AIR DISPERSION MODELING

-Report-

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1 Introduction

The “Public Enterprise for State Roads” proposes to construct the A2 highway Gostivar – Kichevo, part of which is the Bukojchani – Kichevo branch.

As part of the Environmental and Social Impact Assessment that is being conducted for the proposed branch, an air dispersion modelling analysis has been undertaken to assess the impact of the air pollutants from the construction activities and the traffic on the future highway on the ambient air quality.

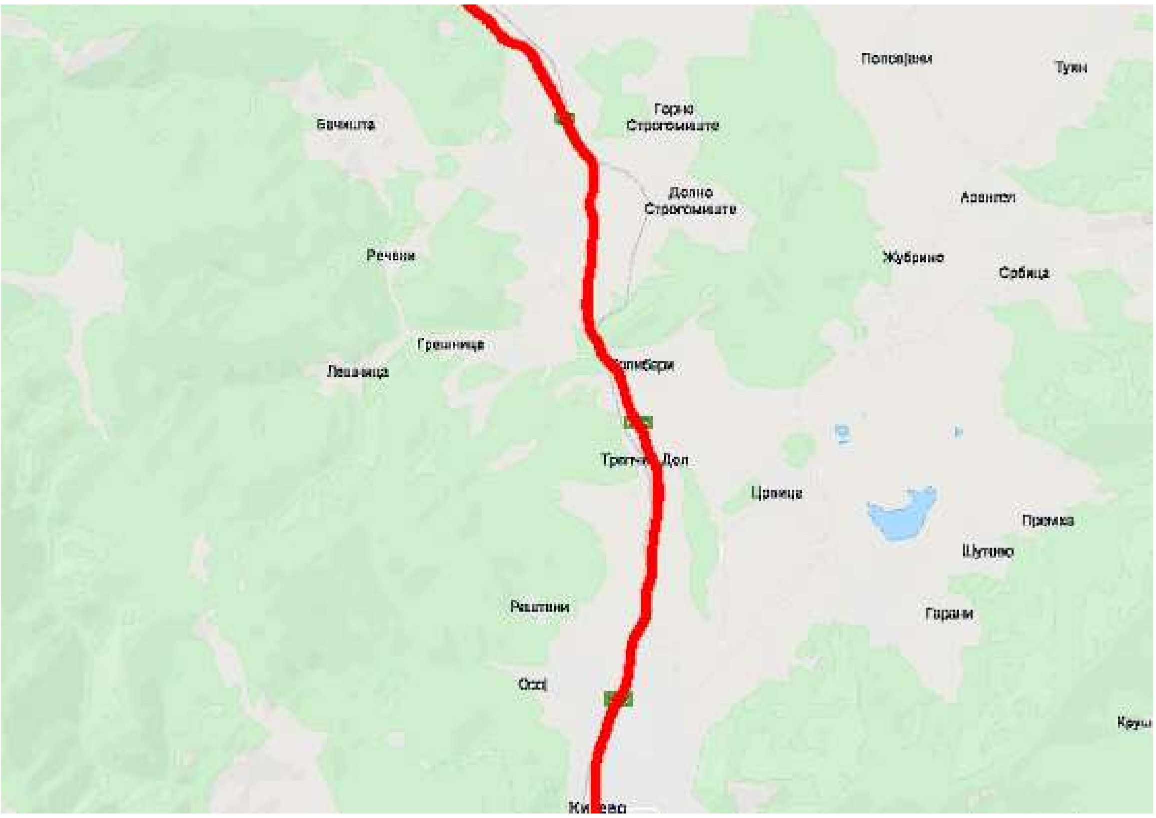

Figure 1 Map showing the existing road

At present, the traffic takes place on the regional road that passes through several small settlements and the town of Kichevo as shown in fig. 1. Fig. 2 shows the route for the new highway which is mostly away from the settlements and runs down a 730 m long tunnel.

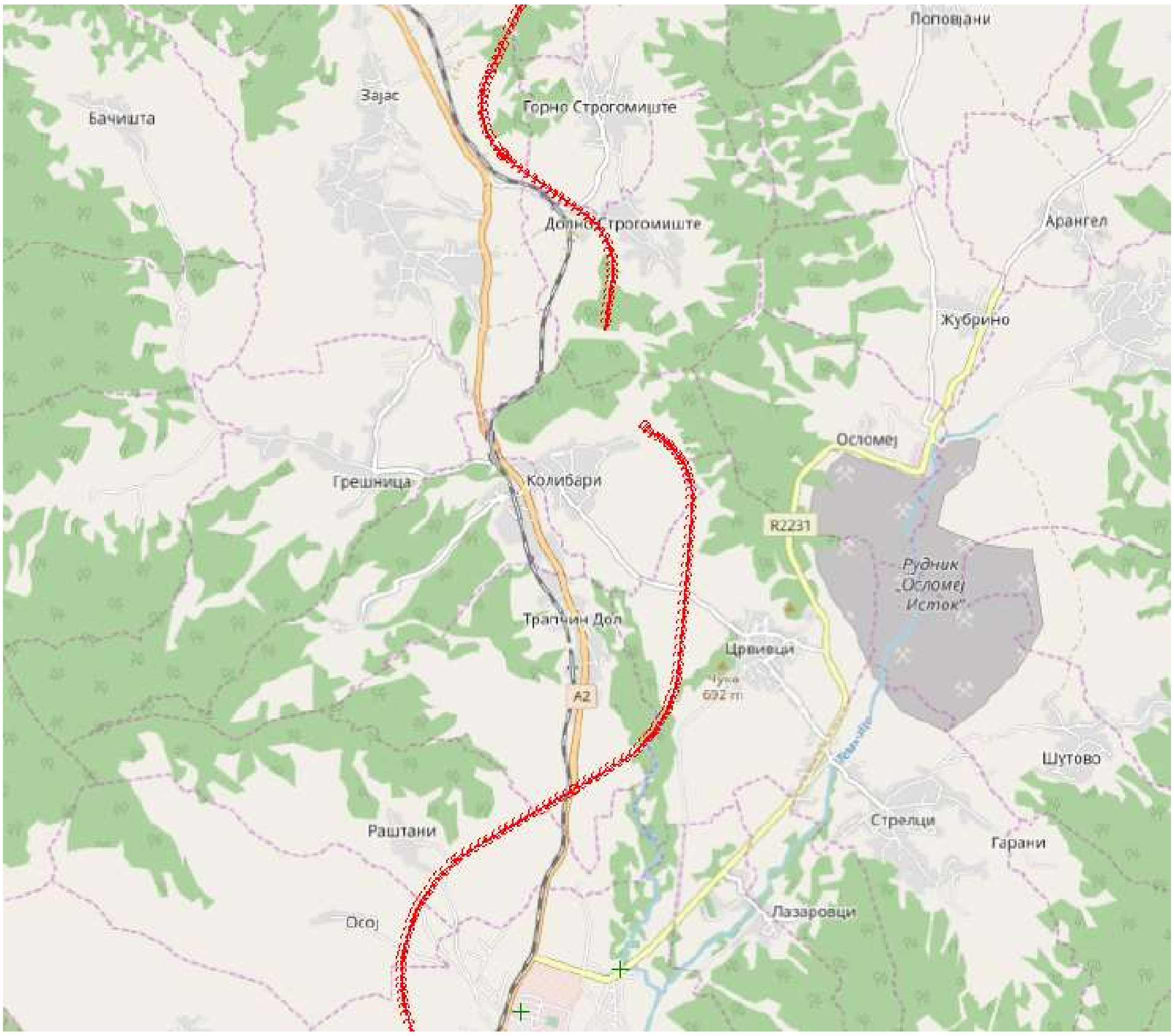

Figure 2 Route of the proposed highway branch

This report describes the air dispersion modeling analysis for PM10 from the construction activities which will most probably start in 2020 and NO_2, PM10, PM2.5 and CO during the highway operational phase. The operational phase of the highway is planned to begin in 2023, while 2040 has been reviewed as a future year. For the purpose of this assessment the following scenarios have been set up:

1. Base Year – 2018
2. Construction Year – 2020
3. Start year – 2023 with and without the highway being constructed
4. Future year – 2040 with and without the highway being constructed

The guidance Air dispersion modeling report requirements(for detailed air dispersion modeling) http://www.theairshed.com/wp-content/uploads/2018/03/EA-requirements-for-dispersion-modelling.pdf was followed in preparing this report and the recommendations were met as much as it was possible.

The Macedonian environmental legislation lacks a definition of “significant impact” and therefore the model results added to the background concentrations have been compared with the national and the European air quality standards with PM2.5 being an exception since no background data were available for it.

2 Environmental Air Quality Standards

Ambient air limit values for the concentrations of particulate matter (PM10), sulphur dioxide, nitrogen dioxide and carbon monoxide, according to the *Decree on the limit values of concentrations and types of polluting substances in the ambient air and alarm thresholds, deadlines for complying with the limit values, tolerance margins for the limit values, target values and long term goals (O.G.RM No.50/05*), are shown in Table 1. Tolerance margins and approaching rates are not shown in the table because the deadlines have expired since2011. Only the values for phase 1 are shown because the date of entering into force of the phase 2 limit values is not known yet.

Table 1 Ambient air limit values for SO2, PM10, NOx, benzene, SO2 and CO

Substance	Unit	Limit Value	Allowed exceedance per year
SO2 1 Hour 24 Hours Year (protected areas)	μg/m^3	 350 125 20	 24 times 3 times
PM10 24 часа Година	μg/m^3	 50 40	 35 times
NO_2 1 hour Year (human health protection) Year (vegetation protection)	μg/m^3	 200 40 (NO_2) 30 (изразени како NO_2)	 18 times
CO Daily (8 hourly mean)	mg/m^3	10	

The national air quality standards follow the air quality standards set in Annex 11 to the Directive 2008/50/EC on ambient air. Table 2 is an excerpt from table B thereof.

Table 2 Limit values (μg/m^3)for concentrations of certain pollutants in the air as determined in Directive 2008/50/EC

Pollutant	Hourly	24 hourly	Annual
NO2	200 (18 exceedances permitted per year)		40
PM10		50 (35 exceedances permitted per	40

		year	
PM2.5			25
SO2	350 (24 exceedances permitted per year)	125 (3 exceedances permitted per year)	
CO		10000 (8 hourly mean)	
Benzene			5

3 Baseline Environmental Air Quality

No data on the air quality along the future highway were available except those obtained from the automatic ambient air quality monitoring station placed in Kichevo and run by the Ministry of Environment and Physical Planning (http://air.moepp.gov.mk/?page_id=175&parameter=SO2&station=Kicevo). This station is located within the town and records data for a limited number of pollutants (O_3, CO, NO_2, SO_2 and PM10). Some of the data are with a number of missing values. Concentrations of all the measured pollutants except those for PM10 are far below the limit values. CO and PM10 concentrations are much higher during heating seasons suggesting that they are predominantly emitted from household heating units (Figure 3).

77 exceedances of the PM10 daily limit value were registered in 2018 and almost all of these were during the heating season.

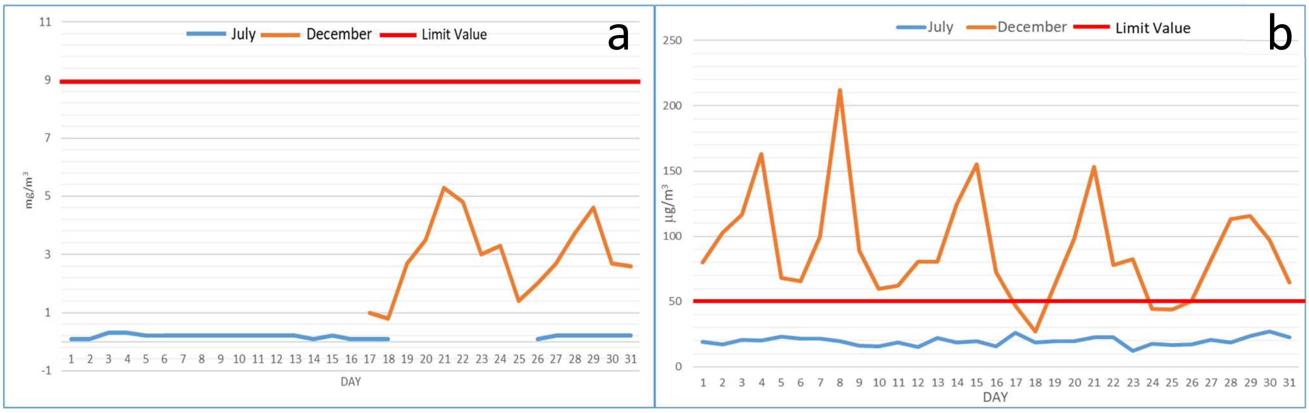

Figure 3 Daily concentrations of CO (a) and PM10 (b) at the monitoring station in Kichevo in July and December 2018 (Source: MOEPP Monthly Reports)

In order to minimize the impact of missing values, a five-year dataset covering the period from 2014 through 2018 was examined. The results are shown in

Table 3 to

Table 7.

The PM10 measuring device was out of operation for most of the summer time in 2019, and the results obtained for 2019 during its operation until October suggest higher level of PM10 in the air than the two previous years (around 52 $\mu g/m^3$). Based on the available data, a forecast has been made for 2020 (the year when the construction activities are expected to take place) and 2023 (the expected starting service year.

Table 3 Monthly averages of PM10 concentrations in the air as measured at the Monitoring station in Kichevo - missing data have not been taken into account (Source: MOEPP database)

	2014	2015	2016	2017	2018	Average
Jan	142.2	214.3	116.5	115.0	73.5	132.3
Feb	107.6	125.6	68.5	87.2	57.0	89.2
Mar	76.0	87.3	53.4	48.7	43.3	61.7
Apr	56.5	59.3	40.7	36.1	29.9	44.5
May	35.7	42.8	28.4	22.6	23.0	30.5
Jun	41.6	30.4	29.9	24.2	17.5	28.7
Jul	40.1	38.0	36.0	27.1	20.0	32.2
Aug	45.6	36.1	35.8	31.2	26.0	34.9
Sep	40.2	33.9	40.9	20.4	22.7	31.6
Oct	65.3	49.0	51.6	34.7	38.4	47.8
Nov	127.9	83.2	90.3	63.7	65.5	86.1
Dec	136.5	152.3	137.1	61.8	90.5	115.6
Average	76.3	79.3	60.8	47.7	42.3	

Table 4 Monthly averages of NO_2 concentration in the air as measured at the Monitoring station in Kichevo - missing data have notbeen taken into account (Source: MOEPP database)

	2014	2015	2016	2017	2018
Jan				42.7	
Feb				34.8	
Mar				32.6	
Apr				29.6	
May			8.6		14.6
Jun			8.3		18.2
Jul			11.9		15.6
Aug			14.0		17.0
Sep			16.0		19.2
Oct			14.2		24.6
Nov			21.4		
Dec			43.4		21.7
Average			17.2	34.9	18.7

Table 5 Monthly averages of CO concentration in the air as measured at the Monitoring station in Kichevo - missing data have not been taken into account (Source: MOEPP database)

	2014	2015	2016	2017	2018	Average
Jan	2400	2137.0	2327	2388		2313.0
Feb	1900	1426.8	1162	1467	1081	1407.4
Mar	458	957.3	759	752	1108	807.1
Apr	458	968.2	757	642	1121	789.2
May	909	407.4	781	802	205	575.7
Jun		384.5	550	448	125	353.2
Jul		468.9	426		130	341.6
Aug		374.6	264		142	260.4
Sep		374.8	273		172	273.1
Oct		746.6	616			681.5
Nov		1281.9	1185			1233.3
Dec	1498	1763.2	2033		1550	1710.9
Average	1376.7	1023.5	1011.6	1453.4	765.1	

Table 6 Monthly averages of SO_2 concentration in the air as measured at the Monitoring station in Kichevo - missing data have not been taken into account (Source: MOEPP database)

	2014	2015	2016	2017	2018	Average
Jan	0.7	2.3	0.7	1.6	1.0	1.3
Feb	0.8	2.0	0.7	0.8	1.7	1.2
Mar	0.8	1.2	0.4	1.0	1.6	1.0
Apr	0.8	1.2	0.4	1.0	1.6	1.0
May	0.3	1.1	0.4	0.5	0.5	0.6
Jun	0.3	0.9	0.7	0.5	0.5	0.6
Jul	0.3	1.0	0.5	0.8	0.5	0.6
Aug	0.3	0.7	0.5	0.7	0.3	0.5
Sep	0.4	0.7	0.7	0.8	0.8	0.7
Oct	0.6	0.7	0.9	1.2	0.5	0.8
Nov	1.3	0.7	1.1	1.6	0.5	1.0
Dec	1.5	1.9	0.7	1.6	1.0	1.3
Average	0.7	1.2	0.6	1.0	0.9	0.9

Table 7 Monthly averages of O_3 concentration in the air as measured at the Monitoring station in Kichevo - missing data have not been taken into account (Source: MOEPP database)

	2014	**2015**	**2016**	**2017**	**2018**
Jan	25.0	23.7	16.1	36.7	19.9
Feb	25.0	29.5	30.9		29.6
Mar	39.6	36.6	39.0		45.1
Apr	39.8	36.1	40.0		45.1
May	39.1	41.6	40.4	46.7	51.5
Jun	38.8	39.3	37.5	40.4	49.6
Jul	39.4	44.1	43.7	48.0	57.2
Aug	38.6	39.4	44.5	44.3	53.6
Sep	23.9	32.4	35.1	29.1	32.2
Oct	27.4	18.7	28.7	20.5	
Nov	16.2	20.8	34.8	13.5	
Dec	14.2	16.4	34.2	26.2	27.1

Since PM10 originate mostly from heating in cold seasons, the community is focused on reducing emissions from such sources. Two programs are ongoing presently aiming at substituting wood burning stoves with pellets and gas. A significant number of households are expected to switch to pellets during the winter 19/20. Although the trend line in Figure 4 forecasts much lower concentrations, It is reasonable to expect a reduction of PM10 down to an annual average of 20 $\mu g/m^3$ in 2040.

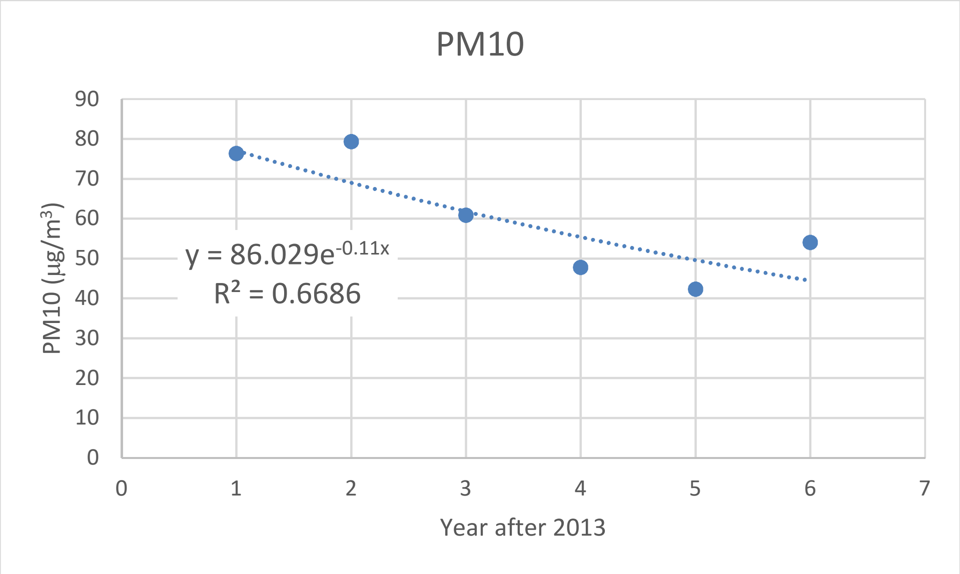

Figure 4 Concentrations of airborne PM10 from 2014 to 2019

PM2.5 is only monitored at two locations in the capital city of Skopje, about 63 km north-east from Kichevo. One of these is in the city center and the other at the periphery. An attempt was made to assess the PM2.5/PM10 ratio by comparing the data for these locations. The historical data collected so far indicate a small difference in PM10/PM2.5 ratio. It is lower in the city center, but the correlation coefficient is lower at the periphery.

A three-day monitoring campaign less than 20 m from the existing road at the eastern edge of the town of Kichevo was carried out in December 2019. The hourly values show a higher PM2.5/PM10 ratio and a higher correlation coefficient. Having in mind the significant difference in the ratio values and the shortness of the monitoring period, no valid conclusion can be made on the long term concentrations of PM10 in the ambient air along the road.

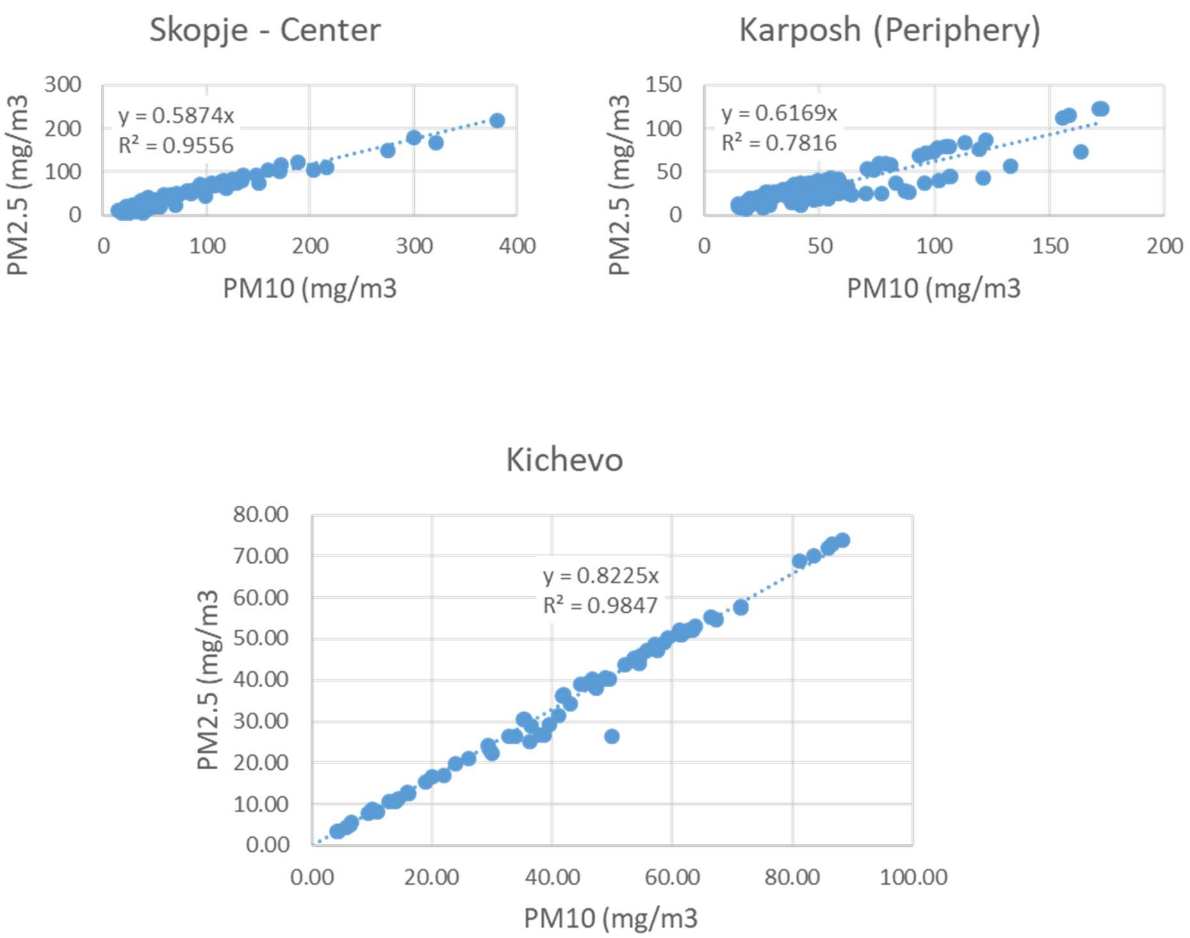

Figure 5 PM2.5 vs PM10 graphs for Skopje-Center, Skopje-Karposh and Kichevo (Linear coeffitients indicate PM2.5/PM10 ratio)

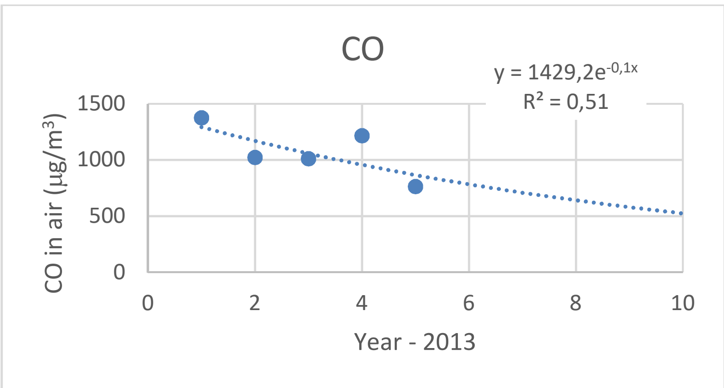

Figure 6 Air concentrations of CO from 2014 to 2018

The average annual concentrations of SO_2 in ambient air vary randomly between 0.6 and 1.2 μg/m^3. Therefore, no significant changes in the background SO_2 concentrations in the ambient air are expected in the future Years.

The concentrations of PM10, NO_2, CO and SO_2 were examined against the wind direction. The hourly average concentrations of the pollutants for wind direction groups are shown in Figure 7 to Figure 10.

Obviously, the distribution of background concentrations of the pollutants do not share the same pattern.

Concentrations of PM10 are highest when wind blows from north. NO_2 exibits a similar pattern, but the maximum concentrations are more evenly arranged between northwest and west.

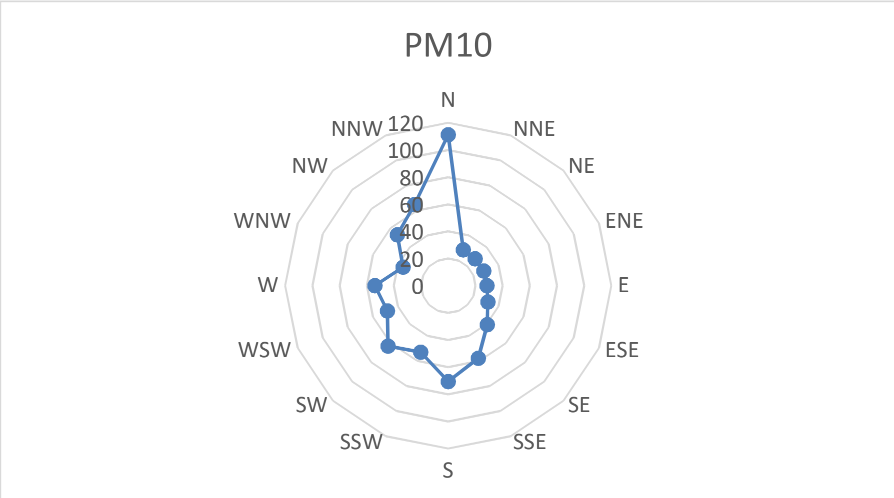

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Figure 7 Plot of average hourly concentrations of PM10 vs wind direction for 2018

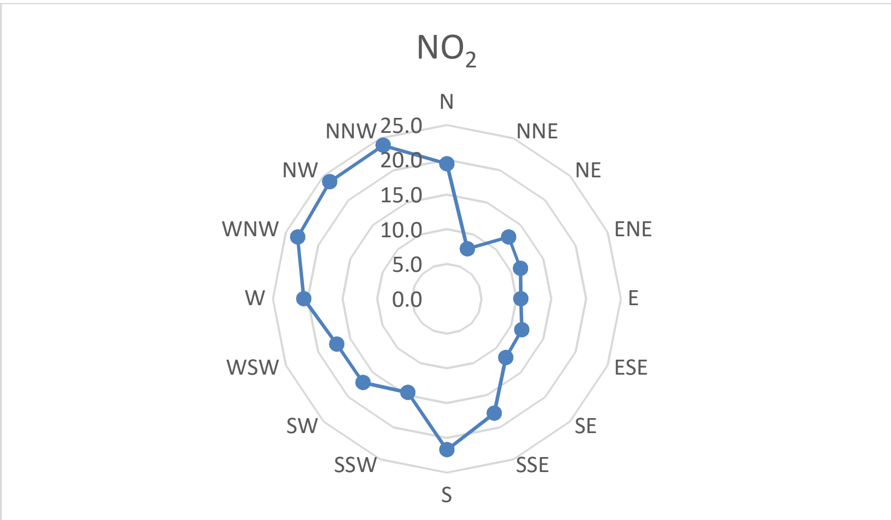


Figure 8 Plot of average hourly concentrations of NO_2 vs wind direction for 2018

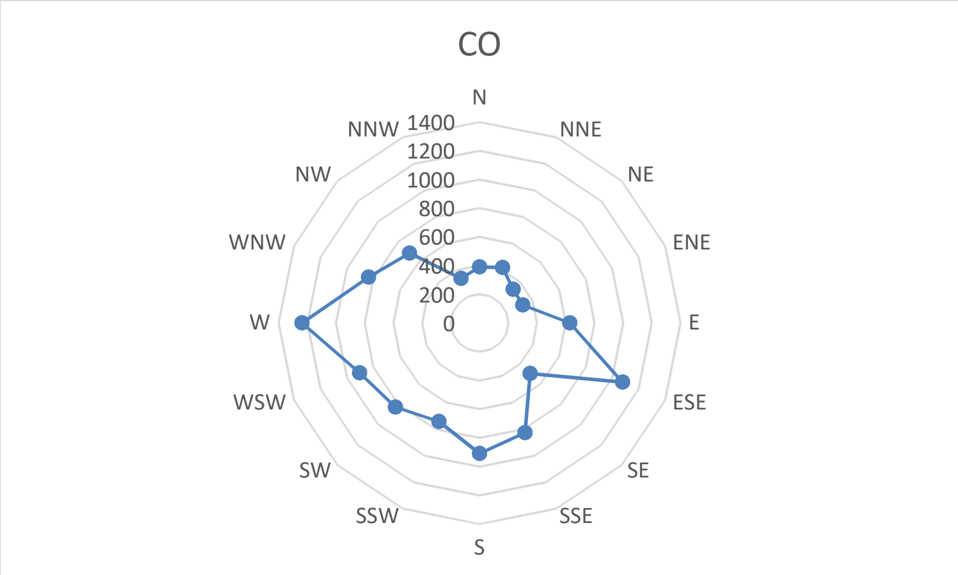


Figure 9 Plot of average hourly concentrations of CO vs wind direction for 2018

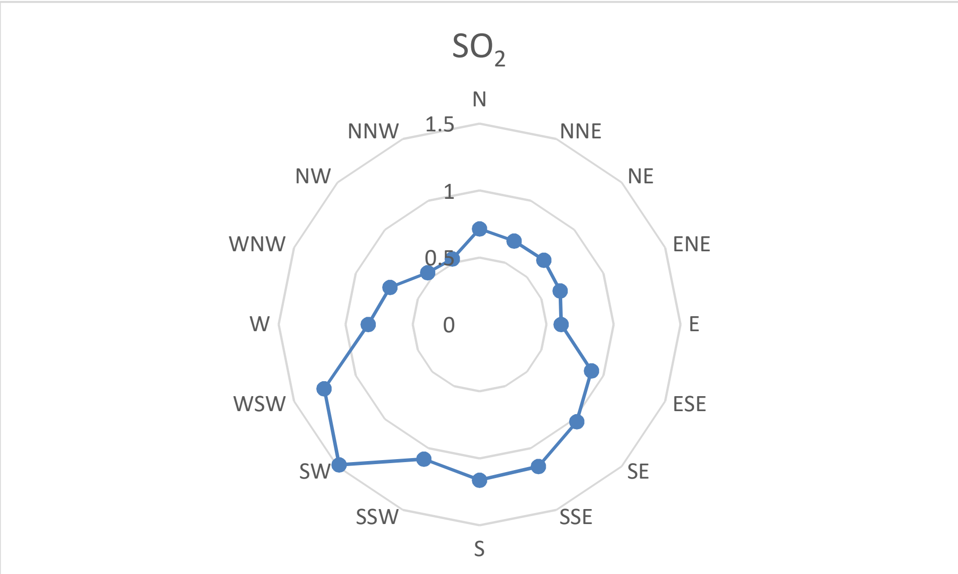


Figure 10 Plot of average hourly concentrations of SO_2 vs wind direction for 2018

AIR DISPERSION MODELING METHODOLOGY

1 Modeling Approach

The air emissions from construction and use of the motorway have been analysed by means of AERMOD version 18081 software package of the USEPA (United States Environmental Protection Agency) with its Windows interface (AERMOD VIEW release 9.6) from LAKES ENVIRONMENTAL Co. This model is used extensively to assess pollution concentration and deposition from a wide variety of sources. For the purpose of this exercise emissions from transport in both the construction and exploitation phases were dealt with as line area sources. Emissions from excess soil dump sites were dealt with as from area sources. Information on the sources of emission is given later in this report.
Aermod is a steady state Gaussian-plume model and is usually applied when dispersion from point sources is modeled. However, it can also be used in cases of linear sources such as highways provided that meteorology may be considered uniform within the modeled area, and periods of calm are rare. Gaussian models provide poor results in situations with low wind speeds, where the three-dimensional diffusion is significant. Other models such as CALINE 4 are also limited regarding wind speed.

The meteorological data for this assessment cover an area within a radius of 12 km and the calm period is 2.19%. The only drawback of using AERMOD in this assessment can be the steadiness of the sources of emissions. However, in absence of historical data on variation of traffic frequency the same uncertainty would occur regardless the model used for assessment.

Relevant meteorological data were obtained from Lakes Environmental Co. as MM5 Met Data (Regional Mesoscale Model for Creating Weather Forecast and Climate Projections). A three-year data set covering the period from 2016 through 2018 was examined. Meteorological data are dealt with later in Ch. 2.4.

2 Construction Phase

It has been assumed that the motorway construction activities will take place in 2020.

It is quite certain that the construction activities will not take place on the whole route simultaneously. However, as a worst-case scenario, it was assumed that the construction works will take place throughout the year 2020 along the entire highway section.

The model predicts ground level concentrations due to emissions of polluting substances. Following data are required to perform modeling:

- Emission sources (type, characteristics, emission rate)
- Terrain data (topography)
- Data on nearby buildings
- Receptor coordinates and heights
- Meteorological data

By means of the software package the expected average annual concentrations, maximum daily concentrations as well as the 98 percentiles of the latter, equivalent to exceedance of 7 days per year have been calculated.

2.1 Emission Sources

Road construction air emissions are generated by the following activities:

- Blasting and excavating
- Material loading and unloading
- Transportation of earth and other materials along the haul roads and the motorway alignment (including movement of empty dumpers)
- Wind erosion and
- Emissions of exhaust gas from vehicles and other machinery.

2.1.1 Emissions from drilling and blasting

No blasting program has been prepared yet. Therefore, no data on emissions from these activities are available. However, due to the short time required and low emission rate from drilling and blasting, a negligible error may be expected by excluding these emissions from modeling.

2.1.2 Emissions from traffic on haul roads and motorway alignment

Access roads to and from dump and borrowing sites have not been clearly defined yet, and therefore, the shortest possible routes have been taken into account. An important part of the route on which the earth and other materials will be transported, will be the motorway alignment itself

It has been foreseen that about 240000 m^3 earth have to be excavated transported and disposed of on three landing sites and about 700000 m^3 just to be excavated and reused. In addition, 170500 m^3 tampon material has to be brought to construct the motorway. If dumpers of 15 m^3 are to be used, about 55000 tours will be made during the construction period. Considering that the dumpers will travel 5 kilometers in one direction, 550000 kilometers will be traveled in total during the construction period.

A suitable methodology for assessment of particulate matter emissions from different types of roads, including haul roads has been developed by US Environmental Agency (USEPA). This method is extensively used in a number of countries including Australia (NPI). According to Chapter 13.2.2-2 of AP-42 (Air Protection Emission Factors: AP-42), particulate matter (PM10) air emissions from vehicles movement on different types of roads can be assessed by applying the following empirical equation:

$$\mathrm{E} = k \cdot \left(\frac{SL}{12}\right)^{a} \cdot \left(\frac{W}{3}\right)^{b} \cdot \left(1 - \mathrm{E}_{ff}\right) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Where:

k, a,b - Empirical coefficients
SL - Silt content (g/m^2)
W - Average mass of vehicle (t)
Eff - Efficiency of abatement measures

Table 8 Constants for equation 1 (Source: AP 42 Ch.13.2.2)

	Particulate matter class		
	PM-2.5	PM-10	PM-30*
k (kg/VKT)	0.042	0.42	1.36
a	0.9	0.9	0.7
b	0.45	0.45	0.45

* (Vehicle Kilometer Traveled)

It is envisaged that access roads surfaces are kept wet by regular water spraying and three water trucks will be engaged for this purpose. The application of such an abatement system may reach an efficiency of 90 % but, as the worst case scenario, an efficiency of 70 % was applied for the calculations.

According to the above, the PM10 air emissions arising from material transportation will be:

$$\mathrm{E} = 0.42 \cdot \left(\frac{8.3}{12}\right)^{0.9} \cdot \left(\frac{40}{3}\right)^{0.45} \cdot (1 - 0.7)$$

$$\mathrm{E} = 0.27\ kg/VKT$$

Accepting an active truck plume surface of 8 m, an emission factor of $2.9 \cdot 10^{-5}$ g/m^{2}s is calculated.

2.1.3 Material loading and unloading

The emissions generated by material loading at the excavating site and unloading at the landing site have been estimated according to the instructions in chapter 13.2.4 of AP – 42 where the application of the following equation is recommended:

$$\mathrm{E} = k \cdot 0.0016 \cdot \frac{\left(\frac{U}{2.2}\right)^{1.3}}{\left(\frac{M}{2}\right)^{1.4}} \quad \text{..(2)}$$

Where:

E - Particulate matter emission factor (kg/t)

k - Particulate matter size coefficient - dimensionless (Values are given in Table 9)

U - Average wind speed (m/s)

M - material moisture (%)

Table 9 Values for k in equation 2 (Source: AP 42 Ch.13.2.4)

PM size	K
PM 2.5	0.053
PM5	0.2

PM 10	0.35
PM 15	0.48
PM 30	0.74

According to the meteorological data, the average wind speed during 2016 through 2018 was 3.19 m/s. No confirmed data on material moisture are available and the suggested value is 10%.

By applying equation (2) an emission rate of $1.6 \cdot 10^{-6}$ g/m^2s, or 1,477 g/s has been calculated.

2.1.4 Emissions from open areas

For assessing the emissions from open area caused by wind erosion, the emission factor given in the Emission Estimation Technique Manual for Cement Manufacturing of the Australian Department of Environment, water, Heritage and Arts (0.3 kg/ha/h or $8{,}33 \cdot 10^{-6}$ g/m^2s) was used. Unlike material transportation and handling, the emissions from open area are continuous and depend only on the wind speed and soil characteristics.

Three landing sites with an overall area of 97100 m^2 have been planned along the motorway construction site. Accordingly, an emission rate of 0.81 g/s has been calculated.

2.1.5 Emissions from internal combustion engines

The overall power of the machinery engaged for carrying out the earthworks will be about 12610 kW.

The average emission factor for internal combustion engines is 0.754 g/kWh and therefrom an average emission rate of 2.45 g/s has been derived. The whole machinery will certainly not operate simultaneously. So the emission rate will be even lower.

2.2 Terrain

The terrain along the adopted route is both flat and elevated crisscrossed with existing and temporary watercourses which flow into Zajaska River. The above sea level of the road varies between 650 and 750 while the closest hills reach 900 m asl. Vast part of the terrain is rural. Only a very small part on the south may be considered sub-urban.

2.3 Impact of Nearby Buildings

There are no buildings along the envisaged construction site that may have impact on the airborne particulate matter dispersion. The terrain configuration will rather have certain impact.

2.4 Receptors

A uniform Cartesian receptor network has been created covering an area of 12 X 12 km with a density of 250 X 250 m.

Five sensitive receptors were detected within the modeling area during the construction phase. These receptors were chosen based on the number of people living or gathering there. They are listed in Table 10 below.

Table 10 Locations of sensitive receptors

Receptor Name	UTM Coordinates	
	X (m E)	Y (m N)
Primary School	496450	4596350
Mosque	495921	4596534
University	496790	4596510
Military Barracks	496320	4596910
Sports Center	497320	4597330

All the coordinates in this study are in UTM (Universal Transverse Mercator) – T-34.

SRTM3 maps (shuttle Radar Topography Mission) were used for the terrain topography. The terrain with the modeling domain and the receptor grid is shown in Figure 11.

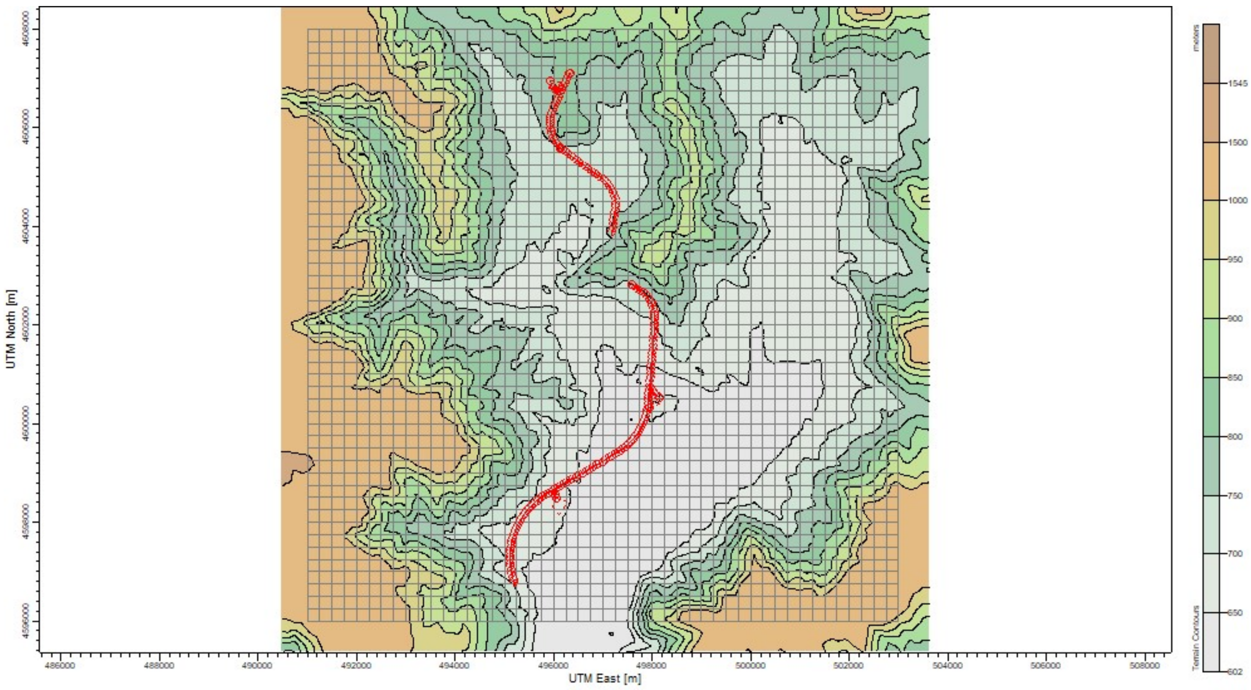


Figure 11 Terrain topography and receptor grid

For better orientation, a geo referenced photography of the terrain is inserted in the background as shown in (Figure 12).

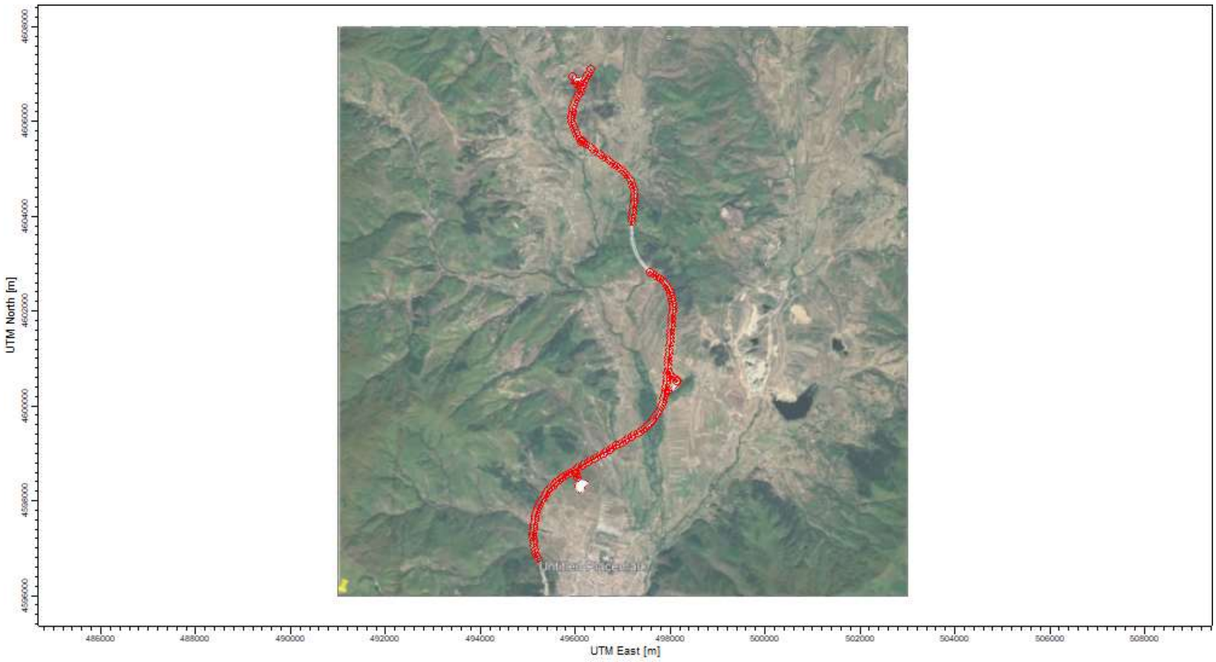


Figure 12 Satelite photography in the background of the modeling domain

2.5 Meteorological Data

Since no continuous hourly values of meteorological data as required for performing air dispersion modeling were available on site, these were purchased from Lakes environmental as MM5 (Regional Mesoscale Model for Creating Weather Forecast and Climate Projections) meteorological model. These data are preprocessed for use with Aermet View and then with Aermod View software package air dispersion modeling.

A three year set of data has been purchased covering the period from 01.01.2016 to 31.12.2018.

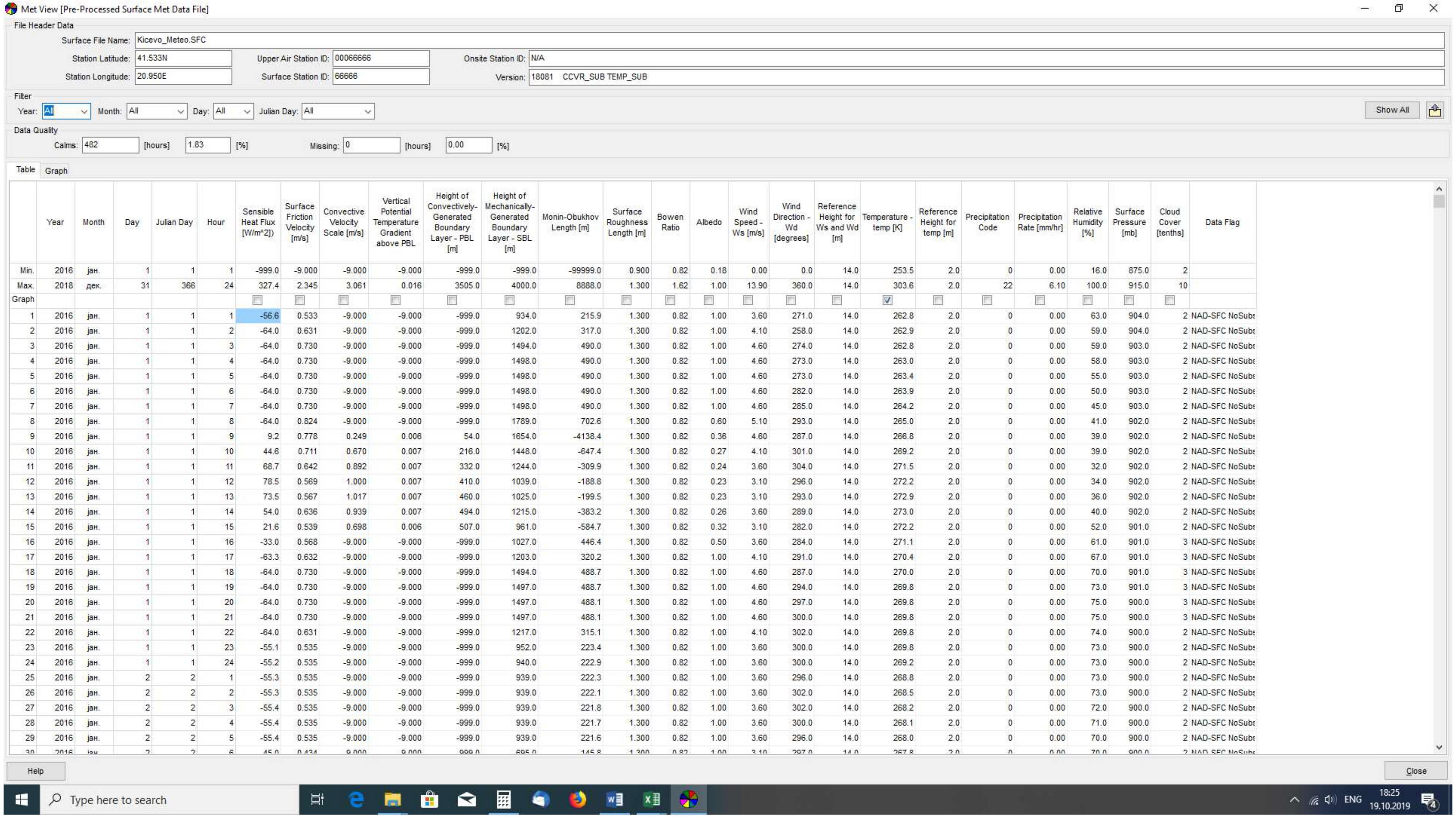
The following is a non-exhaustive list of data included in the package:

- Wind speed
- Wind direction
- Temperature
- Atmospheric pressure
- Relative humidity
- Cloud coverage
- Ceiling height
- Global solar radiation
- Precipitation rate

The data for the first few hours of 2016 are shown in Figure 13.

Based on the dada received, analyses of wind classes, wind rose and the precipitation data were performed. The wind rose for years 2016-2018 is given in Figure 14, the wind class frequency distribution is given in Figure 15and precipitation data in Figure 16 respectively.

The analyzed data reveal that the study area is dominated by winds from the west-northwest. The winds are frequent (calm only 2.19%), and the intensity is moderate. The maximum wind speed is less than 11 m/s.



	Year	Month	Day	Julian Day	Hour	Sensible Heat Flux [W/m^2])	Surface Friction Velocity [m/s]	Convective Velocity Scale [m/s]	Vertical Potential Temperature Gradient above PBL	Height of Convectively-Generated Boundary Layer - PBL [m]	Height of Mechanically-Generated Boundary Layer - SBL [m]	Monin-Obukhov Length [m]	Surface Roughness Length [m]	Bowen Ratio	Albedo	Wind Speed - Ws [m/s]	Wind Direction - Wd [degrees]	Reference Height for Ws and Wd [m]	Temperature - temp [K]	Reference Height for temp [m]	Precipitation Code	Precipitation Rate [mm/hr]	Relative Humidity [%]	Surface Pressure [mb]	Cloud Cover [tenths]	Data Flag
Min.	2016	јан.	1	1	1	-999.0	-9.000	-9.000	-9.000	-999.0	-999.0	-99999.0	0.900	0.82	0.18	0.00	0.0	14.0	253.5	2.0	0	0.00	16.0	875.0	2	
Max.	2018	дек.	31	366	24	327.4	2.345	3.061	0.016	3505.0	4000.0	8888.0	1.300	1.62	1.00	13.90	360.0	14.0	303.6	2.0	22	6.10	100.0	915.0	10	
Graph																										
1	2016	јан.	1	1	1	-56.6	0.533	-9.000	-9.000	-999.0	934.0	215.9	1.300	0.82	1.00	3.60	271.0	14.0	262.8	2.0	0	0.00	63.0	904.0	2	NAD-SFC NoSubs
2	2016	јан.	1	1	2	-64.0	0.631	-9.000	-9.000	-999.0	1202.0	317.0	1.300	0.82	1.00	4.10	258.0	14.0	262.9	2.0	0	0.00	59.0	904.0	2	NAD-SFC NoSubs
3	2016	јан.	1	1	3	-64.0	0.730	-9.000	-9.000	-999.0	1494.0	490.0	1.300	0.82	1.00	4.60	274.0	14.0	262.8	2.0	0	0.00	59.0	903.0	2	NAD-SFC NoSubs
4	2016	јан.	1	1	4	-64.0	0.730	-9.000	-9.000	-999.0	1498.0	490.0	1.300	0.82	1.00	4.60	273.0	14.0	263.0	2.0	0	0.00	58.0	903.0	2	NAD-SFC NoSubs
5	2016	јан.	1	1	5	-64.0	0.730	-9.000	-9.000	-999.0	1498.0	490.0	1.300	0.82	1.00	4.60	273.0	14.0	263.4	2.0	0	0.00	55.0	903.0	2	NAD-SFC NoSubs
6	2016	јан.	1	1	6	-64.0	0.730	-9.000	-9.000	-999.0	1498.0	490.0	1.300	0.82	1.00	4.60	282.0	14.0	263.9	2.0	0	0.00	50.0	903.0	2	NAD-SFC NoSubs
7	2016	јан.	1	1	7	-64.0	0.730	-9.000	-9.000	-999.0	1498.0	490.0	1.300	0.82	1.00	4.60	285.0	14.0	264.2	2.0	0	0.00	45.0	903.0	2	NAD-SFC NoSubs
8	2016	јан.	1	1	8	-64.0	0.824	-9.000	-9.000	-999.0	1789.0	702.6	1.300	0.82	0.60	5.10	293.0	14.0	265.0	2.0	0	0.00	41.0	902.0	2	NAD-SFC NoSubs
9	2016	јан.	1	1	9	9.2	0.778	0.249	0.006	54.0	1654.0	-4138.4	1.300	0.82	0.36	4.60	287.0	14.0	266.8	2.0	0	0.00	39.0	902.0	2	NAD-SFC NoSubs
10	2016	јан.	1	1	10	44.6	0.711	0.670	0.007	216.0	1448.0	-647.4	1.300	0.82	0.27	4.10	301.0	14.0	269.2	2.0	0	0.00	39.0	902.0	2	NAD-SFC NoSubs
11	2016	јан.	1	1	11	68.7	0.642	0.892	0.007	332.0	1244.0	-309.9	1.300	0.82	0.24	3.60	304.0	14.0	271.5	2.0	0	0.00	32.0	902.0	2	NAD-SFC NoSubs
12	2016	јан.	1	1	12	78.5	0.569	1.000	0.007	410.0	1039.0	-188.8	1.300	0.82	0.23	3.10	296.0	14.0	272.2	2.0	0	0.00	34.0	902.0	2	NAD-SFC NoSubs
13	2016	јан.	1	1	13	73.5	0.567	1.017	0.007	460.0	1025.0	-199.5	1.300	0.82	0.23	3.10	293.0	14.0	272.9	2.0	0	0.00	36.0	902.0	2	NAD-SFC NoSubs
14	2016	јан.	1	1	14	54.0	0.636	0.939	0.007	494.0	1215.0	-383.2	1.300	0.82	0.26	3.60	289.0	14.0	273.0	2.0	0	0.00	40.0	902.0	2	NAD-SFC NoSubs
15	2016	јан.	1	1	15	21.6	0.539	0.698	0.006	507.0	961.0	-584.7	1.300	0.82	0.32	3.10	282.0	14.0	272.2	2.0	0	0.00	52.0	901.0	2	NAD-SFC NoSubs
16	2016	јан.	1	1	16	-33.0	0.568	-9.000	-9.000	-999.0	1027.0	446.4	1.300	0.82	0.50	3.60	284.0	14.0	271.1	2.0	0	0.00	61.0	901.0	3	NAD-SFC NoSubs
17	2016	јан.	1	1	17	-63.3	0.632	-9.000	-9.000	-999.0	1203.0	320.2	1.300	0.82	1.00	4.10	291.0	14.0	270.4	2.0	0	0.00	67.0	901.0	3	NAD-SFC NoSubs
18	2016	јан.	1	1	18	-64.0	0.730	-9.000	-9.000	-999.0	1494.0	488.7	1.300	0.82	1.00	4.60	287.0	14.0	270.0	2.0	0	0.00	70.0	901.0	3	NAD-SFC NoSubs
19	2016	јан.	1	1	19	-64.0	0.730	-9.000	-9.000	-999.0	1497.0	488.7	1.300	0.82	1.00	4.60	294.0	14.0	269.8	2.0	0	0.00	73.0	901.0	3	NAD-SFC NoSubs
20	2016	јан.	1	1	20	-64.0	0.730	-9.000	-9.000	-999.0	1497.0	488.1	1.300	0.82	1.00	4.60	297.0	14.0	269.8	2.0	0	0.00	75.0	900.0	3	NAD-SFC NoSubs
21	2016	јан.	1	1	21	-64.0	0.730	-9.000	-9.000	-999.0	1497.0	488.1	1.300	0.82	1.00	4.60	300.0	14.0	269.8	2.0	0	0.00	75.0	900.0	3	NAD-SFC NoSubs
22	2016	јан.	1	1	22	-64.0	0.631	-9.000	-9.000	-999.0	1217.0	315.1	1.300	0.82	1.00	4.10	302.0	14.0	269.8	2.0	0	0.00	74.0	900.0	2	NAD-SFC NoSubs
23	2016	јан.	1	1	23	-55.1	0.535	-9.000	-9.000	-999.0	952.0	223.4	1.300	0.82	1.00	3.60	300.0	14.0	269.8	2.0	0	0.00	73.0	900.0	2	NAD-SFC NoSubs
24	2016	јан.	1	1	24	-55.2	0.535	-9.000	-9.000	-999.0	940.0	222.9	1.300	0.82	1.00	3.60	300.0	14.0	269.2	2.0	0	0.00	73.0	900.0	2	NAD-SFC NoSubs
25	2016	јан.	2	2	1	-55.3	0.535	-9.000	-9.000	-999.0	939.0	222.3	1.300	0.82	1.00	3.60	296.0	14.0	268.8	2.0	0	0.00	73.0	900.0	2	NAD-SFC NoSubs
26	2016	јан.	2	2	2	-55.3	0.535	-9.000	-9.000	-999.0	939.0	222.1	1.300	0.82	1.00	3.60	302.0	14.0	268.5	2.0	0	0.00	73.0	900.0	2	NAD-SFC NoSubs
27	2016	јан.	2	2	3	-55.4	0.535	-9.000	-9.000	-999.0	939.0	221.8	1.300	0.82	1.00	3.60	302.0	14.0	268.2	2.0	0	0.00	72.0	900.0	2	NAD-SFC NoSubs
28	2016	јан.	2	2	4	-55.4	0.535	-9.000	-9.000	-999.0	939.0	221.7	1.300	0.82	1.00	3.60	300.0	14.0	268.1	2.0	0	0.00	71.0	900.0	2	NAD-SFC NoSubs
29	2016	јан.	2	2	5	-55.4	0.535	-9.000	-9.000	-999.0	939.0	221.6	1.300	0.82	1.00	3.60	296.0	14.0	268.0	2.0	0	0.00	70.0	900.0	2	NAD-SFC NoSubs

Figure 13 Preprocessed meteorological data

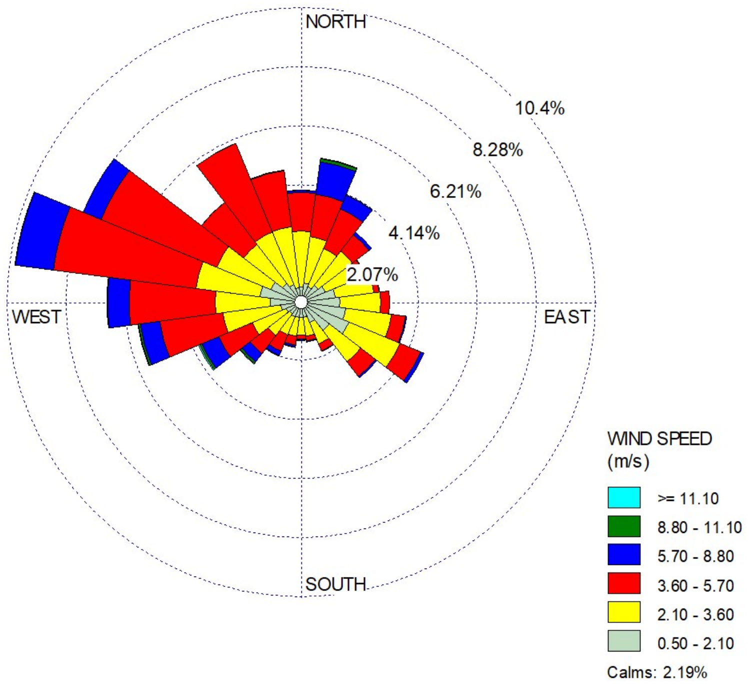


Figure 14 24 directions wind rose and wind speeds for 2016 to 2018

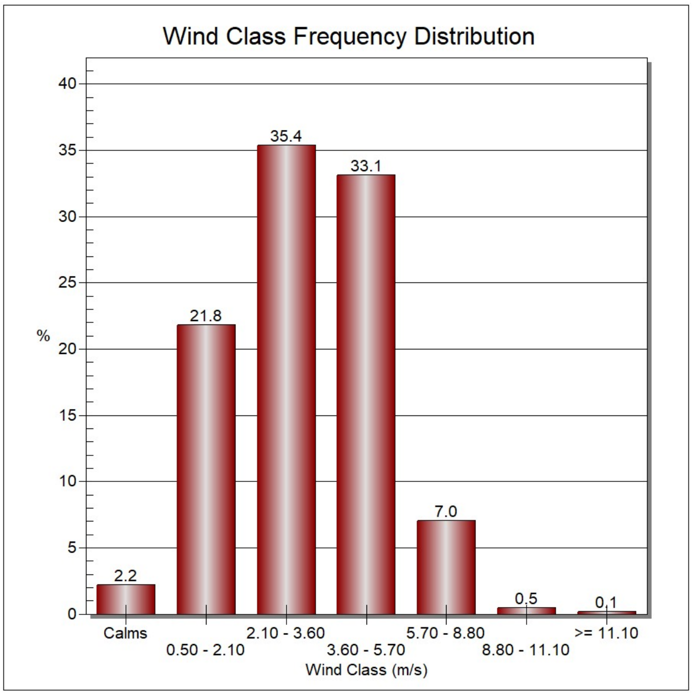


Figure 15 Wind classes graph

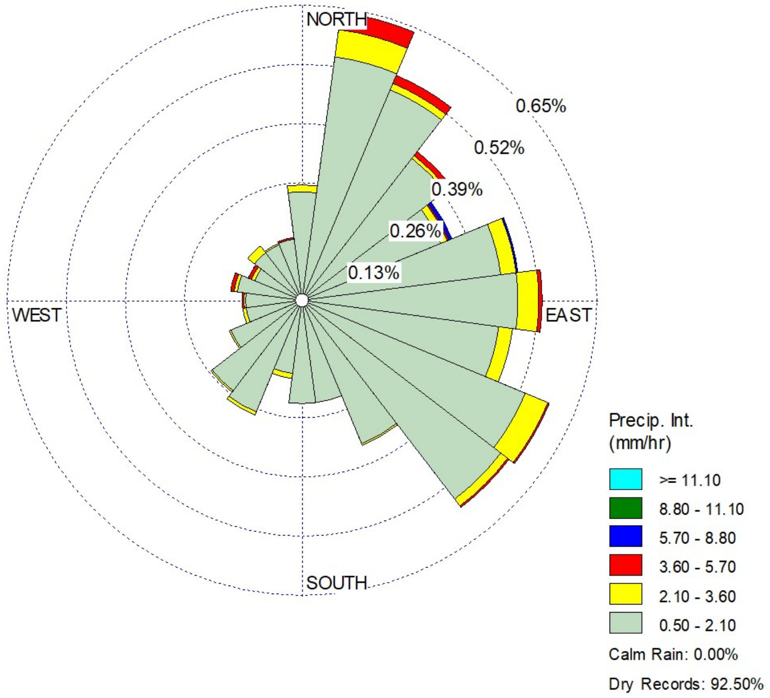


Figure 16 Intensity of precipitations and their distribution according to wind directions

2.6 Results

Using the data on the activities, meteorology and the expected emission rates during the motorway construction period, the airborne particulate matter dispersion modeling was carried out.

The maximum 24 hour and annual concentrations of PM10 due to construction activities were calculated (Figure 17). A summary of the results is shown in Table 11.

One should bear in mind that maximum 24 hour concentrations are only reached once in the studied period. The concentrations shown in the figures are not simultaneous.

Contours of 90th percentile of PM10 concentrations are shown in Figure 18. It indicates the concentrations that are exceeded 2% of the time (14 days in two years).

Table 11 Expected peak concentrations of PM10 during construction period (construction activities only)

Average period	Background µg/m³	AQ limit value µg/m³	Peak concentration Construction activities only µg/m³	UTM coordinates	
				X	Y
24 h	40	50	294.7	497250	4605500
Annual (2020)	40	40	70.9	497250	4604500

Table 12 Expected peak concentrations of PM10 during highway construction at sensitive locations

Averaging Period	ID	Concentrations (mg/m^3)			UTM Coordinates (m)	
		Background	Air Quality Limit	Peak (Construction only)	X	Y
(m)						
24-HR	Primary School	40	50	5.50	496450.00	4596350.00
24-HR	Mosque	40	50	7.98	495921.00	4596534.00
24-HR	University	40	50	5.56	496790.00	4596510.00
24-HR	Military barracks	40	50	7.03	496320.00	4596910.00
24-HR	Sports Center	40	50	6.60	497320.00	4597330.00
ANNUAL	Primary School	40	40	0.65	496450.00	4596350.00
ANNUAL	Mosque	40	40	0.92	495921.00	4596534.00
ANNUAL	University	40	40	0.66	496790.00	4596510.00
ANNUAL	Military barracks	40	40	0.93	496320.00	4596910.00
ANNUAL	Sports Center	40	40	0.84	497320.00	4597330.00
24-HR 90th Percentile	Primary School	40	50	1.84	496450.00	4596350.00
24-HR 90th Percentile	Mosque	40	50	2.29	495921.00	4596534.00
24-HR 90th Percentile	University	40	50	1.77	496790.00	4596510.00
24-HR 90th Percentile	Military barracks	40	50	2.39	496320.00	4596910.00
24-HR 90th Percentile	Sports Center	40	50	2.13	497320.00	4597330.00

According to the results, the ground level ambient air limit concentrations may be exceeded due to the motorway construction activities alone at certain points within the construction site or very close to it. The impact on the sensitive receptors is apparent but not high.

The background concentration is quite high and having in mind uncertainties related to meteorological data, emission factors and variability of emission rates, the air quality limit values may be breached occasionally, especially in autumn and winter.

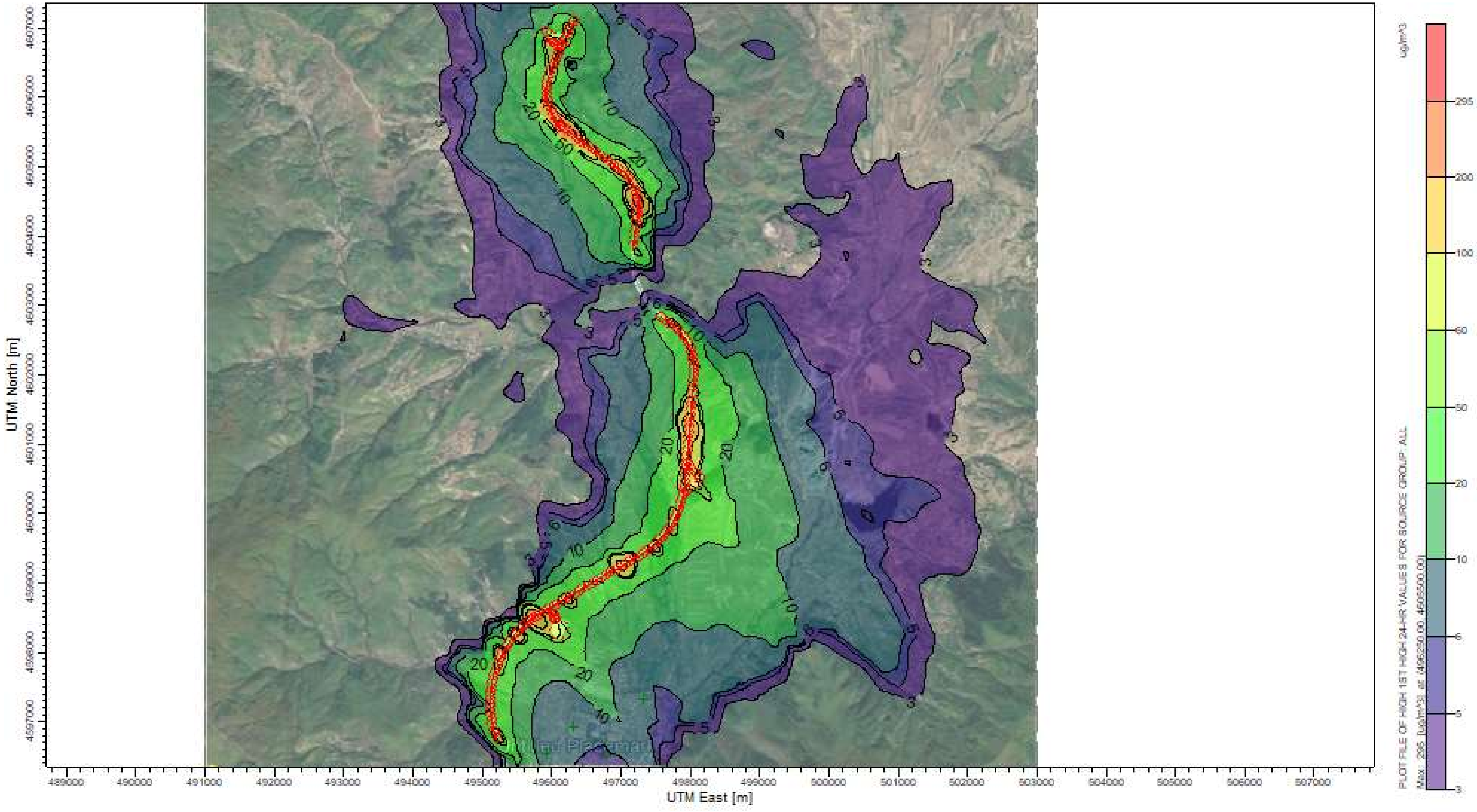


Figure 17 Maximum 24 hour concentrations of PM10 resulting from the motorway (construction only)

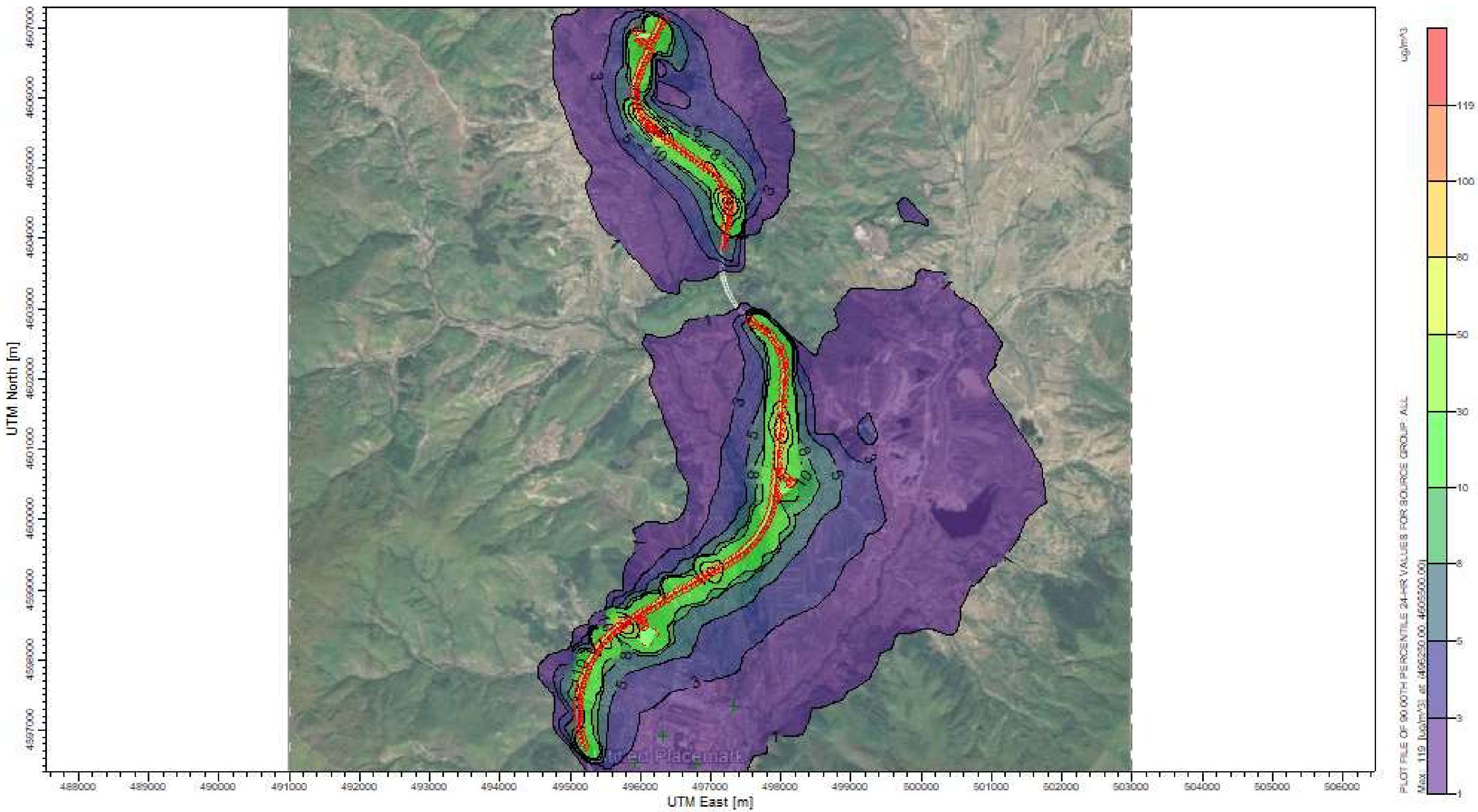


Figure 18 Contours of 90th percentile of PM10 concentration due to the motorway construction (construction activities only)

3 Operational Phase

For the purpose of this assessment the following scenarios have been worked out:

- Basic year air quality assessment

  Having in mind that full year data collected for the project refer to 2018, this year has been assigned as the basic year for the project impact assessment.

- Opening year air quality assessment (with and without the highway being constructed)

  2023 is considered as opening year according to the PESR.

- Future year air quality assessment (with and without the highway being constructed).

  Beginning of the fourth decade of the century and twenty years after starting the highway construction works (2040).

3.1 Emissions

The motorway traffic emissions originate from:

- Vehicle engines exhaust gases
- Tires wearing at the road surface
- Brakes
- Fuel evaporation (tank vents)

The air emission rate is determined by factors such as number and kind of vehicles, power of the engines, traveling velocity, type of fuel and conditions of the road.

The traffic volume was determined in 2017 and an annual growth rate of 5% has been assumed for the next twenty years. Based on these data the Average Annual Daily Traffic has been calculated as shown in Table 13.

Table 13 Expected average annual daily traffic until 2040 (Source: "MAIN DESIGN for dimensioning of the pavement structure of highway A2 Gostivar-Kicevo section: Bukojcani – Kicevo" (Балкан Консалтинг, 2019).)

Year	AADT	PC	LT	BUS	HT
2017	5658	4602	689	71	296
2018	5941	4832	723	75	311
2019	6238	5074	760	78	326
2020	6550	5327	798	82	343
2021	6877	5594	837	86	360
2022	7221	5873	879	91	378
2023	7582	6167	923	95	397

2024	7961	6475	969	100	417
2025	8359	6799	1018	105	437
2026	8777	7139	1069	110	459
2027	9216	7496	1122	116	482
2028	9677	7871	1178	121	506
2029	10161	8265	1237	128	532
2030	10669	8678	1299	134	558
2031	11202	9112	1364	141	586
2032	11763	9567	1432	148	615
2033	12351	10046	1504	155	646
2034	12968	10548	1579	163	678
2035	13617	11075	1658	171	712
2036	14297	11629	1741	179	748
2037	15012	12210	1828	188	785
2038	15763	12821	1920	198	825
2039	16551	13462	2016	208	866
2040	17379	14135	2116	218	909

Year	Vehicles per hour					Vehicles per second				
	AADT	Passenger Cars	Light Trucks	Busses	Havy Trucks	AATS	PC	LT	BUS	HT
2018	5941	4832	723	75	311	0.0688	0.0559	0.0084	0.0009	0.0036
2023	7582	6167	923	95	397	0.0878	0.0714	0.0107	0.0011	0.0046
2040	17379	14135	2116	218	909	0.2011	0.1636	0.0245	0.0025	0.0105

There are no national emission factors developed for different categories of vehicles under different road conditions. Therefore, German emission factors published in the *Handbook Emission Factors for Road Transport – HBEFA*, publicly available at https://www.hbefa.net were applied.

Aggregated emission factors for four types of vehicles were retrieved at five year intervals from 2015 to 2040 (Emission factors for 2018 and 2023 were calculated as a linear function in the respective five-year interval (Table 14).

Benzene emissions are minor and are only assigned to Passenger cars and light commercial vehicles exhaust gases (0.001 g/km). Evaporative emissions are even lower (in the order of 10^{-6} g/km). In addition, neither data on benzene emissions, the concentration of which is regulated under the Directive 2008/50/EC is available in the handbook nor it has been monitored at the air quality monitoring station.

The traffic emissions of SO_2 are too small, even for 2040 traffic, for a detailed modeling to be undertaken.

The existing road passes through several settlements in the immediate vicinity of houses and religious buildings where people gather. It is normal to expect an increase in traffic as projected in the documents and without scheme to have a significant impact on air quality. Five receptors were chosen to illustrate the impact of traffic on the air quality in the with-scheme scenarios.
Seven additional sensitive receptors were identified for the no-scheme scenarios.

Table 14 Emission factors for motor vehicles (Source: HBEFA https://www.hbefa.net)

	Vehicle	Emission factors (g/km)		
		2018	2023	2040
CO (g/km)	Buss	1.3258	0.752	0.223
	HT	0.7986	0.37	0.199
	LT	0.7446	0.498	0.383
	PC	1.242	1.16	0.626
NOx (g/km)	Buss	4.257	2.569	1.299
	HT	1.987	1.266	1.13
	LT	1.0226	0.586	0.121
	PC	0.151	0.123	0.086
PM10 (g/km)	Buss	0.027	0.039	0. 11
	HT	0.1320	0.137	0.109
	LT	0.176	0.116	0.11
	PC	0.061	0.05	0.03
PM2.5 (g/km)	Buss	0.0880	0.089	0.061
	HT	0.128	0.072	0.066
	LT	0.048	0.037	0.017
	PC	0.018	0.015	0.013

As tire, asphalt and brakes abrasions are not taken into account in the German emission factors presented in HBEFA, the corresponding NAEI (National Air Emissions Inventory) values were added to PM10 and PM2.5 emission factors.

The emission factors presented in Table 14 above are given in g/vehicle/km. Multiplying these factors by the length of the branch and the number of vehicles per second, emission factors in g/s are obtained. Since the highway is considered a 22 m wide and 12.7 km long line area source, the following emission rates in $g/m^2/s$ have been determined (Table 15):

Table 15 Emissions from traffic on the Bukojchani – Kichevo branch of the A2 highway

Year	Pollutant	Emission rate ($g \cdot s^{-1}$)		Emission rate ($g \cdot m^{-2} \cdot s^{-1}$)	
		With Scheme	No scheme	With Scheme	No scheme
2018	PM10		0.0424		1.25E-07
	PM2.5		0.0297		8.74E-08
	NOx		0.3367		3.48E-06
	CO		0.9626		9.95E-06
2023	PM10	0.0372	0.0354	1.33E-07	3.66E-07
	PM2.5	0.0239	0.0228	8.55E-08	2.35E-07
	NOx	0.2983	0.2841	9.00E-06	2.94E-06
	CO	0.8067	0.7682	2.89E-06	7.94E-06
2040	PM10	0.0732	0.0697	2.62E-07	7.21E-07
	PM2.5	0.0431	0.0410	1.54E-07	4.24E-07
	NOx	0.4089	0.3894	1.46E-06	4.02E-06
	CO	1.4535	1.3840	5.20E-06	1.43E-05

The traffic flow varies substantially throughout a year. It is much more intensive in summer, especially in August and September. There are also some seasonal variations in share of different classes of vehicles. Finally, traffic volume varies even within a single month. In order to minimize the uncertainty due to traffic variations, variable (monthly) emissions were applied for the dispersion modeling by assigning an appropriate factor to each month. Unfortunately, no full year with traffic data was available. Therefore, the second half of 2019 was combined with the first half of 2015 having in mind the yearly 5% growth rate (Table 17).

Table 16 Monthly traffic multipliers

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
MADT	4040	4330	4829	6089	6535	6729	9437	10884	7157	6395	4040	4330
Seasonal factor	0.65	0.69	0.77	0.98	1.05	1.08	1.51	1.75	1.15	1.03	0.65	0.69

Although the shares of classes of vehicles differ in time, a good correlation has been determined between the total hourly traffic volume and the emission. The equations, correlation coefficients and the graphs for September 2018 are given in Figure 19.

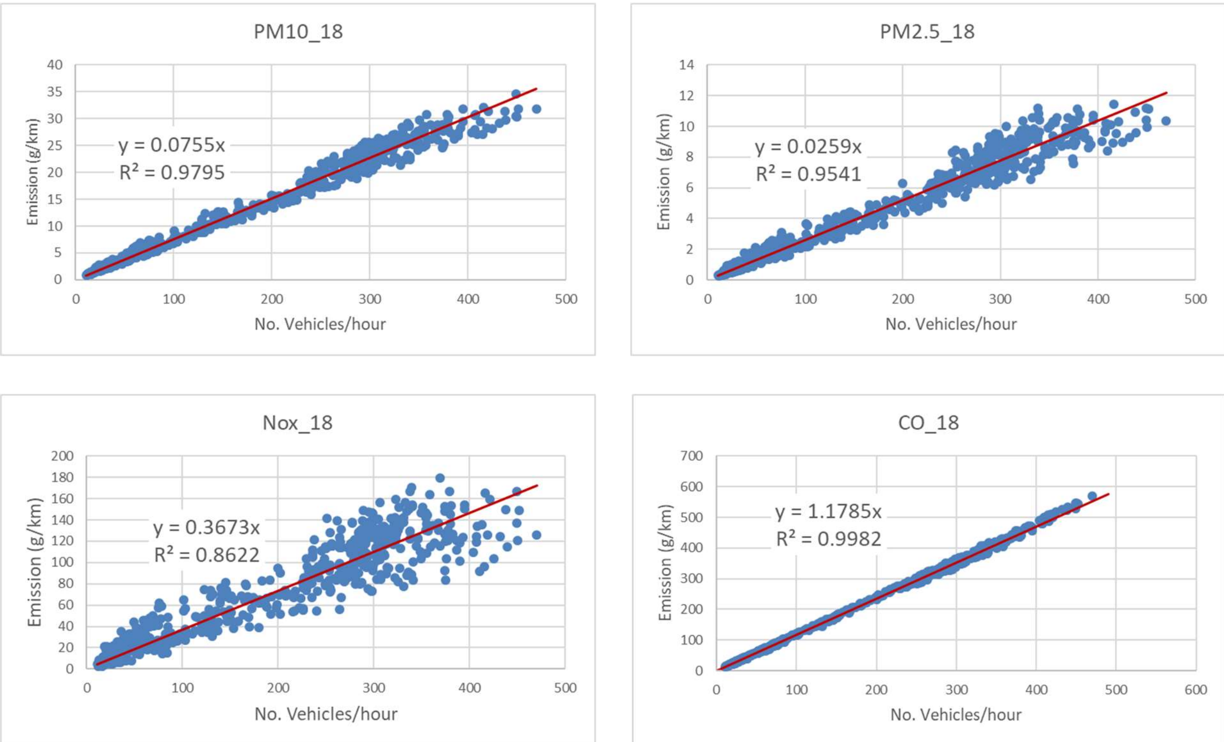


Figure 19 Graphs of emission rates vs number of vehicles per hour. Coeffitients represent emission factors in g/vkt

Having no reliable data on O_3 concentration in the ambient air, NO_2 was modeled assuming that all NOx oxidizes to NO_2 (Tier 1).

The modeling area, topography, meteorological data and the receptor grid are the same as for the construction phase of the project. Meteorological data for the baseline air quality assessment was correctly chosen and corresponds to the base year (2018). However, the same set of data was used for the future years as no predictive hourly meteorological data are available for three or 20 years in advance.

3.2 Results

As the ambient air concentration limits and time averaging differ for various pollutants in both the national and EU legislation, the dispersion modeling results for each scenario and pollutant are presented in separate tables.

3.2.1 PM10

As 24-hour and annual air quality limit values for PM10 have been set in the Directive 2008/50/EC, the maximum daily and the average annual concentrations were modeled for both no-scheme and with-scheme sets of scenarios. In addition, the 90th percentile of 24 hour values which indicate the values that are reached or exceeded 35 (36.5) days in a year were calculated. The model results show that the traffic impact on PM10 concentration with No-Scheme scenario (Table 17) is higher compared to the With-Scheme scenario (Table 18). This is due to the bigger surface (more lanes) of the proposed new highway. In addition, lower impact on sensitive receptors is foreseen as the highway alignment is moved away from most of the dwellings.

Table 17 Model results summary for PM10 (No-Scheme scenario)

Year	Average period	Background	AQ limit value	Peak concentration traffic only	UTM coordinates	
		μg/m³	μg/m³	μg/m³	X	Y
2018	24 h (Max)	42,3	50	4.98	495750	4605600
	Annual	42,3	40	1.33	496500	4597850
	24 h (90th perc.)	42,3	50	2.22	496500	4597850
2023	24 h (Max)	40	50	4.17	495750	4605600
	Annual	40	40	1.11	496500	4597850
	24 h (90th perc.)	40	50	1.86	496500	4597850
2040	*24 h (Max)*	*20*	*50*	*8.89*	*495750*	*4605600*
	Annual	20	40	2.14	496500	4597850
	24 h (90th perc.)	20	50	3.57	496500	4597850

Table 18 Model results summary for PM10 (With-Scheme scenario)

Year	Average period	Background	AQ limit value	Peak concentration traffic only	UTM coordinates	
		μg/m³	μg/m³	μg/m³	X	Y
2023	24 h (Max)	40	50	2.60	496250	4605500
	Annual (2020)	40	40	0.60	497250	4604500
	24 h (90th perc.)	40	50	1.10	496250	4605500
2040	24 h (Max)	20	50	5.12	496250	4605500
	Annual (2020)	20	40	1.19	497250	4604500
	24 h (90th perc.)	20	50	2.17	496250	4605500

The concentrations shown in tables 17 and 18 appear within the traffic lanes or very close to them. The impact of traffic on the new highway on sensitive receptors (Tables 19 and 20) is much lower because the distances from the proposed highway to the sensitive receptors are bigger.

Table 19 PM10 sensitive receptor summary for the basic year (2018) – No -Scheme scenario

Averaging Period	ID	Concentrations (μ/m³)			UTM Coordinates (m)	
		Background	Air Quality Limit	Peak (Traffic only)	X	Y
24-HR (Max)	School	42,3	50	0.5332	496450	4596350
24-HR (Max)	Mosque	42,3	50	0.9210	495921	4596534
24-HR (Max)	University	42,3	50	0.3973	496790	4596510
24-HR (Max)	Military barracks	42,3	50	1.1047	496320	4596910
24-HR (Max)	Sports Center	42,3	50	0.3485	497320	4597330
24-HR (Max)	House	42,3	50	8.1655	495852	4605509
24-HR (Max)	House	42,3	50	6.7961	495797	4605571
24-HR (Max)	Mosque	42,3	50	3.1350	496428	4601896
24-HR (Max)	House	42,3	50	3.7551	496608	4601490
24-HR (Max)	House	42,3	50	5.5305	496637	4601465
24-HR (Max)	House	42,3	50	3.3308	496784	4601039
24-HR (Max)	House	42,3	50	7.5701	496886	4600879
Annual	School	42,3	40	0.0538	496450	4596350
Annual	Mosque	42,3	40	0.0897	495921	4596534
Annual	University	42,3	40	0.0361	496790	4596510
Annual	Military barracks	42,3	40	0.1357	496320	4596910
Annual	Sports Center	42,3	40	0.0315	497320	4597330
Annual	House	42,3	40	1.1816	495852	4605509
Annual	House	42,3	40	0.9932	495797	4605571
Annual	Mosque	42,3	40	0.6204	496428	4601896
Annual	House	42,3	40	0.5892	496608	4601490
Annual	House	42,3	40	0.6990	496637	4601465
Annual	House	42,3	40	0.6350	496784	4601039
Annual	House	42,3	40	0.8994	496886	4600879
24-HR 90th Percentile	School	42,3	50	0.1250	496450	4596350
24-HR 90th Percentile	Mosque	42,3	50	0.2236	495921	4596534
24-HR 90th Percentile	University	42,3	50	0.0810	496790	4596510
24-HR 90th Percentile	Military barracks	42,3	50	0.2992	496320	4596910
24-HR 90th Percentile	Sports Center	42,3	50	0.0726	497320	4597330
24-HR 90th Percentile	House	42,3	50	2.6771	495852	4605509
24-HR 90th Percentile	House	42,3	50	2.2043	495797	4605571
24-HR 90th Percentile	Mosque	42,3	50	1.2895	496428	4601896
24-HR 90th Percentile	House	42,3	50	1.1818	496608	4601490
24-HR 90th Percentile	House	42,3	50	1.3459	496637	4601465
24-HR 90th Percentile	House	42,3	50	1.3001	496784	4601039
24-HR 90th Percentile	House	42,3	50	1.9463	496886	4600879

Table 20 PM10 sensitive receptor summary for the opening year (2023) – No-Scheme scenario

Averaging Period	ID	Concentrations ($\mu g/m^3$)			UTM Coordinates (m)	
		Background	Air Quality Limit	Peak (Traffic only)	X	Y
24-HR (Max)	School	40	50	0.2159	496450	4596350
24-HR (Max)	Mosque	40	50	0.4771	495921	4596534
24-HR (Max)	University	40	50	0.1682	496790	4596510
24-HR (Max)	Military barracks	40	50	0.4412	496320	4596910
24-HR (Max)	Sports Center	40	50	0.1445	497320	4597330
24-HR (Max)	House	40	50	3.5541	495852	4605509
24-HR (Max)	House	40	50	2.9788	495797	4605571
24-HR (Max)	Mosque	40	50	1.6239	496428	4601896
24-HR (Max)	House	40	50	2.1576	496608	4601490
24-HR (Max)	House	40	50	3.3144	496637	4601465
24-HR (Max)	House	40	50	1.7253	496784	4601039
24-HR (Max)	House	40	50	3.5122	496886	4600879
Annual	School	40	40	0.0281	496450	4596350
Annual	Mosque	40	40	0.0479	495921	4596534
Annual	University	40	40	0.0188	496790	4596510
Annual	Military barracks	40	40	0.0713	496320	4596910
Annual	Sports Center	40	40	0.0165	497320	4597330
Annual	House	40	40	0.6412	495852	4605509
Annual	House	40	40	0.5379	495797	4605571
Annual	Mosque	40	40	0.3175	496428	4601896
Annual	House	40	40	0.2965	496608	4601490
Annual	House	40	40	0.3544	496637	4601465
Annual	House	40	40	0.3227	496784	4601039
Annual	House	40	40	0.4832	496886	4600879
24-HR 90^{th} Percentile	School	40	50	0.0664	496450	4596350
24-HR 90^{th} Percentile	Mosque	40	50	0.1243	495921	4596534
24-HR 90^{th} Percentile	University	40	50	0.0468	496790	4596510
24-HR 90^{th} Percentile	Military barracks	40	50	0.1699	496320	4596910
24-HR 90^{th} Percentile	Sports Center	40	50	0.0404	497320	4597330
24-HR 90^{th} Percentile	House	40	50	1.4980	495852	4605509
24-HR 90^{th} Percentile	House	40	50	1.2535	495797	4605571
24-HR 90^{th} Percentile	Mosque	40	50	0.7100	496428	4601896
24-HR 90^{th} Percentile	House	40	50	0.6177	496608	4601490
24-HR 90^{th} Percentile	House	40	50	0.7109	496637	4601465
24-HR 90^{th} Percentile	House	40	50	0.7113	496784	4601039
24-HR 90^{th} Percentile	House	40	50	1.0415	496886	4600879

Table 21 PM10 sensitive receptor summary for 2040 – No-Scheme scenario

Averaging Period	ID	Concentrations ($\mu g/m^3$)			UTM Coordinates (m)	
		Background	Air Quality Limit	Peak (Traffic only)	X	Y
24-HR (Max)	School	20	50	0.5842	496450	4596350
24-HR (Max)	Mosque	20	50	0.9398	495921	4596534
24-HR (Max)	University	20	50	0.3313	496790	4596510
24-HR (Max)	Military barracks	20	50	0.8692	496320	4596910
24-HR (Max)	Sports Center	20	50	0.2847	497320	4597330
24-HR (Max)	House	20	50	7.0014	495852	4605509
24-HR (Max)	House	20	50	5.8681	495797	4605571
24-HR (Max)	Mosque	20	50	3.1990	496428	4601896
24-HR (Max)	House	20	50	4.2503	496608	4601490
24-HR (Max)	House	20	50	6.5292	496637	4601465
24-HR (Max)	House	20	50	3.3987	496784	4601039
24-HR (Max)	House	20	50	6.9189	496886	4600879
Annual	School	20	40	0.0553	496450	4596350
Annual	Mosque	20	40	0.0944	495921	4596534
Annual	University	20	40	0.0371	496790	4596510
Annual	Military barracks	20	40	0.1404	496320	4596910
Annual	Sports Center	20	40	0.0325	497320	4597330
Annual	House	20	40	1.2630	495852	4605509
Annual	House	20	40	1.0596	495797	4605571
Annual	Mosque	20	40	0.6255	496428	4601896
Annual	House	20	40	0.5842	496608	4601490
Annual	House	20	40	0.6981	496637	4601465
Annual	House	20	40	0.6358	496784	4601039
Annual	House	20	40	0.9519	496886	4600879
24-HR 90th Percentile	School	20	50	0.1309	496450	4596350
24-HR 90th Percentile	Mosque	20	50	0.2448	495921	4596534
24-HR 90th Percentile	University	20	50	0.0922	496790	4596510
24-HR 90th Percentile	Military barracks	20	50	0.3348	496320	4596910
24-HR 90th Percentile	Sports Center	20	50	0.0795	497320	4597330
24-HR 90th Percentile	House	20	50	2.9510	495852	4605509
24-HR 90th Percentile	House	20	50	2.4694	495797	4605571
24-HR 90th Percentile	Mosque	20	50	1.3986	496428	4601896
24-HR 90th Percentile	House	20	50	1.2168	496608	4601490
24-HR 90th Percentile	House	20	50	1.4005	496637	4601465
24-HR 90th Percentile	House	20	50	1.4012	496784	4601039
24-HR 90th Percentile	House	20	50	2.0517	496886	4600879

Table 22 PM10 sensitive receptor summary for the opening year (2023) – With-Scheme scenario

Averaging Period	ID	Concentrations (μg/m³)			UTM Coordinates (m)	
		Background	Air Quality Limit	Peak (Traffic only)	X	Y
24-HR (Max)	School	40	50	0.0597	496450	4596350
24-HR (Max)	Mosque	40	50	0.0923	495921	4596534
24-HR (Max)	University	40	50	0.0563	496790	4596510
24-HR (Max)	Military barracks	40	50	0.0695	496320	4596910
24-HR (Max)	Sports Center	40	50	0.0612	497320	4597330
Annual	School	40	40	0.0068	496450	4596350
Annual	Mosque	40	40	0.0099	495921	4596534
Annual	University	40	40	0.0067	496790	4596510
Annual	Military barracks	40	40	0.0096	496320	4596910
Annual	Sports Center	40	40	0.0079	497320	4597330
24-HR 90th Percentile	School	40	50	0.0183	496450	4596350
24-HR 90th Percentile	Mosque	40	50	0.0250	495921	4596534
24-HR 90th Percentile	University	40	50	0.0183	496790	4596510
24-HR 90th Percentile	Military barracks	40	50	0.0251	496320	4596910
24-HR 90th Percentile	Sports Center	40	50	0.0206	497320	4597330

Table 23 PM10 sensitive receptor summary for 2040 – With-Scheme scenario

Averaging Period	ID	Concentrations (μg/m³)			UTM Coordinates (m)	
		Background	Air Quality Limit	Peak (Traffic only)	X	Y
24-HR (Max)	School	20	50	0.11751	496450	4596350
24-HR (Max)	Mosque	20	50	0.18175	495921	4596534
24-HR (Max)	University	20	50	0.1108	496790	4596510
24-HR (Max)	Military barracks	20	50	0.13696	496320	4596910
24-HR (Max)	Sports Center	20	50	0.12052	497320	4597330
Annual	School	20	40	0.01342	496450	4596350
Annual	Mosque	20	40	0.01942	495921	4596534
Annual	University	20	40	0.01326	496790	4596510
Annual	Military barracks	20	40	0.01896	496320	4596910
Annual	Sports Center	20	40	0.01546	497320	4597330
24-HR 90th Percentile	School	20	50	0.03602	496450	4596350
24-HR 90th Percentile	Mosque	20	50	0.04928	495921	4596534
24-HR 90th Percentile	University	20	50	0.03602	496790	4596510
24-HR 90th Percentile	Military barracks	20	50	0.04946	496320	4596910
24-HR 90th Percentile	Sports Center	20	50	0.04052	497320	4597330

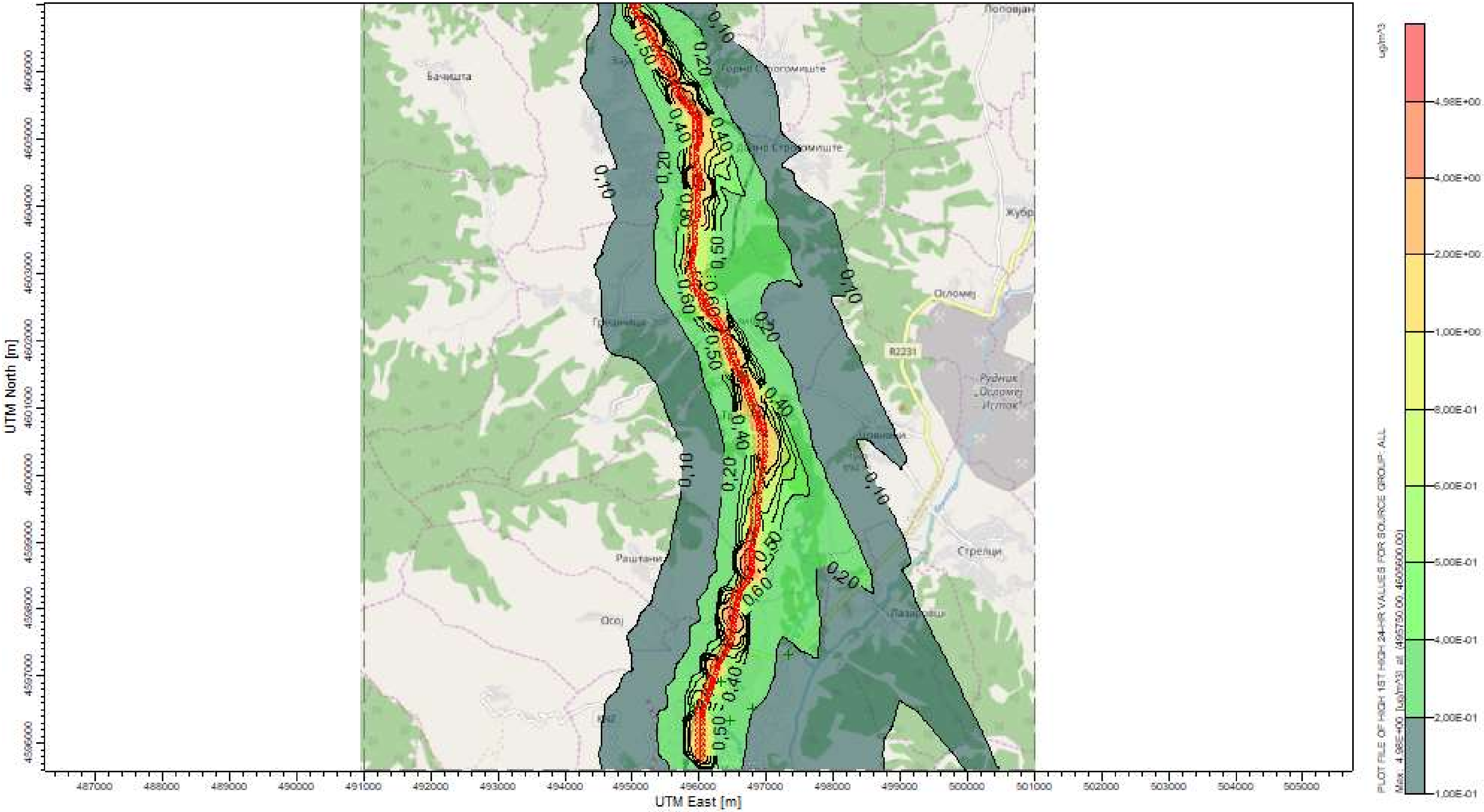


Figure 20 Contours of the maximum 24 hour concentrations of PM10 in 2018 – No Scheme (Traffic only)

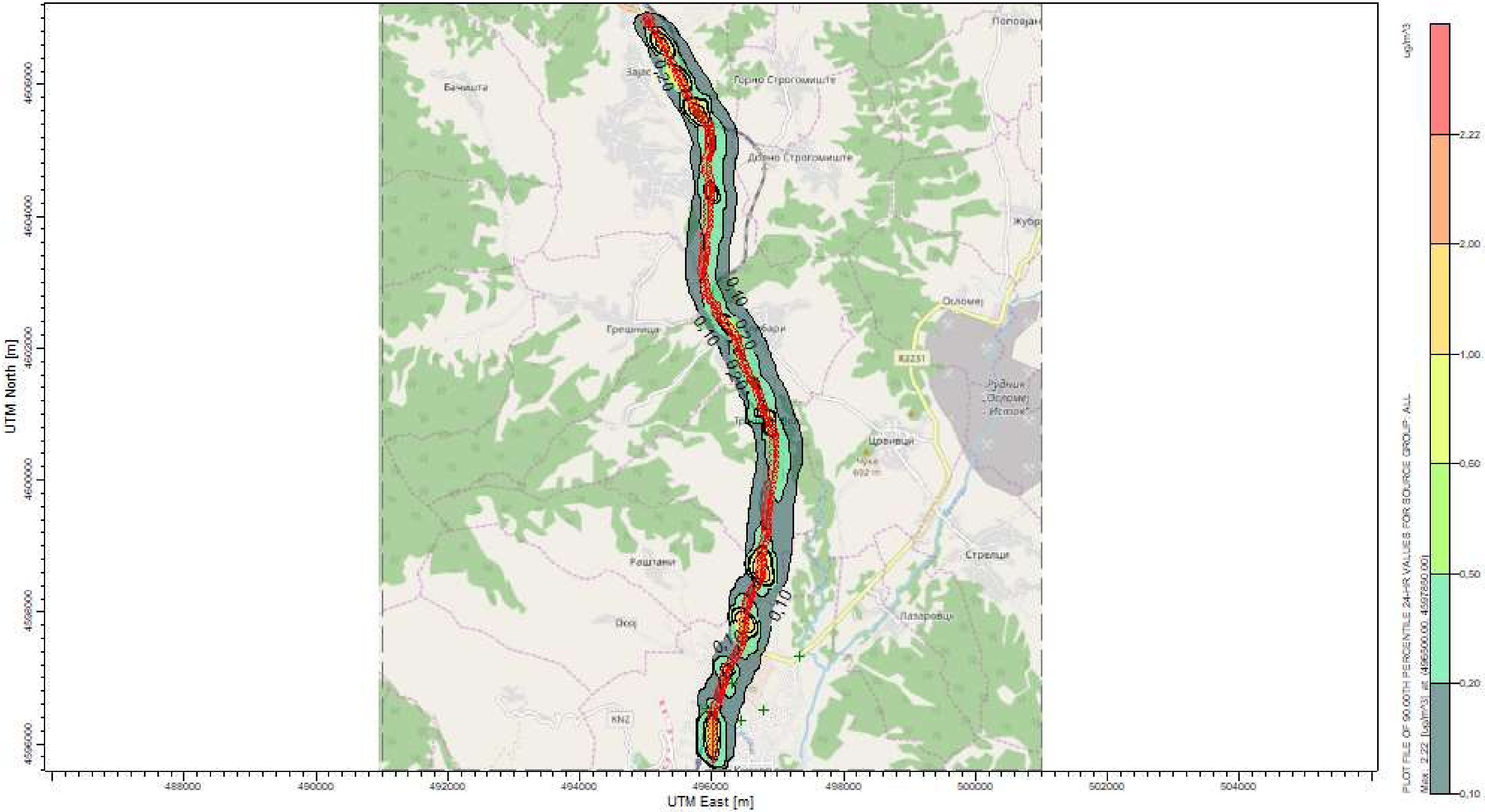


Figure 21 Contours of 90th percentile of PM10 of PM10 concentrations in 2018 – No Scheme (Traffic only)

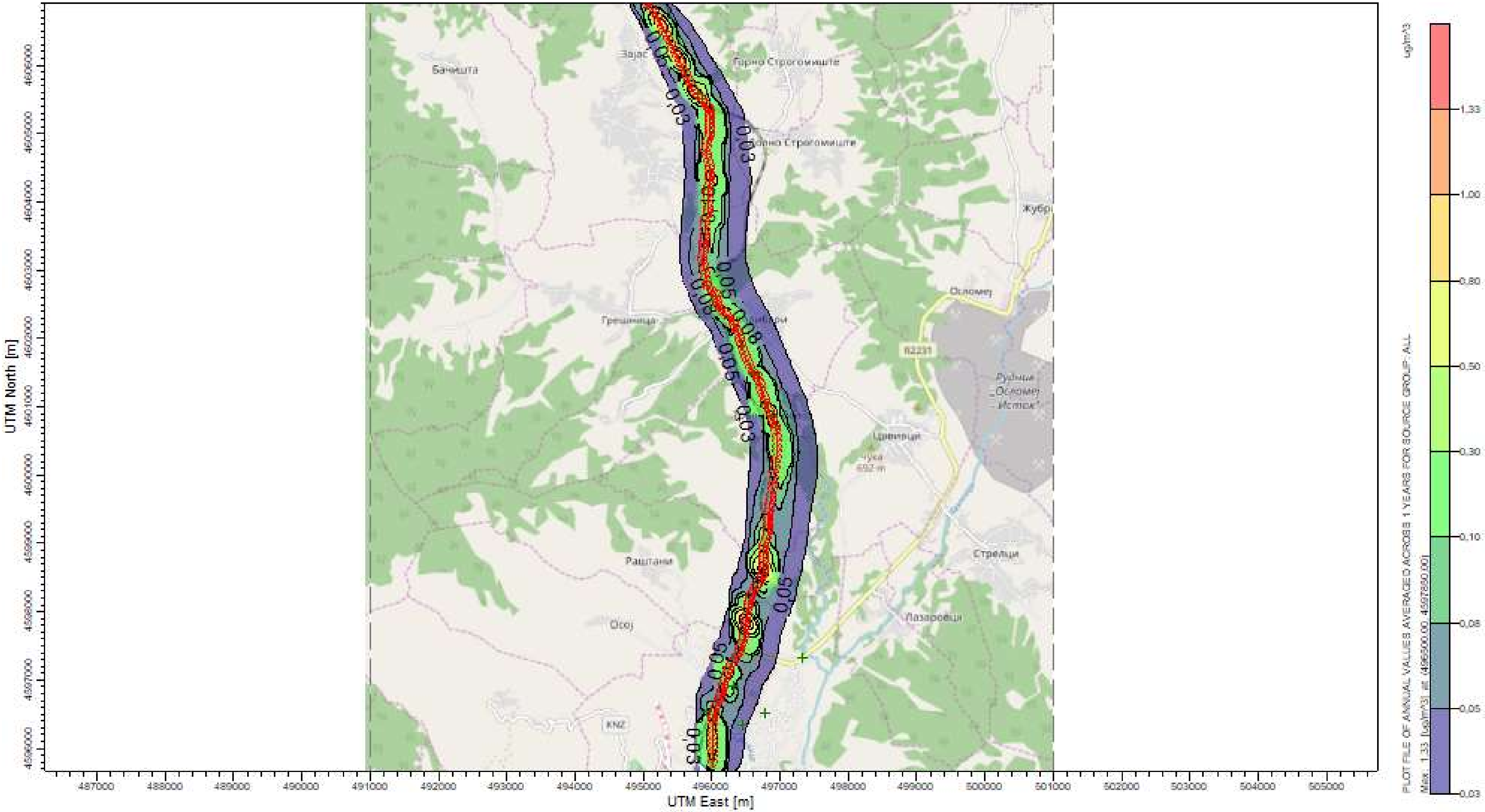


Figure 22 Contours of average annual PM10 concentrations in 2018 – No Scheme (Traffic only)

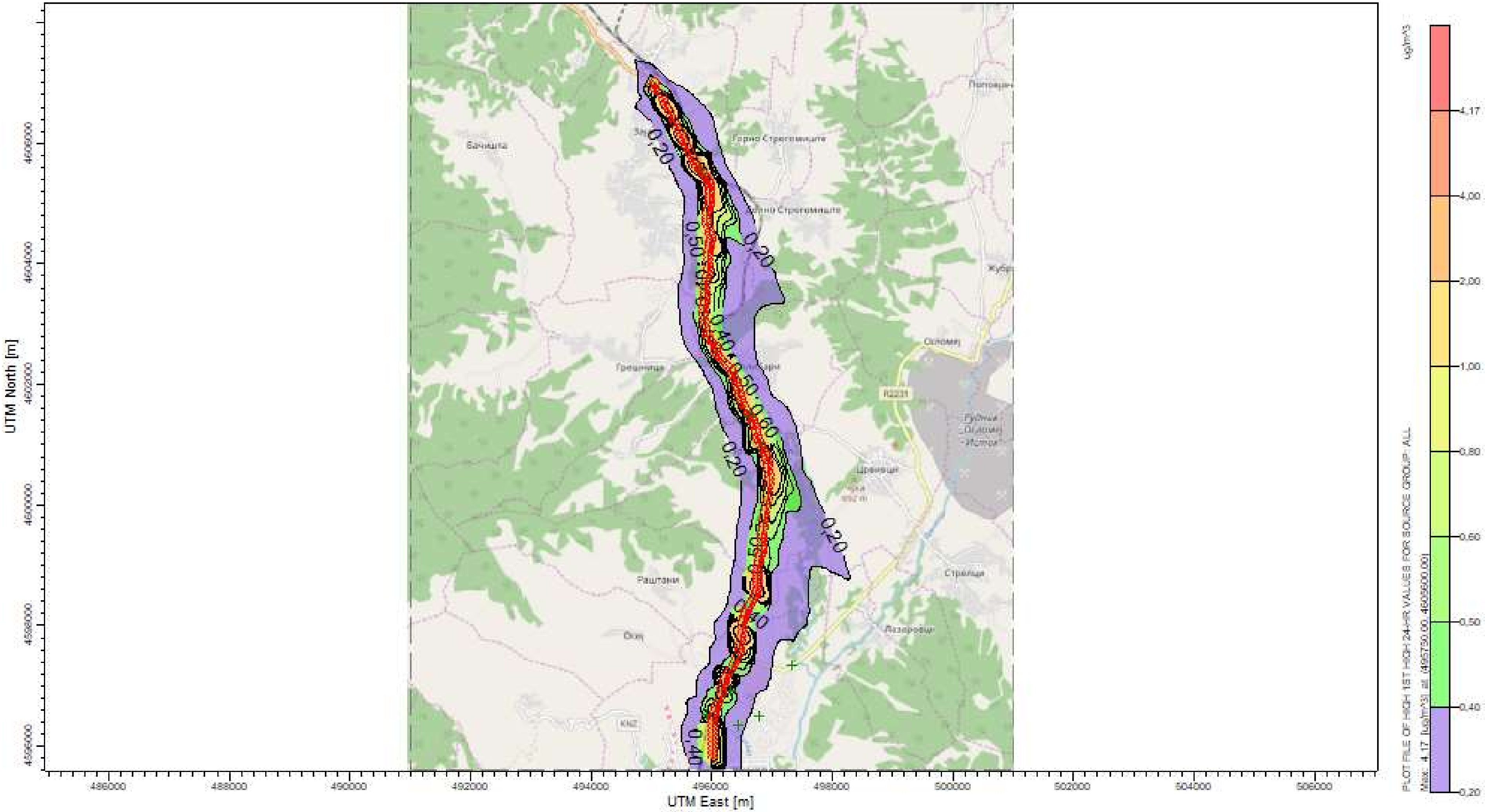


Figure 23 Contours of the maximum 24 hour concentrations of PM10 in 2023 – No Scheme (Traffic only)

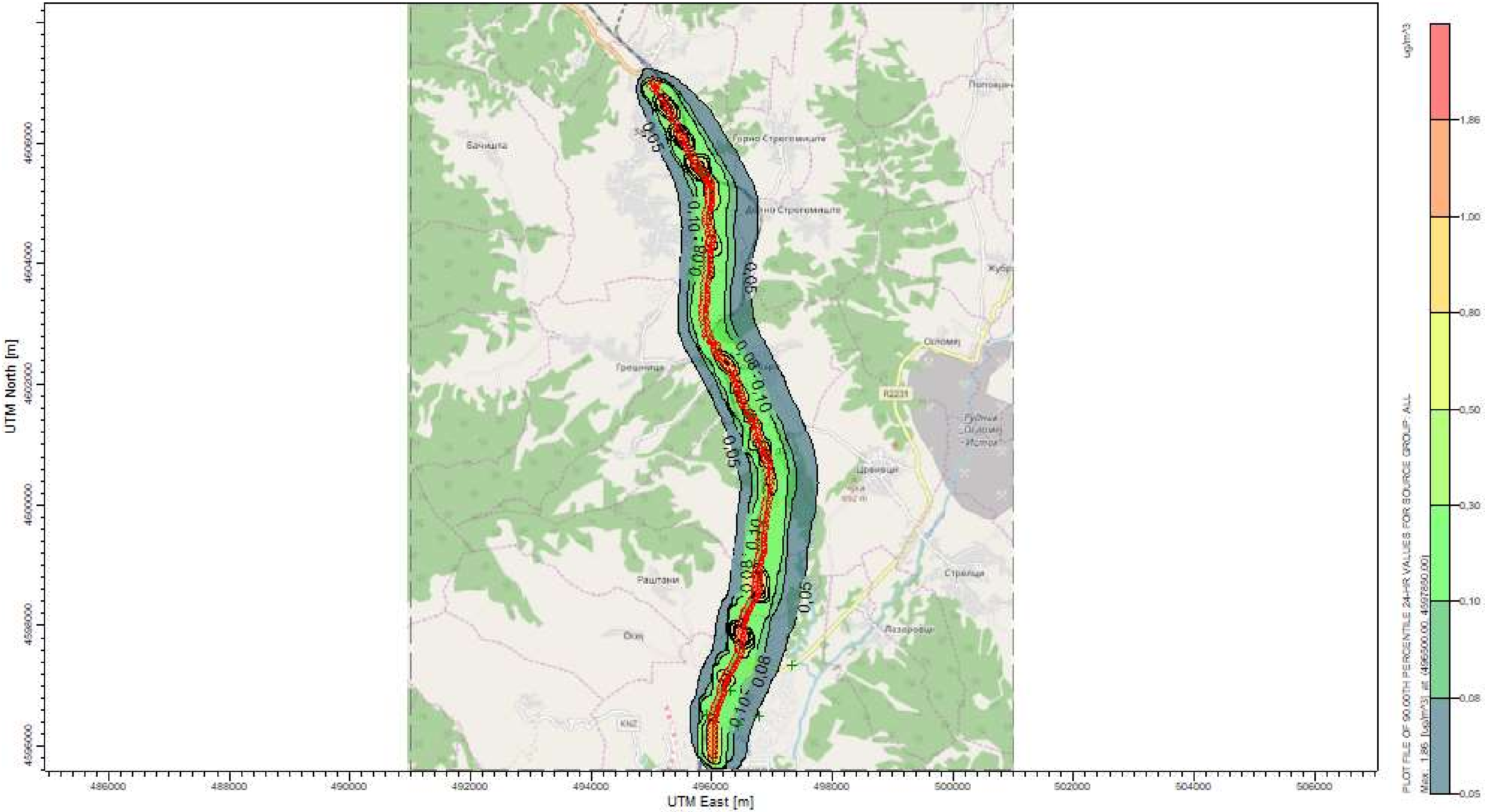


Figure 24 Contours of 90th percentile of PM10 of PM10 concentrations in 2023 – No Scheme (Traffic only)

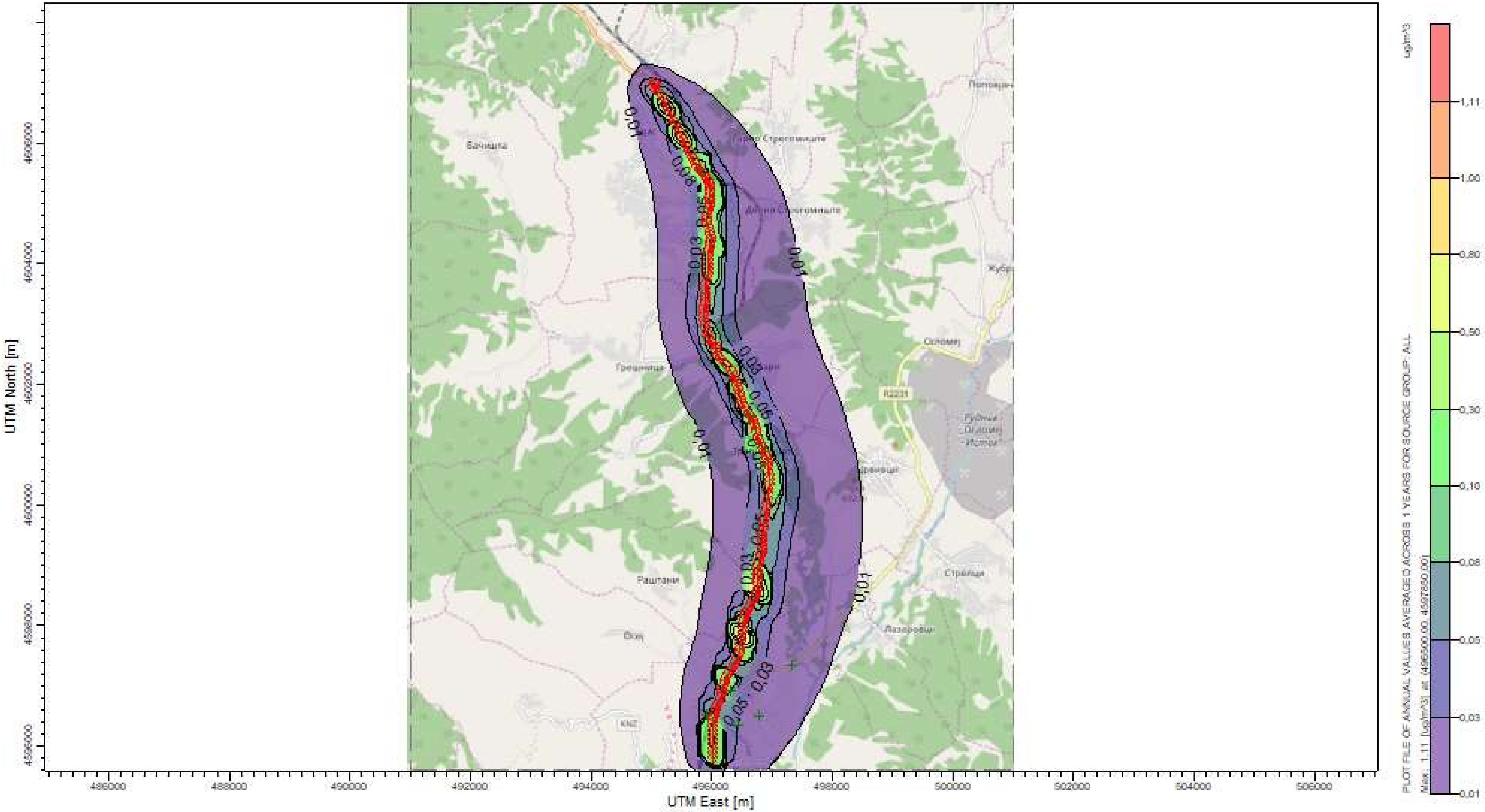


Figure 25 Contours of average annual PM10 concentrations in 2023 – No Scheme (Traffic only)

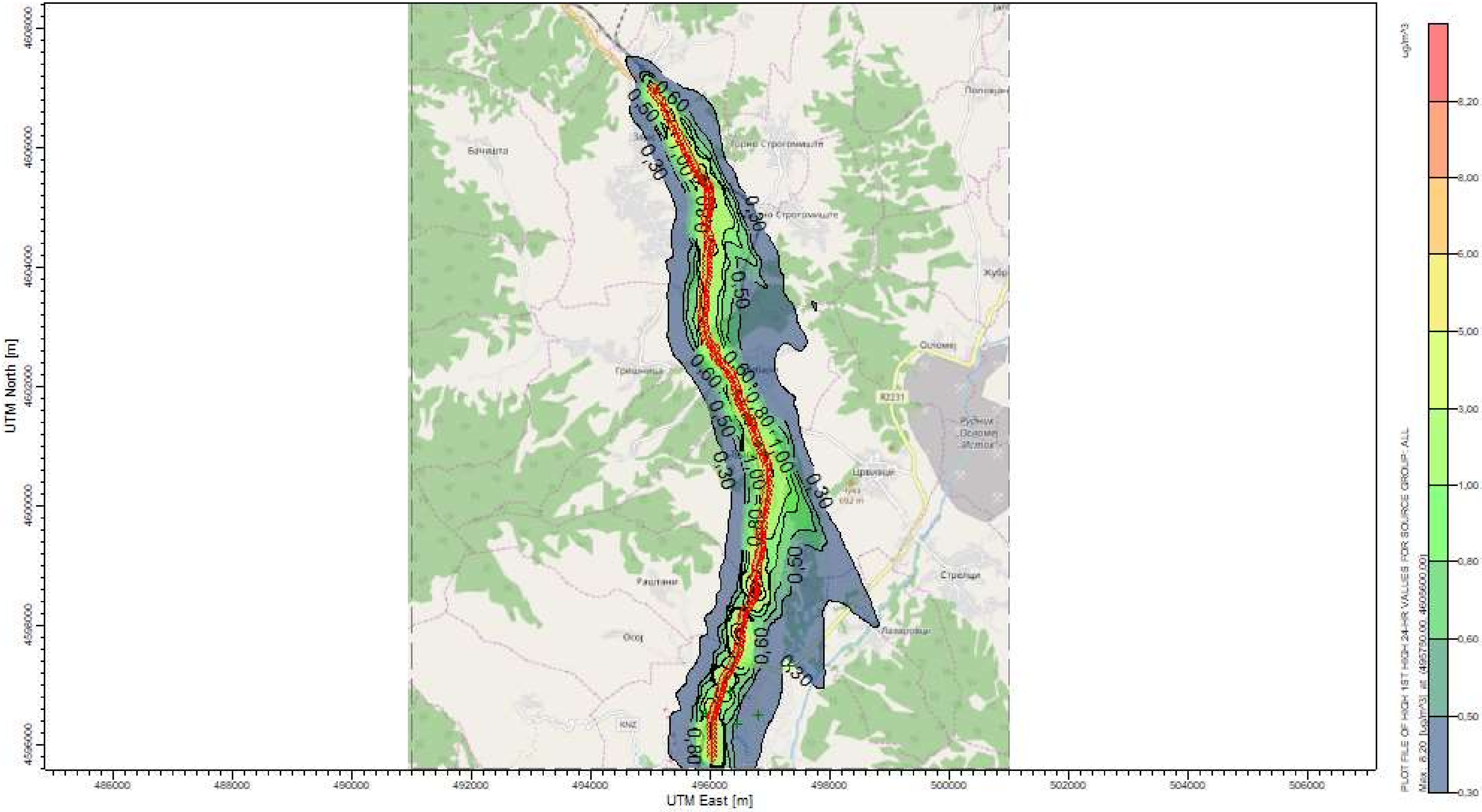


Figure 26 Contours of the maximum 24 hour concentrations of PM10 for 2040 – No Scheme (Traffic only)

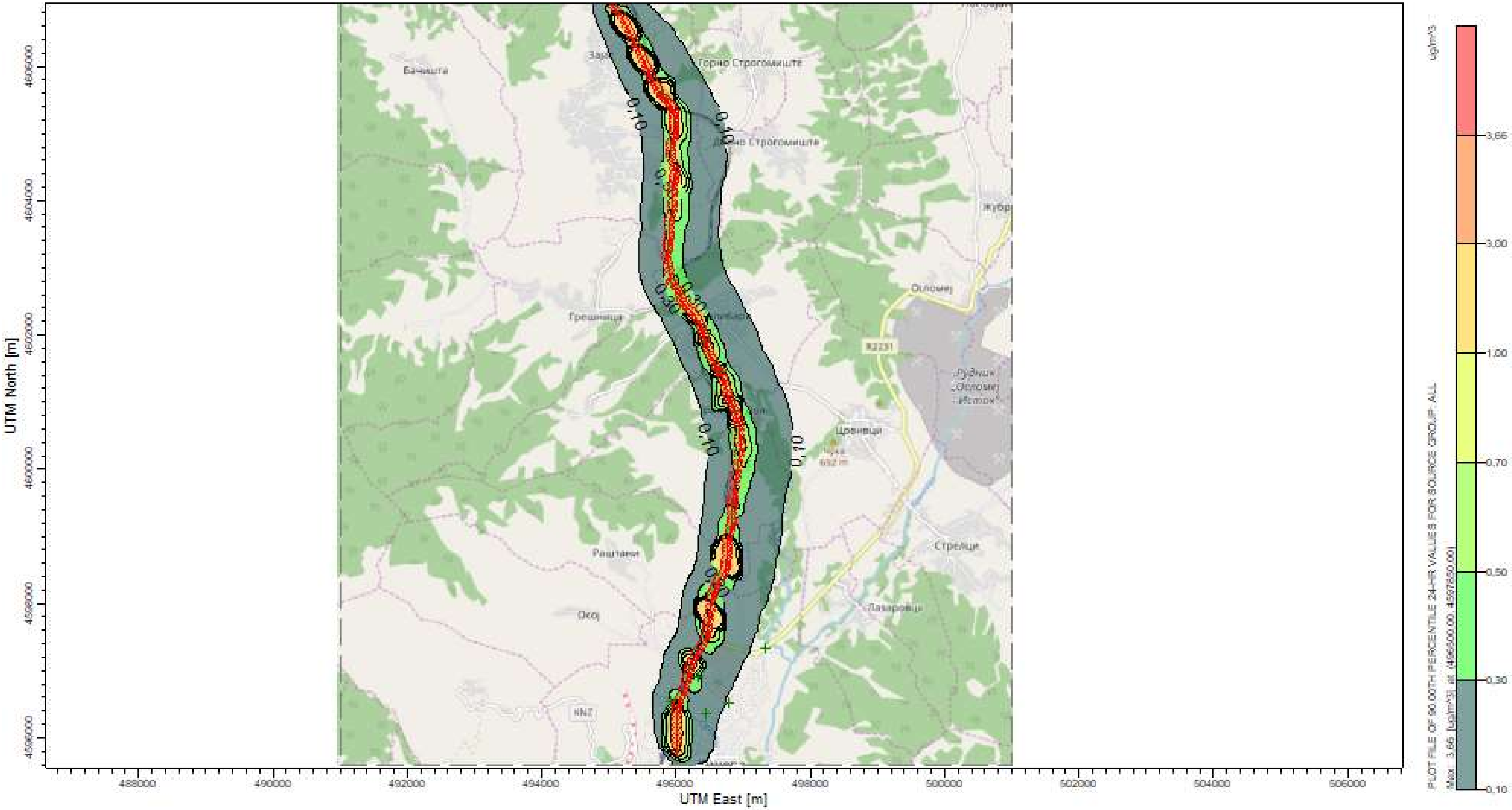


Figure 27 Contours of 90th percentile of PM10 of PM10 concentrations in 2040 – No Scheme (Traffic only)

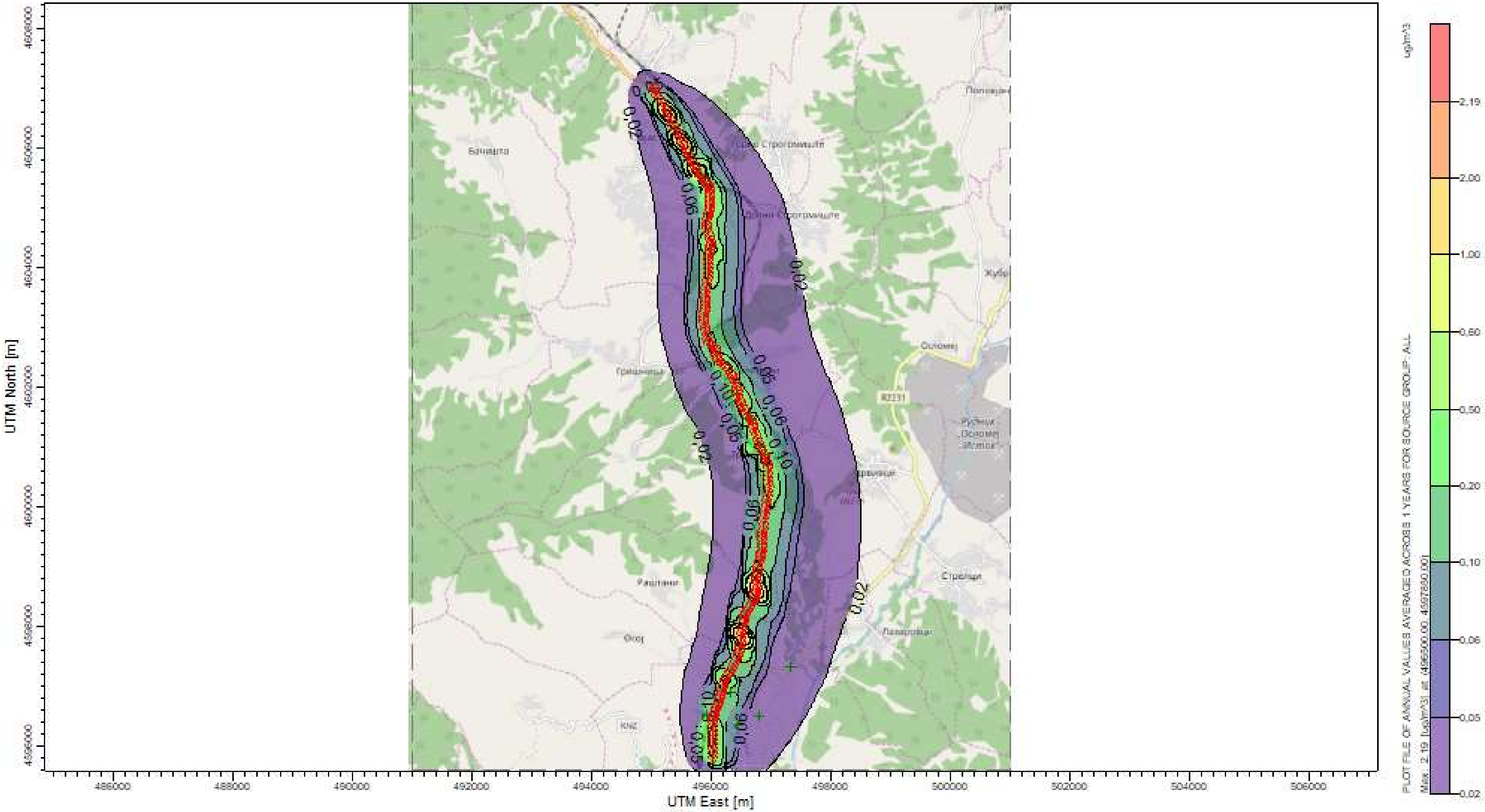


Figure 28 Contours of average annual PM10 concentrations in 2040 – No Scheme (Traffic only)

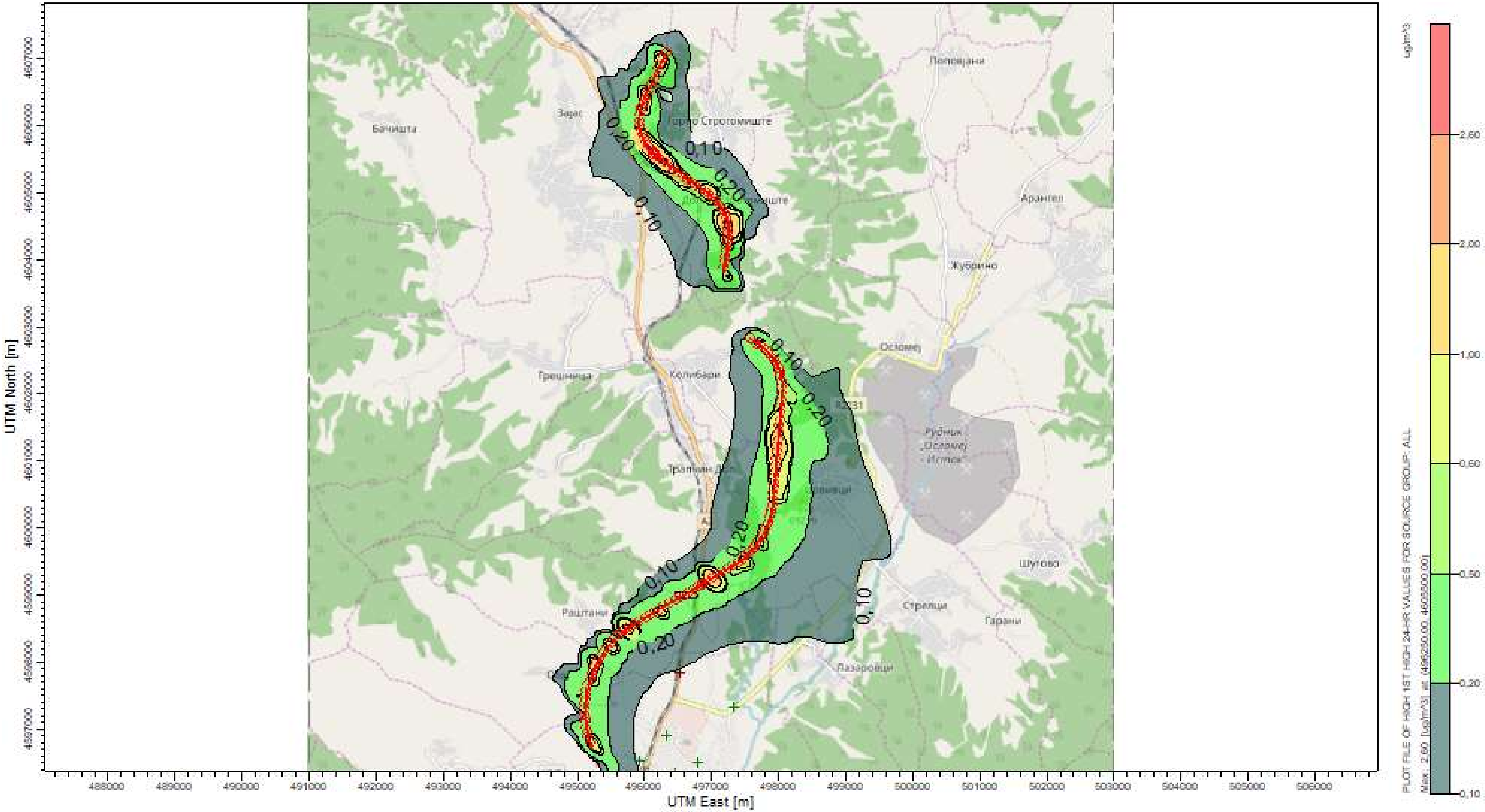


Figure 29 Contours of the maximum 24 hour concentrations of PM10 for 2023 – With Scheme (Traffic only)

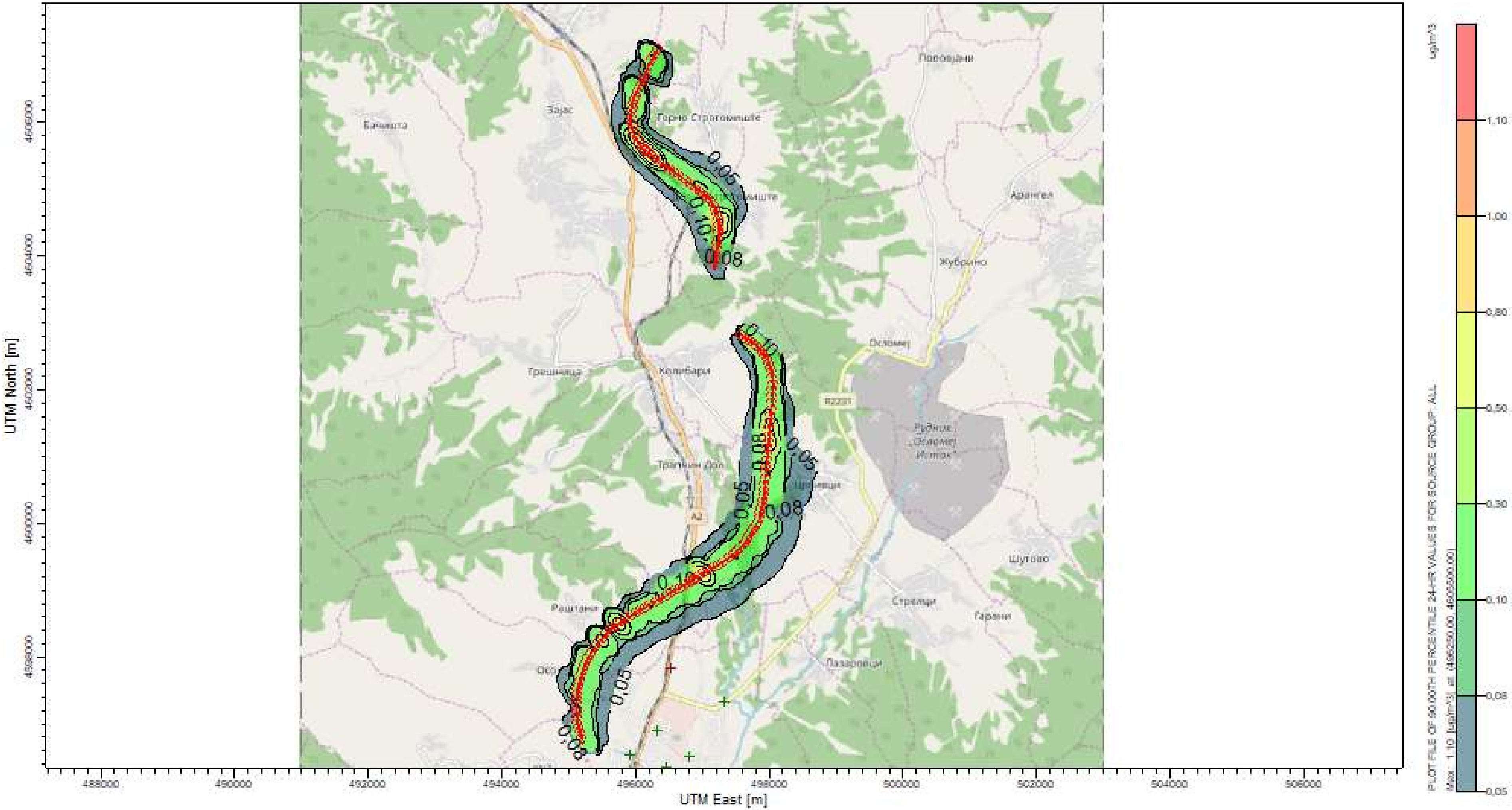


Figure 30 Contours of 90th percentile of PM10 of PM10 concentrations in 2023 – With Scheme (Traffic only)

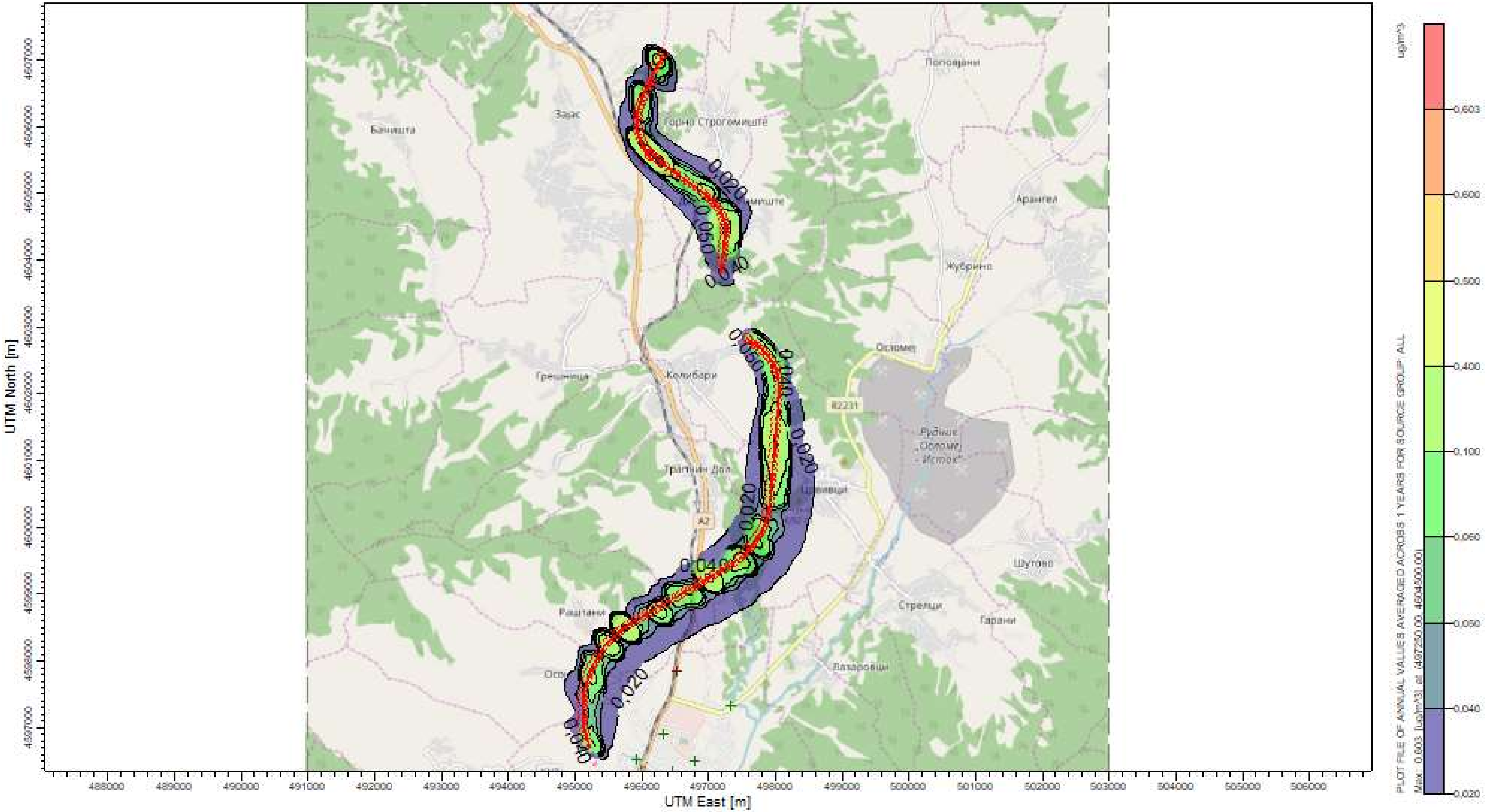


Figure 31 Contours of average annual PM10 concentrations in 2023 – With Scheme (Traffic only)

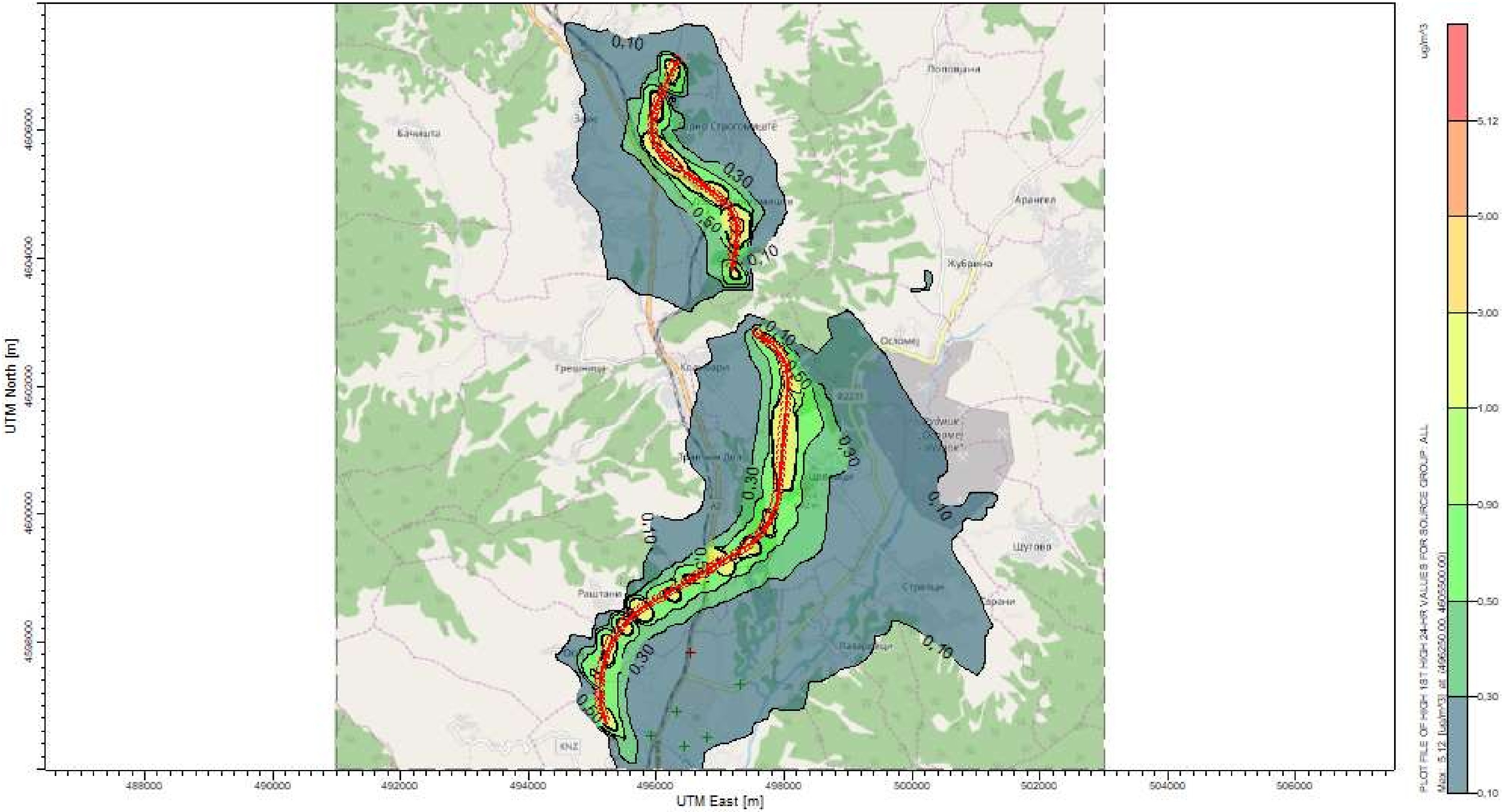


Figure 32 Contours of the maximum 24 hour concentrations of PM10 for 2040 – With Scheme (Traffic only)

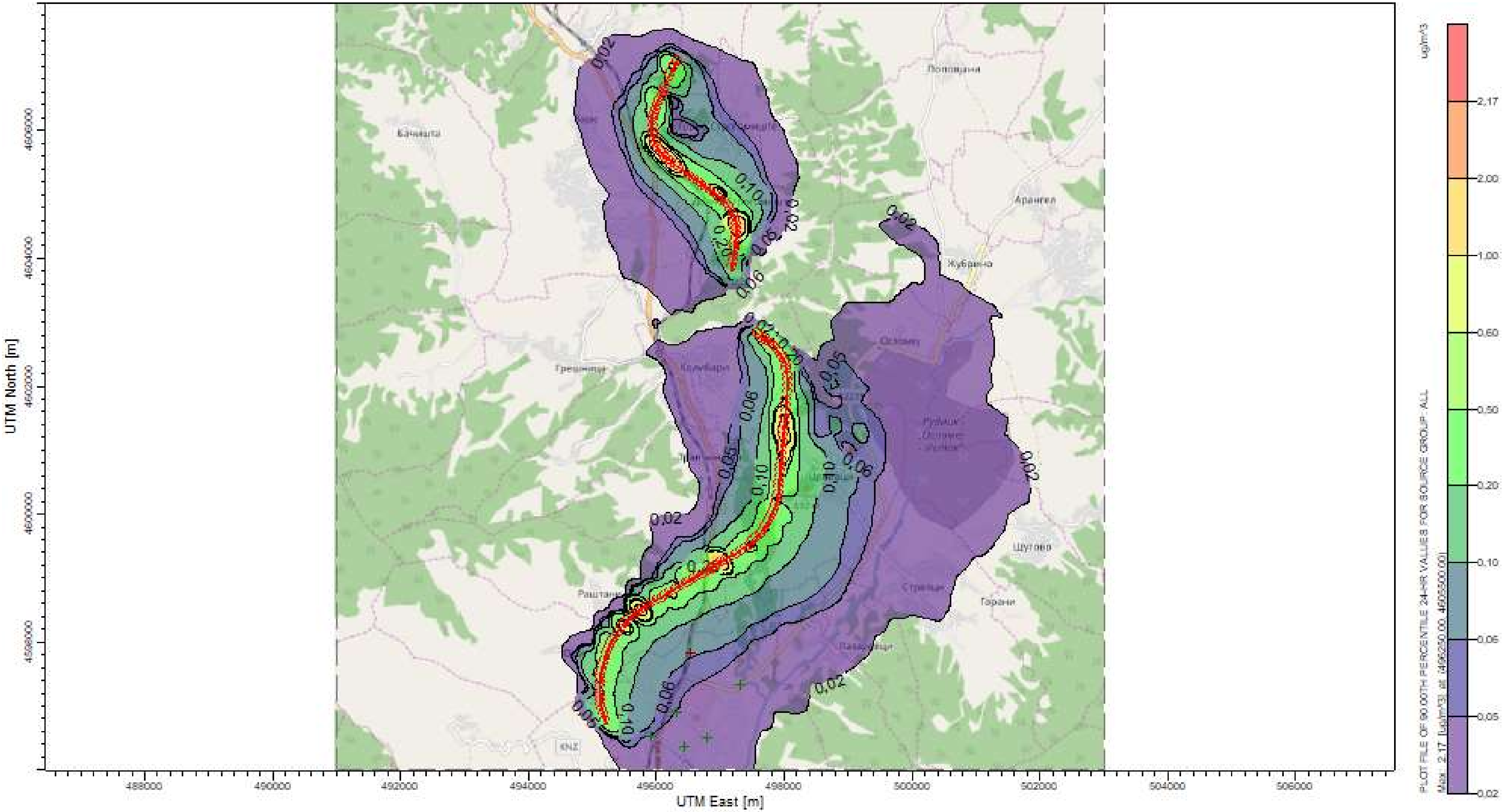


Figure 33 Contours of 90th percentile of PM10 of PM10 concentrations in 2040 – With Scheme (Traffic only)

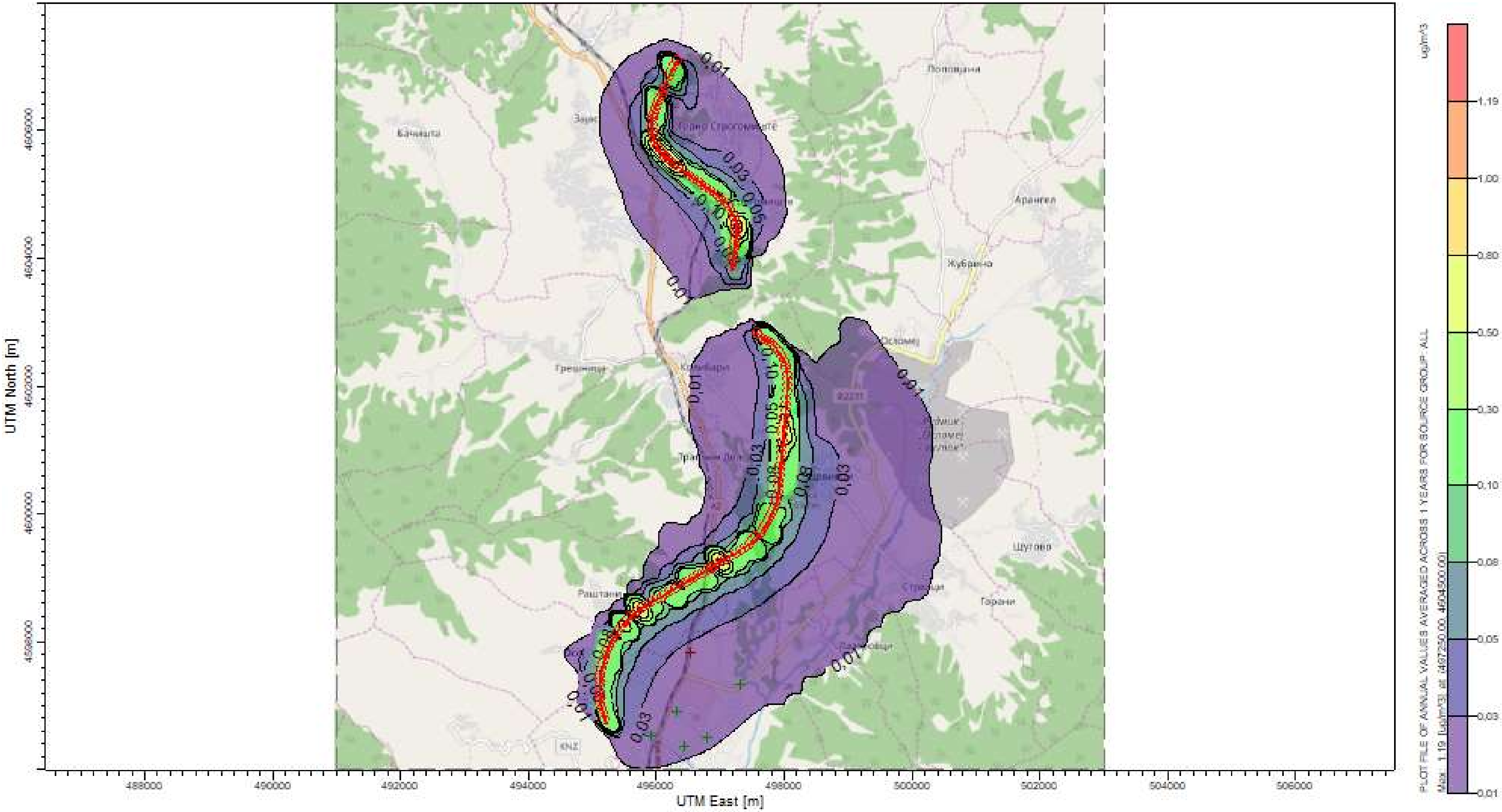


Figure 34 Contours of average annual PM10 concentrations in 2040 – With Scheme (Traffic only)

3.2.2 PM2.5

Models of PM2.5 emitted from road traffic have been worked out despite the fact that concentrations of PM2.5 are not monitored anywhere close to the existing road. Only annual average concentration is regulated in the Directive 2008/50/EC. Nevertheless, the daily concentrations were also modeled. Maximum concentration values in no-scheme and with-scheme scenarios and their locations are shown in Table 24 and Table 28 respectively.

Table 24 Model results summary for PM2.5 (No-Scheme scenario)

Year	Average period	Background	AQ limit value	Peak concentration	UTM coordinates	
		μg/m³	μg/m³	μg/m³	X	Y
2018	24 h (Max)	42,3	50	3.4936	495750	4605600
	Annual	42,3	40	0.9335	496500	4597850
2023	24 h (Max)	40	50	2.6743	495750	4605600
	Annual (2020)	40	40	0.7145	496500	4597850
2040	24 h (Max)	20	50	4.8250	495750	4605600
	Annual (2020)	20	40	1.2892	496500	4597850

Table 25 PM2.5 sensitive receptor summary for the basic year (2018) – No -Scheme scenario

Averaging Period	ID	Concentrations (μg/m³)			UTM Coordinates (m)	
		Background	Air Quality Limit	Peak (Traffic only)	X	Y
24-HR (Max)	School			0.2584	496450	4596350
24-HR (Max)	Mosque			0.5709	495921	4596534
24-HR (Max)	University			0.2013	496790	4596510
24-HR (Max)	Military barracs			0.5280	496320	4596910
24-HR (Max)	Sports Center			0.1730	497320	4597330
24-HR (Max)	House			4.2533	495852	4605509
24-HR (Max)	House			3.5648	495797	4605571
24-HR (Max)	Mosque			1.9434	496428	4601896
24-HR (Max)	House			2.5820	496608	4601490
24-HR (Max)	House			3.9664	496637	4601465
24-HR (Max)	House			2.0647	496784	4601039
24-HR (Max)	House			4.2031	496886	4600879
Annual	School		25	0.0336	496450	4596350
Annual	Mosque		25	0.0573	495921	4596534
Annual	University		25	0.0226	496790	4596510
Annual	Military barracs		25	0.0853	496320	4596910
Annual	Sports Center		25	0.0197	497320	4597330
Annual	House		25	0.7673	495852	4605509
Annual	House		25	0.6437	495797	4605571
Annual	Mosque		25	0.3800	496428	4601896
Annual	House		25	0.3549	496608	4601490
Annual	House		25	0.4241	496637	4601465
Annual	House		25	0.3862	496784	4601039

Annual	House		25	0.5783	496886	4600879

Table 26 PM2.5 sensitive receptor summary for the opening year (2023) – No -Scheme scenario

Averaging Period	ID	Concentrations (μg/m³)			UTM Coordinates (m)	
		Background	Air Quality Limit	Peak (Traffic only)	X	Y
24-HR (Max)	School			0.1386	496450	4596350
24-HR (Max)	Mosque			0.3063	495921	4596534
24-HR (Max)	University			0.1080	496790	4596510
24-HR (Max)	Military barracs			0.2833	496320	4596910
24-HR (Max)	Sports Center			0.0928	497320	4597330
24-HR (Max)	House			2.2820	495852	4605509
24-HR (Max)	House			1.9126	495797	4605571
24-HR (Max)	Mosque			1.0427	496428	4601896
24-HR (Max)	House			1.3853	496608	4601490
24-HR (Max)	House			2.1281	496637	4601465
24-HR (Max)	House			1.1078	496784	4601039
24-HR (Max)	House			2.2551	496886	4600879
Annual	School		25	0.0180	496450	4596350
Annual	Mosque		25	0.0308	495921	4596534
Annual	University		25	0.0121	496790	4596510
Annual	Military barracs		25	0.0458	496320	4596910
Annual	Sports Center		25	0.0106	497320	4597330
Annual	House		25	0.4117	495852	4605509
Annual	House		25	0.3454	495797	4605571
Annual	Mosque		25	0.2039	496428	4601896
Annual	House		25	0.1904	496608	4601490
Annual	House		25	0.2275	496637	4601465
Annual	House		25	0.2072	496784	4601039
Annual	House		25	0.3103	496886	4600879

Table 27 PM2.5 sensitive receptor summary for 2040 – No -Scheme scenario

Averaging Period	ID	Concentrations (µg/m³)			UTM Coordinates (m)	
		Background	Air Quality Limit	Peak (Traffic only)	X	Y
(m)			25			
24-HR (Max)	School		25	0.1386	496450	4596350
24-HR (Max)	Mosque		25	0.3063	495921	4596534
24-HR (Max)	University		25	0.1080	496790	4596510
24-HR (Max)	Military barracs		25	0.2833	496320	4596910
24-HR (Max)	Sports Center		25	0.0928	497320	4597330
24-HR (Max)	House		25	2.2820	495852	4605509
24-HR (Max)	House		25	1.9126	495797	4605571
24-HR (Max)	Mosque		25	1.0427	496428	4601896
24-HR (Max)	House		25	1.3853	496608	4601490
24-HR (Max)	House		25	2.1281	496637	4601465
24-HR (Max)	House		25	1.1078	496784	4601039
24-HR (Max)	House		25	2.2551	496886	4600879
Annual	School		25	0.0180	496450	4596350
Annual	Mosque		25	0.0308	495921	4596534
Annual	University		25	0.0121	496790	4596510
Annual	Military barracs		25	0.0458	496320	4596910
Annual	Sports Center		25	0.0106	497320	4597330
Annual	House		25	0.4117	495852	4605509
Annual	House		25	0.3454	495797	4605571
Annual	Mosque		25	0.2039	496428	4601896
Annual	House		25	0.1904	496608	4601490
Annual	House		25	0.2275	496637	4601465
Annual	House		25	0.2072	496784	4601039
Annual	House		25	0.3103	496886	4600879

Table 28 PM2.5 Model result summary– With-Scheme scenario

Year	Average period	Background	AQ limit value	Peak concentration	UTM coordinates (m)	
		µg/m³	µg/m³	µg/m³	X	Y
2023	24 h (Max)			1.6693	496250	4605500
	Annual (2020)		20	0.3874	497250	4604500
2040	24 h (Max)			3.0060	496250	4605500
	Annual (2020)		20	0.6978	497250	4604500

Table 29 PM2.5 sensitive receptor summary for the opening year (2023) – With-Scheme scenario

Averaging Period	ID	Concentrations (μg/m³)			UTM Coordinates (m)	
		Background	Air Quality Limit	Peak (Traffic only)	X	Y
24-HR (Max)	School	40	50	0.03835	496450	4596350
24-HR (Max)	Mosque	40	50	0.05931	495921	4596534
24-HR (Max)	University	40	50	0.03616	496790	4596510
24-HR (Max)	Military barracks	40	50	0.04469	496320	4596910
24-HR (Max)	Sports Center	40	50	0.03933	497320	4597330
Annual	School	40	40	0.00438	496450	4596350
Annual	Mosque	40	40	0.00634	495921	4596534
Annual	University	40	40	0.00433	496790	4596510
Annual	Military barracks	40	40	0.00619	496320	4596910
Annual	Sports Center	40	40	0.00505	497320	4597330

Table 30 PM2.5 sensitive receptor summary for 2040 – With-Scheme scenario

Averaging Period	ID	Concentrations (mg/m³)			UTM Coordinates (m)	
		Background	Air Quality Limit	Peak (Traffic only)	X	Y
24-HR (Max)	School			0.06907	496450	4596350
24-HR (Max)	Mosque			0.10683	495921	4596534
24-HR (Max)	University			0.06513	496790	4596510
24-HR (Max)	Military barracks			0.0805	496320	4596910
24-HR (Max)	Sports Center			0.07084	497320	4597330
Annual	School		20	0.00789	496450	4596350
Annual	Mosque		20	0.01141	495921	4596534
Annual	University		20	0.0078	496790	4596510
Annual	Military barracks		20	0.01114	496320	4596910
Annual	Sports Center		20	0.00909	497320	4597330

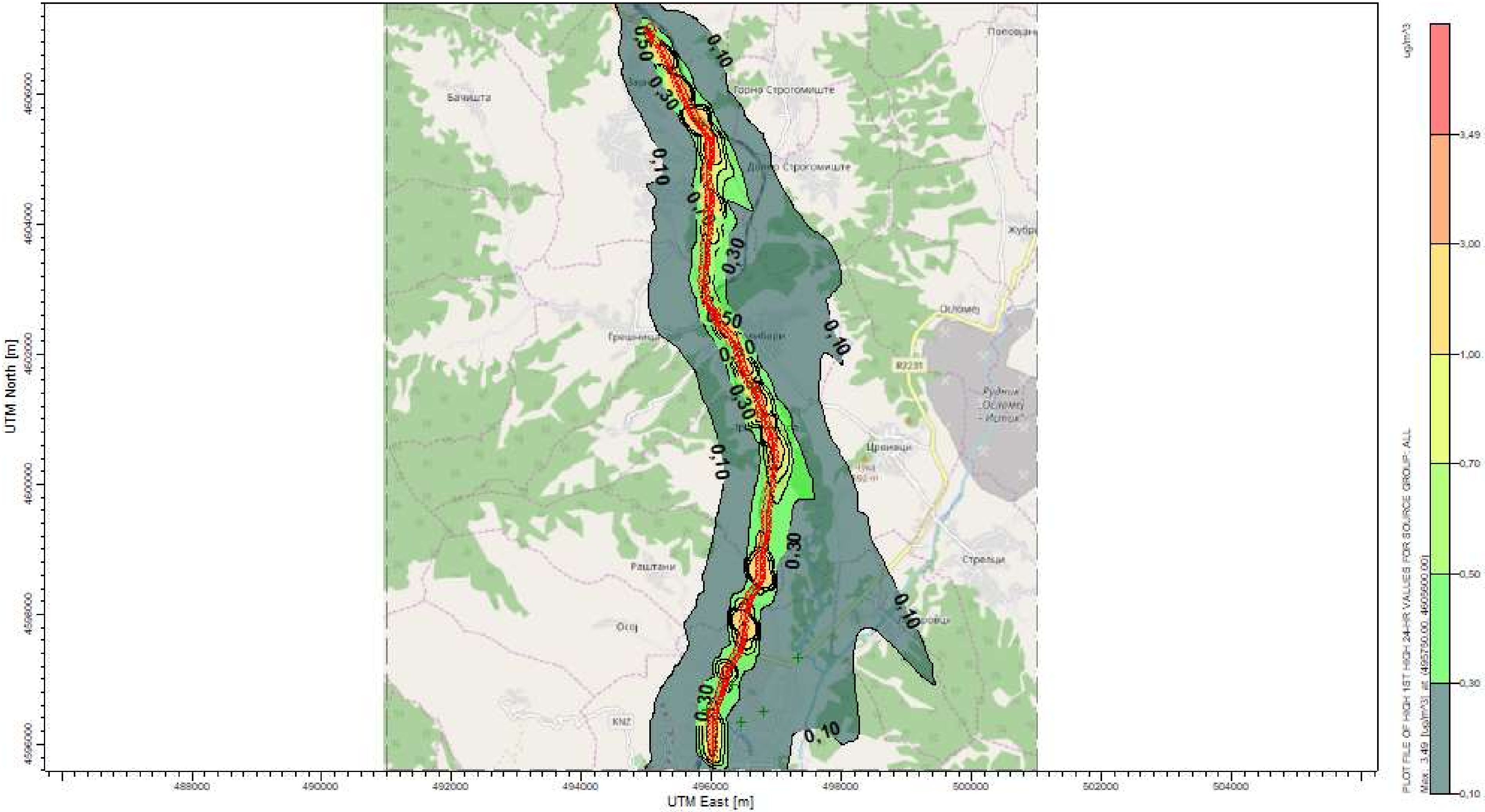


Figure 35 Contours of the maximum 24 hour concentrations of PM2.5 in 2018 – No Scheme (Traffic only)

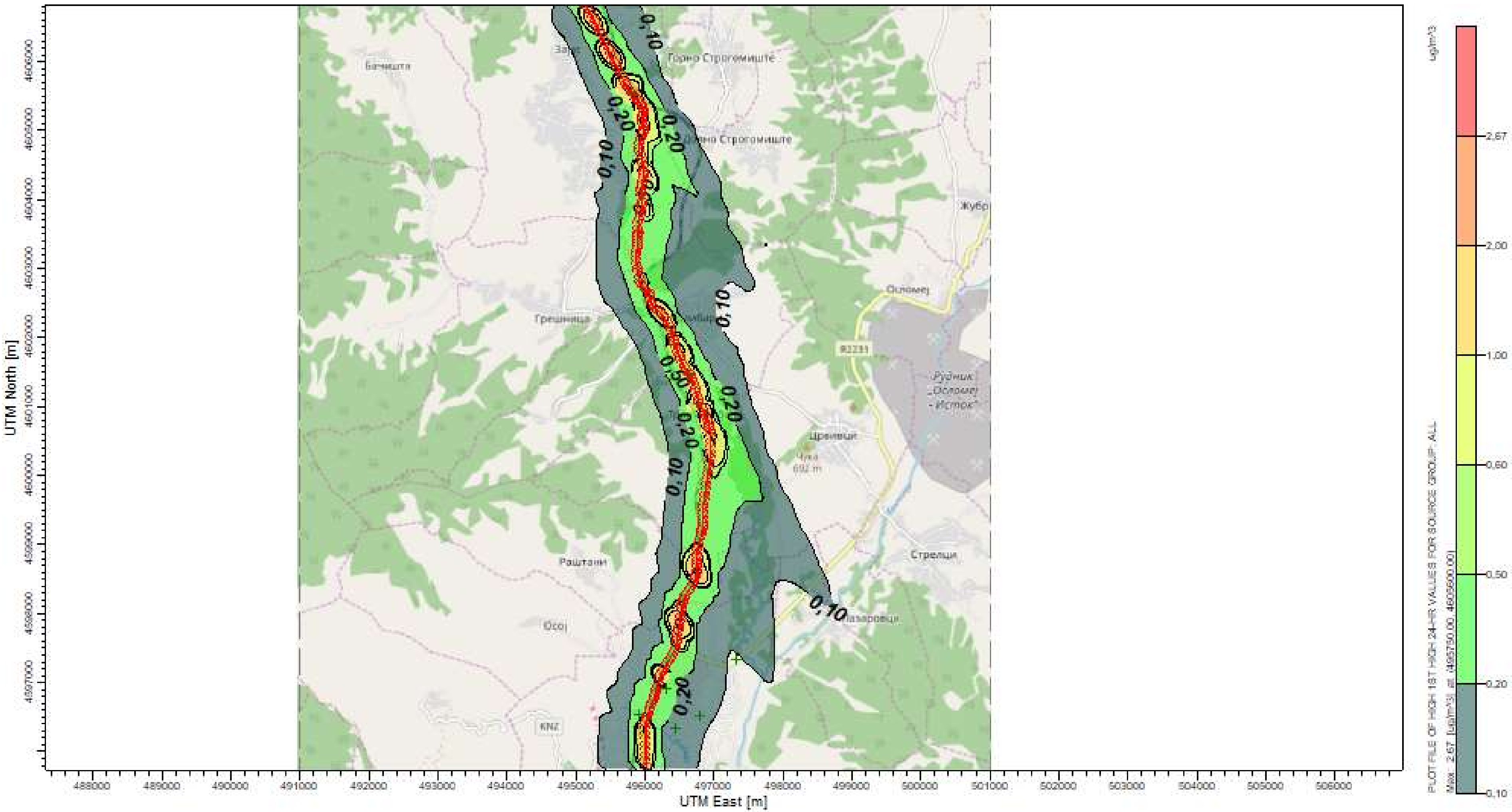


Figure 36 Contours of the maximum 24 hour concentrations of PM2.5 in 2023 – No Scheme (Traffic only)

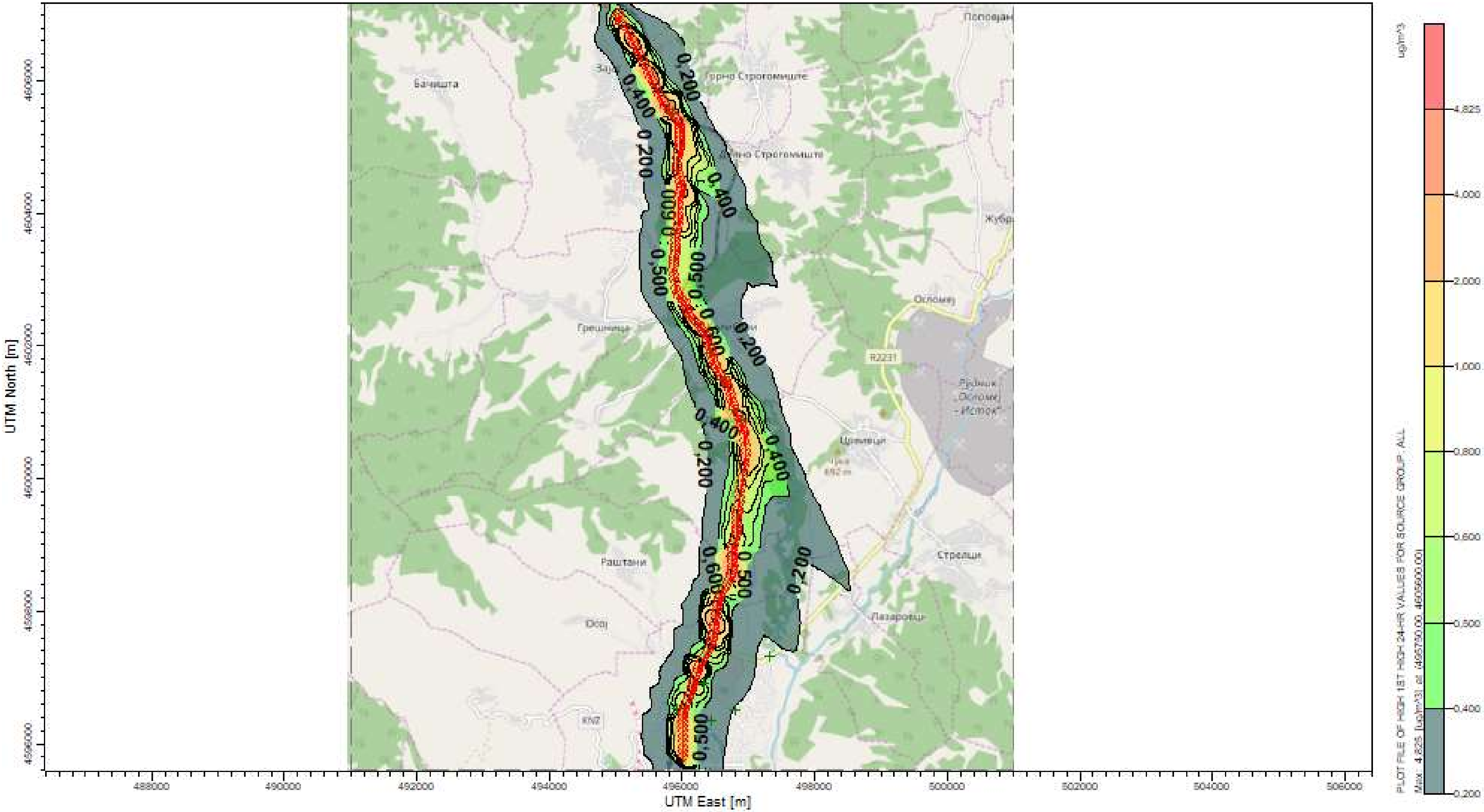


Figure 37 Contours of the maximum 24 hour concentrations of PM2.5 in 2040 – No Scheme (Traffic only)

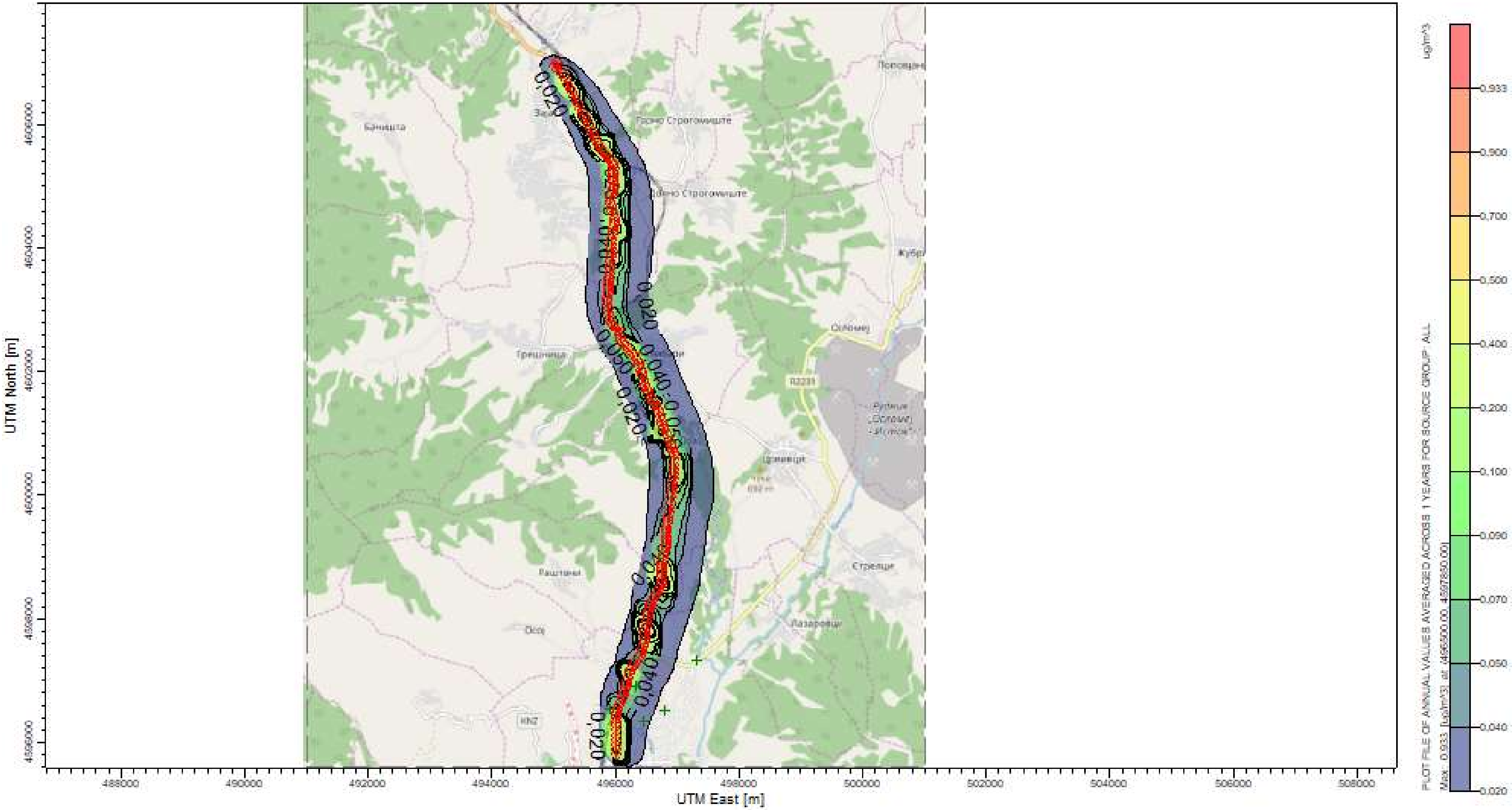


Figure 38 Contours of the average annual concentrations of PM2.5 in 2018 – No Scheme (Traffic only)

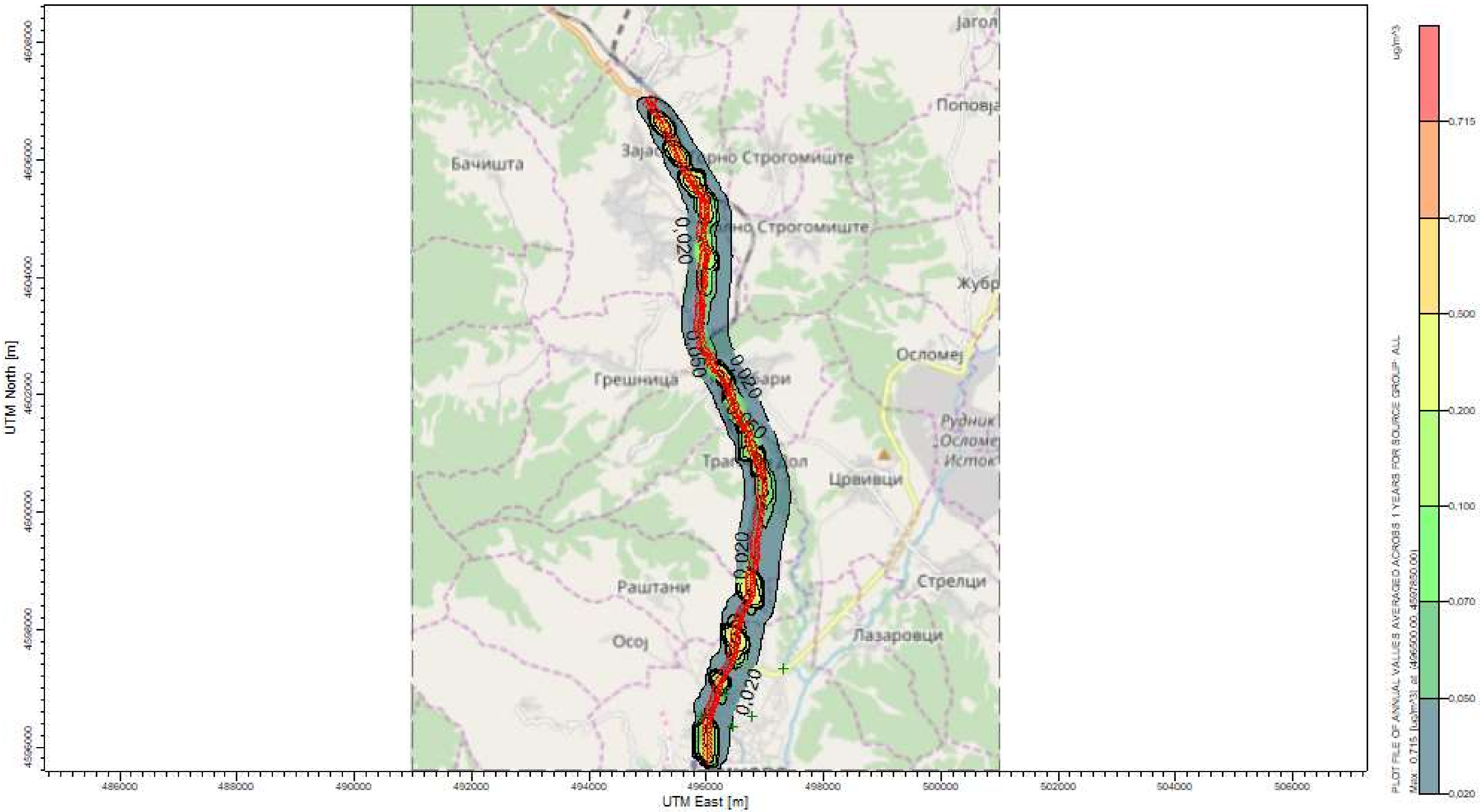


Figure 39 Contours of the average annual concentrations of PM2.5 in 2023 – No Scheme (Traffic only)

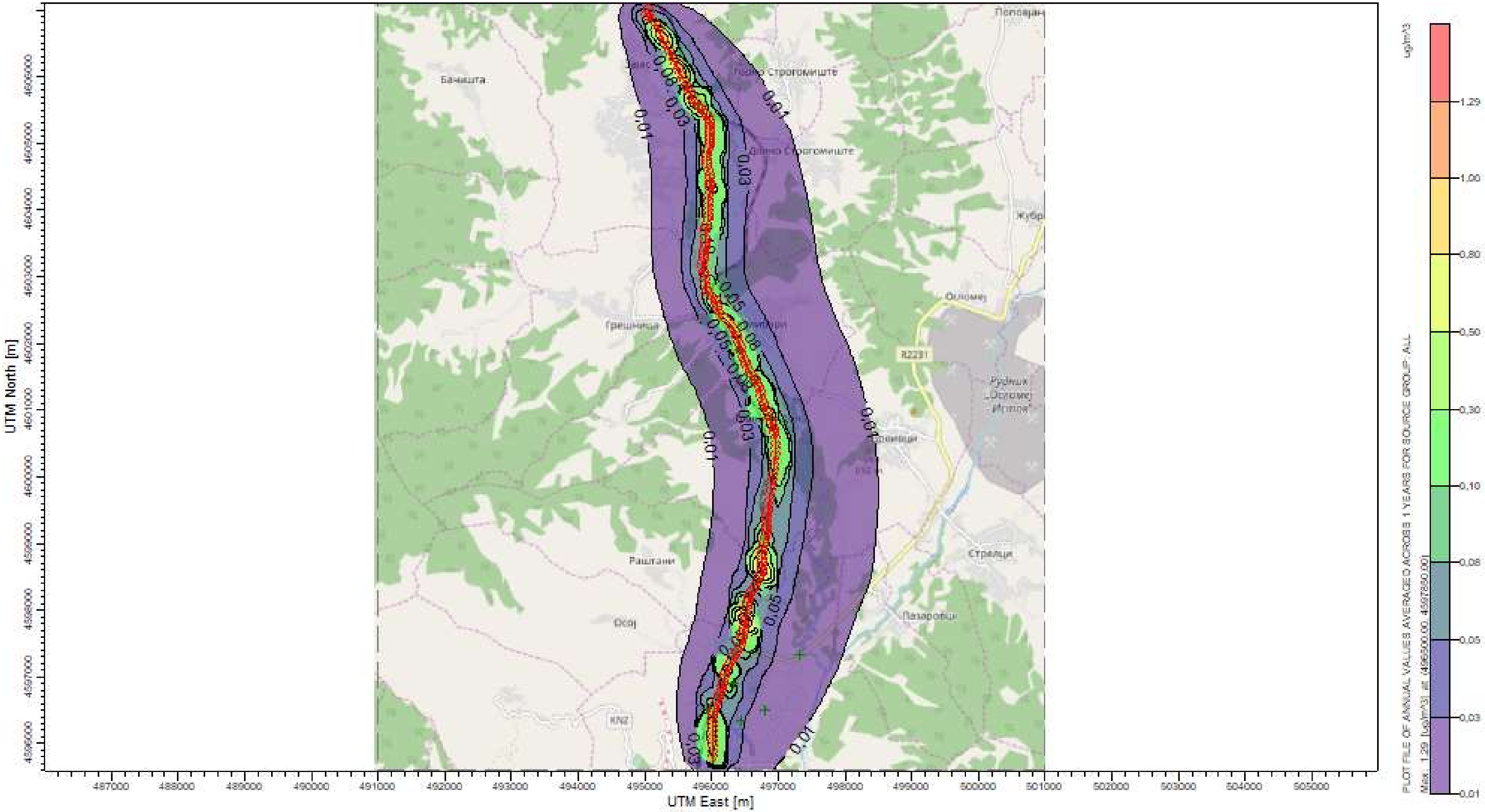


Figure 40 Contours of the average annual concentrations of PM2.5 in 2040 – No Scheme (Traffic only)

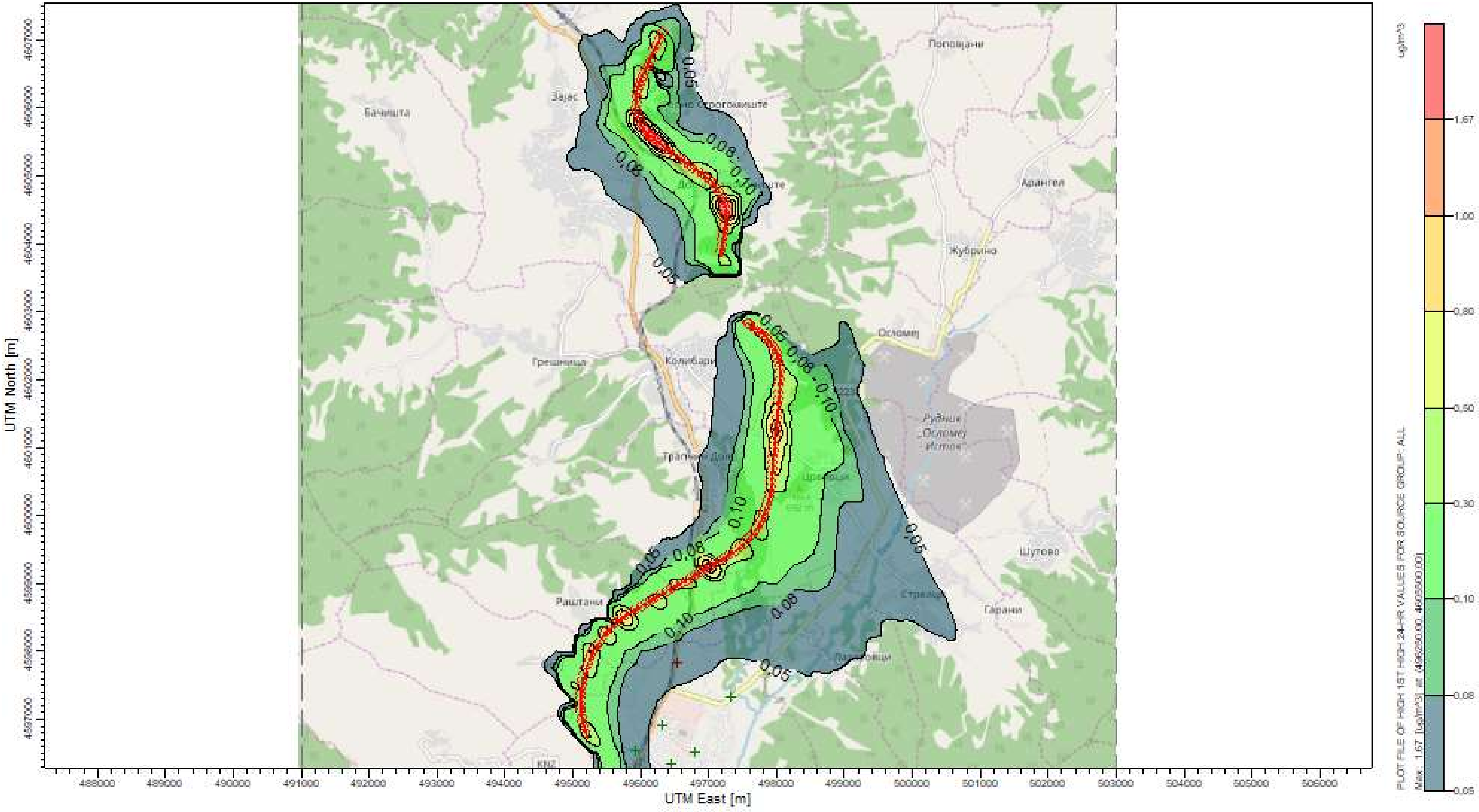


Figure 41 Contours of the maximum 24 hour concentrations of PM2.5 in 2023 – With Scheme (Traffic only)

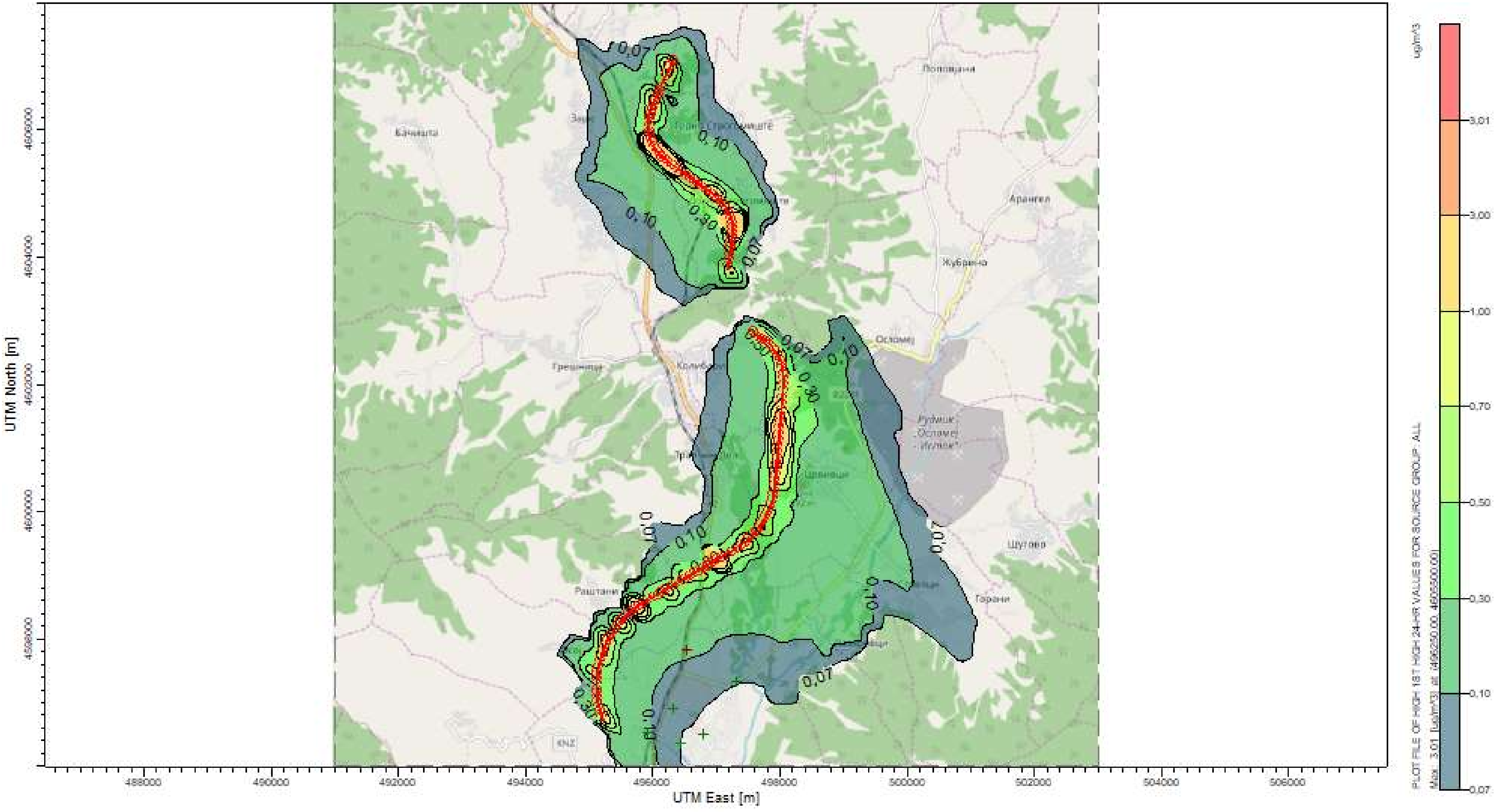


Figure 42 Contours of the maximum 24 hour concentrations of PM2.5 in 2040 – With Scheme (Traffic only)

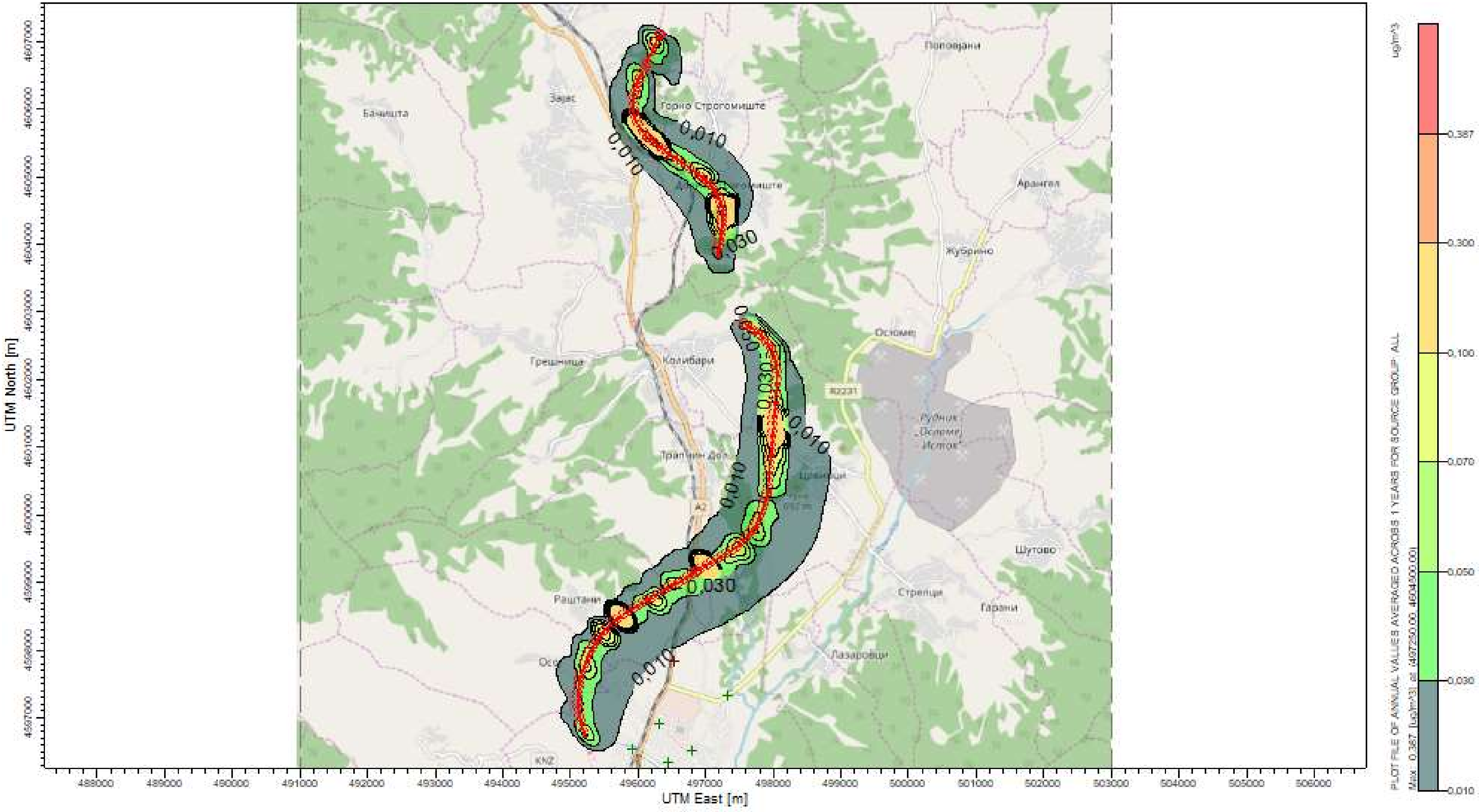


Figure 43 Contours of the average annual concentrations of PM2.5 in 2023 – With Scheme (Traffic only)

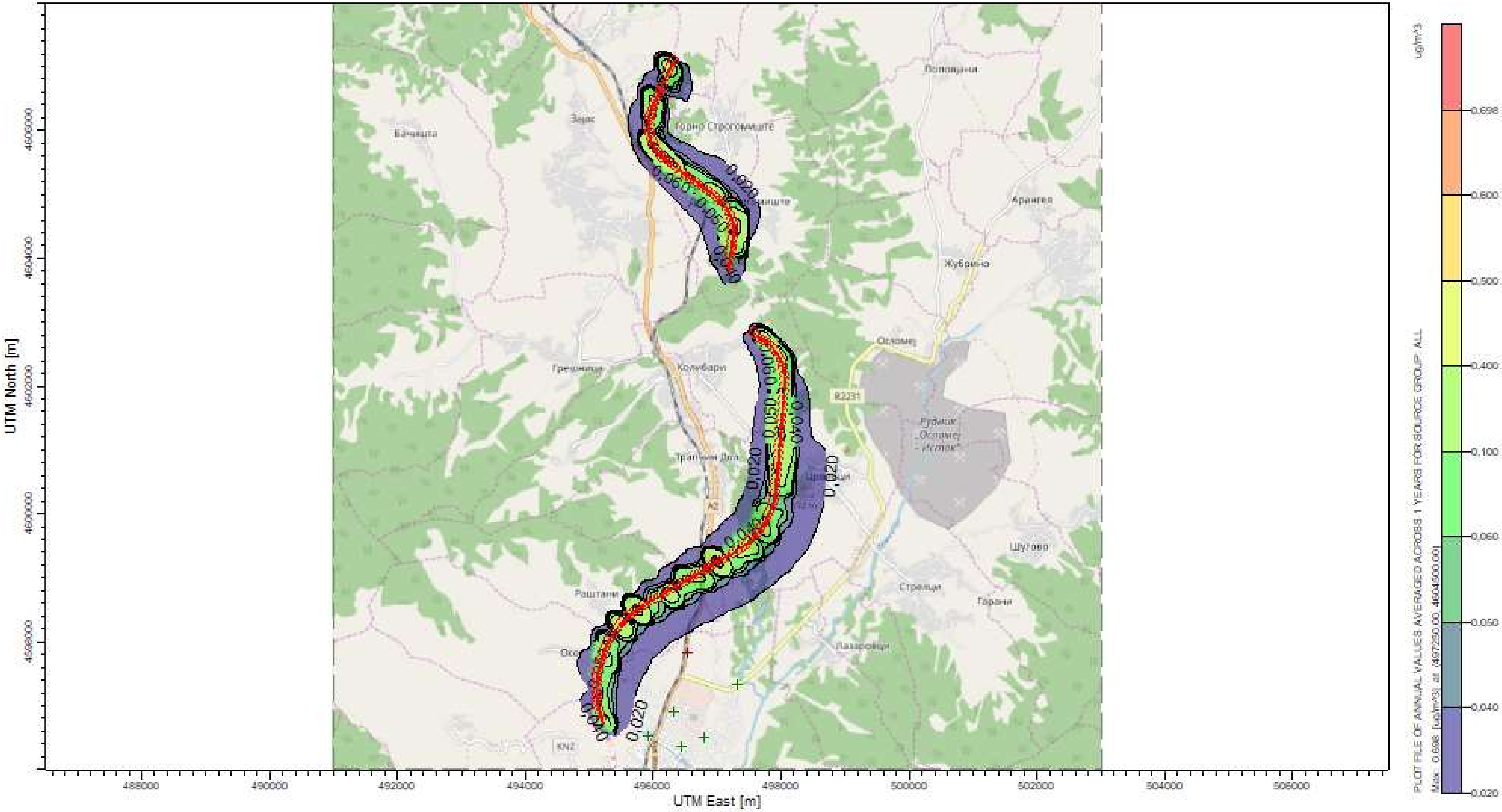


Figure 44 Contours of the average annual concentrations of PM2.5 in 2040 – With Scheme (Traffic only)

3.2.3 Carbon monoxide

Ambient air concentration of CO is regulated based on consequent 8h average concentration. Maximum 8 hour concentrations in all scenarios are predicted within the highway alignment. Results are presented in Table 31 and Table 35. The predicted CO concentrations at sensitive receptors with and without the project being implemented are shown in Table 32 to 34 and Table 36 to 37. Calculated ground level concentrations of CO resulting from traffic on the highway are negligible compared to the environment air quality limit. The background level is considerable but rather low compared to the EQL. Nevertheless, one can say that the traffic CO emissions will have a minor impact on the air quality along the highway.

Table 31 Model results summary for CO (No-Scheme scenario)

Year	Average period	Background	AQ limit value	Peak concentration	UTM coordinates	
		μg/m³	μg/m³	μg/m³	X	Y
2018	8 h (Max)	765	10000	306.62	495750	4605600
	8 h (99.8th perc.)	765	10000	161.27	495500	4606100
2023	8 h (Max)	765	10000	244.68	495750	4605600
	8 h (99.8th perc.)	765	10000	128.69	495500	4606100
2040	8h (Max)	765	10000	440.66	495750	4605600
	8 h (99.8th perc.)	765	10000	231.77	495500	4606100

Table 32 CO sensitive receptor summary for the basic year (2018) – No -Scheme scenario

Averaging Period	ID	Concentrations (μg/m³)			UTM Coordinates (m)	
		Background	Air Quality Limit	Peak (Traffic only)	X	Y
8-HR (Max)	School	765	10000	15.78	496450	4596350
8-HR (Max)	Mosque	765	10000	37.83	495921	4596534
8-HR (Max)	University	765	10000	12.19	496790	4596510
8-HR (Max)	Military barracks	765	10000	31.50	496320	4596910
8-HR (Max)	Sports Center	765	10000	9.86	497320	4597330
8-HR (Max)	House	765	10000	223.64	495852	4605509
8-HR (Max)	House	765	10000	190.34	495797	4605571
8-HR (Max)	Mosque	765	10000	119.97	496428	4601896
8-HR (Max)	House	765	10000	162.90	496608	4601490
8-HR (Max)	House	765	10000	255.27	496637	4601465
8-HR (Max)	House	765	10000	127.68	496784	4601039
8-HR (Max)	House	765	10000	224.78	496886	4600879
8-HR 90th Percentile	School	765		10.76	496450	4596350
8-HR 90th Percentile	Mosque	765		18.76	495921	4596534
8-HR 90th Percentile	University	765		7.61	496790	4596510
8-HR 90th Percentile	Military barracks	765		21.27	496320	4596910
8-HR 90th Percentile	Sports Center	765		6.34	497320	4597330
8-HR 90th Percentile	House	765		148.75	495852	4605509
8-HR 90th Percentile	House	765		133.09	495797	4605571
8-HR 90th Percentile	Mosque	765		77.92	496428	4601896
8-HR 90th Percentile	House	765		110.35	496608	4601490
8-HR 90th Percentile	House	765		115.84	496637	4601465
8-HR 90th Percentile	House	765		69.22	496784	4601039
8-HR 90th Percentile	House	765		123.57	496886	4600879

Table 33 CO sensitive receptor summary for the opening year (2023) – No -Scheme scenario

Averaging Period	ID	Concentrations ($\mu g/m^3$)			UTM Coordinates (m)	
		Background	Air Quality Limit	Peak (Traffic only)	X	Y
8-HR (Max)	School	765	10000	12.59	496450	4596350
8-HR (Max)	Mosque	765	10000	30.19	495921	4596534
8-HR (Max)	University	765	10000	9.73	496790	4596510
8-HR (Max)	Military barracks	765	10000	25.13	496320	4596910
8-HR (Max)	Sports Center	765	10000	7.87	497320	4597330
8-HR (Max)	House	765	10000	178.46	495852	4605509
8-HR (Max)	House	765	10000	151.89	495797	4605571
8-HR (Max)	Mosque	765	10000	95.73	496428	4601896
8-HR (Max)	House	765	10000	130.00	496608	4601490
8-HR (Max)	House	765	10000	203.70	496637	4601465
8-HR (Max)	House	765	10000	101.89	496784	4601039
8-HR (Max)	House	765	10000	179.38	496886	4600879
8-HR 90^{th} Percentile	School	765		8.59	496450	4596350
8-HR 90^{th} Percentile	Mosque	765		14.97	495921	4596534
8-HR 90^{th} Percentile	University	765		6.07	496790	4596510
8-HR 90^{th} Percentile	Military barracks	765		16.97	496320	4596910
8-HR 90^{th} Percentile	Sports Center	765		5.06	497320	4597330
8-HR 90^{th} Percentile	House	765		118.70	495852	4605509
8-HR 90^{th} Percentile	House	765		106.20	495797	4605571
8-HR 90^{th} Percentile	Mosque	765		62.18	496428	4601896
8-HR 90^{th} Percentile	House	765		88.06	496608	4601490
8-HR 90^{th} Percentile	House	765		92.44	496637	4601465
8-HR 90^{th} Percentile	House	765		55.23	496784	4601039
8-HR 90^{th} Percentile	House	765		98.61	496886	4600879

Table 34 CO sensitive receptor summary for 2040 – No -Scheme scenario

Averaging Period	ID	Concentrations (μg/m³)			UTM Coordinates (m)	
		Background	Air Quality Limit	Peak (Traffic only)	X	Y
8-HR (Max)	School	765	10000	22.68	496450	4596350
8-HR (Max)	Mosque	765	10000	54.37	495921	4596534
8-HR (Max)	University	765	10000	17.52	496790	4596510
8-HR (Max)	Military barracks	765	10000	45.27	496320	4596910
8-HR (Max)	Sports Center	765	10000	14.17	497320	4597330
8-HR (Max)	House	765	10000	321.41	495852	4605509
8-HR (Max)	House	765	10000	273.55	495797	4605571
8-HR (Max)	Mosque	765	10000	172.41	496428	4601896
8-HR (Max)	House	765	10000	234.12	496608	4601490
8-HR (Max)	House	765	10000	366.87	496637	4601465
8-HR (Max)	House	765	10000	183.50	496784	4601039
8-HR (Max)	House	765	10000	323.06	496886	4600879
8-HR 90th Percentile	School	765	10000	15.47	496450	4596350
8-HR 90th Percentile	Mosque	765	10000	26.96	495921	4596534
8-HR 90th Percentile	University	765	10000	10.94	496790	4596510
8-HR 90th Percentile	Military barracks	765	10000	30.57	496320	4596910
8-HR 90th Percentile	Sports Center	765	10000	9.11	497320	4597330
8-HR 90th Percentile	House	765	10000	213.79	495852	4605509
8-HR 90th Percentile	House	765	10000	191.27	495797	4605571
8-HR 90th Percentile	Mosque	765	10000	111.99	496428	4601896
8-HR 90th Percentile	House	765	10000	158.60	496608	4601490
8-HR 90th Percentile	House	765	10000	166.48	496637	4601465
8-HR 90th Percentile	House	765	10000	99.47	496784	4601039
8-HR 90th Percentile	House	765	10000	177.60	496886	4600879

Table 35 Model results summary for CO (With-Scheme scenario

Year	Average period	Background	AQ limit value	Peak concentration	UTM coordinates	
		μg/m³	μg/m³	μg/m³	X	Y
2023	8 h (Max)	765	10000	103.29	496000	4605750
	8 h (90th perc.)	765	10000	55.22	496250	4605500
2040	8 h (Max)	765	10000	210.09	496250	4605500
	8 h (90th perc.)	765	10000	119.71	496250	4605500

Table 36 CO sensitive receptor summary for the opening year (2023) – With -Scheme scenario

Averaging Period	ID	Concentrations (μg/m³)			UTM Coordinates (m)	
		Background	Air Quality Limit	Peak (Traffic only)	X	Y
8-HR (Max)	School	765	10000	5.02	496450	4596350
8-HR (Max)	Mosque	765	10000		495921	4596534
8-HR (Max)	University	765	10000	7.65	496790	4596510
8-HR (Max)	Military barracks	765	10000		496320	4596910
8-HR (Max)	Sports Center	765	10000	4.28	497320	4597330
8-HR 90th Percentile	School	765		1.34	496450	4596350
8-HR 90th Percentile	Mosque	765		1.96	495921	4596534
8-HR 90th Percentile	University	765		1.31	496790	4596510
8-HR 90th Percentile	Military barracks	765		1.67	496320	4596910
8-HR 90th Percentile	Sports Center	765		1.42	497320	4597330

Table 37 CO sensitive receptor summary for 2040 – With -Scheme scenario

Averaging Period	ID	Concentrations (μg/m³)			UTM Coordinates (m)	
		Background	Air Quality Limit	Peak (Traffic only)	X	Y
8-HR (Max)	School	765	10000	2.57	496450	4596350
8-HR (Max)	Mosque	765	10000	3.93	495921	4596534
8-HR (Max)	University	765	10000	2.42	496790	4596510
8-HR (Max)	Military barracks	765	10000	2.92	496320	4596910
8-HR (Max)	Sports Center	765	10000	2.82	497320	4597330
8-HR 90th Percentile	School	765		1.34	496450	4596350
8-HR 90th Percentile	Mosque	765		1.96	495921	4596534
8-HR 90th Percentile	University	765		1.31	496790	4596510
8-HR 90th Percentile	Military barracks	765		1.67	496320	4596910
8-HR 90th Percentile	Sports Center	765		1.42	497320	4597330

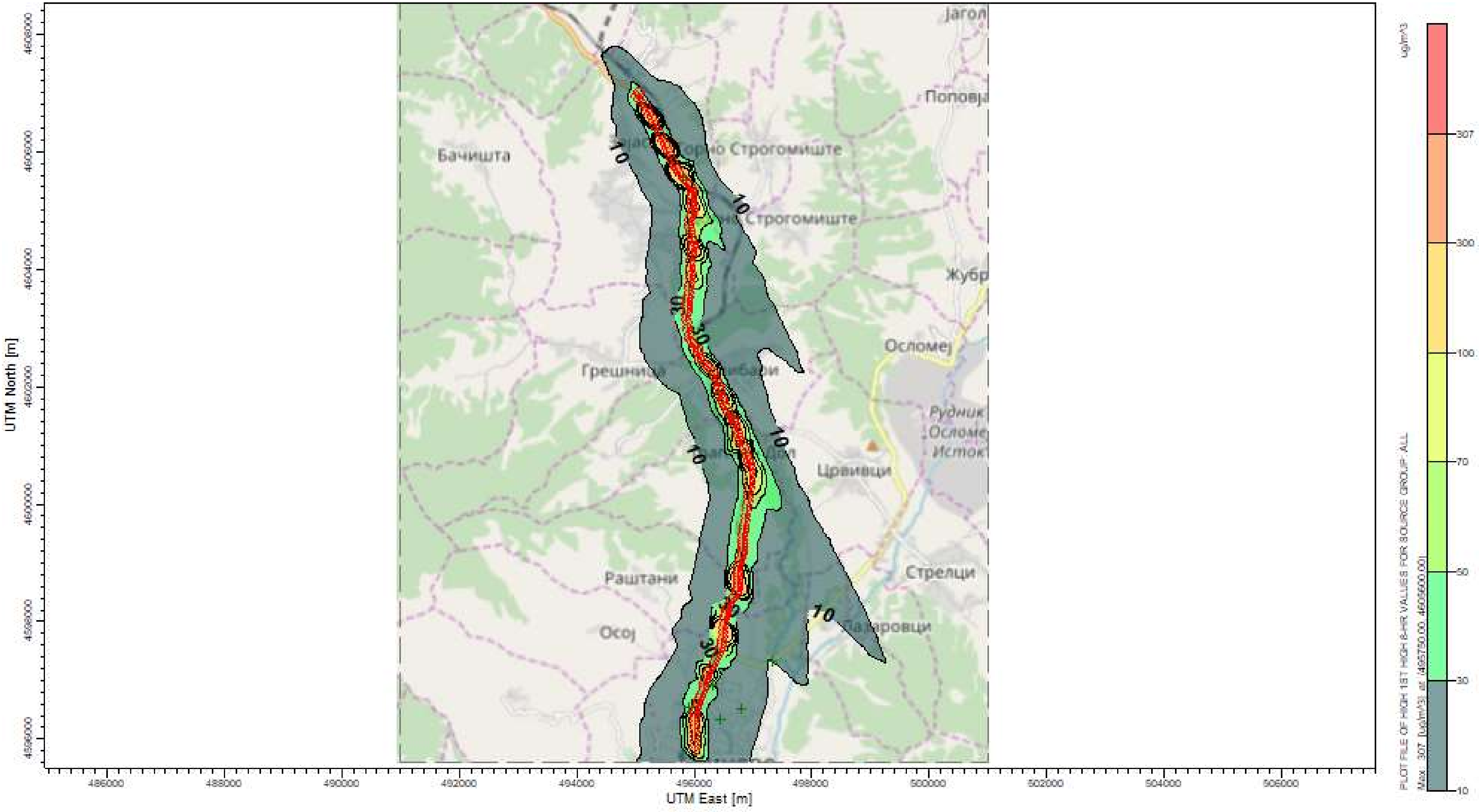


Figure 45 Plot of maximum 8 hour concentrations of CO in 2018 – No scheme scenario (Traffic only)

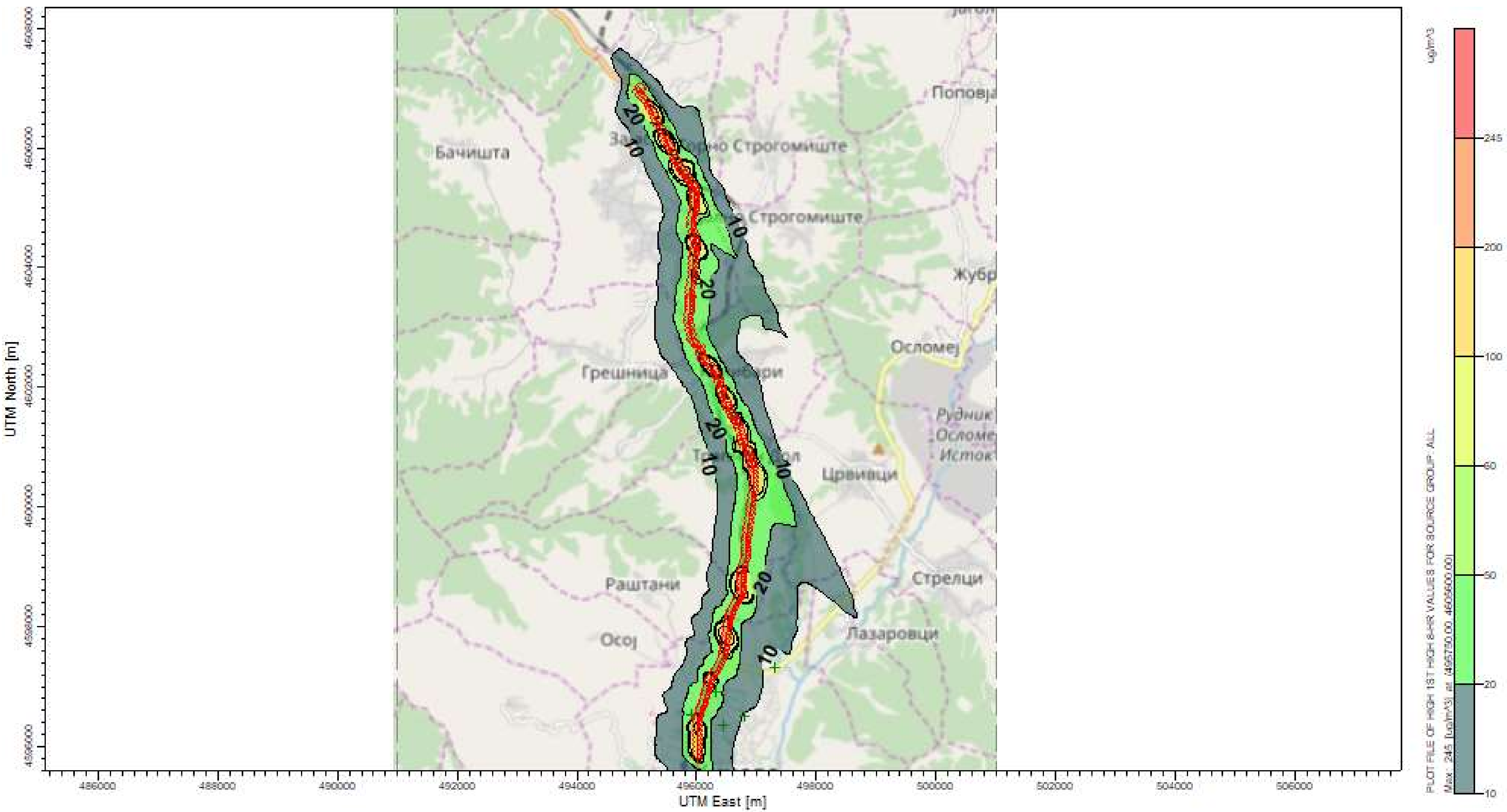


Figure 46 Plot of maximum 8 hour concentrations of CO in 2023 – No scheme scenario (Traffic only)

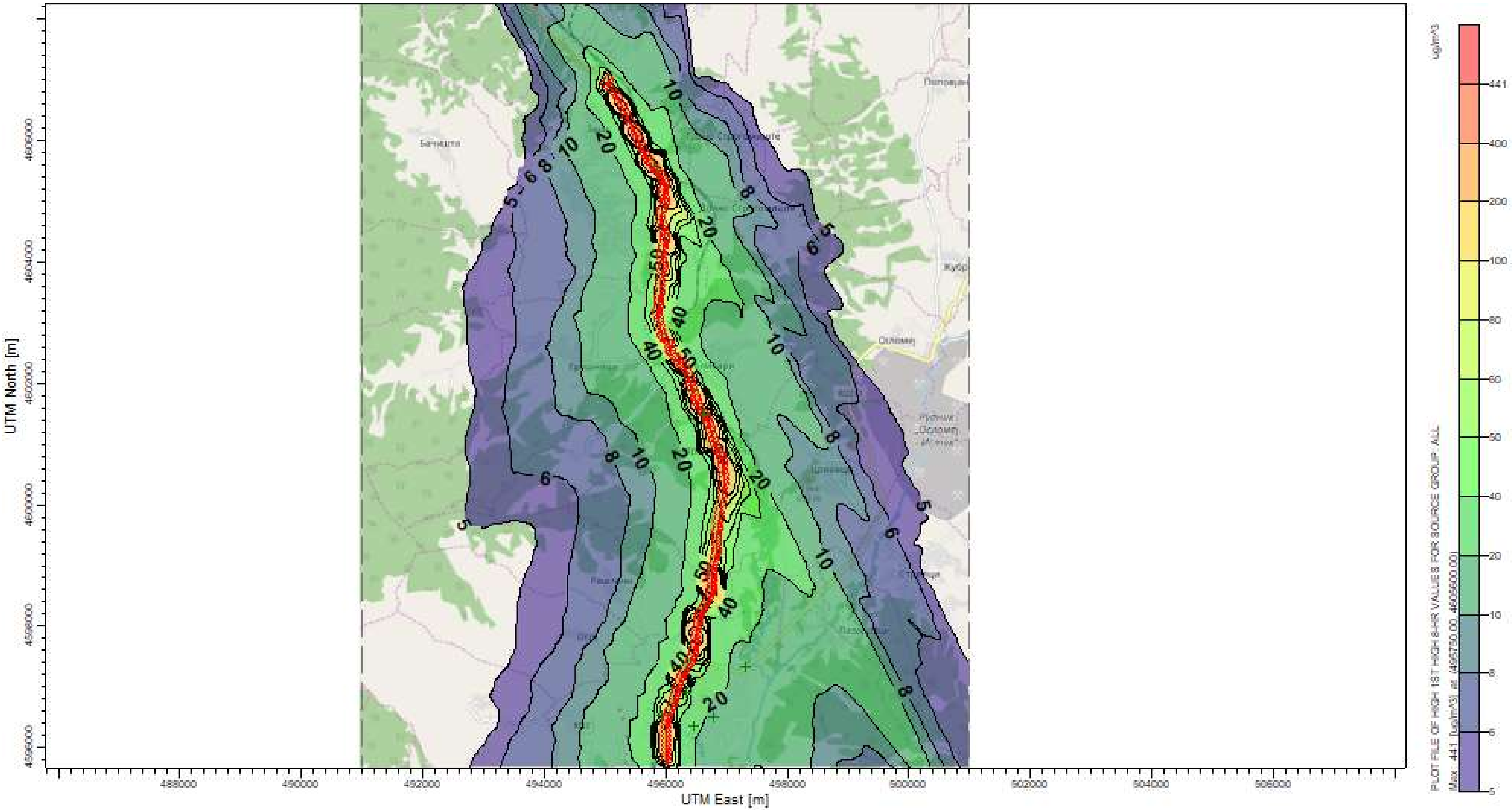


Figure 47 Plot of maximum 8 hour concentrations of CO in 2040 – No scheme scenario (Traffic only)

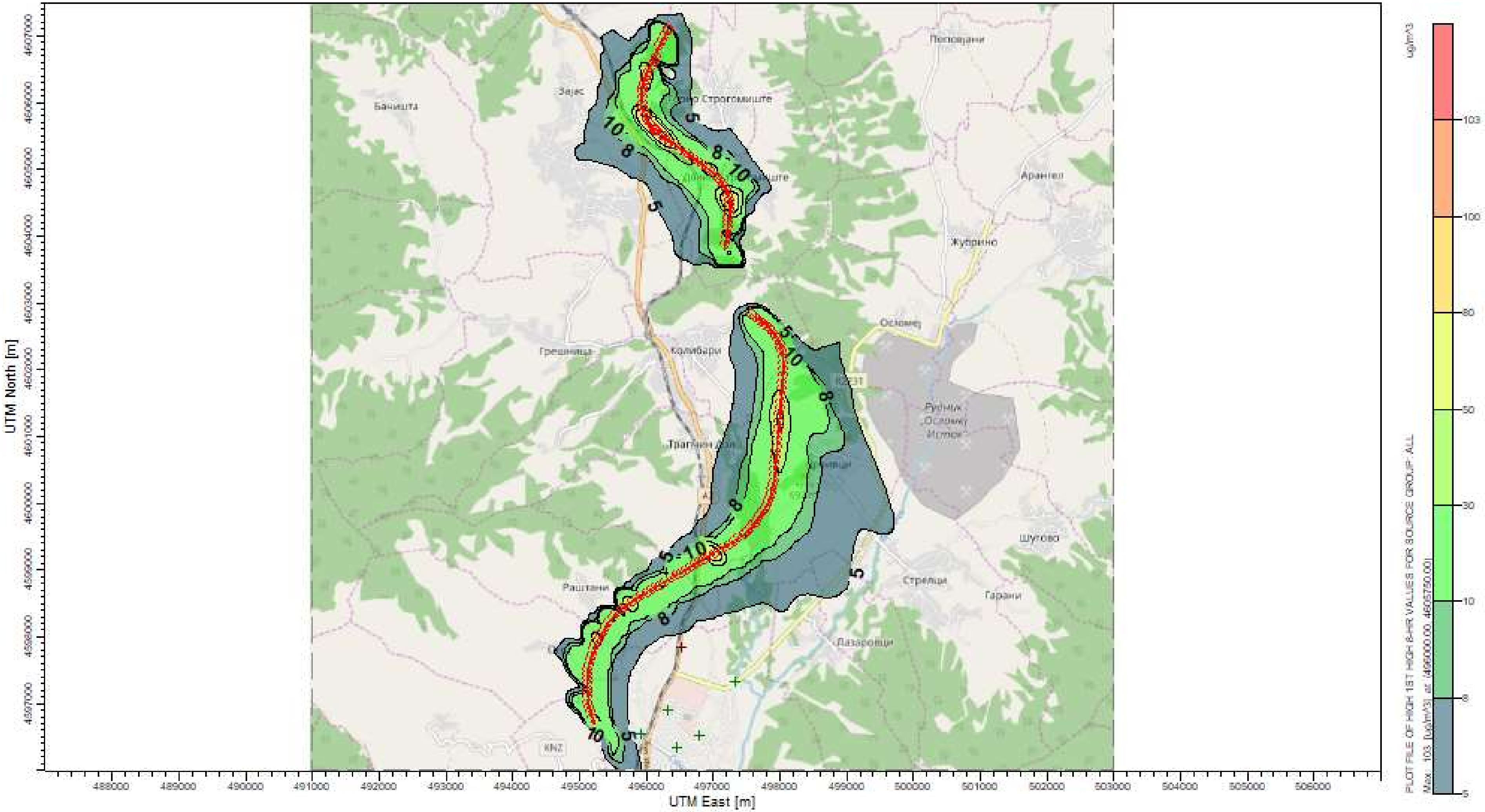


Figure 48 Plot of maximum 8 hour concentrations of CO in 2023 – With scheme scenario (Traffic only)

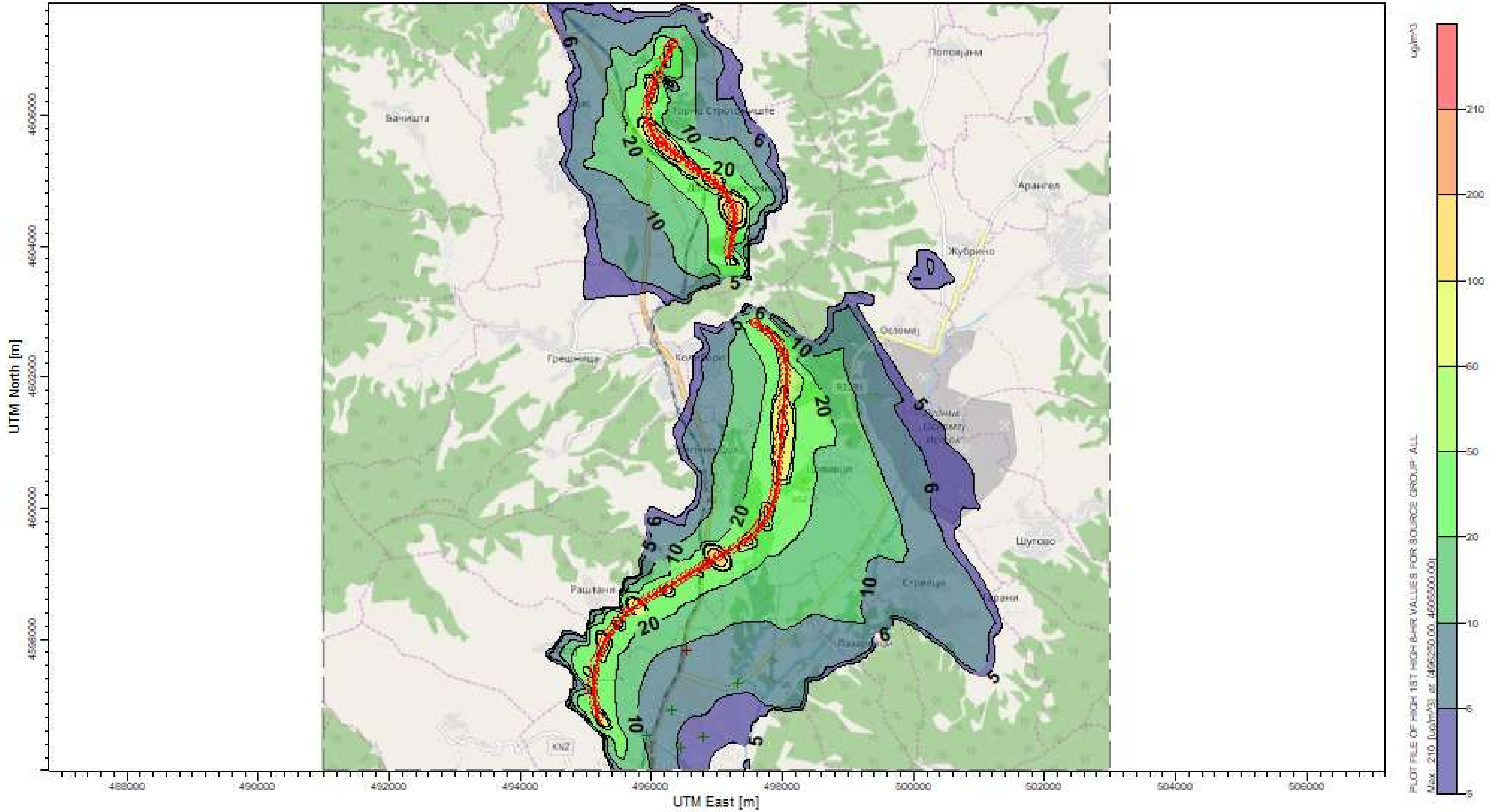


Figure 49 Plot of maximum 8 hour concentrations of CO in 2040 – With scheme scenario (Traffic only

3.2.4 Nitrogen dioxide

Lacking reliable data on ozone concentration in the ambient air, nitrogen dioxide dispersion was modeled assuming that all NO is converted to NO_2. The initial NO_2 concentration in the vehicles exhaust gas is considered negligible. Summary of no scheme model results is presented in Table 38 and those with the new highway in operation are presented in Table 42.

The impact of no scheme traffic NO_2 emissions on sensitive receptors is shown in Table 39 to 41. In Table 43 and 44 the impact of traffic emissions with the new highway in operation are presented.

The most affected sensitive receptors close to the existing road will no longer be so exposed to traffic emissions.

Table 38 Model results summary for NO_2 (No-Scheme scenario)

Year	Average period	Background	AQ limit value	Peak concentration	UTM coordinates	
		mg/m³	mg/m³	mg/m³	X	Y
2018	1 h (Max)	23.6	200	319.83	495750	4605600
	Annual	23.6	40	10.33	496500	4597850
	1 h (99.8th percentile)	23.6	200	140.1	496500	4597850
2023	1 h (Max)	23.6	200	270.38	495750	4605600
	Annual	23.6	40	8.72	496500	4597850
	1 h (99.8th percentile)	23.6	200	118.35	496500	4597850
2040	1 h (Max)	23.6	200	370	496500	4597850
	Annual	23.6	40	11.96	496500	4597850
	1 h (99.8th percentile)	23.6	200	162.23	495750	4605600

Table 39 NO_2 sensitive receptor summary for the basic year (2018) – No -Scheme scenario

Averaging Period	ID	Concentrations (mg/m³)			UTM Coordinates (m)	
		Background	Air Quality Limit	Peak (Traffic only)	X	Y
1 h (Max)	School	23.6	200	12.40	496450	4596350
1 h (Max)	Mosque	23.6	200	31.81	495921	4596534
1 h (Max)	University	23.6	200	7.71	496790	4596510
1 h (Max)	Military barracs	23.6	200	49.41	496320	4596910
1 h (Max)	Sports Center	23.6	200	13.60	497320	4597330
1 h (Max)	House	23.6	200	174.42	495852	4605509
1 h (Max)	House	23.6	200	135.18	495797	4605571
1 h (Max)	Mosque	23.6	200	128.96	496428	4601896
1 h (Max)	House	23.6	200	208.33	496608	4601490
1 h (Max)	House	23.6	200	228.31	496637	4601465
1 h (Max)	House	23.6	200	139.27	496784	4601039
1 h (Max)	House	23.6	200	179.61	496886	4600879
Annual	School	23.6	40	0.26	496450	4596350
Annual	Mosque	23.6	40	0.43	495921	4596534

Annual	University	23.6	40	0.17	496790	4596510
Annual	Military barracs	23.6	40	0.65	496320	4596910
Annual	Sports Center	23.6	40	0.15	497320	4597330
Annual	House	23.6	40	5.70	495852	4605509
Annual	House	23.6	40	4.79	495797	4605571
Annual	Mosque	23.6	40	2.99	496428	4601896
Annual	House	23.6	40	2.84	496608	4601490
Annual	House	23.6	40	3.37	496637	4601465
Annual	House	23.6	40	3.06	496784	4601039
Annual	House	23.6	40	4.34	496886	4600879
1 h (99.8th percentile)	School	23.6	200	9.53	496450	4596350
1 h (99.8th percentile)	Mosque	23.6	200	17.16	495921	4596534
1 h (99.8th percentile)	University	23.6	200	6.87	496790	4596510
1 h (99.8th percentile)	Military barracs	23.6	200	20.58	496320	4596910
1 h (99.8th percentile)	Sports Center	23.6	200	6.05	497320	4597330
1 h (99.8th percentile)	House	23.6	200	114.64	495852	4605509
1 h (99.8th percentile)	House	23.6	200	105.21	495797	4605571
1 h (99.8th percentile)	Mosque	23.6	200	59.47	496428	4601896
1 h (99.8th percentile)	House	23.6	200	61.63	496608	4601490
1 h (99.8th percentile)	House	23.6	200	79.69	496637	4601465
1 h (99.8th percentile)	House	23.6	200	63.31	496784	4601039
1 h (99.8th percentile)	House	23.6	200	97.09	496886	4600879

Table 40 NO2 sensitive receptor summary for the opening year (2023) – No -Scheme scenario

Averaging Period	ID	Concentrations (mg/m³)			UTM Coordinates (m)	
		Background	Air Quality Limit	Peak (Traffic only)	X	Y
1 h (Max)	School	23.6	200	10.48	496450	4596350
1 h (Max)	Mosque	23.6	200	26.88	495921	4596534
1 h (Max)	University	23.6	200	6.51	496790	4596510
1 h (Max)	Military barracs	23.6	200	41.74	496320	4596910
1 h (Max)	Sports Center	23.6	200	11.49	497320	4597330
1 h (Max)	House	23.6	200	147.36	495852	4605509
1 h (Max)	House	23.6	200	114.20	495797	4605571
1 h (Max)	Mosque	23.6	200	108.95	496428	4601896
1 h (Max)	House	23.6	200	176.01	496608	4601490
1 h (Max)	House	23.6	200	192.88	496637	4601465
1 h (Max)	House	23.6	200	117.66	496784	4601039
1 h (Max)	House	23.6	200	151.74	496886	4600879
Annual	School	23.6	40	0.22	496450	4596350
Annual	Mosque	23.6	40	0.37	495921	4596534
Annual	University	23.6	40	0.15	496790	4596510
Annual	Military barracs	23.6	40	0.55	496320	4596910
Annual	Sports Center	23.6	40	0.13	497320	4597330
Annual	House	23.6	40	4.82	495852	4605509
Annual	House	23.6	40	4.05	495797	4605571

Annual	Mosque	23.6	40	2.53	496428	4601896
Annual	House	23.6	40	2.40	496608	4601490
Annual	House	23.6	40	2.85	496637	4601465
Annual	House	23.6	40	2.59	496784	4601039
Annual	House	23.6	40	3.67	496886	4600879
1 h (99.8th percentile)	School	23.6	200	5.12	496450	4596350
1 h (99.8th percentile)	Mosque	23.6	200	96.85	495921	4596534
1 h (99.8th percentile)	University	23.6	200	88.89	496790	4596510
1 h (99.8th percentile)	Military barracs	23.6	200	50.24	496320	4596910
1 h (99.8th percentile)	Sports Center	23.6	200	52.07	497320	4597330
1 h (99.8th percentile)	House	23.6	200	67.32	495852	4605509
1 h (99.8th percentile)	House	23.6	200	53.49	495797	4605571
1 h (99.8th percentile)	Mosque	23.6	200	82.02	496428	4601896
1 h (99.8th percentile)	House	23.6	200	5.12	496608	4601490
1 h (99.8th percentile)	House	23.6	200	96.85	496637	4601465
1 h (99.8th percentile)	House	23.6	200	88.89	496784	4601039
1 h (99.8th percentile)	House	23.6	200	50.24	496886	4600879

Table 41 NO2 sensitive receptor summary for the future year (2040) – No -Scheme scenario

Averaging Period	ID	Concentrations (mg/m^3)			UTM Coordinates (m)	
		Background	Air Quality Limit	Peak (Traffic only)	X	Y
1 h (Max)	School	23.6	200	14.36	496450	4596350
1 h (Max)	Mosque	23.6	200	36.84	495921	4596534
1 h (Max)	University	23.6	200	8.92	496790	4596510
1 h (Max)	Military barracs	23.6	200	57.22	496320	4596910
1 h (Max)	Sports Center	23.6	200	15.75	497320	4597330
1 h (Max)	House	23.6	200	201.99	495852	4605509
1 h (Max)	House	23.6	200	156.54	495797	4605571
1 h (Max)	Mosque	23.6	200	149.35	496428	4601896
1 h (Max)	House	23.6	200	241.26	496608	4601490
1 h (Max)	House	23.6	200	264.39	496637	4601465
1 h (Max)	House	23.6	200	161.28	496784	4601039
1 h (Max)	House	23.6	200	207.99	496886	4600879
Annual	School	23.6	40	0.30	496450	4596350
Annual	Mosque	23.6	40	0.50	495921	4596534
Annual	University	23.6	40	0.20	496790	4596510
Annual	Military barracs	23.6	40	0.76	496320	4596910
Annual	Sports Center	23.6	40	0.18	497320	4597330
Annual	House	23.6	40	6.60	495852	4605509
Annual	House	23.6	40	5.55	495797	4605571
Annual	Mosque	23.6	40	3.47	496428	4601896
Annual	House	23.6	40	3.29	496608	4601490
Annual	House	23.6	40	3.91	496637	4601465

Annual	House	23.6	40	3.55	496784	4601039
Annual	House	23.6	40	5.03	496886	4600879
1 h (99.8th percentile)	School	23.6	200	11.03478	496450	4596350
1 h (99.8th percentile)	Mosque	23.6	200	19.86702	495921	4596534
1 h (99.8th percentile)	University	23.6	200	7.9593	496790	4596510
1 h (99.8th percentile)	Military barracs	23.6	200	23.83248	496320	4596910
1 h (99.8th percentile)	Sports Center	23.6	200	7.01191	497320	4597330
1 h (99.8th percentile)	House	23.6	200	132.7632	495852	4605509
1 h (99.8th percentile)	House	23.6	200	121.8436	495797	4605571
1 h (99.8th percentile)	Mosque	23.6	200	68.86355	496428	4601896
1 h (99.8th percentile)	House	23.6	200	71.36898	496608	4601490
1 h (99.8th percentile)	House	23.6	200	92.27969	496637	4601465
1 h (99.8th percentile)	House	23.6	200	73.31601	496784	4601039
1 h (99.8th percentile)	House	23.6	200	112.4312	496886	4600879

Table 42 Model results summary for NO2 (With-Scheme scenario)

Year	Average period	Background	AQ limit value	Peak concentration	UTM coordinates	
		mg/m^3	mg/m^3	mg/m^3	X	Y
2023	1 h (Max)	23.6	200	139	497000	4599250
	Annual	23.6	40	4.72	497250	4604500
	1 h (99.8th percentile)	23.6	200	61.76	496250	4605500
2040	1 h (Max)	23.6	200	189	497000	4599250
	Annual	23.6	40	6.02	497250	4604500
	1 h (99.8th percentile)	23.6	200	83.85	496250	4605500

Table 43 NO2 sensitive receptor summary for the opening year (2023) – With-Scheme scenario

Averaging Period	**ID**	**Concentrations (mg/m^3)**			**UTM Coordinates (m)**	
		Background	**Air Quality Limit**	**Peak (Traffic only)**	**X**	**Y**
(m)						
1 h (Max)	School	23.6	200	4.67	496450	4596350
1 h (Max)	Mosque	23.6	200	4.70	495921	4596534
1 h (Max)	University	23.6	200	5.47	496790	4596510
1 h (Max)	Military barracs	23.6	200	5.47	496320	4596910
1 h (Max)	Sports Center	23.6	200	6.49	497320	4597330
Annual	School	23.6	40	0.054	496450	4596350
Annual	Mosque	23.6	40	0.079	495921	4596534
Annual	University	23.6	40	0.053	496790	4596510
Annual	Military barracs	23.6	40	0.075	496320	4596910

Annual	Sports Center	23.6	40	0.062	497320	4597330
1 h (99.8th percentile)	School	23.6	200	2.344	496450	4596350
1 h (99.8th percentile)	Mosque	23.6	200	3.088	495921	4596534
1 h (99.8th percentile)	University	23.6	200	2.111	496790	4596510
1 h (99.8th percentile)	Military barracs	23.6	200	2.745	496320	4596910
1 h (99.8th percentile)	Sports Center	23.6	200	2.107	497320	4597330

Table 44 NO2 sensitive receptor summary for the future year (2040) – With-Scheme scenario

Averaging Period	ID	Concentrations (mg/m³)			UTM Coordinates (m)	
		Background	Air Quality Limit	Peak (Traffic only)	X	Y
1 h (Max)	School	23.6	200	6.38	496450	4596350
1 h (Max)	Mosque	23.6	200	6.41	495921	4596534
1 h (Max)	University	23.6	200	7.46	496790	4596510
1 h (Max)	Military barracs	23.6	200	7.46	496320	4596910
1 h (Max)	Sports Center	23.6	200	8.85	497320	4597330
Annual	School	23.6	40	0.07	496450	4596350
Annual	Mosque	23.6	40	0.10	495921	4596534
Annual	University	23.6	40	0.07	496790	4596510
Annual	Military barracs	23.6	40	0.10	496320	4596910
Annual	Sports Center	23.6	40	0.08	497320	4597330
1 h (99.8th percentile)	School	23.6	200	3.03	496450	4596350
1 h (99.8th percentile)	Mosque	23.6	200	4.20	495921	4596534
1 h (99.8th percentile)	University	23.6	200	2.88	496790	4596510
1 h (99.8th percentile)	Military barracs	23.6	200	3.75	496320	4596910
1 h (99.8th percentile)	Sports Center	23.6	200	2.88	497320	4597330

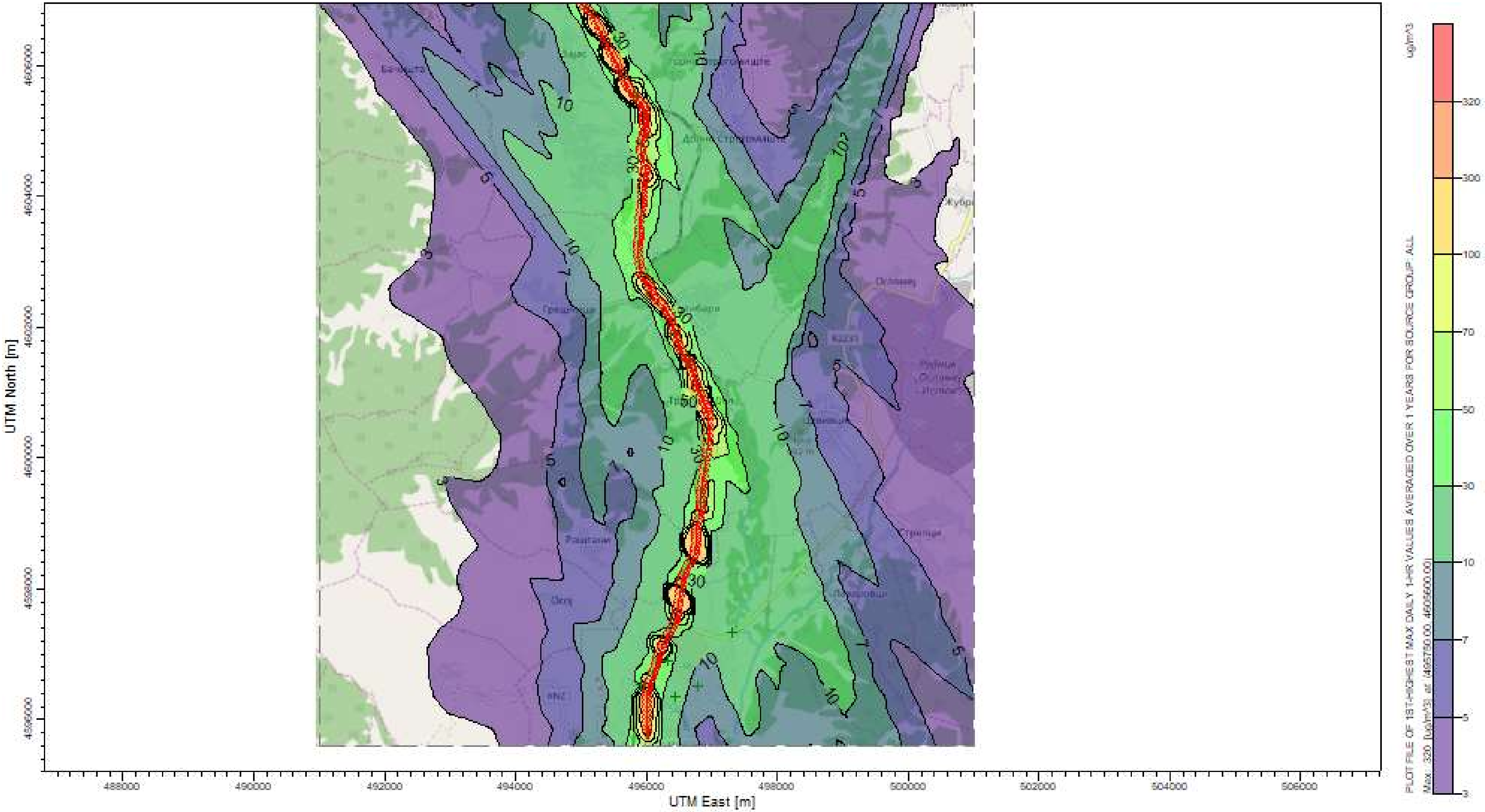


Figure 50 Contours of maximum hourly concentrations of NO_2 in 2018 (traffic only)

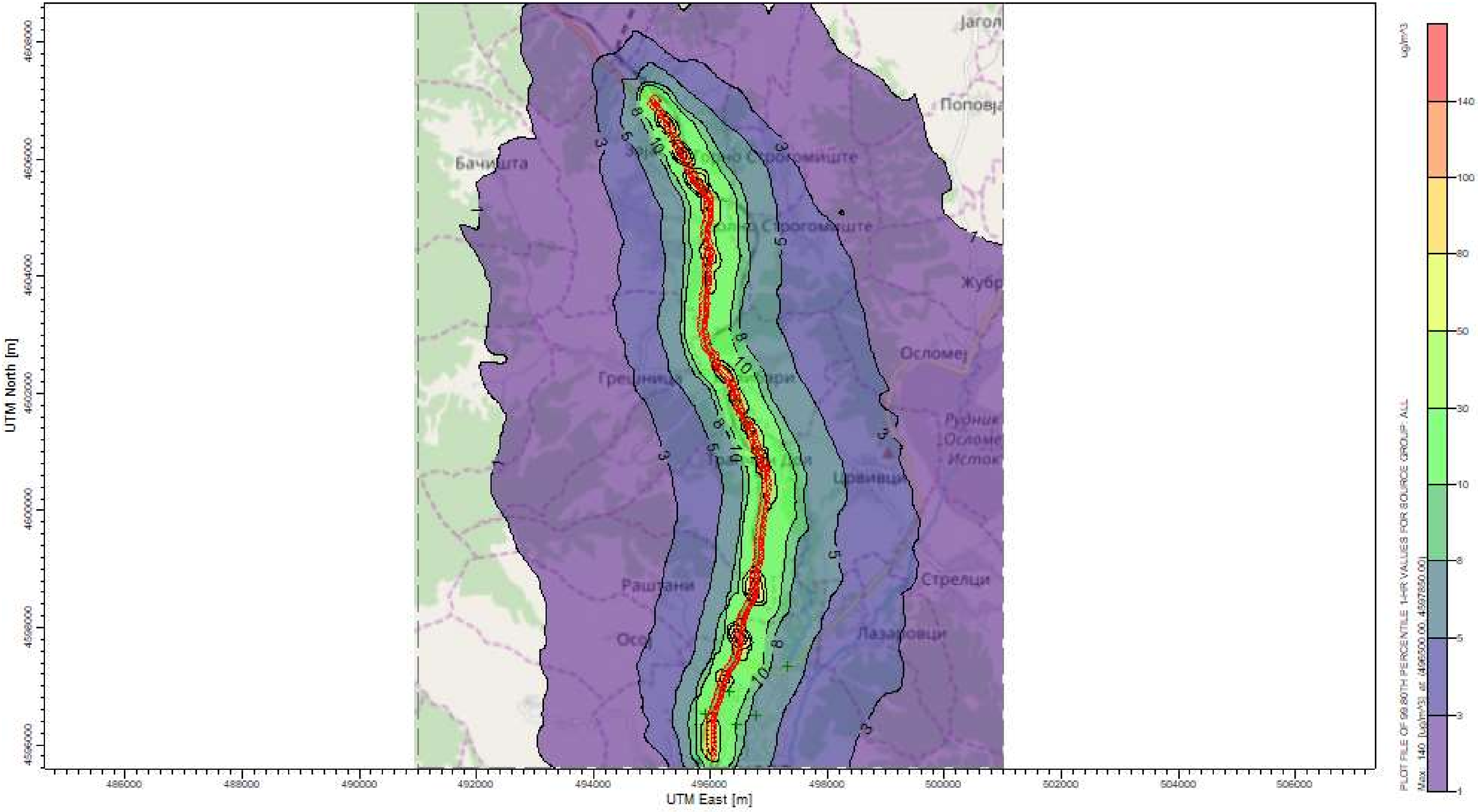


Figure 51 Contours of 99.8 percentile hourly concentrations of NO_2 in 2018 – No scheme scenario (traffic only)

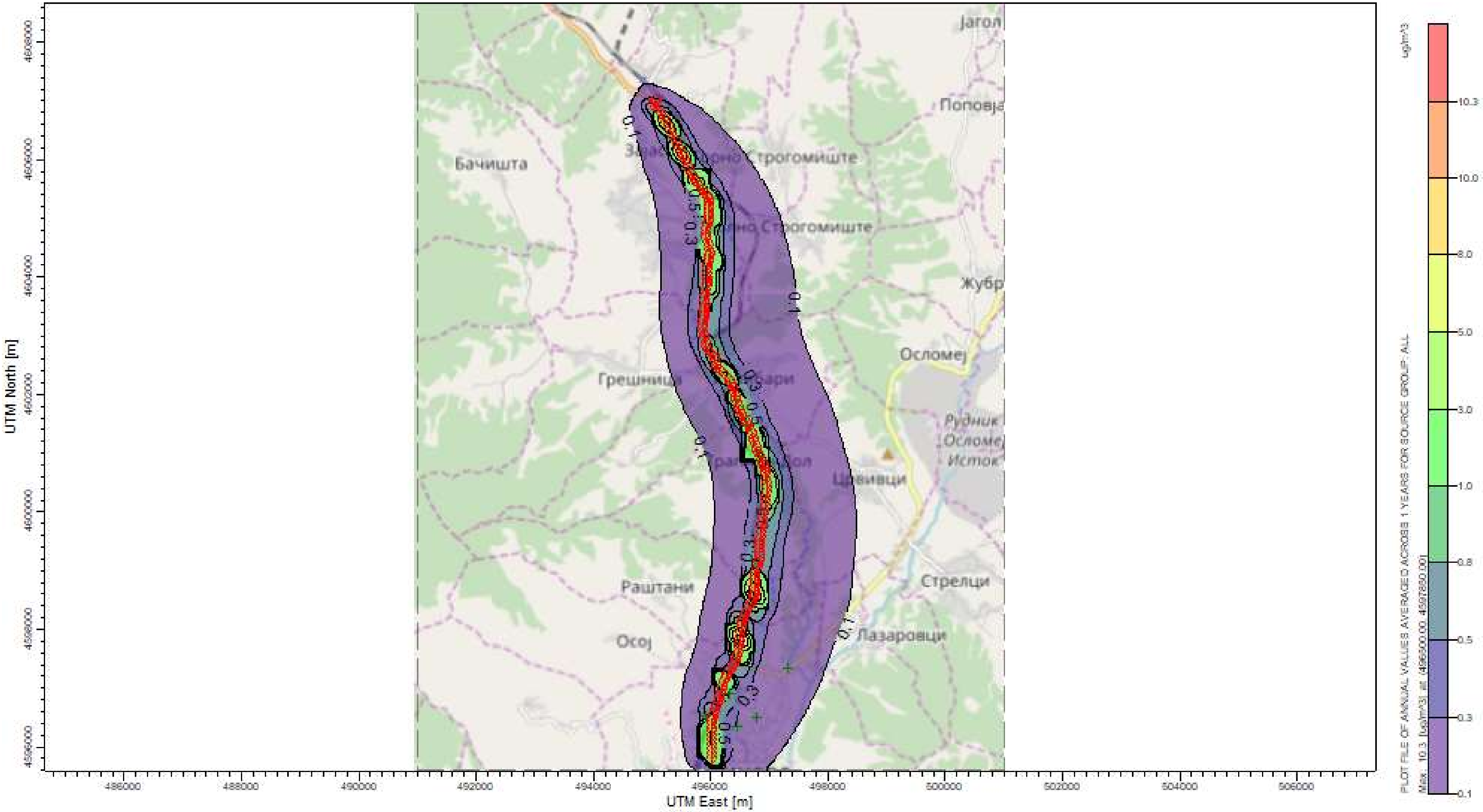


Figure 52 Contours of average annual concentrations of NO_2 for 2018 – No Scheme scenario (traffic only)

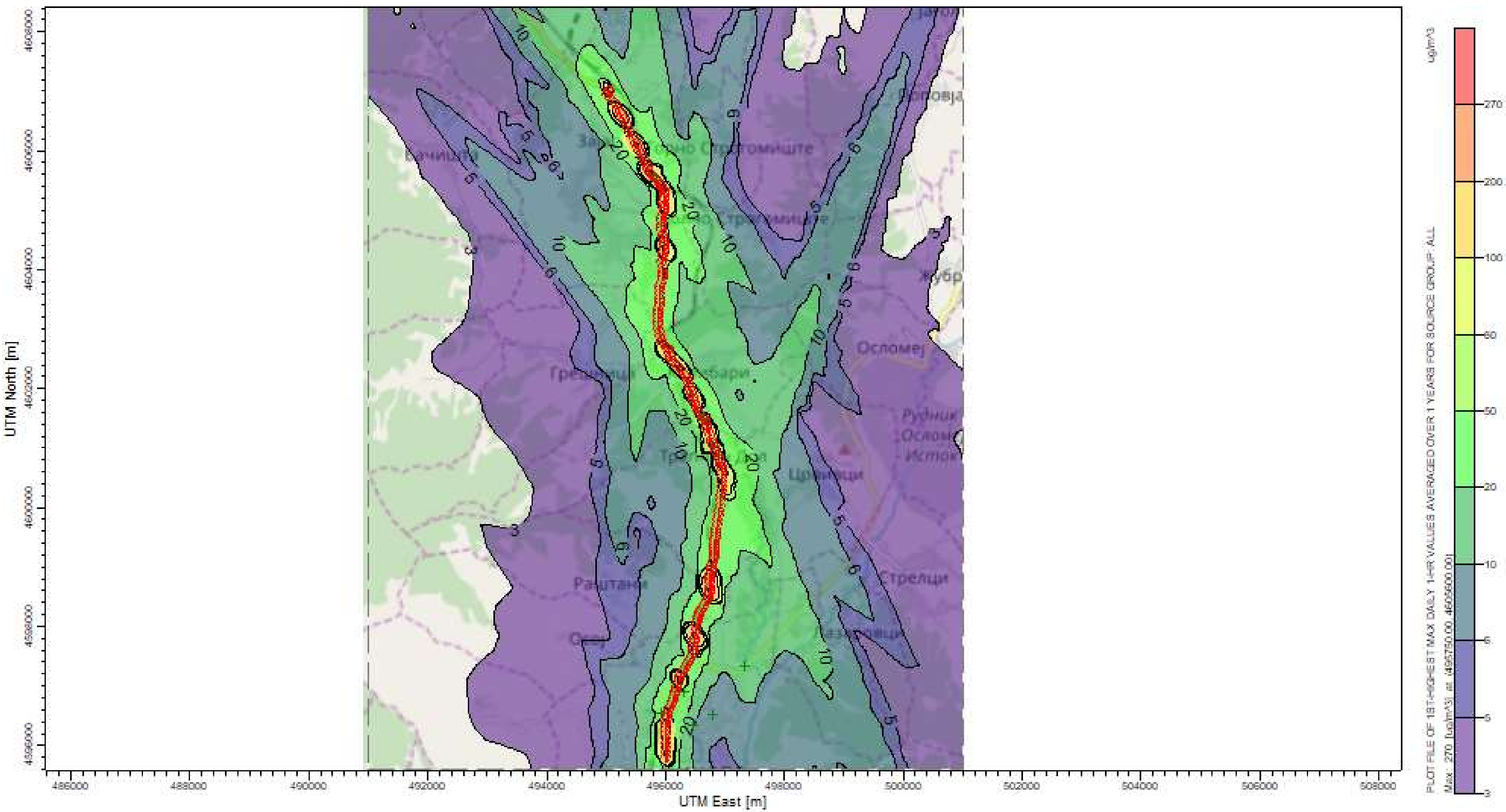


Figure 53 Contours of Maximum 1 hour concentrations of NO_2 for 2023 - No scheme scenario (Traffic only)

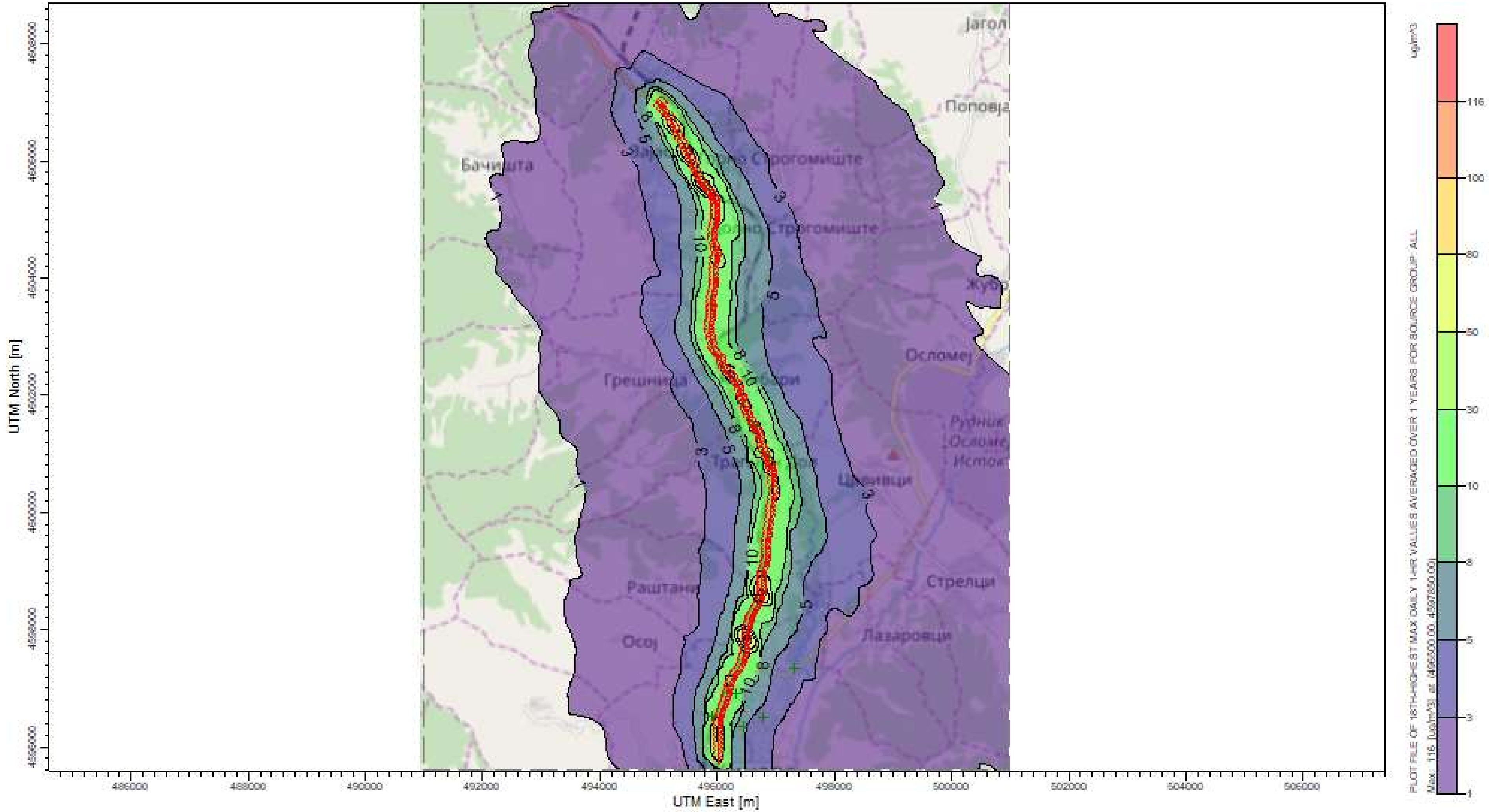


Figure 54 Contours of 99.8 percentile (18th highest) 1 hour concentrations of NO_2 for 2023 - No scheme scenario (Traffic only)

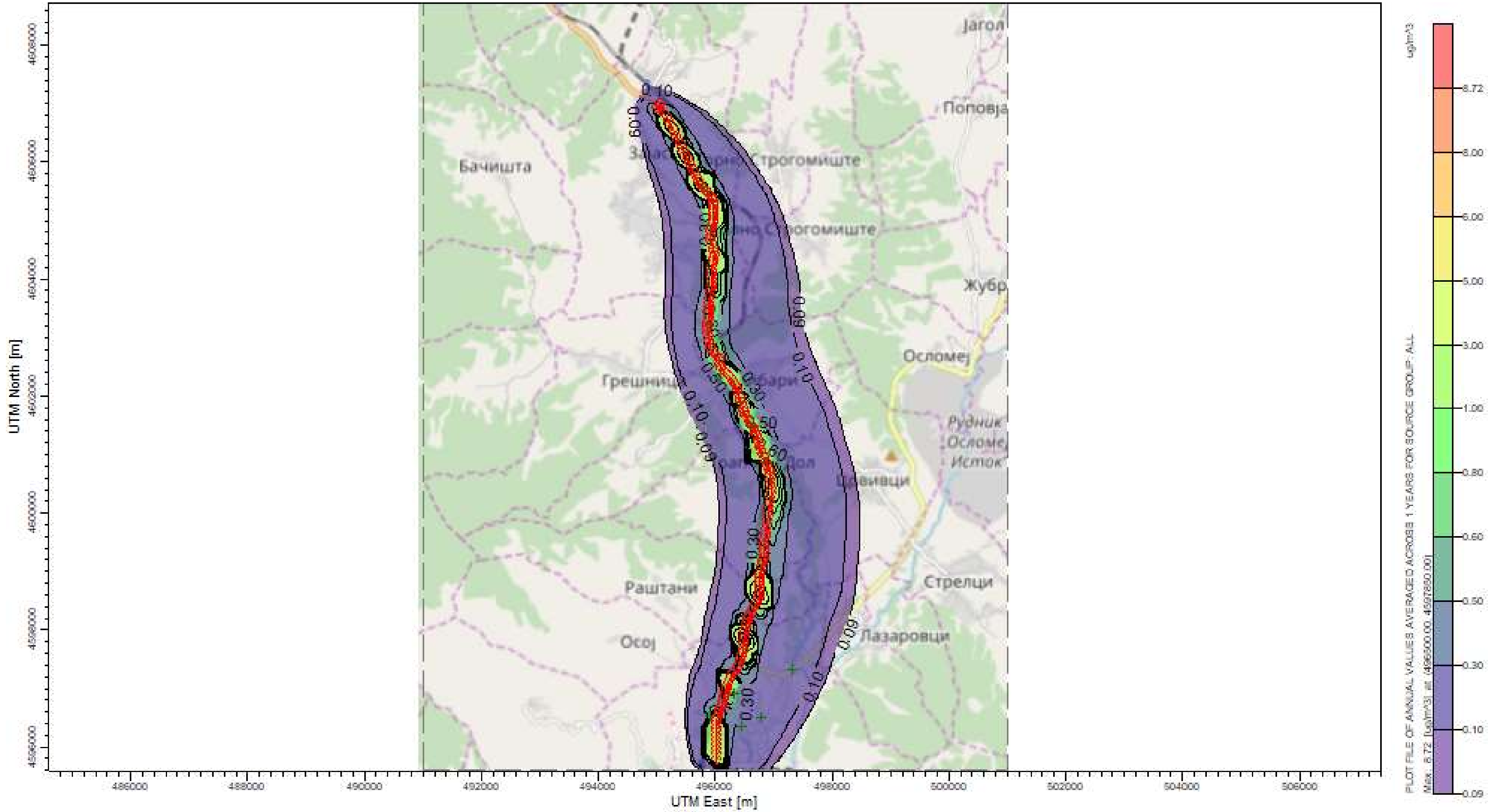


Figure 55 Contours of average annual concentrations of NO_2 for 2023 – No Scheme scenario (traffic only)

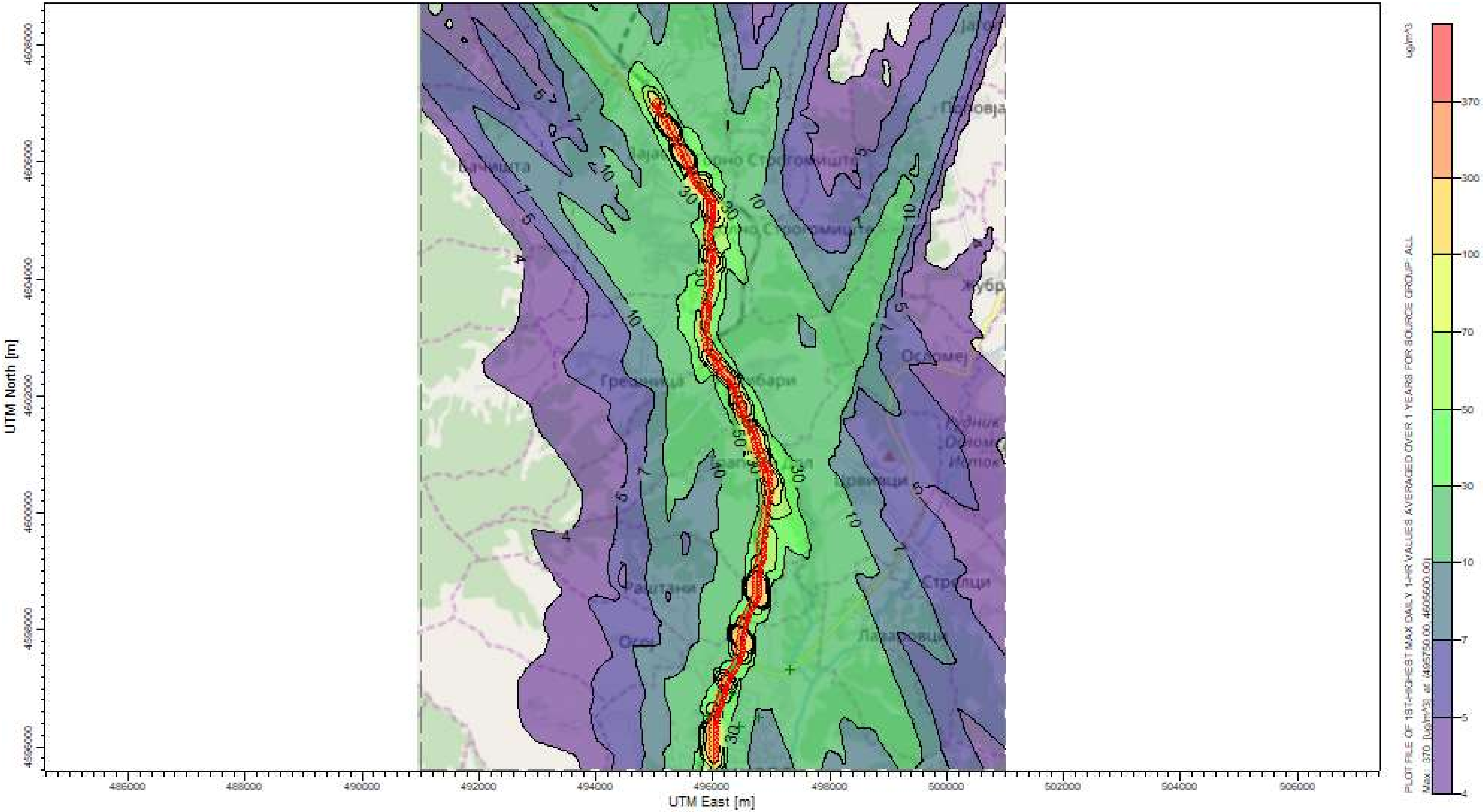


Figure 56 Contours of Maximum 1 hour concentrations of NO_2 for 2040 - No scheme scenario (Traffic only)

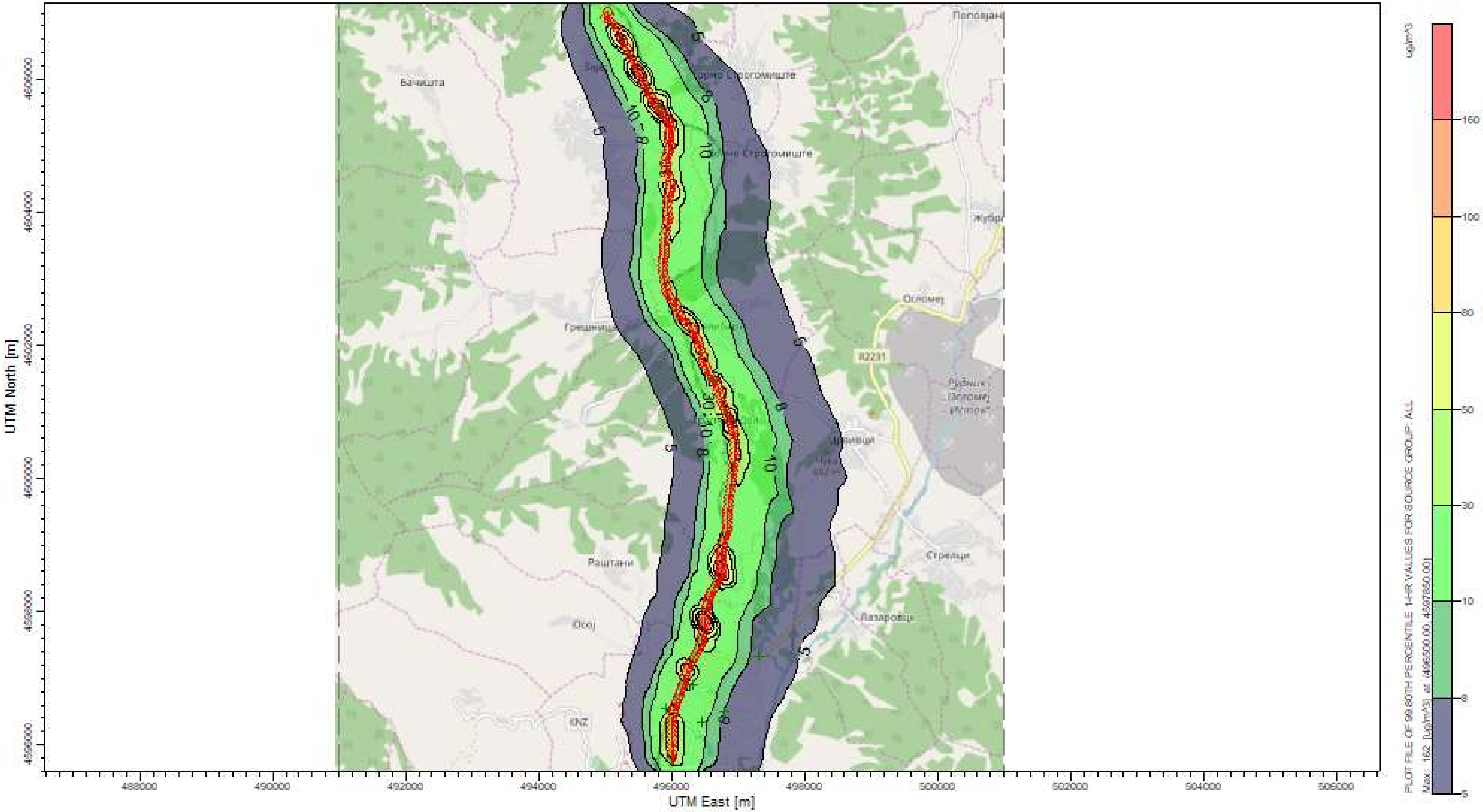


Figure 57 Contours of 99th percentile 1 hour concentrations of NO_2 for 2040 - No scheme scenario (Traffic only)

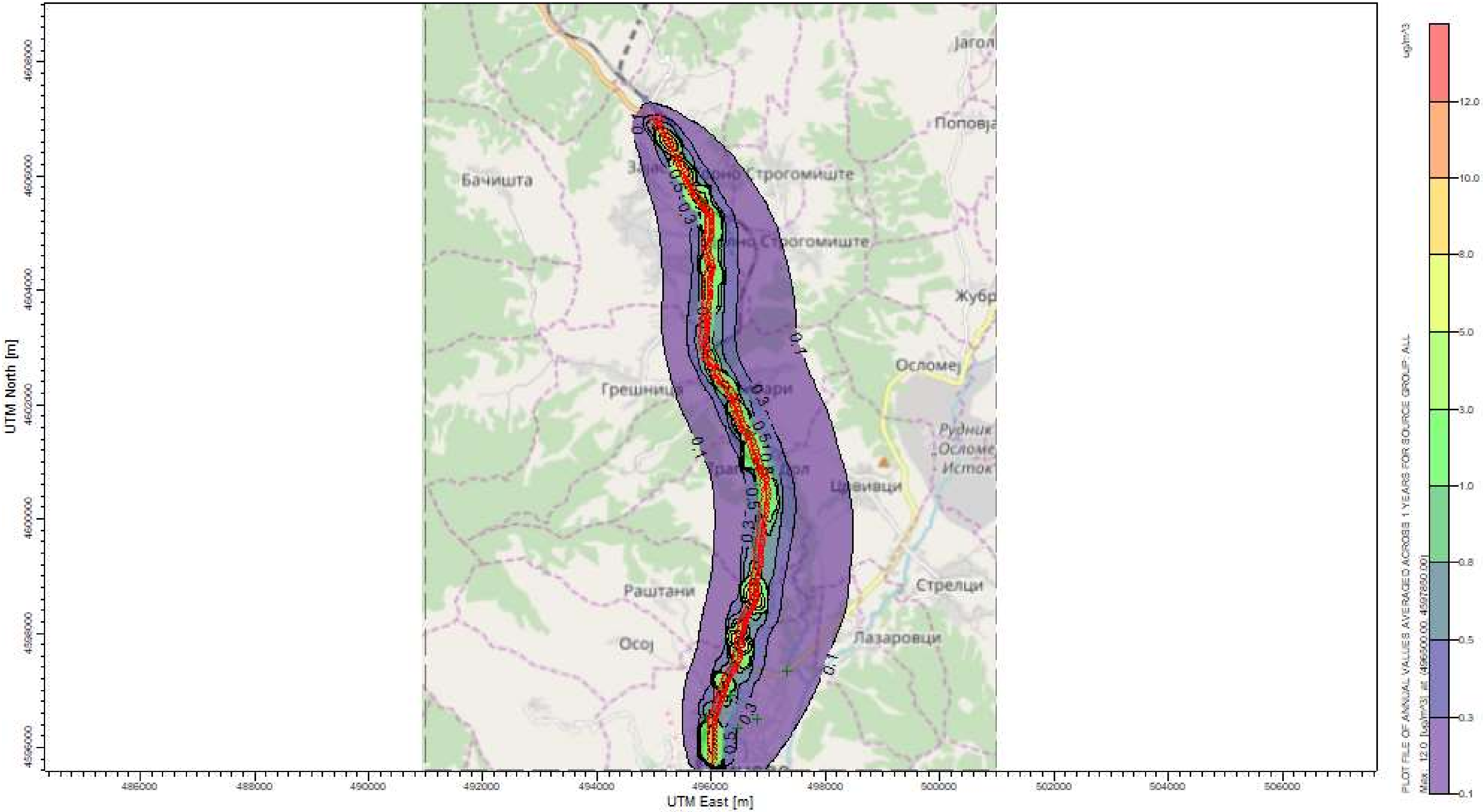


Figure 58 Contours of average annual concentrations of NO_2 for 2023 - No scheme scenario (Traffic only)

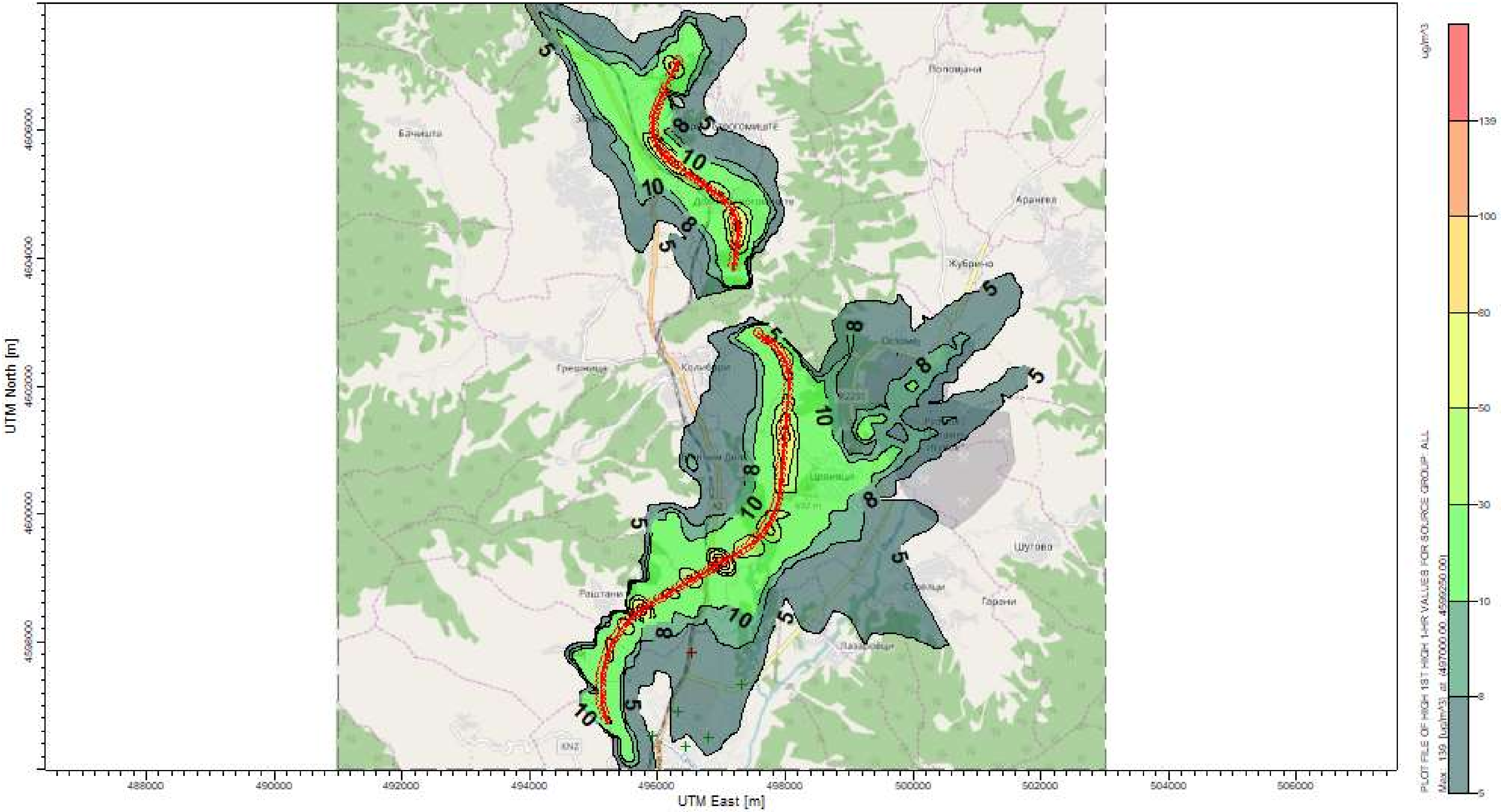


Figure 59 Contours of Maximum 1 hour concentrations of NO_2 for 2023 - With scheme scenario (Traffic only)

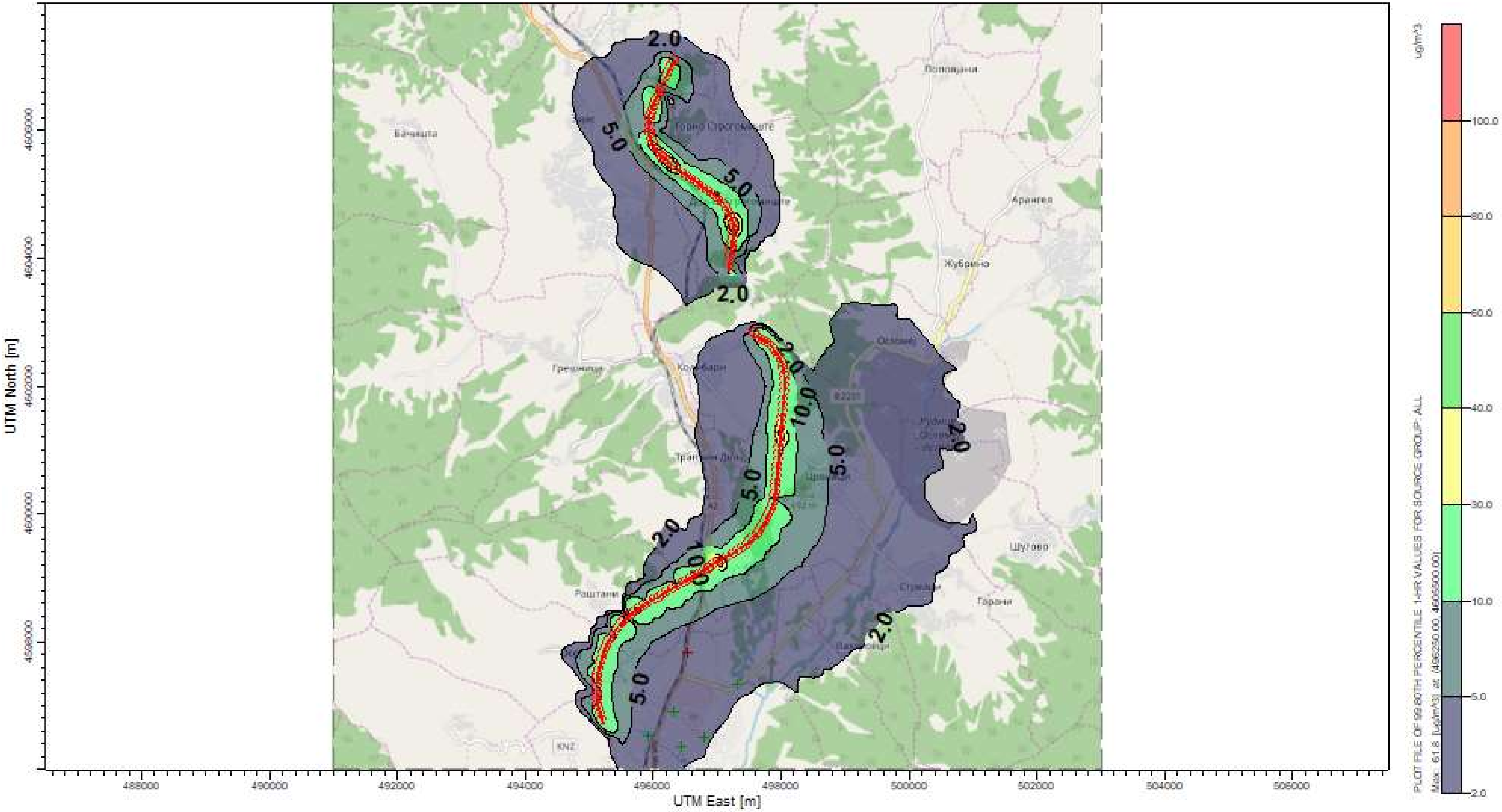


Figure 60 Contours of 99th percentile 1 hour concentrations of NO_2 for 2023 - With scheme scenario (Traffic only

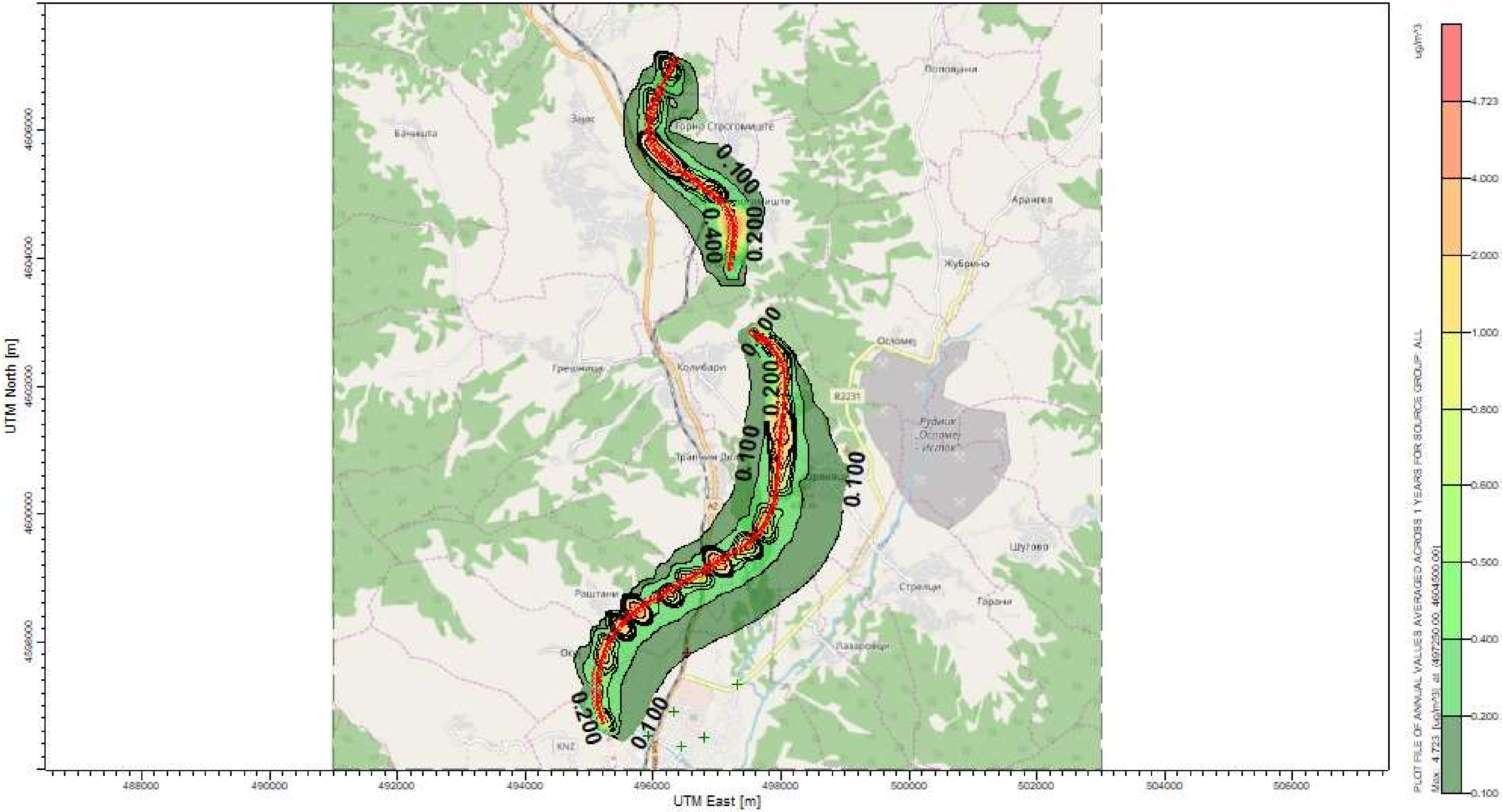


Figure 61 Contours of average annual concentrations of NO_2 for 2023 – With Scheme scenario (traffic only)

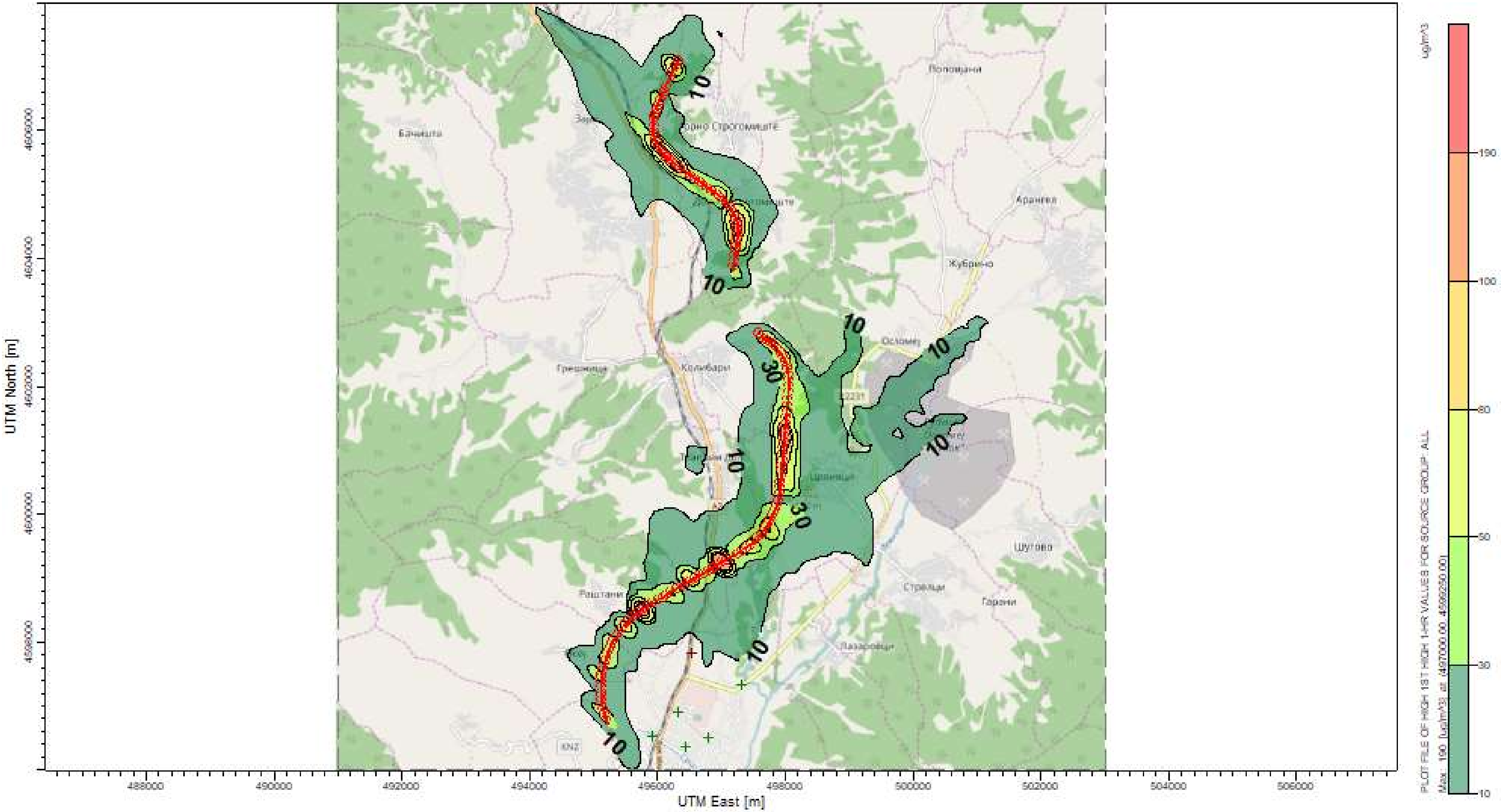


Figure 62 Contours of Maximum 1 hour concentrations of NO_2 for 2040 - With scheme scenario (Traffic only)

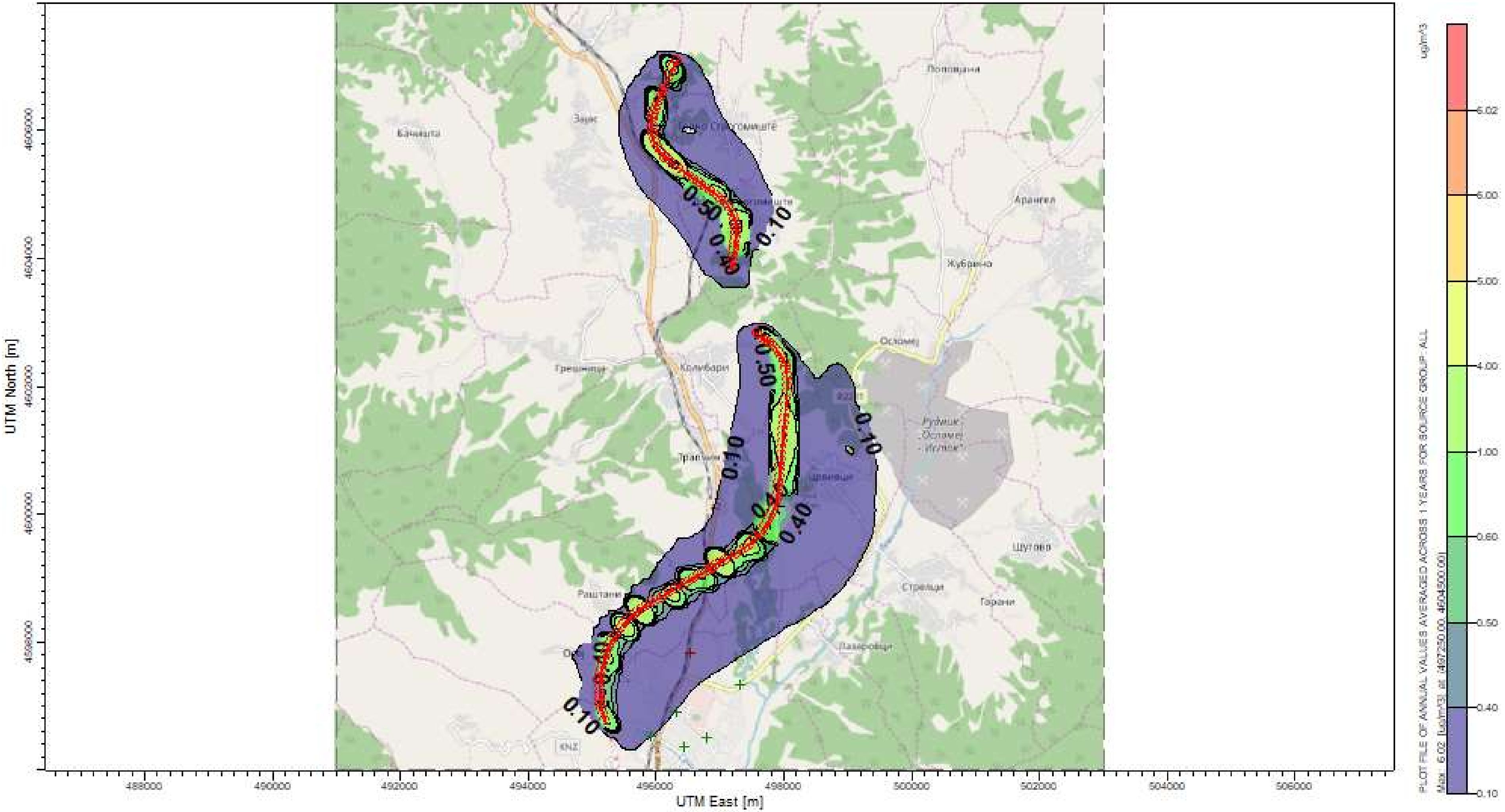


Figure 63 Contours of average annual concentrations of NO_2 for 2040 – With Scheme scenario (traffic only)

4 Uncertainties

Traffic volume variations, emission factors used, meteorological data, terrain characteristics and the model used are the sources of uncertainty of the model results.

4.1 Traffic

Until recently there were no data on traffic volume and its daily and hourly distribution. A permanent traffic counter was installed in July 2019 and it produces reliable information on traffic distribution on daily and hourly basis with short periods of missing data. Obviously, traffic flow is not steady. For the first four months of its operation (July to October 2019), the traffic counter showed a significant variation of the average daily traffic. It varied from 6395 in October to a maximum of 10884 in August with a mean of 8468 v/d. In order to reduce the uncertainty from traffic variations, monthly multipliers were assigned to emission factors. However, average daily traffic variations within a month remain a source of uncertainty and this is within the range of ±40%.

Generally, uncertainties increase with shortening the averaging time. Therefore, the highest uncertainty is expected on NO_2 modeling results.

4.2 Emission factors

The emission factors used for the purpose of modelling have been retrieved form HBEFA and are based on the German fleet. The North Macedonian fleet is couple of years older and it probably leads to an underestimation of 10 to 20%.

4.3 Meteorological data

MM5 (Fifth Generation Mesoscale Model) developed by the PENN University and the National Center for Atmospheric research is still widely used in absence of an archive based on direct measuring. Under certain conditions it is at least as reliable as the WRF (Weather Research and Forecasting) model (Ground level and lower troposphere).

4.4 Terrain

SRTM (Shuttle Radar Topography Mission) maps were used to determine the elevations of the terrain. SRTM maps are continuously improved and they are considered reliable. Most of the uncertainties in the no scheme scenario arise from the type of land use which affect the Monin-Obukhov length. More than 90% of the terrain is rural, but there are small parts, especially at the south end where the existing road passes through the town of Kichevo.

5 Validation

Figures in tables 17 to 44 above already show that concentrations of the pollutants due to traffic are minor compared to their ambient air concentrations and make no noticeable impact. Nevertheless, a three-day monitoring campaign has been carried out in order to compare the monitored and modeled results. For this reason, a monitoring site was arranged consisting of a traffic counter, air concentration monitors for CO, PM10 and PM2.5 and a small unit for meteorological measurements.

5.1 Traffic and emissions

A SIERZEGA bidirectional traffic counter was installed some 150 m south from the Shell Oil petrol station in the east part of Kichevo (Figure). The instrument was operational from 13:00 10 December 2019 to 13:00 13 December 2019. Hourly values of vehicles and their classes were recorded and later downloaded via internet.

Figure 64 Location of counter and meteorological equipment

Traffic emission factors were calculated based on the traffic (vehicles per hour) and the emission factors (German) collected from HBEFA. Records on traffic counting with calculated emissions are shown in Table 45.

5.2 Meteorological data and air concentrations

Meteorological data and pollutant concentrations were recorded from 01:00 11 December to 23:00 13 December 2019 some 40 m south from the Shell Oil petrol station (Figure). The choice of a suitable location was limited due to the need for power supply for the instruments and the requirement of their owners not to leave the instruments unattended. The location is not ideal for a reference point, but having in mind that a small number of cars are refilled there and that VOCs are not modeled, this location was accepted.

PM10, PM2.5, CO and meteorological parameters were continuously monitored and the hourly average values were recorded. Monitoring NO_2 and NOx was not possible at the time.

There was a significant number of records of calm weather with wind velocity less than 0.3 m/s. These appeared during nights and late afternoons. As a rule, the most severe pollution periods are associated with calm or very low wind speed conditions. This exercise was not an exclusion.

Concentrations of all three pollutants increased during nights and late afternoons. Due to the low wind speed the program could not run in these intervals. Emissions data refers to a 600 m line area source.

Table 45 Total traffic and calculated traffic emission for 11th to 13th December 2019 at the control point

		Traffic	Emissions (g/s)		
Day	Hour	Vehicles/hour	PM10	PM2.5	CO
11	1	53	9.77E-04	7.22E-04	1.13E-02
11	2	39	7.09E-04	5.10E-04	9.39E-03
11	3	52	1.15E-03	8.40E-04	1.11E-02
11	4	45	9.88E-04	7.10E-04	1.05E-02
11	5	89	1.45E-03	1.05E-03	2.06E-02
11	6	257	4.87E-03	3.54E-03	5.85E-02
11	7	320	6.11E-03	4.46E-03	7.10E-02
11	8	308	5.47E-03	3.99E-03	6.95E-02
11	9	519	1.09E-02	7.95E-03	1.14E-01
11	10	552	1.22E-02	8.79E-03	1.24E-01
11	11	658	1.47E-02	1.07E-02	1.45E-01
11	12	629	1.48E-02	1.06E-02	1.42E-01
11	13	639	1.55E-02	1.12E-02	1.42E-01
11	14	597	1.37E-02	9.95E-03	1.31E-01
11	15	695	1.63E-02	1.18E-02	1.51E-01
11	16	657	1.50E-02	1.09E-02	1.43E-01
11	17	545	1.23E-02	8.92E-03	1.19E-01
11	18	499	1.18E-02	8.54E-03	1.08E-01
11	19	435	9.92E-03	7.17E-03	9.64E-02
11	20	334	7.72E-03	5.58E-03	7.35E-02
11	21	331	8.03E-03	5.80E-03	7.26E-02
11	22	233	5.61E-03	4.04E-03	5.16E-02
11	23	182	4.24E-03	3.05E-03	4.11E-02
12	24	116	2.68E-03	1.93E-03	2.63E-02
12	1	98	2.31E-03	1.68E-03	2.03E-02

12	2	39	8.63E-04	6.18E-04	9.10E-03
12	3	39	9.79E-04	7.11E-04	8.28E-03
12	4	61	1.51E-03	1.09E-03	1.35E-02
12	5	158	3.68E-03	2.67E-03	3.44E-02
12	6	325	7.67E-03	5.56E-03	7.06E-02
12	7	492	1.17E-02	8.49E-03	1.07E-01
12	8	542	1.23E-02	8.92E-03	1.18E-01
12	9	631	1.47E-02	1.07E-02	1.39E-01
12	10	590	1.43E-02	1.04E-02	1.28E-01
12	11	665	1.47E-02	1.06E-02	1.47E-01
12	12	628	1.51E-02	1.10E-02	1.36E-01
12	13	698	1.60E-02	1.17E-02	1.52E-01
12	14	718	1.64E-02	1.19E-02	1.58E-01
12	15	736	1.71E-02	1.24E-02	1.58E-01
12	16	743	1.78E-02	1.29E-02	1.64E-01
12	17	568	1.43E-02	1.03E-02	1.22E-01
12	18	503	1.20E-02	8.66E-03	1.09E-01
12	19	465	1.04E-02	7.49E-03	1.04E-01
12	20	430	1.00E-02	7.29E-03	9.30E-02
12	21	333	7.91E-03	5.74E-03	7.18E-02
12	22	236	4.50E-03	3.27E-03	5.33E-02
12	23	167	3.38E-03	2.46E-03	3.64E-02
12	24	126	2.52E-03	1.83E-03	2.84E-02
13	1	87	1.39E-03	1.02E-03	1.98E-02
13	2	49	1.03E-03	7.48E-04	1.10E-02
13	3	40	8.83E-04	6.35E-04	9.26E-03
13	4	36	7.28E-04	5.19E-04	8.62E-03
13	5	175	3.48E-03	2.55E-03	3.85E-02
13	6	282	6.18E-03	4.49E-03	6.21E-02
13	7	447	9.60E-03	6.97E-03	9.87E-02
13	8	560	1.18E-02	8.61E-03	1.23E-01
13	9	595	1.31E-02	9.45E-03	1.33E-01
13	10	554	1.18E-02	8.58E-03	1.23E-01
13	11	559	1.23E-02	8.95E-03	1.22E-01
13	12	567	1.15E-02	8.34E-03	1.26E-01
13	13	377	8.68E-03	6.27E-03	8.32E-02

Table 46 Meteorological parameters for 11th to 13th December 2019 at the control point

Day	Hour	Temp (°C)	P (hPa)	RH (%)	Wv (m/s)	Wd (°)
11	1	5.38	940.35	940.35	0.50	78
11	2	5.52	940.29	940.29	0.54	63
11	3	5.15	939.89	939.89	0.22	40
11	4	5.08	939.61	939.61	1.00	69
11	5	4.87	939.84	939.84	1.06	68
11	6	4.50	939.99	939.99	1.23	67
11	7	4.38	940.33	940.33	0.93	71
11	8	4.36	940.66	940.66	1.42	67
11	9	4.42	941.17	941.17	1.22	69

11	10	4.95	941.23	941.23	1.66	73
11	11	5.35	940.79	940.79	0.90	82
11	12	5.60	940.33	940.33	0.46	68
11	13	5.40	940.11	940.11	0.36	8
11	14	5.24	939.85	939.85	0.79	63
11	15	4.93	939.70	939.70	1.65	71
11	16	4.66	939.67	939.67	0.96	69
11	17	4.05	939.57	939.57	0.30	69
11	18	3.86	939.61	939.61	0.13	252
11	19	4.05	939.80	939.80	0.21	36
11	20	3.89	939.71	939.71	0.17	343
11	21	3.78	939.48	939.48	0.12	325
11	22	3.71	939.07	939.07	0.06	12
11	23	3.56	938.82	938.82	0.08	216
11	24	3.43	938.38	938.38	0.06	268
12	1	3.46	937.97	937.97	0.21	316
12	2	3.44	937.58	937.58	0.03	169
12	3	3.43	937.05	937.05	0.13	289
12	4	3.24	936.61	936.61	0.16	303
12	5	3.37	936.35	936.35	0.09	64
12	6	3.29	936.39	936.39	0.14	326
12	7	3.38	936.41	936.41	0.10	4
12	8	3.69	936.65	936.65	0.13	123
12	9	4.32	936.79	936.79	0.18	163
12	10	4.95	936.62	936.62	0.35	107
12	11	5.81	935.95	935.95	0.45	138
12	12	7.00	935.24	935.24	0.39	89
12	13	7.28	934.56	934.56	0.41	151
12	14	7.08	934.24	934.24	0.47	165
12	15	7.41	933.97	933.97	0.30	147
12	16	6.62	933.80	933.80	0.19	302
12	17	6.45	933.84	933.84	0.12	215
12	18	6.16	933.92	933.92	0.11	137
12	19	5.69	933.98	933.98	0.22	298
12	20	5.46	933.82	933.82	0.17	188
12	21	5.07	933.61	933.61	0.17	280
12	22	5.11	933.48	933.48	0.12	287
12	23	4.88	933.35	933.35	0.13	280
12	24	4.78	932.81	932.81	0.20	304
13	1	4.50	932.36	932.36	0.09	205
13	2	4.54	932.29	932.29	0.07	288
13	3	4.60	931.85	931.85	0.16	3
13	4	4.41	931.52	931.52	0.24	175
13	5	4.19	931.58	931.58	0.18	249
13	6	3.87	931.56	931.56	0.12	177
13	7	3.75	931.52	931.52	0.06	176
13	8	4.18	931.52	931.52	0.12	71
13	9	4.81	931.53	931.53	0.12	141
13	10	5.74	931.20	931.20	0.70	141
13	11	7.26	930.37	930.37	0.18	119
13	12	8.14	929.51	929.51	0.55	165
13	13	8.29	928.70	928.70	0.60	140

5.3 Background concentrations

Background concentrations are considered to be the ambient concentrations that exist in the absence of traffic on the roads under consideration. Having in mind that this exercise was carried out in winter conditions, the local contribution is a significant factor. In this report the least concentration recorded during the monitoring time is considered to be a background concentration.

Following background concentrations have been adopted for this report:

PM10: 10 $\mu g/m^3$

PM2.5: 5 $\mu g/m^3$

CO: 1.39 mg/m^3

5.4 Results

The results obtained from modeling are presented together with recordings of measured concentrations of PM10, PM2.5 and CO in Table 47 below.

Table 47 Monitoring results for PM10, PM2.5 and CO and modeled traffic contribution

Day	Hour	PM10 ($\mu g/m^3$)		PM2.5 ($\mu g/m^3$)		CO (mg/m^3)	
		measured	Modeled traffic contribution	measured	Modeled traffic contribution	measured	Modeled traffic contribution
11	1	12.86	0.363	10.77	0.266	2.28	0.00417
	2	9.51	0.0045	7.97	0.028	2.14	0.000052
	3	6.54	0.18	5.56	0.129	2.02	0.00171
	4	4.20	0.15	3.41	0.11	2.00	0.00162
	5	4.33	0.225	3.52	0.16	1.95	0.00317
	6	5.65	0.75	4.50	0.55	1.95	0.00908
	7	6.39	0.96	5.02	0.7	2.14	0.01102
	8	10.97	0.84	8.15	0.62	2.10	0.01079
	9	13.95	1.725	10.71	1.234	2.24	0.0177
	10	19.05	1.89	15.50	1.354	2.43	0.01912
	11	23.99	3.045	19.81	2.25	2.40	0.0296
	12	20.10	3.075	16.72	2.25	2.09	0.02903
	13	10.17	2.835	8.88	2.05	2.08	0.02647
	14	14.34	1.71	11.25	1.125	2.18	0.01469
	15	22.10	1.89	16.92	1.357	2.39	0.01714
	16	29.41	1.89	24.16	1.244	2.56	0.01618
	17	35.40	1.14	30.39	0.81	2.83	0.01092
	18	41.84		36.47		2.85	
	19	44.68		38.89		2.84	
	20	41.81		36.17		2.41	
	21	35.27		30.41		2.75	
	22	46.78		40.10		2.65	
	23	46.08		39.41		3.04	
	24	53.66		45.35		2.63	
	1	47.13		39.69		2.79	
12	2	52.16		43.59		3.04	

	3	61.13		52.07		3.03	
	4	61.02		51.28		2.81	
	5	55.86		47.00		2.73	
	6	54.75		45.93		2.37	
	7	46.91		38.73		2.40	
	8	53.52		44.52		2.61	
	9	60.99		51.25		2.55	
	10	57.04	5.865	48.72	4.21	2.65	0.05186
	11	62.66	5.4	52.14	3.96	2.15	0.0528
	12	43.08	3.24	34.41	2.37	1.91	0.02926
	13	38.57	2.91	26.74	2.042	2.13	0.02653
	14	38.08	2.55	26.78	1.833	1.87	0.02414
	15	36.27	2.55	25.11	1.894	2.08	0.02429
	16	50.00		26.37		2.01	
	17	33.93		26.47		2.00	
	18	41.08		31.30		3.26	
	19	57.61		47.01		2.84	
	20	54.58		43.85		3.11	
	21	61.78		51.59		2.84	
	22	63.42		52.17		3.12	
	23	67.17		54.56		3.32	
	24	71.44		57.39		3.16	
13	1	71.43		57.79		2.30	
	2	49.43		40.10		2.62	
	3	66.42		55.18		2.68	
	4	63.78		53.09		1.95	
	5	47.33		38.18		1.61	
	6	36.48		28.83		1.39	
	7	29.67		23.39		1.49	
	8	32.87		26.53		2.08	
	9	61.45		50.92		1.74	
	10	48.96	4.845	40.21	3.486	1.90	0.04965
	11	59.31	2.025	50.35	1.462	1.90	0.01988
	12	57.00	1.92	47.75	1.397	1.46	0.02106
	13	26.04	1.47	20.91	1.056	1.49	0.01396

Local activities in the area such as house heating, industry, emissions from open areas etc. have very strong impact on the ambient air quality that is by orders of magnitude higher than the expected impact of traffic.

Certain relationship between the modeled and measured concentrations of PM10 and PM2.5 have been noticed as shown in Figure 5 and Figure 6, but it only indicates the share of traffic generated particulates in the overall particulates concentration. As the traffic generated CO contribution is less than 1% of the ambient CO concentration, changes in traffic emissions of CO are practically undetected.

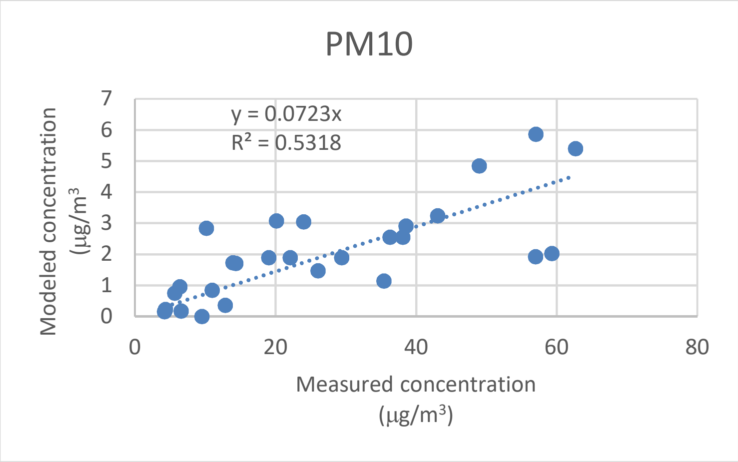


Figure 65 Modeled concentration (traffic only) vs measured ambient air concentration of PM10

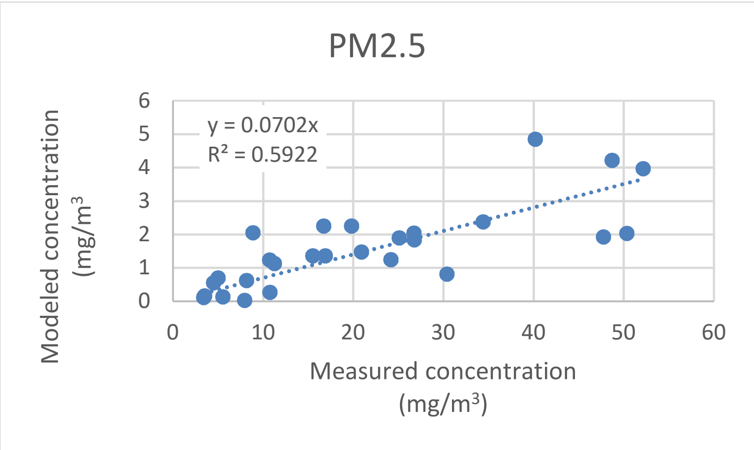


Figure 66 Modeled concentration (traffic only) vs measured ambient air concentration of PM2.5

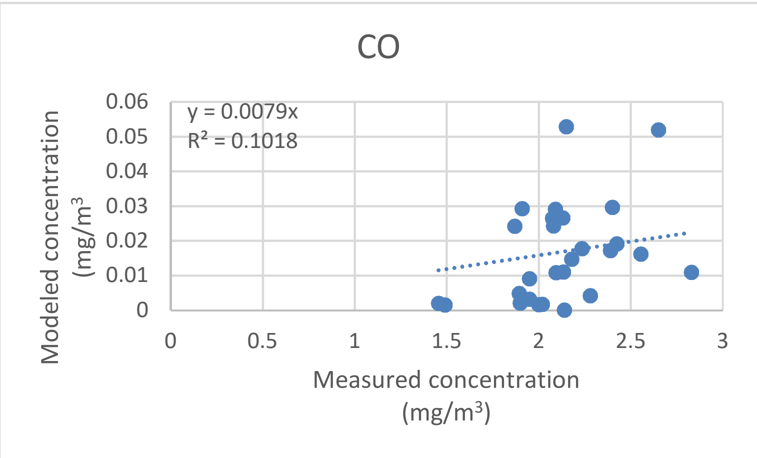


Figure 67 Modeled concentration (traffic only) vs measured ambient air concentration of CO

6 Conclusions and Recommendations

The Kichevo – Bukojchani branch of the proposed A2 Highway is placed away from most of the sensitive receptors exposed to traffic emission from the existing road.

Traffic flow on the proposed highway is rather low and consequently, low emission rates are expected.

The model showed that maximum concentrations appear on the highway lanes themselves and usually rapidly drop with side distance.

The inconclusive results of the validation attempt are due to monitoring site location, weather conditions and local activities. Determining the right monitoring site, background concentration, local activities impact and duration of observation for future modeling must be carried out in great detail which is both costly and time requiring.

The results of PM10 air emissions dispersion modeling show that airborne dust during construction may contribute to breaching environmental quality standards. Even at a reduction efficiency of 70% some locations, although in a rather limited number of days, may face concentrations of particulate matter higher than the EQS limits. On the construction site itself the concentrations of PM10 sometimes may be expressed in mg/m^3 rather than in $\mu g/m^3$. Therefore. permanently undertaking measures for particulate matter emission reduction is of utmost importance.

The construction contractor has to prepare a particulate matter emission management program which will include but will not be limited to the following measures:

Water spraying

This measure is already present in the project documentation and a number of trucks will be engaged for the purpose. However, one should have in mind that wetting should be carried out at least three times per day and, when the weather conditions require, even more frequently. On the other hand, care should be taken of the intensity of spraying in order to avoid land erosion.

Barriers

Stationary construction sites such as concrete bases and others should be fenced by protective barriers. The barriers should be placed at right angles to the dominant wind at intervals of 15 times the barrier height.

Vegetation

As soon as a surface is no longer in use or is finished it should be vegetated to prevent dust emission. Particular care should be paid to watering after vegetation.

Avoiding vehicles and machinery idling

The vehicles and other machinery should be switched off when not in use. In addition, the producer's instructions should be followed for cooling (typically 3 to 5 minutes after termination of work) and heating (typically 3 to 5 minutes depending on the vehicle or machine).

7 References

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