OCCUPATIONAL HEALTH & SAFETY IN SMALL & MEDIUM SCALE MINING

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OUTLINE

- GGMC's responsibility for OHS & mine safety
- Investigation of Mining Accidents
- Legal Aspects of OHS
- Causes of mining accidents
- THE SCIENCE AND TECHNOLOGY USED IN DETERMINING THE MAXIMUM BENCH HEIGHT IN SMALL AND MEDIUM SCALE MINES IN GUYANA
- RESULTS
- Measures to curb Accidents
- Conclusion

GGMC'S RESPONSIBILITY

- OHS responsibility in mining is shared by the Environmental and Mines Divisions of the GGMC.
- GGMC's responsibility for and commitment to OHS in mining is reflected in its OHS Policy Statement.
- OHS in mining is governed by the Mining Act and Regulations (including the Codes of Practice), and Guidelines for best practices, such as those set out by the ILO.

GGMC'S RESPONSIBILITY

- GGMC collects and compiles data on fatal mining accidents.
- When a fatal accident occurs, a CWO is issued over the area or claim, so that work can immediately cease on the area in question.

INVESTIGATION OF ACCIDENTS

- On receiving a report of a mining accident, GGMC dispatches technical officers to the area to investigate the accident and take appropriate action.
- MO issues a CWO on the area or claim.
- MO collects information on accidents based on a ‘GGMC Accident Report Form’.

INVESTIGATION OF ACCIDENTS

- MO collects statements from eye witnesses (on the accident).
- Recommendations of charges under the Mining Act and Regulations.
- Recommendation for improved safety.
- Other recommendations that may be considered useful.
  - The long-term (and hopefully short term) result would reduced occurrences of accidents and less loss of life and injury.

LEGAL ASPECTS OF OSH

- **Regulations 121 & 214** state that the MO may order work to cease on a mine or any part of the mine where there is an imminent danger to life and limb.
- **Regulation 122** - MO shall give notice in writing to the owner, manager or person in charge in cases of defects and for defects to be corrected.
- **Regulation 125** – manager of the mine in case of an accident that involved serious injury to any person shall give notice in writing to the MO and shall notify the Commissioner via telephone.

LEGAL ASPECTS OF OSH

- Section 126 of the Mining Act 1989 empowers MO to <u>enter premises</u>, <u>inspect, take records and issues instructions</u> as part of an accident investigation. Under this Section, the MO may give written instructions to cease work, withdraw personnel and for machine to stop operating.
- Section 127 vests the GGMC with the power to issue notices to an operator for: submission of data, attending the GGMC to answer questions and to furnish the GGMC with documents relating to the operation. *It is an offence for failing to comply.*

CAUSES OF MINING ACCIDENTS

- Anthropogenic (man-made)
  - Excessively high pit wall (for the type and qualities of the soil).
  - Removal of toe material and the undercutting of the mine face (commonly practiced in hydraulicking operations)
  - Presence of large external loads on pit walls and benches (increase surcharge).
- Natural
  - High pore water pressure/saturation of soil material.
  - Piping of material at the pit wall or mine face.
  - Structural weakness (cracks, fissures, segregation of different soil strata)
  - Seismic activity.

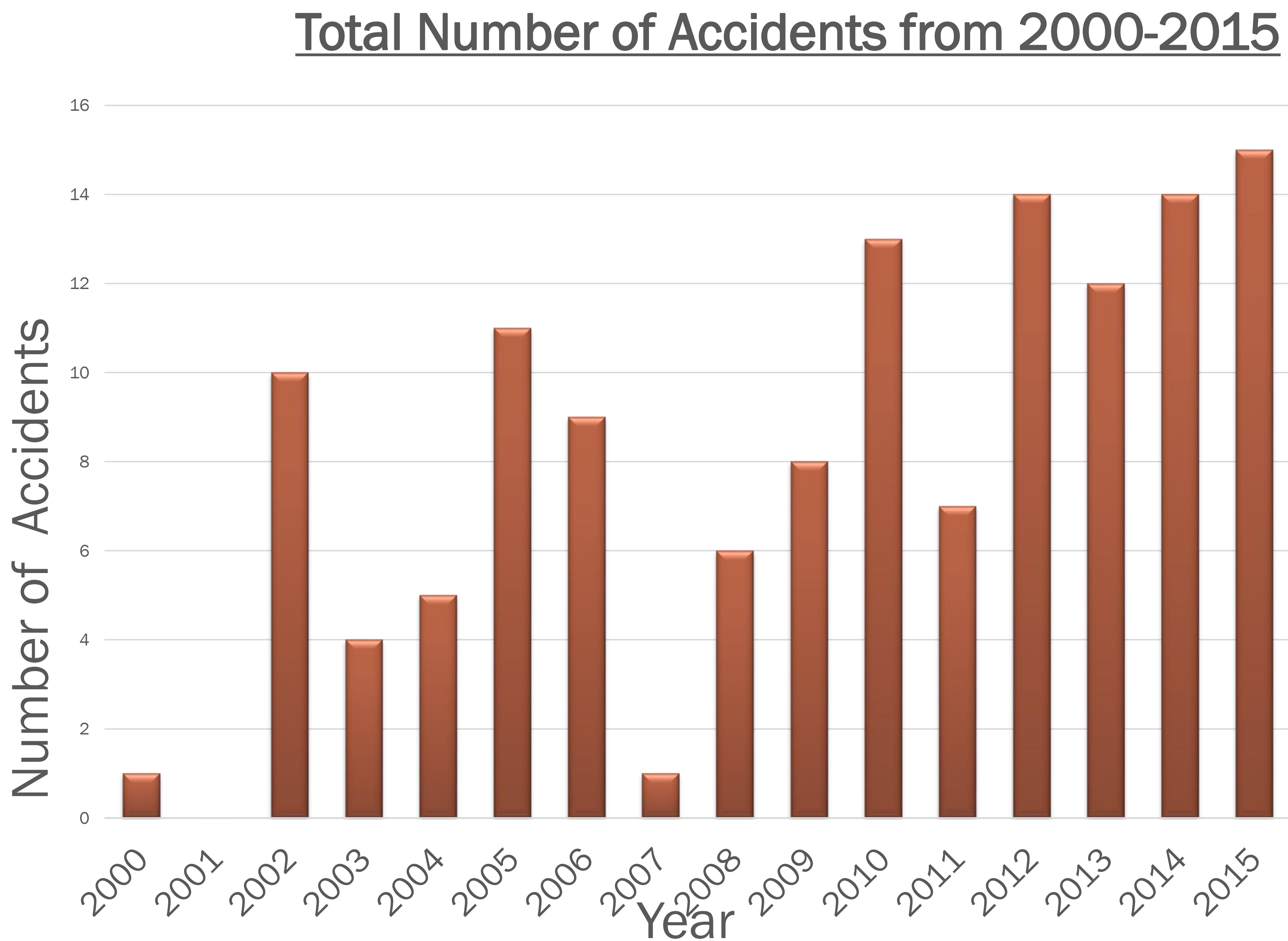
CAUSES OF MINING ACCIDENTS

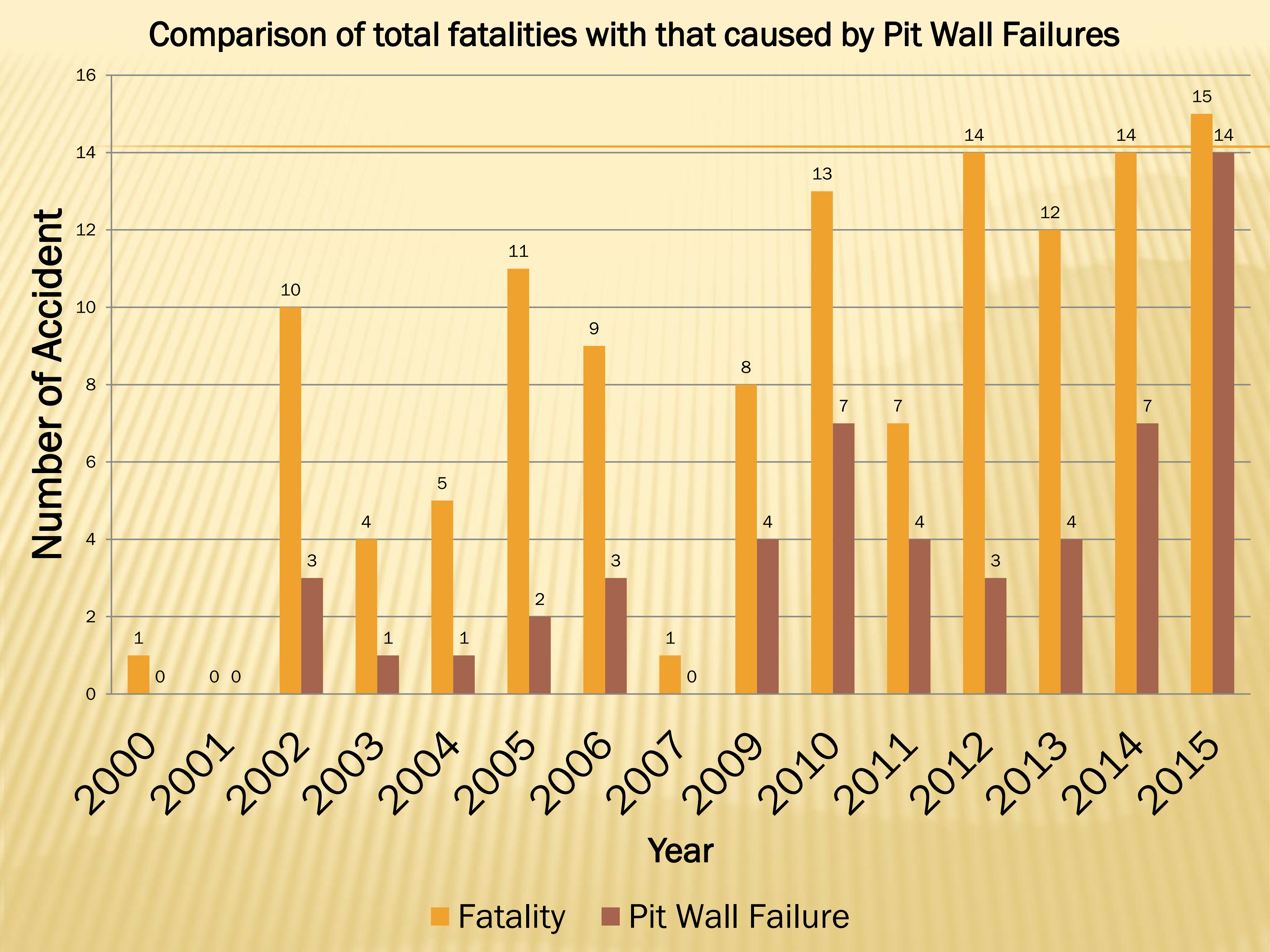
- Undisturbed soil stays in place because opposing horizontal and vertical forces are evenly balanced. When an excavation for a mine pit is created the soil that provides horizontal support is removed.
- Most of the fatal mining accidents (52%) that occurred over the past six years resulted from pit wall failure – 72% in 2014 -2015.
  - *Debris from* pit wall collapsed and buried pit workers
  - This led to serious injuries and most often deaths.
- Other causes of accidents are due to: falling trees (around the mine pit and camp), drowning and vehicle accidents.


Bad and Dangerous mining practice

St. Elizabeth, Mahdia - an example of bad mining practice, pit depth 80 ft.

Year	# of Mining Fatalities		Year	# of Mining Fatalities
2000	1 (0)		2008	6 (1)
2001	-		2009	8 (4)
2002	10 (3)		2010	13 (7)
2003	4 (1)		2011	7 (4)
2004	5 (1)		2012	14 (3)
2005	11 (2)		2013	12 (4)
2006	9 (3)		2014	14 (7)
2007	1 (0)		2015	*15 (14)

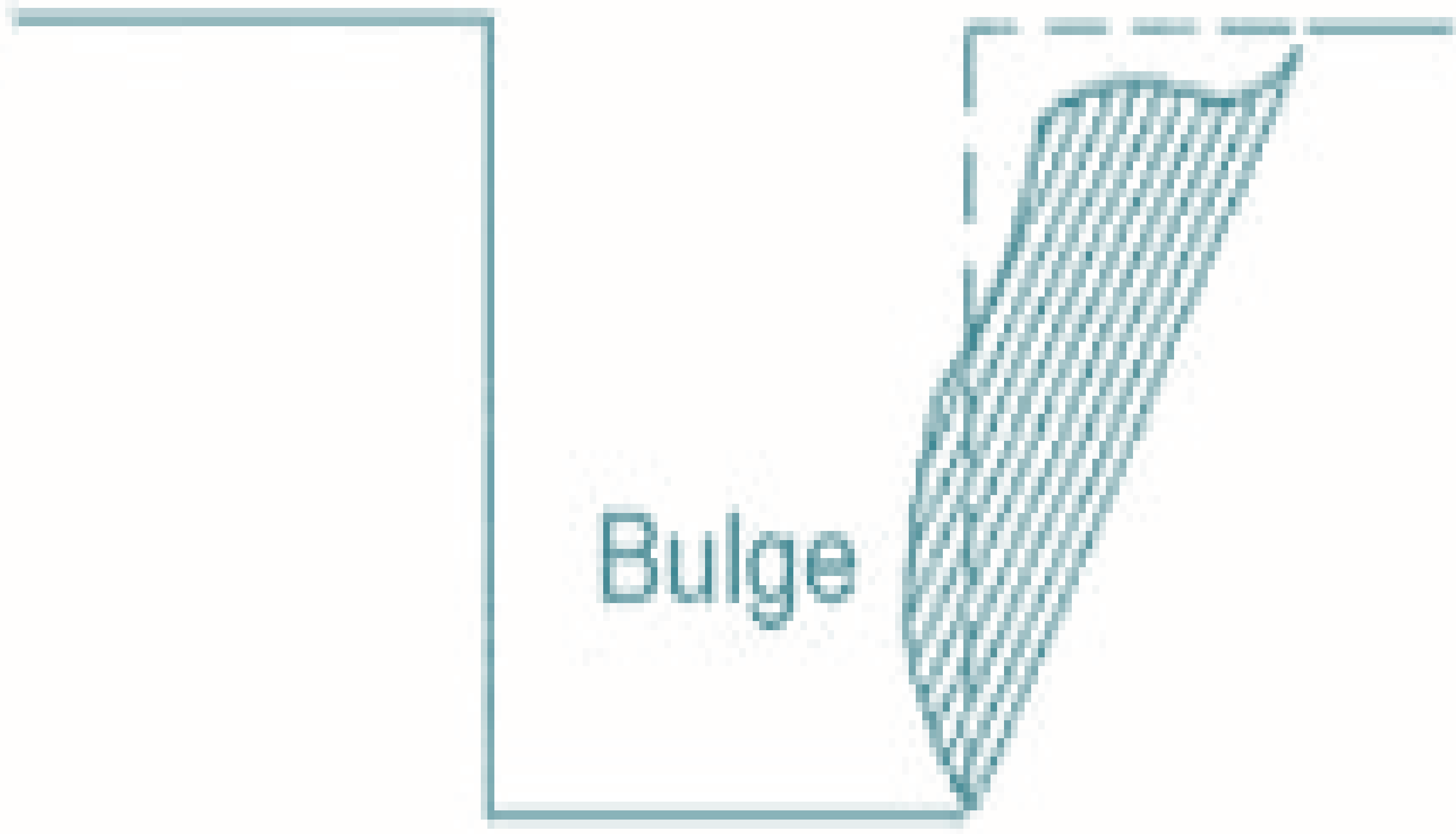

Total Number of Accidents from 2000-2015
Number of Accidents
Year
0
2
4
6
8
10
12
14
16
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015


Comparison of total fatalities with that caused by Pit Wall Failures
Number of Accident
0
2
4
6
8
10
12
14
16
1 0
0 0
10 3
4 1
5 1
11 2
9 3
1 0
8 4
13 7
7 4
14 3
12 4
14 7
15 14
2000
2001
2002
2003
2004
2005
2006
2007
2009
2010
2011
2012
2013
2014
2015
Year
Fatality
Pit Wall Failure

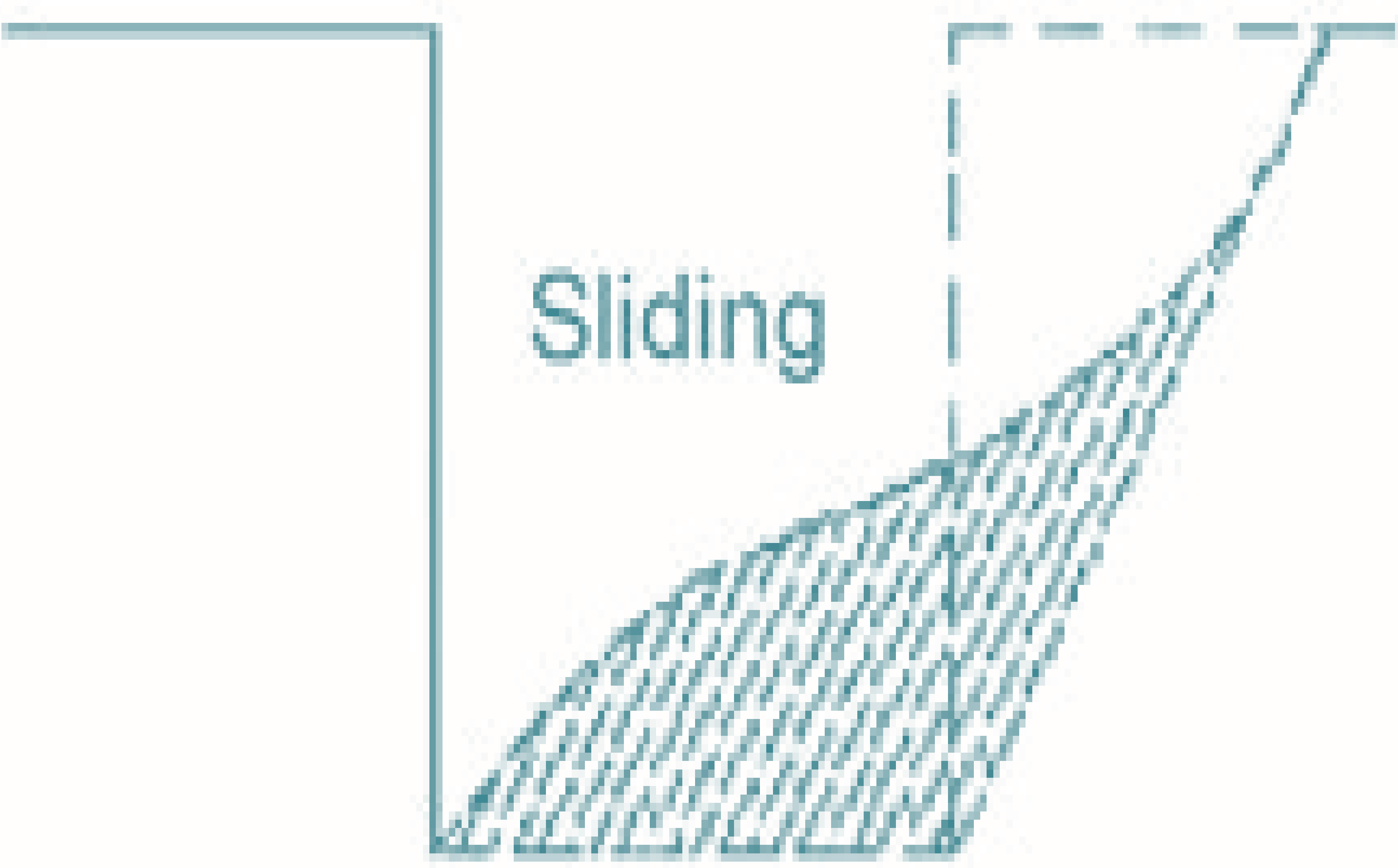
SOIL STABILITY

- Soil stability is dependent on the type and qualities of the soil. Soil types include clayey, sandy, alluvial, etc. Soil qualities include **granularity, saturation, cohesiveness,** and **unconfined compressive strength.**
- Granularity – size of soil grains
- Saturation – how much water soil will absorb
- Cohesiveness – how well soil holds together.
- Unconfined compressive strength – how much pressure it takes a sample to collapse.

HOW DOES PIT WALL FAILURE OCCURS?



HOW PIT DOES WALL FAILURE OCCURS?



HOW PIT DOES WALL FAILURE OCCUR?

THE SCIENCE AND TECHNOLOGY USED IN DETERMINING MAXIMUM BENCH HEIGHT

- THE PROPER DESIGN OF BENCH AND PIT SLOPES IN OPEN PIT MINING IS IMPORTANT FOR THE **SAFETY OF PERSONNEL**, **EQUIPMENT** AND **FOR THE OVERALL ECONOMICS OF THE OPERATION.**
- BENCH/SLOPE FAILURES CAN RESULT IN FATALITIES, EQUIPMENT DAMAGE AND LENGTHY DISRUPTION OF PRODUCTION SCHEDULES.
- THERE ARE SEVERAL QUANTITATIVE METHODS OF DETERMINING THE MAXIMUM BENCH HEIGHT IN OPEN PIT MINES, RANGING FROM THE SIMPLE WEDGE ANALYSIS TO ANALYSES INVOLVING THE USE OF COMPUTERS.

SAMPLING METHODOLOGY AND TESTS

- Samples of in-situ pit wall clay material were collected in PVC samples tubes measuring 2 inches in diameter and approx. 8 inches in length. The tubes were driven into the consolidated clay layer overlying the mineralized layer/horizon in deep open pit mine faces in North West Mining District, Potaro Mining District, Cuyuni Mining District and Berbice Mining District (AMC).

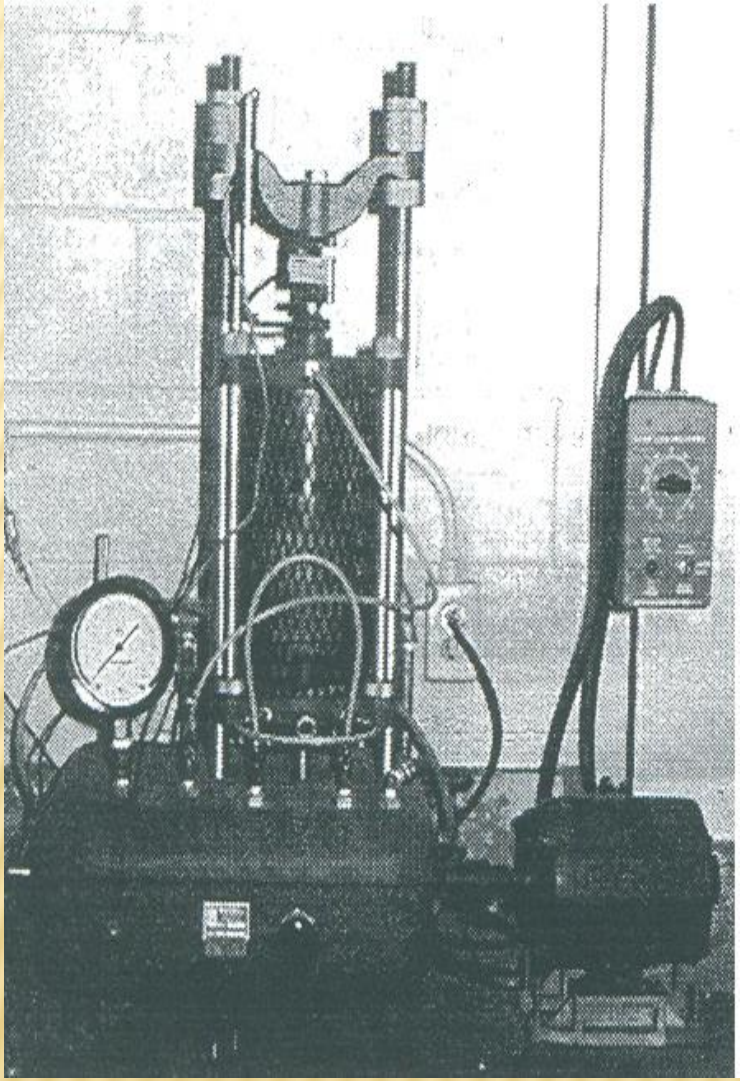
- All samples were taken from the open pit wall, above the water table – three (3) samples per location were collected.

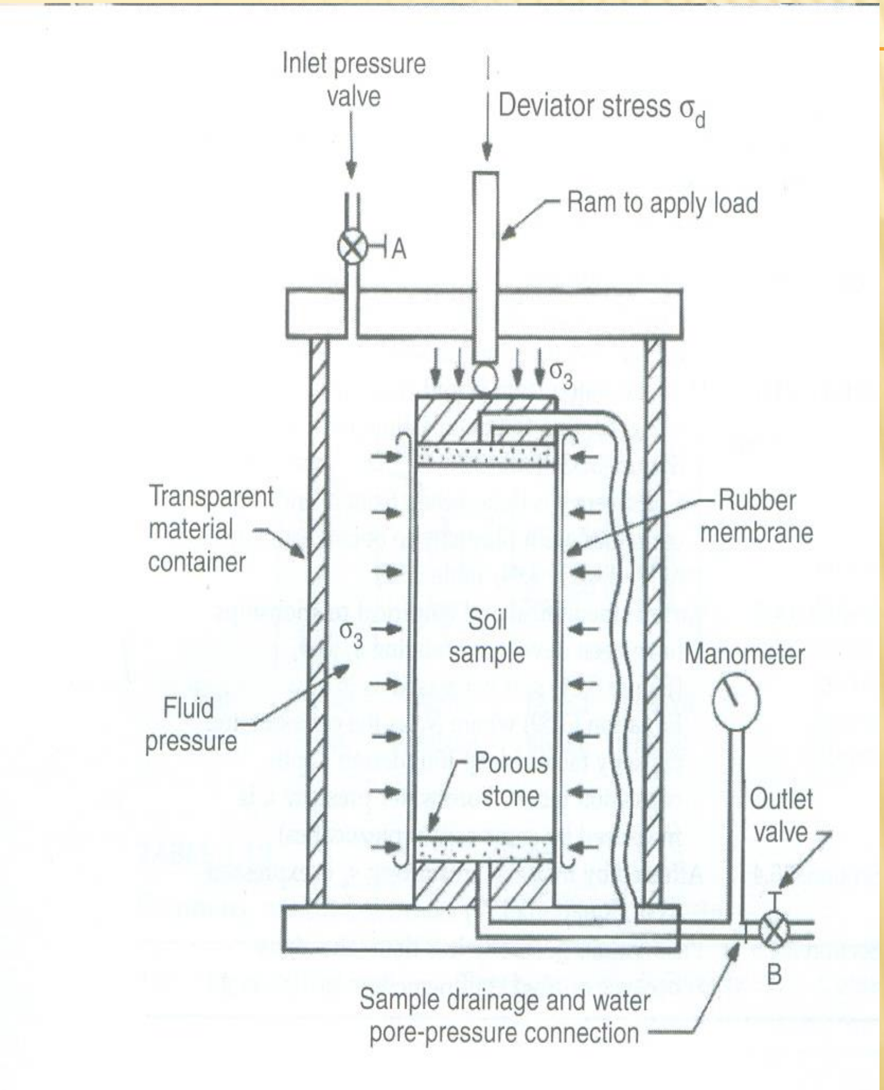
PIT WALL SAMPLING

SAMPLING METHODOLOGY AND TESTS

- Filled/partially filled sample tubes were wrapped in plastic to prevent moisture loss, labelled, logged and delivered to the OBMI soils laboratory, in Linden, at the earliest opportunity (to prevent moisture loss) for the following tests:
  - **Triaxial Test** (Unconsolidated undrained (UU) or Q test)
  - **Atterberg Limits** (Plastic Limit, Liquid Limit)
  - **Moisture content**
  - **In-situ unit weight** (wet, dry).
- Laboratory results were used to compute the maximum bench height (Hmax) using methods of quantitative analysis of planar failure ("AN EXAMINATION OF EMPLACED SHEAR STRENGTH OF CLAYS AND THE MAXIMUM BENCH HEIGHT IN SMALL AND MEDIUM SCALE OPEN PIT GOLD/DIAMOND MINES, Glasgow, 2007).

TRIAXIAL COMPRESSION APPARATUS



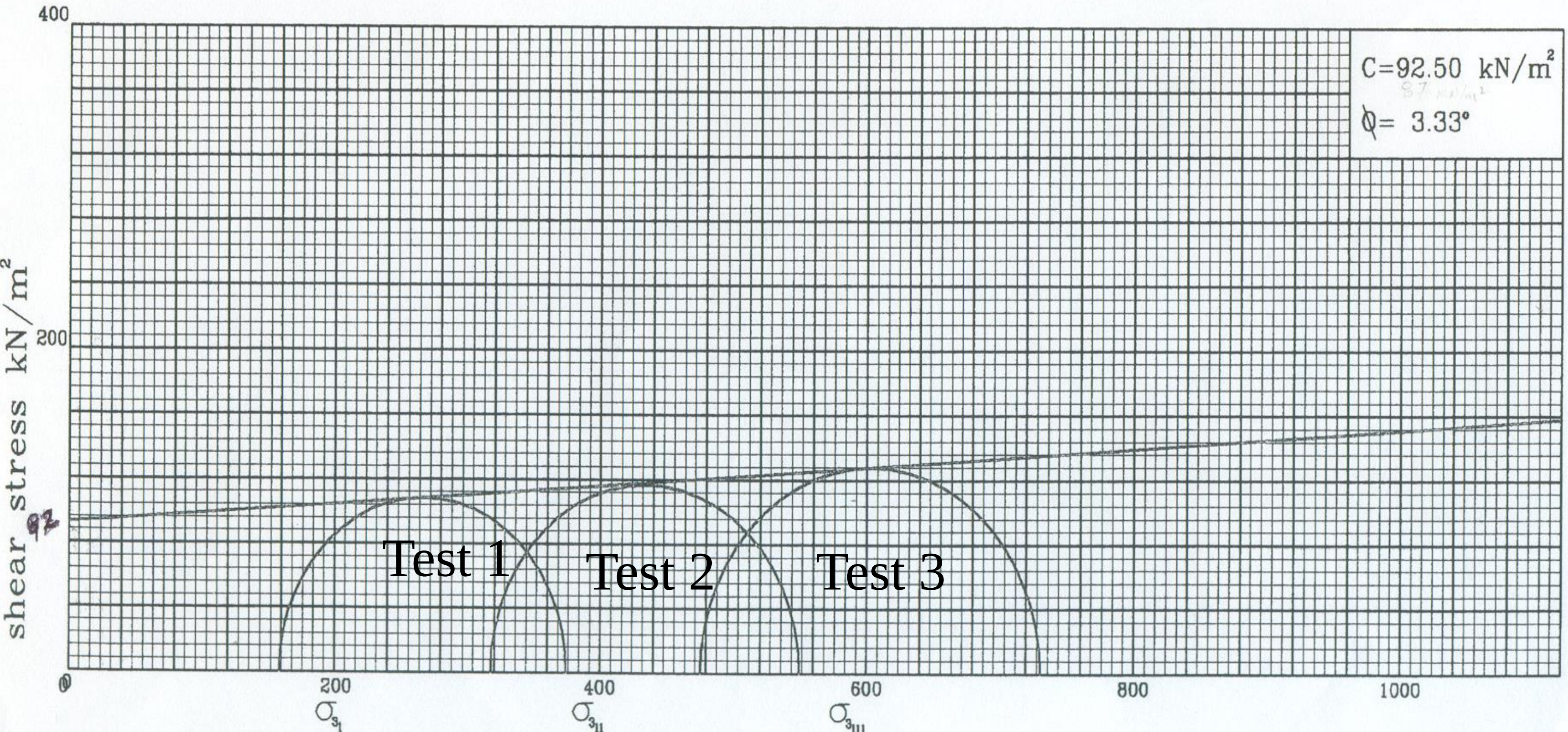


TRIAXIAL COMPRESSION APPARATUS AND CHAMBER ARRANGEMENT.

TRIAXIAL COMPRESSION TEST RESULTS
MOHR CIRCLES

Project:	
Site: Pitwall, Big Creek, NWD	
Bore Hole No:	
Sample No: 4-A,B,C	
Depth: 40 FT	

Specimen	Cell Pressure kN/m^2	Deviator Stress kN/m^2	$\sigma_1 - \sigma_3$ kN/m^2	σ_3 kN/m^2	σ_1 kN/m^2
1	158.59	215.64	215.64	158.59	374.23
2	317.18	232.46	232.46	317.18	549.64
3	475.77	254.75	254.75	475.77	730.52



SUMMARY OF SOIL TEST RESULTS AND MAXIMUM BENCH HEIGHT (H_{max})

NORTH WEST DISTRICT

LOCATION & SAMPLE DEPTH	MOIST-URE CONT-ENT, W, %	LIQUID LIMIT W_L, %	PLASTC LIMIT, Wp, %	UNIT WEIGHT, Y, kN/m^3	PLASTIC-ITY INDEX I_p, %	TRIAXIAL Compres sion (C, Ø) kN/m^2 , Ø^o	H_{MAX} = 2C/Y,, m (ft)	F.S	SOIL DESCR -IPTION
Purpleheart 45ft, 55 ft, 75 ft.	29.4	42.9	37.2	18.2 (wet) 14.06 (dry)	5.7	55.03 2.92^o.	**6.05 m 19.8ft**	1.8	Pale yellow brown, purple grey inorganic silt.
Big Creek (40 ft)	34.2	34.3	26.6	19.6 (wet) 14.6 (dry)	7.7	92.5 3.33^o.	**9.4 m 30.8ft**	1.52	Pale yellow brown and olive grey inorganic silt.
World Bank, Arakaka (8 ft)	37.2	55.9	44.0	13.88	11.9	31.71 9.44^o.	**4.6 m 15 ft**	1.65	Red and dark brown inorganic silt.

SUMMARY OF SOIL TEST RESULTS AND MAXIMUM BENCH HEIGHT (H_{max}), MAHDIA

LOCATION & SAMPLE DEPTH	MOIST-URE CONT-ENT, W, %	LIQUID LIMIT W_L, %	PLASTC LIMIT, Wp, %	UNIT WEIGHT, Y, kN/m^3	PLASTIC-ITY INDEX I_p, %	TRIAXIAL Compression (C, Ø) kN/m^2, Ø^o	H_{MAX} = 2C/ Y, M;, (FT)	F.S (approx)	SOIL DESCRIPTION
St. Elizabeth (55 ft)	19.9	21.2	17.3	20.1 (wet) 16.76 (dry)	3.9	67.99 4.84^o.	**8.1m (26.6ft)**	2.26	Light grey mottled with pale yellow/reddish/and brown clayey silt.
White Hole (25 ft)	26.6	33.7	24.0	19.17 (wet) 15.17 (dry)	9.7	70 10^o.	**7.3 m (24 ft)**	1.86	Light grey mottled with pale yellow, red and brown clayey silt. H= 7.3m (24 feet). Retrofitted.
Red and White Hole (20 ft)	20.6	31.7	21.1	20.7 (wet) 17.24 (dry)	10.6	96 8.5^o.	**9.2 m (30.3ft)**	1.5	Light grey mottled with reddish brown and pale yellow silty clay. H= 9.2 metres (30 feet). Retrofitted.

SUMMARY OF SOIL TEST RESULTS AND MAXIMUM BENCH HEIGHT (Hmax) – CUYUNI & BERBICE.

LOCATION & SAMPLE DEPTH	MOIST-URE CONT-ENT, W, %	LIQUID LIMIT W_L, %	PLASTC LIMIT, Wp, %	UNIT WEIGHT, Y, kN/m³	PLASTIC-ITY INDEX I_p, %	TRIAXIAL Compression (C, Ø), kN/m², Øº	H_{MAX} = 2C/Y, m (ft)	F.S	SOIL DESCRIPTION
Aranka Backdam Cuyuni (25ft)	34.2	44.9	35.0	18.53(wet) 13.77(dry)	9.9	64.16 Ø =3.78º.	**6.92m (22.7ft)**	1.53	Reddish brown and pale yellow clayey silt.
Aroaima, Panel 40, B/ce (30 ft)	32	27.8	22.1	20.47(wet) 15.5(dry)	5.7	64.07 Ø = 0º	**6.26m (20.5ft)**	1.3	Bottom layer. Soft grey inorganic silty clay to clayey silt.

RESULTS

- THE MAXIMUM BENCH HEIGHT IN CLAYEY MATERIAL IS SITE (AREA) SPECIFIC AND DEPENDS ON THE GEOLOGY, STRUCTURE, HYDROLOGY AND HISTORY OF THE SITE.
- THE PLANAR FAILURE ANALYSIS (SIMPLE WEDGE ANALYSIS) PROVIDES A RAPID ASSESSMENT TOOL FOR THE DETERMINATION OF THE MAXIMUM BENCH HEIGHT IN CLAYEY SLOPES.
- WEDGE ANALYSIS IN CLAY SOILS IS GENERALLY CONSIDERED TO YIELD REASONABLE RESULTS IN SLOPES THAT ARE VERTICAL OR NEARLY SO AND IS COMMONLY USED IN BRAZIL TO ANALYSE FORCES TO BE RESISTED BY ANCHORED CURTAIN WALLS.

RESULTS

- THE MAXIMUM BENCH HEIGHT FOR CLAY SOILS TESTED SO FAR WAS 9.4 METRES (31 FEET). FOR IMPROVED SAFETY, ESPECIALLY IN HYDRAULICKING OPERATIONS, BENCHING SHOULD ALWAYS BE PRACTICED IN DEPOSITS (OVERLAIN BY CLAYS AND SAPROLITES) DEEPER THAN 31 Feet.

- THE (WORKING) MAXIMUM BENCH HEIGHT SHOULD ALSO TAKE INTO CONSIDERATION ANY HISTORY OF BENCH/SLOPE FAILURE IN AND AROUND THE MINESITE.


2015.05.19 11:06


2015.05.19 11:07

Dangerous overhanging material in a pit wall


2015.08.17 17:11


2015.08.18 16:35


2015.08.18 16:34

GUIDELINES TO CURB PIT WALL FAILURE

- Pit wall greater than 31 feet requires benching. However bench height should be lower depending on the soil type and environmental conditions (water-laden soil will require a lower bench height and less steepness).
- High pit walls must have benches and where possible ‘chopped down’ with backhoes.
- No undercutting of high working face. This can cause accidental death by slumped material covering pit workers.

GUIDELINES TO CURB PIT WALL FAILURE

- "Jetman" and other pit workers must be standing at a distance of at least 1 ½ times the height of the mine face.
- Loose rock or soil on mine face or pit wall must be removed or scaled, working from the top of the face/wall downwards.
- Bench height greater than 31 feet requires benching. Slope will depend on soil type, environment and work done at site.
- Keep trees, piles of loose overburden and equipment away from the edge of the mine pit as these exert a surcharge on ground.

CONCLUSION

- Pit wall failures are the major causes of fatal mining accidents in Small and Medium Scale mining operations. The height of the pit wall/bench face is one major factor that affect the stability of slopes.
- Adequate benching and sloping of pit walls are required to minimise pit wall failures and thus prevent accidents and deaths.
- Rain, cracks, ponding of water, vibration and pressure from heavy duty equipment can make soil unstable and increase the risk of pit wall failure.
- Signs of danger in pit walls are cracks, bulges or clumps of soils that fall from the pit face.