ANGLO-CHINESE JUNIOR COLLEGE
JC 2 Preliminary Examinations 2016

GEOGRAPHY 9730/01
Higher 2

Paper 1 Physical Geography

Time: 3 hours **19 August 2016 (Friday)**

READ THESE INSTRUCTIONS FIRST

Write your Centre number, index number and name on all the work you hand in.
Write in dark blue or black pen.
You may use a soft pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, highlighters, glue or correction fluid.

Section A
Answer **all** questions.

Section B
Answer **two** questions, each from a different topic.

Insert 1 contains all the Figures and Table referred to in the question paper.
Diagrams and sketch maps should be drawn whenever they serve to illustrate an answer.
The world outline map may be annotated and handed in with relevant answers.
You are reminded of the need for good English and clear presentation in your answers.
The number of the marks is given in brackets [ ] at the end of each question or part question.
Bundle your answers for Section A and those for Section B separately – i.e. you should have two bundles – one for Section A and one for Section B.

On the **cover sheet** provided, include:
- Your name and index no.
- The question numbers of the question you have attempted in the boxes provided, and place the cover sheet as the top page over your answers to Section A.

This document consists of 5 printed pages, including this cover page.
Insert consists of 10 printed pages.

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[Turn Over

Section A

Answer **all** the questions in this section.

Question 1, 2 and 3 carry 12 marks and Question 4 carries 14 marks.
You should allocate your time accordingly.

Lithospheric Processes, Hazards and Management

1. Fig. 1A shows a cross section through the plate boundary where the North American and Caribbean plates meet. Figs. 1B and 1C show information about the volcanic eruption of the Soufriere Hills on the Caribbean volcanic island arc of Montserrat (a LDC).

   (a) Describe and explain the major tectonic processes operating in the development of the volcanic island arc of Montserrat in Fig. 1A. **[5]**

   - The volcanic island arc of Montserrat is located along the destructive plate boundaries – where the heavier oceanic North American plate subducts under the lighter Caribbean plate.
   - As the North American plate is being subducted, a trench is formed first at the interface with the adjoining slab as the descending plate plunges under the overriding plate, the edges of the two plates will come under tremendous amount of stress and pressure.
   - The compressional forces at convergent subduction plate boundaries cause the sediment of the accretionary wedge to be intensely folded and faulted.
   - Frictional drag induced by the subduction, together with heat from conduction from the hotter lithosphere at depth, creates conditions of lower temperatures and high pressures, and alters or metamorphoses the local rocks, including that of the oceanic crust and the sediments of the accretionary wedge. This type of metamorphism is termed as blueschist metamorphism.
   - The subducting basaltic ocean crust contains hydrous minerals like amphiboles, some of which are formed by hydrothermal alteration as seawater seeped through hot, fractured, young ocean crust at the mid-ocean ridge – seafloor metamorphism.
   - As the oceanic plate sinks deeper into the mantle the pressure and temperature increase, and at 100 -200 km below the surface, metamorphic dewatering process (dehydration) liberates water from the descending crust.
   - The hot fluids gradually seep upward into the overlying wedge of hot mantle. The addition of water to the already hot mantle rocks lowers their melting temperature resulting in partial melting of ultramafic mantle rocks to yield mafic (basic) magma.
   - The result is a magma which is a hybrid of the different sources of

material derived from oceanic sediments, oceanic crust, and upper mantle.

- The newly-formed magma created in this manner is less dense than the surrounding mantle rocks and will slowly rise. Through the rise, the magma undergoes further alteration as it reacts with the overlying crust alongside with fractional crystallization.
- Ferromagnesium minerals which have higher melting points will crystallise (solidify) at earlier and at greater depths, and the rest of the molten magma which ascends will progressively have lower ferromagnesium content, and comparatively, higher silica content, making it more acidic (felsic) than basic (mafic) in its mineral constituent. The higher the silica content, the more viscous the lava, and the more explosive the eruption will be – andesitic magma is formed.
- the rising magma (which is usually andesitic in composition) will be emplaced in the overriding oceanic crust (mafic in mineral composition) where it will cool and crystallize and when they go above the water surface, volcanic island arcs like Montserrat will be formed. Volcanoes of the volcanic island arc tend to be made up of andesitic rocks
- Forms strato-volcanoes or composite cones/volcanoes

(b) Using evidence from Figs. 1A, 1B and 1C, explain the nature of **three** volcanic hazards associated with the eruption of the Soufriere Hills. **[3]**

- **Fig. 1A:** *Pyroclastic flows* – dense mixtures of fluidized hot rock fragments, lava particles and ash buoyed up by hot gases, containing as much as 80% of unconsolidated material. The flow is fluidized because it contains water and gas from the eruption. Very high temperature.
- **Fig. 1B:** *Lava flows* – streams of molten rock that pour or ooze from an erupting vent. In this case, the lava flows are more likely to be viscous andesitic lava.
- **Fig. 1C:** *Lahar* (due to the presence of rivers shown in Fig. 1C) – a hot or cold mixture of water and rock fragments flowing down the slopes of a volcano and/or river valleys. When moving, a lahar looks like a mass of wet concrete that carries rock debris ranging in size from clay to boulders more than 10 m in diameter. Also known as volcanic mudflow. May develop when the pyroclastic materials fall into and mix with the rivers.

(c) Using evidence from Figs. 1B and 1C, explain why people living on Montserrat found it hard to manage the effects of this volcanic eruption. **[4]**

Fig. 1B:

- "This was the first recorded eruption of this volcano." – not expecting and hence may not have been predicted.
- May not be prepared as they have no previous experience of managing the effects of volcanic eruption
- "On July 18th 1995, Soufriere Hills, a volcano on the Caribbean island of Montserrat began erupting. The volcano was still hissing and rumbling in October 1997." – the volcano continued to erupt for over two years.
- Destruction of over 80% of the buildings and the capital city, Plymouth affected – most important buildings might have been affected.

Fig. 1C:

- Agriculture land might be affected – affecting the growth and production of cotton and fruits – affecting availability of food and business
- A small island pf 102 square km so a large proportion was affected
- Difficulty in receiving aid

Atmospheric Processes, Hazards and Management

2. Fig. 2A shows the locations of three cities in Africa while Fig. 2B shows the climographs of these cities.
Fig. 2C shows the global impact of El Niño 1997-98.

(a) Describe and account for the climatic characteristics shown in the climographs of three cities in Fig. 2B. **[6]**

Gao:

- Lowest total annual precipitation of 200 mm among three cities with wetter period from May to October. August is the wettest month with 70 mm of precipitation with 5 days of precipitation. Drier period at the end of the year and beginning of the year.
- The overhead sun and ITCZ reaches this latitude in July (summer for the northern hemisphere) leading to intense heating and rising air, low pressure, drawing in air from the sea. As the air rises, adiabatic cooling, condensation, cloud formation and rain forms, thus the wet season for the station.
- The ITCZ moves to the southern hemisphere in January and its place is taken over by the sinking limb of the Hadley cell leading to anticyclonic conditions of aridity (adiabatic warming as the air sinks,

leading to lack of condensation an accounting for the dry seasons for the 6 months of the year.

Bobo-Dioulasso:

- Total annual precipitation is 1000mm with a clear seasonality of precipitation – highest precipitation in the months of July, August and September with the September having the highest number of days with precipitation of 16 days. Drier period in December and January with 0 day with precipitation.
- The dry season in December and January is explained by the fact that during this period, the station is north of the ITCZ and the station under the influence of the dry Harmattan winds. The precipitation starts in February as the ITCZ moves northwards with the migration of the overhead sun in the northern hemisphere. the ITCZ draws in moist south west monsoon which are onshore, bringing in rain to the station in the middle of the year.

Abidjan:

- Highest total annual precipitation of 1700mm. Precipitation for every month of at least 50 mm throughout the year. Higher precipitation in May, June and July as well as in October and November. Highest precipitation in June with 400 mm and 18 days with precipitation.
- The station is near the coast and under the influence of the onshore southwest monsoon winds for most of the year. In fact the station is located south of the ITCZ all year around and receives precipitation from the onshore monsoon as the wind comes inland towards the low pressure of the ITCZ.
- Seasonal migration of pressure belts due to variations in temperature highlighting the ITCZ or monsoonal trough – causing monsoonal rain in the middle of the year where southern hemisphere is having winter (high pressure) – Southwest Monsoon brings in rain in the middle of the year. In winter, the ITCZ moves southwards but it still ends up near the city and hence the onshore winds bring rain to the city.

(b) Describe and account for the impacts of El Niño on the regions labelled 1 and 2 in Fig. 2C. **[6]**

- When the ENSO conditions set in, ocean-surface temperatures, ocean currents, and wind patterns alter, it leads to changes to the location of where convection and precipitation will occur.
- Under El Nino Conditions, as the Equatorial current is weakened by the weak Trades winds, warm waters that under normal conditions are confined to the western Pacific Ocean, now extends eastwards across the Pacific Ocean resulting comparatively warmer waters off Region 1 (Peru) and cooler waters near Region 2 (Papua New

Guinea).

- o In terms of temperature, there is warmer-than-normal on the west coast of continents and cooler-than-normal on the east coast of continents. From the perspective of the ocean basin, there is cold water on the western edge of the ocean basin and warmer on the eastern edge – e.g. warm waters over at the Peruvian / Western edge of the South American coast and colder-than-normal waters over Papua New Guinea.
- o In terms of atmospheric pressure, consequently, Papua New Guinea will be under the influence of sinking air (high pressure) of the reversed Walker circulation.
- o Since the air is sinking and warming adiabatically, there will be no condensation or convection, and thus will not produce precipitation.
- o El Nino results in drier weather for Papua New Guinea, Australia and South-east Asia. If this continues, drought conditions will prevail in Papua New Guinea, Australia and South-east Asia.
- o On the eastern side of the Pacific Oceans, abnormal warming of ocean waters due to El Nino will results in warmer conditions in Region 1 (Peru).

Hydrologic Processes, Hazards and Management

3. Figs. 3A and 3B show the hydrological responses to rainfall in arid areas.

(a) With reference to Figs. 3A and 3B, explain how climate and geology affect stores and flows within the hydrological system in arid areas. **[5]**

- o The intense precipitation is the main input in this region – high rainfall intensity
- o Interception is minimum or (fails) due to absence of vegetation and higher rainfall intensity
- o High rates of evaporation after the rain event due to high temperature
- o Bare ground - lack of vegetation on the ground – raindrop impacts leading to inwashing of fines and compaction of ground – resulting in lower infiltration and higher overland flow
- o Rapid overland flow gives a short lag time and a high peak discharge leading to flashy hydrographs as seen in Fig. 3B which has steep rising and recession limbs
- o Due to higher overland flow, there is impact on sub-surface flows and storages – a lower water table and little base flow – hence streams rapidly run dry

(b) Describe and explain the possible channel pattern that rivers in such arid areas would be associated with. **[3]**

- Braided channels have multiple channels known as anabraches and are characterised by mid-channel bars.
- In arid areas, rainfall is intense and of a short duration, leading to the generation of HOF.
- This condition can result in the fluctuation of discharge in the channel.
- During the rain and right after the rain, with higher discharge and higher velocity, erosion takes place and eroded materials are transported along the channel.
- After some time, the river will have lower discharge and lower velocity, leading to incompetence and incapacity, resulting in deposition of materials, eventually forming braided channel patterns with mid-channel bars in the channels.

(c) Describe the methods you would use to measure variations in infiltration. **[4]**

Task: To find out the variations in infiltration rates

- As the area shown shows variation in terms of vegetation density and differences in slope height and gradient, an investigation into the variations in infiltration would consider the factor of vegetation density and slope height.
- **The hypothesis can be as follows:** The higher the density of vegetation and the greater the slope height the higher the infiltration rate. In order to obtain representative samples of data, the choice of sample site should include sites with differing vegetation density, and at different slope heights as shown in the map in Fig 1.
- **Sampling method:** As such a stratified random sampling method would be used. When sites 1 and 3, or 2 and 4 are compared, these would show the influence of slope height on infiltration rates, while if sites 1 and 2 or 3 and 4 are compared, it shows the influence of vegetation density on infiltration rates.

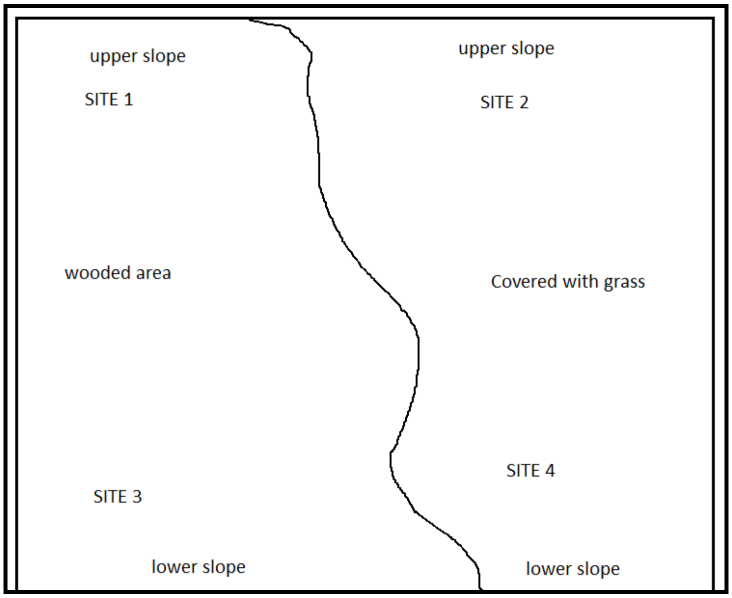


Fig. 1

- In order to obtain the data for infiltration rates, an infiltrometer which can be a metal or plastic pipe tubing can be used. The tubing is driven about 5cm into the ground with the aid of a wooden block and mallet. The top part of the tube should be parallel with the ground. A 30 cm metre ruler is affixed to the inside part of the tube. Water is poured into the tubing to the brim, and allowed to it lower to the pre-determined top marking (could be 10 cm above the ground as shown in Fig. 2).

Fig. 2: Set-up for the infiltrometer and the 2 levels of water for infiltration experiment

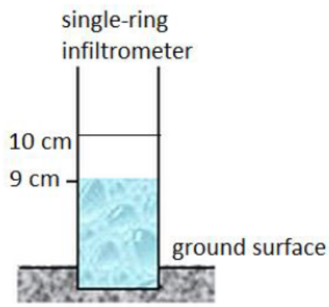


Fig. 3: Recording sheet for infiltration rates

Site Location		Vegetation type	Slope height	Date
……………………………….		……………………..	………………..	……………….
Time difference (min)	Cumulative time (min)	Depth of water infiltrated	Infiltration rate (cm / min)	Infiltration rate (cm/hr)
		1 cm		
		1 cm		
		1 cm		

- Start the stopwatch, and wait for water to drop to the 9 cm marking, and note and record the time table for that level of water drop in the recording sheet shown in Fig. 3. The process of adding water to the 10 cm mark and recording the time taken for it to be lowered to the 9 cm mark will be repeated over approximately 45 minutes or up to the point where the take time is similar over 2 or 3 readings as that would indicate that steady state has been reached.

- After the appropriate calculations are done, infiltration rate in cm per hour is plotted against the time interval to show the variations in rates since the start of each experiment as shown in Fig. 4.

Lithospheric and Atmospheric Processes, Hazards and Management

4. Fig. 4A shows the earthquake intensity zones and tropical storm (typhoon) intensity zones of the Philippines – a multiple hazard zone.

Fig. 4B shows a mass movement on a slope after the Typhoon Parma hit the Philippines in 2009.

(a) Explain why the Philippines is vulnerable to tectonic hazards like earthquakes and atmospheric hazards like tropical storms. **[6]**

Note: Students need to explain ***why*** and ***how*** these hazards take place in the Philippines.

- The Philippines is a volcanic island arc and hence located along the destructive plate boundaries where a heavier oceanic plate subducts under a lighter oceanic plate.
- Bonus: In fact, the islands of the Philippines are located on a

converging zone where the Eurasian plate is subducting under the Philippines Sea Plate.

- Because of the subduction zone, many active faults exist under the Philippines islands.
- The compressional force causes crustal stresses and shallow, intermediate, and deep earthquakes occur in the narrow Benioff zone at the subduction zone.
- At the shallow depths (less than 100 km), the two rigid lithospheric plates are pushing against each other. Earthquakes result from compressive movements where the overriding plate moves upward and the subducting plate moves downward and pull-apart (tensional) fault movements which occur near the surface within the subducting plate as it is bent downward (causing normal faulting) and snaps in tensional failures, as the overriding plate is lifted up from below and thrust faulting as the descending lithosphere slides beneath the upper plate.
- At great depths, compression results when the mantle resists the downward motion of the descending plate, forming intermediate- and deep-focus earthquakes

- Tropical storms (hurricanes, typhoons willy willies, cyclones etc) occur most frequently in tropical or sub-tropical waters where temperatures are in excess of 27°C over wide areas. The Philippines is located in the tropical waters of the Philippines Sea and the South China Sea and hence there is a source of very warm and moist air: ocean with surface temperatures over 27°C with warm water to a depth of 70m.

- The tropical cyclones require input from the coriolis force to produce rotation so they are not found proximate to the equator. The Philippines is not at the equator and hence there is Coriolis force at where the islands are located – the Philippines is located between 4°-10°N. A large-enough coriolis force to initiate the necessary rotary motion and produce a circular pattern of winds. Hurricanes need vorticity (spin around a centre) to give the low pressure system initial rotation.
- The ITCZ is nearby the Philippines during the northern hemisphere summer in the middle of the year. Hence there is pre-existing disturbance – in this case is caused by the convergence of trade winds.
- In the northern hemisphere they are most frequent between June and November – during the summer. They tend to affect eastern coastal areas and are most devastating when they strike low lying heavily populated coasts and the islands like the Philippines. The location of the Philippines meets all these requirements and hence the Philippines is vulnerable to tropical cyclones.

(b) Explain how tropical cyclones develop intense rainfall and high wind speed. **[4]**

- A chain reaction that pulls hot, humid air from the surface of the ocean up to high altitude where the air becomes cold and water vapour condenses into thick clouds.
- This growing air mass becomes increasingly dense causing the atmospheric pressure to grow.
- The increasing pressure pushes the growing mass of clouds outward away from the centre to create the spiraling bands of clouds (towering cumulonimbus clouds) that hurricanes are known for.
- As the air mass spirals outward, its pressure decreases and the dense air plunges back towards the ocean surface where it started.
- It now picks up vapour again from the warm waters below and is sucked back into the centre of the depression to begin its journey anew.
- As the cycle continues, the surface pressure at the center drops lower and lower causing the circulation of the air to strengthen and the winds to grow increasingly stronger.
- There is high pressure gradient force created both horizontally and vertically and this causes the wind speed to go up.
- The coriolis force as well as atmospheric instability could also be one of the principal fuelling mechanisms producing high winds.
- Intense rainfall is produced due to the constantly high supply of warm ocean water (above 28°C and at about 60m deep) which evaporates to provide high humidity.
- The rising warm air with high humidity condenses producing latent heat which keeps the air unstable.
- Buoyant and rising cumulonimbus clouds of enormous vertical extent have the ability to produce intense rain.

(c) Using the concept of shear strength and shear stress, describe and explain how and why such a mass movement in Fig. 4B takes place on a slope. **[4]**

- The mass movement in Fig. 4B is landslide.
- As the coherent block moves downward and outward along the curved slide plane, it commonly rotates with formation of back-tilted slopes. Sometimes there is no such back-tilted slope.
- There are rotational movements along a curved slide plane, i.e., a curved surface of rupture which can be visible or inferred, characterized by sliding of land as a coherent large slump block.
- At mid-slope and at the toe: dominant mass movement is flow as there is loss of coherence
- Move only short distances; their arcuate movements tend to restore equilibrium soon because the driving mass decreases and the resisting

mass increases

- Landslides take place because of multiple reasons:
    - Geological:
        - Usually occur on less strong rocks. They are commonly associated with permeable caprock (e.g. sandstone) overlying an impermeable substratum (e.g. clay) – lower shear strength
        - When it rains, water is able to percolate through the porous or permeable rock but it cannot pass through the impermeable layer.
        - As a result, water is accumulated at the base of the impermeable rock layer – and lubricates the upper layer which will fail as slumping – increasing the shear stress with high pore water pressure – water also adds weight, increasing shear stress
    - Heavy rainfall: Landslides are often associated with the times of heavy rainfall derived from tropical storms and cyclones, suggesting that water plays an important role in destabilizing the slope. The role of water includes: increasing pore pressure, lubrication, and adding weight to the slope – both increasing shear stress and decreasing shear strength
    - Relief: Common on steep slopes or over-steepened slopes such as marine cliffs or actively retreating escarpments – increasing the shear stress
    - Earthquakes: Earthquakes can cause vibration (increasing shear stress) and trigger slope instability.

Section B

Answer **two** questions, each from a different topic. Each question carries 25 marks.

Lithospheric Processes, Hazards and Management

5 EITHER

(a) Explain the evidence that support the plate tectonic theory. **[9]**

1) Age and depth of oceanic sediments

- A succession of cruises that began in 1969, the American drilling ship Glomar Challenger collected evidence that there were no sediments older than about 200 million years on the sea floor, that the sediments on the sea floor were relatively thin, and that they became thinnest closer to the mid-oceanic ridges.
- In short, the age and depth of sediment increases with increasing distance from the mi-oceanic ridges.
- This clearly supports the convection mantle currents and sea floor spreading hypothesis.
- Upwelling of magma contributes to the formation of new crusts at the spreading centers while the two divergent flows causes sea floor spreading bringing away the older sediments form the spreading centers.

2) Dating of volcanic activities

- In the examination of Iceland, it is found that the most recent volcanic activity occurs in a band down the center of the island (central depression), and moving away to the east and west, the volcanoes become progressively older.
- Upwelling of magma contributes to the active volcanic activities along the central depression while the two divergent flows causes sea floor spreading bringing away the older lava and volcanoes form the spreading centers.

3) Paleomagnetism

- The earth has an impermanent magnetic field with reversal of polarity between normal polarity and reverse polarity.
- Certain rocks, such as basalt, are very rich in iron and become weakly magnetised with respect to the earth's magnetic field at the time they solidify. These rocks thus preserve a record of the magnetic field at the time of rock formation.
- When magma (molten rock containing minerals and gases) cools to form solid volcanic rock, the alignment of the magnetite grains is "locked in", recording the Earth's magnetic orientation or polarity

(normal or reversed) at the time of cooling.

- If earth's magnetic field reversed intermittently, new basalt forming at the crest of the oceanic ridge would be magnetised according to the polarity at the time it cooled.
- If the sea floor spreading hypothesis were correct, one would expect to find on either flank of the ridge alternating bands of rock with either normal or reversed polarities and this pattern will be symmetrical on both sides of the rift valley where the new crusts are formed.
- If the youngest rocks which are formed during the present polarity (lets say the normal polarity) are located near the mid-oceanic ridges, then the older rocks which are formed during the previous reverse polarity are found away from the ridges, proving the convection mantle current and sea floor spreading idea.

4) Geothermal heat distribution

- Geothermal heat distribution over most parts of the ocean floor is similar to that of the continents but over the mid-oceanic ridges, it is several times that of the average value.
- These irregularly high values reflect the emplacement of hot mantle-derived materials in the vicinity of the ridge crests – i.e. these high values are due to the heat produced by the injection of mantle materials. This evidence helps support the sea floor spreading hypothesis.

5) Negative gravity anomalies

- A gravity anomaly is the difference between the observed/measured value of gravity at any point on earth and the computed theoretical value.
- Negative gravity anomaly is said to occur when the observed value is lower than the theoretical one, while a positive gravity anomaly happens when the observed values exceeds that of the theoretical value.
- Gravity anomaly is <u>negative</u> at the oceanic trenches.
- How it supports the Plate Tectonic Theory:
    - Reasons for negative anomaly:
        - These very strong negative gravity anomalies can mean only that such locations are underlain by rocks of lower density than those at depth on either side.
        - Geo-physicists assume that the less dense rocks of the negative zone must be held down by some force to prevent them from floating upward to a level appropriate to their density.
        - The force might be provided by a descending convection current which is regarded as the force leading to subduction

(b) ‘It is easier to account for tropical karsts than temperate karsts.’ Discuss the validity of this statement. **[16]**

Some of the key criteria to consider in answering this question:
- Variety of landforms
- Complexity in explanation – processes
- Multiple theories and explanation

It is possible for argue that in terms of variety, tropical karsts are of fewer variety compared to the temperate karsts and hence it is easier to account for tropical karsts than temperate karsts. However, the processes accounting for the formation of tropical karsts are complex and there are a number of theories (or ways of formation) and hence we could also argue that in terms of complexity of processes and number of ways (theories) of formation, it may not be necessarily easier to account for tropical karsts than temperate karsts. For example, for tower karst, there is the evolution theory that attempts to explain how the cone karsts (formed either by the surface solution or underground solution theory) can evolve into tower karsts by vertical and lateral weathering and erosion as well as slope retreat by mass movement. There is also Sarawak formation which attempts to explain how tower karsts are formed with different geological setting such as
- The removal of less resistant beds which sandwich the limestone layer – less resistant rocks are weathered differentially and eroded first, leaving behind the more resistant and massive limestone as tower karst
- The removal of less competent limestone strata- differential solution – more jointed and hence more vulnerable limestone is weathered and eroded first while less jointed limestone is left behind as tower karst.

OR

(a) Using the concept of rock cycle, explain the formation of igneous, sedimentary and metamorphic rocks. **[9]**

- The rock cycle is a general model that describes how various geological processes create, modify, and influence rocks and that the main rock types are formed by a set of interlinking processes and products that occur at or near the Earth’s surface. Through these series of interlinked processes, one rock type can be converted into another rock type. In short, any rock types can be converted into any other rock types as long as the conditions are right and appropriate for their respective formation.

- **Igneous rocks** - form in two very different environments. All igneous rocks start out as melted rock, (magma) and then crystallize, or freeze. Volcanic processes form extrusive igneous rocks. Extrusive rocks cool quickly on or very near the surface of the earth. Fast cooling makes crystals very fine, and these become fine-textured igneous rock, and basalt would of an example of such an extrusive igneous rock. Andesite and rhyolite are other examples of extrusive igneous rocks. Rhyolite is the lightest coloured volcanic rock. Rhyolite often occur in the form of volcanic ash and other pyroclastic material. It is associated with violent volcanic eruption, and it would be the material of the volcanic ejecta and often would be the rock type of pyroclastic flows.

- Intrusive igneous rocks cool in plutons deep below the surface of the Earth. Slow cooling allows the growth of large crystals. Crystals in intrusive rocks are visible without magnification. Granite has the same minerals as rhyolite, but in much larger crystals. Diorite is the intrusive version of andesite, granodiorite is the intrusive version of dacite, and gabbro is the intrusive version of basalt.

- **Sedimentary rocks** – Once the igneous rock is at the surface, it is exposed to the surface agents of physical and chemical weathering, and would eventually be reduced to fine sediments and fragments. In fact, sedimentary rocks formation begins with igneous, metamorphic, or other sedimentary rocks. When these rocks are exposed at the earth's surface they begin the long slow but relentless process of becoming sedimentary rock. The following are the steps towards the formation of a clastic sedimentary rock.
- Weathering: All rocks are subject to weathering. Weathering is anything that breaks the rocks into smaller pieces or sediments. This can happen by the forces of like wind, rain, and freezing water.
- Erosion: The combination of weathering and movement of the resulting sediments is called erosion.
- Deposition: The sediments that form from these actions are often carried to other places by the wind, running water, and gravity. As these forces lose energy the sediments settle out of the air or water. As the settling takes place the rock fragments are graded by size. The larger heavier pieces settle out first. The smallest fragments travel farther and settle out last. This process of settling out is called deposition.
- Lithification is the changing of sediments into rock. There are two processes involved in this change. They are compaction and cementation.
- Compaction occurs after the sediments have been deposited. The weight of the sediments squeezes the particles together. As more and more sediments are deposited the weight on the sediments below increases. Waterborne sediments become so tightly squeezed together that most of the water is pushed out.
- Cementation happens as dissolved minerals become deposited in the spaces between the sediments. These minerals act as glue or cement to bind the sediments together.

- Through the above processes, sedimentary rocks are deposited in layers as strata, forming a structure called bedding. The surface separating each bedding layer is called the bedding planes. The process of sedimentary rock formation takes millions of years to complete only to begin a new cycle of rock formation.

- Examples of sedimentary rocks formed through the process of lithification include conglomerate, breccia, sandstone, mudstone, and limestone. The difference amongst all these different clastic sedimentary rocks lies in the degree of roundness and in the size of the sediments that form the rock.

- Once the sedimentary rock is formed, it can be conveyed to a convergent subduction plate boundary where it is either subducted and eventually converted to magma, and then finally emerged at the surface as a volcanic igneous rock, or it could be subjected to high pressure and heat to become a metamorphic rock. A sedimentary rock could also under the entire cycle of sedimentary rock formation to become another sedimentary rock without going to igneous or metamorphic rock formation.

- Metamorphic rocks – Metamorphic rocks form under intense heat and pressure. Metamorphic rocks start out as igneous rocks, sedimentary rocks or other types of metamorphic rocks, but through heat or pressure, change characteristics such as sheen, tightness of grain and hardness. Examples of metamorphic rocks include marble which is the metamorphic version of limestone or dolomite, while gneiss and schist often are metamorphic version of sandstone or some acidic igneous rocks.

- There are particular environments that lead to the formation of metamorphic rocks:

    - Contact Metamorphism occurs when magma comes in contact with an already existing body of rock. During the process, the existing rocks temperature rises and also becomes infiltrated with fluid from the magma. The area affected by the contact of magma is usually small, from 1 to 10 km. Contact metamorphism produces non-foliated (rocks without any cleavage) rocks such as marble, quartzite, and hornfels.
    - Regional Metamorphism occurs over a much larger area. Regional metamorphism is caused by large geologic processes such as mountain-building at convergent plate boundaries. Regional metamorphism usually produces foliated rocks such as gneiss and schist.
    - Dynamic Metamorphism: It is the result of physical forces, i.e., mechanical deformation during mountain building. It happens when there is intense folding and breaking of rocks which results in shearing and grinding. These huge forces of heat and pressure cause the rocks to be bent, folded, crushed, flattened, sheared, pulverized and minerals are strung out in streaks and bands

(b) The best way to manage the negative effects of the earthquakes is by mitigation and rapid response - but not by prediction.

To what extent do you agree with this statement? **[16]**

"Only fools and charlatans predict earthquake." – Charles Richter

Earthquake prediction may not be the most effective means of managing the impacts of the earthquake hazards. In the case of earthquakes, the physical factors such as predictability of the earthquakes (particularly the short term one as it is useful) as well as the magnitude of the earthquakes are beyond our control.

The difficulties with short-term prediction stem partly from the fact that the mechanisms and processes associated with earthquakes are hidden under the ground, where they are not amenable to study and monitoring.
But a more significant problem is that earthquakes are highly inconsistent in terms of their precursor phenomena. For example, after several notable successes in predicting earthquakes on the basis of foreshocks, radon anomalies, ground tilting, and anomalous animal behavior as in the case of 1975 Haicheng Earthquake, Chinese scientists suffered a major setback when the Tangshan quake of 1976 struck with no discernible warning signs. Hence any success in prediction seems to be an isolated case and the success cannot be replicated.

However, we are also certain that in the case of earthquakes, we know the places vulnerable to earthquakes and we could predict the possibility of earthquakes on a long term basis. In addition, we are also certain that buildings kill people during earthquakes. In light of these, mitigation, particularly the implementation of aseismic-design for buildings in the earthquake-prone areas could be one of the major means of managing the impacts of the earthquake hazards. Of course, this in turn is controlled by technology, expertise, finance and practicality (in the case of old development).

- The suggested approach is to use a number of case studies and discuss the effectiveness of the prediction, mitigation and responses based on case studies.

The following examples could be used:
- Paso Robles earthquake, California, 2003
- Kobe earthquake, 1995
- Bam earthquake, Iran 2003
- Haicheng earthquake, China 1975

Key ideas
- Prediction is difficult – hence the best way is to mitigate and respond
- To be effective, use a variety of hard engineering and "soft" engineering methods like land use planning and hazard zone mapping

- High level of community preparedness
- Quick and efficient search and rescue efforts during the “golden hours”

Atmospheric Processes, Hazards and Management

6 EITHER

(a) Account for the global variations of incoming solar radiation at ground level. **[9]**

- The data from Fig. 5 shows that different latitudes receive different amount of insolation at different month of the year.

Describing the spatial (across the latitudes such as 0°N, 30°N, 90°N) and temporal (Jan, Feb March or March Equinox, June Solstice) distribution of insolation on ground level

- 90°N: no insolation from October to March. Starts to receive insolation from March Equinox which peaks at June Solstice with the amount of 520 Wm^{-2}. After June Solstice, the insolation amount declines till zero at September Equinox.
- 0°N: consistently high amount of insolation hovering around 400 Wm^{-2} with two peaks during March Equinox and September Equinox with 440 Wm^{-2}. A slight dip is observed during the June Solstice with the insolation value of 390 Wm^{-2}.
- 30°N: lowest insolation between the December Solstice and March Equinox with the value of 230-240 Wm^{-2} peaking at 480 Wm^{-2}in June Solstice.
- 60°N: Similar pattern like 30°N but generally lower value of insolation temporally compared to 30°N. Insolation value during the December Solstice and March Equinox is less than 100 Wm^{-2} and it peaks at June Equinox with the value of 460 Wm^{-2}.

Explaining the spatial and temporal distribution

- Earth’s orbit around the sun and Earth’s rotation on its tilted axis
- Albedo
- Cloud cover
- Aspect

Key ideas:

1) Earth’s orbit around the sun and Earth’s rotation on its tilted axis

- The tilt of the Earth’s rotational axis, the Earth’s revolution around the sun causes:
  - the annual changes in the height of the Sun above the horizon
  - the seasons
- by controlling the intensity and duration of sunlight (insolation) received by locations on the Earth.
- The influence of Earth’s tilted rotational axis and its orbital revolution around sun in a year on insolation and temperature can be understood in terms of how these two fundamental phenomenon manifest their influence

- latitudinally
- on the apparent migration of the overhead sun
- length of day and night

Latitude:

- Latitude determines the annual distribution of insolation by controlling the angle at which the sun's rays strike the surface.
- The intensity of solar radiation is largely a function of the angle of incidence, the angle at which the Sun's rays strike the Earth's surface.
  - If the Sun is positioned directly overhead or 90° from the horizon, the incoming insolation strikes the surface of the Earth at right angles and is most intense – hence latitudes like 0°N and 30°N receive intense insolation
  - If the Sun is 45° above the horizon, the incoming insolation strikes the Earth's surface at an angle. This causes the rays to be spread out over a larger surface area reducing the intensity of the radiation.
- The angle at which the sun's rays strike the surface becomes more oblique polewards of the equator.
- As a result, assuming a cloud-free atmosphere, there is a general latitudinal decrease of insolation from equator to the poles at the earth's surface
- Now it is understandable why less insolation is received at high latitudes such as 90°N:
  - *The same amount of insolation is spread over a larger surface*
  - *The same solar beam undergoes more severe atmospheric dilution by reflection, scattering and absorption in passing through a thicker layer of air*

Migration of the overhead sun:

- When the sun is directly overhead, insolation is most intense, and thus peaks during that part of the year for that particular location.
- *The receipt of insolation varies throughout the year as the Earth revolves around the sun while rotating on its tilted axis leading to the apparent migration of the overhead sun*.
- The Tropics (23.5°N and 23.5°S) are the two latitudes where the sun is directly overhead at noon on the two solstices – during June 21 and December 22.
  - The sun is directly overhead at noon on the Tropic of Cancer on June 21 – June Solstice (the beginning of summer in the Northern Hemisphere and the beginning of winter in the Southern Hemisphere).
  - The sun is directly overhead at noon on the Tropic of Capricorn on December 22 (the beginning of winter in the Northern Hemisphere and the beginning of summer in the Southern Hemisphere).

- The sun is directly overhead at the Tropic of Cancer, 23.5°N on June 21 (northern hemisphere summer solstice), and as result, the highest insolation is received at that latitude, as well as the highest temperature should be located there. Away from this latitude, there is a progressive decrease in insolation, and at this time of the year, the South Pole is in complete **B** darkness (zero insolation) for 24 hours, while the North Pole shows high summer maximum.

- On December 22, the northern hemisphere will experience its winter solstice, and the overhead sun would have migrated to 23.5°S at the Tropic of Capricorn. The southern hemisphere would thus be experiencing its summer. The North Pole would be in complete darkness for 24 hours at this time of the year
- When the overhead sun is at the Equator, that period is termed as the Equinoxes, and the northern hemisphere experiences the spring equinox on March 21, and the autumn equinox on September 23, and vice versa for the southern hemisphere.
- Since the overhead sun passes over the Equator twice, this thus accounts for the two insolation maxima at March Equinox and September Equinox

Length of the day and night:

- *Due to the earth rotating on a tilted axis, and its orientation at different seasons of the year, each place on the earth's surface experiences different lengths of day and night through the year.*
- During the two equinoxes, the circle of illumination cuts through the North Pole and the South Pole and all locations on the Earth experience 12 hours of day and night.
- On the June solstice, the circle of illumination is tangent to the Arctic Circle (66.5° N) and the region above this latitude receives 24 hours of daylight.
- The Arctic Circle is in 24 hours of darkness during the December solstice.

2) Cloud Cover

- With the presence of the atmosphere with its gases, water vapour and clouds, the average annual distribution of solar energy shows the following pattern:
- There is a general decrease of energy inputs towards the poles, with local anomalies. Most of these are caused by clouds.
- Higher values of insolation are found over the Saharan, Australian and Asian deserts as these regions are practically cloud-les.
- Lower values of insolation occur in regions of high cloudiness such as Iceland, the Aleutian Islands in the north Pacific, the Congo Basin, part of West Africa, and over South-east Asia.

3) Albedo

- The amount of insolation absorbed by a surface is partly dependent on the albedo of the surface.
- Albedo is the degree of reflectivity of a surface.
- Thus albedo can affect the energy budget of a location and its temperature.
- Darker surfaces have a lower albedo and absorb more solar energy than do lighter surfaces. The albedo of a surface is also a function of the incidence angle of solar radiation (that is, the amount of solar energy a surface absorbs will depend on the solar altitude).
- Newly fallen snow has an albedo of approximately 0.90, meaning that it reflects about 90% of incoming radiation.

- In contrast, melting snow has an average albedo of 0.50, meaning that it absorbs 50% and reflects 50% of the incoming radiation.
- Because a darker surface absorbs more solar radiation, snow covered by dust (dirty snow) melts faster than clean snow. The albedo of sea ice varies with ice age.

4) Aspect

- Aspect refers to the direction which a slope is oriented in relation to the sun.
- A slope that faces the sun for most parts of a year (equatorward-facing) is termed as the sun-facing slope or ubac slope.
- The slope that faces away from the sun (pole-facing) is termed as the non sun-facing slope or adret slope.
- Slopes that face the sun receive more insolation than slopes that face away from the sun. For valleys in the northern hemisphere which is aligned east-west:
  - *North-facing: non sun-facing or adret slopes*
  - *South-facing: sun-facing or ubac slopes*
  - *North-facing slopes are cooler than South-facing slopes*
  - *The steeper the South-facing slope: the higher the angle of the sun's rays to it and therefore the higher the temperature.*
- At higher latitudes, the factor of aspect is particularly pronounced in winter when the sun remains relatively low in the sky.
  - For example in Hawaii, a 30° South-facing slope receives around 650 cal/sq. cm/ day, while a 30° North-facing slope receives only 175 cal/sq. cm/day.

(b) Describe the characteristics of ITCZ (Inter-Tropical Convergence Zone). Why is it important in understanding the global atmospheric circulation? **[16]**

- Description of the characteristics of the ITCZ should cover the key ideas like thermal equator, climatic characteristics of the ITCZ area (temperature, precipitation, wind), convergence of the two trade winds, location and migration of the ITCZ and explain this migration.
- The second part should include the brief explanation of the global atmospheric circulation and its components (three cells, surface wind belts and upper air wind)
- Specific explanation of the formation of the Hadley Cell, Ferrel Cell and Polar Cell and how these formations are linked to the ITCZ – paying specific attention to key processes operating at the rising limb, sinking limbs, surface wind belt and upper air of the respective cells
- Well-labelled diagrams would be very useful in the explanation of the components of the global atmospheric circulations
- Also explain the seasonal migration of the ITCZ and how this leads to the migration of the cells and respective wind belts.

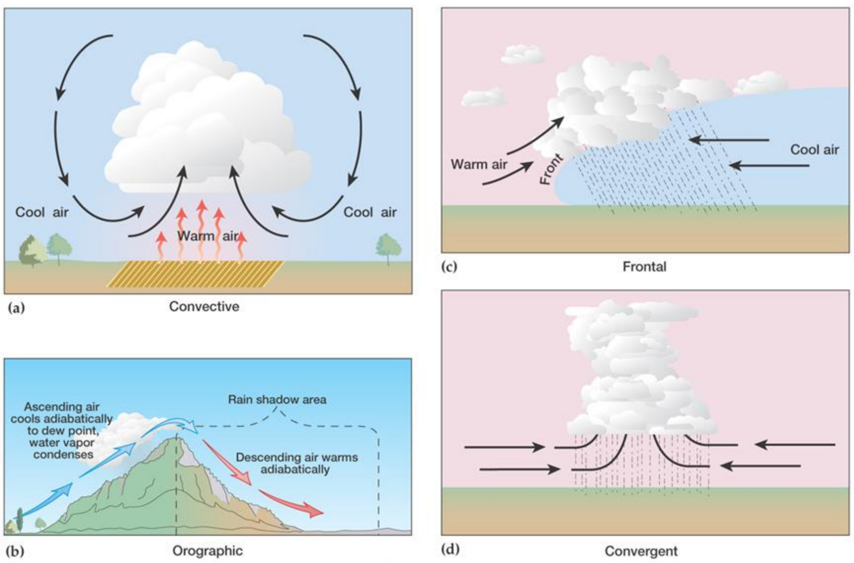
OR

(a) Discuss the various ways by which air is uplifted and explain the weather conditions associated with atmospheric stability and instability. **[9]**

Air can be uplifted by:

1. orographic barrier (orographic / relief rain)
2. convectional uplift (convectional rain)
3. convergent uplift
4. *frontal barrier (frontal / cyclonic rain)*

Brief explanation of these uplift mechanism with well-labelled sketches is required here.



Weather conditions associated with atmospheric stability and instability

Atmospheric Stability

- The atmosphere is said to be stable when air parcels sink or do not rise up to form clouds or will form low clouds.
- <u>Atmospheric stability</u> occurs *when rising air parcel is cooler than the surrounding air.*
- This is when the <u>ELR curve</u> in the graph (tephigram) is <u>to the right of the DALR and SALR curve</u> as in Fig. 6A.
- The DALR and SALR display steeper rates of change with height compared to the ELR.
- Weather conditions: clear sky with no or little clouds and no precipitation

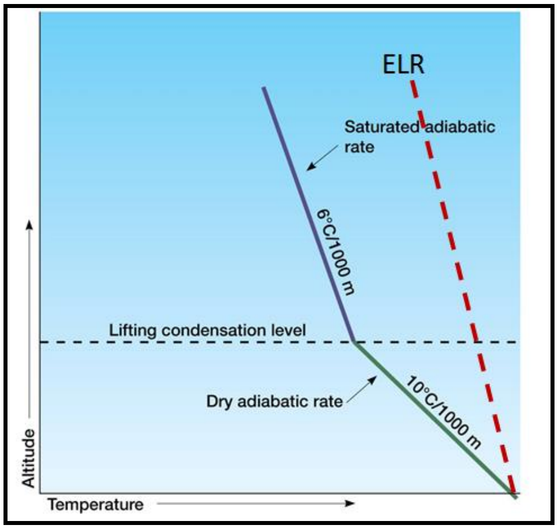


Fig. 6A: Atmospheric stability

Atmospheric Instability

- The atmosphere becomes unstable when the *ELR is greater than both the DALR and the SALR* (Fig. 6B where the ELR curve is to the left of the DALR and SALR curves).
- The environmental air temperature falls rapidly with height, so that any air parcel cooling at DALR is always warmer and less dense than the surrounding air. Its buoyancy will give it an upward thrust, so that convection is encouraged, and clouds could form.
- As the air parcel rise, it first cools adiabatically at the DALR. When temperature is lowered to reach the dewpoint temperature, condensation occurs, and clouds form. This elevation is indicated in Fig. 6B as the lifting condensation level. The air parcel will continue to ascend, but now cool at the SALR.
- Weather conditions: cloudy and rainy

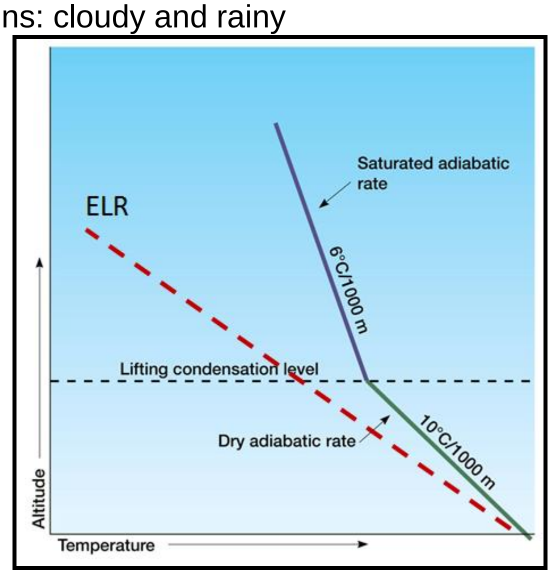


Fig. 6B: Atmospheric instability

(b) Developed Countries (DCs) are better able to manage the negative effects of tropical cyclones compared to Less Developed Countries (LDCs).

To what extent do you agree with this statement?

[16]

- In wealthier societies and DCs, the impact in the sense of loss of life may be low (due to evacuations, education etc), but structural damage may be extremely costly.
- Conversely, in poorer regions and LDCs loss of life from a similar scale event maybe high in comparison, seriously impacting a society. But the financial damage will be a lot less – low value of houses and property - although this does not take into account the worth of the property to a person – which is obviously higher in poorer regions – no insurance and taken generations to achieve.
- The impacts of hurricane events in poorer societies will also mean long term impacts as the people would have lost so much more which cannot easily be replaced.

Reasons for differences in impacts:
High level of economic development means:
- Better monitoring, timely warning system, and more systematic evacuation of population
- Higher level of community preparedness, shelters preparation, food and water readiness
- Higher quality of buildings and homes - better chances of withstanding high winds and floodwaters Better healthcare system, and emergency or disaster rescue preparedness
- Could have greater impact on economic losses due to higher level of economic acitivities that are destroyed or disrupted.

At times, it may not be the level of economic development that determines the impact, it could be the following:
- Magnitude of event: wind speed, storm surge, extent of flooding
- Human factor: failure of some hazard mitigation measures, eg. failure of the leeves and the flooding of New Orleans during Hurricane Katrina, 2005
- Cooperation of people and the density of population:

It may not always be possible to issue such a warning in time for adequate evacuation of these areas. Because the storm surge and even gale force winds can reach an area many hours before the centre of the storm warnings must be issued long enough before the storm strikes that the surge and winds do not hinder the evacuation process.

The effectiveness of the warning systems also depends on the populace to heed the warning and evacuate the area rather than ride out the storm, and the state of preparedness of local government agencies in terms of evacuation and disaster planning.

New Orleans is a particularly notable example. Since most of the city is at or below sea level, a storm surge of 6 meter from a category 4 or 5 hurricane would most certainly flood the city and choke all evacuation routes.

Even with 24 hours' notice of the approaching surge (which would mean as soon as the storm entered the Gulf of Mexico) it would be difficult to evacuate or convince people to evacuate within that 24 hour period. When some population started to evacuate New Orleans with a population of 1 million before Hurricane Katrina hit, many were put off by the massive traffic jams out of city, and in fact, turned back. The large no. of people who stayed on in New Orleans added to the failure of reduction of negative impacts. Shows that even for locations with high level of economic development, successful mitigation is not always possible.

	Cyclone Nargis	**Hurricane Katrina**
Date	May 2nd 2008	August 29th 2005
Wind speeds	215km per hour – category 4	285 km per hour – Category 5
Size of storm surge	At least 4 metres	8.5 metres
Relief of the coastline affected	Low lying Irrawaddy delta, an area of islands and rivers	Low lying Mississippi delta
Number of deaths	At least 138,000 people, this official death toll from the Burmese government is rumoured to be too low	1836 deaths
Number of homeless	3.2 million people	60,000
Economic cost	$10billion	Over $100 Billion
Responses	Despite India tracking the cyclone it hammered the Burmese coast with little notice given to the Burmese people, who have low levels of technology and low literacy rates.	The hurricane was spotted and tracked by the National Hurricane centre. Mass evacuation orders were made, 1,000 people were bussed out of New Orleans an hour. The response after the storm was criticised for being slow, numbers but the US army did arrive to help.
Aid received	Burma refused initial aid attempts from foreign countries for 2 days, and only then allowed in people with visas. Eventually, India, Italy, Bangladesh,Malaysia, The UK and USA committed troops, food aid and cash to the country.	Internal aid from FEMA, a branch of the US government was $85 billion. The US corps. of engineers set about draining New Orleans immediately

Hydrologic Processes, Hazards and Management

7 EITHER

(a) Discuss the physical and human causes of river flooding. **[9]**

Students need to discuss the following flood-causing factors with reference to specific case studies:
- Climatic factors – high intensity, long duration and high frequency rainfall, snow melt, La Nina, tropical cyclones
- Human factors – dam failure, levee failure

In addition, the following flood-intensifying factors can be discussed:
- Geologic factors – impermeable ground, steepness of the slopes

- Vegetation – bare ground vs vegetated land
- Human factors – urbanisation

(b) With reference to specific examples, assess the extent to which flood magnitude and frequency determine the effects of river flooding. **[16]**

Using the following case studies, students are to argue that flood magnitude (linked to recurrence interval) and flood frequency indeed determines the effects as higher the flood magnitude and flood frequency, the greater will be impacts. However, the role of other factors – particularly the human factors such as presence of prediction/mitigation/responses in DCs which have a higher level of economic development – must be discussed as they help reduce/minimise the effects of the river flooding.

- 1974, 1988 Bangladesh floods
- 2010 Singapore floods
- The Great Floods of 1993, Mississippi, USA
- 2005 levee failures in Greater New Orleans

Key Ideas:

- Level of economic development – wealth of the nations – leading to effective prediction, mitigation and management due to presence of technology, expertise and finance
- Level of economic development vs natural factors (flood magnitude, flood frequency)

OR

(a) Explain how local variations in river velocity result in different fluvial features/landforms in a meandering channel. **[9]**

Students are to explain how local variations in river velocity leads to formation of river cliffs and point bars in the presence of helicoidal flow in the meandering channels.

The students are also required to discuss the formation of riffles and pools as some kind of self-adjusting mechanism to balance energy expenditure along a stream as velocity varies.

(b) Conflicts of interest arising from the management of the trans-border rivers are largely affected by politics.

To what extent do you agree with this statement? **[16]**

It could be argued that most conflicts of interest arising from the management of the trans-border rivers are largely due to economic reasons as the riparian states are vying for the shared water resources of the trans-border rivers as seen in the case of Mekong River Basin and the Colorado River. The need for economic development, industrialisation and urbanization forms the main reason for the existence of the conflicts of interest. Of course the role of politics in these case studies is important in determining the nature of conflict (overt or covert) as well as how these conflicts are resolved successfully. The classic example of how the politics is largely affecting the conflict of interest is the case of Jordan River in which the conflicts of interest between Jordan and Israel is rooted in the way the two countries view water which is largely affected by the politics of clash of the civilisations.

- The proposed structure for each case study: Briefly describe what was done to the river basin and what management actions are taken. Then describe what could be the possible conflicts of interests between riparian states – conflicts of interest over shared water resources, damming, water quantity and quality. Comment on the nature of the conflict of interest – political, economic or environmental.
    - Use Colorado River and Mekong River to show how the economics and politics affect the conflicts of interest
    - Use Jordan River case study to illustrate the unique nature of the case where the politics take the center stage