Design and Development of Multi-Sensor ADEP for Bore Wells Integrated with IoT Enabled Monitoring Framework

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Abstract – Typically, about 51% of the groundwater satisfies the drinking water worldwide and is regarded as the major source for the purpose of irrigation. Moreover, the monitoring and assessment of groundwater over bore wells is essential to identify the effect of seasonal changes, precipitations, and the extraction of water. Hence, there is a need to design a depth sensor probe for bore wells so as to analyze/monitor the quality of underground water thereby estimating any geophysical variations like landslides/earthquakes. Once the depth sensor probe is designed, the data is collected over wireless sensor network (WSN) medium and is stored in cloud for further monitoring and analyzing purposes. WSN is the major promising technologies that offer the real-time monitoring opportunities for geographical areas. The wireless medium in turn senses and gathers data like rainfall, movement, vibration, moisture, hydrological and geological aspects of soil that helps in better understanding of landslide or earthquake disasters. In this paper, the design and development of geophysical sensor probe for the deep bore well so as to monitor and collect the data like geological and hydrological conditions. The data collected is then transmitted by wireless network to analyze the geological changes which can cause natural disaster and water quality assessment.

Keywords – Depth Sensor Probe, Bore Wells, Groundwater, WSN, Cloud, Hydrological and Geological Features, Water Level, Water Quality.

I. INTRODUCTION

Groundwater is the water that is found beneath the cracks and spaces in soils, rock, and sand. It is stored and thus moves through the geological formations slowly of soil, rocks, and sands termed aquifers. Water source is a significant and essential aspect in various fields like farm and agriculture production and also it is a quality of life. The level of water monitoring for the source of water like bore well, water tank and so on. the process of monitoring for instance, once the level of water level drops beyond the level of threshold for pumping in the borewell, the pump motor might be damaged because of dry running. In such a case, the level of water and controlling the pump water consequently turn out to be essential task [1]. There were several other circumstances like monitoring the level of water and is employed for preserving them to study the usage of water source.

Water is considered as world's richest substances. Among 100% of water content, about 98.8% is in the form of soil system and ice form. The groundwater should be below 0.3% in the streams, atmospheres, oceans, and in turn the Earth's groundwater which is lesser than 0.003%. Water is considered as the incredible one that is needed for the entire establishment of organisms, whereas, due to increase in population, excess need of water also rises for domestic needs and further uses. Any portable water quality based on nature and the human behavior primarily. Hence, the quality of water should be sustained so as to conserve the quality of water in an optimum manner for each citizen. The TDS, pH level, DO (dissolving oxygen), and TSS (total suspended solids) and so on were considered as the major water parameters for assessing the quality. Thus, the water quality enhancement and biodiversity, diarrhea host, and several other diseases like chemical toxins may make persons at risk [2, 3]. On behalf of the ground water supplies contamination of water makes the storage tank establishment, and after the treatment of water may be in occurs or else through avoidance. As of the water quality determination which attains quality over pollutants and contamination is measured over areas by a biological test. The water samples assessment in turn evolves the ground water quality [4-8].

The effective employment of a landslide detection application needs management of huge data amounts from the wireless sensor network, keeping its integrity and accuracy and guaranteeing low-latency sensed data transmission through effectual energy utilization. The wireless sensors are considered as the most leading technologies which could record fast variations in the data and in turn transmit the data sensed to a center of analysis of data from remote aggressive zones. The technology of WSN has capable to process transmit, and capture quickly of serious data having high-resolution for monitoring actual aspects [9-13]. This in turn has the benefits of sensor deployment which requires low conservation that is idyllic for the hostile framework. The effectual management of those resource restraints in turn regulates the network time and collection of data frequency as well as the transmission and processing collection.

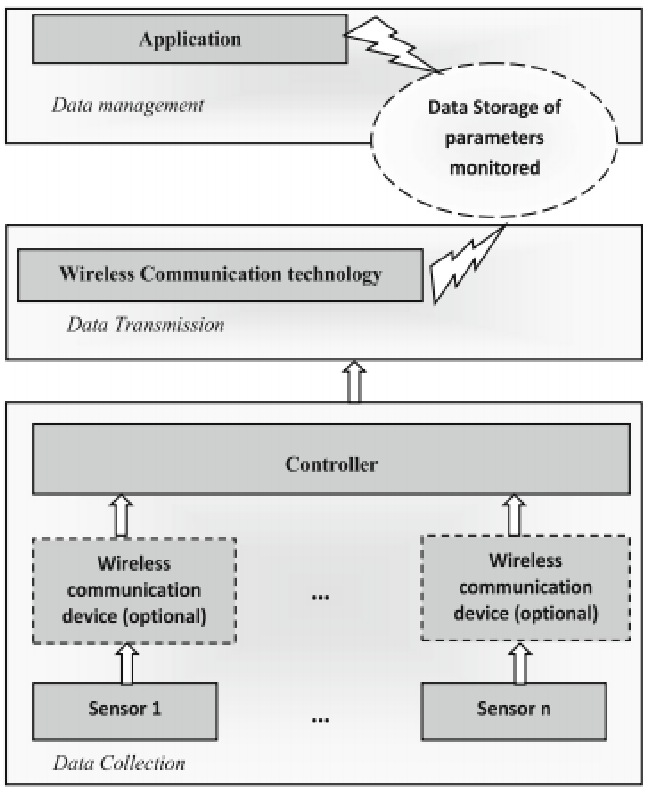

Fig 1. Smart Monitoring System Using Sensors in Deep Bore Well

The selection of appropriate geophysical sensors needs a complete understanding and knowledge of the natural disaster phenomena, the parameters that will trigger the earthquakes and landslides and the deployment of hydrological areas. The landslides that are induced by rainfall occur commonly in the areas that are landslide prone where there is a prolonged intensity, heavy, high-intensity or medium condition of rainfall. At such conditions of rainfall, the infiltration of rain in turn causes transient pore pressure responses, instability, a safety factor reduction, variations in height of water table, a shear strength reduction that holds rock or soil, a soil weight increase, and the angle of repose reduction. Once the intensity of rainfall is greater than the saturated slope hydraulic conductivity, overflow might happen [14]. The most important physical singularities that was observed for initial landslides warning were variations in humidity content, pore pressure, movement, vibrations inside the earth, and rainfall. Afterward cautious study, the geophysical sensors are desired intended for analyzing/monitoring those variations should be employed and selected.

The experimental setup length might be adjusted depending on the sensors number that is employed for monitoring and analyzing purposes. The data bit before the association sensor displays 00, whereas after the sensor gets connected to the system, the system will search data automatically and the data conversion takes place. Then the converted data is then stored in cloud.

The residual part of this manuscript is systematized as shown: section II is the depiction of related work section at which the various existing techniques employed so far are reviewed. The proposed methodology of the proposed system is depicted in section III. The performance analysis of the proposed mechanism is projected in section IV. At last, the section V concludes the overall workflow of proposed scheme.

II. RELATED WORKS

This section offers the detailed depiction of review on various existing techniques employed so far. The author in the paper [15] developed a bore well prosthetic system for rescuing the children trapped from the bore well in a short period of time. In last few years, there occurs a number of deaths due to bore wells in India. The projected design is competent of handling such scenarios once the child is being stuck to the bore wells at bottom and middle. This in turn reduces the involved risk at the time of rescuing the child process on analyzing the situation. This in turn offers an optional one in detection of crack inside the rocket casing, boilers, and the pipelines. In [16] presented a system that focuses on monitoring the level of water and their data visualization. This in turn offers a real-time data that is recorded by the logger data. The key aspect for water level measurement was their level of pH. The monolithic voltage-to-frequency converter VFC320 was employed for identifying the digital pulses and those frequencies were multiplexed over frequency division multiplexing, FM generation modulation and transmitted over the FM transmitter. The [17] suggested a validation and design of novel Eddy current probe (EC) which was employed for the detection of deep surface cracks and in turn characterizes the graphite bricks properties like those employed for making the Advanced Gas-cooled reactor (AGR). In this approach, a asymmetrical curved gradiometer probe was devised and in turn optimizes for enhancing the conductivity and defects in graphite.

The [18] introduced a novel ECT probe design for integrating the distributed ECT system of inspection (DSECT) which is employed for the inspection of crack in the inner regions of ferromagnetic pipes. This system in turn comprises of giant magneto-resistive sensor (GMR) sensors, a pneumatic system and is the excitation of rotating magnetic field and a data analysis center that acts as a host. The design of parameter probe termed probe diameter, the excitation coil, and GMR sensor number is being optimized with the use of numerical optimization depending on the desirability approach.

In [19] reviewed a study which reveals that KHSB South eastern part might be polluted and about 30% of that zone is feeble for deprived protective zone for the capacity pollutants. Adequately this effort in turn contaminates an applied practice of geological techniques, modelling geo-electrical combination, and D-Z parameters, bore hole logging in the assessment of groundwater resource process. Thus, this approach was recommended for the areas having alike geological setup highly. In [20] reported the usage of fiber optic sensing system of distributed temperature that spatially resolve the temperatures along with while U-tube length in the perpendicular bore geothermic well. The probe of optic fiber in a U-tube offers temperature data spatially with resolution of 2-m over TRT period. The data of spatial temperature in the U-tube offers a potential platform for determining various characteristics of bore test like ground properties as the depth function that enable more precise models of imminent ground heat exchanger.

The [21] discussed and reported the short-term variation monitoring employed widely as multi-geophysical parameters in Latur-Killari regions in western India, the region that witnesses the major earthquake devastation by 1993. The abnormal rise in the temperature of atmosphere higher than 20 °C at height 11200 m has been observed in air-light which is just 100 km far away from the Latur at the period of monsoon. Such an abnormal rise in temperature with respect to seismic areas for 1993 Latur earthquake with thorough ground water level monitoring and helium gas for about a week was performed in the study area. In [22] suggested a scheme to design an open-ended coaxial probe depending on the RG405 modelling semi-rigid geometry of coaxial probe for serving the analysis of single frequency with sensing depth at 2 GHz with the utilization of FEKO electromagnetic simulation. This review in turn confirms the published studies initially, at very limited sensing depth in water-Teflon combinations and thus expresses the sensing depth of layered skin-fat-muscle combination at 2 GHz which is limited to skin only.

In [23] employed automatic mapping water detector (AMWD) for locating the aquifers through comparative pits and the review of electric resistivity (ER) on examining the brininess of groundwater. AMWD in turn generates the form of output having potential difference curves and the profile maps that are interpreted together for investigating the aquifers. By using ER survey, configurations of Schellenberger were carried at the demarcated locations and the values of resistivity have been analyzed for establishing the groundwater quality relations. The WSN evolution has raised growth in monitoring real-time emergency and critical applications. A Alert System and Drought Forecast (DFAS) [24] was established which employs communication through mobile for alerting the users. In contrast, this projected system employs collection of real-time data, wireless sensor nodes transmission, satellite network, an Internet and the Wi–Fi. The actual data streaming over wideband offers a wider audience connectivity with experts to laymen that could offer a ability of experts pool for analyzing the data of landslide and in turn offers information to the government. [25] designates a prototype of WSN for greenhouses environment monitoring. An network of investigational monitoring of soil by means of a WSN was offered by [26]. It describes a state-of-the art scheme that syndicates several kinds of sensors for offering measurements to deform monitoring functions. [27] deliberated the slip surface localization topic in WSN that could be employed for the prediction of landslide.

The [28] Projected a view on embedded device and sensors which is the LoRa-reliant wireless sensor system and an insubstantial Message Queue Transfer (MQTT) protocol. The scheme primarily involves a sensor node similar to retailers, and subscripts include Raspberry, desktop clients and a MQTT broker. LoRa wireless sensor network, the sensors were small and have in-built instrumentations employed for the water quality assessment. In [29] suggested a technique on assessing the quality of water in a real-time basis in the Bristol Floating Harbor that showed the quality of water successfully in real time and in turn tracks the information on real-time data over several parameters of water quality management. The new system reveals in what way the intelligent society attains information from the wireless network. The environment can thus be incorporated to the metropolitan water system for attaining enhanced rate of efficiency.

The [29] suggested the reliable, better, and a cost-efficient method for sensing could be assessed by the nitrate-nitrogen concentration in the water. The traditional devices [30] for sensing were difficult and are cost effective in nature for running the continuous retail environment due to their drawbacks. IIPs (Ion-imprinted polymers) were considered as a helpful technique for enabling the low-cost sensor creation having perceptive gratefulness's.

III. PROPOSED WORK

This section is the detailed explanation of proposed system implemented i.e., the design and development of geophysical sensor probe for the deep bore well so as to monitor and collect the data like geological and hydrological conditions. The data collected is then transmitted by wireless network to analyze the geological changes which can cause natural disaster and water quality assessment.

Design and placement of the multi-sensor aqua deep earth probe (ADEP)

Several sensors intended for analyzing landslides are recognized and are suppressed in underground on behalf of measuring the pertinent hydrological and geological properties. An Aqua Deep Earth Probe (ADEP) has been devised for deploying those sensors to the various location stack. The ideal depth for ADEP which is to be deployed should be similar as the bedrock depth at that location. The design of ADEP employs a structure of heterogeneous one with various kinds of geophysical sensors at various positions. The hydrological and geophysical properties at each ADEPs location in turn recognize the total number of geophysical sensors required and their corresponding positions on the ADEP. These sensors are deployed or placed in or out of ADEP as per each specific deployment strategy. All those geophysical sensors of ADEP are interconnected to the nodes of wireless network over the board of data acquisition.

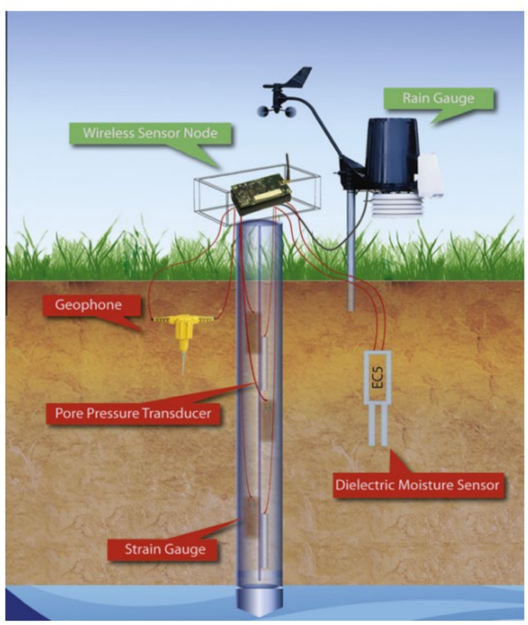

Fig 2. Design and Multi-Sensor ADEP Placement

Placement of Sensors

The geophysical sensors design and spatial distribution on DEP were recognized by several factors that includes soil layer numbers, properties of soil, hydraulic conductivity, variability, and impermeable layer presence, height of water table, bore hole depth for DEP deployment, and the desired method of deployment needed for each geophysical sensor.

- Let the deep length from the earth's surface be l,
- Let n be the depth of l from the maximum number of soil layers
- The ith soil layer thickness be ti, here i differs from i=1, 2…, n,
- A number of soil layer on depth of water table be i=wt,
- A maximum impermeable layer's number in the bore used hole intended for deployment of dep remain m,
- An impermeable layer depth from the earth surface can be dim (with the thickness of soil layer as the impermeable layer), here im differs from im=1, 2..., m
- An imth impermeable layer thickness be tim, where im varies from im=1, 2..., m

Thus, a formula intended for respective sensor placement location is determined in addition the sensors number required meant for the deployment were recognized as shown:

Deployment of Dielectric moisture sensor

The deployment of one dielectric sensor for moisture at least on behalf of measuring the soil moisture at ezh layers of soil is needed. Thus, the extreme dielectric sensors number is provided by **eqe (1).**

$$N_{DMS}(\text{theoretical})=n \tag{1}$$

Though, the soil is composed of permeable and the impermeable layers. This must be noted that, once the layer of impermeable is beyond the permeable layer, then the water will infiltrate over the permeable layers and in turn leak out over impermeable layer at similar amount that causes water table balanced which loosen the particles and might lead to instability of slope. Hence, it is essential for inserting the sensors to the impermeable layer and a permeable soil layer. Moreover, an addition of sensors at respective impermeable layer, an additional device is needed for soil above the real water table for measuring the variations caused in hydrological water table assets. Therefore, the number of optimum sensor essential is specified in **equ (2).**

$$N_{DMS}(\min)=m+1 \tag{2}$$

A sensor that was positioned at bottom layer of a borehole, i=n is specified in **equ (3).**

$$PDMS(n) = l - \frac{1}{2}t_i = l - \frac{1}{2}t_n \tag{3}$$

By using the equation, the dielectric moisture sensor needed and their position is determined.

Deployment of piezometer transducer for pore pressure

The deployment of one pore pressure piezometer at least sensor is essential at each soil layer for measuring the pore pressure. The number of theoretical piezometer sensor for pore pressure is specified in **equ (4)**

$$N_p(\text{theoretical})=n \tag{4}$$

The positioned sensor in the borehole's bottom layer i=n, the senor placed at any type of soil starting from i=n-1 to i=1, and in turn the sensor placed at impermeable layer of soil is being determined by using the formula employed for dielectric moisture sensor correspondingly. The placed pore pressure piezometer at any other layer of soil above impermeable layer is recognized using the **equ (5)**

$$P_p(im-1) = l - \sum_{j=n}^{j=im} t_j - \frac{1}{2}t_{im-1} \tag{5}$$

The placed piezometer pore pressure on any one layer of soil under layer of impermeable was recognized in **equ (6)**

$$P_p(im+1) = l - \sum_{j=n}^{j=im+2} t_j - \frac{1}{2}t_{im+1} \tag{6}$$

Deployment of strain gauge

The strain gauge is attached at the outside layer of ADEP. It measures the induced movement caused by sliding layers of soil. The depth of water table is not appropriate to the Strain gauges placement of sensor. So as to capture the movements efficiently at the areas of landslide prone could be in any other directions, the strain gauge is placed either in direction x, y or the separated three gauges through 120^0. Henceforth number of strain gauge sensors theoretically is specified in **equ (7)**

$$N_{SG}\text{ (theoretical)}= n*3+3 \tag{7}$$

Each layer of vulnerable field consist of 3 sensors kinds positioned at predictable movement path. In addition, 3 sensors were positioned at ADEP's central portion. Hence, the utmost strain gauge sensors number are specified in **equ (8).**

$$N_{SG}\text{ (min)}= 2*m+3 \tag{8}$$

Tiltmeter

The tiltmeter purpose is to seize the angle change knowledgeable by DEP all through slope instability. In each of the soil layers, tiltmeters were positioned for capturing the tilt in an accurate manner. The presence of impermeable and intense rainfall contributes the instability of slope. Hence, the tiltmeters were positioned in the impermeable layers, besides too tiltmeter is positioned in DEP center.

Consequently, tiltmeters least sum was specified in **equ (9)**

$$N_T\text{ (min)}=m+1 \tag{9}$$

Geophone deployment

For measuring the vibrations experienced at the slope instability, the geophone is employed and are placed at the earth surface. These geophones were deployed at entire regions i.e., middle, crown, and middle of hill in the areas of landslide prone. The 3 geophones at specific regions might perform the technique of triangulation that offers vibration detection. Hence, the number of theoretical geophones is specified in **equ (10)**

$$N_G\text{ (theoretical)}=r*3 \tag{10}$$

Here, r is the distinctive regions number in the field of landslide deployment. Also, the variations can be caused by slope instability by using at least one geophone at each region. The current deployment comprises of three regions. Hence. The optimum number of geophones is specified in **equ (11)**

$$N_G\text{(min)}=3 \tag{11}$$

Rain gauge

To measure the rainfall intensity rain gauge is employed. They could be deployed separately from ADEP's at various regions. The theoretical rain gauges number is specified in **equ (12)**

$$N_{RG}\text{(theoretical)}=r \tag{12}$$

The field of deployment must have one rain gauge as a minimum. Consequently, the rain gauges least number is specified through **equ (13)**

$$N_{RG}\text{(theoretical)}=1 \tag{13}$$

There were some specific methods of deployment for each sensor. The sensors of dielectric with the geophones external to the ADEP in corresponding soil layers as the strain gauge were attached to the outermost surface of ADEP. The tiltmeters are positioned in ADEP and multiple-sensors of pore pressure were positioned at various depths of similar bore hole. The sensor of respective pore pressure is being involved to the separate ADEPs have fewer cross-sectional areas on comparing DEPs employed for any other sensors. The deployed rain gauges were positioned over ground in the height that are predetermined.

The deployed Aqua deep earth probes in a manner of spatial distribution so as to ensure several conditions of variations in geological factors. The data collected from the sensor is then kept in framework of cloud on the data transmission through medium of wireless network.

Wireless Network medium to transmit data to cloud for monitoring and analyzing purpose

Monitoring Water quality

The monitored key parameters in a projected system are turbidity, conductivity, pH and water level. The proposed system block diagram is exposed in **Fig 3**. A forms of the central part controller in the IoT enabled quality of water system of monitoring. As realized, it is detected that most of IoT dependent resolutions employ a controller having exterior Wi-Fi. Such strategies are not power efficient, cost effective and too outcome in circuit of complexity. In this approach, microcontroller TI CC3200 was a single chip having in-built module of Wi-Fi and ARM Cortex M4 core, that could be interconnected to the adjacent Wi-Fi hotspot intended for connectivity of internet. The Sensors are interfaced directly to the controller meanwhile the projected scheme is to monitor internal ground water quality.

The parameters of sensor like water level, pH, turbidity and conductivity were restrained on placing sensors that are sent to cloud framework using controller placed at various solutions of water. The parameters measured could be viewed using LCD. From the sensors, the data are sent to cloud with the use of controller. The threshold level is set in the cloud depending on standards provided by WHO. The message is sent from cloud to users from cloud for the mobiles of users once the value exceeds the threshold. The mobile application was employed at which the attained values on each sensor at cloud might be viewed. It could be employed by means of both water quality monitoring establishments along with users.

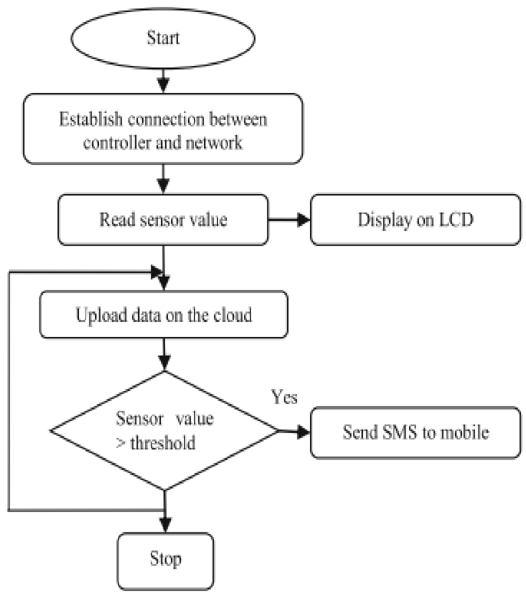

Fig 3. Updation of Sensor Data Flow Chart

The cloudiness degree of water is Turbidity. The sensors of opto-electronic like LDR and LED were employed for measuring the turbidity. The light is being reflected and transmitted through the solids that are suspended and the reflected light was then established through sensor. Thus, the LDR is semiconductors that are highly resistance. Once the light falls at device that are having high frequency, the fascinated photons through the semiconductor device in turn bids the enough electrons bound energy for jumping band of conduction. From the presented approach, the detachment among LDR and LED was about 9 cm. The behavior of permitted electrons ensuing electricity therefore let down resistance. The level of Water was being sensed for water depth determination in bore wells. It is carried out through probe technique. Three probes were employed so as to specify the level of water like medium, low, and high.

Computation of WQI (water quality index):

For water quality index scheming of initial necessity for assigning the weight for the substance that might make higher water impact formerly essential to compute the comparative the substance weight using in **equ (14)**

$$W_i = [w_i / \sum w_i] \tag{14}$$

Here, W_i is regardedas the relative index and the $\sum w_i$ is considered as the parameters weight sum.

Then the quality of the water was computed by the use of **equ (15)**

$$Q_i = C_i / S_i * 100 \quad (15)$$

Where $C_i S_i$ signifies to the BSI standard values

After that, for computing the WQI there is a need to compute SI_i with the following **equ (16)**

$$SI_i = W_i * Q_i \quad (16)$$

$$\text{WQI} = [\sum SI_i] \quad (17)$$

The Water quality classification based on rate of WQI of the Percentage is samples of the water quality.

Water level monitoring and geological variations analyzing

All through intense or the heavy rainfall, a sensor for moisture is the initial sensor for saturating on comparing other kinds of sensors, and data might continue unaltered once afterwards the content of volumetric water reaches 100%. From this point, the system will offer an initial cautionary initially. By way of time evolutions and in case the degree of rainfall relics the similar one, or the intensity has increased, values of pore pressure has changed were seen corresponding to infiltration rate. Once the system in turn identifies the pore pressure too saturated, the system offers next or second level warning. On this period, the warning will be issued to local community and the officials of government and in case rainfall still persists, for saving human life from further disaster, the local community is advised for evacuating the locations. Additionally, if the system obtains an alteration in the sensor values movement accompanied by the value of high pore pressure, this might issue the forthcoming or third level of caution.

At whatever time if the value of pore pressure decreases deeply, because of a rainfall reduction, the issued warning will be detached. Accompanied by the systems of three level warning, the landslide outcomes modelling software were associated for evading false alarms. The modeling of Landslide software includes the data of raw sensor from the deployment field site accompanied by data from lab setup, soil tests, and other land data for determining safety factor (term FS employed to enumerate the stability of slope). Based on the outcomes of threshold level attainment, each grid point might be marked 'safe' or 'unsafe'. This execution is combined into the software of data visualization, and the outcomes were streamed to the website in a real time basis.

IV. PERFORMANCE ANALYSIS

The performance analysis of proposed system is depicted in this system. The outcomes attained are shown in tabulation and graphical representation.

Performance analysis for monitoring groundwater level and quality

The performance estimation is made to estimate the level of groundwater level in bore wells using pressure and the flow detector and the outcomes attained are shown below **Fig 4.**

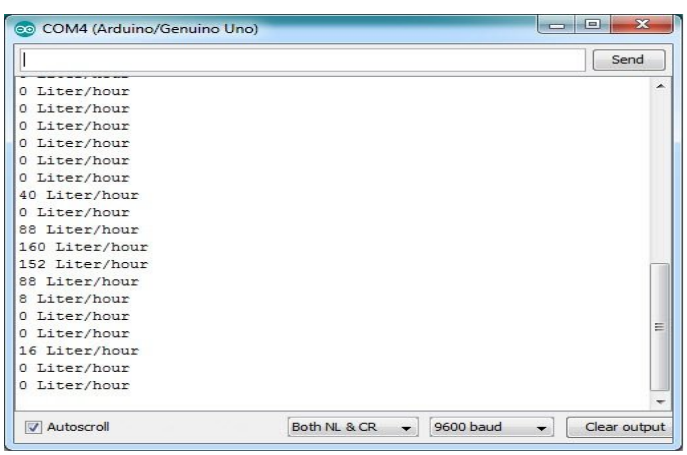

Fig 4. Flow Sensor Readings Representation

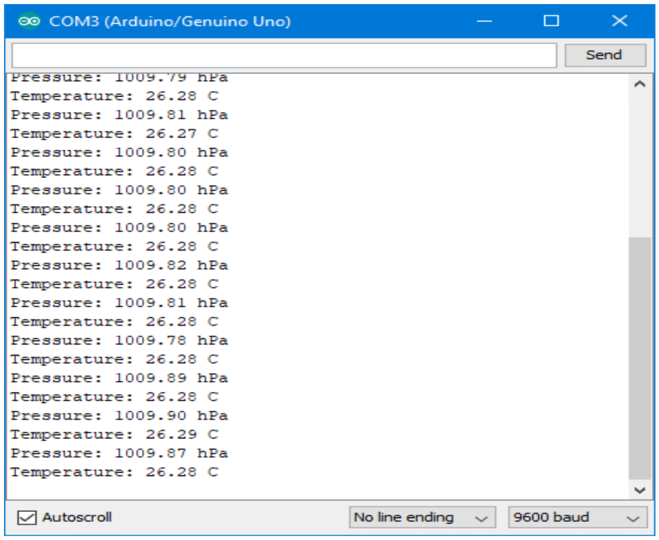

Fig 5. Pressure Sensor Reading Illustration

Fig 4 is the illustration of flow sensor reading representation. The reading attained from the flow sensor per hour is being stored and the samples of some reading representation are projected. The reading represents the amount of water flow in liters per hour. Similarly, the depiction of pressure sensor reading is illustrated in **Fig 5**. The pressure and temperature of the ground water readings are illustrated in terms of hPa and C. Figure 6 is the illustration of Mininet dashboard. The topology of Mininet dashboard is shown below in **Fig 6.**

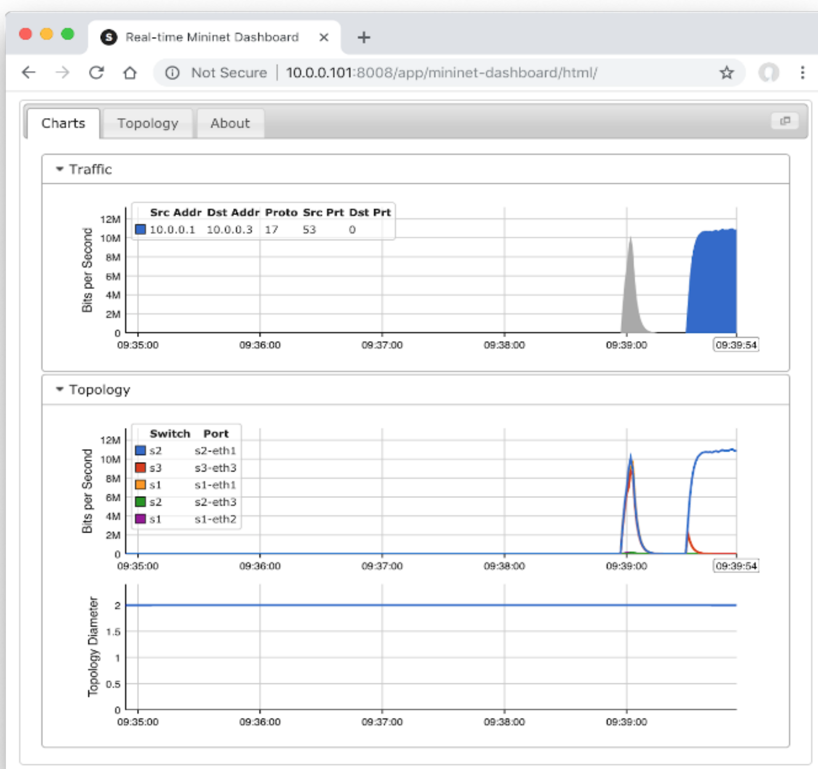

Fig 6. Mininet Dashboard Representation

Table 1 is the tabulated values for analyzing sensor to measure the levels of water from bore well to storage tanks for 30-liter tank size that shows the flow rate and water level in percentage with time to fill the storage tank. As the flow rate increases the water level also increases and the time taken varies accordingly.

Table 1. Water Level Analyzing From Bore Wells to Storage Tanks of 30 Liters

Flow rate	Water level in %	Flow rate in %	Time (sec)
48	0	7.2	15
54	0	8.4	14
64	10	9.6	13
80	20	12	11
96	30	14.4	9
120	40	18.07	7
168	50	25.3	6
208	60	30.8	5
264	70	40	3
352	80	53	2
504	90	75.9	1
664	100	100	0

Table 2 is the tabulated values for analyzing sensor to measure the levels of water from bore well to storage tanks for 20-liter tank size that shows the flow rate and water level in percentage with time to fill the storage tank. As the flow rate increases the water level also increases and the time taken varies accordingly.

Table 2. Water Level Analyzing From Bore Wells to Storage Tanks of 20 Liters

Flow rate	Water level in %	Flow rate in %	Time (sec)
48	0	7	20
56	0	8.2	18
72	10	10.5	16
96	20	14	15
128	30	18.8	13
160	40	23.5	11
192	50	28.2	9
232	60	34	8
320	70	47	6
456	80	67	4
616	90	90.3	2
680	100	100	0

Table 3. Water Level Analyzing From Bore Wells to Storage Tanks of 15 Liters

Flow rate	Water level in %	Flow rate in %	Time (sec)
48	0	9.5	17
64	0	12.6	14
72	10	14.2	12
88	20	17.4	11
136	30	26.9	9
160	40	31.7	8
176	50	34.9	7
208	60	40.4	6
296	70	58.7	4
408	80	80	3
496	90	98.4	1
504	100	100	0

Table 3 is the tabulated values for analyzing sensor to measure the levels of water from bore well to storage tanks for 15-liter tank size that shows the flow rate and water level in percentage with time to fill the storage tank. As the flow rate increases the water level also increases and the time taken varies accordingly.

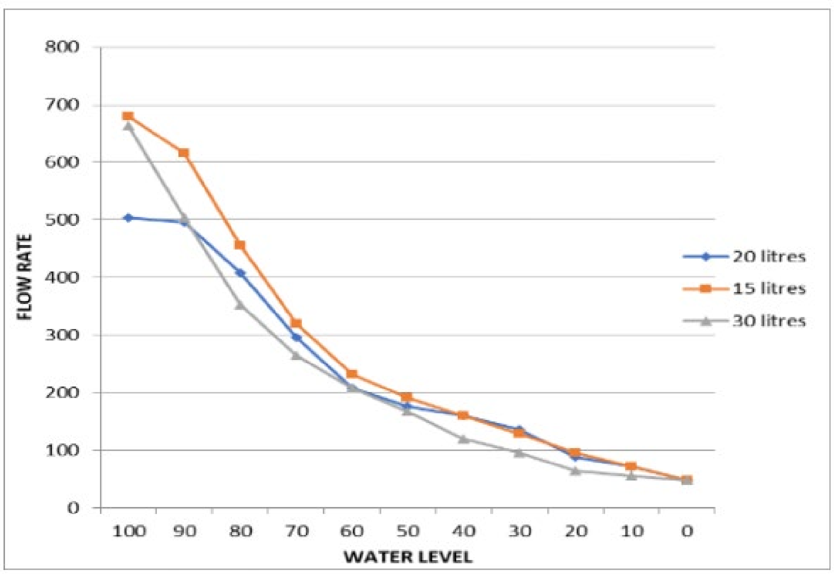

Fig 7. Water Level Analyzing Comparison for Various Level of Storage Tank from Bore Wells

Fig 7 is the representation of analyzing water level comparison various tank sizes like 15, 20, and 30 liters of storage tank from bore well sensors. The x-axis the depiction of water levels and y-axis the flow rate. For 30 liters of water level the flow rate is supposed to be lower on comparing 20 and 15 liters, whereas in case of 15 liters the flow rate is higher than 20 and 30 liters.

Table 4. Assessment of Physicochemical Parameter Comparison for Groundwater Samples S1-S7 with WHO Standards

Parameters	S1	S2	S3	S4	S5	Mean	WHO
pH	7.0	8.4	8.13	8.10	7.5	8.0	7.0-8.5
TDS (Total dissolved solids)	386.20	285.00	217.00	149.00	651.00	337.64	500
Temperature, ^{0}C	26.3	26.7	26.8	27.1	27.5	26.9	-
Chloride	190.90	148.04	128.80	60.70	276.84	162.26	250
Calcium	49.12	39.48	40.12	7.86	71.76	41.67	75
Alkalinity	177.75	163.34	124.91	153.7	134.52	150.85	120
COD (chemical oxygen demand)	8	8	16	8	16	11.2	255
TH (Total Hardness)	253.56	160.24	158.64	94.55	171.46	164.09	200

Table 4 depicts the assessment of physiochemical parameter comparison for the samples of groundwater s1 to s7 with their mean vales and WHO standards. The parameters like pH, turbidity, chloride, TH, TSDS, COD, calcium, alkalinity, and temperature are estimated.

Performance analysis of natural disaster occurrence monitoring from depth sensor probe

The performance analysis of natural disaster like earthquake landslide, intense rainfall occurrence monitoring from depth sensor probe is estimated and outcomes attained are represented below

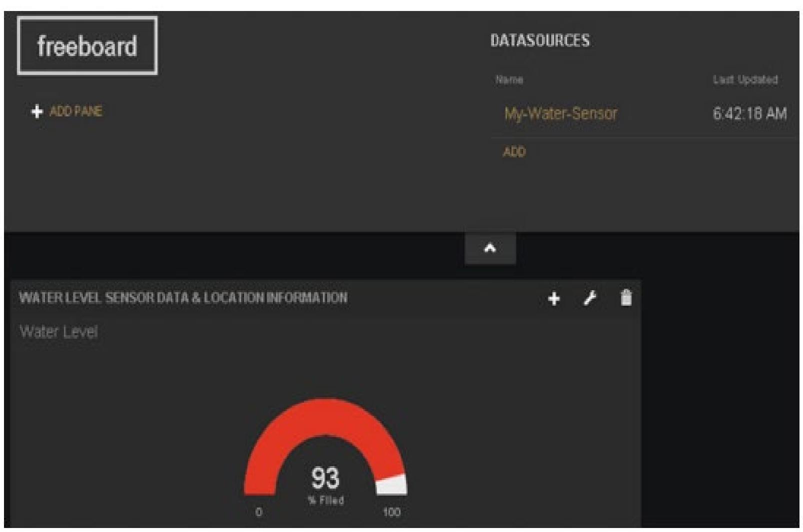

Fig 8. Water Level Visualization Showing the Percentage of Water Level Filled

Fig 8. is the illustration of water level visualization that shows the level of water filled in percentage. Similarly, the visualization software snapshot showing real-time streaming for location 5 in the center portion of hill region for the period July 18 to 20 by 2020 is shown in **Fig 9**.

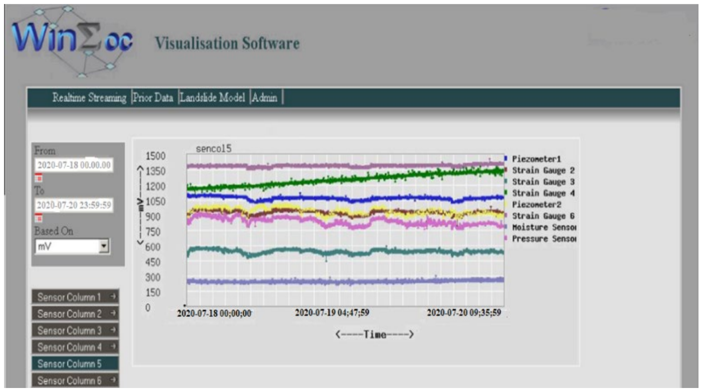

Fig 9. Real-Time Streaming Software Snapshot for Location 5 in the Center Portion of Hill for a Period July 18-20 (2020)

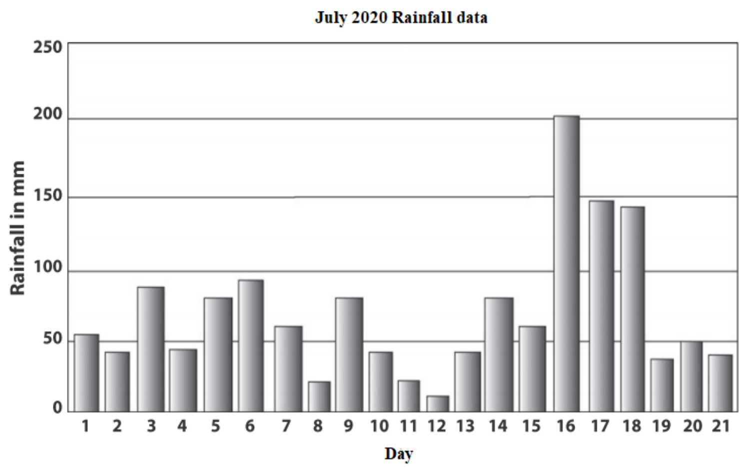

Fig 10. Rainfall Data in July 2020 Attained From Sensor Probe of Bore Wells

Fig 10 shows the rainfall data recorded in July 2020 attained from sensor probe of deep bore well is assessed and the data recorded is represented graphically. The highest range of rainfall is recorded on July 16 whereas the lowest one was recorded on July 12 as per the reading attained from bore wells sensor probe.

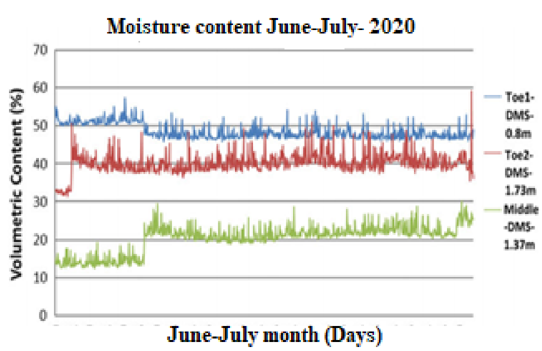

Fig 11. Variability of Spatio-Temporal Moisture Content from June-July 2020

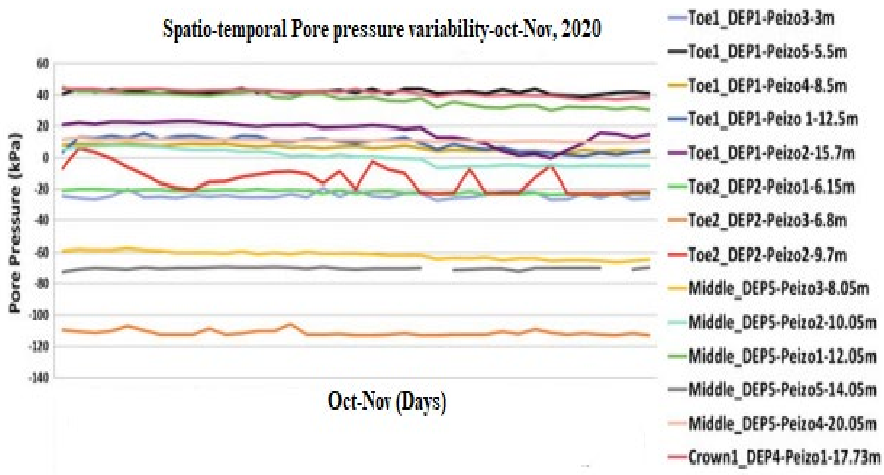

Fig 12. Variability of Spatio-Temporal Pore Pressure on Oct-Nov Period

Fig 11 is the representation of variability in Spatio-temporal moisture content from June-July 2020. The moisture content is measure in terms of month vs volumetric content in percentage. Likewise, the Spatio-temporal variability of pore pressure between period oct-Nov, 2020 is shown in **Fig 12**. The piezoelectric pressure is measured by the sensor probe and the graphical illustration of the piezo sensor is projected in **Fig 12**.

V. CONCLUSION

In this approach, a design and development of depth sensor probe for deep bore well is introduced. The data collected from various sensors are transmitted over wireless medium and are stored in cloud application so as to gather data for further monitoring or analyzing purposes. The sensor designed is a multi-sensor aqua deep earth probe (ADEP) that comprises of dielectric moisture sensor, pore pressure piezometer transducer, strain gauge, Tiltmeter, Geophone, and rain gauge. These sensors were designed and deployed to fix them in correct position and are connected to wireless network medium which was responsible for transmitting data from sensors to cloud framework. From the cloud application, the data is assessed and the details of water quality and level are monitored thereby analyzing any possible causes of natural disasters like landslides, earthquake and so on. the performance of the sensor data recorded is illustrated and the data analyzed for certain period of time was represented as outcomes. Therefore, the proposed sensor is capable of offering real-time bore well sensor data that were applicable for further applications in various fields.

Data Availability
No data was used to support this study.

Conflicts of Interests
The author(s) declare(s) that they have no conflicts of interest.

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Ethics Approval and Consent to Participate
The research has consent for Ethical Approval and Consent to participate.

Competing Interests
There are no competing interests.

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