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The particularities of firefighting in the mountain forests

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Abstract. This paper aims at identifying and presenting the particularities of mountain forest fires. It examines their initiation and spread on the one hand, and the techniques and the methods of intervention on the other hand. As characteristics of natural factors that influence the risk of fire in the mountain forests, there are identified the parameters which influence and customize the fires of this type. After a brief overview of the initiation features and spread of the fires in the mountain forests, there are identified the fire types that can be found in the forests. It is presented for each the method of action and the technique of intervention in order to localize clear the fire. There are particularly presented the features of intervention actions in the mountain forests from Suceava County. Finally the paper presents brief conclusions regarding the degree of protection of the forests from Suceava.
Key Words: initiation, propagation, localization, elimination of fire.

Rezumat. Acest articol doreşte să identifice şi să prezinte particularităţile incendiilor de pădure examinând iniţierea şi răspândirea pe de o parte cât şi tehnicile şi metodele de intervenţie pe de altă parte. Plecând de la caracteristicile factorilor naturali care influenţează riscul de incendiu în pădurile de munte s-au identificat parametrii care influenţează şi diferentiază incendiile de pădure. După o scurtă trecere în revistă a condiţiilor de iniţiere şi răspândire a incendiilor în pădurile de munte s-au identificat tipurile de incendii care pot avea loc pe domeniul forestier. S-a prezentat pentru fiecare caz metodele de acţiune şi tehnicile de intervenţie pentru stingerea incendiilor. Deasemeni sunt prezentate metodele de acţiune în incendiile de pădure din judeţul Suceava.
Cuvinte cheie: iniţierea, extinderea, localizarea, stingerea incendiului.

Introduction. Human existence also means one's exposure to a series of risks: floods, drought, landslides, strong earthquakes, fires or technological accidents (Ozunu et al 2007; Petrescu & Ozunu 2008; Petrescu-Mag et al 2009; Petrescu-Mag & Stefanescu 2009; Petrescu-Mag 2009).

"The forests of Romania are under the influence of weather and climate fluctuations, which are typical for the continental climate of Europe. Periodically, there are recorded episodes of drought or excessive drought with repercussions upon the vitality of the existent forests, especially on the plantations and the regenerations which are to be installed. On a prolonged drought, the risk of forest fire is very high" (Barbu & Popa 2001).

The forest fires of 2010, from Russia, in the Moscow region, come to counter the idea that a major risk of fire would only exist for the forests from the Mediterranean Europe (Grece, Spain). This excludes the possibility of grouping as "Reduced risk of fire" of the forests from the cold and wet areas (as example the forests of Bucovina, or others, Flannigan & Van Wagner 1991; Martell & Sun 2008).

The management of the emergency situations as a result the forest fires is an activity of national interest, given the frequency of production and the dimension of the effects of these types of risk (O.M.A.I. no.1475/2006).

The initiation and the spread of fires in the mountain forests. The initiation of a forest fire may be due to various causes as long as the conditions of the appearance of the "fire triangle" (fuel, air and ignition source) are occurred (Burlui 2011; White et al 1996). The climatic conditions (temperature, humidity, currents of air and rainfall) have a

contribution as favouring factors and act as a catalyst of the reaction of oxidation in every type of forest fire (Giglio et al 2000). This is also the case of forest fires in Suceava County.

The influence of the natural factors mentioned (Table 1) upon the risk of forest fire is sustained by their manifestation during the production of fires in four forest ranges. These ranges are first four as number of produced fires, in the period 1990 - 2009 (Inspectorate for Emergency Situations "Bucovina" Suceava County, Statistical data).

Table 1

The presence of climatic factors / day of fire / forest ranges
(Regional Meteorological Center "Moldova" Iaşi, Statistical data)

No.	The date of fire production	Climatic factors			
		Max. temp. [C°]	Min. Humid. [%]	Wind max. speed [m/s^{-1}]	Rain Average day [L/m^2]
I			Forest Range Pojorata		
1.	16.03.1990	14.4	19	**14**	**1**
2.	01.09.1990	**22**	29	**12**	**1.5**
3.	26.04.1994	13.5	42	**16**	**1.2**
4.	11.08.1994.	**24**	48	**20**	1.6
5.	16.08.1998	**24.7**	42	**12**	1.7
6.	13.03.2001	6.4	31	**24**	1.5
7.	15.07.2002	**23.5**	38	**18**	5.1
8.	27.05.2003	**20.8**	**14**	**22**	**1**
9.	20.07.2003	**21.5**	50	**28**	5.8
10.	29.03.2008	5.2	39	**34**	3.7
II			Forest RangeVama		
11.	16.03.1990	14.4	19	**14**	**1**
12.	17.03.1990	14.4	19	**14**	**1**
13.	02.08.1998	**24.7**	42	**12**	1.7
14.	16.11.2000	12.8	30	**10**	**0.2**
15.	03.05.2003	**20.8**	**14**	**22**	**1**
16.	20.03.2007	12	24	**34**	2.4
17.	28.03.2008	5.2	39	**34**	3.7
III			Forest Range Patrauti		
18.	26.02.1998	**19**	31	**14**	**0.1**
19.	25.05.1998	**26.2**	36	9	4.2
20.	03.10.1999	**28.4**	37	**14**	**1.9**
21.	10.04.2003	**26.5**	22	**14**	**0.6**
22.	15.05.2003	**31.2**	25	**12**	**0.5**
23.	03.04.2004	**21.8**	32	9	**0.6**
24.	02.04.2006	**18.6**	30	**12**	2.4
25.	29.03.2008	**20.6**	20	**12**	**0.5**
IV			Forest Range Marginea		
26.	25.03.1990	**24.5**	16	**14**	**0.4**
27.	03.11.1993	**16.8**	51	9	2.2
28.	07.04.1998	**27**	30	9	1.7
29.	26.03.2000	**16.3**	48	9	**1.1**
30.	20.06.2000	**32.2**	47	**18**	1.3
31.	08.03.2001	**20.4**	24	9	**1**
32.	02.02.2002	**18.1**	24	8	**0.4**
33.	11.04.2005	**21.9**	16	**10**	4.1

Note: With bold figures there are written the values of the climatic parameters which favour the production and the spread of fires. These are above the normal limits of that period of the year. The parallels between the values recorded, related to the average annual values and the critical values of fire, are presented in the table below.

Table 2

The values of the climatic factors from the days of the fires in relation to the average annual values and the critical values of fire

Nr. crt.	The indicator	Value / day / fire		Average annual value		Critical values of fire	
		min	max	min	max	min	max
0	1	2	3	4	5	6	7
1.	Temperature	5.2	**32.2**	5.8	13.8	**17**	**33**
2.	Humidity	**14**	**51**	17	83	**0**	**60**
3.	Wind speed[m/s^{-1};km/h]	**9/32.4**	**34/122.4**	8.5/30.6		**1.1/4**	**10.2/37**

Comparatively analyzing the data of Table 2, columns 2 and 3 – value/day/fire with columns 6 and 7 – critical values of fire, it can be observed the fact that the values of the three indicators (maximum and minimum limits) – temperature, humidity, wind – recorded in the days when the forest fires were reported, with the exception of the minimum limit of temperature, it goes within critical intervals, favourable to the initiation of forest fires. In this aspect, the maximum value of temperature goes to 0.8 units to the maximum limit of the critical value. The humidity of the air (recorded values) goes within the two limits (+14;-9). The speed of the wind goes beyond the critical limits (+7.9 / 28.4;+23.8 / 85.4).

The spread of the fire. The way and the degree of the spread of a forest fire: affected surface and the speed of the development, give its level of danger (Roy 1999).

Photo 1. Forest fire with open flames.

The spread of the forest fires is mainly determined by the influence of the natural factors, with the exception of the intentional fires.

Photo 2. Forest fire, with great emission of smoke (Pojorâta – 29.03.2008).

The natural factors with direct contribution to the spread of the fires are:

* **the structure and the composition of the vegetation**, which, because of its combustibility (feature synthesized in the combustibility index), has the property of maintaining the burning once initiated, and it leads to the spread of fire. This way, the reaction of oxidation, once initiated, self-maintains and it develops as a chain reaction. This is interrupted only in the moment when one of the three elements of "the fire triangle" is eliminated.

* **the currents of air** are essential to the spread of the fires. This is a decisive fact and it is produced on several levels, as follows:

- the natural alimentation of the fire with oxygen, accelerating the burning;
- the raising of the hot air in the atmosphere, and with it the carbon dioxide and the other products of the burning, which can slow the process of burning;
- the directioning of the flames towards the surrounding combustible material;
- the transport of the incandescent combustible particles to long distances, which leads to the spread of the fire "on leaps" at long distances.

* **the landforms** can favour or unfavour the spread of forest fires, thus:

- the slope conditions the inclination of the flames in relation to the soil and thus the speed of the propagation of fire increases, being given the natural tendency of raising the flames vertically;
- the convexity and the concavity can accelerate or slow the contribution through the oxygen which reaches the fire because of the movement of the currents of air. Thus, a fire initiated at the top of the slope usually develops faster than one initiated in an unventitaled depression;
- the altitude can influence the spread of the fire through the role played by the atmospheric pressure in determining the degree of rarefaction of the air with consequences upon the temperature index;
- the natural obstacles: (rocks, streams) can play the role of stop factor of the fire.

The influence of these factors is made during the three phases of the fire: **the water evaporation** from the combustible material, **the inflammable gase emission** through **pyrolysis** and **the ignition followed by the burning itself**.

No matter the influence of these factors, the fire generates a strong emission of thermic energy through which it self-maintains and it develops. The exchange of heat generated by the forest fires, with the environment can be realized through three physical processes: **the conduction**, which permits the step by step spread of the kinetic energy produced by the movement of the gases; **the thermic radiation**, which corresponds to the way of spread of the energy as the infrared waves (the main way of spreading the fires); **the convection**, which is related to the movements of hot air orizontally and vertically. Ths is influenced by the power of the currents of air and the dimension of the slope. This process can contribute to the uncontrolled transport of incandescent combustible particles to long distances. This leads to the triggering of secondary burning point (the so called fire leaps). This is also a major obstacle factor which can contribute to the delay of the intervention.

Material and Method

Types of forest fires. A forest fire can evolve as different forms, each of them being in a direct relation with the characteristics of the forest vegetation and the influence of the natural factors from that specific area. Thus, there can be distinguished (Ciobanu & Ioras 2007):

* **underground fires or under the foliage layer**, where the oganic material, contained in the litter, humus, peat or the tree roots, burns, having as main characteristics:

- low speed of spread, max. 1 km / 24 hours;
- they are more difficult to be noticed and can be propagated easily in different directions, taking by surprise the intervention personnel;
- it doesn't develop flames at sight;

- it can degenerate into litter fires;
- it spreads usually by conduction;
- they can be noticed after the “mark” it leaves on the surface of the soil: smoke at the cracks, high temperature and an increased dryness only in certain directions, the drying of the vegetation which is not touched by fire.

* **litter fires**, where the lower layers of vegetation burn from the soil of the forest (the layer of grass and shrub), having as main characteristics:
- a high speed of propagation, up to 1 km / hour;
- it is strongly influenced by the natural factors, especially by the wind, the slope and the precipitations;
- it develops with flames, at sight;
- is a generator of smoke and high temperatures;
- it has the most favourable conditions of propagation;
- it can degenerate in underground fires, canopy fires or mixt;
- is generally spread through radiation;
- it is influenced by the wind and can take by surprise the technique and the intervention staff.

Photo 3. Litter fire (Pojorâta – 29.03.2008).

*** canopy fires**, where the superior part of the trees burns. It has the following main characteristics:
- it gives large amounts of heat;
- the flames are visible, manifesting as a crown, a wall, a wave of fire;
- the speed of propagation is very high, between 8 – over 25 km / hour;
- are strongly influenced by the climatic factors – wind and precipitations;
- most of the times it attacks the litter too;
- regularly spreads through convection and radiation;
- the propagation can easily be done through “leaps of fire”;
- the intervention is much more difficult and it is needed to attack the burning point from the level of the crown of the trees.

These three types of fires can manifest singularly or individually, under two or three types simultaneously in an affected area. In the last case these fires are categorized as being **mixt fires or combined**.

The localization of the fire. The operations of localization of the forest fire refer to the multitude of actions and activities which are successively taken in an organized way and according to some work procedures throgh an operational and logistical plan, aiming at limiting its spread. In other words, a forest fire is considered to be localized in the moment when its surface is not growing. Also there is no possibility of opening new burning points, because of “the leaps of fire”. The forces of intervention take over the operative situation and continue the operations of liquidation of the fire.

At the moment of the localization of the forest fire, the technical and organizational measures are at a maximum level. All the structures are mobilized to ensure the

management of this type of risk. It is concentrated the maximum of forces and means for intervention. The time of localization of the fire is considered to be the period of time elapsed since the first arrival of the forces of intervention and the moment in which the fire is under control, in the sense reducing the possibilities of spreading. The fire area is considered to be the surface covered by the fire in the moment of its localization.

Photo 4. Localized forest fire, in course of liquidation (Pojorâta – 29.03.2008).

The liquidation of the fire. The liquidation of a forest fire refers to a series of actions and activities that are undertaken in sequence, organized, according to certain procedures, in the operational and the logistical plan, aiming at stopping its action. A forest fire is considered to be liquidated when they were identified and eliminated all the outbreaks of the fire, at sight and hidden, from the basis horizon or from the secondary ones; where there were produced spreads through “leaps of fire” (Ene 2008). In practical terms, this thing is achieved by suppressing the contribution of at least one of the elements of the “triangle of fire”: the combustible material, the oxygen, the heat source.

Depending on the evolution of the fire, during the process of extinguishment, there may occur maneuvers, usually without the need of additional forces and means of intervention.

Photo 5. Operations of liquidation forest fire (Pojorâta – 29.03.2008).

The localization and the liquidation of the forest fires is done through procedures, techniques and specific methods, different from those which are used during the other types of forests.

Besides, the time of localization and the liquidation of the forest fires it is in most of the cases higher than in the case of technological fires because the rapid evolution. This fact is due to the fact that a forest fire can spread totally uncontrolled in space and time. Thus, the number of forces and means to mobilize as well as the burned area are considerably higher in the case of forest fires than in other types of fires.

Techniques and methods of firefighting in the mountain forests. Observing the forest fires is crucial in the execution of intervention actions (Lentile et al 2006). The moment of the observation and of the announcement related to the moment of the initiation of the forest fire can determine the burnt surface, the type of fire, the forces and the means which are mobilized in order to conduct the intervention.

Techniques of intervention. According to the type of fire, the way of manifestation, the speed of propagation and the influence of the natural factors in the mountain forests, there can be used several techniques:

- **according to the position towards the front** of the fire:
- from the front, in the case of the fires with a low spread speed of, when there is no possibility of taking by surprise, in the case of underground fires, as well as in the case of using the method of firefighting "fire-counterfire";
- from the back of the front, in the case of violent fires, with tall flames, when there is the danger of taking by surprise the intervention staff;
- from the side of the front, when there are natural obstacles in front of it, in order to prevent the return on the flank.
- **according to the intervention tools and the techniques used**:
- ground operations, with the mobilization of personnel and the technology of intervention, moving on the ground, in case of all types of fires;
- air operations, with the use of the aircraft specially designed for fighting with forest fires, in case of canopy fires, violent and which included large areas and when there are adequate sources of water nearby.
- **according to the extinguishing substance used**:
- water;
- water and additives;
- protective gels;
- inert dust (dust, soil, sand).

Methods of intervention. The methods used in order to locate and extinguish the forest fires take into consideration the annihilation of the contribution of one or more factors which form "the triangle of fire" – the combustible material, the oxygen or the burning temperature.

- The removal of **the combustible material** refers to:
  - Clearing of a strip of protection from the front;
  - The creation of some inert spaces (strips) of protection from the front, by plowing the land;
  - The use of protective gels;
  - Realization of the artificial pruning;
  - Removal of the combustible material from the forest, as a result of the forestry-technical works;
  - The directed fire through the "fire – counterfire"method.

- **The reduction of the content of oxygen**:
  - The usage of inert powders (dust, soil, sand etc);
  - The usage of beaters or other improvised means;
  - The discharge of water, as an extinguishing substance, pulverized or fog at high pressure, the enrichment of the fire environment with water vapors.

Photo 6. Firefighting with the reduction of the content of oxygen (Pojorâta – 29.03.2008).

- **The reduction of the burning temperature**:
  - The transfer of heat through the discharged water at the extinguishment;

Breaking the burning chain is produced when an imbalance occurs between the quantity of produced heat. This fact contributes to the burning process and the amount of heat transmitted to the environment. The maximum efficiency (100%) of heat transfer is achieved, in theory, when the entire amount of water sent on the flame is transformed in vapors. This involves the use of pulverized water, at high pressure, with a large dispersion in order to realize the intramolecular contact. In practical terms, this is not possible because the intervention actions require the use of a compact water jet. This is to be sent strongly, to a fixed point, at as large distances as possible.

- The transfer of heat to the environment; This is done naturally. In the conditions of the reduction of ambient temperature (at night), the amount of heat transferred will be greater;
- Reduction of the temperature due to the influence of weather conditions (precipitations).

There are situations when great forest fires can be extinguished due to rainfall in the burning area. The violent forest fires are harder to extinguish through conventional methods, if the weather conditions are unfavourable in this regard: drought, high temperatures, low humidity, lack of precipitations, strong winds.

Results and Discussion. The intervention for extinguishing the fires in the mountain forests involves two main features, different from the lowland forests: the realization of the access and ensuring the sources of water for the firefighting.

Ensuring the access. The access in the mountain forests is usually difficult because of the terrain. In Suceava County, the main landforms are arranged from East to West in parallel longitudinal strips from North to South. The altitudinal range is diverse, with heights from 225m, in the riverbed of Siret, to 2100m, Pietrosul Calimanilor peak. The forests from the Suceava County are mostly located in mountainous areas, hardly accessible, crossed by torrential ruptures. The steep slopes determine a reduced accessibility for the people and the intervention squads in case of fire. This leads to difficult operation and intervention with consequences on the spreading of fores fires. In the case of the Suceava County forests, the forest roads have a density of only 0,005 km/ha (Suceava forest departament, statistical data), which represents 27-35% of the optimum of the Romanian network (Bezeriuc et al 2003) and 11% of the average forest roads from other European countries (Dobre 2009). Even these existent roads, after the floods from June – July 2010, have suffered significant damage (223 km) (Inspectorate for Emergency Situations "Bucovina" Suceava County, Statistical data).

Ensuring the water supply for the firefighting. In the case of the forests from the Suceava County, with a hydrographic network of 1370 km, of which 395 km of rivers, 975 km of streams and 0.31 square km of lakes and ponds, reported to a surface of 439.862 ha, it results a density of water courses of 0.003 km/ha of forests (Suceava forest departament, statistical data). This low density of water courses together with the lack of facilities and the hidrotechnical reservoirs, which should provide a safe and stable water reserve; the reduced accessibility of the means of intervention to these existent water sources, as well as the uneven repartition of these in the territory, make a negative influence upon the risk of forest fire. The lack of whater supply combined with the difficult accessibility of the intervention team bring the firefighters forces to find auxiliary methods of firefighting.

Thus in the forests of Suceava, in order to ensure the necessary water, it is made: It brings some water supplies in basins and tanks, with the use of forestry tractors, which are then used on the fire.

The realization of some motor pumps relays. An unapproved method, by sending cascading water under pressure, from the base of the slope, from motor pump to motor pump, with the use of intermediary accumulation containers for the water (plastic barrels of 50 – 200 liters). The schematic presentation of the intervention device is made in the Appendix.

Conclusions. The forest fires are clearly distinguishable from the rest of the types of fires, both in terms of initiation, observation, spread and carrying the intervention actions. At the same time, they differ according to several parameters, including the zoning of the forest district. This is translated in terms of landforms, but also according to the degree of the forests protection in different locations.

Table 3

The WWF indicators concerning the status of the protected forest areas in different countries of Europe (Ene 2008).

No.	Country	General note concerning the protected forest areas
1	Slovakia	66
2	Hungary	58
3	Belgium (Flanders)	55
4	Finland	55
5	Spain	55
6	Greece	53
7	Netherlands	50
8	Poland	47
9	Turkey	47
10	Austria	45
11	Estonia	45
12	Sweden	40
13	Belgium (Walloon)	40
14	UK	40
15	Switzerland	39
16	Lithuania	39
17	Romania	39
18	Norway	34
19	Germany	25
20	Latvia	24

Evaluation of the forest areas was done accounting to the following indicators:

- data quality;
- the involvement of the Government;
- protection tendency;
- the ecological representativeness;
- national geographic distribution;
- vegetation distribution;
- plans of management;
- quality of the management;
- quality of the protection.

Summarising the information presented above, we can draw the following conclusions:

- The forest fund of Romania and, implicitly, of the Suceava County, has a reduced degree of protection towards the fire, both in terms of silvic criteria (composition and structure, fito-sanitary status, way and discipline in exploitation), and in terms of intervention conditions in fires (low accessibility, reduced water supplies, undersized technical equipment, compared to the level of risk) – the 17th place out of 20 from Europe;

- The climatic factors – temperature, humidity, wind – have a decisive contribution in the initiation and the spread of fires in the forests of Suceava County, in the period 1990-2009;

The evolution of forest fires in the period 1990 – 2009 was not uniform in time and space. The physical and geographical characteristics of the terrain, the climatic component and the anthropogenic factor have influenced the differention of the risk of fire for the same cathegory of forest vegetation.

In order to compensate for the deficit of water sources, it can be chosen the realization of the motor pump relay.

Given the fact that in the period under review 74.25% of the forests fires were litter fires with a speed of spread of maximum 1 km / hour, 0.76% of underground fires with a speed of spread of maximum 1 km / 24 hours, we can estimate that the level of weather danger for the forests from Suceava can be considered to be ”Moderate” (Ene 2008).

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The Appendix: The plan of the intervention device in case of a forest fire, where “The motor pump relay” is marked.

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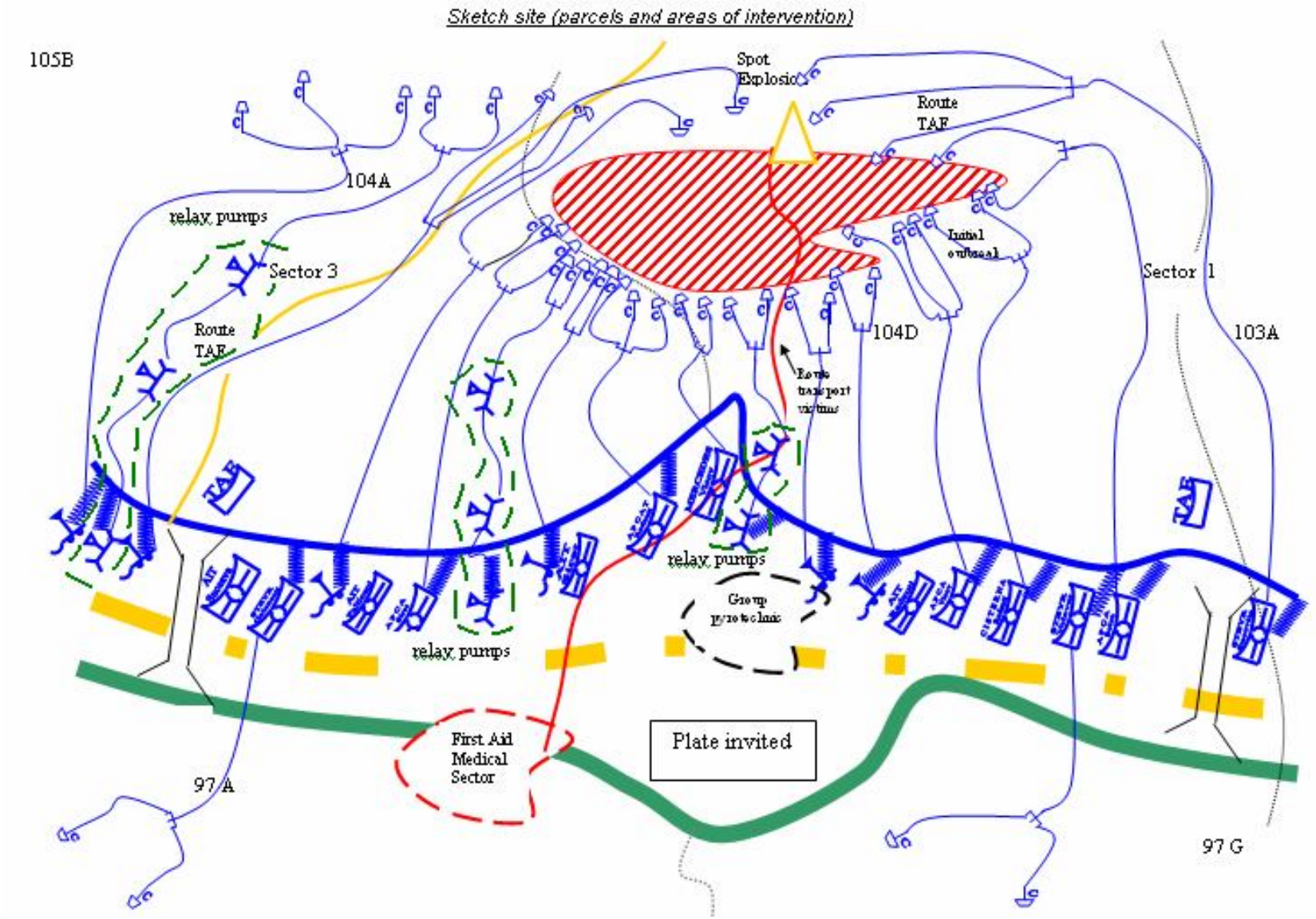
Sketch site (parcels and areas of intervention)
105B
Spot
Explosio
Route
TAF
104A
relay pumps
Sector 3
Route
TAF
Initial
epicenter
Sector 1
104D
103A
relay pumps
relay pumps
First Aid
Medical
Sector
Plate invited
97 A
97 G