL-Hilla in Iraq; according to the data collected from the Iraqi meteorological organization over successive twenty five years.

Introduction

For water engineering and research one of the most important aspects of hydraulic aspects deals with representing the topography of rivers, floodplains, estuaries or coastal areas. Commonly, flood model applications use digital elevation models, based on high quality and high resolution topographic airborne laser data. The digital elevation model of the water body itself is normally represented by simplified and interpolated data based on manually collected terrestrial fieldwork data. As well as a lack of spatial and high resolution water body data, the modeling of shallow areas like meadows, estuaries or riverbanks is highly time consuming or even impossible. Frequent urban flooding over the past decades have identified an urgent need to improve and increase our modeling efforts and to address more explicitly the effect model input data has on the uncertainty in the simulation results. Society demands reliable and detailed information on magnitude and likelihood of hazardous flood events for design of flood mitigation. For this, the assumption of the shape of the water body has to be solved and modeling improved by using the actual shape. Currently, the multi-beams SONAR is the main technique for bathymetry measurement on submerged continental surfaces. This technique has several limitations: a limited spatial extension, a use on navigable rivers, a minimum detectable depth around 1.5 m. These limitations have an impact on opportunities for hydraulic and ecological studies in inland waters. In particular on rapid growth and and high ecological potential rivers, which are usually low depth and running water rivers. To map large linear rivers bathymetry, bathymetric (or hydrographic or green) LiDAR seems to be a suitable remote sensing technique, complementary to SONAR (Feurer D. et al., 2002). LiDAR sounding works with a scanning laser pulses emission-reception (some mJ) at a steady-frequency. Duration between emisson and reception is converted into distance (Laser telemetry). Its specifity is the use of pulses in two wavelengths: an infrared pulse (1064 nm) reflected from the water surface, and a green pulse (532 nm) which penetrates the water surface and is reflected from the floor. On other system components (scanning system, central inertial, D-GPS,…), bathymetric LiDAR has no differences compared to topographic LiDAR systems (Tulldahl H.M. et al., 2004). Currently, it exists literature references on accuracy and limits of bathymetric

LiDAR on coastal areas. However, only a few exists on rivers and inland waters (Hilldale, R. C. & Raff D. 2007), (Kinzel, P. J. et al., 2007), (McKean, et al., 2006).

COMPONENT OF THE SYSTEM

Referring to Figure (1) of the drawings, a block diagram is shown of a water level measuring system in accordance with a preferred embodiment of the invention. The system includes a laser which produces or emits a visible beam onto a telescope .laser transmitter output has a sine wave modulation, the method is called beam-modulation telemetry. Because of the single frequency component in the modulation, this technique sometimes is called tone ranging. The laser beam, as reflected by the water surface, and receive by same transmitted telescope. The redirected beam is received by a signal detector after traveling over distance L (i.e., the distance between Water surface and signal detector).

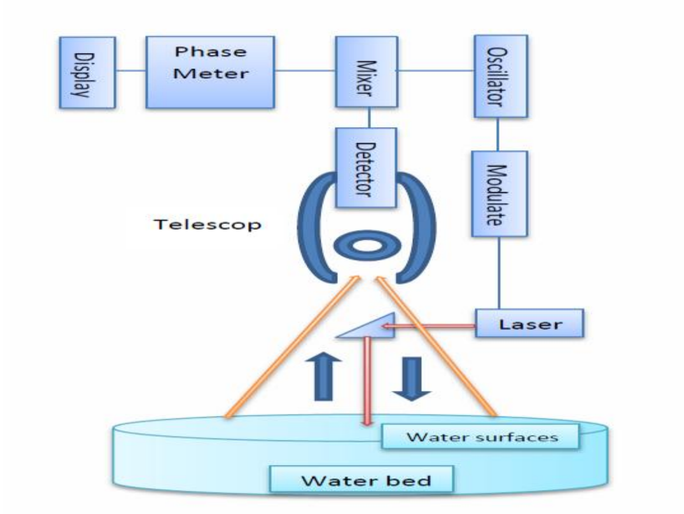

Figure 1: Water level measurement diagram

Range is determined by measuring the phase angle ϕ_r between the transmitted sine wave signal and the received sine wave signal. This phase angle can be related to a time delay tr similar to that measured in the pulse-measurement technique. The relationship between phase angle delay ϕ_r , modulation frequency fmod , and time delay tr , is:

$$t_r = \frac{\phi_r}{2\pi f_{\text{mod}}} \qquad (1)$$

Then, according to Equation (1), the range R will be:

$$R = \frac{ct_r}{2} = \frac{c\phi_r}{4\pi f_{\text{mod}}} \qquad (2)$$

The distance to the level water (Level) can be readily calculated using simple equation. $L_{level} = R + L$ Where L (the distance between surface and Bottom water River which already known in this case), Level and R is Know at steady state (Guenther G.C. 1985).

If the R increased this indicated the L decreased and the new date for the water level river become is

$$L = L_{evel} - R \qquad (3)$$

Measurement and Calculations

The methods we developed were first dedicated to GLFW model when targets are an on low deep river. This model is based on equations developed for coastal waters (Guenther G.C. 1985). To describe the received temporal waveforms (power, function of time) of the LiDAR system, we write the LiDAR return as the sum of multiple waves echoes:

$$P(t) = P_S(t) + P_{bsc}(t) + P_b(t) + P_{bg}(t) \quad + P_N(t) \tag{4}$$

Where P(t) is total power received; Ps(t) is power returned by the water surface; Pbsc(t) is power returned by the water column; Pb(t) is power returned by the bottom; Pbg(t) is the background power returned by the air column; PN(t) is noise power. In this paper, we will only focus on surface only since the bottom returns proportional to (1-reflectance at the interface air / water for wavelength (ρλ)). Since ρλ which using in this work too high so Pb(t) can be approximately neglected .

The Other formulations of received powers can be found in (Lesaignoux A. 2006). Power received from surface Equation of received power from the water surface is:

$$P_S(t) = \frac{\rho P_T(t) T_{atm}^2 \eta_r \eta_t A_r \cos^2(\theta_o)}{\pi L^2} \tag{5}$$

Where:

- ρ is the reflectance at the interface air / water,
- $P_T(t)$ is the transmitted pulse by laser (W),
- T^2_{atm} is the transmission coefficient of the atmosphere,
- η_t et hr are efficiencies optical transmission and reception,
- η_r is the area of the receptor (m^2),
- θ_0 is the incidence angle of laser (rad),
- L is flying height of the sensor in relation to the water surface (m).

Location and area description

The studied area is located around the City of Hilla (Babylon Governorate), 100 km south of city of Baghdad, between Longitude (44026- 65" & 44031-00") E and Latitude (32026-30" & 32031-30") N covering area of about 117 km² (Figure 2). Shatt AL-Hilla which passes through the AL-Hilla City, divides, the city in two parts (Figure 3).

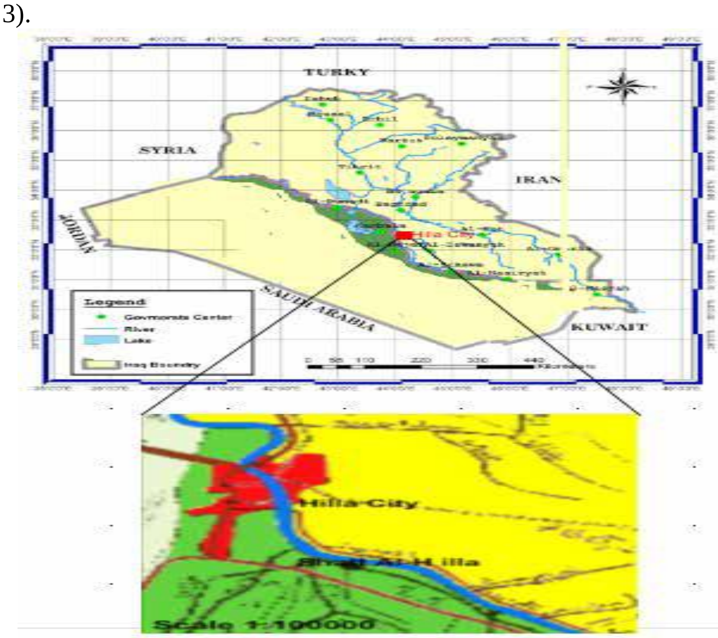

Figure 2: Location of the studied area (Al-Enezy, 2012).

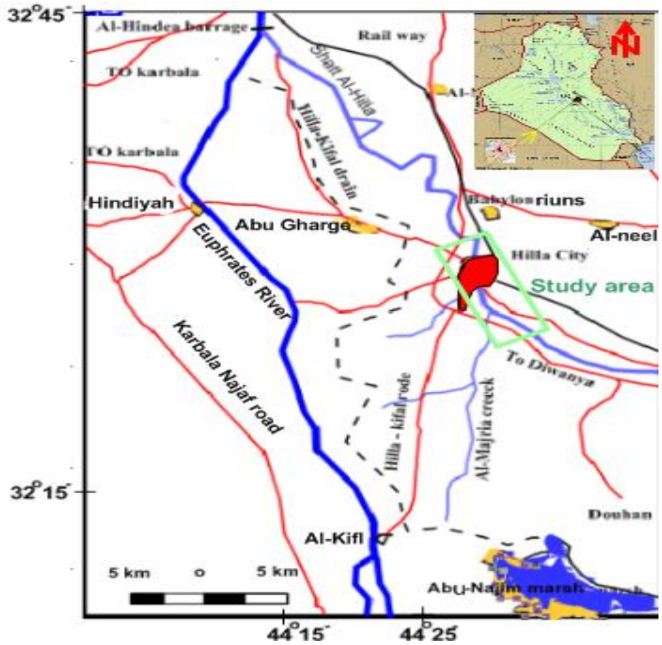

Figure 3: Shatt Al-Hilla channel within the studied area, modified (Swiss C. T. 1985).

Climatology and Rainfall City of Hilla

To find out the impact of climate and rainfall on the rising river levels should study the impact of these factors to determine the accuracy of the measurement:

Generally, the climate of the studied area is dry and hot in summer and cold with limited rain in winter with remarkable differences in the temperature degree and wind in the area accompanied usually by dust storms (Al-khatteb, A.A. 1988). According to the data collected from the Iraqi meteorological organization, the monthly averages of climatological parameters over successive twenty five years are given and their variations within the study area are presented (Table 1) and (Figure 4).

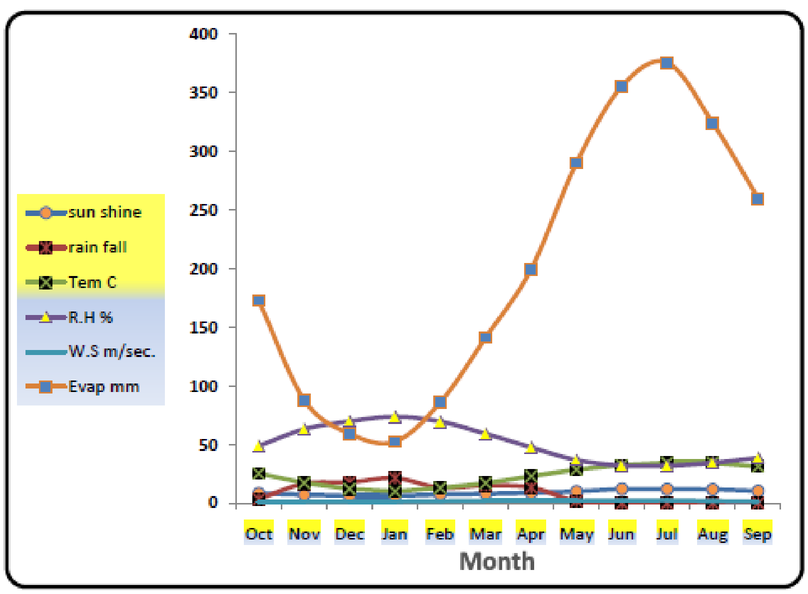

Figure 4: Variations among long term monthly averages of the examined climatic parameters with time.

Metrological Rainfall data show that the rainfall period within the studied area occurs during the months of October to January. The highest long term monthly average rainfall is (21.45 mm) (January) while the lowest average is zero (July-August). In general the rainfall events within the area are heavy and last only for short periods of time (Figure 5). Such high intensity rainfall has a great influence on groundwater replenishment and on leaching of soluble salts from soil profiles to the shallow groundwater systems. Comparison between annual rainfall values with the long term average annual rainfall (103.36 mm) (Figure 6) shows that 9 of water years are above this value and represent wet water years conditions while the other 12 water years are under this level representing dry water years conditions.

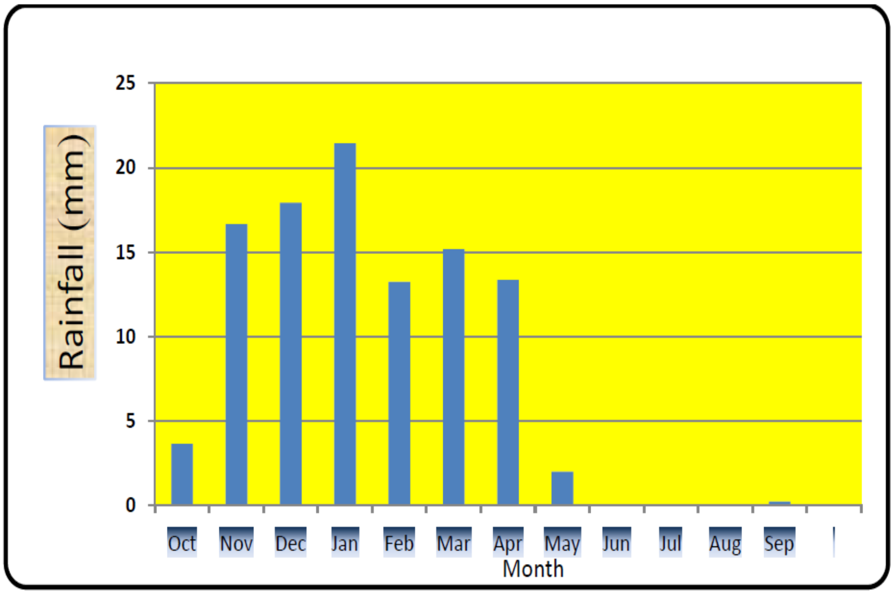

Figure 5: Monthly average Rainfall over the period (1984-2009) within Hilla City (Al-Enezy, 2012).

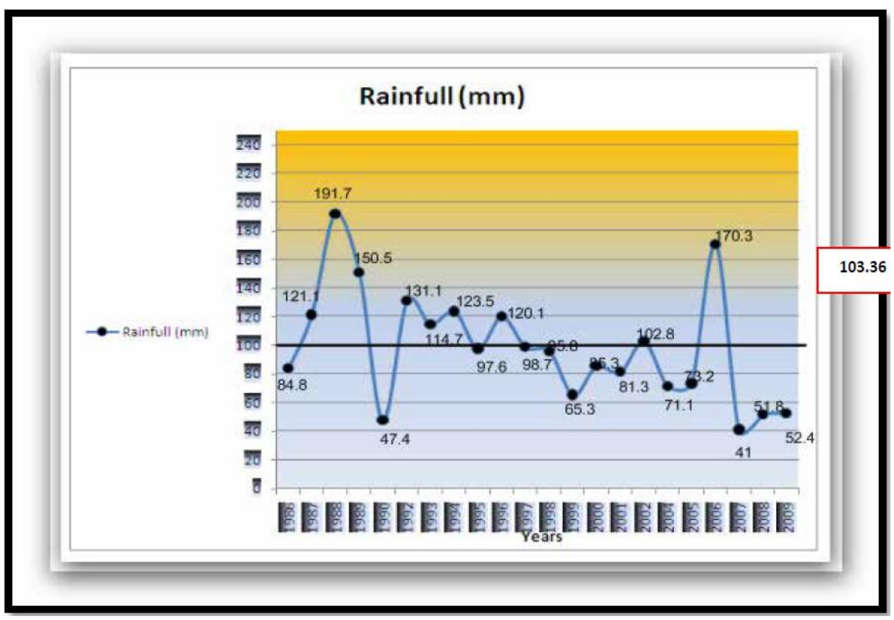

Figure 6: Variation of the average annual rainfall over the period (1984 -2009) within Hilla City (Al-Enezy, 2012).

Results and discussion

In this study, we wanted to assess the minimal water depth detectable by a system LIDAR on a river in using three laser wavelengths 530,632.8 and 810nm.

Figure (7) shows the change received power to increase the concentration of mud density in the water using a laser wavelength 530 nm, when comparing the reflection of clear water and bad water where it was found that the power received to detector when clear water more than the bad water.

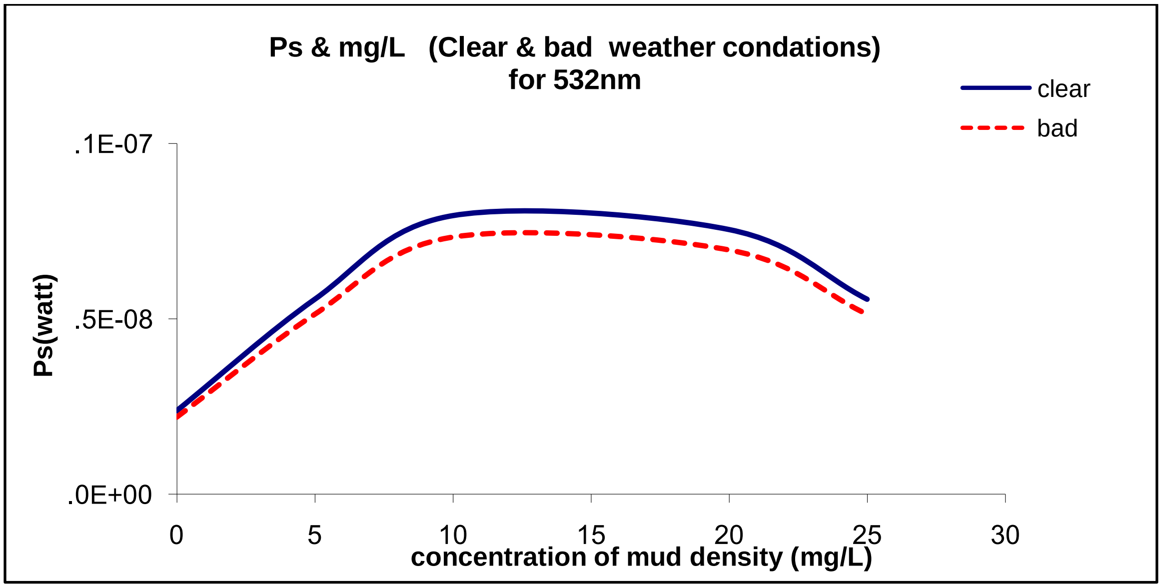

Figure 7: power receiving detector as a function mud density of laser wavelength 530nm.

Figure (8) shows the change received power to increase the concentration of mud density in the water using a laser wavelength 632.8 nm, also when comparing the reflection of clear water and bad water where it was found that the power received to detector when clear water more than the bad water.

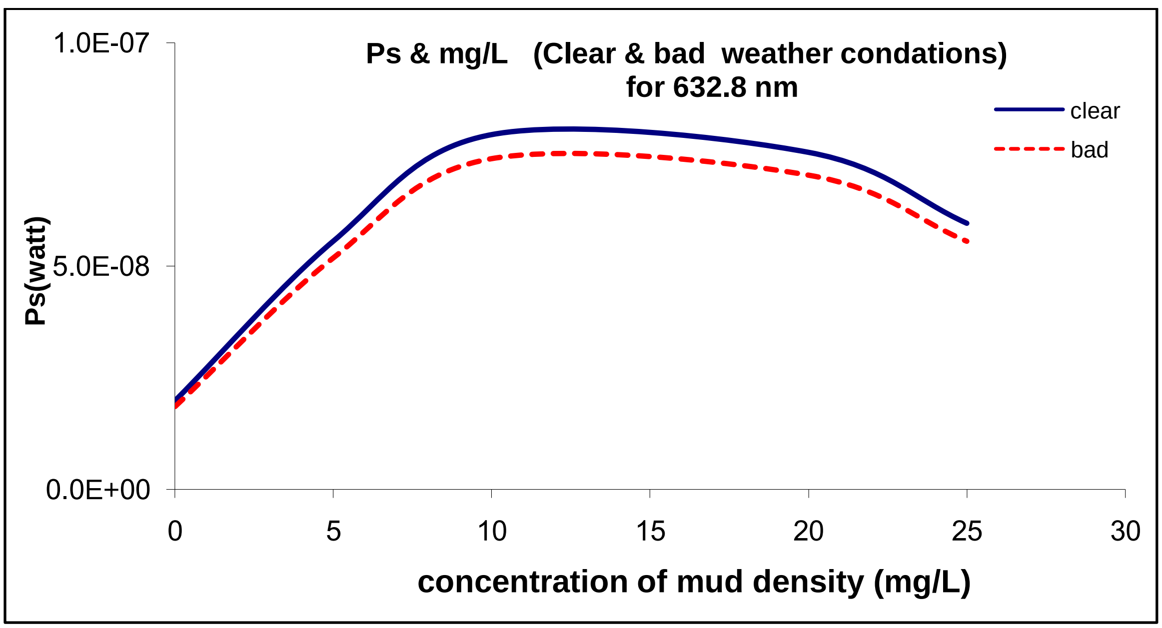

Figure 8: power receiving detector as a function mud density of laser wavelength 632.8nm.

Figure (9) shows the change received power to increase the concentration of mud density in the water using a laser wavelength 810 nm, also when comparing the reflection of clear water and bad water where it was found that the power received to detector when clear water more than the bad water.

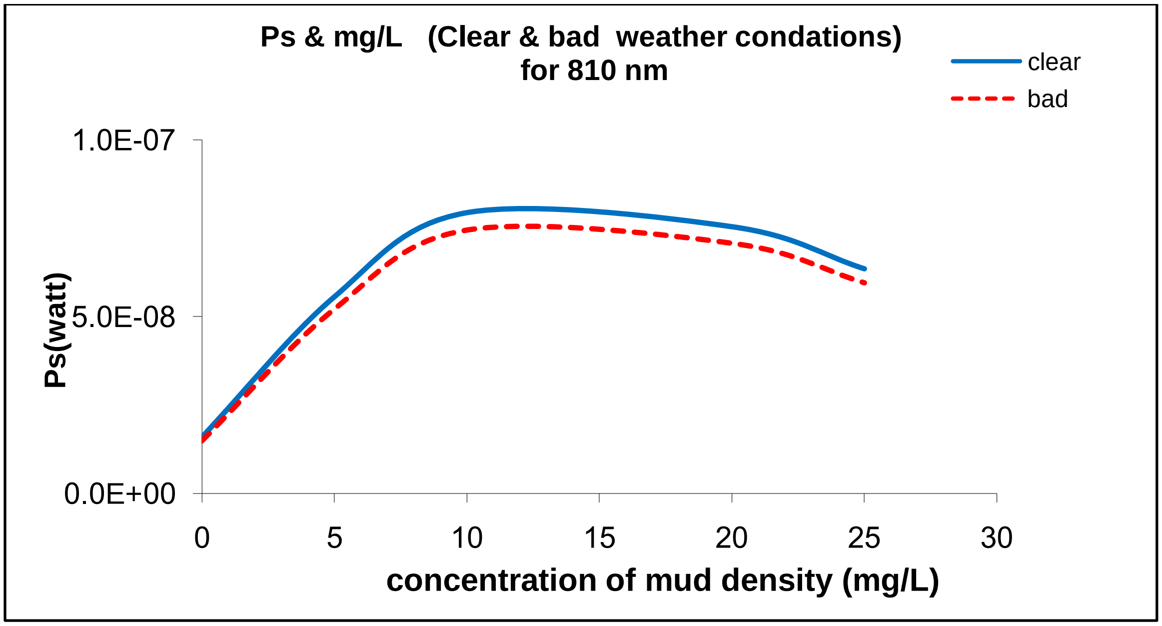

Figure 9: power receiving detector as a function mud density of laser wavelength 810nm.

The above Figures received power increases with mud density this may attributed to the composite of the mud and have maximum value 10mg/L for all wavelengths, after this value the received power decreases also for all wavelengths this may be attributed to the increases of the composite of the mud absorption.

The received power increases with laser wavelengths and it have maximum value at 810nm as shown in Figure (10).

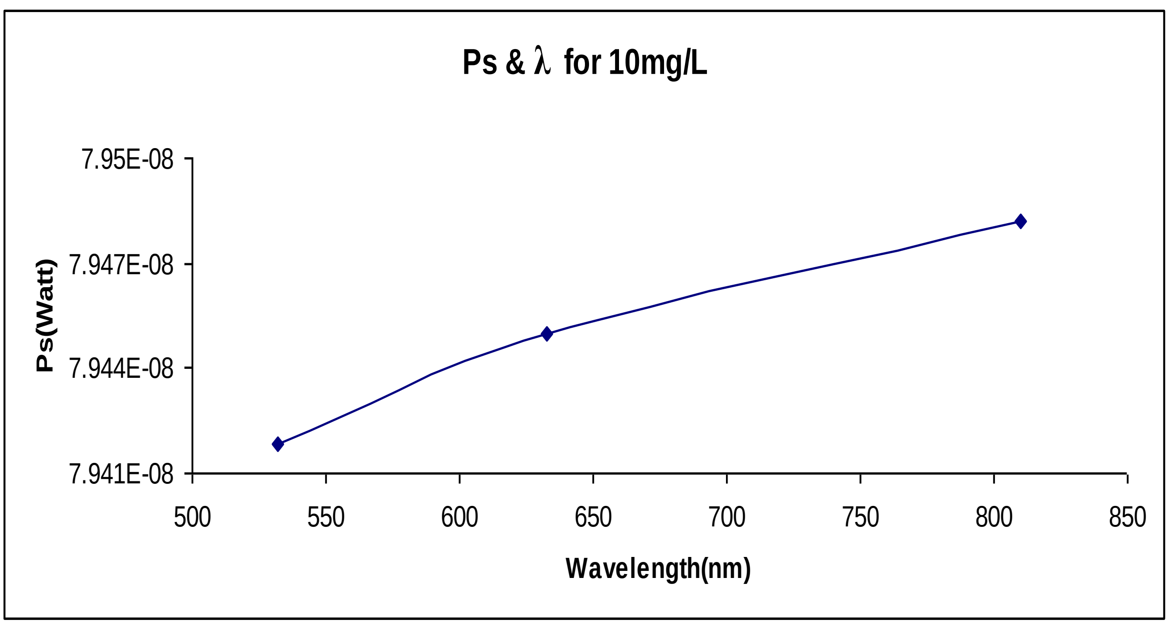

Figure 10: power receiving detector as a function of laser wavelengths.

Conclusion

From this study, we can conclude the following:-

- Laser systems can be used for high reliability in measuring and determining the water level in rivers.
- Laser beam of wavelength (810 nm) is more suitable to have more than wavelengths of (650 nm, and 530 nm) as used in laser LIDAR of determining the water level in rivers.
- The best use of laser beam LIDAR is through clear water.
    - The received power increases with laser wavelengths and it have maximum value at 810nm.

Table 1: Long term mean monthly averages of climatic parameters within Hilla meteorological station (1984-2009) (Al-Enezy, 2012).

Month	Sun shine (H)	Rain fall (mm)	Average Temp. (^0C)	Relative Humidity (%)	Wind speed (m/s)	Evaporation (mm)
Oct	8.465	3.643	25.32	48.782	1.19	172.75
Nov	7.330	16.678	17.43	63.260	1.161	88.065
Dec	6.301	17.913	12.23	69.913	1.352	59.382
Jan	6.380	21.45	10.35	73.894	1.352	52.485
Feb	7.521	13.22	13.02	69.761	1.815	85.950
Mar	8.160	15.177	17.15	59.272	2.295	141.340
Apr	8.844	13.356	23.01	47.636	2.033	199.809
May	10.098	1.995	28.84	36.782	2.114	290.368
Jun	12.200	0.008	32.51	32.043	2.442	355.719
July	12.106	0.000	34.81	32.000	2.680	375.669
Aug	11.750	0.000	34.41	34.521	1.966	324.352
Sep	10.489	0.213	30.95	38.739	1.490	260.052
Long term annual averages	9.137	8.637	23.31	50.525	1.824	200.495

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