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INVESTIGATION OF OIL POLLUTION AT THE TAPA MILITARY AIRFIELD

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1. Geological Profiles (2 sheets)
2. Map of the Studied Region
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0. SUMMARY.

This report concerns a preliminary investigation of the oil pollution at Tapa Military Airfield.

Geology and groundwater conditions in the region have been examined.

Water samples from wells were analyzed in order to identify the oil types with a view to evaluate the risk of the pollution.

The results of the investigation indicate that there are three areas which are heavily polluted with jet fuel. In one area the free phase of jet fuel on the water table was nearly 1 m thick, and in another area the jet fuel has penetrated the underground to at least 15-20 m below the surface. The entire polluted area is estimated to 16 km^2.

The major part of the groundwater resource is heavily polluted and unfit for drinking purpose, and the remaining part is threatened. Parts of one of the major river systems are already polluted

If no remedial action is taken the pollution will spread to the entire groundwater resource and to the major river systems in the area.

It is suggested to clean up the free oil on the water table and to introduce preventive measures on the airfield in order to stop the source of pollution.

In order to optimize the remedial action it is necessary to carry out further investigations to establish the extend of pollution and the direction of the pollution flow.

1. BACKGROUND.

During the years many spills and accidents have occurred on military bases in Estonia. One airbase, TAPA Airbase, is not only considered to be the largest airbase in Estonia, but it is also located right beside the town TAPA with 10.000 inhabitants.

For many years the inhabitants have "complained" about the quality of the drinking water. The water smelled and tasted of oil and in some cases it is even said to burn.

Oil has also been discovered in rivers and in the wetlands surrounding the airfield.

The situation is grave and the authorities have given the Tapa-project first priorities.

The aim of this project is not only to make an environmental assessment of the Tapa region, it is also a cooperation between Estonia and Denmark on transfer of technology and know-how concerning prevention and remedy of groundwater pollution.

On the basis of an Estonian wish for a proposal to remedy a large jet fuel pollution from TAPA Airbase, the project group wants to:

1. undertake a study of jet fuel pollution from the airbase at Tapa

2. carry out a project for prevention and remedy of the pollution

3. systematize the preliminary work concerning various types of oil pollution and describe a prevention/remedy concept, which support the

Estonian environmental authorities in their development of techniques and tecknologies to prevent and remedy groundwater pollution of this character.

This report concern item 1 only.

The work have been funded by The Estonian Ministry of Environment and the Danish National Agency for Environmental Protection.

The work has been a joint effort between:
Geoestonia; Estonia
Estonian Land Reclamation Project, Estonia
Ferskvandscenteret, Denmark
Hedeselskabet, Denmark

2. GEOGRAPHY.

Tapa City is located in the northern part the Republic of Estonia, about 80 km from Tallinn. The location of the city is shown in figure 2.1. The number of inhabitants is around 10.000 at the present moment.

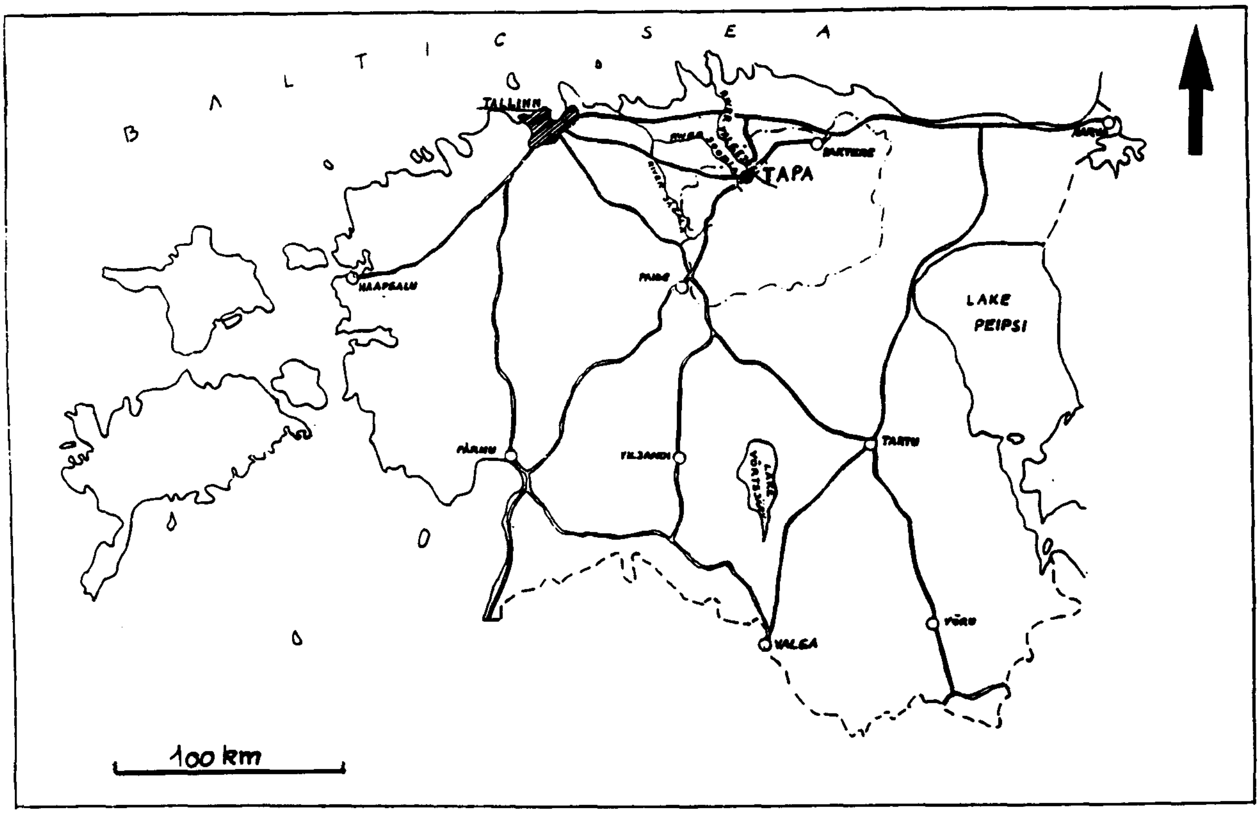


Fig. 2.1. Location of Tapa.

Tapa City is an important railway junction. Here are situated wagon and locomotive depots, some smaller industrial enterprises, transportation companies and gasoline stations.

The dominant pollution source is considered to be the Soviet military airbase, see fig. 2.2 .

The airbase was built in the 1950-ties.

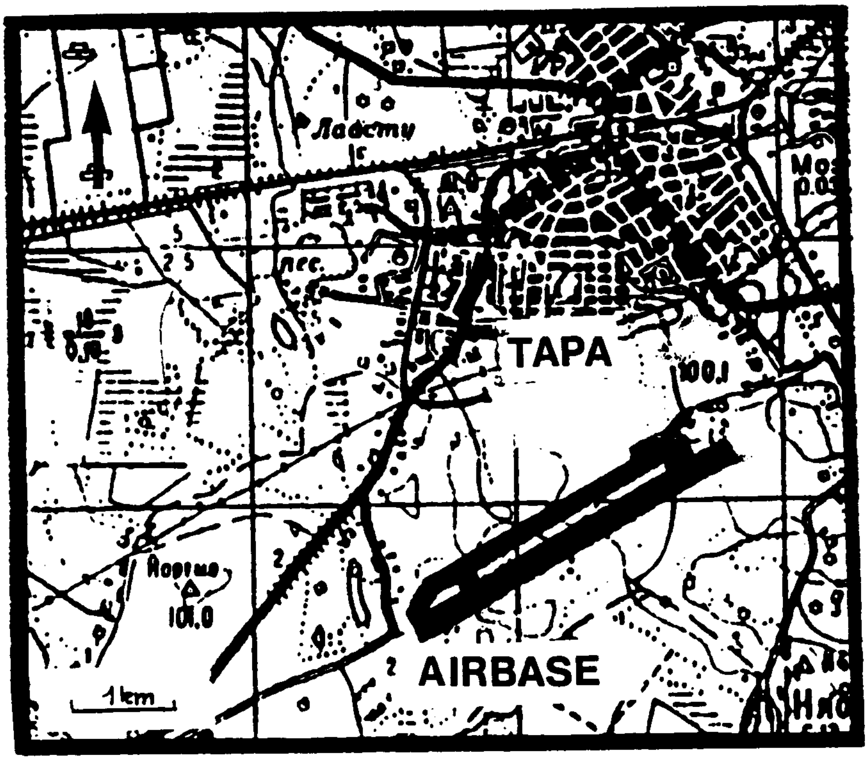


Fig. 2.2. Location of the military airbase.

3. POLLUTION SOURCES IN THE INVESTIGATED AREA.

3.1 Tapa City

There are reported several events of oilspill in Tapa City which have caused pollution of soil and groundwater. The main pollution sources are oildepots, boilerhouses and filling stations. Fig. 3.1 shows the location af hot spots in Tapa City.

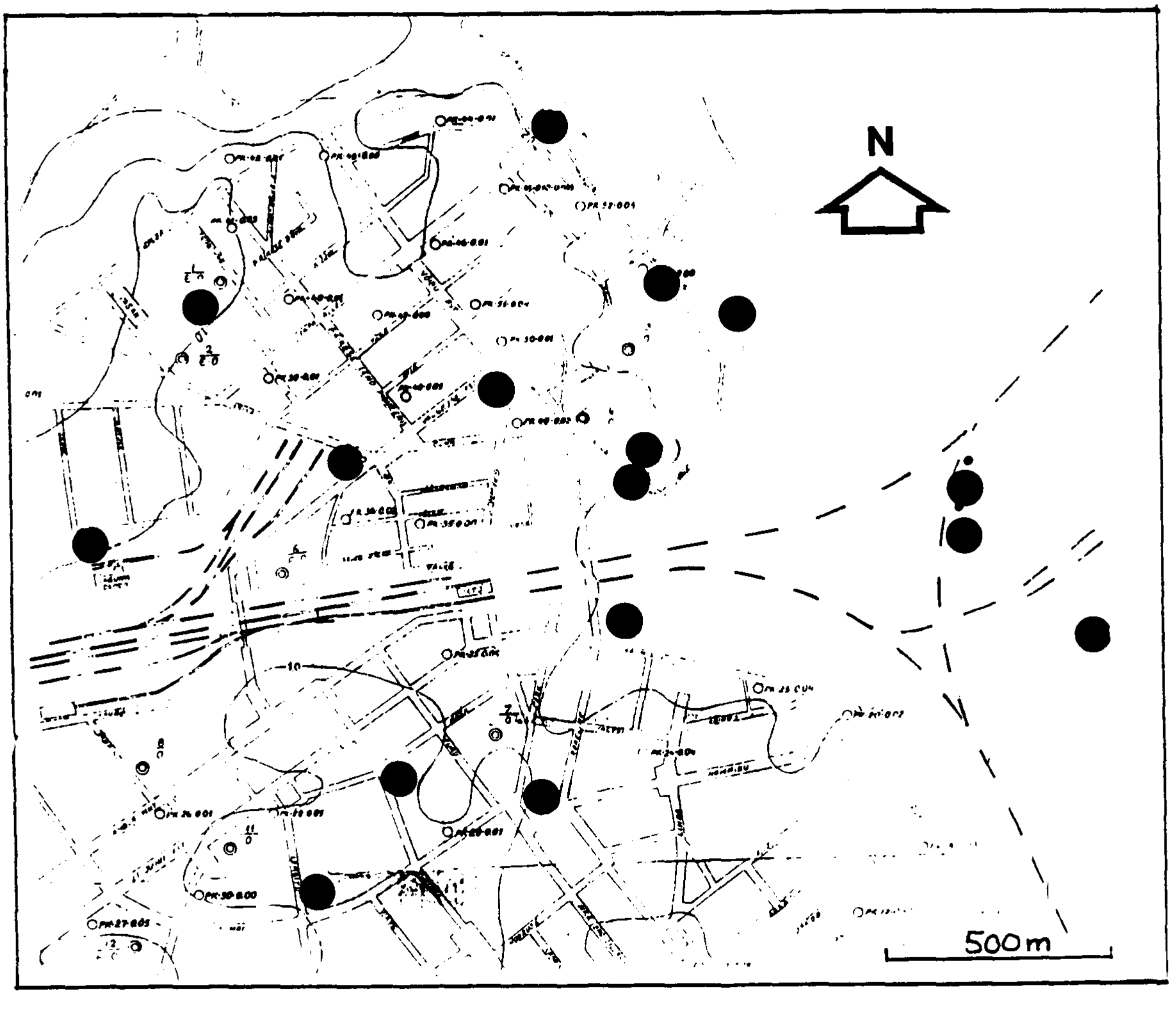


Fig. 3.1. Location of "hot spots" in Tapa City.

3.2 The Military Airbase

On the Russian military airbase, which until recently was closed for non military personal, several events of leaking or pouring out of oil products have occurred.

On of the main reasons for the these events is the presence of old installations for distribution of jetfuel at the airbase, i.e. pipelines and fuel tank storages. Careless handling of oilproducts and the lack of drainage systems with oilseparators are additional factors. In enclosure 2 the most important "hot spots" at the airfield are shown.

Hot spots are located on the map according to visual judgement due to lack of authentic topographic maps over the airfield.

The precepitation drainage system at the airfield consists of 62 **vertical open wells**. Inspection of these wells showed the presence of free oilproduct on the the watertable. Is is clear that the drainage wells have been used for pouring out excess jet fuel and that the wells have functioned as a drainage route to the limestone aquifer for overflowing jetfuel during tanking of aircrafts.

One larger pollution area is the surrounding of **the fuel unloading place**, mrk. 1 on enclosure 2. Several tons of jet fuel have been discharged here. Underground fuel tanks were located here earlier, but these tanks are now removed from this area.

The pipeline, that leads fuel into the fueltank area (mrk. 2 on enclosure 2), starts at the unloading place. The first part of the pipeline is buried in the ground, placed in a protection tube. Until 1986 the pipeline connections were made with simple joints, which now are replaced with a more efficient type of joints.

The fueltank area is surrounded in three direction by walls, 3 meter high, made of clayey till. In order to protect against infiltration of jet fuel into the ground, a seal of clay (20 cm) has been laid out under the fueltanks in some places. In case of an accident the oilproducts are spreading directly on the ground. There exists no drainagesystem with oilseparator to collect the oilspill.

From the fueltank area an overground pipeline distributes the jetfuel to a smaller fuel storage (mrk. 3 on enclosure 2) nearby **the filling place** for the aircrafts. The construction of the smaller storage is similary to that of the big. Further on, an underground pipeline leads fuel to the filling stands at the take-off path (mrk. 4 on enclosure 2).

Although there is no data about greater accidents on the airfield, the contaminations by oil products increased in July of 1986 in several wells north of the airfield. Also in Februar 1990 and Januar 1992 a notable increase in oilcontamination was reported both in drinking water wells and in a limestone corst area northwest of the airfield.

It can be concluded, that on the military airbase there exist several "hot spot" areas, where spilling from leakage and accidents and careless handling of oilproduct has caused severe contamination of the groundwater.

4. REGIONAL GEOLOGY.

The studied region is located on the N-W slope of Pandivere Upland. The surface elevations are 85-105 m above sea level. The surface declines in all directions from the central part of the region, where the military airfield is situated. The steepest declines are towards N-E and W.

The geology of the Tapa area can be described by an upper Quaternary sequens, of a thickness of 0,5 - 4 meter, consisting of clayey and sandy till and meltwater deposits. The thickness of Quaternary sediments is smallest in the centre of the military airfield (0,5-1 m) and becomes thicker, up to 3 meters, in the periphery of the airfield.

Below the Quaternary deposits are found a sequens of upper Ordovician limestone and marls, with a thickness of 135 meter. The limestones are lithified and the upper 30 meters are intensively fractured.

Beneath the limestone and marls are found sandstones of Lower Ordovician and Upper Cambrian age, with a thickness of 40 meter, underlain by a 40 meter thick layer of blue Cambrian clay. The Cambrian blue clay are underlain by a 90 meter thick sequens of Vendian sandstone, which is lying on the crystalline basement rocks.

A general geological profile is shown in fig. 4.1. With a detailed geological cross sections.

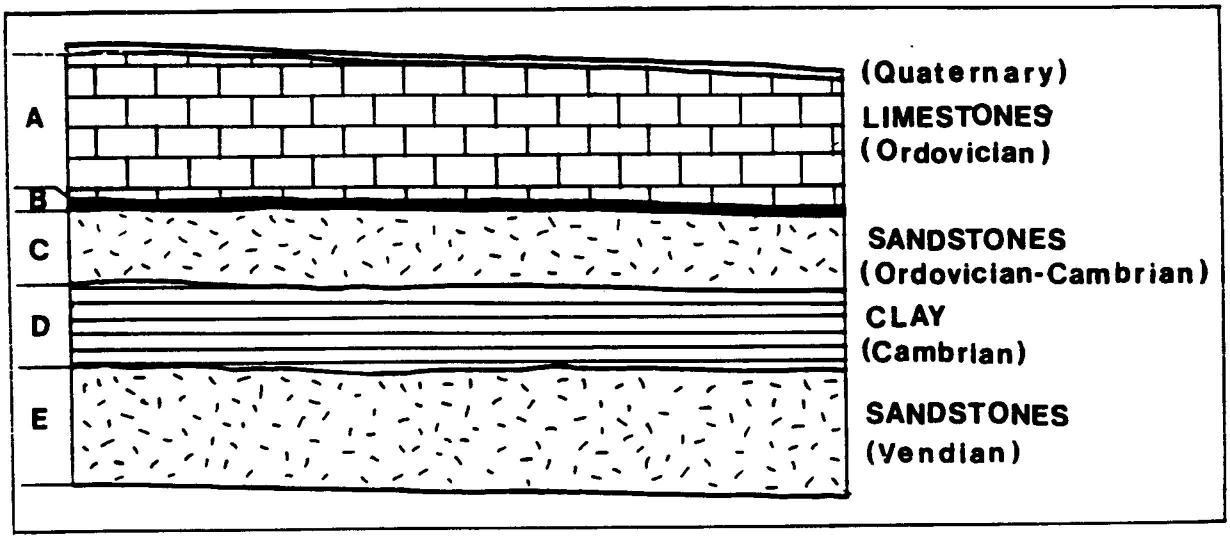


Fig. 4.1 Geological cross section af the area. A-E refering to hydro-stratigraphic units.

There are two major rivers in the Tapa area, Valgejôgi River and Soodla River. Valgejôgi River is around 5 m deep and is flowing practically on Ordovician limestones. Soodla River is more shallow and the river bed consists of Quaternary sediments. These major rivers are shown on fig. 2.1.

5. HYDROGEOLOGICAL CONDITIONS AND WATER SUPPLY.

There are **three major groundwater complexes** in the region. **The upper water complex** is connected to the Ordovician limestone series and consists of several water horizons divided by relativly impervious layers of clayey limestone and marls. The upper water complex (A) is shown in fig. 4.1.

The middle water complex (C on fig 4.1) is connected to sandstone sequences of Ordovician and Cambrian age. This water complex is separated from the upper one by the relatively impervious Dictyonema shale, marked B in fig. 4.1.

The lower groundwater complex (mrk. E in fig. 4.1) is the Cambrian - Vendian water complex. This water complex is separated from the Ordovician - Cambrian complex by 40 meter of Cambrian blue clay, marked D in fig. 4.1.

The upper part of the Ordovician water complex (A) shows very high values of transmissivity, due to presence of several fracture systems. The water table is from 86-98 meters a.s.. Groundlevel at the airfield is around 99 meter a.s.

In the centre of the airfield there is located a groundwater divide, from where the groundwater is flowing towards northeast, north and northwest, see fig. 5.1. Most of the groundwater is drained by the major rivers in the area, that is Valgejögi River and Soodla River.

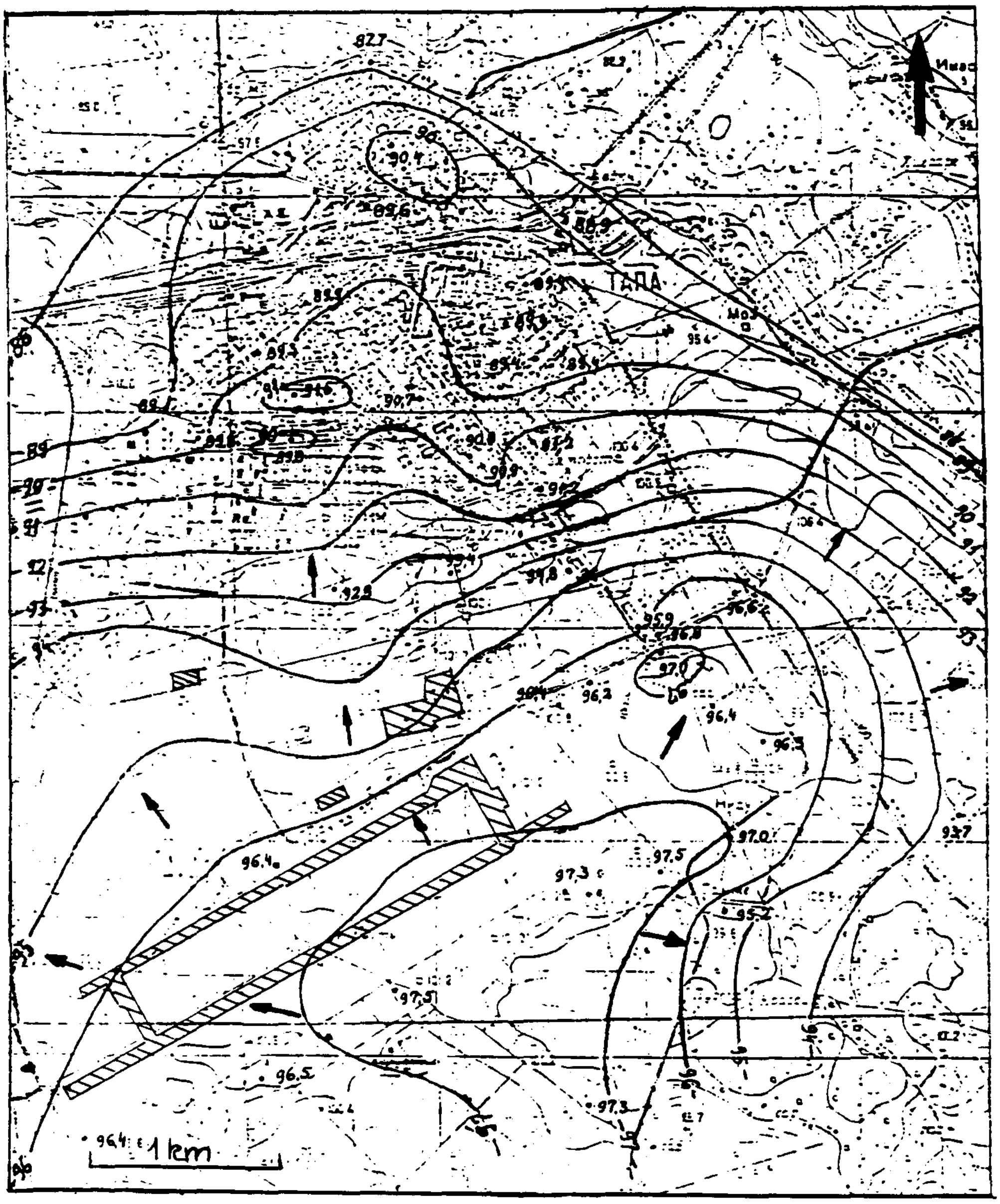


Fig. 5.1. Potentiometric surface of the upper Ordovician water horizon. Contourinterval is 1 meter. Arrows show direction of flow.

The water supply of Tapa was earlier based on shallow private wells, using water from upper horizons of the Ordovician water complex (A). Due to the severe oil contamination of the groundwater, now only one well in Tapa is using water from a lower horizon of this upper water complex (at depths 106-130 m).

The main water resource in Tapa City is, at the present time, the Ordovician - Cambrian water complex (**the middle complex**, C). Nine wells are extracting water from this water complex.

The Cambrian - Vendian water complex (E) is not used in the Tapa water supply although one well exists. It will not be possible, in the planning of the future water supply of Tapa, to calculate with these water resources, because they are almost entirely exploited by waterworks of other northern Estonian cities.

Because of the structure of the water supply in Tapa, with polluted shallow private wells, the water is at the present time distributed to the individuel households in tanks.

6. METHODS OF INVESTIGATION.

During the investigation the following work was done:

- collecting data in the archives
- water sampling and analysis
- drilling and geophysical works.

6.1. Collecting of materials.

Collection of historical data and map materials was done with help from Estonian Geological Survey Centre. Data about wells were collected from archives of the Estonian Agricultural Constructing Centre's department of building and installing. Data about the Quarternary surface layer was collected at the State Institute of Construction Research.

6.2. Water Sampling and Analysing.

Two different methods of sampling water from wells has been used.

While sampling water from running wells, 1-2 buckets of water were pumped out before the sample was taken. From pumping stations of deep wells, the water samples were taken before the pneumatic storage tank.

When sampling from closed down wells, a Grundfos MP-1 pump was used. The samples were taken after pumping in 10 minutes.

In all opened wells the water level was measured with sounding equipment. The presence of jet fuel film was determined with a special sampler. The results of the soundings are shown in enclosure 3.

The water samples were kept in 1 litres glassbottles with tight lid. When analysed by the flourimetric method, the samples were conservated with 10 ml hexane per 1 water. For the gaschromatographic analyses, the water samples were conservated with 5 ml 4M sulforacid per 1 water.

As only flourescent compounds are registered with the flourimetric method, the analyses only gives a rough estimate of the content of oilcomponents in the water. In order to quantify the specific oilcomponents, gaschromatographic analyses were carried out.

The results of the chemical analyses are shown in tabel 7.1. A description of the flourimetric and the gaschromatographic methods are given in enclosure 4.

6.3. Drilling and Geophysical Work.

Several old drinking water wells, closed due to contaminated water, were opened in Tapa and in the closest surrounding of the airfield in order to get hydrogeological data.

As existing wells and drainage wells didn't give enough information about water levels, 8 drill holes of max 7 m depth were drilled in the closest surrounding of the airfield. The drill holes were cased with 108 mm diameter casing pipe in the extent of the Quaternary sediments.

Geophysical work was carried out by the Estonian Geological Survey Centre. The goal of the investigations was to identify the geological character of deposits and the construction of wells. Therefore 9 wells were opened in the surroundings of the airfield. Additionally wels were opened in Tapa city and it's vicinity to determine the direction of the groundwater flow.

7. RESULTS OF FIELD WORK AND CHEMICAL ANALYSES.

In the very beginning of the investigation the field work covered a large area from Jäneda to Moe and to Ambla-Karkuse line in the south (see fig. 7.1, dotted line contour). Later the investigations were concentrated in a very contaminated region between Jootme, Tapa, Moe and Näo (fig. 7.1, steady line contour).

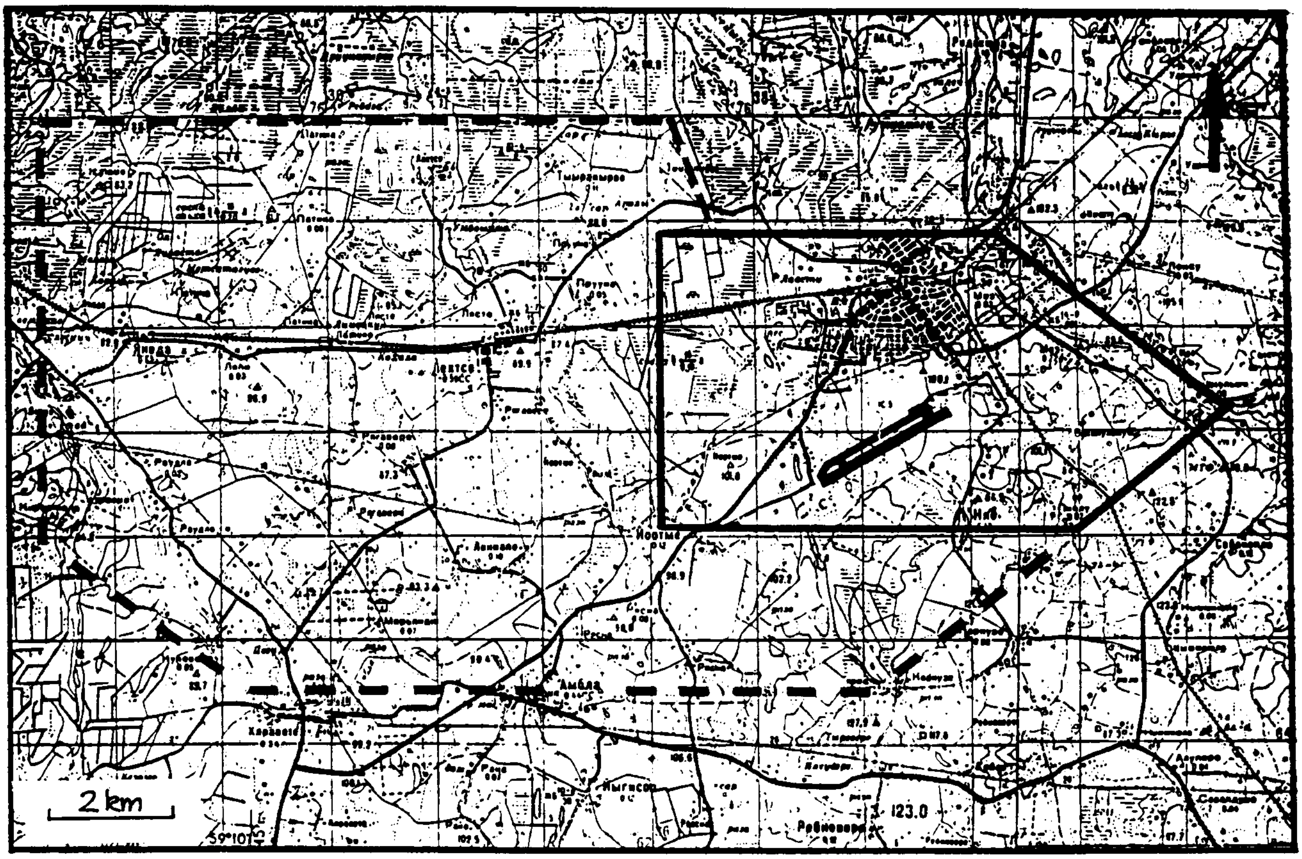


Fig. 7.1. Investigated area.

As the severe groundwater contamination caused by the Tapa military airbase turned out to be the main subject of investigation, no further investigation of other pollution sources in the Tapa City were carried out during this stage of work.

Field work data is presented in enclosure 2 and 3. The results of the chemical analyses are shown in table 7.1.

Table 7.1. Results of water analyses.

	Fluorimetric analyses ug/l 30.04.92	Gas Cromatograph analyses ug/l			
Well no.	Oil Products	Benzene	Toluene	Xylene	Jet Fuel
PK-108	123,0	-	10	-	70
PK-127	39,7	-	-	-	-
PK-112	43,5	-	-	-	-
PK-130	46,9	-	-	-	100
PK-115	126,0	-	-	-	200
SK-103	47,3	-	-	-	20
PK-250	251,0	-	-	-	-
A-1003	87,1	-	5	-	160
A-1004	3190,0	11	-	40	1070
PK-128	51,1	-	-	-	60
PK-8	174,0	-	-	-	-
A-1008	81,2	-	-	-	350
PA-11	54,9	-	-	-	-
PK-1	32,1	-	-	-	-
PK-16	91,1	-	13	-	130
SK-14	32,4	-	-	-	-
PK-5	553,0	-	-	-	40
PK-33	103,0	-	-	-	-
PK-59	166,0	-	-	-	-
PK-27	518,0	7	-	-	360
PA-8	412,0	-	-	-	-
PA-6	521,0	-	-	-	-
PA-3	323,0	-	-	-	-
PA-2	969,0	162	6	264	5730
PK-72	1519,0	90	90	1490	169700
PA-4	57,9	10	40	110	5670

PK = Drill well. PA = Drill hole. SK = Dug well. A = Spring.
-: below detection level.
For location of wells see enclosure 2.

The results of the fluorometric analyses compared to the gaschromatographic analyses show a high degree of inconsistency, see table 7.1. In several samples oilproducts are detected by the fluorimetric method but not by gaschromatography. This can be explained by the presence of other flourescent organic compounds, e.g. humus. It can therefore be concluded, that the use of fluorimetric analyses to detect oilproducts, can give erroneous results and that gaschromatography is to be preferred. In the following we are only concerned with results obtained by gaschromatographic analysis.

The gas chromatography analysis gives information on both the type of oil product and type of the most dominant compounds. From the analysis it can be concluded that the water is contaminated by a jet fuel oil, with a boiling range from 80-280 °C. This correspond to jet fuel of the wide-cut type, a fuel type containing relative many different compounds opposed to the jet fuel of the kerosine type. The dominat compounds are aliphatic n-alkanes, especially the n-C_9, n-C_{10} and n-C_{11}. In addition, the jet fuel contains the monoaromatic hydrocarbons: benzene, toluene and xylene. The concentration of the monoaromatic hydrocarbons is shown in table 7.1.

7.1 The extent of contamination

The chemical analyses and observations in the field show that the groundwater is heavily contaminated on the airfield in the area from the fuel unloading place (mrk. 1 on encl. 2) to the take-off paths, which is the area north of the take-off paths.

In the spring of 1992 degraded jetfuel was noticed in a ditch and a dug hole near the filling stand, and in the vertical drainage wells along the take-off path (mrk. 4 and with hatched green lines in encl. 2). This area is approximately 2 ha.

During several years, and also in the spring of 1992, jet fuel has been flowing out of the ground on the slope at Paide Road from Rauakôrve Brook up to the railway of the military base (area marked with hatched green lines NW of airfield in encl. 2). In the area of Rauakôrve Brook and Paide Road crossing the outflow was most intensive. The area of free jet fuel is approx. 5 ha.

Nearby in the brushwood there are small ponds (old gravel opencasts) which had up to 3 cm thick jet fuel layer on their surface. In Feb. 1992, 2 m^3 of jet fuel were collected here and used for heating. In May 1992, 3-6 m^3 of jet fuel were burned off the surface of the ponds to avoid reinfiltration to the groundwater.

Water sample taken from well PA-4, located NE of the small ponds, shows a jetfuel concentration around 6 mg/l, see table 7.1.

The highest concentration of jet fuel is found in well no. PK-72, located in the southern part of Tapa, about 700 meter NE of the airfield. The water from this well was dark grey containing black lumps of degraded oil.

The mapping of the extent of free oil on the water table has shown, that NE of the airfield there is an area of approx. 12 ha where the layer has a thickness of 90 cm, see enclosure 2 (shown with hatched green lines). The exact extension towards NE is not known. Due to different depht of wellcasing, free oil does not appear in all wells in this area.

The barrier for the distribution of free jet fuel may theoretically be an area, where the surface of limestone declines and the thickness of less permeable deposits of the Quaternary surface layer increases. In such regions where the relief also declines, jet fuel outflow on the surface may occur during periods of high water level, see fig. 7.2. Areas of free jet fuel appearance require more detailed investigation.

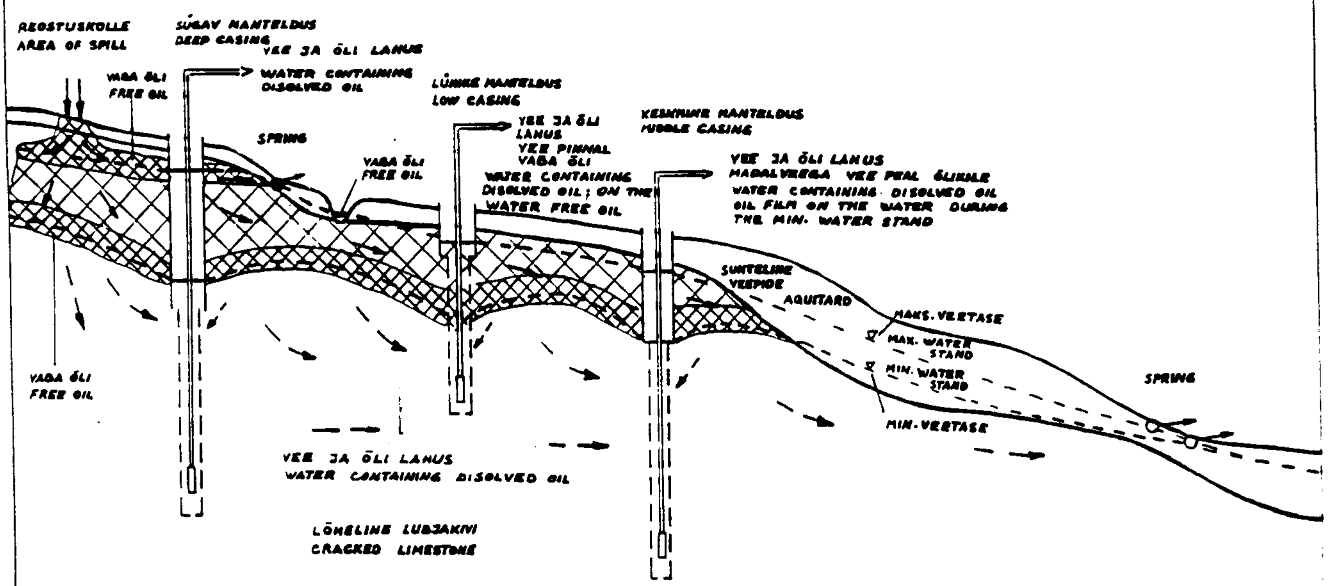


Fig. 7.2. Cross section showing the influence of wellcasing, geology and landscape relief on the appearence of free oilproduct.

According to the water samples, taken from drill holes which were made during the field work it can be concluded, that jet fuel contamination has not been detected south of the airfield, see table 7.1, well no.PA-3, PA-6, PA-8 and PA-11. This is in accordence with the direction groundwater flows.

The distribution pattern of the contaminated groundwater may also be favoured by fissure belts in NE - SW direction.

In peripheral parts of the studied region a content of dissolved jet fuel in water samples has been detected. For example in table 7.1 spring No.1003 at Jootme village, well No.PK-27 at Tapa and well No.PK-16 at Moe village are situated respectively 3 km, 1,5 km and 4,5 km from the "hot spot" area. The origin of the contamination at Moe village needs a more detailed investigation.

The jet fuel has also spread into deeper water horizons. Analyses of water samples, taken from working drinkingwater wells of Tapa water supply, i.e. well No. PK 108, table 7.1, contain jet fuel. Working interval of this well is a depht of 106-130 m, which correspond to the lower horizon of the Ordovician water complex.

The water of the Cambrian-Ordovician water complex is locally contaminated as shown in analyses from well No.PK 128 and No.PK 130. Working intervals of these wells are located below the relatively impervious dictyonema shale, respectively at dephts of 131-154 m and 135-163 m.

The pollution of the Cambrian-Ordovician water horizon may be caused by the intensive drawdown of water levels, due to a high degree of exploitation of this water horizon. The discharge from the two wells, No. PK 128 and No. PK 130, in March 92 was respectively 946 m^3/d and 374 m^3/d.

In water samples from well No. PK 112 and PK 127 (Cambrian-Ordovician water complex), located northwards from the "hot spot" area, oilproducts are not detected.

To sum up it can be concluded, that the investigation has revealed three heavily contaminated areas with free oilproduct on the water table:

- a large area, approximately 120 ha NE of the airfield, streching from the airfield towards the Valgejögi River

- a small area, approx. 2 ha near the filling stands at the airfield

- an area, approx. 5 ha NW of the airfield, at Paide Road by the crossing of Rauakôrve Brook

These areas are shown in enclosure 2 with hatched green lines.

Between these three areas a region is located, where jet fuel appears as film on the water table. This area, approx. 400 ha, is marked in enclosure 2 with green spots.

Water containing dissolved jet fuel is found in a region which stretches up to Valgejôe River in the east, the railway line in the north and Jootme Village in the west, shown with a dashed red line in enclosure 2. This area is at least 1100 ha.

It can be concluded, that in the heavily contaminated area NE of the airfield, the jet fuel contamination reaches down to at least 15-20 m in the upper water horizon of the Ordovician water complex.

Furthermore it can be concluded, that the dissolved jet fuel locally has penetrated down into the deeper Cambrian-Ordovician water complex.

The entire contaminated area, estimated at the present moment, is approx. 16 km^2.

8. ESTIMATION OF RISK.

Hazard assessment

Oil products consist of a mixture of hydrocarbons, with different chemical, physical and toxicological properties. For this reason, each oil type will migrate and transport differently in the environment and possess different toxicological properties. A risk assessment of the four most common oil types is shown in table 8.1.

Table 8.1. Risk assessment of the four most common types of oil.

Pollutant	Dispersion	Toxicity
Gasoline	Mobile -risk of evaporation and leaching	Acutely toxic - moderately carcinogenic
Diesel	Relatively mobile - risk of evaporation and leaching	Slight, acute toxicity - probably carcinogenic
Jet Fuel	Mobile - risk of evaporation and leaching	Moderately acute toxicity - probably carcinogenic
Lubricant	Immobile - no risk of evaporation or leaching	Chronically toxic - carcinogenic

As can be seen, the jet fuel possess dispersion and toxicological properties which make it one of the most problematic oil products. The reason for this is the relative high content of the monoaromatic compounds, benzene, toluene and xylenes (BTX).

The BTX compounds, especially benzene, are known to be acutely toxic and carcinogenic even at low concentrations. Studies on jet fuel do not give adequate evidence of carcinogenicity in humans, but because of the content of benzene, which is known to be carcinogenic in humans, jet fuel must be characterized as potentialy carcinogenic.

In addition jet fuel can be considered to be relatively mobile also because of the content of BTX. The BTX are the most soluble and most volatile compounds in the oil. The solubility of jet fuel is around 30 mg/l, with the BTX as the most soluble. The consequence is that jet fuel will act as a continuous source for dissolution of BTX in the groundwater. A relative high content of these compounds will result in a relative mobile oil.

Enviromental assessment

The pollution from the Tapa military airfield has spread to a very large territory, estimated 16 km^2, and has also affected the water quality in deeper groundwater aquifers. The upper water horizon of the Ordovician water complex is entirely contaminated in Tapa city. The water of two Cambrian-Ordovician water horizon wells nearby the airfield is also contaminated with jet fuel.

It has not been possible to calculate the exact volume af jet fuel on the groundwater. A more precise risk assessment with calculation of e.g. dissolution factor, is outside the scope of this investigation.

The preliminary risk assessment based on the results of the investigation is described in the following chapters.

The continuing spreading of oilcomponents constitutes a threat to the water supply of Tapa city. Diminishing the strength of pollution sources, i.e. by closing down the airbase, will not influence on this assessment, because of the great volume of water allready contaminated.

The influence of oilproducts on the newly planned water supply at Moe, about 3,5 km west from Tapa, has not yet been investigated. It cannot be excluded, that there is a risk for contamination also of this new water supply of Tapa.

The investigation has shown, that in certain spring areas the recipients are heavily contaminated, which has a severe effect on the fauna.

If the spreading of jet fuel continues, it may influence more severely the water quality of the major river systems.

These rivers have their falls into the Gulf of Finland and a contamination of the river water will therefore have an effect on the enviroment of the Gulf.

Another aspect of the jet fuel contaminaton, is the risk to the indoor climate of houses located in the more heavily contaminated areas.

It is very likely, that under certain circumstances, toxic vapors of oilcomponents, such as benzene, toluene and xylene will penetrate the basement-floor and affect the indoor climate.

In summary, jet fuel must be considered to pose a potential environmental hazard. The Danish limit of oil in drinking water is 10 ug/l. The concentration in the water in Tapa is considerably above this in 14 of the total of 26 samples. This, together with the potential environmental hazard, shows that the contamination in Tapa pose a serious threat to the environment.

9. SUGGESTIONS FOR REMIDIAL ACTIONS.

According to the preliminary risk assessment, it is necessary to set up some initiatives in order to diminish the jet fuel contamination's affect on the enviroment of the Tapa region.

At the present time the aim of remedial action will be to minimize the strenght of pollution sources at the airfield, and to set up pumpsystems at strategic locations, in order to skim off oil from the water table. The preliminary proposal for remedial actions will be described in the following.

Pollution sources.
The first initiative, in order to stop further pollution, should be to prevent further spill/leakage at the airfield.
All installations there (pipelines, tanks, filling stands, vertical drainage wells etc.) should be checked, visually and by pressure tests or tracer tests. It will be nessesary to make new drawings of the installations and to set up new procedures for handling the jet fuel.

Remidial actions.
The first step will be to implement oilskimming systems in the heavily contaminated area NE of the airfield. At first a testsystem, consisting of 10 skimming pumps and 10 draw down pumps, covering an area up to 1 ha will be installed. Further separation will take place in on site oilseparators. The skimmed of water will be reinfiltrated into the ground. The oilskimming system will not include the cleaning up of dissolved oil in the water.

The results from the test field will be used in the future planning of more detailed remedial actions.

The next step is to clean up the area of free oil at Rauakôrve Brook, NW of the airfield. It is suggested to make a system of ditches, parallel to the slope of the surface, to collect the oil. More detailed topographic maps are needed.

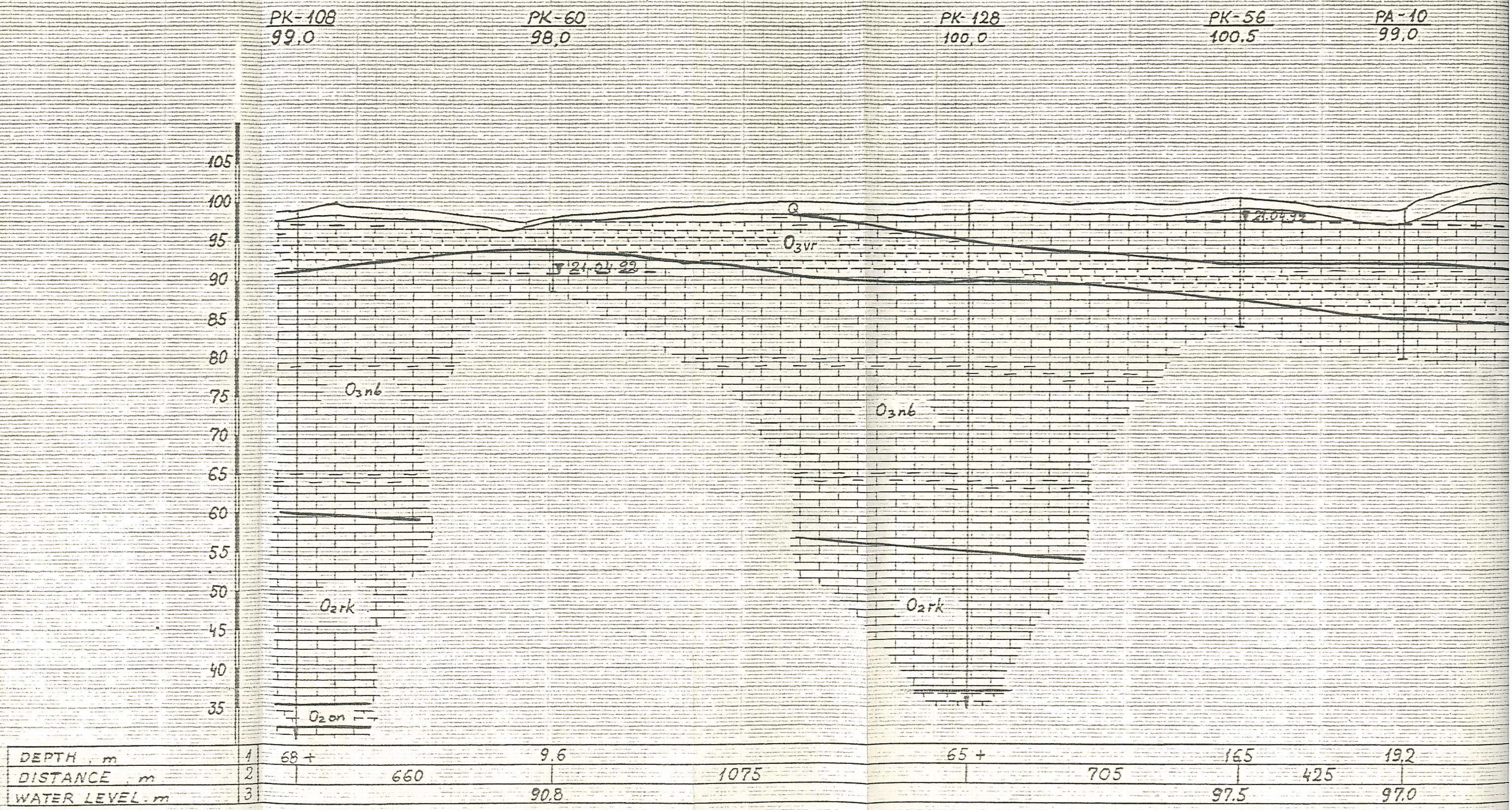
Enviromental assessment.

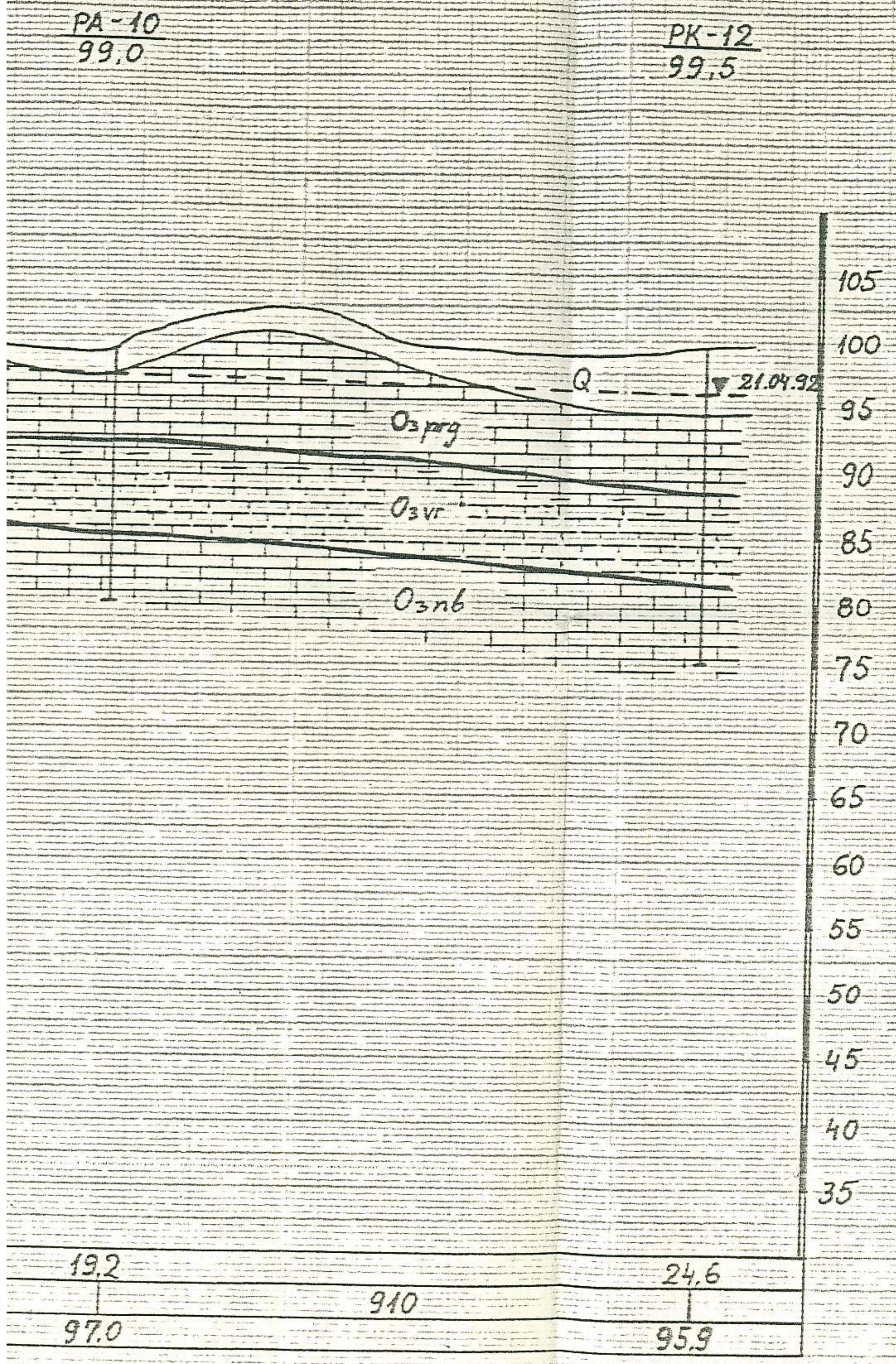
In order to set up the optimal remidial actions, both from an eviromental and an economical point of view, it is nessesary to make a detailed risk assessment.

The information about the distribution of the jet fuel contamination is so far not sufficient. In order to get more information about the extent and spreading of jet fuel further investigations are therefore nessesary. The investigation program will contain the following items:

- a more thorougly mapping of the extent of jet fuel
- investigations of fracture zones at the airfield
- a more detailed hydrogeological investigation
- computer simulations
- investigation of the waterquality at Moe Water Supply
- evaluation of the degradation potential in the groundwater

PROFILE VI – VI'





TINGMÄRGID

CONVENTIONAL SIGNS

Q	PINNAKATTE SETTED QUATERNARY SEDIMENTS
▦	LUBJAKIVI LIMESTONE
▩	LUBJAKIVI, SAVIKAS CLAYEY LIMESTONE
▤	MERGEL MARL
▬	DIKTÜONEEMAKILT DICTYONEMA ARGILLITE
▥	LIIVAKIVI SANDSTONE
☐	SAVI CLAY

LADESTIK FORMATION	LADE, KIHISTU LAYER	
ÜLEMORDOVIITSIUM (O_3) UPPER ORDOVICIUM	$O_3 prg$	PIRGU
	$O_3 vr$	VORMSI
	$O_3 nb$	NABALA
KESKORDOVIITSIUM (O_2) MIDDLE ORDOVICIUM	$O_2 rk$	RAKVERE
	$O_2 ou$	OANDU
	$O_2 kl$	KEILA
	$O_2 jh$	JÕHVI
	$O_2 id$	IDAVERE
	$O_2 kk$	KUKRUSE
	$O_2 uh$	UHAKU
	$O_2 ls$	LASNAMÄE
	$O_2 as$	ASERI
ALAMORDOVIITSIUM (O_1) LOWER ORDOVICIUM	$O_1 kn$	KUNDA
	$O_1 vl$	VOLHOVI
	$O_1 lt$	LATORPI
	$O_1 pk$	PAKERORDI
ALAMKAMBRIUM ($Є_1$) LOWER CAMBRIUM	$Є_1 ts$	TISKRE
	$Є_1 lü$	LÜKATI
	$Є_1 ln$	LONTOVA

OS. JUH.	M.METSUR		05.92
GEOL.INS.	M.SALU		05.92
JOON.	M.SALU		05.92

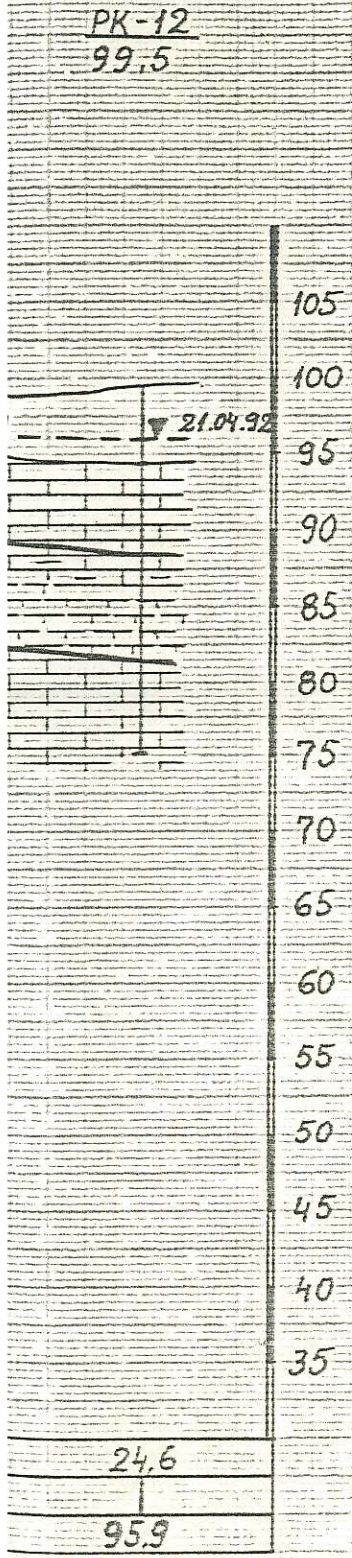
O

JÄRVA MK

TAPA-LEHTSE-J
KONNA NAFTAR
UURIMI

GEOLOOGILINE

M 1:10000 ; 1



TINGMÄRGID

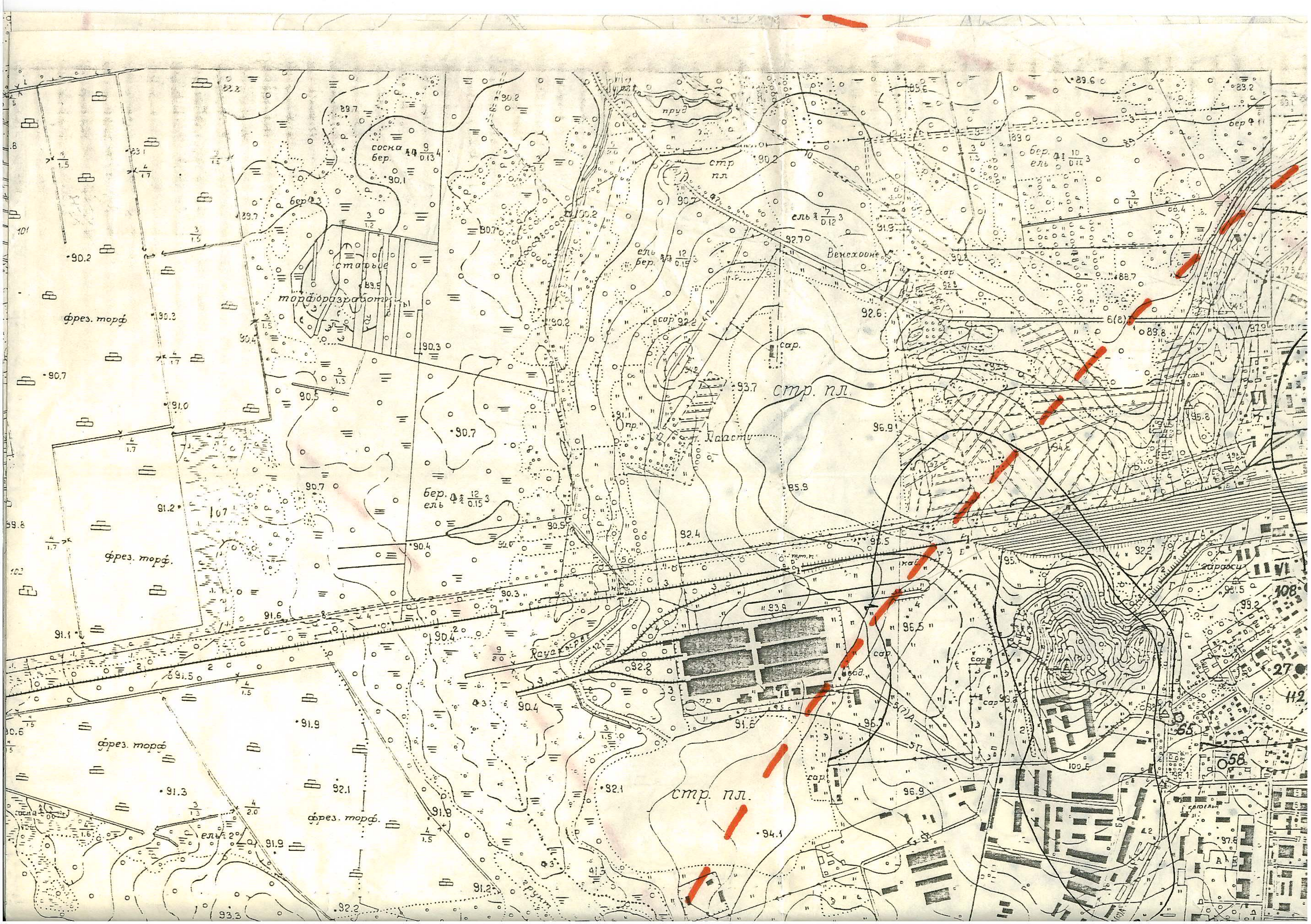
CONVENTIONAL SIGNS

Q	PINNAKATTE SETTED QUATERNARY SEDIMENTS
▦	LUBJAKIVI LIMESTONE
▦	LUBJAKIVI, SAVIKAS CLAYEY LIMESTONE
▤	MERGEL MARL
■	DIKTÜONEEMAKILT DICTYONEMA ARGILLITE
⁘	LIIVAKIVI SANDSTONE
☰	SAVI CLAY

LADESTIK FORMATION	LADE, KIHISTU LAYER	
ÜLEMORDOVIITSIUM (O_3) UPPER ORDOVICIUM	$O_3 prg$	PIRGU
	$O_3 vr$	VORMSI
	$O_3 nb$	NABALA
KESKORDOVIITSIUM (O_2) MIDDLE ORDOVICIUM	$O_2 rk$	RAKVERE
	$O_2 on$	OANDU
	$O_2 kl$	KEILA
	$O_2 jh$	JÕHVI
	$O_2 id$	IDAVERE
	$O_2 kk$	KUKRUSE
	$O_2 uh$	UHAKU
	$O_2 ls$	LASNAMÄE
	$O_2 as$	ASERI
ALAMORDOVIITSIUM (O_1) LOWER ORDOVICIUM	$O_1 kn$	KUNDA
	$O_1 vl$	VOLHOVI
	$O_1 lt$	LATORPI
	$O_1 pk$	PAKERORDI
ALAMKAMBRIUM (ϵ_1) LOWER CAMBRIUM	$\epsilon_1 ts$	TISKRE
	$\epsilon_1 lü$	LÜKATI
	$\epsilon_1 ln$	LONTOVA

LISA 1
ENCLOSURE 1

OS. JUH.	M.METSUR		05.92	00070911 - GL		
GEOL. INS.	M. SALU	M.Salu	05.92	JÄRVA MK, LÄÄNE-VIRU MK		
JOON.	M. SALU	M.Salu	05.92	TAPA-LEHTSE-JÄNEDA PIIRKONNA NAFTAREOSTUSE UURIMINE	STAADIUM U	LEHT 4
						LEHTI 4
				GEOLOOGILINE PROFIIL M 1:10000; 1:500; 1:1000	RAS „EESTI MAAPARANDUSPROJEKT"	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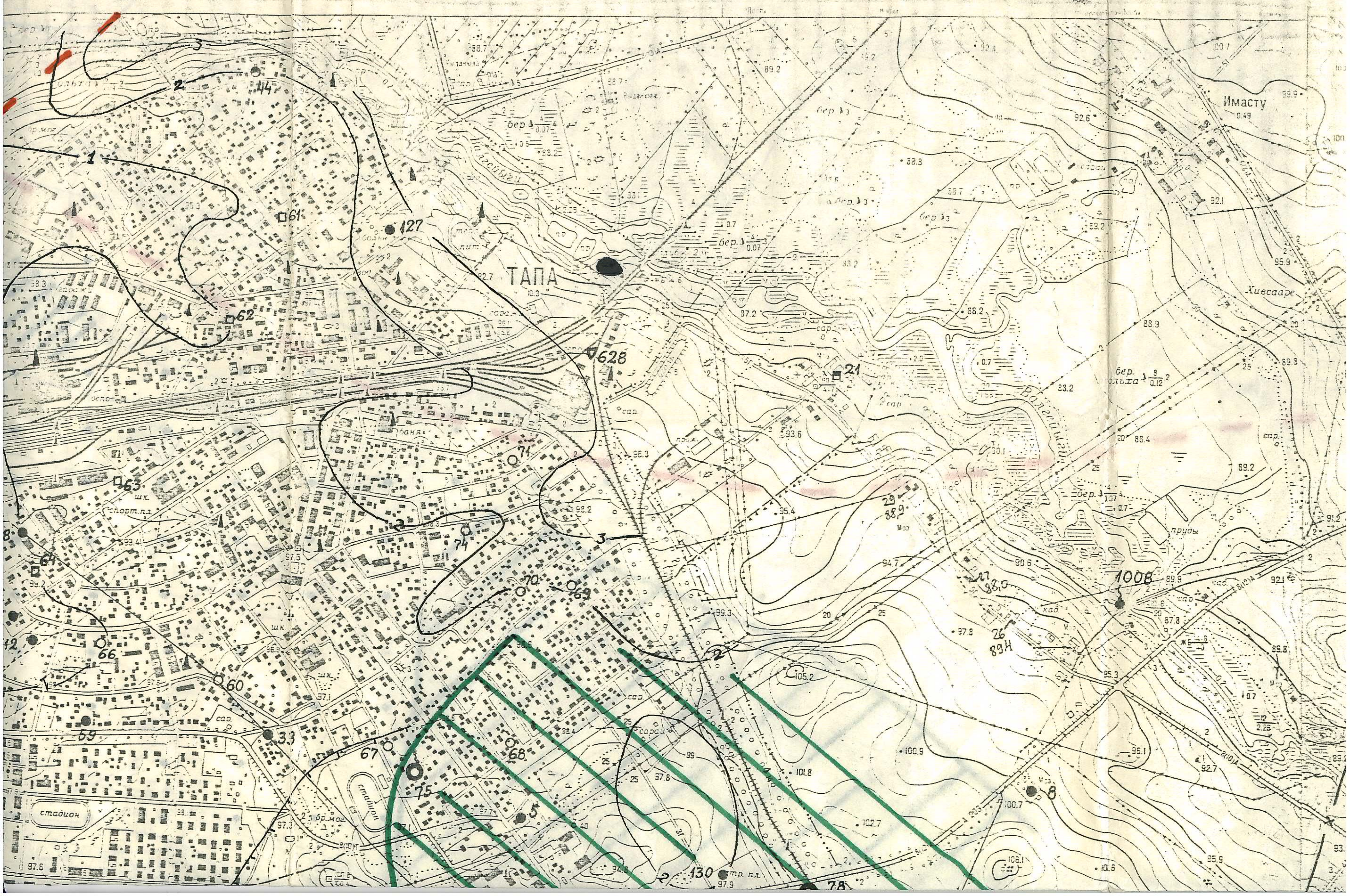
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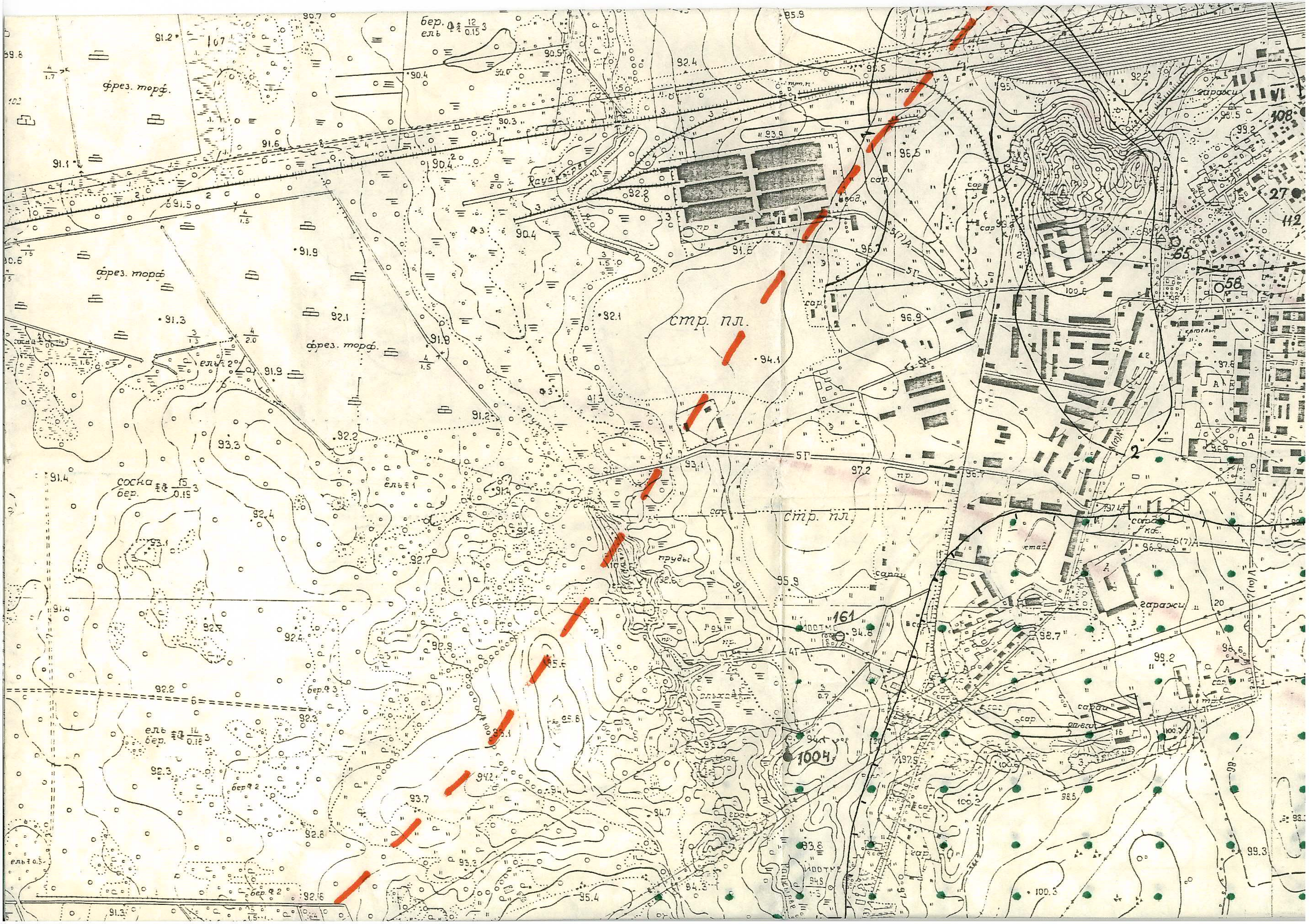
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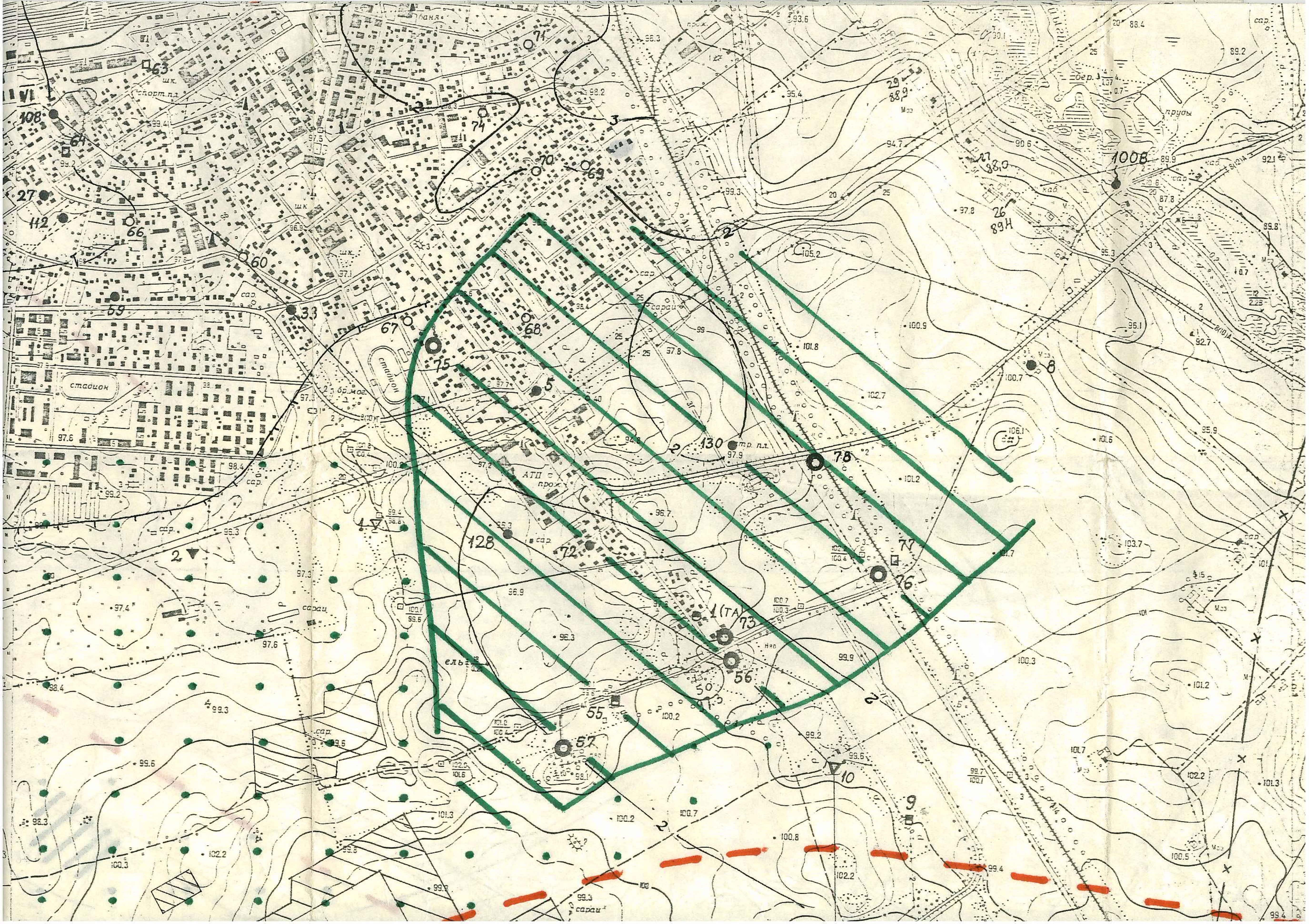
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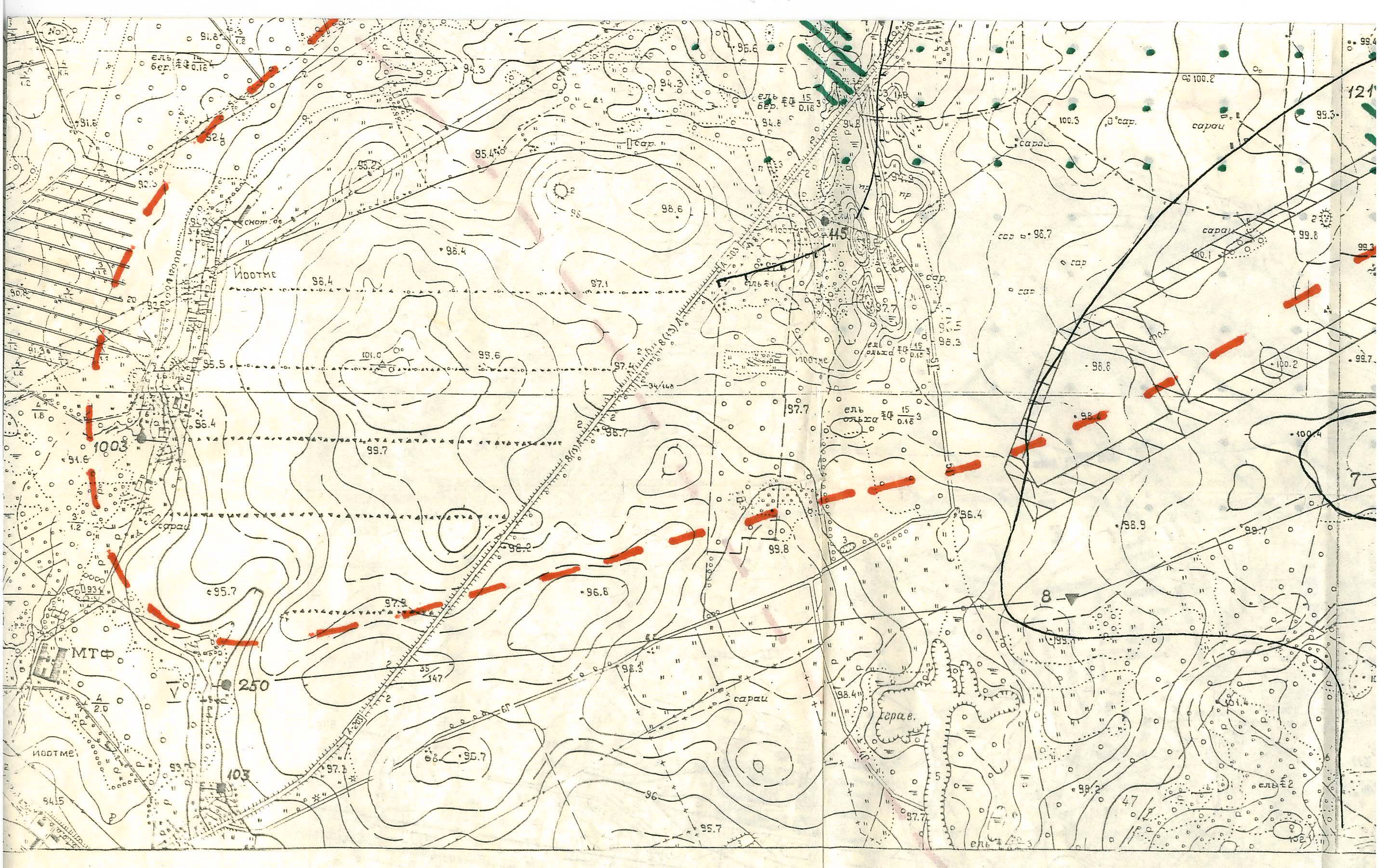

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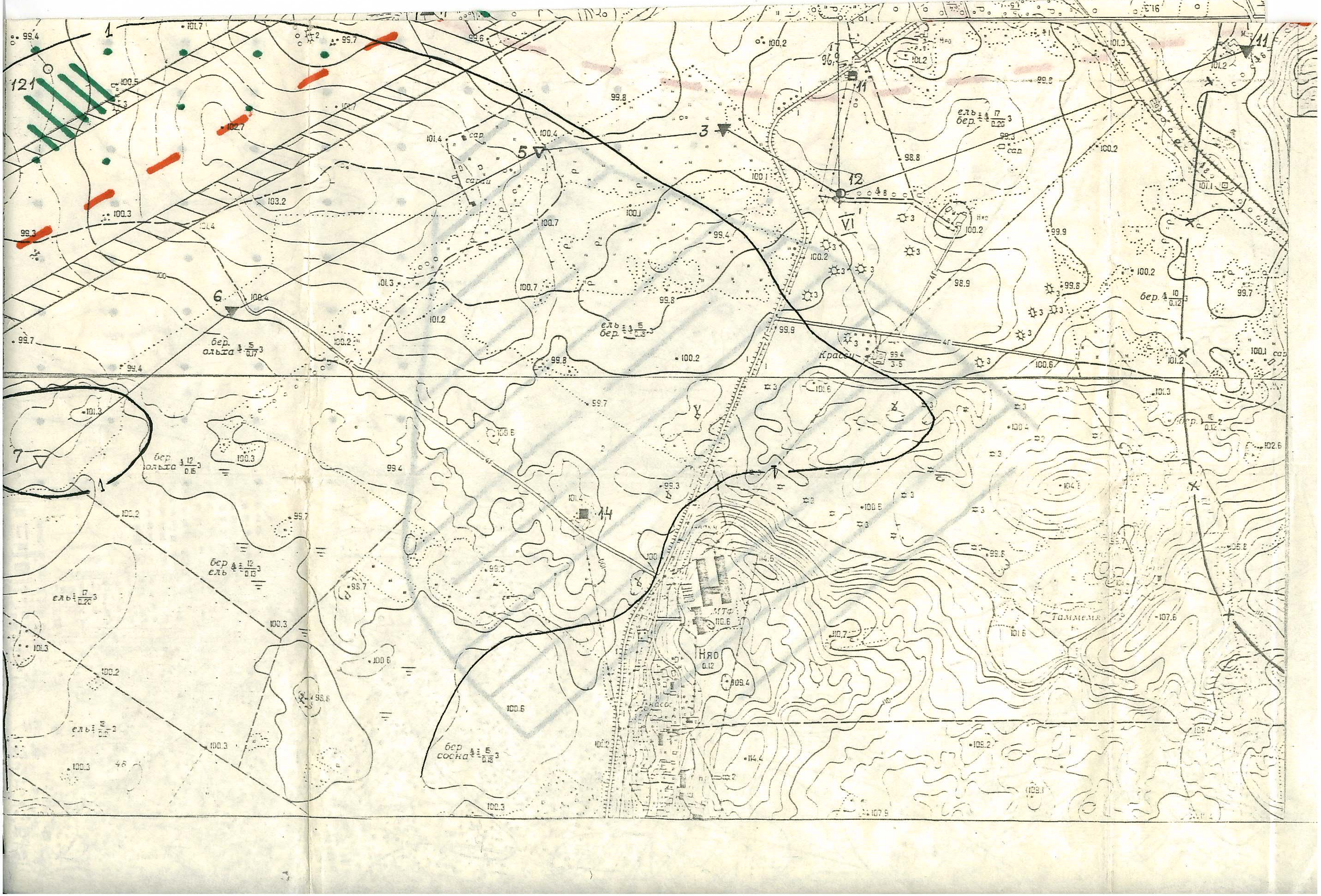
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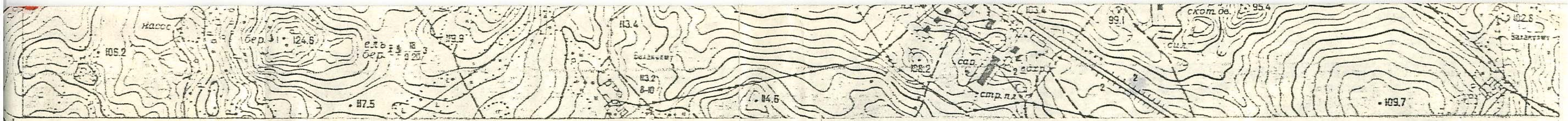

TINGMÄRGID
CONVENTIONAL SIGNS

□ ▬ ■ — SALVKAEV (SK)
DUG WELL

○ ◐ ◐ ● ◎ — PUURKAEV (PK)
DRILLED WELL

▽ ▼ — PUURAUK (PA)
DRILL HOLE

— ALLIKAS (A)
SPRING

▲ — POTENTSIAALNE REOSTUSALLIKAS
(VEDELKÜTUSEL TÖÖTAV KATLAMAJA)
POTENTIAL SOURCE OF POLLUTION
(HEATING HOUSE, WHAT IS USING
FUEL OIL)

□ ○ ▽ — MÕÕDETUD ON VEETASE, VEEPROOVI
POLE VÕETUD
IN THIS WELL OR HOLE WATER
LEVEL WAS MEASURED

▬ ◐ — FLUORIMEETRILINE ANALÜÜS, KUI
STANDARDIKS OLI TOORNAFTA
FLUORESENCE SPECTROSCOPY
ANALYSES, IF CRUDE OIL HAS
BEEN USED AS STANDARD

▨ ◐ — FLUORIMEETRILINE ANALÜÜS, KUI
STANDARDIKS OLI LENNUKIPETROOL
FLUORESENCE SPECTROSCOPY
ANALYSES, IF JET FUEL HAS
BEEN USED AS STANDARD

■ ● ▼ — GAASKROMATOGRAAFILINE ANALÜÜS
GAS CHROMATOGRAPHIC ANALYSES

◎ — VEEPINNAL ON VABA ÕLI KIHT
FREE OIL ON THE WATER SURFACE

▭ — MOE VEEHAARE ; MOE WATER INTAKE AREA

—x— — II SANITAARTSOON
II PROTECTION ZONE OF WATER INTAKE

— LENNUVÄLI JA REOSTUSALLIKAD
AIRFIELD AND SOURCES OF
POLLUTION

/// — VABA ÕLI
FREE OIL

⁘ — ÕLI KILE
OIL FILM

● — MASUUT
BLACK OIL

— NAFTAPRODUKTIDEST
REOSTUNUD ALA
CONTAMINATED AREA

— VORMSI LADEME (O_3vr)
SAVIKATE LUBJAKIVIDE JA
MERGLITE AVAMUSE PIIR
BOUND OF EXPOSURE
AREA CLAYEY LAYERS
OF VORMSI STAGE (O_3vr)
LIMESTONES AND MARLS

— PINNAKATTE
SAMAPAKSUSJOON
THICKNESS ISOLINE OF
SURFACE LAYER

LISA 2
ENCLOSURE 2

OS. JUH.	M.METSUR		05.92	00070911 - GL		
GEOL.INS.	M.SALU	M.Salu	05.92	JÄRVA MK, LÄÄNE-VIRU MK		
				TAPA-LEHTSE-JÄNEDA PIIRKONNA NAFTAREOSTUSE	STAADIUM	LEHT	LEHTI
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				FAKTILISE MATERJALI KAART M 1:10 000	RAS „EESTI MAAPARANDUSPROJEKT"		

ENCLOSURE 3. Water table elevation and thickness of free oil.

Dug well (SK) Drill well (PK) Drill hole (PA)	Water level ABS. elevation, m (04.92)	Thickness of free oil in cm
SK-21	86,6	n.m.
SK-55	96,6	n.m.
SK-61	91,0	n.m.
SK-62	90,4	n.m.
SK-64	89,9	n.m.
SK-9	96,7	n.m.
SK-11	97,4	n.m.
SK-14	98,1	n.m.
PK-1 (TA)	96,3	n.m.
PK-44	88,0	n.m.
PK-56	97,0	35
PK-57	96,6	80
PK-58	90,4	n.m.
PK-59	90,5	n.m.
PK-60	91,2	n.m.
PK-65	91,5	n.m.
PK-66	91,9	n.m.
PK-67	91,4	n.m.
PK-68	91,8	n.m.
PK-69	89,9	n.m.
PK-70	89,9	n.m.
PK-71	89,9	n.m.

Dug well (SK) Drill well (PK) Drill hole (PA)	Water level ABS. elevation, m (04.92)	Thickness of free oil in cm
PK-72	95,9	n.m.
PK-73	97,4	8
PK-74	90,1	n.m.
PK-75	90,5	1
PK-76	96,9	90
PK-115	95,1	n.m.
PK-161	94,2	n.m.
PK-12	95,9	n.m.
PA-1	93,6	film
PA-2	93,4	film
PA-3	98,1	n.d.
PA-4	94,2	film
PA-5	98,3	n.d.
PA-6	98,5	n.d.
PA-7	97,0	n.d.
PA-8	96,8	n.d.
PA-628	89,4	400
PA-10	97,5	n.m.
PA-11	94,8	n.d.

n.m. = not measured
n.d. = not detected

For location of wells see enclosure 2.

§ENCLOSURE 4. Analytic methods.

Fluorimetric analyses.

The intensity of fluorescence was estimated with the spectrofluorophotometer RF-540 ("Shimadzu", Japan) under the following conditions: Stimulation 310 nm slit 5 nm, Emission 360nm slit 5 nm, Sensitivity "high", Ordinate scale 2. When the intensity of emission under those conditions exceeded the range of the scale because of the great content of oil in the sample, the hexane extract of the sample was diluted with the same hexane that was used while extraction of the sample. The purity of hexane was always checked before measuring and the emission of hexane (usually 0.5-2 %) substracted from the result of the measurment. According to that corrected measuring result,the content of oil product in the sample was calculated using crude oil "Ekofish" in hexane (2 ng/ml) as a comparison standard and assuming that the intensity of emission was proportionally dependent on its concentration during the measuring period.

In the obtained index essentially reduces the pollution of all different oil fractions to the amount of proportionally fluorescent crude oil. Due to the different content of fluorescent substances the weight concentration of the oil product may substancially differ from the obtained index of oil equivalent. In case of pollution by Diesel fuel, for example, the oil equivalent of pollution may be S times smaller than the weight concentration of the pollution. In case of pollution by aircraft fuel the difference is even greater as pure aircraft fuel contains little fluorescent admixture. The oil equivalents of heavy black oil may be up to 2 times greater than their weight pollution level.

After the measurement, fluorescence spectrum (of the same dilution) between 250...500 nm was registered synchroneous stimulation with the difference 25 nm in the wavelength. The ratios of emission intensities on the different wavelengths proved to be decisive: light engine fuels are characterized by the maximum wavelength of 290...300 nm (gasoline, petroleum). Diesel fuels are characterized by the maximum wavelength
of apr. 310 nm with an abrupt decrease of emission on longer wavelengths, black oils are characterized by relatively high intensities of emission around the wavelength of ca 350...370 nm which in case of heavy black oil may exceed the maximum of 310 nm.

As only fluorescering compounds are registered with the fluorescence method, it's not enough precise a method to determine the extent of the pollution. These compounds form only one part of the fuel's composition and don't have to be connected with fuels at all.

Gas chromatographic analyses

HEDESELSKABET has measured the content of oil in the ground water by the gas chromatograph method (GC/FID). The extraction has been carried out in the following way:

- 120 ml water sample was extracted with 2.5 ml pentane
- the extraction has be carried out for 10 minutes.
- the extract was kept on Na_2SO_4
- temperature program 40 - 310 C
- flame ionization detector (FID)