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Review report on the study catchment area

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The Malčanska River is a right-side tributary of the Nišava River in eastern Serbia. The Malčanska River Basin covers the hilly landscape. The main erosion factors in this area are terrain topography, slope, soil type, geology, climatic conditions, and vegetation. Also, human activities have a considerable influence on the intensity of erosion, above all by affecting the vegetation cover.

The data and information on catchment physiographic characteristics

The physiographic characteristics of the Malčanska River Basin, encompassing its topography, geology, soil types, slope gradients, and land cover, contribute significantly to the dynamics of the erosion process within the basin area. The interaction of these factors in the Malčanska River Basin influences water flow, how vegetation fixes the soil, and how susceptible the land is to water erosion. Features like elevation changes and slope influence runoff velocity and sediment transport, while geological and soil compositions determine the soil's resistance to erosive processes. The distribution and type of vegetation cover can significantly reduce or intensify erosion.

- **Geology**

Parent material dictates the mineral composition and texture of the resulting soils, essential to their susceptibility to erosion. Also, the advancement stage of soil solum development constitutes a significant factor. In that way, soils formed from softer, more fragile parent material tend to be less resistant to erosion than soils derived from hard, compact rocks.

Although the Malčanska River Basin covers a relatively small area (35.2 km^2), the geological structure is very complex. It includes unconsolidated sediments (clay, silt, sand, gravel), consolidated sediments (sandstone, conglomerate, siltstone), and limestones. The generalized geological map shows the geological structure created according to Serbia's geological maps (1979), which is 1:100,000 (Figure 1).

Consolidated sediments cover a significant part of the river basin, 21.32% (7.51 km^2). Those sediments include mostly Permian red sandstone (15%, or 5.28 km^2) and Mesozoic sediments such as sandstone, conglomerate, and siltstone (6.32%, or 2.23 km^2). Permian red sandstone is widespread in the northwestern part of the basin and, to a lesser extent, in the southeast. Mesozoic sediments (sandstone, conglomerate, and siltstone) occur mainly in the eastern part of the basin and, to a lesser extent, at the edge of Permian red sandstone. Those consolidated sediments as a parent material are susceptible to mechanical disintegration, so they provide a lot of tiny particles that participate in the soil mineral components, making it loamy, occasionally sandy, well-drained, and thus water erosion-prone.

Limestones cover the more minor but significant part of the Malčanska River Basin (15.18%, or 5.34 km^2). Cretaceous age limestones, argillaceous limestones, and clayey limestones (6.86% of the basin, or 2.42 km^2) are spread as small areas in the eastern and central parts of the basin. Layered and banked limestones and dolomites Jurassic age (5.61% of the basin, or 1.97 km^2) cover the edge of the consolidated sediments in the northwestern and southeastern parts of the basin. Soils formed on limestone are shallow because they take a long time to form when the limestone dissolves.

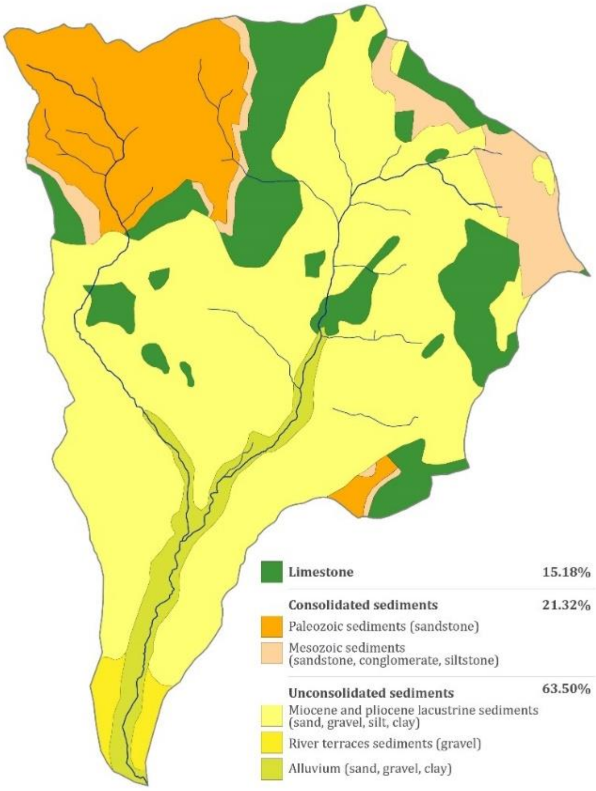

Figure 1: Geology map of the Malčanska River basin (according to Serbia's geological maps (1979), 1:100,000)

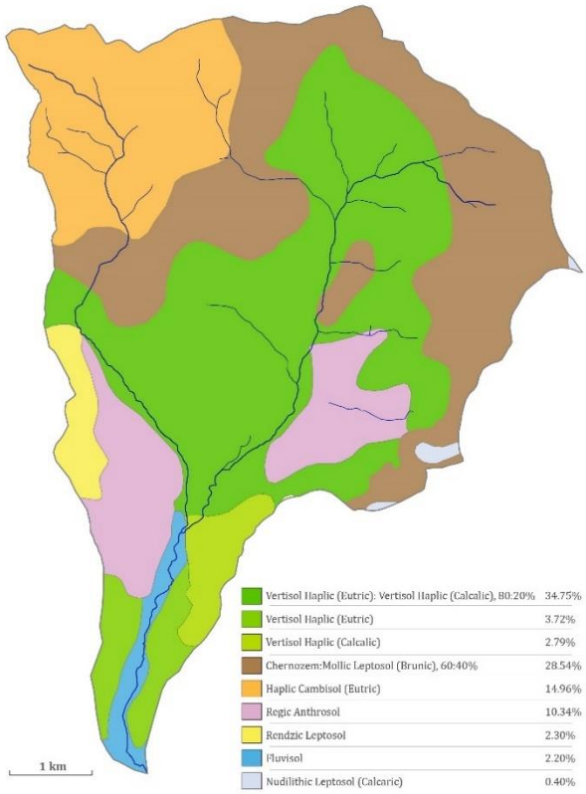

Figure 2: Soil map of the Malčanska River basin (according to Serbia's Soil maps (1963), 1:50,000)

- **Soil**

In a relatively small area of the Malčanska River Basin, the soil type is primarily determined by the parent material, and diverse soil types are represented. Soil types are shown on the soil map, created according to Serbia's Soil maps (1963), 1:50,000 (Figure 2). This map is highly generalized, but soil sampling provides better and more detailed information on soil distribution.

Central and southern parts of the Malčanska River Basin are covered mainly through different Vertisols, 41.26% (14.52 km^2). Those soils are formed on lacustrine deposits and accumulative river terraces. Soils are often clayey, shallow to medium-deep, and poorly drained. Clay particles reduce soil erodibility, but on the other hand, this is the most fertile part of the basin, so that human activity can intensify an erosion process. In the central part of the basin mixture of Haplic Cambisol (Eutric) and Haplic Cambisol (Calcalic) cover 34.75% (12.23 km^2), while downstream, at the south, there are two smaller areas (3.72% or 1.31 km^2) of Haplic Cambisol (Eutric), and Haplic Cambisol (Calcalic), 2.79% or 0.98 km^2.

Areas covered by limestone are characterized by Mollic Leptosol (Brunic), mostly shallow or occasionally medium-deep; the texture is loamy or clayey, and the soil is moderately drained. This area's soil is less erosion-prone than soils formed on red sandstone.

Haplic Cambisol (Eutric) cover is formed on red sandstone in the northwestern areas of the basin (14.96%, or 5.27 km^2), but also in the southeastern part of the basin (this area is not shown on the map because of the map generalization). This soil is loamy primarily but occasionally clayey or sandy, well-drained, medium-deep to deep. Those areas are erosion-prone, and numerous gullies cover the terrain.

Other soils that occur in the Malčanska River basin are Regic Anthrosol on lacustrine deposits (10.24%, or 3.64 km^2), Rendzic Leptosol on lacustrine deposits (2.3%, or 0.81 km^2), Fluvisol on alluvium (2.2%, or 0.78 km^2), and Nudilithic Leptosol on limestone (0.05%, or 0.02 km^2).

- **Topography**

Variations in elevation, slope steepness, and the shape of the land directly affect how water interacts with the soil particles, determining the type and intensity of the erosion process. The most important topography components in the Malčanska River Basin that influence erosion are elevation, relief shape, slope, and stream valleys.

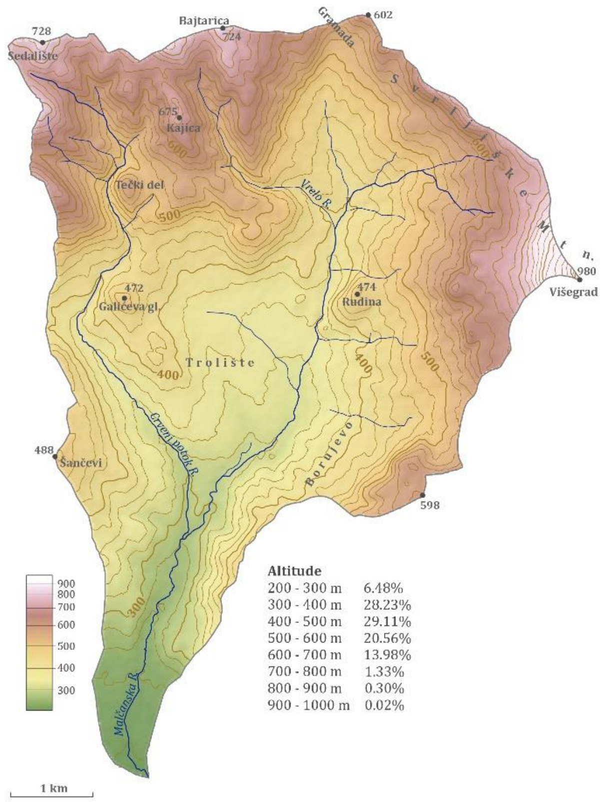

Figure 3: Topography map of the Malčanska River Basin (derived using 30 m DEM)

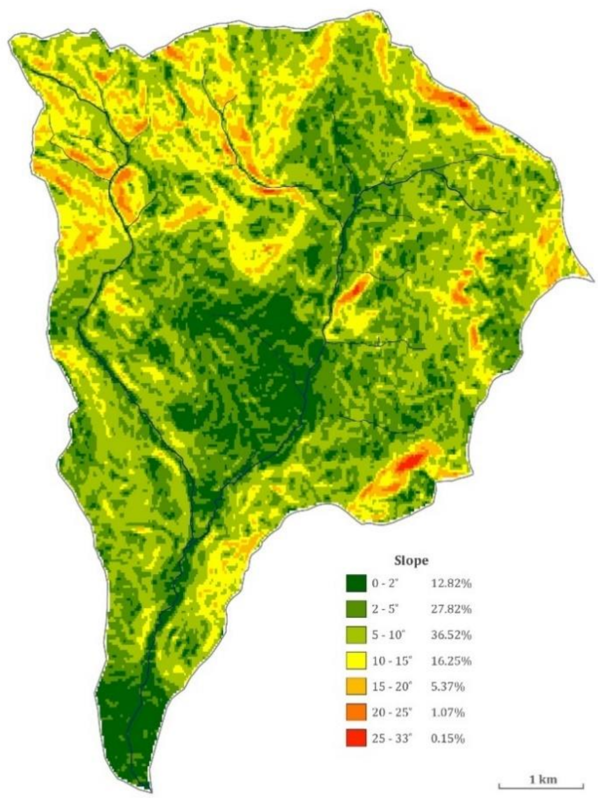

Figure 4: Slope map of the Malčanska River Basin (derived using 30 m DEM)

The Malčanska River Basin covers mainly the hilly landscape at an elevation of 211 to 980 m. The average elevation of the basin is 461 m. Altitude zones can be noticed on the topography map of the Malčanska River Basin, derived using 30 m DEM, as well as Serbian topographic maps 1:50,000 (1972) (Figure 3). The largest area of the basin (77.89%) is in the 300 to 600 m altitude zone. The zone under 300 m covers 6.48%, and over 700 m covers only 1.65% of the basin. Terrain elevation impacts the erosion process primarily through climatic variations. Initial terrain observations in the Malčanska River basin confirmed that higher elevations have wetter and colder conditions, and evaporation is weaker, which can increase erosion intensity. Also, snowmelt in high-elevation areas increases water flow, leading to more intense erosion. The highest parts of the basin are at the northwestern, northern, northeastern, and eastern boundaries. The terrain in the Malčanska River Basin has considerable relief energy over short distances, so differences in height are also significant. This is one of the most critical erosion factors, especially in the basin's northern, eastern, northeastern, and northwestern parts.

The area with extremely rugged relief is located at the northwest, in the upstream parts of the Crveni Potok River and Vrelo River basins, where steep hill slopes and frequent changes in relief aspects led to significant reshaping of the relief. This is one of the factors that caused rill and gully erosion, sharp ridges, and deep valleys in some areas. Slope values for the Malčanska River Basin are generated using DEM 30 m and presented on the slope map (Figure 4). The largest part of the basin (36.52%) lies in the 5 - 10° slope zone. The area inclined more than 10° covers only 22.84% of the basin but is very important for intensifying erosion and inducing rill and gully erosion. Central and southern parts of the basin are mostly relatively flat, with slope values under 5°.

The river system of the Malčanska River includes the main river – the Malčanska River, and some of its tributaries. The length of the Malčanska River is 11.02 km, and the density of the river network is 0.98 km/km^2. The Malčanska River is the only perennial river in the basin. The main tributaries of the Malčanska River, the Crveni Potok, and the Vrelo are perennial streams only in the downstream sectors. In contrast, the upstream sectors have the characteristics of intermittent and ephemeral streams. They are often characterized by the absence of water in the river bed for most of the year. In the basin's hilly areas, erosion within the gully system is active exclusively during and briefly after periods of rainfall or snowmelt. The stream valleys in the hilly areas are narrow and steep, and vertical erosion dominates, while in the downstream sections of the largest streams, the valley sides are open and of low slope.

- **Climatic Characteristics**

The climate of the Malčanska River Basin is temperate-continental, characterized by pronounced seasons. In March and April, the temperature is still low, especially at high altitudes, the weather is unstable, and the primary rainfall maximum is in the second half of the spring and beginning of the summer. Summers are warm and drier than spring, with rare penetration of cold fronts. Autumns are long and warm with low rainfall. The secondary maximum of precipitation occurs at the end of November or early December. Snowfall occurs mainly during December, January, and February but sometimes in October and March, especially in the higher parts of the basin. The duration and thickness of the snow cover varies by year, but it does not last long most of the time. Annually, there is an average precipitation of 600 to 700 mm. Despite the modest precipitation values, rainfall events play a crucial role in the water erosion processes within the Malčanska River basin, combined with other factors such as relief, soil, vegetation coverage, terrain slope, and others. The intensity of rainfall proves to be an equally, if not more, crucial factor in water erosion compared to the quantity of precipitation. This holds in both the hilly regions in the northern areas of the basin and the more level terrains in the central, southern, and eastern areas of the basin.

- **Vegetation**

Vegetation, especially dendroflora, plays a fundamental role in erosion control through various processes. Vegetation roots bind soil particles and enhance water infiltration, preventing their detachment and transport by water. The canopy intercepts rainfall, reducing the impact of raindrops on the soil surface. Vegetation enhances soil structure, while forest vegetation and shrubs especially decelerate water runoff, decreasing the intensity of the erosion process.

CORINE Land Cover database (2018) was used to study the vegetation in the basin of the Malčanska River (Figure 5). Forests have the most important role in water erosion control. Only 18.07% of the basin is covered by forest. It is primarily a broad-leaved forest (16.94%), mainly in the northwest and smaller areas throughout the basin. Balkan sessile oak (*Quercus delechampii*) is the most widespread and, to a lesser extent, the European hornbeam (*Carpinus betulus*). Field research showed that trees are rarely old and thick, so the canopies are small, the oaks often grow from stumps, and soil protection is reduced. A few small coniferous forest areas (*Pinus sylvestris)* are in the north basin.

In the hilly areas of the northwest, forests are often interspersed with woodland/shrub areas (6.21% of the basin area), where the soil is even less protected from water erosion. Pastures and natural grassland cover 6.98% of the basin. Grass-covered areas provide good soil protection, but field research showed that grass is sparse in some areas of the basin, so soil protection is decreased. Natural grassland covers areas in hilly terrain (5.05% of the basin area) and is mixed with forest and shrubs. In general, northwest areas of the basin are best protected from the erosion process.

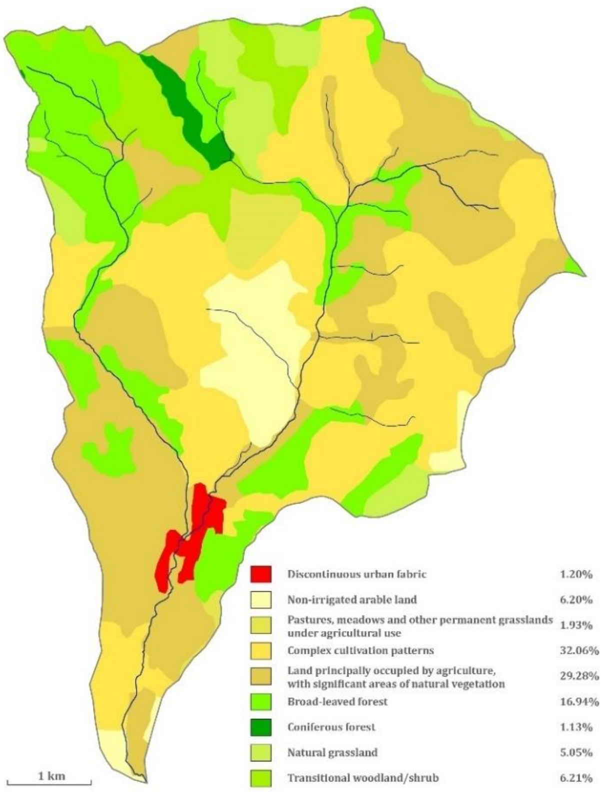

Figure 5: Land Cover (Corine) map of the Malčanska River Basin

According to the CORINE Land Cover database, different types of agricultural land cover 67.55% of the Malčanska River Basin. Agricultural land is spread mainly in the basin's central, southern, and eastern parts, and the main crops include wheat, corn, vineyards, orchards, clover, and sunflower. Agricultural production is extensive and implies small fields. Cover crops and crop residues can protect the soil from erosion, while bare soil in agriculture is more susceptible to erosion, especially during heavy rainfall. The preliminary field investigation revealed that fields lack protection for most of the year.

Land degradation

Land degradation, encompassing a spectrum of issues, detrimentally affects the land's capacity for ecological functioning and sustaining ecosystem services. It also poses a considerable economic threat by diminishing agricultural productivity and escalating production costs as fertile soils are eroded or depleted, adversely impacting food security and livelihoods.

Initial field research across most of the Malčanska River Basin has been conducted. Land degradation manifests in various forms in this region, but erosion processes are especially notable. Field observations in the northeastern areas of the basin revealed the presence of rill and gully linear erosion. Interestingly, these areas are forested and not typically associated with gully erosion. However, the forests here are sparse and frail. The erosion in these areas is influenced by a combination of rugged terrain, steep slopes, and loamy and sandy soils that are highly susceptible to erosion. Similar patterns of gully erosion under comparable conditions have been noted in a smaller section in the southeastern part of the Malčanska River Basin. This indicates a consistent pattern of erosion process across different parts of the basin, linked to both natural landscape features and soil characteristics.

In the basin's central, southern, and eastern parts, field observations revealed the presence of sheet erosion, a process less immediately noticeable as it tends to remove a thin soil layer across large areas uniformly. The full extent of this erosion can only be accurately assessed through more comprehensive research. Given that these areas are primarily agricultural, the cultivation of the soil likely intensifies the erosion process. During the initial field research, we also observed a network of rills formed following heavy rainfall, although such distinct rill formations are uncommon in these agricultural areas of the basin. Additionally, it was observed that numerous plots, previously used for agriculture, are now uncultivated and have reverted to natural vegetation, predominantly grass and shrubs. This shift away from agricultural land use, or deagrarization, undoubtedly plays a significant role in the erosion dynamics within the Malčanska River basin. Across the entire basin, there is a decrease in human activity. That seems to lead to a reduction in soil degradation processes, including erosion. Logging, overgrazing in open spaces and forests (by goats), and uncultivated plots reclaimed by vegetation contribute to a decline in erosion intensity.

During the initial field research, it was impossible to determine other aspects of land degradation, including soil salinization, soil acidification, nutrient depletion, soil contamination, and the loss of organic matter. Following more detailed soil sampling and analysis, these factors will be thoroughly investigated in subsequent stages.

Initial field observations that have been conducted offer just a preliminary understanding of the erosion status in the Malčanska River Basin. However, more detailed research will be conducted to gain an accurate and reliable picture of the erosion intensity and impact. Further studies will also be crucial in formulating effective mitigation and soil conservation methods developed for the specific conditions of the basin.

Current soil conservation practices

The Malčanska River Basin lacks notable soil conservation practices, particularly in erosion control. The only conservation effort observed during the initial field research is the planted coniferous forest in the northwestern part of the basin, which is most threatened by erosion. However, a noticeable issue in that part of the basin emerges in heavy gully erosion, casting a shadow over the general state of soil conservation. The coniferous forest area is too small to reduce sediment production significantly. The absence of remarkable conservation initiatives exposes this area to increased risks of soil further soil degradation.

The largest part of the Malčanska River Basin is used for agricultural production, mainly wheat, corn, vineyards, orchards, sunflower, clover, and others. Agricultural production implies small plots, minimal labor inputs, farm mechanization, and fertilizers. Additionally, the constant decline in agricultural productivity results from the declining population in rural areas. Many fields are entirely abandoned and have not been farmed for years. This area also lacks notable soil conservation practices, such as contour plowing, cover cropping, strip cropping, covering soil with mulch, retention ponds or basins, terracing, and others. The only observed measure are grassed waterways, where grass, bushes, and three channels the water flow and stabilize the riverbanks. The benefits and drawbacks of currently implemented soil conservation measures are assessed by SWOT analysis (Table 1).

Table 1. The SWOT analysis of currently implemented soil conservation measures in the study area

STRENGHTS	WEAKNESS
▪ Soil and climate suitable for agronomic crops ▪ Mobilization of relevant stakeholders ▪ The engagement of governmental stakeholders in promoting soil erosion control ▪ The existence of forest cover ▪ Low degree of anthropogenic transformation of the environment ▪ The existence of legal regulations related to soil and water protection	▪ Persistence of soil erosion ▪ Persistence of runoff ▪ Deficient catchment information ▪ Lack of multi-stakeholder cooperation and partnership
OPPORTUNITIES	**THREATS**
▪ Identification of appropriate methods to control erosion ▪ Communication network with relevant stakeholders and target groups ▪ Increase in public awareness and support	▪ Environmental degradation of land ▪ Lack of public awareness ▪ Lack of promoting the participatory approach to soil management practices ▪ Lack of implementation of appropriate measures to control soil erosion ▪ Limited material resources ▪ Some erosion control technologies require investments not affordable by an individual farmer

Preliminary sampling

The first stage of research on erosion processes in the Malčanska River Basin involves conducting initial sampling to identify suitable soil and sediment collection sites, which is essential for sediment fingerprinting. This is important for ensuring a complete understanding of the diverse factors influencing soil erosion in the basin. A 500-meter grid for soil sampling was designed to encompass a variety of soil types, geological formations, slopes, altitudes, and land uses. This sampling approach allows for a more nuanced analysis of how different environmental and anthropogenic factors contribute to soil erosion, helping evaluate and compare the effectiveness of various soil erosion research methodologies under different conditions.

A total of 35 soil samples were taken under various conditions during the initial phase of the investigation: soil (Vertisols, Mollic Leptosol, Haplic Cambisol, Regic Anthrosol), geology (sandstone, conglomerate, limestone, lacustrine sediments), land cover (forest, shrub, pastures, and natural grassland, crop plots), and slope. Some soil samples were analyzed entirely and others partially, as the recent sampling needed more time for a complete analysis of all collected samples. Available results showed that the previously established sampling grid would effectively capture the basin's heterogeneity and the various factors influencing soil erosion. The sampling grid will ensure that the diverse environmental conditions are adequately represented in the research.

As part of the same research initiative, it was essential to identify suitable locations along river courses for river sediment sampling. Two appropriate hydrological profiles were found on the main river, two on the Crveni Potok tributary and one on the Vrelo tributary. While these initial sampling sites meet the research requirements, we remain open to exploring additional sites to ensure a comprehensive representation of sediments formed in the river basin. Although preliminary sampling is performed, detailed analyses of these samples still need to be conducted.

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