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# Contribution Of Road Projects To Water Pollution

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**Abstract**
Road construction is a scale intervention in nature and landscape requiring knowledge of the impact of an alignment. Water pollution by the construction and operation of roads depends on their uninterrupted use and is a function of traffic volume. A system of sub-programs was developed in order to analyze real data from a project and assess the impact caused by the construction and operation of roads to the ecologic potential of space. The part of the software program run to estimate the impacts on the quality of runoff waters is analyzed, showing the way data are furnished and how the results could be managed. The study mainly focuses to underground and drinkable water models. The impacts are given in connection to road alignment elements. Appropriate management of road rainwater runoff and the selection of control measures against pollutants depend on various parameters and are presented in the paper.
***Keywords:*** *Impact; Pollution; Environment; Underground Water; Road Function.*

## 1. Introduction

Rainwater rinses dust from the atmosphere and impermeable urban surfaces (roads, bridges, parking lots, roofs) and in the form of runoff transports out of the road dissolved colloids and solids in a heterogeneous mixture which contains inorganic and organic compounds, oils, fats and heavy metals. The polluting substances can remain permanently on the surface or can be removed from the street by re-suspension or by road runoff water. It seems that road runoff itself plays an important role both as a source of pollutants, as well as material absorption of pollutants [1]. A large amount of pollution from road runoff is transferred directly into water bodies [2].

The pollution risks for surface- or ground- water due to the operation of roads could be categorized in various scale degrees. For instance, an alpine area without vegetation cover, is characterized by as excessive to very large pollution risks, a shallow aquifer on bedrock, is judged as being in very large to large pollution risk, a swamp area of glacial gravels (classified material) could be recognized as having a medium-to-minimum risk potential, and an aquifer covered by thick clay and silty sediments exhibits little or no pollution risk.

The type of road surface (asphalt or concrete) seems to have little effect on the quality of effluents [3]. Road surface contaminants deposited on the carriageway in an urbanized area originate from many sources. Industrial processes, land use activities, the "precipitation" of air pollutants, the use of the pavement itself, and other activities contribute to the loading of particles in urban road decks. These materials are then brought in water received from stormwater runoff where they constitute an important part of the general pollution problems of urban waters. Road traffic of motor vehicles is directly or indirectly responsible for the disposal of significant quantities of material on roadways in urban areas, e.g. 13 parameters with highest concentrations of pollutants [4]. Significant levels of toxic heavy metals, asbestos and slowly biodegradable oil and rubber are directly deposited from motor vehicles along with large amounts of particulate materials indirectly contributed by traffic. Though largely inorganic, these particles relate to solids and nutrients that represent a serious source of water pollution in metropolitan areas.

Heavy metals are toxic to aquatic life, and can contaminate underground water [5]. For the most common pollutants associated with traffic on roads, zinc (Zn) and lead (Pb) are expected to show higher concentrations in road runoff waters [6]. Fuels are the main source of lead; however, it seems that only a small proportion of lead is removed by road runoff water, while the greater part can be dispersed in the atmosphere or settle in the roadside soil [7]. A relatively high level of Zn can be explained with the presence of metal protection guardrails, and the wear of tires and breaks [8]. Service roads have been found to exhibit high polycyclic aromatic hydrocarbons (PAH) concentrations, while in pedestrian ways and bike routes the highest Zn concentrations have been measured [4]. Lead and zinc have higher concentrations during the winter or first spring months due to the use of deicing salts [9].

The construction of a new road is a significant scale intervention in nature and the landscape and any standardization effort with the help of mathematical models, which are necessarily generalized, requires deep knowledge of the impact of an alignment on the ecosystem and the landscape [10]. The tendency to apply universal mathematical models for completely different projects, without any adjustment, should be treated with constructive criticism [11]. This does not mean that rules and applicable relationships to be used in the construction and improvement of models do not exist and there is no need to search for them. On the contrary, a great effort should be in this direction. Such an effort is the subject of environmental impact determination achieved by various systems. A system of sub-programs of this type has been developed in the Transport Engineering Laboratory of Democritus University of Thrace in order to analyze real data from a project and assess the impact caused by both the construction and operation of roads to the ecologic potential of space.

In the following sections, the part of the program referring to the impacts due to road construction and operation on the quality of runoff waters which terminate their flow in soil surface or underground soil layers and can be used as drinkable will be analyzed. The aim is for the prevailing idea behind the software to be understood, and to show the way the relationship between the user and the computer is interactively developed during the data import process, as well as when the management of results is necessary.

## 2. Models of Impacts of Roads on Waters

The model of impacts of roads on the quality of groundwater and drinking water searches the ways through which the roads impact the ecosystem during their construction phase as well as during the period they are in service. River systems highway networks have many common characteristics: they are long, linear features of the physical environment. Transporting people, materials, and living organisms is elementary for their function. Basic feature to the continued functioning of both systems is connectivity. The goal of interdisciplinary groups of scientists should be to create an infrastructure for transportation that does not fragment the existing ecological infrastructure of the space they transverse. Due to their linearity, roads strongly intervened in the groundwater system and -for different construction projects- different effects arise; namely: (a) if a pathway lies below the natural water horizon, cuts result to lowering of the horizon if the slopes drain directly, (b) if an area is filled perpendicular to the direction of the water flow, then flow can be slowed or stopped; (c) underground tunnels cause blockage (on slopes for example) or lowering of the horizon of underground waters (in the case of highly porous aquifers); (d) The bridge foundation in river beds cause the destruction (interruption) of the physical state of soil layers and, thus, allow surface water to enter the underlying material. When surface water is contaminated, it can negatively affect the quality of groundwater.

The waterproofing of the land surface and the road surface leads to increased surface water route and thus a slowdown in the regeneration of the water horizon. The flow rate plays an important role in assessing the risk of contamination of drinking water and especially the risk caused by the oil spill after an accident. The possibility of infection is related to the amount of water. The least productive sources are considered to be affected negatively less than the more productive. Although many studies contain reports of groundwater contamination related to roads, so far no attention has been given in the long-term effects of pollution caused by road traffic releases. In the literature, the following substances are reported as contaminants of roads, when are found in elevated concentrations: (a) hydrocarbons; (b) heavy metals; (c) salt (no physical process decomposes NaCl). High grade concentrations are present in solutions within 500-1000 meters from the street and if the flow is in the direction where underground drinking water exits, then the water is infected. WHO recommends limits of 50 ppb for lead and 10 ppb (1970) or 5 ppb (1972) for cadmium. If the top soil layers with invasive and absorptive capacities are removed, the groundwater contamination is greatly increased.

Since the proposed method is implemented in a personal computer environment, certain conditions and terms referring to the technical and organizational equipment must be satisfied. First, the computer system must be able to handle large amount of data. The system addresses simple algorithmic data correlations, mainly in geometric and set-theoretical forms. Easy integration of new or different models (e.g. dispersion of contaminants) must be allowed. Parameter values for simple algebraic operations have to be easily altered. For some of the calculations, it is not possible to find simple algorithms. Generally, individual results are not tucked through a standardized process. Moreover, part of the calculations could not be based on simple algorithms.

Both the system of computer programs and the calculations have to be standardized in order to import new standard methods, algorithms, etc., at anytime, without changing the overall structure of the system. The method allows the dialogue between the user and the program.

## 2.1 Partial model of groundwater

In the partial model of groundwater the effects on groundwater are identified and interpreted. The structure of the model is better understood, if these effects are subdivided into the following three categories: (a) risk to groundwater due to the construction of the road, especially during the construction period; (b) risk to groundwater due on long-term infiltration of pollutants associated with the route (heavy metals, salts); (c) direct risk to groundwater due to road accidents.

In principle, the following input data are required: presence and amount of source water, groundwater flow direction, and soil permeability. Because all this data is not often found on maps there is a need for experts (account managers, for example) to determine the sensitivity of groundwater from geological maps which are usually available. The sensitivity is divided into the following four categories: excessive or very high risk of infection (e.g. bare alpine area); very large to large risk of infection (e.g. shallow layer over bedrock); average to minimal risk of infection (e.g. marsh glacial gravels); minimum or no risk of contamination (e.g. thick clay and silty sediments). The model also requires the identification of drinking water collection facilities along with the protection areas and the bridges of the alignment. From the program of road alignment, the following results are also needed: pavement lane, cuts, fills (embankments), contaminated area.

### 2.1.1 Risk to groundwater due to construction and in the long-term from pollutants

The construction and use of a road lead to groundwater contamination, if the alignment passes through soil layers (in cut) containing water or when waste water penetrates the water table.

The construction of the road pavement and embankments damages the upper soil layers and, therefore, it leads to groundwater pollution. Also, the pavement of the road and the embankment volumes waterproof the surface.

As shown in the flow chart (Fig. 1), the intersect of the union "Pavement lane" and "Fills" with "Sensitivity" ends on surfaces with possible risk to groundwater, at least during the construction period, i.e. on the surface "Risk for the groundwater due to construction". When surface soil layers are removed or when cut sections are created in rock layers, an increased risk is presented. This normally occurs during the construction of cuts. In this case, "Layers with increased risk on groundwater" is the result of intersect of "Cuts" and "Sensitivity". The same risk occurs either during the construction stage or where the road is in use.

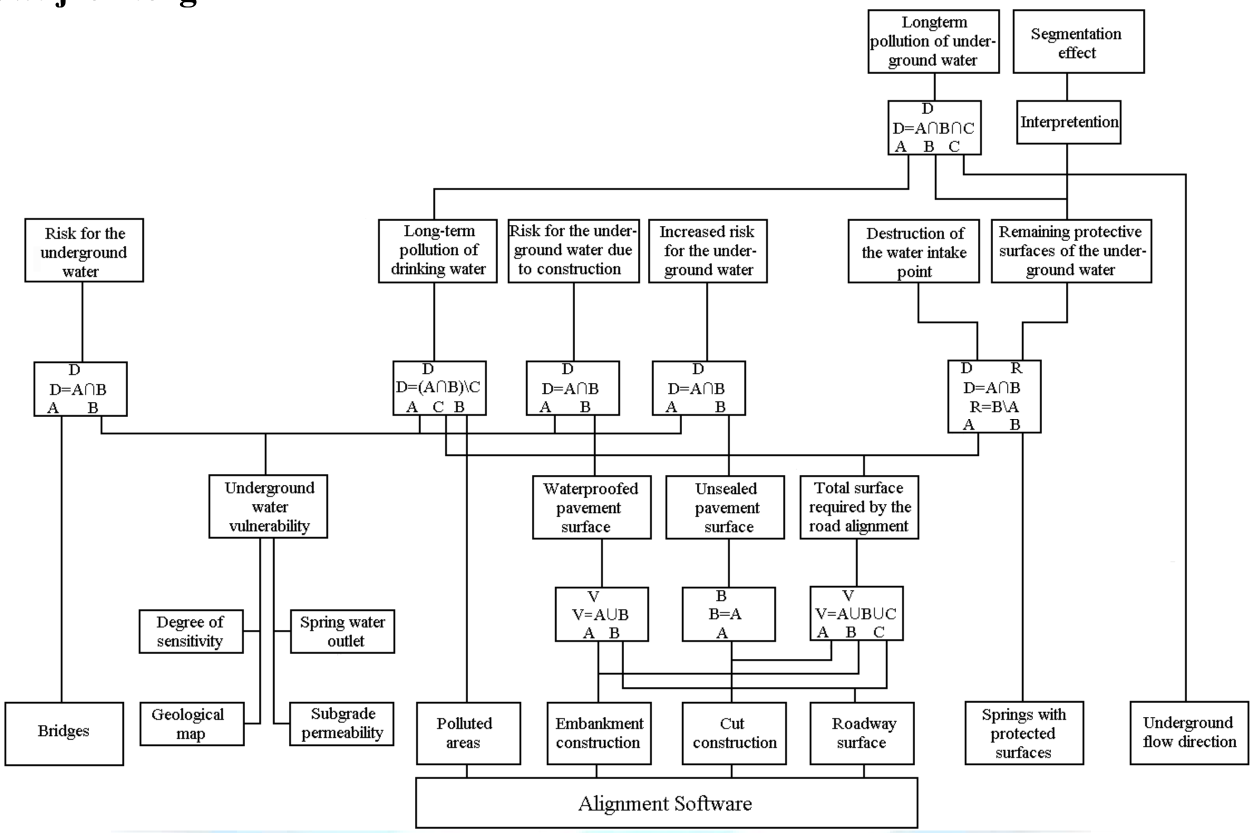


Fig. 1 Flowchart of impacts of a road on groundwater and drinking water.

After a long period, contaminants (heavy metals, salts, oil) that have penetrated the soil can leach into groundwater and contaminate it. Different mechanisms have influence on the transport of pollutants, e.g. diffusion, adsorption, precipitation, decay, in the groundwater. The precise manner in which such contaminants are diffused is not fully known. As shown in Fig. 1, the surfaces "Contaminated areas" from the alignment program, which intersect with "Groundwater sensitivity" terminate at surfaces which may cause long-term risk to groundwater. The degree of risk to groundwater depends on the sensitivity level.

The capital letter symbols used in Fig. 1 have the following meaning: A=surface waters; B=total surface needed for the alignment; C=surface area of roadway lane, $D=A\cap B$; V=total surface area required by the road, $V=A\cup B\cup C$; and R=remaining surfaces of waters, $R=B\setminus A$.

Main impacts of bridges are caused directly by stormwater runoff or by runoff generated during maintenance activities such as bridge deck cleaning. Painting, surface treatments, substructure repair, joint repair, drainage structures repair, and pavement repair may also cause impacts to receiving waters depending on storm event timing, duration, and intensity. Bridges above open channels with large amounts of truck traffic are the main locations where emergent accidents could occur [12]. Bridges pose a special risk (e.g. in case of accidents) in sites crossing areas with groundwater having high contamination sensitivity. These sections of the alignment present a direct risk to groundwater. As shown in the flowchart in Figure 1, hazards to ground water due to road accidents are determined by the intersect of "Sensitivity" (vulnerability) and "Bridges".

## 2.2 Partial model of drinking water

Drinking water may be affected by contaminated groundwater pumped in an infected spring. The worst case is when the alignment passes through the area surrounding a point of water intake destroying its usefulness. The contaminants associated with traffic (especially salt and lead) are also washed into groundwater by infiltration and contaminate the drinking water. Thus, the resulting effects in the drinking water can be divided into three categories, as it is depicted in the flowchart in Fig. (a) direct contamination of drinking water; (b) destruction of drinking water collection systems located in the transition zone: to determine the risk posed by the alignment on water protection areas the results from the alignment program "Embankments surface", "Deck surface" and "Cuts surface" are united and then they intersect with the "Water protection areas". This provides the systems with their protected surfaces that would be affected by the construction of the road and whose function would thus be destroyed. The "Rest" is composed of the areas not directly affected by the construction of the road ("Remaining surfaces"); and (c) delayed contamination of drinking water.

### 2.3 Remote & long-term appearance of contaminants

In the immediate road vicinity, the resulting contaminated water penetrates the water table and then it is transferred to the drinking water intake points. On the way, however, the pollutants are highly diluted (despite the use of salt, intake of drinking water is permitted again after 500 to 1,000 meters, without any risk to health). Accumulated contaminants may also leach from soil to underground water. However, very little is currently known for this process to be quantitatively handled. In other words, even a water protection area located relatively far from the road may be adversely affected if it lies below the level of introduction of contaminants; no risk exits if the protection area is located above this level. If not available, information on the direction of flow of groundwater, then only the relative risk is estimated compared to the risk of other areas. To determine the effect of traffic, "Remaining surfaces" intersect with the "Long-term risk to underground water". The result represents the surfaces which -although not endangered by the construction of the new road- are within areas prone to pollutants associated with traffic, such as salt and heavy metals.

## 3. Input data and measures against water contamination due to road runoff

Regarding the response to pollution of surface water, data will be required on: (a) traffic surfaces and surfaces of populated areas in order to identify the impacts, since they affect both the runoff size and their travel time; (b) surfaces of catchment basins for surface water; (c) areas with landslide and erosion risk; (d) lost surfaces of forest areas since they ceased playing a role in water's diet. Generally, any adverse impacts of rainwater runoff in rural roads can be minimized by wet basins, artificial wetlands, infiltration trenches, etc. (structural measures) or non-structural pollution-control measures or by a combination of measures [13]. Drainage and runoff data will also be needed for the final design of the road.

The protective measures for underground waters should take into consideration the following notions: (a) a protection perimeter must be provided for a source of water intake when the aquifer is vulnerable (there is no surface protection and the aquifer is permeable); (b) the road, the shoulders, the rainwater collectors, and the central road island (if it exists) have to be fully waterproofed, when the alignment crosses the protective perimeter of the water intake either near or away from it; else the removal of the water intake should be addressed; (c) the collected waters must be disposed outside the protection perimeter of the source or processed, if they are sent back to the aquifer or to small supply streams.

Specific protection measures during the works are the mandatory collection of discharged oil from the plant machinery, protection of currents from disturbances due to solid materials, and measures to maintain the supply of currents, especially when they reach their lower level [14].

## 4. Conclusions

The execution of earthworks can affect groundwater. The intersection of the underground aquifer by deep cuts of the pathway may involve risk of lowering the underground water table and may imply direct effect on vegetation (flora) risk of damage or reduction of the performance of water intakes, but, at the same time, contamination of groundwater risk. The construction of high embankments in soils, whereby underground aquifers are passing, involves the compression and lowering of their permeability with direct impact on the yield of aquifers.

Different traffic volumes and road materials affect in a different way the distribution and concentration of pollutants.

The integrated, complete system in computerized form presented here may assist the design of a road alignment and the analysis of environmental impacts on runoff waters caused by the design, construction and operation of a road. The method allows the dialogue between the user and the program. It must be noted that, for a part of the calculations, it is not possible to find simple algorithms.

The computer programs and the calculations are standardized aiming to import new standard methods, algorithms, etc., at anytime, without changing the overall structure of the system.

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