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Development of Ground Fissures a Case Study on Mayogon and Poepaukzu Villages, Pwintbyu Township, Magaway Region

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Department of Geological Survey and Mineral Exploration-DGSE

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Contents

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Abstract

Most of the formation of ground fissures due to groundwater depletion has been reported in all over the world. The study area Mayogon village is located in the eastern part of the Pwintbyu Township, Magway Region where tube well operation activities and other groundwater uses have caused significant groundwater depletion. Due to this fact, the study area recently experienced a sudden appearance of some earth fissures. An interdisciplinary study consisting of an evaluation of land-use changes, checking of soil behaviors, detail recorded discharge wells data, and effects of stream bank collapsing by erosion was conducted to determine the reason for the formation of the earth fissures. The system of well operation analysis strongly revealed that the groundwater level is decreasing with time. Actually, groundwater depletion would lead to the accumulation of subsurface stress causing soil hydro-consolidation which creates the ideal condition for the formation of earth fissures. The formation of earth fissures within the study area are identified by the first rainfall after a long spell of poor rainfall in preceding years and are not related to geological triggering factors. It can be interpreted that these fissures may probably be formed when the soil layers interact with water and may lead to the rapid release of soil compactness combined together with other factors which cause the fissures. Nevertheless, stream bank erosion of Mon Chaung is more common and quite devastating for study area. Therefore, stream channel conservation or stream bank protection work is essentially needed by urgently as an extra-suggest, especially in Gatkon, Mayogon and Poepaukzu villages.

Keywords: Ground fissures, Groundwater depletion, wells operation, land-use changes, triggering factors

မကွေးတိုင်းဒေသကြီး၊ ပွင့်ဖြူမြို့နယ်၊ ရွှေလှေကျေးရွာအုပ်စုမှရိုးကုန်းနှင့် ဖိုးပေါက်စု ကျေးရွာများတွင် မြေလွှာအက်ကွဲကြောင်းများ ဖြစ်ထွန်းပေါ်ပေါက်ခြင်း

ဦးဇော်ဇော်သိန်း၊ ဦးဇော်ထူးနိုင်၊ ဦးဇွဲပြည့်မောင်
ဘူမိဗေဒနှင့် ဓါတ်သတ္တုရှာဖွေရေးဦးစီးဌာန

စာတမ်းအကျဉ်း

မြေလွှာအက်ကွဲကြောင်းများဖြစ်ပေါ်မှုသည် မြေအောက်ရေပြင်လျော့နည်းကျဆင်းမှု၏အကျိုးဆက်ဖြစ်သော မြေသားထုအတွင်း သိပ်သည်းကျစ်လစ်ခိုင်မာမှုအားများ ကွဲပြားခြားနား သွားခဲ့ရခြင်းကြောင့် ပေါ်ပေါက်လာရခြင်းဖြစ်ပါသည်။ သုတေသနပြုလေ့လာခဲ့သော ရိုးကုန်းနှင့် ဖိုးပေါက်စုကျေးရွာများသည် မကွေးတိုင်းဒေသကြီး၊ ပွင့်ဖြူမြို့နယ်၏ အရှေ့ဘက်၊ မုန်းချောင်းနှင့်ဧရာဝတီမြစ်ဆုံရာအနီးတွင်တည်ရှိပါသည်။ အဆိုပါဒေသ၏ မြေသား သဘာဝ ဖြစ်စဉ်ပြောင်းလဲမှု၊ မြေယာအသုံးချမှုပြောင်းလဲလာခြင်း၊ မြေအောက်ရေစုစည်း သိုမှီးရာ ရေအောင်းလွှာ၏ သဘာဝ၊ ရေတွင်းများတူးဖော်မှုနှင့် ထုတ်ယူသုံးစွဲမှု၊ ချောင်းရေ တိုက်စားမှုကြောင့်ကမ်းပါးများပြိုကျမှုအခြေအနေစသည့် အချက်အလက်များအပေါ် ပေါင်းစပ်အခြေခံ ကာ မြေလွှာအက်ကွဲကြောင်းများဖြစ်ပေါ်မှု ဖြစ်စဉ်ကို ရှာဖွေဖော်ထုတ်ခဲ့ခြင်းဖြစ်ပါသည်။ ကျေးရွာများအတွင်းရေတွင်းများ တူးဖော်ထုတ်ယူသုံးစွဲမှု မြင့်တက်လာခဲ့ခြင်းကြောင့် မြေ အောက်ရေပြင်နိမ့်ကျလာသောအခါ မြေသားထုအတွင်း သဘာဝဖြစ်စဉ် ပြောင်းလဲမှုကို ဖြစ်စေခဲ့ပါသည်။ ထိုအခြေအနေမျိုးတွင် အဆိုပါဒေသ၏ ပထမဆုံးရွာသွန်း မိုးသည် အချိန်ကြာမြင့်စွာ ရွာချမှုကြောင့် မြေလွှာအက်ကွဲကြောင်းများကို ရုတ်ချည်း ဖြစ်ပေါ်လာစေခြင်းဖြစ်ပါသည်။ ဘူမိဗေဒဆိုင်ရာ ပြောင်းလဲမှုဖြစ်စဉ်များဖြစ်သော ငလျင်လှုပ်ခြင်း၊ ပြတ်ရွှေ့ များလှုပ်ရှားခြင်းနှင့် မြေထုချပ်ဆိုင်ရာ ပြောင်းလဲရွှေ့လျားခြင်း စသည်တို့နှင့် သက်ဆိုင်မှုမရှိ သည်ကို လေ့လာတွေ့ရှိခဲ့ရပါသည်။ သုတေသနပြုလေ့လာခဲ့သော ဒေသ၏ မြေသားထုအတွင်း ရေနှင့်ထိတွေ့လျှင်ကျစ်လစ်သိပ်သည်းမှုအား အလျင်အမြန် လျော့ကျသွားစေတတ်သည့် ပြောင်းလဲမှု ဖြစ်စဉ်များကို ပေါ်ပေါက်စေသော အခြားအချက်အလက်များနှင့် ပေါင်းဆုံမိသွား သောကြောင့် မြေလွှာအက်ကွဲကြောင်းများ ဖြစ်ပေါ်လာရခြင်း ဖြစ်သည်ဟု လေ့လာသုံးသပ်မိပါသည်။ နှစ်စဉ် ကြုံတွေ့နေရသော ချောင်းရေတိုက်စားမှုနှင့် ရေလွှမ်းမိုးမှု များသည် အဆိုပါ ဒေသ၏ အိမ်ရာနှင့် လယ်ယာမြေများကို များစွာထိခိုက်ပျက်စီးစေခဲ့ပါသည်။ ရေလမ်းကြောင်း ထိန်းသိမ်းမှုနှင့် ရေတိုက်စားခြင်းကြောင့် မြေများ ပြိုကျမှုအပေါ် ပြုပြင်ကာကွယ် ထိန်းသိမ်းရေး လုပ်ငန်းများကို ဦးစားပေးဆောင်ရွက်ရန် လိုအပ်ပါကြောင်း တွေ့ရှိရပါသည်။

Development of Ground Fissures a Case Study on Mayogon and Poepaukzu Villages, Pwintbyu Township, Magaway Region

1. Introduction

Based on the update news on social media Facebook that is an event of ground or earth fissures formations occurred within the Mayogon village, a team of geologist which leading by the author Zaw Zaw Thein (Assistant Geologist), Zaw Htoo Naing (Assistant Geologist) and Zwe Pyae Maung (Geology Assistant-3) from Department of Geological Survey and Mineral Exploration, Ministry of Natural Resources and Environmental Conservation was assigned to investigate for the cause of these earth fissures and their relevant events in future. The total duration of investigation is ten days within 12 to 21 July, 2019.

Figure (1) Group photo recorded by Geologists and local participants

2. Basic concept of Earth Fissures

Earth fissures induced by ground-water depletion have been reported world-widely in many alluvial deposits. Several hypotheses have been proposed to explain the mechanism of their formations, one mechanism or a combination of mechanisms can produce fissures. The most widely accepted of which is differential compaction, as ground-water levels decline in unconsolidated alluvial basins, less compaction and subsidence occurs in the thinner alluvium near the margin of the basin than in the thicker alluvium near the deeper, central part of the basin. The tension that results from the differential compaction stretches the overlying sediment until it fails as a fissure.

Earth Fissures are long and deep cracks in the soil that may be several kilometers long. Their depth can extend to the depth of the groundwater elevation. An Earth Fissures may be linear, arcuate, or sigmoidal. There may be one crack or multiple parallel cracks. In dry regions, the soils above the aquifer are often cemented. These soils appear to be significantly prone to earth fissures initiation. When and where the earth fissures initiates are still secretive? How the stiffness and cementation strength of the top layer affects the earth fissures initiation is unknown.

Field evidence indicates that relative to earth fissures are considerable. However, due to the void space created by their great depth and the erodability of the soil in which they form, they frequently are enlarged into wide and deep gullies by surface water flowing into them. The impressive surface appearances of many fissures were measured in the field. Within the study area, the area and temporal association of earth fissure caused by groundwater withdrawing that related to unfavorable pumping system of groundwater. Consequently, considering the scientific importance and social responsibility, the authors carried out multidisciplinary studies of ground fissures in study area.

3. Earth Fissures in Study Area

Since the first week of June 2019, update news has been reported on social media Facebook that is an event occurred in the northern part of Mayogone village. It is located about 23 km (14 miles) east of Pwintbyu Township, Magway Region where the earth fissures appeared over the past summer, probably during a first fall of the rainy season. Duration of raining time is more about continuously five hours (5 - 10 pm).

In the evening of the second day of June 2019, earth fissures have suddenly appeared in study area especially in the northern part of Mayogone and Poepaukzu Villages. The affected area is privately owned residence land. The earth fissures have various lengths; one of them extended in a northwest direction for a distance of 300 feet and has widths that vary between 1.5 and 2 feet, and depths of 15 feet and more. The unexpected appearance of the earth fissures caused panic among the farmers and people in the area due to concern that the fissures might interfere with future land use.

Nevertheless, some of the old aged villagers are supposed that earth fissures were frequently observed in their youthful time but it was rarely event. Because, it did not pose for problems as the current experience in size and shape because farmers ploughed over them or they disappeared temporarily. So, the study area is assumed that the earth fissures are familiar with the local people.

Figure 2. Update news and earth fissure photo reported on social media Facebook

Figure 3. Some earth fissures photos reported on the social media Facebook

4. Objectives

The main objective of this investigation was to figure out the causes, extents and their relevant events in future with formation of the earth fissures in the study area. We achieved this using under literature review, groundwater studies by interaction with local peoples and checking of soil behaviors. Field mapping includes investigating all earth fissures and domestic wells in villages based on the detail investigation and locating them using hand-held GPS receiver at points along their surface expression.

Figure 4. Investigation of well information by interaction with local peoples

Figure 5. Measuring of the impressive surface appearance in the field

Figure 6. Checking of soil behaviors in the field

Figure 7. Record the location of discharge well by hand held GPS

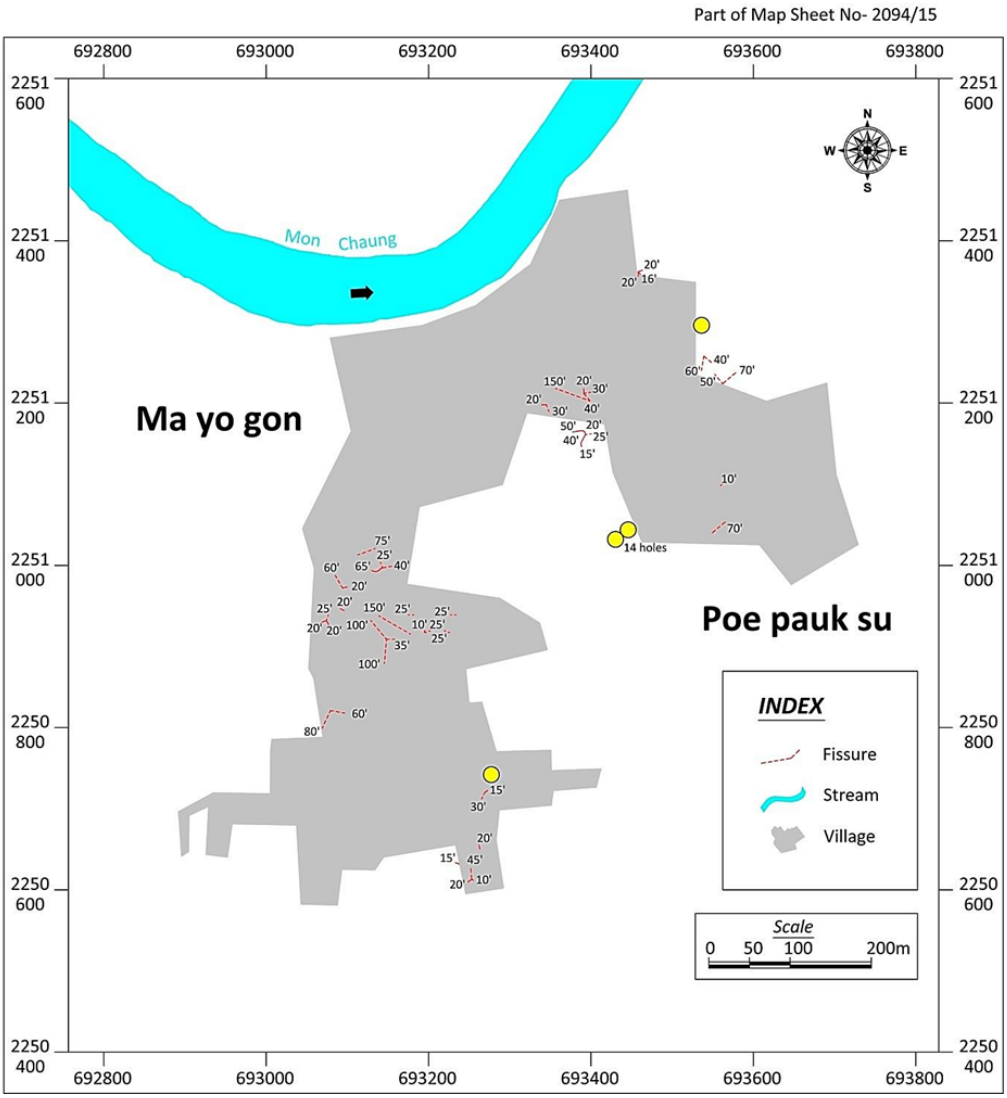

Figure 8. Formation of earth fissures occurrences in study area

5. Geomorphology and Geology

The study area is situated near the junction of Irrawaddy River and Mon stream about 23 km (14 miles) east of Pwintbyu Township, Magway Region. Latitude and Longitude (UTM map sheet-2094/15) is within 94° 45' 00"- 94° 52' 08" E, 20° 18' 13" - 20° 22' 04"N. In the study area, the wide primitive low relief topography permits the alluvial deposit to be developed by playing the principal part in formation of Central Myanmar Basin.

From the analysis of satellite images and topographic maps, the study area can be divided into two geomorphological units Tertiary bedrock (Irrawaddy Formation) and Quaternary age materials include surficial alluvial deposits (clay, silt, sand and coarser materials). Fertile alluvial soils are predominantly located in study area and high importance for farming.

The nearest stream Mon Chaung is flowing into Irrawaddy River where the stream bank erosions were annually occurred. At first, it is noticed that stream bank erosions must therefore be consider in relation to earth fissures. The question is what warning signs should

technically look for to determine whether their particular stream bank may provide some sort of slope-bank failures. Therefore, we focused on earth fissures resulting from ground-water withdrawal. As groundwater is removed from some alluvial aquifers, sediment particles in those aquifers lose some of their ability to support the overburden, the grains become more closely packed, and aquifer volume decreases. The land surface fails in response to the decreased aquifer volume at depth. This type of ground failure proceeds gradually, but, with time, can spread over large areas and cause significant deformation.

Figure 9. Google view of study area

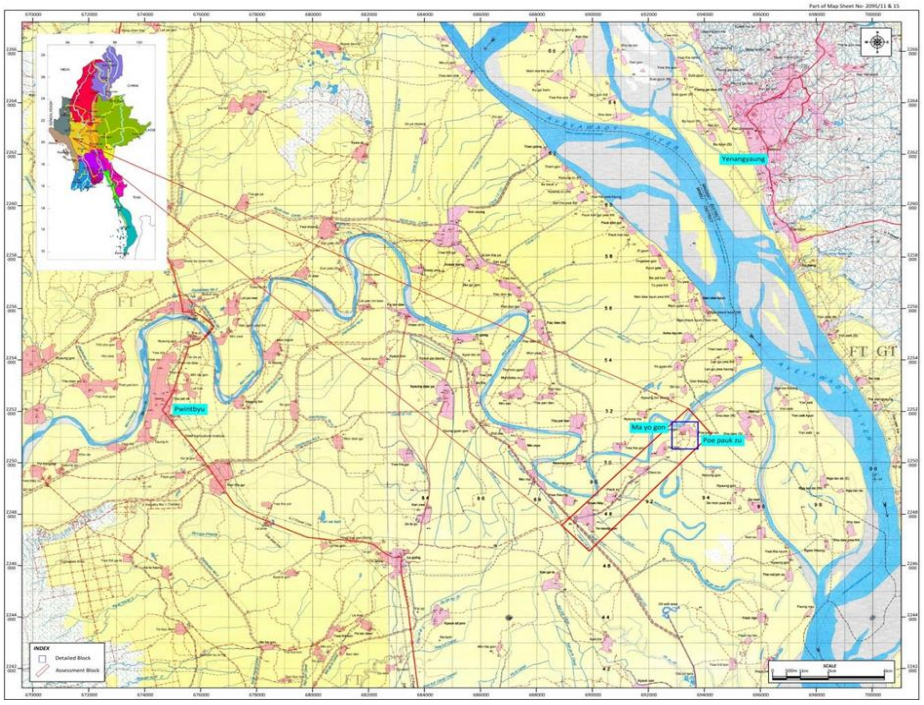

Figure 10. Location map of the study area

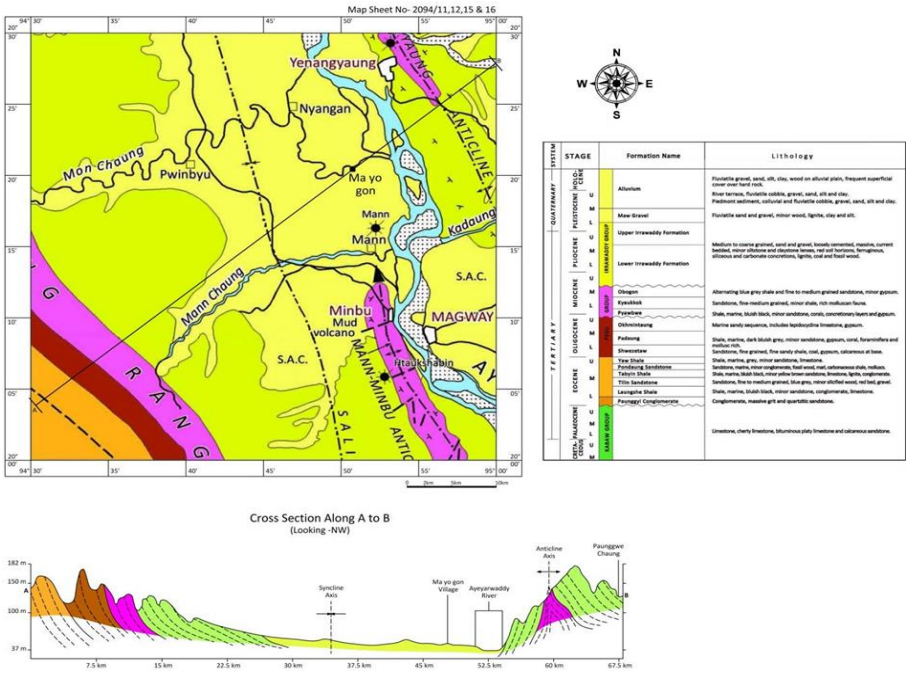

Figure 11. Regional geological setting of the study area

6.Results and Analysis

(i) Land-Use Changes

The study area has been subjected to land-use changes over the past few decades for regarding agricultural activities and residential expansion. In fact, the annual erosion of Mon stream channelization is main factor. We used GIS techniques to delineate the changes of stream modification that entirely took place in the study area. In the current paper, we prepared a detailed land-use changes map by interpreting satellite image, one inch to one mile scale topographic map and 1: 50000 meters scale UTM map making field investigations. The data were essential in developing of different maps to determine land-use changes over past time periods. Actually, the northern part of the villages (Mayogone, Poepaukzu, Gat Kon) near Mon stream were gradually displaced in southern part. Nowadays, the northern portions of three villages were entirely disappeared by stream erosions. It is the one considerable item for hydrological study because the groundwater of newer residence land will be produced in extremely extraction short time period for domestic consumptions. Obviously, the stream modification of Mon stream is directly proportional to the land use changes of study area and will be related to the future geological hazard. Therefore, the land use planning of study area and the stream channel training are essentially needed by officially.

Relocation recorded list of residential house in study area		
Sr. No	Total house	Moving year
1	25	2005
2	78	2017
3	81 (not confirm)	2019

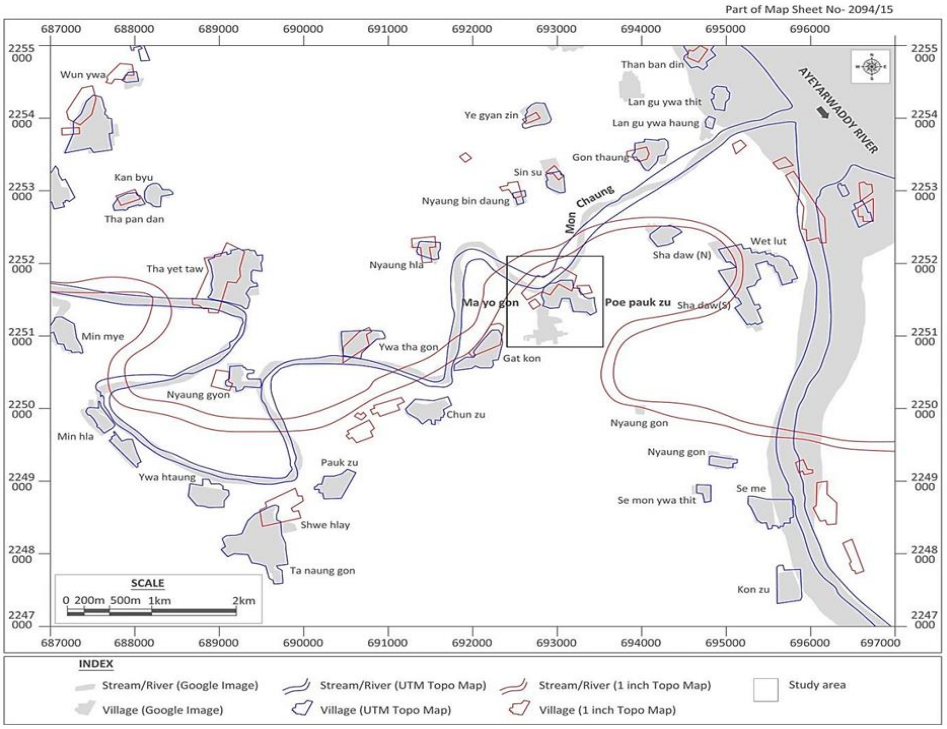

Figure 12. Land use changes map of study area

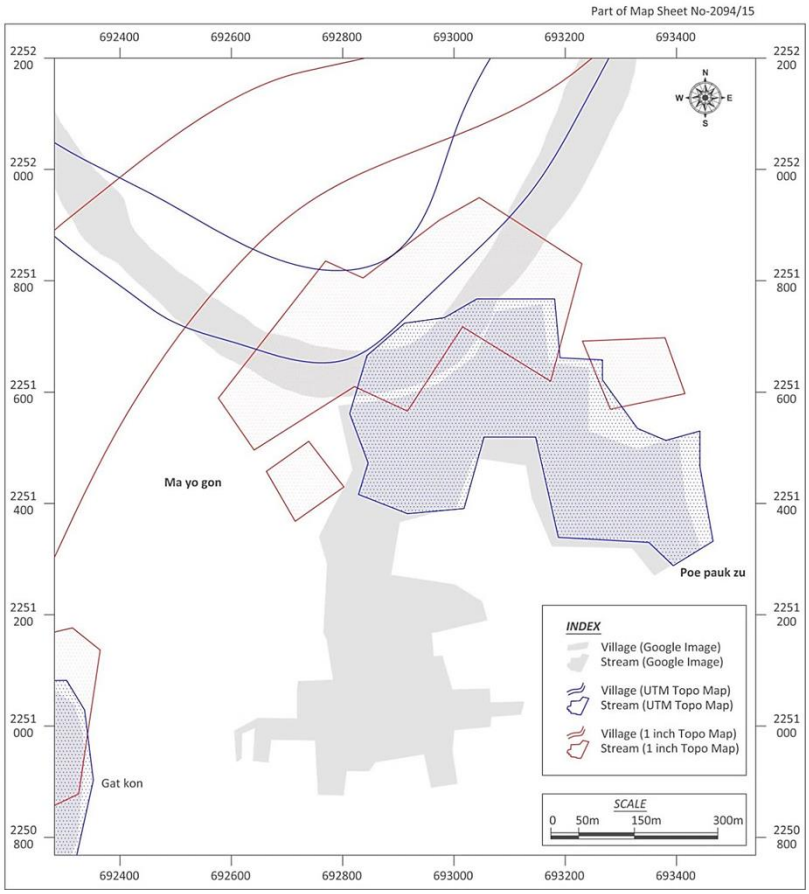

Figure 13. Detail land use changes map of Mayogon & Poepaukzu villages. The light grey color is referred to the current residential area

(ii) Behavior of Soils

Regionally, Central Myanmar has the lowest rainfall and highest potential evaporation and temperature within the country. These climatological factors result in a considerable soil moisture deficiency and a lack of significant surface water availability and the water table fluctuates factors affect groundwater recharge and discharge rates.

In the study region, alluvial soils are relatively young and can be found in alluvial plain. They are fine-textured soils with a dominantly silty clay to clay deposited by fluvial processes at flat or nearly flat areas. Sediments are usually yellow-brown in color whilst the deep portions are blue-grey in color. Physically, it is mostly determined by its structure and its swell-shrink capacity and in fine-grained materials, clays and silts, the permeability is low.

There is no specific type of lithology for earth fissures to occur. If the soil type varies spatially, earth fissures will not be uniform even if the groundwater levels were to decline uniformly within a basin (the same effective stress changes throughout the basin).When there are cemented layers on the top, there is a possibility of initiating earth fissures.

Earth fissures can be formed deep below the ground surface and propagate upwards but their existence is undiscovered. They could widen quickly due to scouring and piping from inflow of surface water during and after heavy rainfall. These earth fissures can cause serious damage to lives and properties.

Soil behaviors are one of the most controlling principal factors for formations of earth fissures, especially due to the tensile stress of soil. Tensile stresses within the soil mass may initiate earth fissure. The earth fissure may extend to the ground surface. We used this suggestion to explain fissure gullies observed in study area. It is theorized that surface run off and infiltration opens and deepens the tension crack, forming cavities with deep thin cracks as tails. Further water infiltration causes the roof of the cavities to collapse, forming potholes. Additional infiltration increases piping, causing the linking of the potholes, which results in collapse, as shown in Figure (14). This mechanism for the growth of the earth fissures due to piping is nearly identical to the mechanism proposed study area. In this mechanism, it is unclear how the tensile stresses originate from groundwater pumping and groundwater elevation change. Also, it is unclear where the eroded sediments go. In study area, many earth fissures show no evidence that they are linked to any drainage basin such as washes to receive any material eroded by piping.

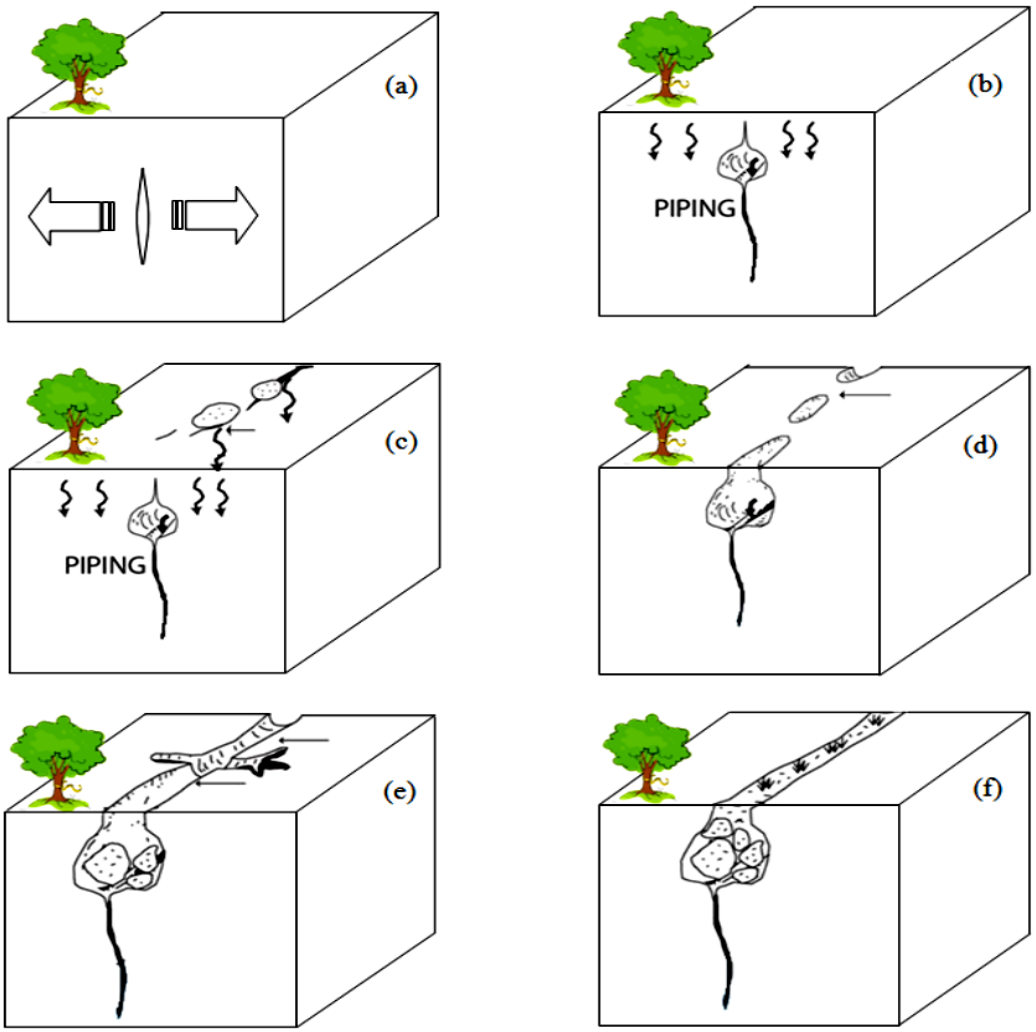

Figure 14. Idealized mechanism for the growth of the earth fissures

(iii) Hydrological Studies

The major aquifer in the study area is the upper basin-fill unit. Many tube wells intersect unconsolidated, semi-unconfined layer. The average depth of full discharge pumping tube well is generally in 100 feet though in some places the depth is more down to about 5-20 feet. Most of the groundwater in the study area is used for domestic consumption, but a minor part is for irrigation. One hundred and twenty five tube wells are detailed investigated by interaction within two villages (Mayogone and Poepaukzu). All of the groundwater wells are operated by manual operation (hand digging). In most cases selection of the drilling site were without professional advice even in the same proximity to previously abandoned holes. Consequently, in hydrological challenging tube wells abandonment still regularly occurs. Pumping rates depend on consumption requirements and vary from well to well. The higher the pumping rate the more rapid the decline in groundwater.

Theoretically, when groundwater is pumped from an unconfined aquifer in the soil, a groundwater cone of depression is formed around the well. The size and shape of the cone of depression depends on many factors, such as the pumping rate, the type of aquifer

material, the amount of water in storage and the thickness of the aquifer. The shape of the cone of depression automatically leads to differential settlement. More settlement is expected near the well than further away from it.

Based on the wells investigation of the study area, the pumping rates of groundwater were significant in the last two years because the machinery pumping is more popular than manual hand pumping. According to this fact leads to the formation of earth fissures and that statement will be completely satisfying for the whole investigation.

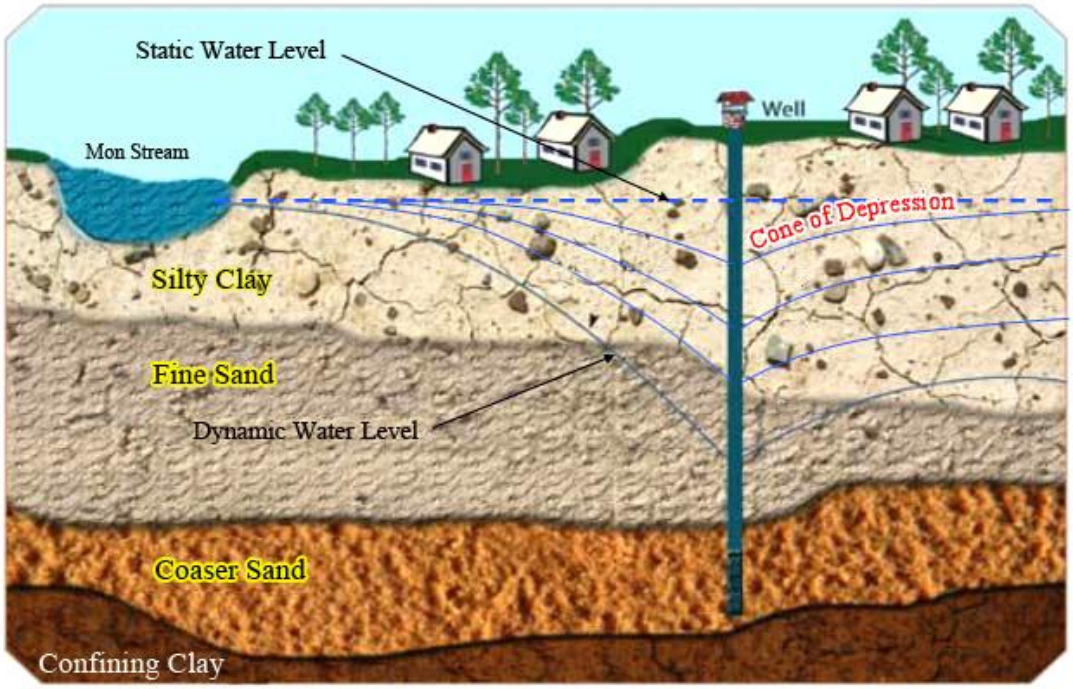

Figure 15. Idealized sketch photo of decline of ground water level by cone of depression

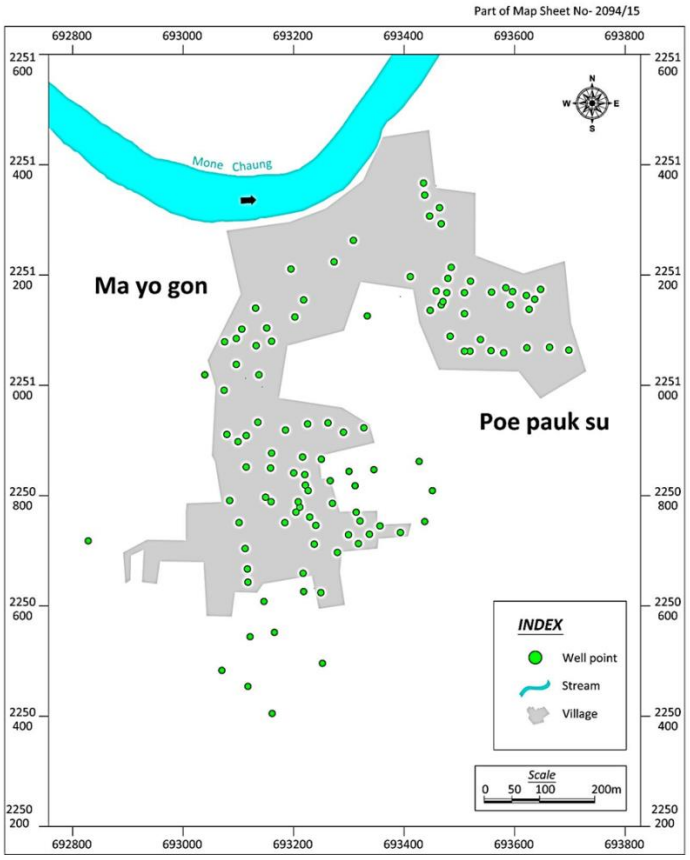

Figure 16. Well location map of the study area

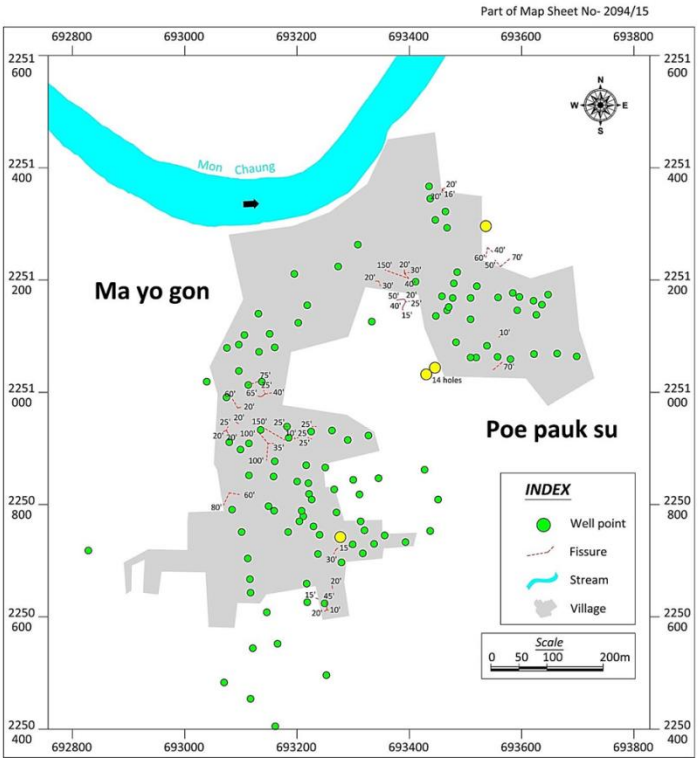

Figure 17. Overlay map of the well location and fissure expression map

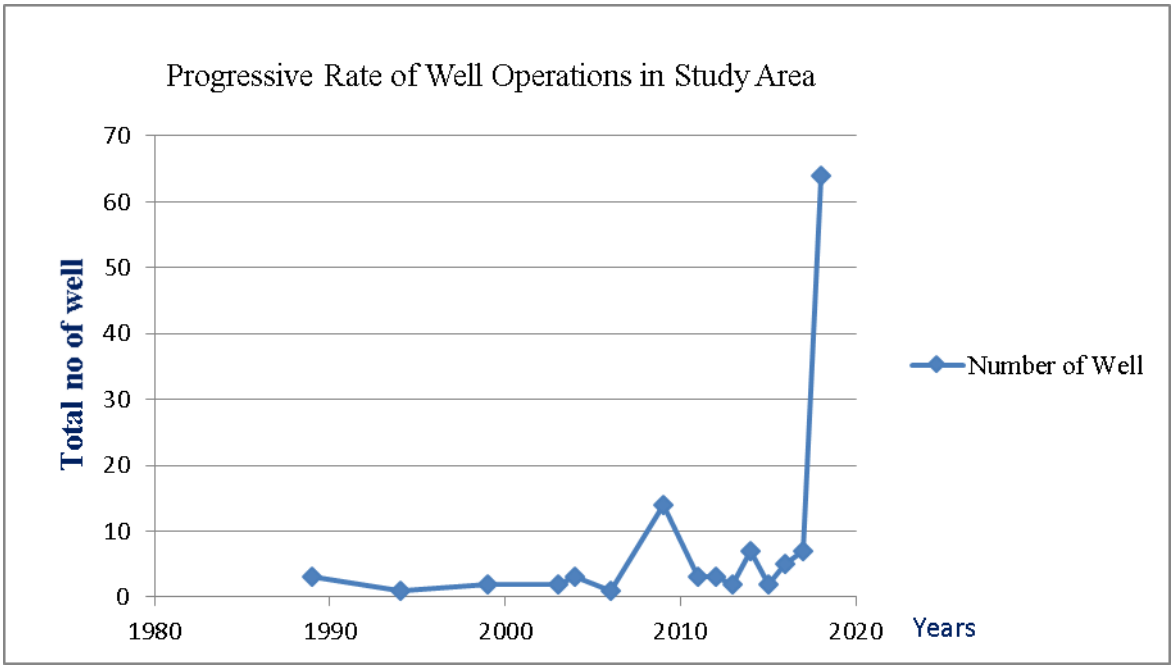

Figure 18. Evaluation chart for progressive rate of operation wells in study area from 1980-2019

7. Discussion and Recommendation

This study suggest that all these fissures have developed in the close vicinity of major Mon streams, during the first rainfall after a long spell of poor rainfall in preceding years and soil behavior of study area. It is clear that the first rain will identify for triggering factor.

The ground fissures are developed on the earth surface by natural process. Not related to geological phenomenon (tectonic, fault related, earthquake fissures).

Although existing earth fissures data are limited, analysis of the data presented suggests that a manifestation of ground-water over pumping.

We conclude that the fissures are suspected to be a result of tensile stress within the soil caused by compaction of unconsolidated sediments. The compaction may be due to increased effective stresses as a result of water-level decline, either as the result of decrease in hydrostatic (pore) pressure in a confined aquifer or dewatering of an unconfined aquifer.

With the absence of appropriate management, water pumping is at a rate that exceeds aquifer safe yield, causing a continuous decline of groundwater.

Information obtained from these studies will provide greater insights into the mechanisms responsible for the initiation, development, and propagation of earth fissures in the study area beyond the scope of this investigation.

Artificial filling of earth fissures with earth materials has no lasting effect upon them. They simply reopen with time.

Erosion is quite intensive and many of people are displaced yearly. Approximate soil conservation measures to check bank erosion need to be intensified.

The study area which is frequently visited by flood and erosion cause damage to crop is a regular feature. Slab type of failures are noted in study region that the sliding and forward toppling of mass into the channel. So, flooded zoning is very important which includes regulation of land use, changing of crop pattern etc.

Existing stream pattern leads to excessive bank cutting which can destroy agricultural land and human settlements. So, suitable channel training methods (transversal protection structures and longitudinal protection structures) should be urgently taken to improve the stream and its banks.

If this is not fulfilled, any executive operation such as stream engineering and modification of the banks will be faced with erosion problems, especially in Mayogone, Poepaukzu and Gatkon villages.

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Appendix 1 Surficial expression photos of earth fissure in the study area


SHOT ON MI 8 SE
AI DUAL CAMERA


SHOT ON MI 8 SE
AI DUAL CAMERA


SHOT ON MI 8 SE
AI DUAL CAMERA


SHOT ON MI 8 SE
AI DUAL CAMERA


SHOT ON MI 8 SE
AI DUAL CAMERA


SHOT ON MI 8 SE
AI DUAL CAMERA

Appendix 2. Sinkholes or piping conditions of study area


SHOT ON MI 8 SE
AI DUAL CAMERA

Appendix 3 Detail information lists of the discharge wells in study area

No	UTM		Depth	Pumping Time		Type of pumping	Name	People	Village	Remark
	Easting	Northing								
1	693472	2251610	30.48	30 years	1989	Mortor pumping	Daw San	4	Mayogone & Pho Pauk Su	
2	693490	2251625	30.48	30 years	1989	Hand pumping	U Tin Aung Win	3	Mayogone & Pho Pauk Su	
3	693334	2251566	30.48	30 years	1989	Mortor pumping	U Than Tun	2	Mayogone & Pho Pauk Su	
4	693505	2251497	30.48	25 years	1994	Mortor pumping	Daw Tin Tin Khine	4	Mayogone & Pho Pauk Su	
5	693546	2251492	24.384	20 years	1999	Mortor pumping	U Win Hlaing	5	Mayogone & Pho Pauk Su	
6	693689	2251372	18.288	20 years	1999	Mortor pumping	U Thein Win	5	Mayogone & Pho Pauk Su	
7	693122	2251388	27.432	13 years	2003	Hand pumping	U Win Htwe	5	Mayogone & Pho Pauk Su	
8	693163	2251322	30.48	16 years	2003	Mortor pumping	U TheinTan	5	Mayogone & Pho Pauk Su	
9	693493	2251449	30.48	15 years	2004	Hand pumping	U Tin Shwe	5	Mayogone & Pho Pauk Su	
10	693208	2251242	30.48	15 years	2004	Hand pumping	U San Hla	4	Mayogone & Pho Pauk Su	
11	693157	2251443	30.48	15 years	2004	Hand pumping	Daw Mya Than Kyi	4	Mayogone & Pho Pauk Su	
12	693503	2251471	30.48	13 years	2006	Hand pumping	U Thaung Hla	2	Mayogone & Pho Pauk Su	
13	693610	2251480	30.48	10 years	2009	Mortor pumping	U San Hla		Mayogone & Pho Pauk Su	
14	693226	2251144	30.48	10 years	2009	Hand pumping	U Tun Naing	5	Mayogone & Pho Pauk Su	
15	639140	2250880	30.48	10 years	2009	Mortor pumping	U Soe Lwin	2	Mayogone & Pho Pauk Su	
16	693127	2251054	27.432	10 years	2009	Hand pumping	U Win Naing Soe	5	Mayogone & Pho Pauk Su	
17	693110	2251094	30.48	10 years	2009	Mortor pumping	U Tin Htay	9	Mayogone & Pho Pauk Su	
18	693175	2251100	30.48	10 years	2009	Mortor pumping	U Soe Win	8	Mayogone & Pho Pauk Su	
19	693140	2251155	30.48	10 years	2009	Mortor pumping	Daw Pauk	5	Mayogone & Pho Pauk Su	
20	693184	2251153	30.48	10 years	2009	Hand pumping	U Than Win	5	Mayogone & Pho Pauk Su	
21	693186	2251180	30.48	10 years	2009	Hand pumping	U Soe Myanig	3	Mayogone & Pho Pauk Su	
22	693161	2251236	36.576	10 years	2009	Hand pumping	U Myint Kyi	6	Mayogone & Pho Pauk Su	
23	693140	2251212	30.48	10 years	2009	Hand pumping	U Maung Swe	6	Mayogone & Pho Pauk Su	
24	693105	2251214	30.48	10 years	2009	Hand pumping	Daw Than Yin	4	Mayogone & Pho Pauk Su	
25	693100	2251294	30.48	10 years	2009	Mortor pumping	U Maung Win	6	Mayogone & Pho Pauk Su	
26	693244	2251458	30.48	10 years	2009	Motor Pumping	Monastry		Mayogone & Pho Pauk Su	
27	693545	2251365	27.432	8 years	2011	Hand pumping	Daw San San Oo	2	Mayogone & Pho Pauk Su	
28	693247	2251122	30.48	8 years	2011	Mortor pumping	U Thet Aung	3	Mayogone & Pho Pauk Su	
29	693266	2251049	33.528	8 years	2011	Mortor pumping	U Win Aung	4	Mayogone & Pho Pauk Su	
30	693263	2251015	30.48	7 years	2012	Mortor pumping	U Myint Wai	3	Mayogone & Pho Pauk Su	
31	693325	2251032	30.48	7 years	2012	Hand pumping	U Sein Lin	3	Mayogone & Pho Pauk Su	
32	693353	2251226	21.336	7 years	2012	Motor Pumping	U Mya Than	7	Mayogone & Pho Pauk Su	
33	693276	2251169	30.48	6 years	2013	Hand pumping	U Zaw	5	Mayogone & Pho Pauk Su	
34	693122	2251341	21.336	6 years	2013	Hand pumping	Daw Mya Than Sint	3	Mayogone & Pho Pauk Su	
35	693535	2251433	30.48	5 years	2014	Hand pumping	U Win Myint Than	2	Mayogone & Pho Pauk Su	
36	693177	2251407	30.48	5 years	2014	Hand pumping	U Maung Ko	3	Mayogone & Pho Pauk Su	
37	693186	2251383	30.48	5 years	2014	Hand pumping	U Cho	5	Mayogone & Pho Pauk Su	
38	693221	2251514	30.48	5 years	2014	Hand pumping	U Maung Naing	3	Mayogone & Pho Pauk Su	
39	693382	2251048	30.48	5 years	2014	Hand pumping	Daw Myint Maw	4	Mayogone & Pho Pauk Su	
40	693346	2251057	30.48	5 years	2014	Hand pumping	U Sein Shwe	6	Mayogone & Pho Pauk Su	
41	693292	2251130	33.528	5 years	2014	Hand pumping	U Aung Sein Nyunt	6	Mayogone & Pho Pauk Su	
42	693242	2251173	30.48	4 years	2015	Hand pumping	U Soe Thein	4	Mayogone & Pho Pauk Su	
43	693065	2251322	24.384	4 years	2015	Motor Pumping	U Tint Wai	4	Mayogone & Pho Pauk Su	
44	693237	2251082	30.48	3 years	2016	Hand pumping	U Myo Min Soe	3	Mayogone & Pho Pauk Su	
45	693210	2251054	30.48	3 years	2016	Mortor pumping	U Aye Thaung	2	Mayogone & Pho Pauk Su	
46	693299	2251527	30.48	3 years	2016	Mortor pumping	U Hla Wai	5	Mayogone & Pho Pauk Su	
47	693305	2251000	30.48	3 years	2016	Hand pumping	U Than Oo	6	Mayogone & Pho Pauk Su	
48	693316	2251218	30.48	3 years	2016	Hand pumping	U Hla Maung Htay	3	Mayogone & Pho Pauk Su	
49	693509	2251392	30.48	2 year	2017	Hand pumping	U Kyaw Soe Moe	4	Mayogone & Pho Pauk Su	
50	693252	2251112	30.48	2 years	2017	Hand pumping	U Kyaw Lin	4	Mayogone & Pho Pauk Su	
51	693234	2251092	30.48	2 years	2017	Mortor pumping	U Maung win	5	Mayogone & Pho Pauk Su	
52	693437	2251500	21.336	2 years	2017	Mortor pumping	U Thet Naing Htwe	4	Mayogone & Pho Pauk Su	
53	693419	2251036	30.48	2 years	2017	Motor Pumping	Daw Aye Ma	4	Mayogone & Pho Pauk Su	
54	693363	2251033	27.432	2 years	2017	Hand pumping	U Sein Naing Oo	3	Mayogone & Pho Pauk Su	
55	693343	2251016	27.42	2 years	2017	Hand pumping	U Ko Ko Naing	4	Mayogone & Pho Pauk Su	
56	693461	2251670	33.528	1 year	2019	Hand pumping	U Yan Naing Tun		Mayogone & Pho Pauk Su	
57	693463	2251648	33.258	1 year	2019	Hand pumping	Daw Marlar OO	2	Mayogone & Pho Pauk Su	
58	693493	2251596	30.48	1 Year	2019	Hand pumping	U Kyaw Thein	7	Mayogone & Pho Pauk Su	
59	693535	2251471	30.48	1 year	2019	Mortor pumping	U Than Naing	4	Mayogone & Pho Pauk Su	
60	693584	2251472	33.528	1 year	2019	Hand pumping	U Win Bo	3	Mayogone & Pho Pauk Su	
61	693622	2251473	30.48	1 year	2019	Mortor pumping	Daw Mya Than Kyi	6	Mayogone & Pho Pauk Su	
62	693652	2251441	30.48	1 year	2019	Double pumping	U Myo Myint Oo	6	Mayogone & Pho Pauk Su	
63	693662	2251459	30.48	1 year	2019	Mortor pumping	U Htay Lwin	3	Mayogone & Pho Pauk Su	
64	693647	2251466	30.48	1 year	2019	Mortor pumping	U Kyaw Zaw Oo	4	Mayogone & Pho Pauk Su	

65	693673	2251477	30.48	1 year	2019	Hand pumping	U Kyaw San Win	4	Mayogone & Pho Pauk Su	
66	693724	2251367	30.48	1 year	2019	Hand pumping	U Nyi Htwe	4	Mayogone & Pho Pauk Su	
67	693648	2251371	30.48	1 year	2019	Hand pumping	U Kyaw Thin	2	Mayogone & Pho Pauk Su	
68	693606	2251362	30.48	1 year	2019	Hand pumping	U Win Myint	8	Mayogone & Pho Pauk Su	
69	693583	2251366	27.432	1 year	2019	Mortor pumping	U Aye Min Lwin	4	Mayogone & Pho Pauk Su	
70	693564	2251386	30.48	1 year	2019	Hand pumping	U Win Khine	4	Mayogone & Pho Pauk Su	
71	693535	2251365	30.48	1 year	2019	Hand pumping	U Tin Aung Htay	4	Mayogone & Pho Pauk Su	
72	693473	2251439	30.48	1 year	2019	Mortor pumping	U Maung Htay	4	Mayogone & Pho Pauk Su	
73	693496	2251455	30.48	1 year	2019	Mortor pumping	Daw Yi Yi Htay	4	Mayogone & Pho Pauk Su	
74	693484	2251474	30.48	1 year	2019	Mortor pumping	U Myint Aye	4	Mayogone & Pho Pauk Su	
75	693511	2251517	30.48	1 year	2019	Hand pumping	U Kyaw Min	2	Mayogone & Pho Pauk Su	
76	693618	2251449		1 year	2019	Mortor pumping	Government		Mayogone & Pho Pauk Su	
77	693359	2251429		1 year	2019	Hand pumping	School		Mayogone & Pho Pauk Su	
78	693251	2251233	30.48	1 year	2019	Hand pumping	U Bo Hein	3	Mayogone & Pho Pauk Su	
79	693211	2251222	30.48	1 year	2019	Hand pumping	U Kyaw Htay Aung	4	Mayogone & Pho Pauk Su	
80	693230	2251073	30.48	1 year	2019	Hand pumping	U Ye Hla	4	Mayogone & Pho Pauk Su	
81	693255	2251064	27.432	1 year	2019	Hand pumping	Daw Nyo Ma	5	Mayogone & Pho Pauk Su	
82	693275	2250927	30.48	1 year	2019	Hand pumping	U Soe Aye	4	Mayogone & Pho Pauk Su	
83	693244	2250929	36.576	1 year	2019	Mortor pumping	U Win Tin Aung	6	Mayogone & Pho Pauk Su	
84	693243	2250962	36.576	1 year	2019	Hand pumping	U Win Htay	4	Mayogone & Pho Pauk Su	
85	693278	2250799	30.48	1 year	2019	Hand pumping	U Kyaw Oo	3	Mayogone & Pho Pauk Su	
86	693187	2250708	30.48	1 year	2019	Mortor pumping	U Myint Than	6	Mayogone & Pho Pauk Su	
87	693143	2250757	30.48	1 year	2019	Hand pumping	U Zaw Min Tun	6	Mayogone & Pho Pauk Su	
88	693096	2250786	30.48	1 year	2019	Hand pumping	U San Win	5	Mayogone & Pho Pauk Su	
89	693147	2250847	30.48	1 year	2019	Hand pumping	U Maung Lwin	4	Mayogone & Pho Pauk Su	
90	693191	2250855	30.48	1 year	2019	Mortor pumping	U Thant Min Zaw	4	Mayogone & Pho Pauk Su	
91	693172	2250911	30.48	1 year	2019	Mortor pumping	U Soe Tint	4	Mayogone & Pho Pauk Su	
92	693143	2250946	30.48	1 year	2019	Hand pumping	U Than Lwin	5	Mayogone & Pho Pauk Su	
	693142	2250970	24.384	1 year	2019	Hand pumping	U Zayar Min Thu	4	Mayogone & Pho Pauk Su	
93	693138	2251007	30.48	1 year	2019	Hand pumping	U Win Maung	5	Mayogone & Pho Pauk Su	
94	693185	2251092	30.48	1 year	2019	Hand pumping	Daw Aye Myaing	5	Mayogone & Pho Pauk Su	
95	693125	2251201	33.528	1 year	2019	Hand pumping	U Yin Min	7	Mayogone & Pho Pauk Su	
96	693139	2251316	30.48	1 year	2019	Hand pumping	Daw Thein Kyi	6	Mayogone & Pho Pauk Su	

97	693453	2251165	36.576	1 year	2019	Mortor pumping	U Kyin Khe	4	Mayogone & Pho Pauk Su	
98	693463	2251056	30.48	1 year	2019	Hand pumping	U Maung win	5	Mayogone & Pho Pauk Su	
99	693339	2251073	30.48	1 year	2019	Hand pumping	Daw Khin Win	3	Mayogone & Pho Pauk Su	
100	693296	2251089	30.48	1 year	2019	Hand pumping	U Lu Maw	5	Mayogone & Pho Pauk Su	
101	693337	2251121	30.48	1 year	2019	Hand pumping	U Soe Than	4	Mayogone & Pho Pauk Su	
102	693326	2251147	30.48	1 year	2019	Hand pumping	U Thant Zin Oo	4	Mayogone & Pho Pauk Su	
103	693371	2251150	30.48	1 year	2019	Motor Pumping	U Nay Lin	5	Mayogone & Pho Pauk Su	
104	693288	2251235	33.528	1 year	2019	Motor Pumping	U Htein Win	6	Mayogone & Pho Pauk Su	
105	693158	2251375	27.432	1 year	2019	Hand pumping	U Nyunt Hlaing	8	Mayogone & Pho Pauk Su	
106	693132	2251405	30.48	1 year	2019	Hand pumping	U Nay Lin	4	Mayogone & Pho Pauk Su	
107	693101	2251382	24.384	1 year	2019	Hand pumping	U Pauk	4	Mayogone & Pho Pauk Su	
108	693228	2251427	30.48	1 year	2019	Motor Pumping	Monastry		Mayogone & Pho Pauk Su	
109	693246	2251141	24.384	1 years	2019	Mortor pumping	U Ko Ko Naing	4	Mayogone & Pho Pauk Su	
105	693477	2251112					U Aye Thaung		Mayogone & Pho Pauk Su	
	689968	2247950	25.908			Mortor Pumping	U Tin Maung Win	4	Htanaunggone	
	689978	2247941	30.48			Mortor Pumping	U Hla shwe	5	Htanaunggone	
	689960	2247874	30.48			Mortor Pumping	U Than Htay Oo	5 Houses	Htanaunggone	
	690006	2248347	36.576			Mortor Pumping	U Kyaw Swe	6	Shwe Hlay	
	689954	2248429	30.48			Mortor Pumping	U Soe Myint Oo	5	Shwe Hlay	
	690739	2249077	30.48			Mortor Pumping	U Aung Kyi Sein	10	Pauk Su	
	690700	2249042	30.48			Mortor Pumping	U Aye Hlaing	5	Pauk Su	
	690667	2249038	30.48			Mortor Pumping	U Win Naung	4	Pauk Su	
	691924	2249983	25.908			Hand Pumping	U Zaw Zaw	2	Chun Zu	
	691873	2249983	30.48			Mortor Pumping	U Thet Tun	9	Chun Zu	
	691844	2250045	30.48			Mortor Pumping	U Yarzar Kyaw	6	Chun Zu	
	692503	2250883	30.48			Hand Pumping	U Aung Than	5 house	Gat Kon	
	692438	2250968	30.48			Hand Pumping	U Soe Pe	5 House	Gat Kon	
	692854	2251021	27.432			Hand Pumping	U Aung Ko	4	Gat Kon	

Appendix 4. Detail measurement of earth fissure geometry in study area

Ground failure (earth fissures) of the study area

Sr. No	UTM coordinates				Elevation(m)	Owner Village	Direction & length	Width & Depth	remark
	Lat	Long	Easting	Northing					
1	20*21.197	94*51.216	693484	2251665	48.8	U Soe Thu-	(1) 320*16ft (2) 070*20ft (3) 180*20ft	1ft *1ft	
2	20*21.140	94*51.261	693565	2251561	40	Daw San	(1) 130*40ft (2) 190*60ft	15 in*1ft	
	20*21.119	94*51.259	693562	2251599			sinkholes		
3	20*21.121	94*51.275	693588	2251527	42		(1) 050*70ft (2) 320*50ft		Same event in last 3 years
4	20*21.053	94*51.272	693585	2251401	39		(1) 050*10ft	6 in*6 in	
5	20*21.023	94*51.265	693575	2251343	40		(1) 050*70ft	1ft*1ft	
6	20*21.019	94*51.197	693456	2251335	41.6	Monastery	(1) 060*14holes	10in*10in	
7						U Aye Thaung	(1) 290*300ft	18in*1ft	
8	20*21.086	94*51.176	693419	2251464	38	school	(1) 350*20ft-260*50ft (2) 080*25ft (3) 210*40ft-160*15ft	15 in*1ft	
9	20*21.001	94*51.031	693169	2251300	41	U Thein Tan	(1) 080*40ft (2) 340*25ft (3) 260*10ft-200*25ft/300*30ft	1ft*18in	
10	20*20.969	94*51.053	693208	2251242	41	U San Hla	(1) 270*25ft	1ft*1ft	Supplied own field
11	20*20.956	94*51.078	693252	2251220	41	U Bo Sein	(1) 290*25ft	9in*1ft	1-2 parallel
	20*20.971	94*51.084	693260	2251242	41		(2) 270*25ft	18in*15in	
12	20*20.956	94*51.052	693204	2251218	40	U Kyaw Htay Aung	(1) 300*150ft	18in*1ft	
	20*20.957	94*51.061	693221	2251220	40		(1) 360*10ft		
							(2) 070*25ft		
13	20*20.865	94*51.108	693303	2251045	41	U Win Aung	(1) 250*25ft	sinkhole	
14	20*20.850	94*51.102	693295	2251023	41	U Bo Tun	(1) 055*15ft (2) 205*30ft		
15	20*20.792	94*51.092	693279	2250916	41	U Soe Aye	(1) 355*45ft	1ft*6in	
	20*20.812	94*51.099	693289	2250953	41		(2) 120*10ft		
							(3) 235*20ft		
							(1) 350*20ft	18in*1ft	
16	20*20.802	94*51.083	693263	2250935	41	U Win Tint	(1) 290*15ft	6in*6in	
17	20*20.953	94*51.034	693174	2251212	41.9	U Soe Myaing	(1) 090*35ft (2) 185*100ft (3) 320*25ft-320*100ft		
18	20*20.955	94*50.993	693105	2251124	41.4		(1)100*60ft (2) 205*80ft		
19	20*20.967	94*50.992	693100	2251235	42	U Mg Win	(1) 20*25ft	1.5in*3.5ft	
	20*20.969	94*51.004	693122	2251247			(2) 150*20ft		
	20*20.987	94*51.003	693120	2251275			(3) 250*20ft		
							(1) 300*20ft	1.5ft*2ft	
							(1)330*60ft		
							(2)075*20ft	1ft*1ft	
20	20*20.010	94*51.015	693139	2251316	41.8	Daw Thein Kyi	(1) 70*75ft		
21	20*21.109	94*51.149	693371	2251501	42	U Aung Zaw Myint	(1)160*30ft (2) 270*20ft	18in*2ft	
22	20*21.116	94*51.176	693417	2251515	42	U Thet Naing Htwe	(1) 140*40ft-290*150ft (2) 260*30ft (3)360*20ft		
23						U Hla Htay Aung	sinkhole		

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