2.04.8 Climatological Information

The West Elk Mine site lies within the North Fork Valley near Somerset, Colorado. At the mine site, the valley is quite narrow and steep-sided and follows a general east-west orientation. A map of west central Colorado showing the mine site and the general vicinity is shown on Figure 1 in Section 2.01. Considerable topographic variation across the mine site, and west central Colorado in general, results in marked fluctuation in seasonal and average precipitation and temperature values for the entire area.

The mountains of the Continental Divide provide an effective barrier to the movement of moisture-laden air that reaches the Eastern Slope of the Rocky Mountains from the Gulf of Mexico. Thus, under this influence, two basic types of climate, semi-arid and undifferentiated highlands are characteristic of the general area where the mine is situated. Temperatures can range below freezing in the winter and yet in the summer, with the exception of higher elevations, can be extremely warm. The precipitation that does fall originates from the Pacific Ocean weather systems and most frequently occurs in the winter.

An on-site weather station was established at the West Elk Mine site in 1997. MCC contracted with IML Air Science of Pace Analytical (Pace) to conduct continuous recording of temperature, wind speed, wind gusts, wind direction, relative humidity, precipitation, barometric pressure and solar radiation. Pace provides annual reports of recorded data to MCC.

Regional

The West Elk Mine baseline climate study area was found to be subject to a synoptic pattern from a westerly direction. This is greatly modified by daily up-canyon (diurnal) and evening down-canyon (nocturnal) wind flows typical of mountainous terrain. Stable air conditions are known to occur in the North Fork, primarily during the winter. From fall to spring, considerable snowfall occasionally accompanies the low-pressure storms. Occurrences of severe weather are infrequent.

Figure 12 shows the West Elk Mine site and the stations that were used for the original permit temperature data collection (Paonia and Paonia 3 SE climatic stations) and precipitation data collection (Paonia, Paonia 3 SE and Wilcox Ranch climatic stations).

Temperature

The closest station to Somerset where temperature data were gathered was Paonia. The monthly temperature summary was recorded for highest maximum temperature observed, lowest maximum temperature observed, and mean monthly temperature. The Paonia 3 SE climatic station was also a source of temperature information. Graphs of the highest and lowest maximum temperatures observed and mean monthly temperatures for each station's period of record are included in Exhibit 22.

According to the data from 1957 and before, the temperature at Paonia 3 SE station has ranged from -28 ^{o}F in January 1913 to 100^{o}F in June, 1927, July and August, 1934. Typically, January has the lowest minimum temperature. July is consistently the hottest month (Colorado Climatologist, Department of Atmospheric Sciences, CSU).

December and February are months that have experienced low minimum temperatures, though not as cold as January, and are markedly distinct from the other months. November, with its lowest monthly mean average temperature of 30.6 ^{o}F, does not approach December, January, or February in experiencing low temperatures. Both November and March do have quite cold days occasionally, however. The lowest recorded November temperature is -10 ^{o}F. The lowest recorded temperature for March is -6 ^{o}F.

The months of May through September clearly comprise the warmest period. The maximum temperatures for May and September are 91 and 94 ^{o}F, respectively. Next are April and October with maximum temperatures of 84 and 86 ^{o}F. The lowest temperatures experienced during this period are 22 ^{o}F in May and 26 ^{o}F in September, and lows of 0 ^{o}F in April and 7 ^{o}F in October.

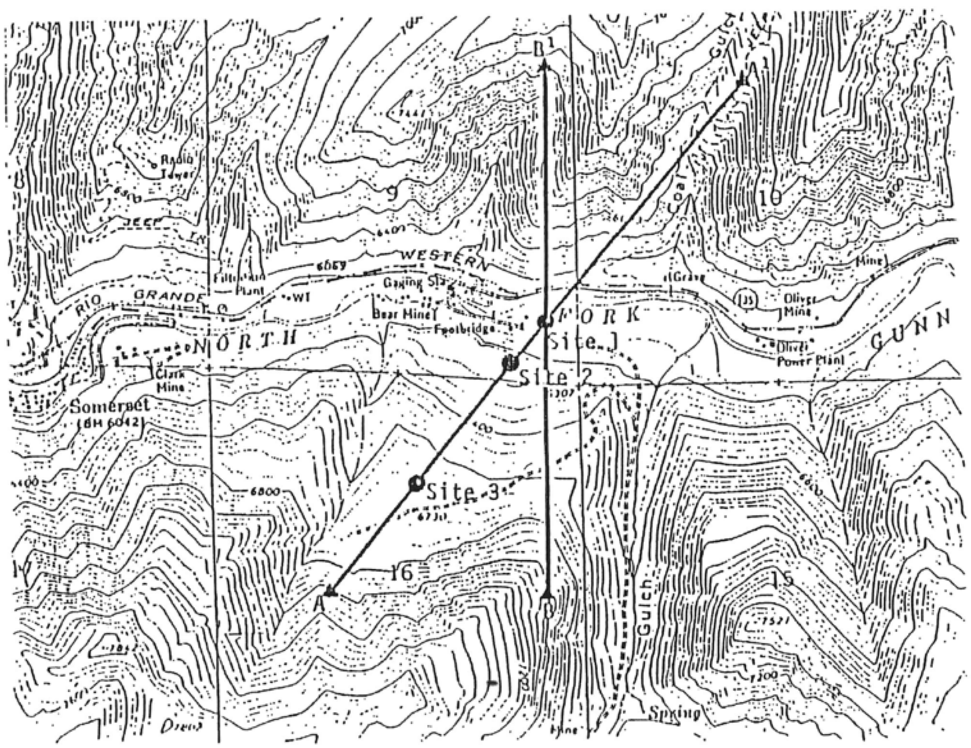

Figure 12 Baseline Meteorlogical Monitoring Site Locations, West Elk Mine

Precipitation

The West Elk Mine study area generally receives 16 inches of precipitation between October and April. There is an increase to 20 inches in the Wooten Mesa-Lion Mesa vicinity and also where the land rises toward the south into the Chain Mountains. Precipitation at higher elevations in the Chain Mountains to the south of West Elk Mine rises to 25 inches, while at the summits of Mount Gunnison and Coal Mountain it is 30 inches.

The May-September precipitation is generally eight inches near the study area. It rises to 10 inches in the Chain Mountains and 12 inches atop Mount Gunnison. It rises to 30 inches in the Lennox Mesa-Lion Mesa vicinity and the Chain Mountains, and to 40 inches atop Mount Gunnison and Coal Mountain (U.S. Department of Commerce, 1956).

Precipitation patterns are not obvious for the area. Precipitation has been lowest between May and November, especially between June and October; yet considerable precipitation has fallen during each of these months in one year or another. All months but November have received more than two inches at least in some years. Precipitation during April and June was most variable; the range between the maximum and minimum precipitation values spans 4.08 and 4.12 inches, respectively. January, August, and October varied more than 3.5 inches between the maximum and minimum values (U.S. Department of Commence, N.O.A.A. Environmental Data Service). See Exhibit 23 for specific information on precipitation at the area monitoring sites.

Paonia Stations

Precipitation values for the Paonia Stations are more complete than those for Wilcox Ranch (McKee, 1975). Monthly precipitation values, based on 51-53 years of data up to 1957 from the Paonia 3 SE station, are summarized graphically in Exhibit 23. An average of 15.75 inches of precipitation was received yearly there.

Highest average precipitation occurred in April (1.66 inches), and lowest in June (0.73 inches). The maximum monthly precipitation fell in March (6.40 inches). January received 4.38 inches in one year. February, April, May, June, August, September, October, and November all have received more than 3.3 inches of precipitation. The maximum precipitation recorded for July (1.97 inches) was noticeably lower than the next lowest recorded maximum (2.88 inches in December).

The minimum monthly precipitation fell during May, June, September, and October (all 0.00 inches). March (0.06 inches), November (0.08 inches), and December (0.09 inches) may also receive relatively low amounts of precipitation. April has always had a minimum precipitation greater than that of any other month. No clear pattern of precipitation distribution emerged for this station either.

The precipitation summary for the Paonia station is based on data from 15-16 years before and including 1972 (McKee, 1975). Data for this period are also summarized graphically in Exhibit 23. Maximum monthly precipitation fell in October (3.43 inches), but February (3.26 inches), April (3.11 inches), June (3.30 inches), September (3.37 inches), and December (3.24 inches) all received more than three inches at least once. The most precipitation recorded for May (1.75 inches) was noticeably lower than the next lowest value which was 2.34 inches in July.

The minimum monthly precipitation fell during October (0.00 inches). However, February (0.08 inches), June (0.06 inches), and July (0.05 inches) received quite low amounts also. December has never received as little precipitation as other months.

February, June, September, and October are the most variable in the amounts of precipitation they have received over the years. April, May, September, November, and December always received at least 0.1 inches precipitation on one or more days during the month. April, June, July, September, October, November, and December have each had 1.0 inch or more precipitation on one day of that month. Comparing this summary with the information on years before 1957 reveals no consistency (Colorado Climatologist, Department of Atmospheric Sciences CSU).

Horse Creek Precipitation Station

A precipitation storage gage was installed near Horse Creek on the south of the mine site. Monthly readings were recorded for several years at this station since June of 1977, weather permitting. The gage was destroyed during floods in late May, 1983. A new gage was installed at a nearby location on September 8, 1983. Monthly readings of precipitation for this station were reported in past Quarterly Hydrology Reports for the West Elk Mine.

Site Specific Conditions

For purposes of this section, Spring is defined as March 1 through May 31 and Summer as June 1 through August 31. Analytical presentations and discussions are included to define the meteorological characteristics of the West Elk Mine.

Site Description

The monitoring program for site specific information included three stations, identified as Site 1, 2, and 3, located in the immediate area of the mine. Figure 12 shows the location of each monitoring site. Site 1 was situated at an elevation of approximately 1,885 m (6,086 ft) above mean sea level (MSL) immediately adjacent to the river and just east and upstream from the mine facilities location. Site 2 was located approximately 260 m (853 ft) southwest of Site 1 at an elevation of approximately 1,908 m (6,260 ft) above MSL. Site 3 was located approximately 945 m (3,100 ft) southwest of Site 1 and further up the side of the river valley canyon at an elevation of approximately 2,038 m (6,687 ft) above MSL.

Several parameters were measured at each site. Wind speed, wind direction, and ambient air temperature were measured at all three sites. Equipment at Site 2 also recorded relative humidity and precipitation. Recovered data were defined as data that passed quality assurance and review as being valid reportable data. The following information summarizes the recovered and reported data as percentages of total possible data quantities for the report period. Any missing data were primarily due to instrument malfunctions.

Parameter	Site 1	Percent Recovery Site 2	Site 3
Wind Speed	70.77	52.97	79.12
Wind Direction	70.49	52.97	79.33
Ambient Air Temperature	68.75	51.65	75.25
Relative Humidity	---	43.93	---
Precipitation	---	53.12	---

Wind

Data collected during the spring and summer quarters of 1977 indicated winds varied at the three sites. Minimum wind speeds ranged from 0.6 mph to 1.4 mph. Maximum wind speeds ranged from 12.4 mpg to 19.7 mph. Mean wind speeds at the three sites were between 5.9 mph and 8.3 mph.

Hourly wind speed data showed a consistent daily pattern that was almost identical for Sites 1 and 2. The wind speed typically increased during the nighttime hours from about 7:00 p.m. Mountain Standard Time (MST), reaching a peak speed of about 10.5 mph at about 7:00 a.m. the next morning. The average wind speed dropped over two or three hours to reach a morning minimum speed of about 6.0 mph. It then rapidly increased to a second maximum of about 9.5 mph by noon, with a subsequent slow decrease to reach a late afternoon minimum of about 5.0 mph.

The average diurnal variation in wind speed at Site 3 was strikingly different from that at Sites 1 and 2. At Site 3, wind speed remained relatively calm throughout the nighttime hours. Starting at about 8:00 a.m., wind speed increased to about 8.0 mph by 11:00 a.m. It stayed at this level until about 3:00 p.m. when it began to decrease to its relatively constant nighttime level. Although the general shape of the diurnal wind speed curve at Site 3 was markedly different from those for Sites 1 and 2, there was a slight hint of an early morning (6:00 a.m.) relative maximum and a morning (8:00 a.m.) relative minimum. However, this behavior was much less predominant than at Sites 1 and 2.

The explanation of this variation is the existence of a well-established drainage flow down the canyon from east to west. A relatively large basin to the east of the area (headwaters of the North Fork of the Gunnison River) provided the volume of air to support this relatively intense flow which was funneled through the narrow canyon past the West Elk Mine site monitoring network. This drainage flow was almost directly opposed to the geotropic or gradient flow which is typically from the southwest. At sunrise, atmospheric heating reduces the horizontal pressure gradient which supports the drainage flow. The wind speed at Sites 1 and 2 dropped to relative minimum within several hours under this influence. Above this low altitude, high speed drainage layer, the winds at Site 3 remained relatively calm throughout the night and well into the morning hours. As discussed later these relatively calm winds were less intense drainage winds themselves.

The pronounced rise in the average wind speed at all sites during the late morning hours was primarily due to the breakup of the surface-based inversion, or stable air, within the valley. As the surface-based inversion was destroyed by solar heating, more vertical mixing of the air which was then associated with light and variable winds was able to occur and the surface air joined with the faster, more freely moving gradient flow at higher elevations. This effect occurred at all three sites, with the winds at Site 3 coupling about an hour sooner than those at Sites 1 and 2.

Another contributor to the rise in wind speed during this period was upslope flow conditions arising primarily from convection due to the more intense heating of the canyon or mountain sides and tops than heating of the valley or canyon bottoms. This convection upslope flow was generally in the direction of the gradient flow and was further reinforced by the mechanism described previously.

As the sun dropped later in the day, the vertical mixing began to diminish. This resulted in less vertical transfer of horizontal momentum from the upper level gradient flow to the surface layer and hence the wind speeds diminished at all three sites. As the sun set, the nocturnal surface-based inversion began to form. Once again, this resulted in the beginning of a drainage flow situation. As these drainage flows funneling through the canyon began to dominate at Sites 1 and 2, the average wind speed increased to its nighttime maximum. Being above the intense drainage layer, Site 3 experienced light drainage winds from higher terrain directly to the south which remained about 4 and 5 mph throughout the night.

Wind Speed and Direction

Because of the extreme topographical influence on the wind flows over the area, joint frequency distribution data between wind speed and direction, or wind roses, were developed for different segments of the day at each site. Complete data listings of all of these frequency distributions were compiled and are graphically presented in Exhibit 24. Each wind rose showed the percentage of time over the reporting period that the wind blew from a particular direction by plotting a bar in the compass direction from which the wind blew, with a length proportional to that percentage of occurrence.

At Sites 1 and 2 between midnight and 8:00 a.m., the drainage flow through the canyon was well established and virtually all winds during this period came out of the southeast. Although the major valley axis at this point runs from east-southeast to west-northwest, there is a bend in the canyon about 3,000 feet to the east which forced the flow to curve around and flow from the southeast. In addition, the minor tributary of Sylvester Gulch empties into the major valley immediately upstream from the monitoring site. Drainage from Sylvester Gulch flows due north, and as it merges with the drainage through the major valley itself, lends a south-southeasterly component to the flow.

Between 8:00 a.m. and 4:00 p.m., three wind regimes were present. During the earlier part of this period, drainage flows continued. Because the minor drainage component from Sylvester Gulch, which most likely ceases almost immediately after sunrise, was not present, the flow exhibited more of an east-southeast behavior. The light drainage through the main valley ceased about 10:00 a.m. After a short transition period, upslope flows began to dominate.

These upslope flows continued until about 4:00 p.m. The period from 4:00 p.m. to 8:00 p.m. was another period of transition. During this time, upslope flows decreased and downslope flows became dominant. By 8:00 p.m., the drainage flow pattern was once again well established.

The wind patterns of Site 3 significantly differed from those at Sites 1 and 2. Drainage flow at Site 3 came out of the south. In fact, there was a small component of the wind out of the south-southwest which opposed the major drainage flow at the lower levels. This indicated that Site 3 was above the major drainage flow at the lower levels and was simply measuring the light drainage from the higher terrain above it directly to the south. Periods of upslope flow also indicated that the terrain to the south of Site 3 dominated the winds at that site. Upslope flows were from the north, with few exceptions.

Temperature

The average diurnal variations in air temperature over the spring quarter at Sites 1 and 3 are presented in Figure 13. Data from the summer quarter are presented in Figure 14. The primary point of interest in both figures is the timing of the early morning temperature increase. During the spring, the temperature began its daytime climb an hour earlier at Site 3 than at Site 1. The air temperature during the summer quarter at Site 3 began its climb an hour earlier than at Site 2, which preceded the climb at Site 1 by an hour.

This indicated that the cold drainage flows diminished in intensity and vanished at the upper sites first. The vertical mixing and resulting upper-level flow coupling, which brought the relatively warmer upper-level air down to the surface, began with Site 3 and proceeded then to the level at Site 2, and finally reached Site 1 deep within the canyon about two or three hours after sunrise. This was easily understood by realizing that the canyon and mountain sides were heated faster than the canyon floor when the sun is low, as during the early morning.

Relative Humidity and Precipitation

The relative humidity at Site 2 averaged 58 percent during the summer quarter. Too little data exist for the spring quarter to make a meaningful comparison. Although this value seemed high, it should be remembered that the site was within a deep mountain canyon sitting at the base of a large mountain range.

The average relative humidity during the summer ranged from a 30 percent to 88 percent. The highest humidity occurred during extremely cold drainage flows. The lower average relative humidities occurred during unstable upslope flows. Overall, relative humidity ranged from five percent to 100 percent.

The total accumulated precipitation at Site 2 for the summer period was l.60 inches. Because of the low data recovery at Site 2 during the spring, the reported accumulation of 0.17 inches was not believed to be representative of the springtime precipitation.

Air Quality

Limited sampling at the West Elk site indicated relatively low concentrations of total suspended particulate matter even with the aridity of the region. The particulate data collected over the reporting period (March 1977 - March 1980) are presented in Exhibit 25. During this reporting period, measured particulate values did not exceed the federal secondary standard for particulates or the Colorado state ambient air standard for particulates (160 μg/m³).

Based on the above data, it appears that the background TSP concentration is on the order of 20 μg/m³, which is typical for a site like the West Elk Mine. The West Elk Mine site is currently subject to minor impacts from anthropogenic sources which detracts slightly from ideal pristine conditions.

Only one high-volume sampler was used. This sampler was located at Site 2 (Figure 12) atop a scaffold with the intakes at a height of 4.7 m above the surface. Site 2 was located near (about 400 m) a local underground coal mine with surface crushing facilities and unit train load out.

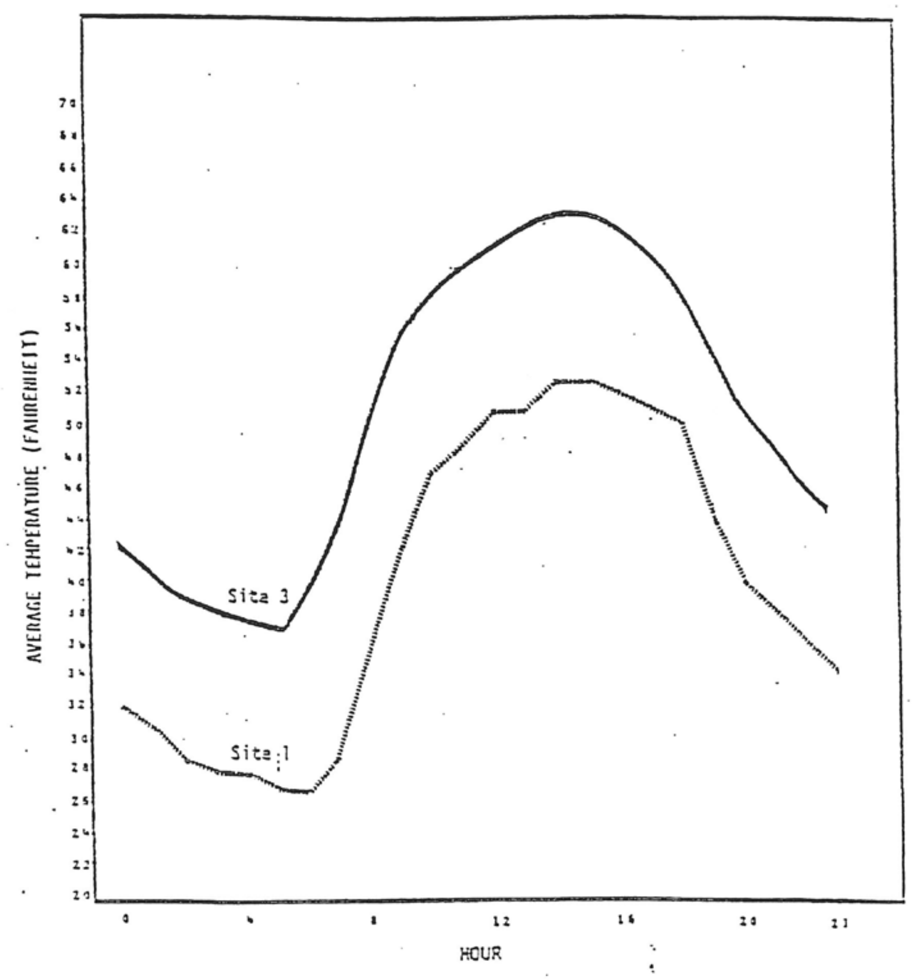

Figure 13 Diurnal Variation of Average Air Temperature at Site 1 and 3 During the 1977 Spring Quarter, West Elk Mine

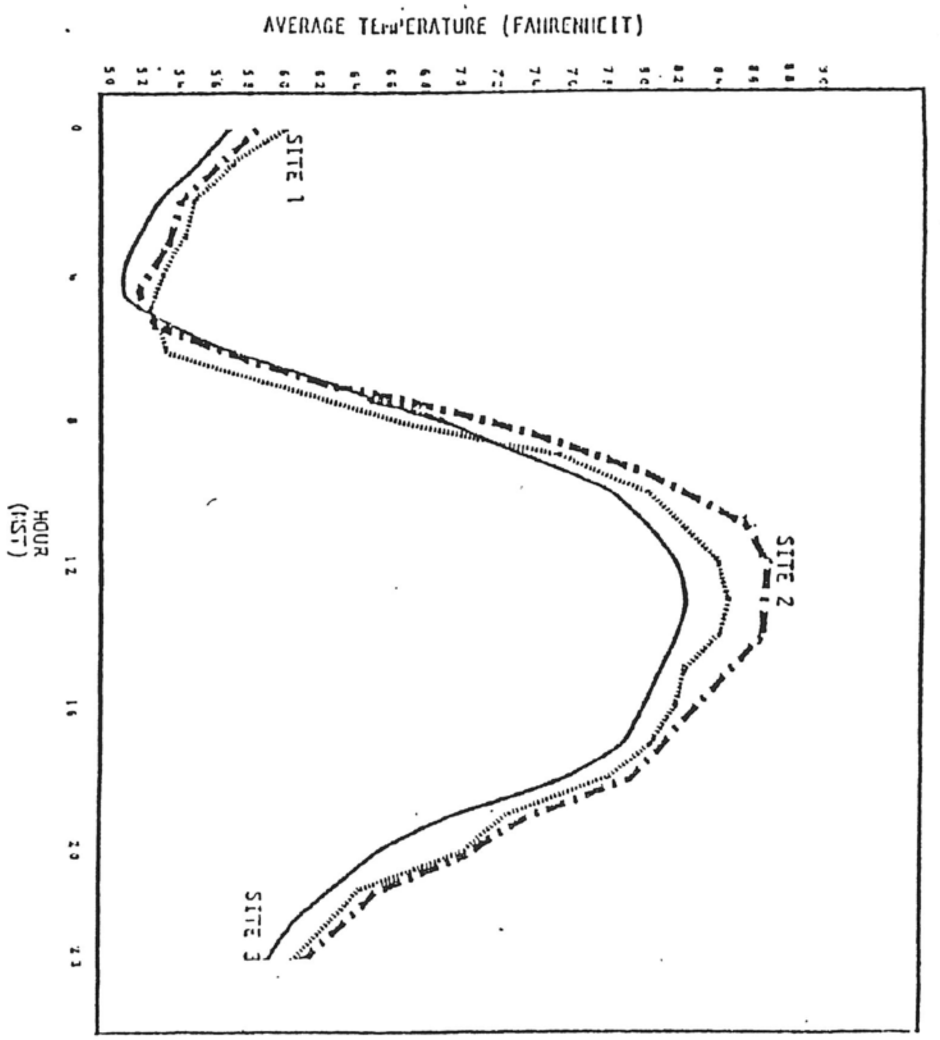

Figure 14 **Diurnal Variation of Average Air Temperature at Sites 1, 2, and 3 During the 1977 Summer Quarter, West Elk Mine**

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