Investigation of soil piping incident at Kottaykkal, Perumannaklari Panchayat , Kanjikuzhinarayil, Malappuram

Field investigation report

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Background:

The Member Secretary, Kerala State Disaster Management Authority (KSDMA) had informed the Director, NCESS on 11 May 2018 that soil piping related incidences have taken place at Kottaykkal, in the Perumannaklari Panchayat in the Malappuram district. He also requested NCESS to investigate the event and furnish a report on the extent of damage, the relief assistance to be extended to the affected parties within the norms of the SDRF/NDRF norms and the possible remedial measures to rejuvenate the land to make it suitable for dwelling /human use. As per the instructions of the Director, the NCESS team led by Shri G. Sankar Senior Consultant visited the affected locality during May 16-17, 2018 and conducted field studies. Senior Revenue officials, Officials of the State Ground water department, representatives of the Perumannaklari Panchayat were also present during the visit. On May 18, 2018 the Hon'ble Minister for Revenue and DM along with the Member Secretary, KSDMA visited the locality and interacted with the NCESS team. The following is the field investigation report of the investigating team.

Location of the affected locality:

The affected locality (Lat N 10^0 59' 09 .9"/ Long E 75^0 57' 58.2 ") is situated in the Kottaykkal area (Fig.1) of Perumannaklari Panchayat near Kottakkal in the Tirur taluk of the Malappuram district of Kerala. The affected site is located about 6km from Kottakkal town in the Perumanna village. This locality is accessible by all-weather roads from the nearby towns.

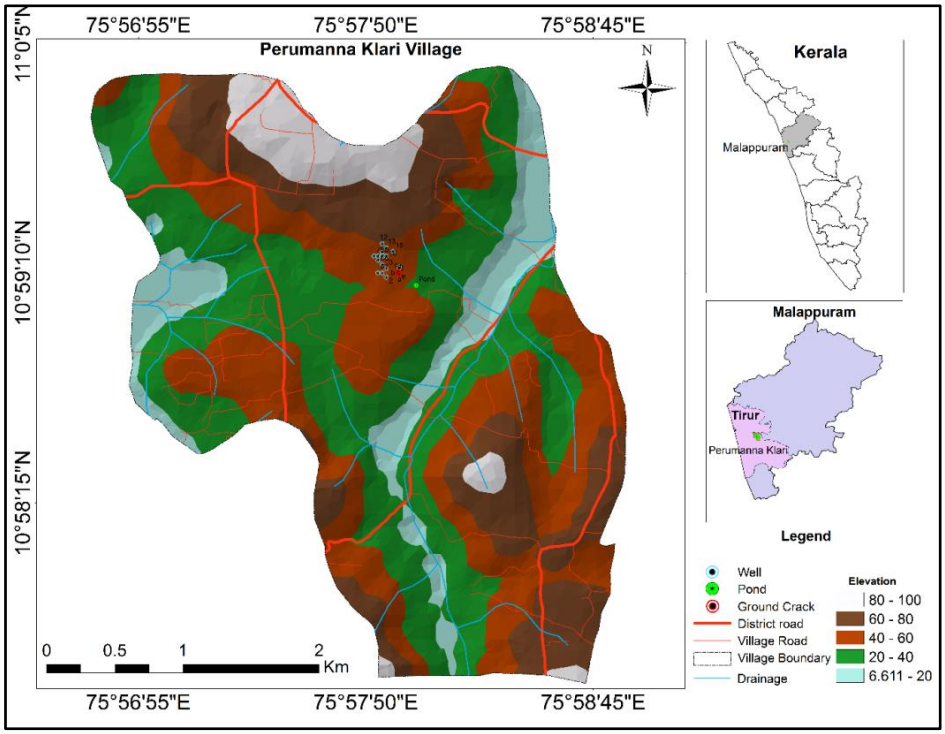

Figure 1 Location of the affected site

Nature of land disturbances occurred in this locality:

Laterite mesas dominate the Malappuram district's topography. Angadipuram in the Malappuram district is famous in the geological community as the type locality of laterites. Similar laterites are observed in most of the localities in the district. Here the laterites are usually forms mesa type landform capped by hard duricrusts which are iron encrustations. Here in the Perumannaklari locality laterites are occurring with hard laterites on top as capping. Depth of weathering is quite deep with the laterite and lithomarge is more than 25 meters at places. The general slope of the area is gentle (< 5^0) and is towards south. This area forms part of the Kadalundi drainage basin.

Deep ground fissures/ cracks with varied displacement were observed in two plots (Figs 2, 3 and 4 in a residential area on a laterite mesa in the Perumannaklari panchayat. Elongated in a roughly E-W direction these fissures form an oval shape bordering the ground subsidence locality. The subsided portion is sloping in the direction of South –South East direction.

Figure 2 Fissure in Zainudin's land

Fig 3 Fissure extending to eastern limit

Figure 4 Ground fissures displacing the basement of the Abdul Rahim"s house

The land had subsided about 30 cm vertically. The horizontal separation is found varying from few mm to 25 cm at places. The ground movements have caused considerable damage to the two houses situated in these areas. The ground cracks were wide open at certain places and posing danger. The matter was noticed by the media and public when a goat was accidently slipped into the crevasse formed by the crack and got killed. The district administration then prevented the locals from entering the affected site. The wide fissures were posing danger to life and property of the locals. Based on the request of the district administration, KSDMA has requested NCESS for an investigation.

This investigation by NCESS was carried out during May 16-17, 2018. As requested by the KSDMA the studies were focussed on the following aspects

1. Extent of damage
2. The relief assistance to be extended to the affected parties within the limits of the SDRF /NDRFnorms
3. Possible remedial measures to rejuvenate the land to make it suitable for dwelling/ human use

Causative factors of the ground subsidence

The ground fissures in this area were first noticed by the locals in 2013. Studies were conducted by CESS (now NCESS) and GWD, Govt. of Kerala in 22.4.2013 indicated that excess draining of water from the clay substrate might have caused shrinkage with slight ground subsidence and emergence of cracks in the hard laterite cap rock. They also ruled out seismicity as a causative factor for the development of ground fissures. In that report it was mentioned that the cracks were noticed from 15.4.2013. One family had abandoned the house and the other continued to live in the dilapidated house, one day prior to this field investigation. During the course of five years, the ground fissures were enlarged and propagated as an oval shape clearly indicating a ground subsidence. Since then the ground had subsided about 30cm. The progressing nature of the ground subsidence indicated that soil erosion is active in the bottom and voids are created to accommodate the overburden. In order to understand the subsurface features two methods were employed. Observe the open wells in the area and conduct geophysical surveys. About 32 wells 7 bore holes and one pond were observed around the affected site; out of this few wells were selected for detailed studies. Multi electrode electrical resistivity surveys were carried out in the east -west direction in the northern and southern boundaries of the affected site.

Electrical Resistivity investigation : Geo-electrical surveys were conducted in affected locality to determine presence of pipes. Two resistivity profiles were laid across the alignment of suspected soil pipes that was in EW direction using the instrument ABEM Terrameter. The first electrode placed in the western side and last electrode at east of the pipe. The survey line 1 was laid near to the subsidence in the south and survey line 2 was laid about 50m north of the subsidence. A total of '64' electrodes at 2m and 3m spacing, the length of the survey line went up to 128m and 192m respectively. The survey mid points is placed at the south and north of the suspected target to get maximum depth details. The Survey was carried out with Wenner, Schlumberger & Dipole - Dipole array to study the earth resistivity responses. The data retrieved is stored in in the ABEM Terrameter and it was transferred to Laptop or PC. The 'WDAFC.EXE' data format convert software can transform data into 'RES2DINV' and measured data is processed using 'RES2DINV' Software.

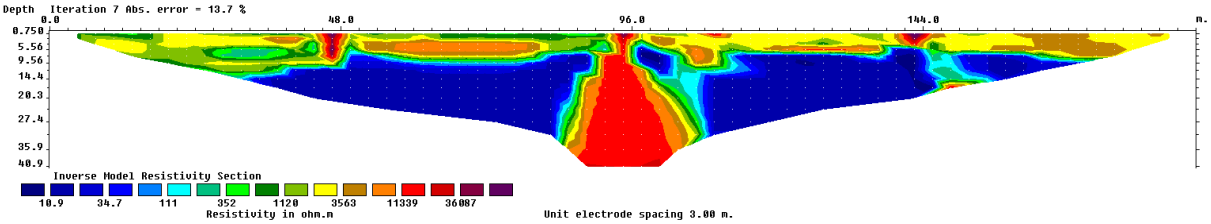

Figure 5 ERT (Schlumberger) taken in the EW profile (survey line 1)

Profile 1 was laid with an electrode spacing of 3.0m and the mid-point of the survey line was near to the subsidence. Schlumberger (Fig.5) Wenner, (Fig.6) and dipole-dipole configurations have been done over the area. Among the three, Schlumberger can be most useful for mapping the tunnel cross-sections. From the section the low resistivity layer is about 6 meters in the resistivity section could be an indication of the groundwater zone. *In the middle of the section a high resistivity zone separate the water saturated area is an indication of the suspected soil pipe*. The configuration fails to map the tunnel bottom even though from physical observations it is known that the actual vertical extent of the tunnel is lesser than the interpreted depth of the array.

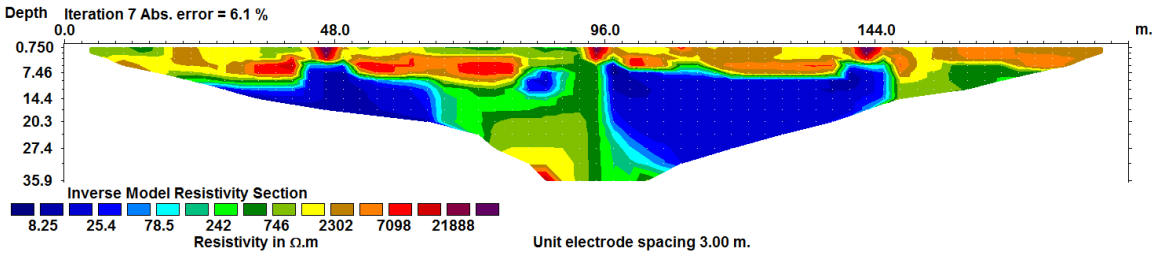

Figure 6 ERT (Wenner array) taken in EW direction - Survey line 1

The qualitative interpretation of the resistivity section indicates that the technique could delineate the conductive zones where the soil pipes are formed. The profile 1 has taken

close to the subsidence and possible orientation of pipe at the location is known. However, the geometry of the soil pipe is not found decipherable from the resistivity section probably due to higher electrode separation in comparison to the diameter of the soil pipe. In profile 2 electrical resistivity survey was carried out parallel to this profile on the northern side of the affected site. Since the suspected pipe in this area is small in size it escaped detection in the survey. In this location the size of the pipe was possibly small to escape the detection from ERT

Survey line 2 was aid at 50m north of the major subsidence at an electrode spacing of 2m and the total lateral extension of 128m.The resultant data (Fig. 7) gives a maximum depth about 16m.The resistivity tomography could not recognize any pipe in this locality as the suspected pipe is much smaller in size in this locality.

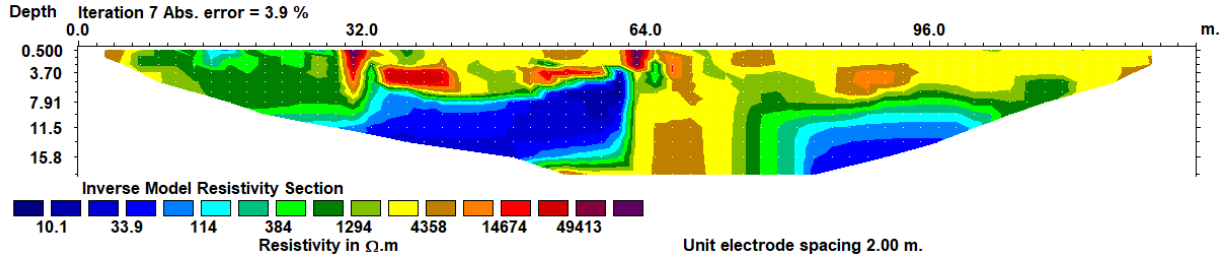

Figure 7 Electrical resistivity tomograph of Schlumberger array

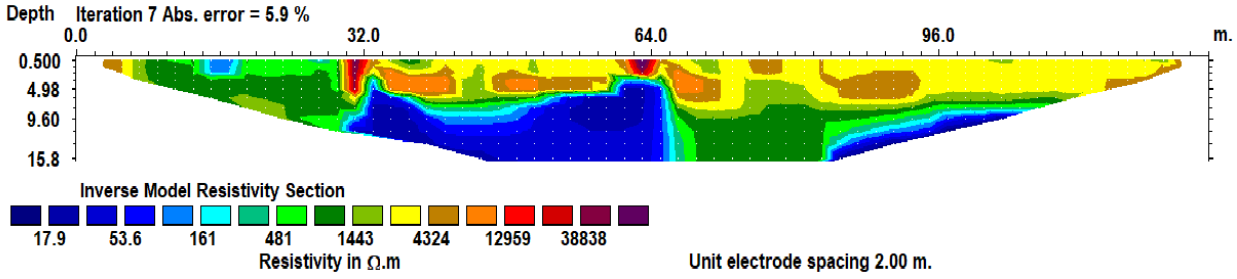

Figure 8 Electrical resistivity tomograph of Wenner Array

Hydrogeological studies: In the Kottaykkal, Perumannaklari Panchayat total 32 wells, 7 boreholes and one pond were studied and analyzed. All the studied wells are present near the affected area. The area is very gently sloping and having a surface slope of 4 ^{o}- 5^{o}. The depth of the water level in the wells varies from ~8 m to 25 m, depending on the terrain configuration. Out of 32, 7 wells are completely dried. 24 wells show some signatures of deformation. The deformation features include cracking in wall of the well, high rate of sedimentation in well and presence of caves inside the well. The cracking in the wall is due to settlement of the land. This land settlement was due to subsurface cavity/ soil pipe. Near the affected site, well nos. 22, 27 shows a NW-SE oriented pipe which has a minimum length of 44m. The maximum depth of crack observed in the well is 12.8

m (well no 9). Below this depth some pipe features are presents in the well (well nos. 13, 14, 15,16,18,19 and 20). Some wells (nos. 14,15,17,18, 20 and 23), lying just upslope side of affected area, are presently dry. However the area recently received good amount of water through the rain fall. In the SE direction of the affected area, four wells (nos. 29,30, 31 and 32) aligned in E-W direction contains the turbid water. However the degree of turbidity varies in all these wells. This suggests a presence of a pipe oriented in E-W direction with at least 144 m length. The turbidity is because of the erosion and dispersion of lithomargic clay. The other wells show clear water in it. Some wells have pipe outlets. As the well 4,5,10,13,21,22 and 27 have pipe features which was covered by rings. Similarly 4 years back (i.e. year 2014) the well 22 experienced over flow due to piping. In the well 27, one SE oriented pipe is exposed. 5 water samples were collected from different wells. The data suggests that the pH values of the well water varies from 5.26-6.25. In the pipe affected area, the TDS value is much higher (236.0 ppm) then the common surrounding values.

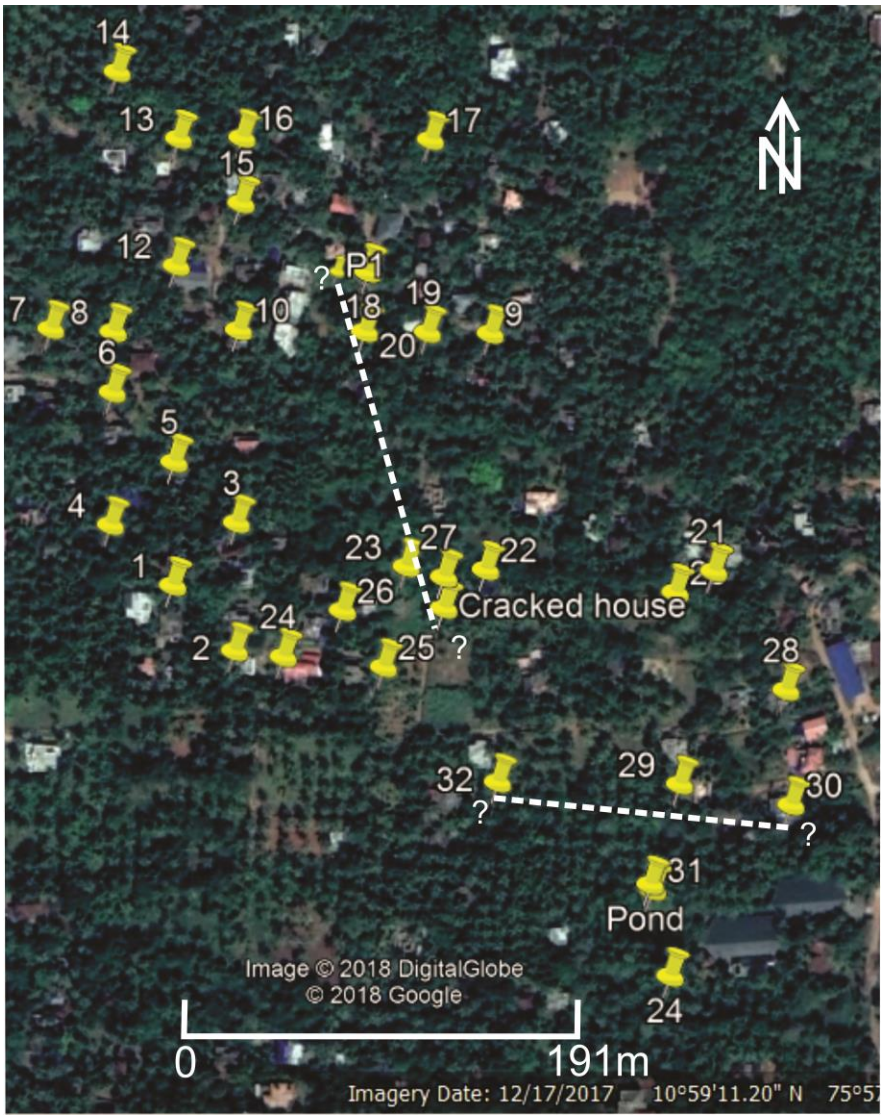

Figure 9 Google Earth image showing various studied wells and location of affected house. The dotted line represents the NNW-SSE and E-W trending soil pipes.

Well no	Location	Water level (m)	Total depth (m)	Features	Rock type	Water quality
1	N 10° 59' 10", E 75° 57' 54''	13.89	15.77	No crack	Laterite	
1a	N 10° 59' 10", E 75° 57' 54''	25	----- --			
2	N 10° 59' 9", E 75° 57' 55''	13.44	---------	Crack at the depth of 8.40m	Laterite	
2a	N 10° 59' 9", E 75° 57' 55''	16	24.38			
3	N 10° 59' 11", E 75° 57' 55''	13.9	13.98	Crack at the depth of 12 m	Laterite	
3a	N 10° 59' 11", E 75° 57' 55''	24	36			
4	N 10° 59' 10", E 75° 57' 53''	14.14	26	Crack at the depth of 9.6 m. Secured covering by ring. Process started 8 year before	Laterite	
5	N 10° 59' 12", E 75° 57' 54''	15.60	16	Crack at the depth of 9.9 m. Secured covering by ring. Process started 8 year before	Laterite	
5a	N 10° 59' 12", E 75° 57' 54''	20	44.4			
6	N 10° 59' 13", E 75° 57' 53''	12.9	14.10	Crack at the depth of 8.9 m.	Laterite	
6a	N 10° 59' 13", E 75° 57' 53''	18.2	60			
7	N 10° 59' 14", E 75° 57' 52''	15.2	16.20	Crack at the depth of 10.80 m.	Laterite	
7a	N 10° 59' 14", E 75° 57' 52''	18	115			
8	N 10° 59' 14", E 75° 57' 53''	16.2	19.40	Crack at the depth of 9.6 m.	Laterite	
8a	N 10° 59' 14", E 75° 57' 53''	24	36			
9	N 10° 59' 14", E 75° 57' 59''	12.8	14.18	Crack at the depth of 12.8 m.	Laterite	
10	N 10° 59' 14", E 75° 57' 55''	15	17.5	Secured with ring at 10 m depth	Laterite	
11	N 10° 59' 15", E 75° 57' 54''	15.3	16.1	No cracks	Laterite	
12	N 10° 59' 16", E 75° 57' 27''	15.1	15.5		Laterite	
13	N 10° 59' 17", E 75° 57' 54''	14.5	15.6	Cave starting at 7.50 m	Laterite	
14	N 10° 59' 18", E 75° 57' 53''	--------	16.30	Crack and cave opening at 14.80	Laterite	
15	N 10° 59' 16", E 75° 57' 55''	-------	17.8	Crack and cave opening at 16.80	Laterite	
16	N 10° 59' 17", E 75° 57' 55''	17.10	17.40	15.5 m cave found	Laterite	
17	N 10° 59' 17", E 75° 57' 58''	----------	15.80		Laterite	
18	N 10° 59' 15", E 75° 57' 57''	--------	16.30	Cark and opening at 13.40	Laterite	
19	N 10° 59' 14", E 75° 57' 58''	13.80	15.40	Cark and opening at 12.10	Laterite	

20	N 10° 59' 14", E 75° 57' 57''	----------	15.60	Cark and opening at 13.60	Laterite	
21	N 10° 59.172' E 75° 58.043'	11.75	13.21	One pipe outlet but closed with rings	Laterite	Clear water
22	N 10° 59.172' E 75° 57.983'	14.12	15.34	4 year back over flowed	Laterite	Clear water
23	N 10° 59.173' E 75° 57.962'	----------	14.59	Cracks up to 6.08 m depth	Laterite	Dry
24	N 10° 59.149' E 75° 57.930'	13.59	14.44	Seasonal well. Filled during rainy season only	Laterite	Clear water
25	N 10° 59.147' E 75° 57.956'	12.24	12.58	Cracks were present since it built	Laterite	Clear water
26	N 10° 59.147' E 75° 57.956'	----------	12.74	----------	Laterite	Dry
27	N 10° 59.170' E 75° 57.972'	15.11	16.89	SE oriented pipe is present, cracks are present	Laterite	Clear water
28	N 10° 59.142' E 75° 58.063'	11.30	12.66	----------	Laterite	Clear water
29	N 10° 59.117' E 75° 58.035'	8.76	9.62	After the incidence. Seasonal well. High rate of sedimentations.	Laterite	Turbid water
30	N 10° 59.112' E 75° 58.065'	8.64	10.17	Lithomargic clay collapsed	Laterite	Turbid water
31	N 10° 59.09' E 75° 58.028'	11.20	11.78	Lithomargic clay collapsed	Laterite	Turbid water
32	N 10° 59.118' E 75° 57.987'	9.31	10.04	----------	Laterite	Turbid water

Table 1 Details of the wells studied in the area

Ground investigation has revealed that it is due to an underground soil erosion called "soil piping" or Tunnel erosion. The "Soil piping" (tunnel erosion) is the subsurface erosion of soil by percolating waters to produce pipe-like conduits below ground especially in non-lithified earth materials. Soil piping or "tunnel erosion" is the formation of subsurface tunnels due to subsurface soil erosion. Piping is an insidious and enigmatic process involving the hydraulic removal of subsurface soil causing the formation of an underground passage (Ingles, 1968). During rain percolating waters carries finer silt and clay particles and forms passage ways. The resulting "pipes" are commonly a few millimeters to a few centimeters in size, but can grow to a meter or more in diameter. They may lie very close to the ground surface or extend several meters below ground. Once initiated they become cumulative with time, the conduits expand due to subsurface erosion leading to roof collapse and subsidence features on surface.

During the last decade many piping incidences were reported from different places in Kerala. Soil piping incidences were reported from many places in Kasaragod, Kannur, Kozhikode Wayanad, Malappuram, Kozhikode, Ernakulam, Idukki and Pathanamthitta. Except Thiruvananthapuram, Kollam and Alapuzha most of the districts in Kerala have the

incidence of soil piping. Soil piping related problems is reported from many places in Malappuram. Recent occurrences in Thenjipalam inside the University Campus, Alathoor padi near Malappuram where a laterite quarry is located and subsurface cavings near Pandikkadu are all related to soil piping.

In Perumnnaklari also the field studies have indicated the presence of soil pipes in this area. The geophysical survey conducted very close to the affected locality has indicated the presence of a void which extending to a depth of 26 meters. The hydrogeological studies also indicated (table 1) the presence of tunnels and caves in few wells. So it is suspected that pipes trending in NW - SE and E-W are present in the area (fig 9). A more detailed study is required map the network of soil pipes in this locality.

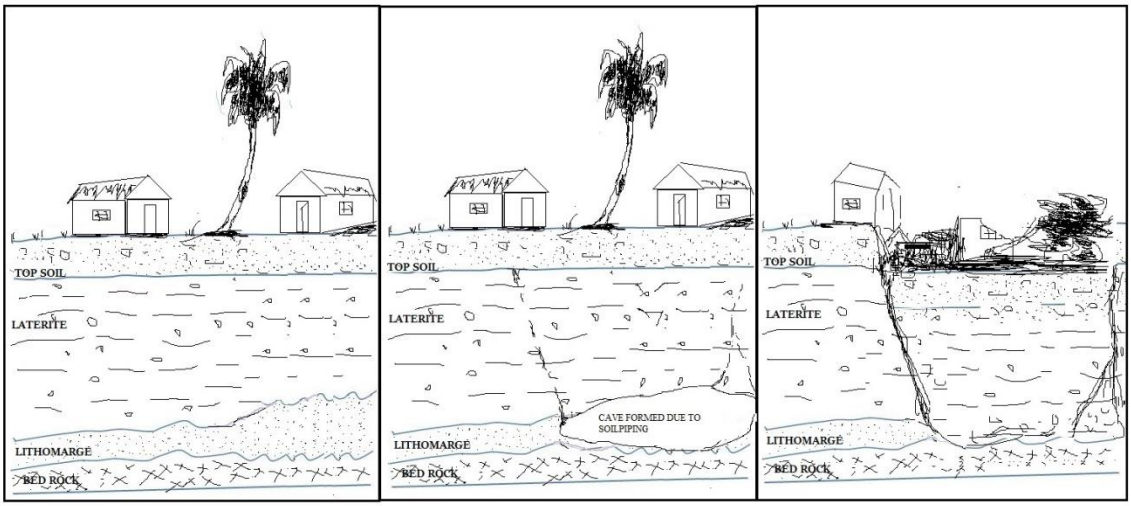

Figure 10 Sketch showing the subsidence related to soil piping in Perumannaklari (not to scale)

Extent of damage:

The land disturbances have taken place in two adjacent residential plots. One belong to the Zainudin Paruthikunnen and the other belonging to Sri Abdul Rahim , Pottachola. **Zainudin Paruthikunnen house and plot**:In the 2013 investigation by CESS it was mentioned that *"The terraced relatively new house belonging to Shri. Zainudeen, Paruthikunnen, is totally damaged with almost all the walls and floor cracked beyond repair. Sub horizontal cracks are noticed on all the walls and basement. Plaster is peeled off exposing the bricks in many places. There is no definite pattern in the cracks. The floor tiles have been dislodged with formation of cavities below on account of ground subsidence. The basement appears to have subsided by few cms. Ground cracks are more prominent on the northern and eastern part of the building. The open well with water on the northern side of the house has developed a crack all around the circular opening at about 5 m depth with an inclination to the south. There is a visible displacement seen*

along the cracked surface. The crack is seen in the laterite profile below the hard vermicular layer."

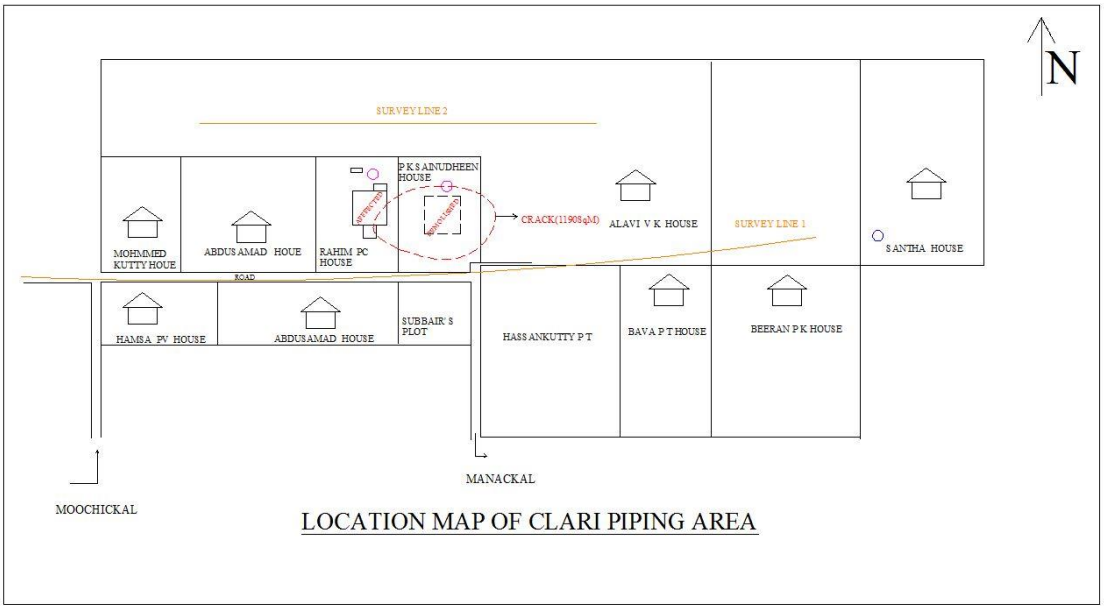

Figure 11 Map showing the extent of the soil piping affected area in PerumannaKlari (Clari)

At the time of this visit the house of Sri Zainudin was completely in a broken down condition (Photo 14). Ground cracks have become huge. The land had subsided about 30 cm causing huge ground fissures of about 17 meters. The subsidence has taken place in an oval shape with elongation in the EW direction (photo 16). The fissures have propagated to the basement of the

Figure 12: Zainudins house Cracks on the wall

Figure 13: Zainudin's house in 2013 (file photo)

old house there by completely destabilising it. Now only basement and remnants (photo 14 and 15) of the building are seen.

Figure 14 Zainudins house (2018)

Figure 15 Zainudin's land where house situated

Figure 16 Ground fissure near Zainudin's house-2018

Due to the ground subsidence the house and the plot cannot be put into any use and should be abandoned. The widened ground cracks are posing danger and it is barricade to prevent people from entering into the compound. Here the loss is total. Repair of this house or resettlement here is ruled out due to progressive subsidence of the ground.

House owned by Sri. Abdul Rahim, Pottachola

The RCC terraced house owned by Sri. Abdul Rahim, Pottachola, situated adjacent to Mr Zainudins house has been severely damaged (Photo 17 and 18) with ground cracks extending into the basement on the South and east side. The SE corner has suffered substantial damage and developed sub-horizontal cracks below the lintel level. The floor of the house and walls are cracked in many places.

Figure 17 Damaged house of Abdul Rahim

Figure 18 Cracked wall of Abdul Rahims house

Figure 19 Abdul Rahims House wall

Figure 20 Cracks affecting the walls and beams

The cracks are discontinuous oriented mostly in east-west direction. The horizontal separation is about 25cms. The extension of the cracks into the building resulted in the development of cracks to the floor and walls of houses (photos 19 and 20). The floor of the houses appears to be tilted towards southeast. The windows and door frames have been separated from the walls with visible displacement. The house was damaged extensively and there is no scope of repair. Ground subsidence is progressing in this locality also and any scope of settlement and human activities cannot be allowed. The house is completely damage and not fit to live.

The affected two plots now pose extreme danger to the local community. It is reported that one goat while grazing in this area accidently fell into the crevasse formed by the ground fissures. So it is recommended that this area should be barricaded and prevents the locals from entering into it. Local panchayat may take appropriate measure to educate the people and put informative boards in this area. The ground subsidence has extended towards east and a small portion of V.K Alavi's property is also affected.

Relief assistance to be extended to the affected parties:

Two houses one belonging to Zainudin paruthikunnen and Abdul Rahim Potachola are totally damaged due to the ground subsidence due to soil piping and any repair or rebuilding is out of question. Soil piping related incidents is included in the state specific disasters in 2016. The total cost of this these two RCC buildings are to be assessed by a competent authority for calculating the compensation. Since both the houses and plots are to be abandoned and the State Disaster management Authority may take an appropriate decision based on the existing provisions in the NDRF/SDRF in this regard. The affected parties should be rehabilitated to a safer area. The revenue department should take over this land (S/Sri Zainudin, Rahim PC and portion of Alavi V K) and provide alternate land or funds to the affected parties.

Possible remedial measures to rejuvenate the land and to make it suitable for dwelling / human use

There are methods to mitigate soil piping and rejuvenate the land for dwelling or other landuse. A combination of mechanical, chemical and vegetative measures are to be employed to halt tunnel development, limit overland flow, promote relatedly even infiltration and neutralise the dispersive sodium present in the clay. Another method is to remove the affected soil and replace it by soil from a new locality devoid of such problems.

Mechanical techniques applied to affected catchments include, where appropriate, the construction of banks, gully checks and terraces which are intended to impede runoff. This is done mainly to regulate water inflow into the affected zone. In Perumannaklari this method may not work since the catchment area is thickly populated and any control in the landuse may not work. Application of lime will certainly retard the chemical weathering of the lithomarge clay. But it is a very slow process. Here in Perumannaklari the soil piping zone is situated about 20-25 meters below the ground surface. Since vegetative measures will be effective only in the top few meters the vegetative measures will not yield desired results. Since the ground fissures are posing danger to the local community the revenue department is requested to acquire the affected area and reclaim the subsurface cave with earth brought from outside and vegetate the area with suitable tree species and allow it to stabilise over a period of time.

Concluding remarks

1. The ground subsidence occurred in Perumannaklari is due to subsurface soil erosion known as soil piping (Tunnel erosion).
2. The place where the ground fissures and subsidence have occurred are in an extreme dangerous condition and locals should be prevented from entering
3. The houses of Mr Zainudin and Mr Abdul Rahim are totally destroyed and beyond any scope of repair. They are also in a very dangerous condition. They should be given suitable compensation
4. Families of Mr Zainudin and Mr Abdul Rahim should be relocated to a safer localtion
5. The road south of the affected site is likely to sink during high rains
6. Soil piping is observed in many places in the Malappuram district such as Calicut university campus at Thenjipalam, Alathoorpadi near Malappuram, Irumboli near Manjeri, Pandikadu etc. since the lateritic topography is present in most of the district the soil piping is likely to be present in most part of the district. Before the construction of major civil infrastructure work it is better to make sure that such problem is not present there.