Determination of silt thickness in Durga Kund for its de-isolation at Varanasi U.P. India

Daya Shankar Singh a, Rakesh Singh b and Ajai Mishra a

aDepartment of Geology, University of Lucknow, Lucknow, India; bCentral Ground Water Board, Bhopal, India

ABSTRACT

In this study, we are focused on the re-connection of Kund to the water table. Kunds are the best ancient architectural construction that was connected to the underground water table and works upon the principle of the Capillary action. But due to the dumping of the sacristy in the Kund, they have been disconnected from the subsurface water source/water table. For the rejuvenation of the Kunds, it should be cleaned through which they could again connect to the water table. For the re-connection of Durga Kund to the water table, first, we have to calculate the silt thickness and cleaned it. So, in this process for the delineation of silt thickness, there are two methods, which have used. The first is based upon the hydrogeological conceptual method and the second is based upon the geophysical method. After applying both the methods, the results were almost same, the estimated thickness of silt was about 3.5 to 4 meters. Now, this result has been established that both the conceptual and practical results are same. It means in this technical time, the Conceptual results are as much reliable as instrumental results.

Introduction

There are a lot of Kunds in India. Durga Kund is one of them. It is situated in the southern portion of the Varanasi District. It is situated adjacent to the Durga Temple. Durga Mandir was built in the 18th century by the queen of Bengal. This temple is dedicated to the Goddess Durga. This Kund is most important for their religious, traditional, and scientific values.

In ancient times, they were the main source of water for the survival of human civilization except to the bank of rivers (Gagic, Dugalic, & Diurovic, 2006). Generally, they are used for drinking purposes and cultural activities. But nowadays, due to the pollution and open structure design of Kund, they are not used for drinking purposes however they are used for the cultural and traditional activities which allow people to pour their incense waste. With the beautiful example of freshwater sources, these kunds are the heritage of our society and future. So, we have to preserve it for our future generation.

This present study is totally based upon the concept of capillary action and it works upon the principle of attraction forces between soil and water molecules (DeBano, 2000; Doerr, Shakesby, & Walsh, 2000). Finally, this attraction decides the amount of retention curve for soil-water (Comegna, Sommella, & Geoderma, 1998; Strand & Wang, 2003) and the height of the water level in that capillary tube. This height also depends upon the sediment size/grain size (Cisar, Williams, Vivas, & Haydu, 2000; Kostka, 2000) while, Gillham (1984) has estimated the height of the capillary fringe to range from 0.01 m for medium sand to greater than 10 m for clay. In Durga Kund area, it has a homogeneous alluvial sedimentary basement. So the water level will be the same in all the surrounding area but the pressure head will differ with respect to the aperture/opening of the structure and the grain size (Abu-Zreig, Rudra, & Dickinson, 2003; Mingorance, Fernández-Gálvez, Peña, & Barahona, 2007; Wiel-Shafran, Ronen, Weisbrod, Adar, & Gross, 2006).

However, for the first time, we have tried to compare the results of conceptual and instrumental methods and the results were almost same.

Study area

Adjacent to the Durga temple, there was a Kund, which is known as Durga Kund. It was believed that this Kund was earlier connected to the Ganga River. Durga Kund is located in the Kashi Vidhyapeeth Block of Varanasi district, Uttar Pradesh. It is located near the Ganga River with the 25° 29’ N latitude and 82° 97’ E longitudes. The elevation of this place from the Mean Sea Level (MNS) is about 80.8 meters. On the way forward from Assi Chauraha to Ravindrapuri, Durga Kund is situated adjacent to Durga Mata Temple as shown in Figure 1. The name of ‘Durga Kund’ comes in important from Kund.

CONTACT Daya Shankar Singh, daya.singhudai@gmail.com; Department of Geology, University of Lucknow, UP, India

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This is an Open Access article distributed under the terms of the Creative Commons Attribution License (http://creativecommons.org/licenses/by/4.0/), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.
Durga Kund is the safest and the most existent kund among other kunds till now.

**Methodology**

There were two methods that were executed for this problem. One is based on the hydrogeological conceptual method and the other is based on the Geophysical method. Both methods were applied in September 2017.

**Hydrogeological method**

For the hydrological method, we have to take a nearby dug well of Durga Kund for the comparative study of the water table. The lithological order (shown in Table 1) of the stratum has been taken from the borewell which is constructed by UP Jal Nigam, nearby Kund. Figure 2 shows that the thickness of the uppermost succession is 28 meters, which is formed by fine sand and silt and this type of sediments support to the best aquifer type. This type of aquifers also supports capillary action, so when the precipitation or evaporation takes place then the response of the water table can be easily seen (Commander & Hauck, 2000; Gerla, 2002; Singh & Mondal, 2004).

According to Bernoulli’s equation,

\[ P + \frac{1}{2} \rho v^2 + \rho g h = \text{Constant} \]  (1)

**Table 1. Lithological succession of Durga Kund Dug well.**

| S. No. | Location | From | Up to | Lithology          |
|--------|----------|------|------|-------------------|
| 1      | Durga Kund 80.8m (surface level) | 52.8m | Fine sand and silt | 52.8 | 19.8 | Course sand |
| 1      | Durga Kund | 19.8 | 13.8 | Clay             |
| 1      | Durga Kund | 13.8 | −102.2 | Course sand |
So,

\[ P + \frac{1}{2} \frac{m}{V} v^2 + \frac{m}{V} g \times h = \text{Constant} \]

Then,

\[ P + \frac{1}{2} \frac{m}{(\pi \times r^2 - l)} \times v^2 \frac{m}{(\pi \times r^2 - l)} \times g \times h = \text{Constant} \]

\[ \text{(2)} \]

where,
- \( P \) = pressure
- \( v \) = speed
- \( V \) = Volume
- \( h \) = height of the fluid (WATER)
- \( \rho \) = density of water
- \( g \) = gravitational acceleration
- \( l \) = length of that area
- \( r \) = Radius of a cylindrical area

So, from Equations (1) and (2),

**Radius of a cylindrical area or well** \( r \) \( \propto \frac{1}{h} \) \( \text{(3)} \)

From Equation (3), radius of the cylindrical area or opening of a tube is indirectly proportional to the height of the fluid or water. Now, the radius of the well is small in comparison to the kund, then according to Equation (3); the height of water should be shallow in the well (Bredehoeft, 1967). The water level of the Kund is shallow (Mould, Frahm, Salzmann, Miegel, & Acreman, 2010). Due to garbage deposition in the Kund, its water is not properly connected to the water table (about 6 meters near Durga Kund Area by Ground Water Department and UP Jal Nigam) so the percolation could not take place (Fernandez Galvez & Mingorance, 2010). Now, Figure 3 is showing that the water level of the Kund from the ground level is 1.51 meters while the thickness of the water column is 6 meters up to the silt in the bottom. Adjacent to the Kund, there is a dug well, in which the water level is 5.59 meters below to the ground level having a water column thickness of 8.26. According to Capillary Height Formula/Jurin’s law (Kholodov et al., 2015)

\[ H = \frac{(2 \times \gamma \times \cos \theta)}{(\rho \times g \times r)} \]

\[ \text{(4)} \]

where,
- \( H \) = the height of water in the column,
- \( \gamma \) = the water–air surface tension = 0.07199 N m\(^{-1}\)
- \( \rho \) = the density of water = 996.2 Kg/m\(^3\)
- \( r \) = the radius of Dug Well = 1.70/2 m, Durga Kund = 5/2 m
- \( g \) = the acceleration due to gravity = 9.8 m/s\(^2\)
- \( \theta \) = the angle of contact for water and sandy soil = 64°

**Geophysical method**

In the geophysical method, the Echo Sounding method was applied. SyQuest Digital Hydro-box Echo Sounder was used for sounding operations at very low and high frequency. The principal sounding lines, using single beam Echo Sounders were run at a spacing of 8 meters. The lines were planned North-South of the Kund. Single Beam at low and High-Frequency Sounding. SyQuest Hydro-box echo sounder operated at 33 kHz and at 210 kHz was used for sounding by the Survey Boat. The speed of advance for sounding operations was restricted up to 1 knot. The data was logged directly into the HYPACK software (Ver.2009) and the digital data display of the Echo Sounder was closely monitored.

(Gribovszki, Kalicz, Szilagyi, & Kucsara, 2008; Gribovszki, Szilagyi, & Kalicz, 2010)

![Figure 3](image-url). Hydro-geological condition of Durga Kund Varanasi.
Result and discussion

In the hydrogeological method, the result is totally dependent upon the concept of Capillary action (Gribovszki et al., 2008, 2010). If a well is dug initially, then the water level will be decided by the capillary height. If the water level is more than the capillary height, it will be just because of garbage/silt thickness. Let us assume that there is a glass filled with water to a certain height, and if a pebble is put into the glass, then the water level in the glass will increase. This increase in the glass will be equal to the volume of the pebble. In the same way, garbage is acting just like a pebble.

In the case study, the physically measured height includes the actual capillary height and height just because of garbage/silt thickness.

So, in the case of Dug well,

Physically measured water height = 8.26 meters  
Calculated water height = 7.60 meters

So, the thickness of garbage/Silt deposits for Well = physically measured Height – Calculated Height [From Equation (4)]  
= (8.26–7.60) meter  
= 0.66 meters.

For Durga Kund,

Physically measured water height = 6 meters  
Calculated water height = 3.5 meters

The thickness of garbage/Silt deposits for Durga Kund  
= physically measured Height – Calculated Height [From Equation (4)]  
= (6–2.58) meter  
= 3.42 meters.

So, in Durga Kund, silt thickness is about 3.5.

At both the places, the difference between the calculated and physically measured height will be equal to the thickness of garbage/Silt deposits. At the dug well, the thickness of garbage is about to match with physically measured garbage thickness which was about to 0.5 meters. In the same way, the garbage thickness is about 3.5 meters in Durga Kund.

In the geophysical method, the Dredging quantity was calculated on the basis of sounding data. It was calculated by HYPACK software for the desired survey area and a report with respect to different depth levels was obtained. The results are summarized in Table 2.

As shown in Table 2, after the depth of 1 meter, we started detecting silt and at 5-meter depth, we did not detect the water. According to Figure 4, the volume of water and silt volume curves are intersecting each other between 3.5 and 4 meters of the water level.

Now it should be the final depth up to where silt and water mixture is reported and after this depth, only silt is reported. Then, this is about 3.5 to 4 meters of the zone where the silt with water is reported which is garbage or silt.

Conclusion

Aquifers are the natural tankers for the holding of freshwater which are formed by the natural eroded and transported sediments. With the help of pore spaces, they are capable to hold and percolate the water. When the precipitation takes place, these pore spaces filled with water and start percolating; it reverses during extraction. These processes are responsible for the fluctuation in the water level. But, due to any reasons when these pore spaces chock or

| S. No. | Water level (meter) | Volume of water (cubic meter) | Dredging/silt volume (cubic meter) |
|--------|---------------------|------------------------------|-----------------------------------|
| 1.     | 0.00 (Water Level)  | 26,509.8                     | 0.0                               |
| 2.     | 1                   | 20,793.9                     | 0.0                               |
| 3.     | 2                   | 15,171.9                     | 0.0                               |
| 4.     | 3                   | 10,012.4                     | 0.0                               |
| 5.     | 4                   | 5364.9                       | 0.0                               |
| 6.     | 5                   | 1342.6                       | 0.0                               |
| 7.     | 6                   | 0.0                          | 7785.5                           |
| 8.     | 7                   | 0.0                          | 13,501.4                         |
| 9.     | 8                   | 0.0                          | 19,217.3                         |
| 10.    | 9                   | 0.0                          | 24,933.2                         |

Figure 4. Graph between the volume of water and of silt volume.
block then they disconnected for the response. The same problem was reported from Durga Kund by pouring the sacristy in the Kund.

So, for the delineation of silt thickness both the methods were applied and the results are the same. The silt or garbage thickness is about 3.5 to 4 meters thick. In this technical time, we can still believe in the hydrogeological concepts.

If we remove this garbage, then Durga Kund will be connected to the natural water level and attain the natural water level head.

Disclosure Statement

No potential conflict of interest was reported by the authors.

ORCID

Daya Shankar Singh http://orcid.org/0000-0002-3062-8662
Rakesh Singh http://orcid.org/0000-0002-1268-1697
Ajai Mishra http://orcid.org/0000-0001-5282-8879

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