F. Kuhn 14 January 2020

Environment of a Railway project in Saudia Arabia Republic

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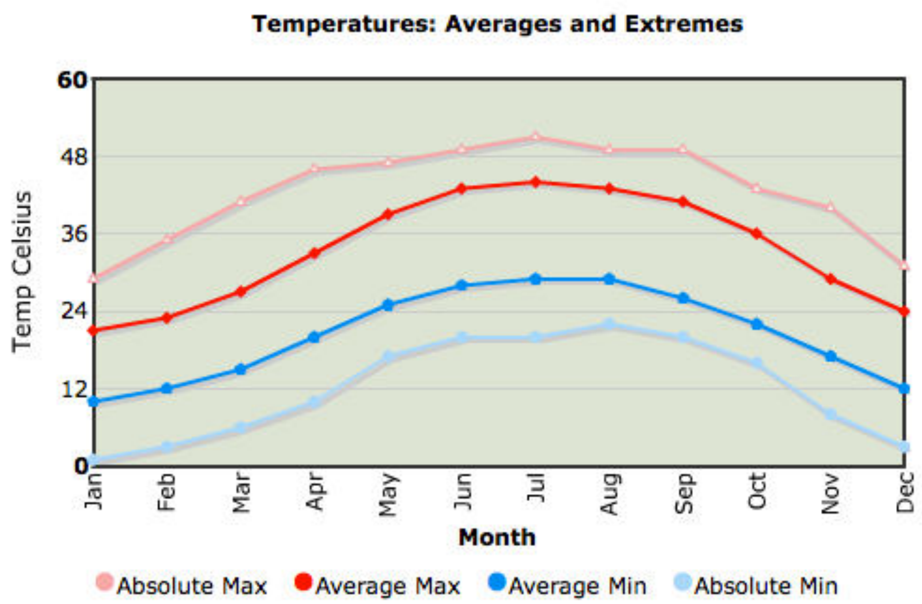
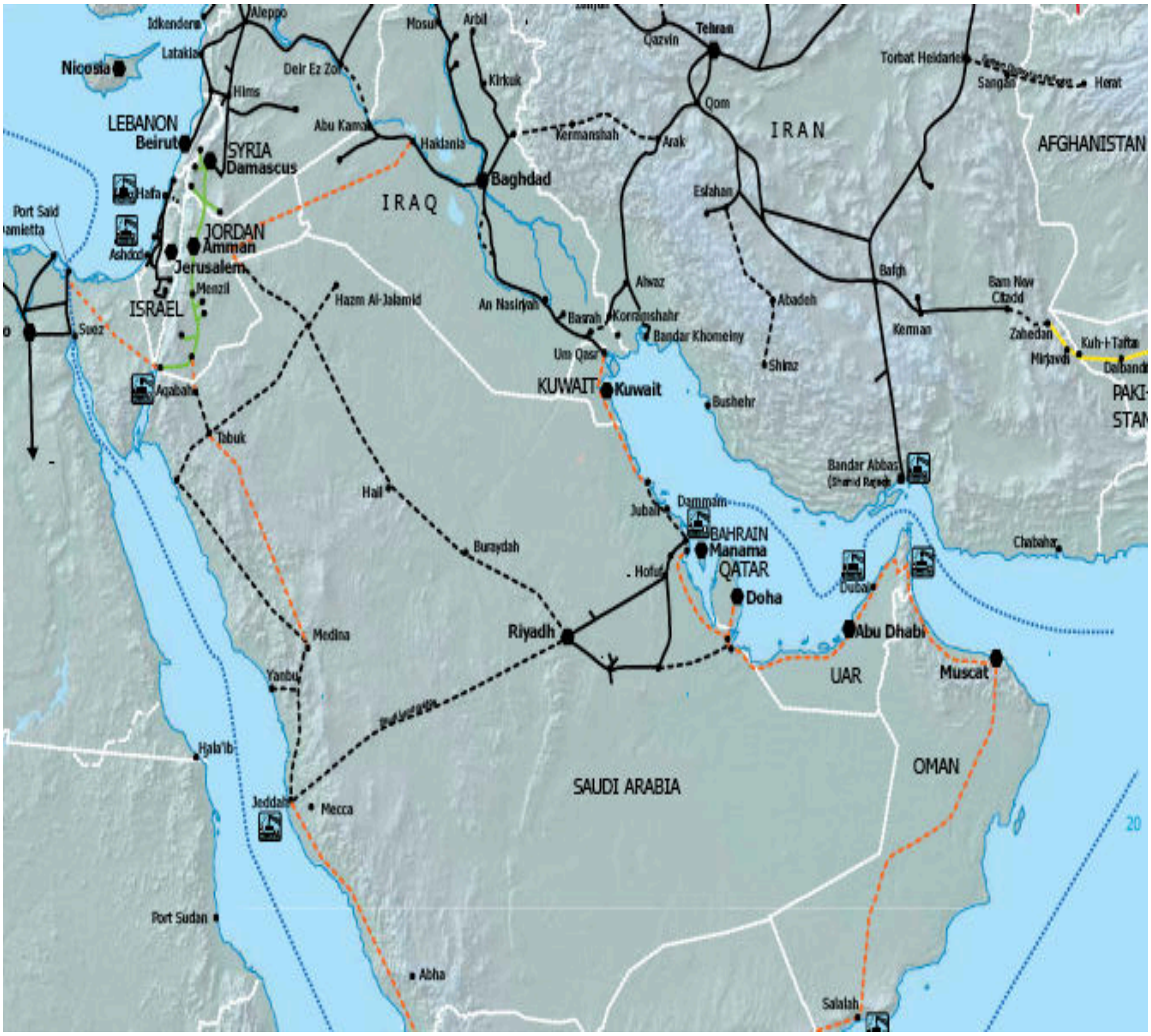
1. Natural environment

Saudi Arabia is one of the world's hottest and driest places, climate can be characterized as a desert's climate, the coastal regions show a marked change of climate from that found in the rest of the country. Nevertheless there is a cool and rainy short period in winter. Winter is warm in most of the country, with high temperatures around 20°C, and cool in the mountains, where the temperatures may fall below freezing at night. Polar air masses that occasionally blow south from Russia can bring some truly cold weather: also between the night and the day temperatures, we record wide fluctuations so we can find differences until 45°C. Temperature can be cooler in some areas like near the sea.

Summer is very hot throughout the country and lasts from May to November. There is generally no rain. In most of the country the highs are around 40°C. Some places are extremely hot, with temperatures often rising above 50°C.



Source : http://www.myweather2.com/City-Town/Saudi-Arabia/Dammam/climate-profile.aspx?month=10



Source: http://www.nationsonline.org/oneworld/map/google_map_saudi_arabia.htm

Summary

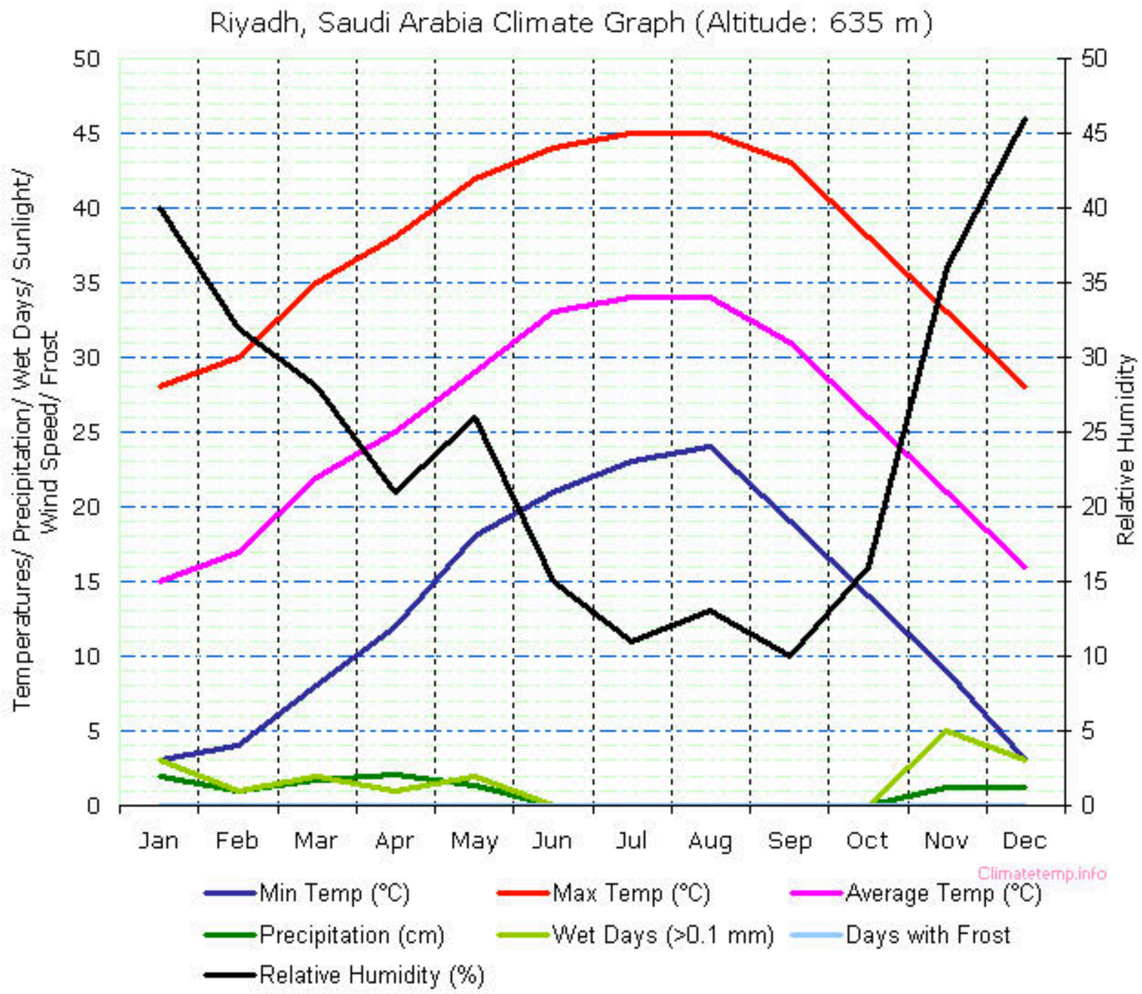
These high temperatures oblige the builders to take care of the quality of trackside equipments installed along the track and in the technical rooms and also in the rolling stocks and the workshops. Expansion joints should take into account these differences in temperature and be installed in the track according to the standards. During the construction of bridges and hydraulic structures, concrete pouring will be implemented early in the morning and protected from too rapid drying to avoid premature shrinkage cracks.

Precipitations

It rains so rarely in Saudi Arabia that cities lack infrastructure to deal with heavy rain. The rain sewers and drainage canals are lacking to deal with a torrent.

Rain is generally scarce, and most of it, originates in the Mediterranean region. In the desert regions rainfall can vary greatly from month to month and year to year. Some places go years without seeing any rain. Rain, when it does come, arrives in the form of deluge in fierce, short-lived storms. Riyadh, and the barren deserts in the south and east get between nothing and 13 cm of rain a year. Rain is mostly likely to fall in February, March and April in Riyadh; and December, January, February and March in eastern Saudi Arabia. The highest rainfall amounts occur on the western slopes of the coastal mountains. Some places here have average annual rainfalls is above 50 cm a year.

The coastal areas of the Red Sea and the Persian Gulf can be as oppressively humid and as they are oppressively hot. In other places the air is often hot and dry during the day and damp at night.



Source : http://www.saudi-arabia.climatemps.com/

The weather statistics displayed above represent the mean value of each meteorological parameter for each month of the year. The sampling period for this data covers 30 years from 1961 to 1990.

Dhahran is located at short distance west of downtown Khobar. It is about 15 km in south of Dammam where there is the railway of our line 1 under assessment. Both are older Saudi port cities on coast of the Persian Gulf.

Dhahran's climate is characterized by extremely hot, humid summers, and cool winters. Temperatures can rise to more than 50 °C in the summer, coupled with extreme humidity (85-100 per cent), given the city's proximity to the Persian Gulf. In winter, the temperature rarely falls below 2 °C or 3 °C, being the lowest ever recorded -0.5 °C in January 1964, with rain falling mostly between the months of November and May. On July 8, 2003, the dewpoint was 35 °C while the temperature was 42 °C, resulting in a heat index of 78 °C.

Climate data for Dhahran, Saudi Arabia (1981-2000) [hide]													
Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Average high °C (°F)	20.8 (69.4)	22.3 (72.1)	25.6 (78.1)	32.4 (90.3)	38.7 (101.7)	41.7 (107.1)	43.3 (109.9)	42.4 (108.3)	40.3 (104.5)	35.6 (96.1)	28.9 (84.0)	23.2 (73.8)	32.93 (91.28)
Daily mean °C (°F)	15.5 (59.9)	16.7 (62.1)	20.6 (69.1)	25.0 (77.0)	30.6 (87.1)	33.4 (92.1)	35.2 (95.4)	34.4 (93.9)	31.9 (89.4)	27.9 (82.2)	22.3 (72.1)	17.0 (62.6)	25.88 (78.58)
Average low °C (°F)	10.2 (50.4)	11.5 (52.7)	14.7 (58.5)	19.7 (67.5)	24.6 (76.3)	27.5 (81.5)	28.9 (84.0)	28.7 (83.7)	25.6 (78.1)	22.0 (71.6)	17.1 (62.8)	12.4 (54.3)	20.24 (68.44)
Precipitation mm (inches)	17.7 (0.697)	15.2 (0.598)	35.3 (1.39)	3.5 (0.138)	1.2 (0.047)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	0.3 (0.012)	18.6 (0.732)	15.7 (0.618)	107.5 (4.232)
Avg. precipitation days	11.0	9.7	16.2	7.6	2.2	0.1	0.1	0.0	0.1	0.6	4.9	10.2	62.7

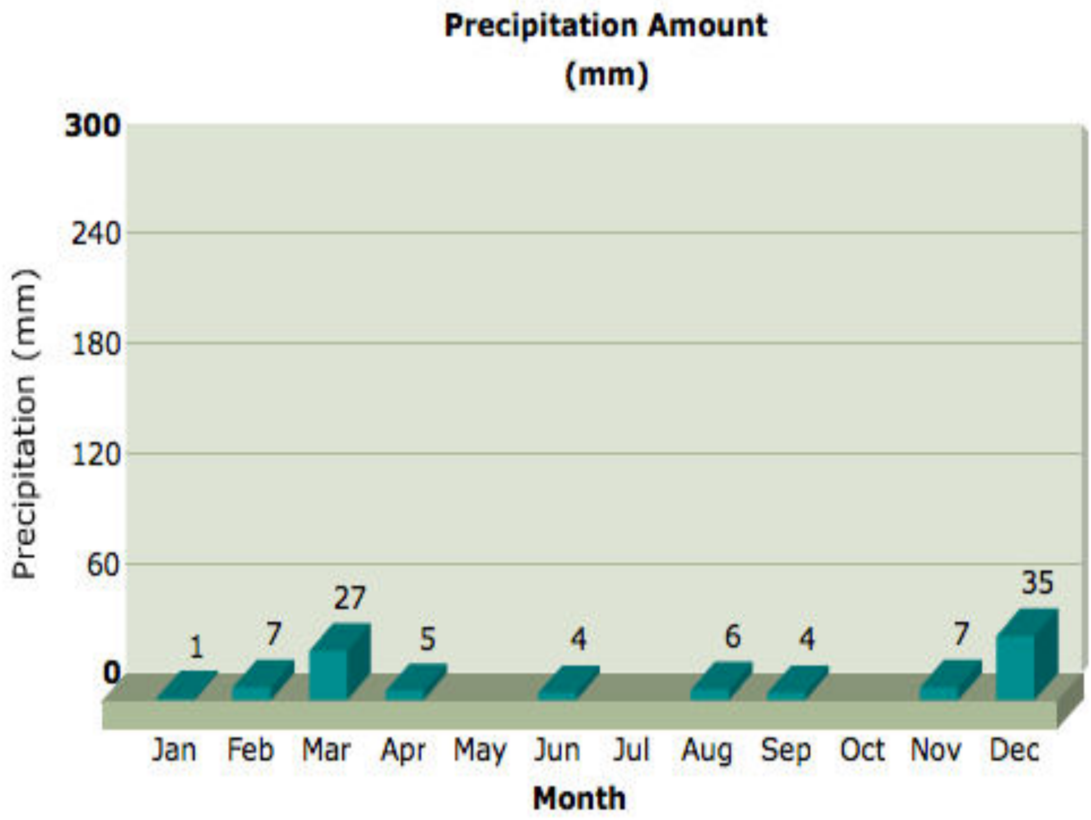
Source : Hong Kong Observatory in Wikipedia http://en.wikipedia.org/wiki/Dhahran

Floods

Cities, such as Jiddah and Makkah, are on low ground and are surrounded by mountains: when rains fall on these mountains, water runs in valleys towards these cities. With poor drainage systems, this continuous flow of water could easily lead to a flash flood.

So floods become natural disaster in Saudi Arabia: they have been the cause of 7 of the 10 most damaging natural disasters in the history of the country between 1900 and 2010.

In the case of the project of railway line 1 between Dammam and Riyadh, we found the floods of 2005 (700 people evacuated, 700 people homeless) and 2010 in Riyadh (275 car crashes) (cf. Yassar A. Alamri).



Source : http://www.myweather2.com/City-Town/Saudi-Arabia/Dammam/climate-profile.aspx?month=10
http://factsanddetails.com/world.php?itemid=1187&catid=52&subcatid=331

Summary

The right of way of the line 1 is for some sections surrounded by hills and sometimes its profile along the line is excavated below the level of the surrounding ground: culverts are built under the platform of the second track in progress and connected to culverts already made under the first track under operation: an hydraulic study should verify if during a heavy rain, natural basins in place or to be achieved can avoid flooding of the railway platform and damage until a train derailment.

The wind (shamal)

The Shamal winds usually blow across the city of Dammam in the early months of the summer, bringing dust storms that can reduce visibility to a few metres. These winds can last for up to six months.

The average daily wind speed in last October has been around 13 km/h or 7 knots. In recent years the maximum sustained wind speed has reached 56 km/h or 30 knots[1].

[1] The knot is a unit of speed equal to one nautical mile (1.852 km) per hour, approximately 1.151 mph.

Wind Speed

The chart below plots the average daily wind speed you can expect for any month. It also shows the maximum, recorded sustained wind speed for each month.

Dhahran (DAHRAN)

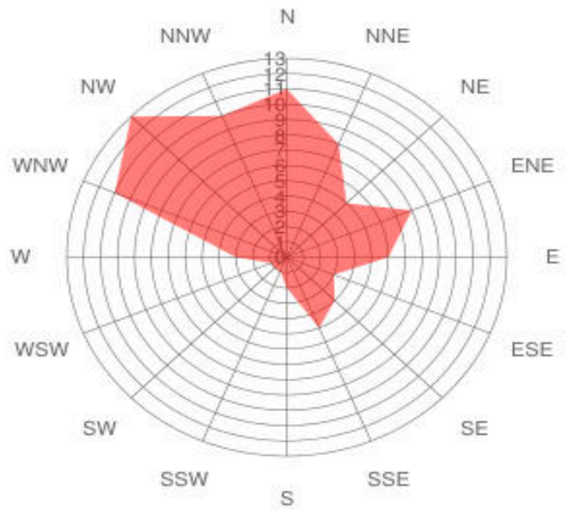
Statistics based on observations taken between 10/2005 - 8/2012 daily from 7am to 7pm local time.

Month of year	Jan 01	Feb 02	Mar 03	Apr 04	May 05	Jun 06	Jul 07	Aug 08	Sep 09	Oct 10	Nov 11	Dec 12	SUM 1-12
Dominant Wind dir.													
Wind probability > = 4 Beaufort (%)	35	46	47	43	55	61	54	37	38	21	34	36	**42**
Average Wind speed (Knots)	10	11	11	11	12	13	12	10	10	8	10	10	**10**
Average air temp. (°C)	18	21	26	31	38	41	42	41	38	33	27	20	31
Select month (Help)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year

Wind direction Distribution (%)

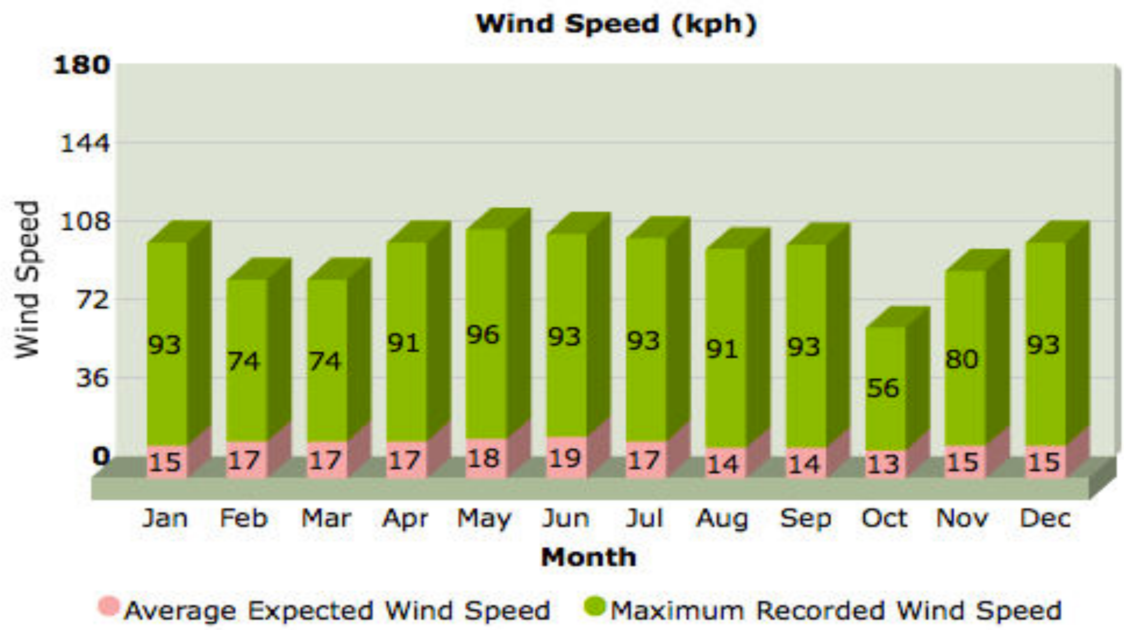
Wind dir. distribution Dhahran all year

© windfinder.com



Source : http://www.windfinder.com/windstats/windstatistic_dhahran.htm

The figure below shows that the mean speed of wind is around 15 km/h but it can rise to 90 to 96 km/h and then the conditions for sand's storm are met.



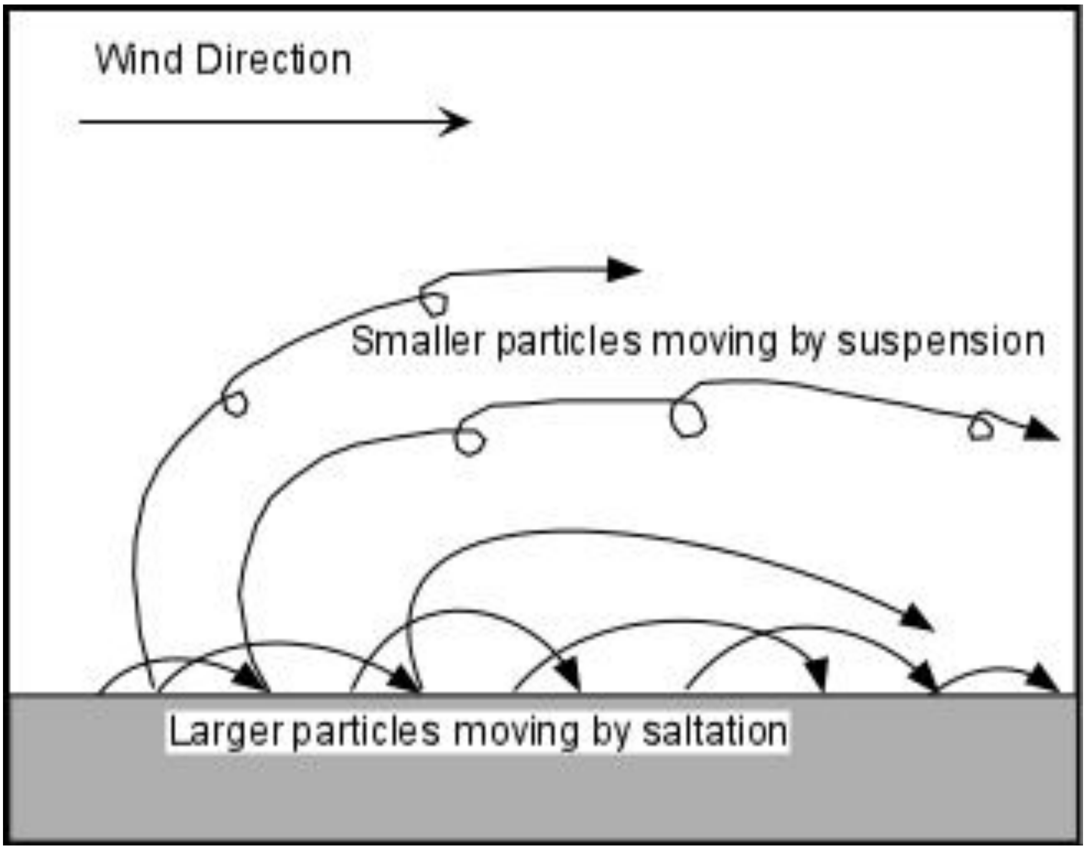
Source:http://www.myweather2.com/City-Town/Saudi-Arabia/Dammam/climate-profile.aspx?month=10

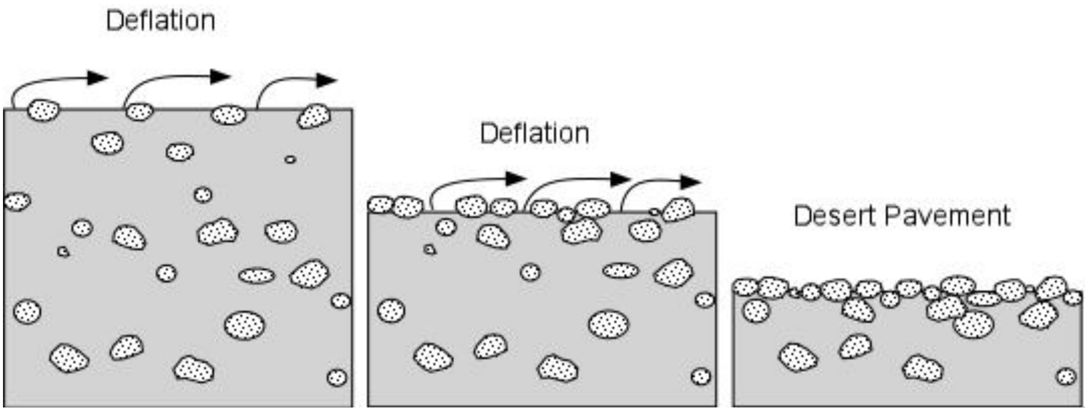
Sand's storm

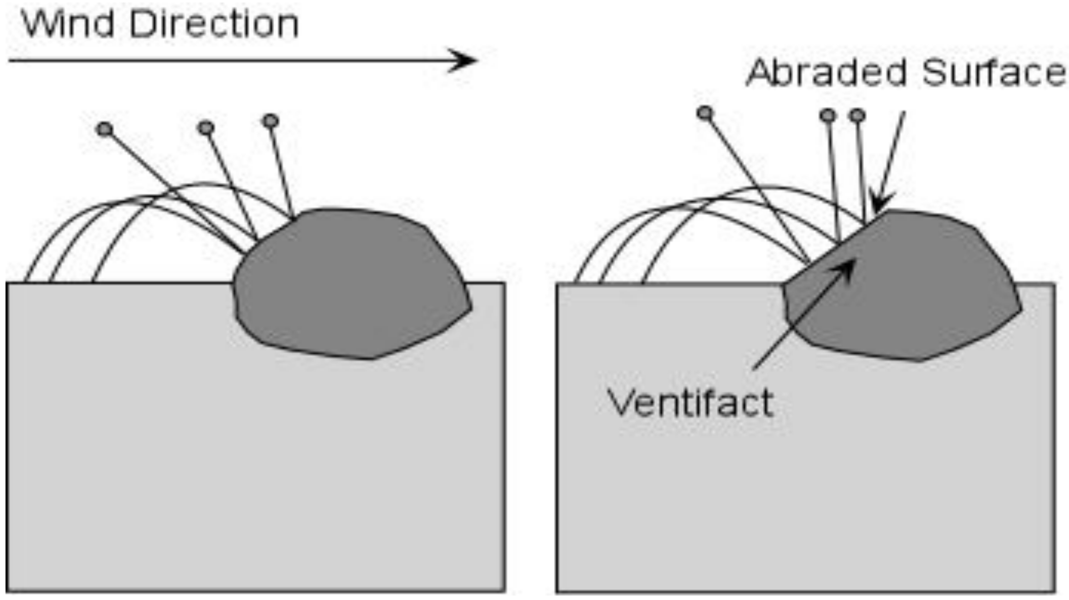
A dust storm or sand storm is a meteorological phenomenon common in arid and semi-arid regions. Dust storms arise when a gust or other strong wind blows loose sand and dirt from a dry surface. Particles are transported by saltation and suspension. It is a process that moves soil from one place and deposits it in another. As the force of wind passing over loosely held particles increases, particles of sand first start to vibrate, then to saltate. As they repeatedly strike the ground, they loosen and break off smaller particles of dust, which then begin to travel in suspension. At wind speeds above that which causes the smallest to suspend, there will be a population of dust grains moving by a range of mechanisms: suspension, saltation and creep.

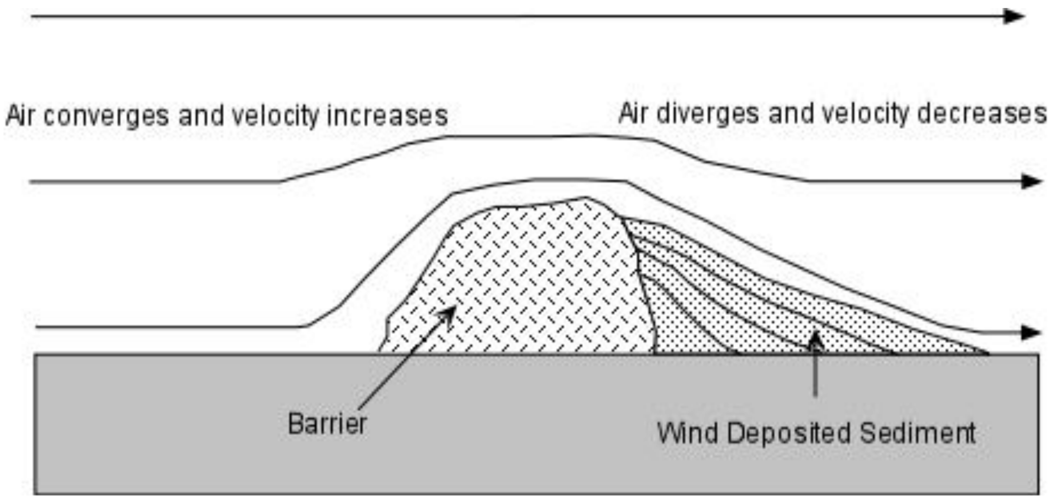
Summary

We see in the figure about the wind speed above that the mean speed of wind is low and not a hazard for operating trains. The recorded maximum wind speed is under 100 km/h that is not also a hazard for operating trains but they must slow down their speed because visibility is also decreasing as the sand 's storm is increasing with the wind's speed.

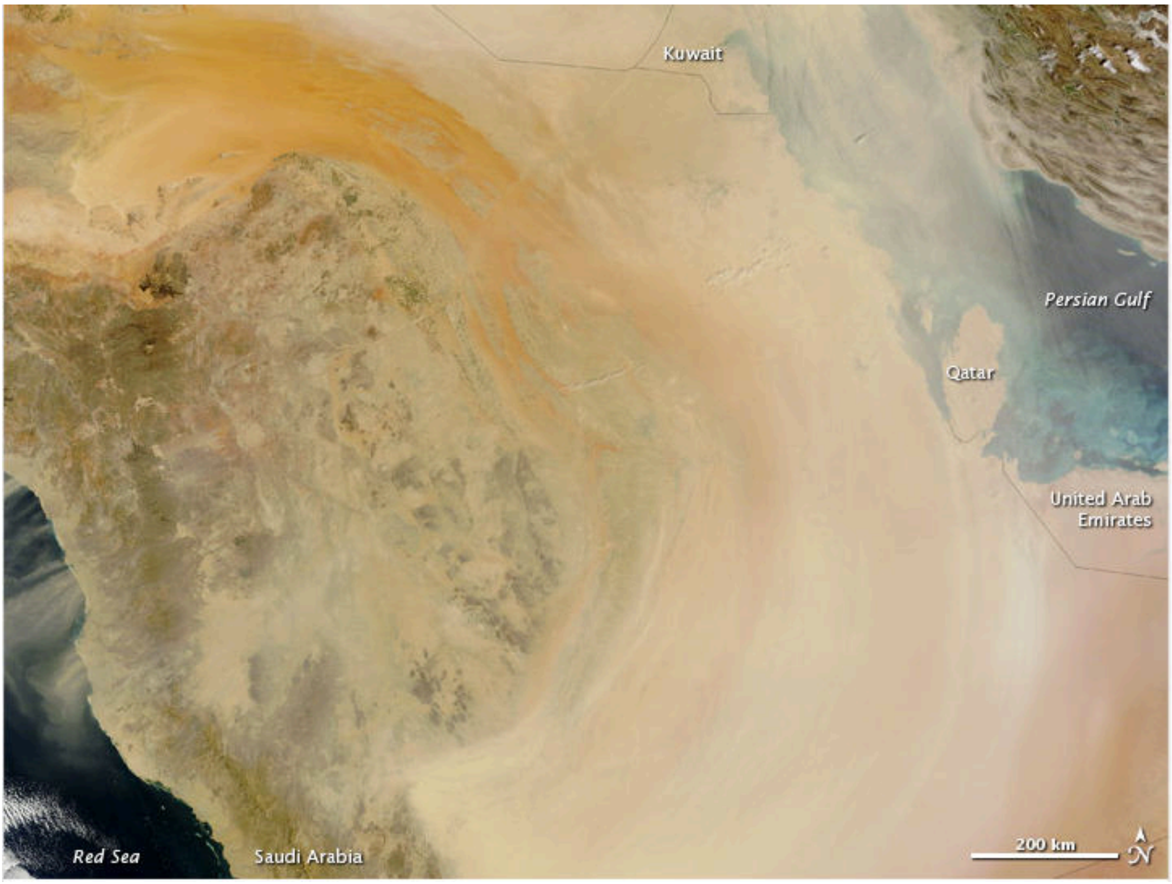

Wind Direction
Smaller particles moving by suspension
Larger particles moving by saltation


Deflation
Deflation
Desert Pavement





Source: http://earthsci.org/education/teacher/basicgeol/windes/windes.html#TranverseDunes



Source: http://earthobservatory.nasa.gov/NaturalHazards/view.php?id=77457

Aggression of sand on railroad

In most parts of Saudi Arabia, geo-morphological processes are marked by the movement of sand and dust, which has reached alarming proportion in recent years for various man-made reasons. Overgrazing by camel and cattle has reduced bushes. Rock crushing, bulldozing, grading, trucking and camel trailing have lost top surfaces and thus accelerated sand and dust movements. As a consequence, built structures are abraded, building materials and utility structures are corroded; walls, columns and poles are pitted, fluted, grooved and are exposed to corrosion; communication poles are sand blasted; glasses lose transparency; painted surfaces get damaged; mechanical equipments are worn; visibility is reduced; communication is disrupted; eyes and throat are infected; food is contaminated; animals are often suffocated and vehicular accidents are increased. In short, built-up areas are adversely affected and human safety is badly endangered.

Massive deposition of sand and dust causes substantial coverage and often complete burial of young plants as well as such important urban features as trails, tracks, railway lines, roadways, pipelines, runways, landscaped areas and high valued land uses. There are historical and contemporary examples of the abandonment of settled areas as a result of such burials.

Prevailing wind

With its small grain size of 0.08 mm diameter, dust has lower specific gravity and higher cohesiveness than sand, which has a grain size ranging from 0.08 to 2.0 mm diameter. Dust travels suspended in wind often lifting to great heights and forming an aerodynamically smooth cohesive surface, thereby allowing high velocity winds to entrain it. Sand, on the other hand, travels in hops and jumps, and rebounds near the surface in what is known as “saltation curtain”, often gaining flight momentum from air stream. Through shifting action during the movement, sand is segregated from dust and are often built into superficial aeolian bedforms. Thus the dynamic action of wind and fine surface materials is crucial to the shaping of the desert landscape, and may be examined in terms of three related processes: deflation, transport and deposition.

Deflation

Deflation is the process whereby sand and dust are removed by wind action. It is induced by human actions, which are initiated by preparation of land for urban and regional developments.

Transport

Sand is transported by abrasive action at a ‘saltation height’ of one meter, while dust may rise to several hundred meters rendering the sky hazy and dull. In the eastern regions of Saudi Arabia, abrasion and transport is pronounced in summer under the impact of the high speed northerly ‘shammal’ winds. Abrading sand and duststorms such as the Libyan ‘ghibli’ in Sahara and the Saudi ‘belat’ in the Arabian Peninsula disintegrate soil, increase surface erodibility, erode building materials, weaken utilities, damage mechanical equipments, and by reduced visibility, disrupts urban and regional transportation. In the western Hejaz region of the Kingdom also, the easterly ‘samoun’ wind is laden with sand and dust and causes like damage. Sand and dust movement is a function of wind erosivity, which depends on the velocity, frequency and intensity of wind, and of surface erodibility, which depends on the kind of vegetation’s cover and type of surface soil.

Deposition

At the depositional stage, dust and sand bury plants, increase road and runway skidding, contaminate household stuffs, and create bouts of allergy and discomfort.
On transit or as sand dunes and ‘draa’, sands overwhelm urban infrastructures and cause desertification, which depopulates settlements and increases migration.

Source: http://www.telegraph.co.uk/news/picturegalleries/worldnews/4967897/Blinding-sandstorm-hits-Kuwait-and-Saudi-Arabia-halting-oil-exports.html

In light of the preceding results and discussion, Riyadh city, Saudi Arabia, is subjected to considerable dust storms almost all year. The fallout sediments are mainly represented by two textural classes, loam and silt loam, of which silt is the dominant fraction. Quartz and calcite were the dominant minerals in the dust samples. The dust contained high $CaCO_3$, averaging 31,8%. Appreciable amounts of heavy metals such as Pb, Zn, Cd, Ni and Co were detected in the fallout sediments.

Maintenance of the railroad's track

Railway safety experts from 13 countries on March 2003 concluded a three-day conference on the hazardous effect of sand movement on railway tracks, recommending three measures to counter the problem.

Safety experts said that most of the train accidents in the Arab and African countries were caused by the accumulation of sand on the rail track and various methods adopted by these countries had failed to provide any tangible result.

"It was therefore imperative for all of us to sit together and find a lasting and effective solution to the crisis," said Khaled Al-Yahya, president of the Saudi Railways Organization.

The conference in its final communiqué stressed on three possible means to contain sand from reaching the tracks. Among the three measures, the experts first listed mechanical means, which they said was found effective in several countries. They also suggested chemical means to stop sand movement.

But the main thrust of the conference was on biological means, that is plantation of trees near the railway track.
“This is a long term solution and will eventually prove more effective,” said an expert at the conference.
http://www.arabnews.com/node/229364

Source : http://www.iorw.org/news_index.html

SRO, in conjunction with contractor Al-Moboty Co has ordered several SRM 500 sand removal machines, which will be delivered by the end of this year, and a Unimat 08-32 4S two-sleeper tamping machine, which will enter service in 2013. Plasser & Theurer is also supplying contracting and track maintenance firm Saudi Archirodon an EM 120 track recording car, which will measure, record and evaluate various track parameters.

Preventing and controlling aeolian sand

In his chapter on dune migration and encroachment, Goudie (2010a, p. 200-201) identifies four main techniques, which are used in order to contain aeolian sand:

- 1. Endorse the deposition of drifting sand by devices such as ditches, barriers, and fences, and vegetation belts.
- 2. Enhance the transportation of sand by aerodynamic streamlining and surface treatments.
- 3. Reduce the sand supply through surface treatments (e.g. water spraying, chemical stabilizers, mulches), fences and vegetation strips.
- 4. Deflect the moving sand by using fences, barriers and tree belts.

When controlling mobile sand dunes, the main techniques are:

- 1. Sand dune removal by mechanical excavation and transportation to new location.
- 2. The dissipation of encroaching dunes by disrupting its aerodynamic profile by reshaping, trenching, or surface treating.
- 3. Dune immobilization using surface strips, fences, etc.

According to Goudie (2010a), these diverse techniques are not very successful, and the best adaptation would be to site and design engineering structures in order to allow the sand free movement. In addition, one alternative is mapping different dune types in order to observe their direction and mobility. Then it would be possible to arrange structures outside of risk-areas. Goudie (2010a, p. 201)[2] notes that, “Avoidance may be better than defence”.

The effects of aeolian sand on infrastructures

According to the Stockholm University report, “Sand causes third derailment in weeks” (Namib Times, 2009b), see figure below, the sand has caused a derailment of a freight train on the railway line between Walvis Bay and Dune 7. Due to extreme windy conditions the sand was able to accumulate rapidly, covering the entire track. The derailment cut Walvis Bay’s railway link to Swakopmund and the rest of the country for one day. Furthermore, an article from the 13th of October reports that Dune 7 has buried benches and other structures (Namib Times, 2009c).

Source : Bovin Mattias, Johnsson Caroline, tutor Christiansson Carl, Stockholm University, dept of Physical Geography and Quarternary Geology, “The effects of Aeolian sand on Infrastructure in Walvis Bay”, report Autumn term 2010 46 p.

Photos on the derailment (The Namib Times, 2009b)

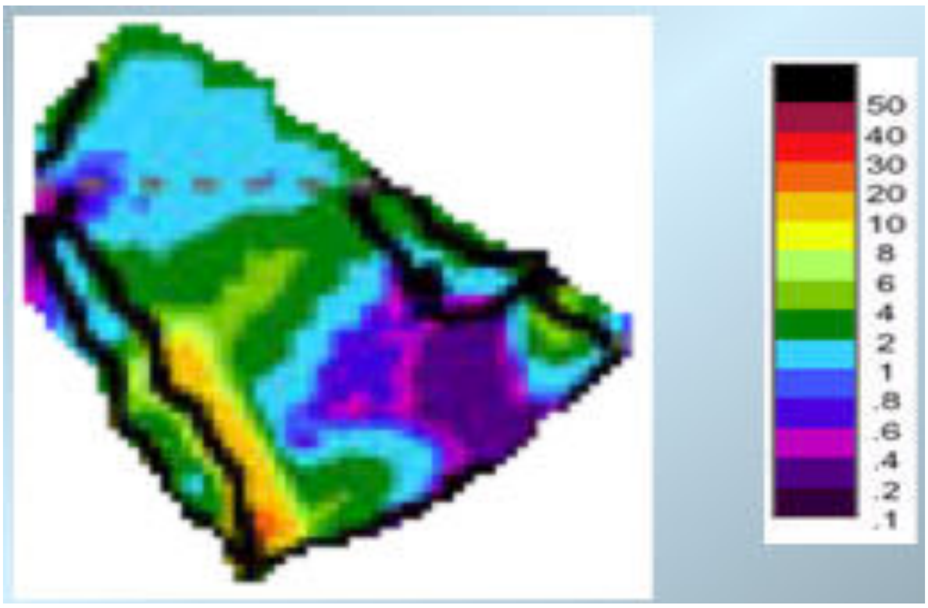
[2] Goudie, Andrew, 2010a: Dune migration and encroachment. In, *Geomorphological Hazards and Disaster Prevention*, eds. Irasema Alcántara-Ayala and Andrew S. Goudie. Published by Cambridge University Press. Copyright Cambridge University Press 2010.

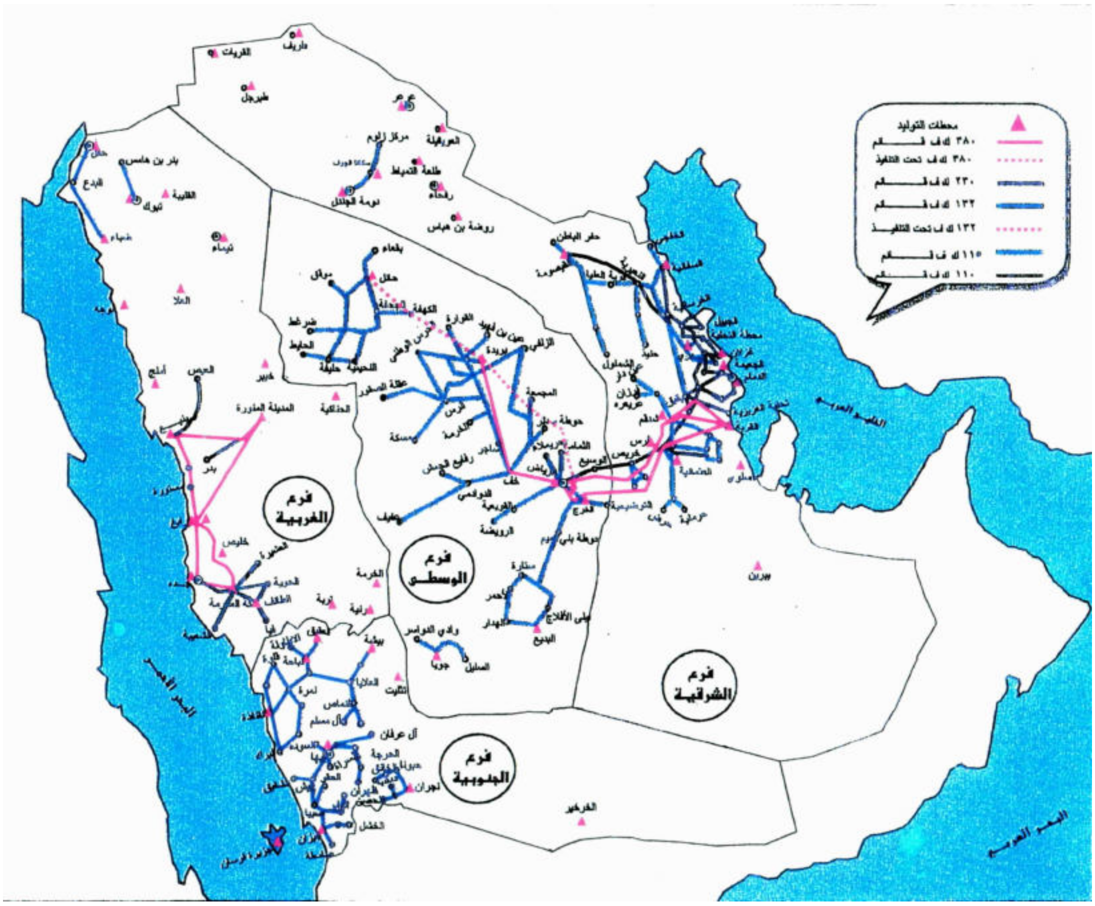
Summary

We note in this chapter on the aggressiveness of the sand action wear on buildings and transport infrastructure such as railways to cause accidents by derailment.
Moreover, the abrasive action of sand on the rails and train wheels can lead to premature wear of the rolling elements such as rails and wheels. If the maintenance of rolling stock and the track does not follow, this can lead to derailment.
As well two actions are to be taken together, the removal of sand on the track from its appearance after a storm and concerted implementation of the first long-term barriers to either side of the railroad right of way to identify the sand locked when they are submerged and plantations which would set the sand in the long term.

Thunderstorms

Lightning is an abrupt electric discharge from cloud to cloud or from cloud to earth accompanied by the emission of light or it is a flash of light that accompanies an electric discharge in the atmosphere, which can scintillate for a second or more.
It is helpful to construct a visual representation of lightning strike densities in countries such as Saudi Arabia in order to locate areas, which are most likely to be stroked, and those, which are not. By knowing where lightning strikes hit we can design better lightning insulation systems for residential, commercial as well as industrial regions. Of most important is the insulation required for power plants and transmission lines wither overhead or underground.
Consider the following approximated maps of lightning strokes in Saudi Arabia:
If we compare the following two figures, we note why it is important to have lightning detection and mappings as illustrative methods in determining the rate of strokes and where most likely they would hit.
Here, it is clear, that the Southern western region of Saudi Arabia is the most attacked by lightning strikes thus resulting in possible faults in power lines in that area as shown in the second figure which is a map showing transmission lines and their voltage rates.





Tamer Al-Alami, “Mapping lightning strikes in KSA: using numerical methods as a tool”, ppt
Flashes per square kilometre per month (from 0,1 to 50)
Detailed mapping with visible contours showing very lighting mostly strikes.

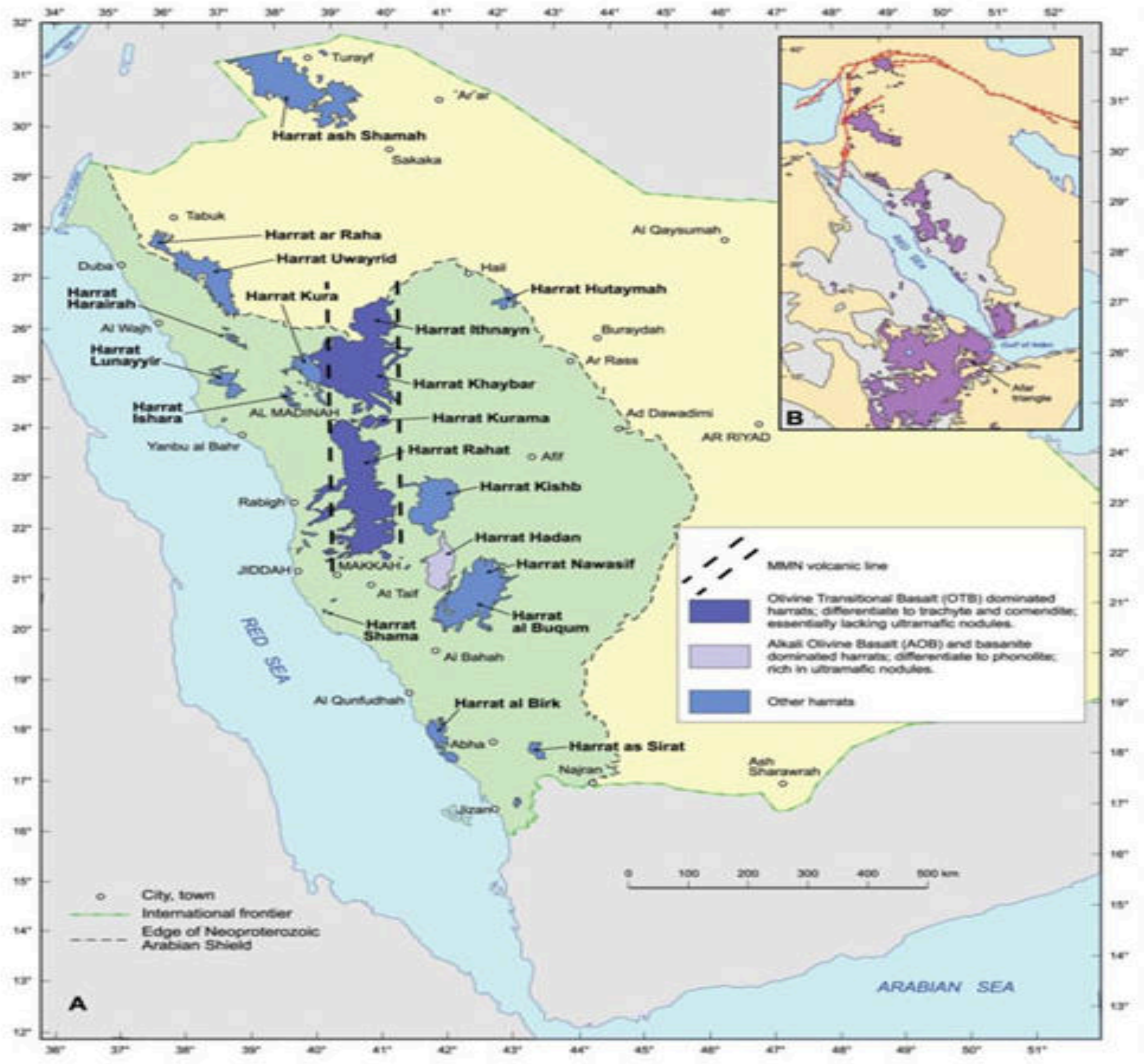
- SCECO-EAST: SCECO (Saudi Consolidated Electric Co.) Is the leading electric power company in Saudi Arabia handling all generation, transmission and distribution activities and operations in the entire Kingdom.
- PDD: The Power Distribution Department mission is to manage the electrical power system of all Saudi Aramco facilities under PDD area of responsibility in a safe, reliable and cost effective manner, exceeding customer’s expectations. PDD was established in January 1983 as a maintenance department then evolving into distribution of power to all facilities).

Summary

It therefore appears that there are numerous thunderstorms in Saudi Arabia followed by lightning especially in areas with dark colors (flashes per square kilometer per month) shown on the map that is west of the Saudi along the Red Sea, but also along the Persian Gulf and especially in a line north west south east between Dammam and Riyadh.
Lightning protection systems to avoid lightning incident of signalling along the line after a thunderstorm must protect electronic equipments along the way.

Earthquakes, and seismic risks
Volcanoes

The Arabian tectonic plate is migrating away from the African Plate at a rate of around 2 cm per year. In north - western and central western Arabia crustal extension is also occurring, and has resulted in significant Cenozoic volcanism. The two most common types of volcanic emission (more than 80 percent) in Saudi Arabia are shield volcanoes, with fairly flat slope, due to thin fluid basalt lava flows.

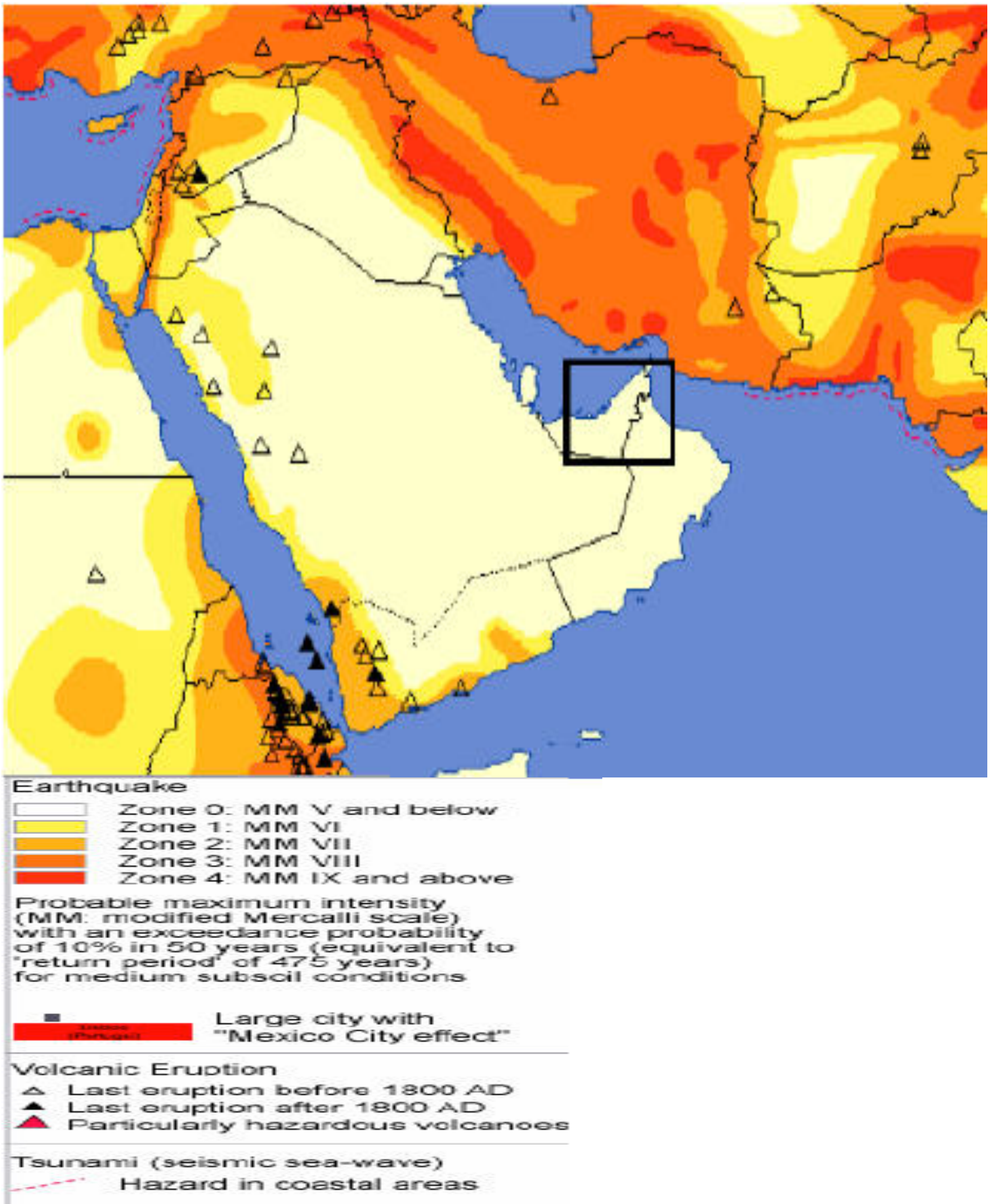


Source: National Centre for Earthquakes and Volcanoes

A: The main Cenozoic lava fields (harrats) in western Saudi Arabia showing the MMN volcanic line.
B: The three-armed rift of the Red Sea – Gulf of Aden – East African Rift zone. The inferred mantle plume is below the Afar triangle.

The more recent basaltic lava fields and volcanoes date from 10 million years ago up to the historic eruptions. They lie along a 900 km line within the shield that extends south from the Great Nafud Desert, through the cities of Al Madinah and Makkah, and then as far south along the coastal plain as Al Qunfudhah. The northernmost 600 km length of this trend takes the form of a north-south graben structure about 600 km long through which the main Cenozoic

basaltic lava fields (harrats) have been erupted. This zone has been named the Makkah-Madinah-Nafud (MMN) Volcanic line, and includes Harrats Rahat, Khaybar and Ithnayn. Harrat Rahat, which extends between Makkah and Madinah, covers about 20,000 km2, and has 644 scoria cones, 36 shield volcanoes and 24 domes. The MMN volcanic line is a weakly propagating rift zone where crustal extension has averaged about 0.054 mm per year over the past 10 million years, and is distinct from the main Red Sea rift zone. It forms the axis of uplift in western Saudi Arabia, and geothermal phenomena are observed along this trend.
Low level geothermal activity and seismicity indicate that the MMN trend remains active. The areas of Cenozoic volcanism and the MMN volcanic line are shown in the map of the harrats.



Source : Shell Global Solutions International BV, « Dubai LNG Seismic Hazard Desk Study », Seismic Hazard Desk, Study Rev A December 2006

Earthquake Seismology

Tectonics of the Arabian Plate

The crust of the earth is composed of many tectonic plates, and most of the major earthquakes occur at the plate boundaries. The eastern and northern margins of the Arabian plate consist of the Zagros and Makran Mountains in Iran, and the Taurus Mountains in southern Turkey, and these form a convergent zone where the Arabian plate collides with the Eurasian plate. The Arabian plate moves in a northeasterly direction between the Owen fracture zone and the Dead Sea fault, with widening of the Red Sea and Gulf of Aden, and collision or subduction with the Makran, Zagros, and Taurus Mountains.

Apart from the seismicity along the axis of the Red Sea and along the Gulf of Aden, considerable activity occurs along the Dead Sea transform fault system, and many earthquakes also occur due to collision at the subduction zone along the Zagros Mountain belt. In the central and western part of the shield some of the Cenozoic volcanic areas are still potentially active, and some seismicity is associated with this low-level volcanism.
As far as Saudi Arabia is concerned, the most active area is along the Gulf of Aqaba (Dead Sea transform fault), where the left lateral movement relative to Sinai is 4 to 5 mm per year. The region of the Gulf has active sinistral transform faults with associated pull-apart basins (the deeps in the Gulf of Aqaba), and hence is an area where large damaging earthquakes occur quite regularly. The last major event was the 1995 Haql earthquake in the Gulf of Aqaba (magnitude 7.3), which caused significant damage on both sides of the Gulf and was felt hundreds of kilometers away. Earthquakes of magnitude 6 are common along the spreading axis of the Red Sea but generally they are not felt onshore and appear to pose little risk to infrastructure. The figure here shows earthquake epicentres greater than magnitude 2 in the SGS catalogue for all years up to 2009.

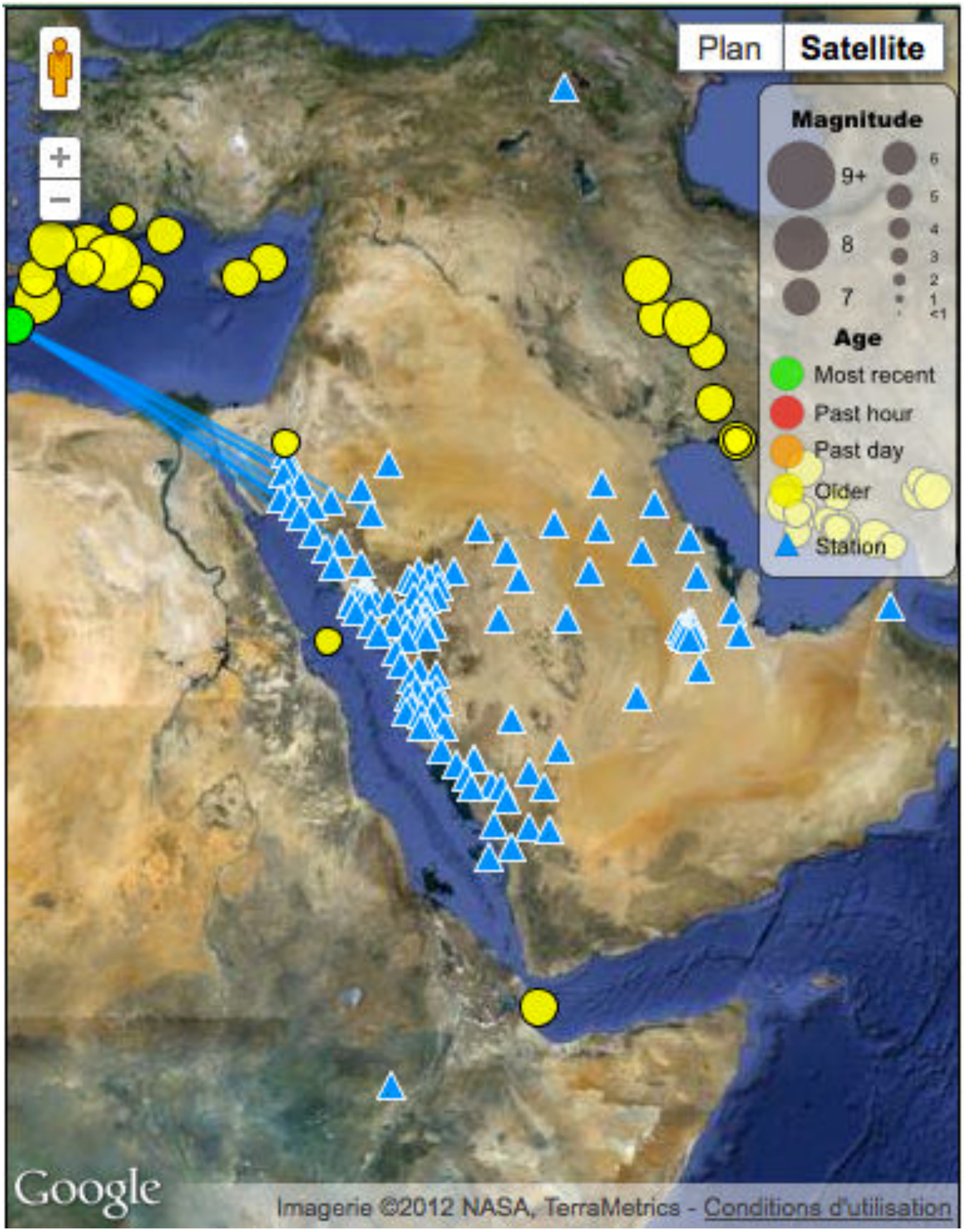
Source: SGS

On 19 May, 2009, 19 earthquakes of M4.0 or greater took place in the volcanic area of Harrat Lunayyir to the north of Yanbu, including a M5.4 event that caused minor damage to structures in the town of Al Ays (40 km to the SE). This event produced the spectacular ground cracks seen in the photograph below. The maximum actual dip-slip offset on the fault in the hard rock in the nearby hills was about 90 cm.

Seismology at Saudia Geological Survey

Permanent stations from the other previous seismograph networks have now been integrated with the SGS national network and upgraded using new broad -band instrumentation and satellite telemetry. Most earthquakes greater than magnitude 2 within the Kingdom are now routinely located and a comprehensive earthquake data- base has also been established for earthquake research. The stations (about 75 at present, see map) are concentrated in western

Saudi Arabia, where most of the seismicity and hence the risk occurs. Eventually when the network of about 100 stations is completed the coverage will enable earthquakes as small as magnitude 2 to be detected and located anywhere within the Kingdom.



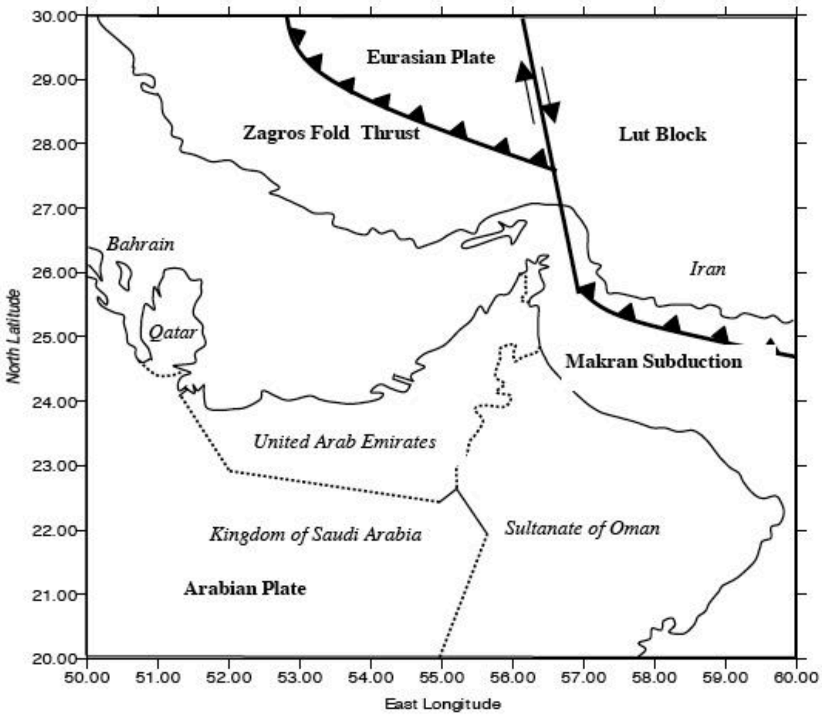
Source: http://www.sgs.org.sa/English/Earthquakes/Pages/default.aspx

The SGS seismograph stations use a standard arrangement, with equipment manufactured by Nanometrics Inc. in Canada. Each broad-band seismometer is on bedrock in an insulated concrete vault about 2 m in depth, and is insulated to minimize temperature variations. Data from remote sites are transmitted via satellite to the SGS processing centre in Jeddah and satellite channel usage is managed via commands from the SGS seismic center.

Typical records of seismic waves arriving at 2 SGS stations from an earthquake in eastern Saudi Arabia are shown. The first wave to arrive is the direct P (compressional) wave, followed by a succession of P and S (shear waves). From the arrival times of these waves we can work out the location of the earthquake.

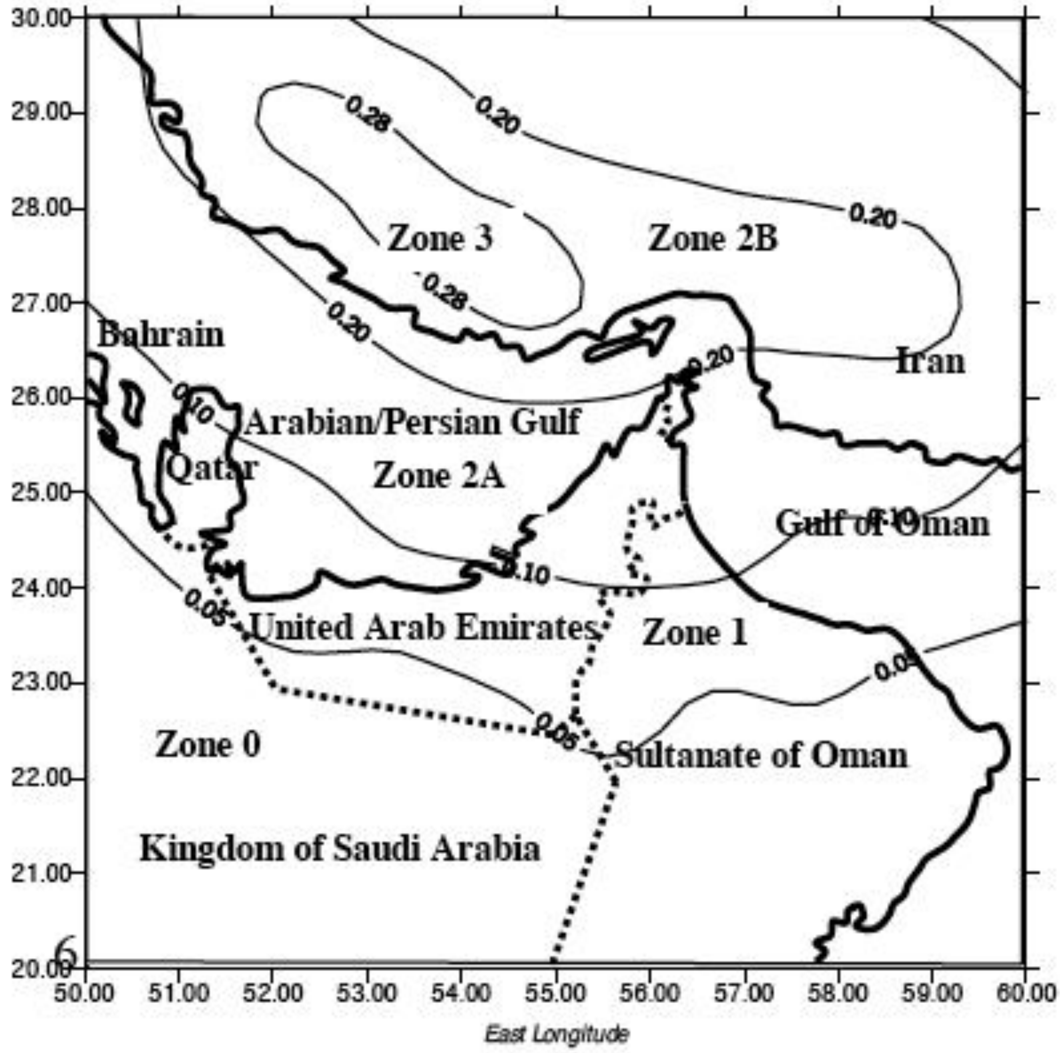
Earthquake risks

The risk of damage from earthquakes is quite low over most of Saudi Arabia, the main areas of risk being near the Gulf of Aqaba and Jizan, with lower risk in the west near the Red Sea and in some of the harrats. The database is used to estimate the expected recurrence rate for earthquakes of different magnitudes in areas of interest, from which statistical estimates of risk are derived. The location can then be placed in the correct zone or level in the building code so that appropriate methods of construction are used. This is particularly important for large infrastructure projects. We undertake risk studies for other government departments as well as for the private sector using our unique catalogue of earthquake activity.



Source: Jamal A. Abdalla and Azm Al-Homoud, American University of Sharjah, UAE, « Earthquake hazard zonation of Eastern Arabia », paper n°1008 in 13th World Conference on Earthquake Engineering Vancouver, B.C. Canada, august 1-6 2004.

Tectonics of UAE and its vicinity



Seismic zoning map of UAE and its vicinity for 475 years return period showing five zones (0,1, 2A, 2B and 3)

Summary

KSA is a country of low seismic activity and scarce past earthquake data. The seismographic installations in the country were commissioned in 1984. Contrary to common belief, there are regions in the country where peak ground acceleration reaches 0,2g and 0,3 g in 50 years for 10 and 5 percent probabilities of excess respectively.

The region between Dammam and Riyadh is quite far from the iranian faults and the red sea faults. A seismic zoning map of UAE and its vicinity for 475 years return period shows five zones (0,1, 2A, 2B and 3) in the figure above: the Saudia Arabia region near east coast (Barhein) is in a zone 0 to compare with others zone 1,2,2B & 3.

Rock Fall Hazards

Landslides are rock, earth, or debris flows on slopes due to gravity. They can occur on any terrain given the right conditions of soil, moisture, and the angle of slope. Integral to the natural process of the earth's surface geology, landslides serve to redistribute soil and sediments in a process that can be in abrupt collapses or in slow gradual slides. Also known as mud flows, debris flows, earth failures, and slope failures, they can be triggered by rain, floods, earthquakes, and other natural causes as well as human-made causes, such as grading, terrain cutting and filling, excessive development, and so on. The factors affecting landslides can be geological or by man-made, and can occur in developed or undeveloped areas, or in areas where the terrain has been altered for roads, houses, utilities, buildings and mining activities.

The Saudi Geological Survey is studying landslides in order to mitigate the risks. Landslides may be more devastating than all other natural hazards combined, and can affect utilities, transportation, and public and private infrastructure. Most of the rock slopes along the descents between the Arabian Shield mountains and the Red Sea coast that cut through the escarpment are subject to slope instability and rock falls, especially after rain storms.

Summary

Along the railway line 1 between Dammam and Riyadh we find some right of way in trench with high chalk bluffs above the track: some chalk stones are put on the bluffs very near of the edge, they could fall on the track before or during a train passing through. It is advised to avoid chalk stones deposit near or above the railroad tracks.

Karst Hazards

Different types of sinkholes have been recognized in Saudi Arabia. The sinkholes are of various sizes, shapes and occur at different depths. Their presence may cause a direct risk to infrastructure such as urban areas, roads, areas being developed, and farmland. Some sinkholes have also appeared in barren uninhabited areas. In recent years more than eight large sinkholes or ground collapses have occurred to the west of Al Khafji and in the An Nu'ayriyah area (northeast Saudi Arabia) due to dissolution of the underlying limestone.

Summary

It does not seem that there are sinkholes under the right of way of line 1 between Dammam and Riyadh. Normally drill tests have been done before the opening of public works: if a sinkhole stays under the tracks, after a rain storm the ballast will desappear slowly under the sleepers and rails. Maintenance surveys have been done to watch that kind of problem.

Loess soil

Loess soil is an unconsolidated well-sorted deposit. It is relatively homogeneous, seemingly non-stratified, and extremely porous. Loess has different definitions, but is generally considered to be wind-blown (aeolian) silt where the sediments were transported by wind. Loess soil mainly consists of quartz, feldspar and mica grains that are angular showing little polishing or rounding. Because the grains are angular, loess often retains the shape of banks for many years without slumping. The soil characteristic called vertical cleavage allows the formation of cave dwellings. Loess may be readily eroded by water, wind and seismic activity. Loess soil occurs in various areas in the Kingdom such as in Jizan city.

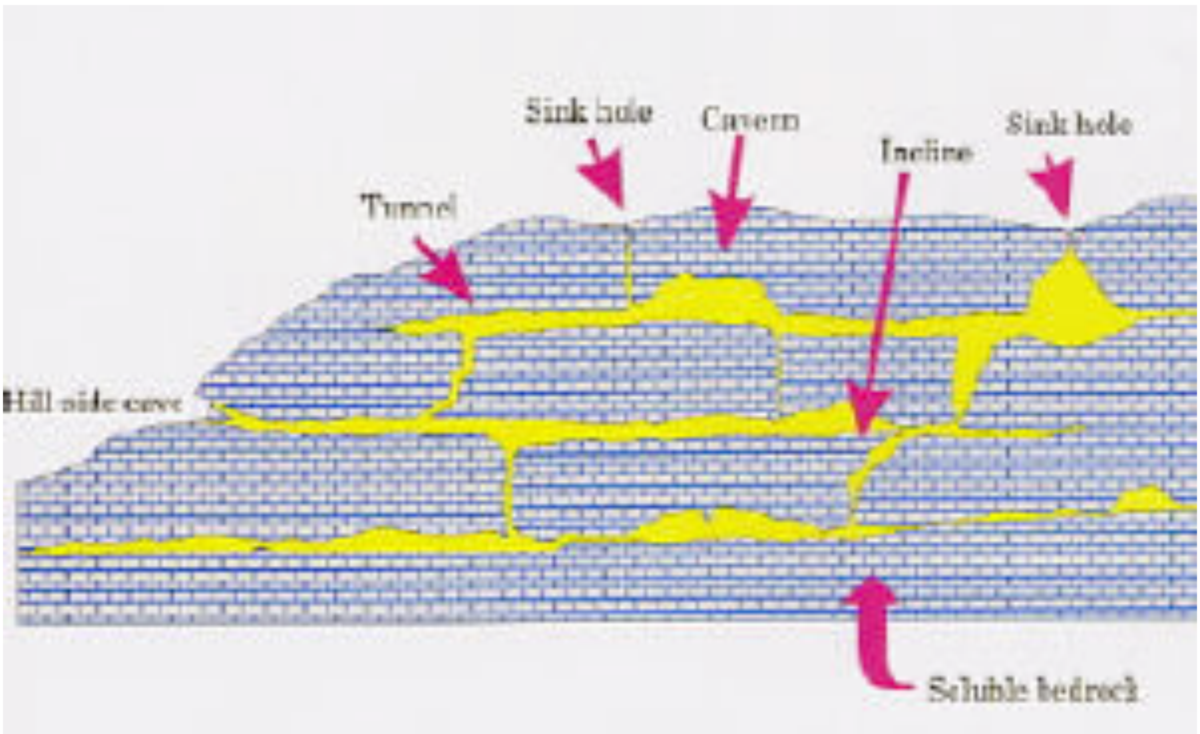
Summary

Along the railway line 1 between Dammam and Riyadh we find some right of way in trench with high loess soil bluffs above the track: some loess soil or vertical cleavage are on the bluffs very near of the edge, they could fall on the track before or during a train passing through after rain storm.

Geology of the caves of Central Saudi Arabia

Caves are airfilled underground voids developed by the former action of water on rock that over a long period of time was dissolved, opening up holes and tunnels in the ground. The holes and tunnels in cave systems are normally interconnected, depending on how the water seeped through the rock along joints and cracks, working its way down to the water table below the surface of the ground.

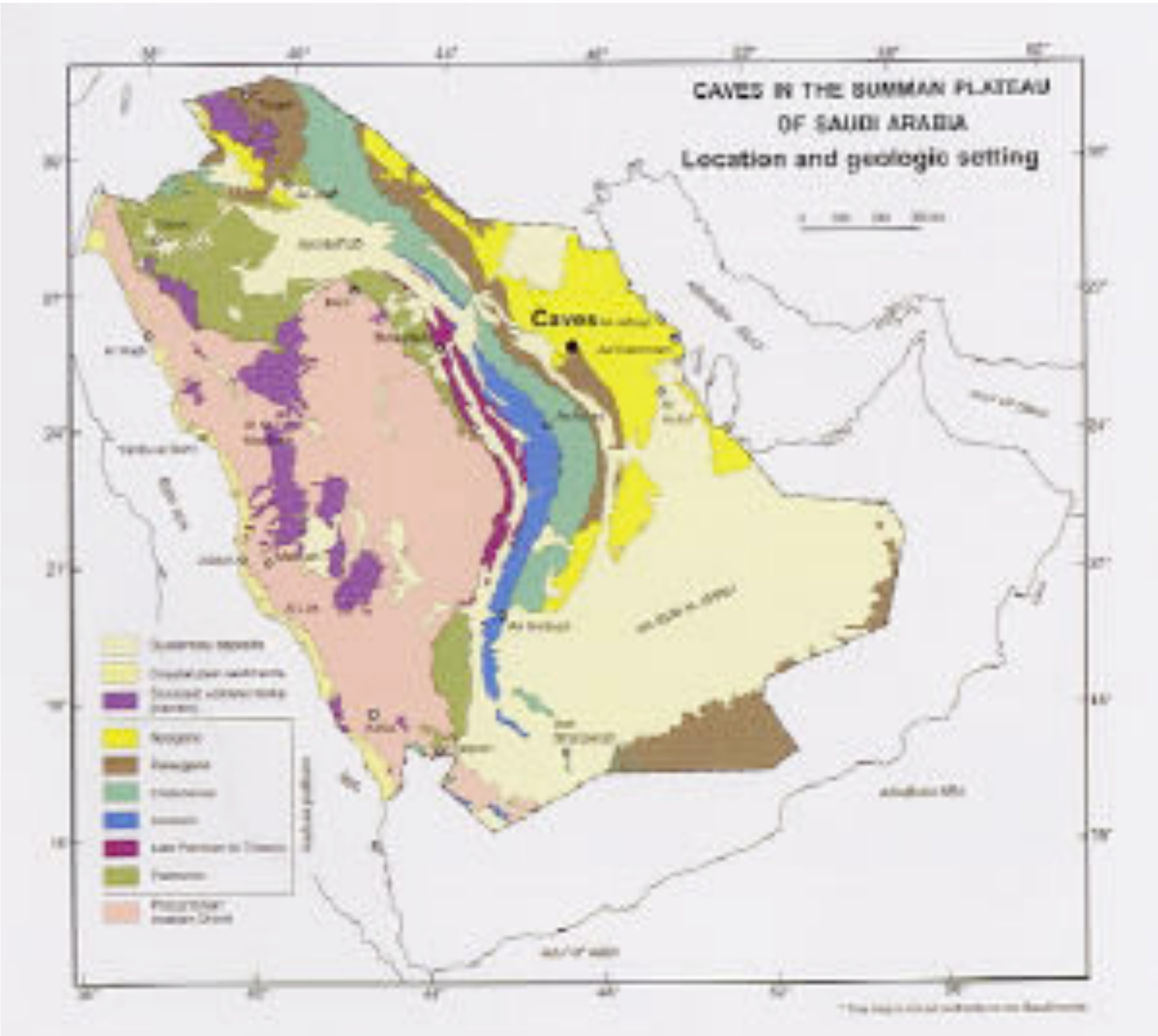
The caves illustrated here are in limestone - the most common type of rock to have caves - which in this part of Saudi Arabia consists of calcium carbonate and small amounts of magnesium carbonate. The rocks found 50 million years ago from the calcareous shells and skeletons of countless organisms that flourished in shallow warm seas that covered the Arabian Peninsula. Over time, the shelly deposits were cemented by additional calcium carbonate, became hard and turned into limestone, forming a geologic unit referred to as the Umm el Radhuma and Rus Formations. Starting 25 million years ago, these formations were raised above sea level by earth movements affecting the whole of the Middle East, and were exposed to wind and rain at the surface.



Typical features of a cave system in limestone

The action of water percolating down through soluble rock is critical for the formation of most caves. Some caves develop because sulphuric acid rises from deep below the surface, but this is rare and it is not known if any of the caves in the Ma'aqala area formed in this fashion. Most likely they all formed by water action - either by falling rain or by streams that sink into the ground through joints and holes.

The process of forming caves in soluble rock is very slow. As rain falls through the air, it absorbs a small amount of carbon dioxide and picks up additional carbon dioxide from the soil. The result is a weak solution of carbonic acid that seeps downward, dissolving the limestone bedrock and opening up cavities and inter-connected channels.



Ain Hit: Diving in the Desert

Southeast of Riyadh near Al Kharj lie several sinkholes that offer direct access to a vast aquifer lying deep below the surface.
The most famous of these holes is Ain Hit where geologists, invited on a picnic by King Abdulaziz, discovered the first surface outcrop of anhydrite in the Kingdom. In recent years experienced cave divers have carried their heavy equipment into Ain Hit down to the edge of a lake 120 meters below the surface. Using breathing equipment they began an exploration of this Dahl's submerged passages, which, they claimed contained the clearest water they had ever seen anywhere in the world.

Caves of the Summan Plateau

Saudi Arabia has hundreds of limestone caves located only a few hours north of Riyadh, offering visitors a cool underground climate and stunning crystal formations.

Perhaps the most visited cave on the Summan Plateau is Dahl Murrubeh. This cave has a large entrance 15 meters wide. A steep slope leads down to a large room softly lit by reflected sunlight. In the summer, the cool and pleasant temperature of this room makes it a perfect refuge from the intense heat on the surface, which can easily surpass 50° C (120° F).

The Jabal Al Qarah Caves, located approximately 13 km east of Al Hofuf, Eastern Province of Saudi Arabia, are an intricate cave system developed in the calcareous sandstone, marl and clay of the Upper Miocene to Lower Pliocene Hofuf Formation. Physiographically, the hill of Jabal Al Qarah is an outlier mesa that is located at the eastern edge of the Shedgum Plateau, the southern extension of the As Summan Plateau, and the larger Syrian Plateau to the north.

Based on cave morphology and interpreted evolutionary history, the Jabal Al Qarah caves appear to be significantly different from other limestone caves reported in the As Summan Plateau. Jabal Al Qarah is known for its tall, linear cave passages and narrow canyons. The boxwork of linear passages are better developed here than any other known cave locations in the Eastern Province. Petrographic data, especially an abundance of well-preserved palygorskite type clay minerals, suggests that the Hofuf Formation was deposited in a mudflat-dominated coastal plain environment.

http://www.sgs.org.sa/English/Earthquakes/Pages/Geohazard.aspx

2. Technological environment

General Environmental Protection Standards Applicable to Existing Facilities

1. All existing major facilities shall be operated and maintained so as to avoid excess of the ambient environmental standards promulgated for the Kingdom. Additional control technology shall be installed where necessary so as to avoid excess of the ambient environmental standards.

2. All existing facilities shall be operated and maintained so as to avoid the discharge of any toxic substance, whether specifically regulated or not, in sufficient quantities to be harmful to public health.

Pollution and SEVESO risks

Regarding the environment of the railway platform, we did not find an inventory of risks, establishments such as refinery, stocks hydrocarbon, gas pipes or water pipes, which could have a impact on a safe operation of trains in the event of an industrial accident or breakdown or explosion. If these institutions exist along the railroad, there is a perimeter of protection around these institutions: after one day trip from Dammam to Riyadh and return, it seems that the cement factories, oil installations, are far enough of the tracks if some fire or explosions happen in these factories.

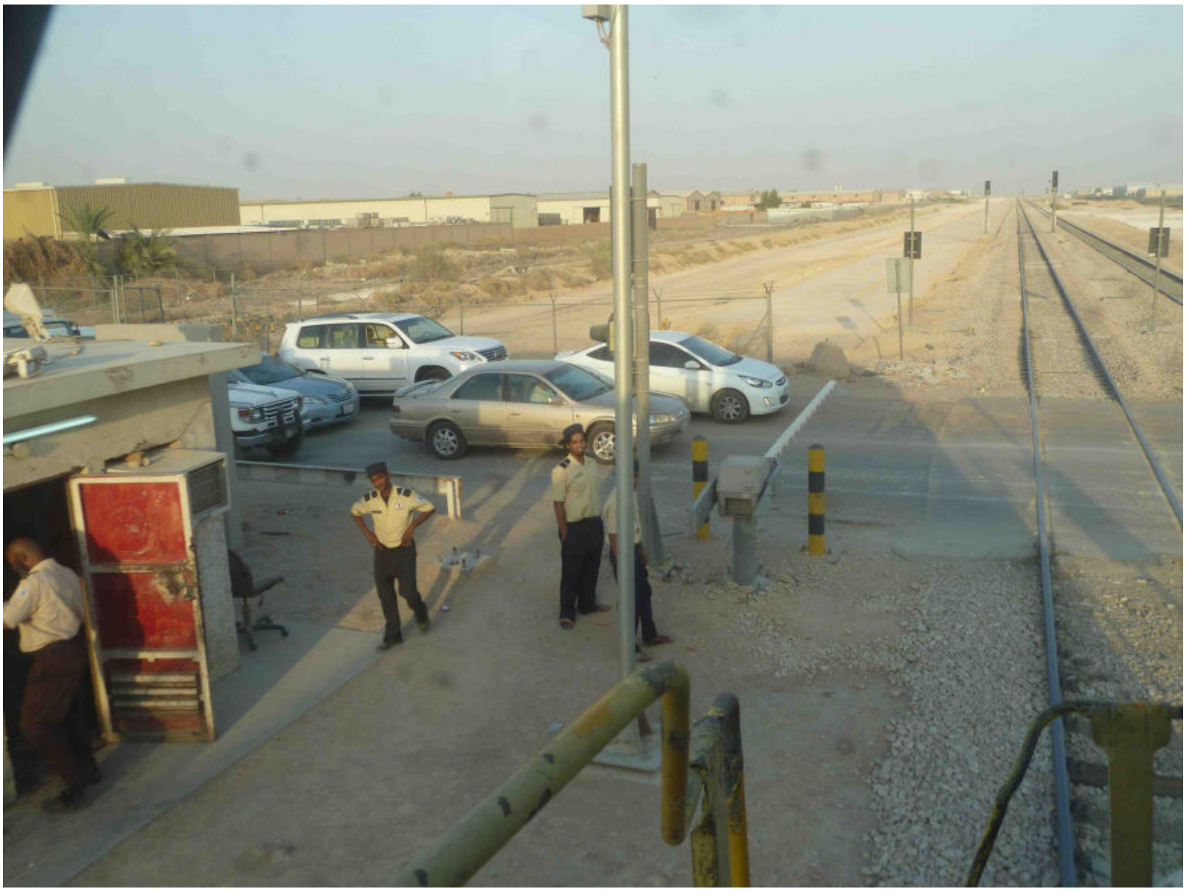
High-voltage lines

Many power lines pass over the railway platform and could be a danger to trains if some steel cable would break: in effect even if the voltage in the broken cable disappears immediately after the break disjunction, perhaps the wire may cause damage to the train passing below until to cause a derailment.

F. Kuhn

Environment of the railway project

The level crossings



F. Kuhn

A level crossing operating

Crossings are protected by signaling for trains and road vehicles as well as two bumps to force motorists to reduce speed of around 10 km / h and guards.


F. Kuhn

A level crossing

Freight trains


F. Kuhn

Freight trains that roll on a track parallel to that passenger trains can be hazardous in case of leakage, explosion or derailment when passing passenger train.

Cement factories

The two plants encountered along the line between Dammam and Riyadh seem sufficiently remote from railroads to present no danger if an explosion might occur in the ovens.

F.Kuhn

Cement plant

F. Kuhn

Cement factory

The oil plants

F. Kuhn

As for cement factories, oil installations seem sufficiently far from the railway line in case of fire or explosion: for big fire nevertheless important measures should be taken against toxic gases, passing trains stopping momentarily.

F. Kuhn

Oil plant

Earthworks site for the second railroad

The public works in progress for the second track should be conducted so as not to interfere with the operation of trains passing over the current single track: surveyors, survey vehicles and earthworks necessary for the second track should not be on the right of way of the track under operation.

F. Kuhn

F. Kuhn

Earthworks in progress to open the necessary space for the railroad

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