



# The Pont du Garde aqueduct and *castellum*: Insight into Roman hydraulic engineering practice

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## 1. Historical background

The Pont du Garde aqueduct, built during 40–60 CE under the reign of Claudius, is composed of many individual hydraulic engineering components (Lewis, 2001:181–188, Hodge 1992:184–190) that worked collectively to deliver water to the Roman city of Nemausus (Green, 1997; Sage, 2011) now the present day city of Nîmes in southern France. Water from the Fontaine d'Eure spring at Uzès was conducted to a regulation basin at Lafoux with an over-capacity diversion channel to the Alzon River designed to deliver a maximum of 40,000 m<sup>3</sup>/day to the ~50 km long channeled aqueduct leading to the Pont du Garde aqueduct/bridge spanning the Gardeon River. A further extension of the channel to a tunnel delivered water to a basin distribution center (*castellum*) 17 m above the city of Nemausus; water delivered to the *castellum* then was conducted through 13 pipelines to city center reservoirs and site locations. The aqueduct flow rate of 40,000 m<sup>3</sup>/day (Hauck and Novak, 1988) was delivered under the 1.2 m wide by 1.10 m high basin's rectangular sluice gate into a 5.5 m diameter, 1.0 m high basin wall supporting 10 *centenum-vicenum* ~30 cm inner diameter pipelines distributed around the basin's periphery together with 3 basin floor pipelines.

The Pont du Garde aqueduct/bridge crossed the Gardeon River near the town of Vers-Pont du Garde in southern France and was a key element of the ~50 km long aqueduct water transport system (Figs. 1 and 2) providing water to Nemausus. While the straight-line distance between the spring source and the terminal distribution *castellum* was ~25 km, the channel path selected by Roman engineers was a winding route measuring ~50 km because of construction difficulties associated with the mountainous Garrigues de Nîmes direct route path (Fig. 1). Roman surveyors selected the longer channel path to avoid difficulties

associated with building numerous tunnels and bridges through mountainous terrain that would accompany the shorter length path that led directly from the spring source to the Nemausus *castellum*. In addition to construction difficulties associated with the mountainous and deep gorge terrain in the northern section of the proposed aqueduct path, further routing changes proved necessary to circumvent the southernmost foothills of the Massif Central known as the Garrigues de Nîmes. These foothills would prove difficult to cross with the shortest length water channel as they were covered in dense vegetation and indented by deep valleys requiring the construction of many small bridges and tunnels. In this area alone, passage through a long section of hills and ravines would require a tunnel between 8 and 10 km long depending on the starting point. A diversion course around the eastern end of the Garrigues de Nîmes mountain range (Fig. 1) was the only practical and economic way of transporting water from the origin spring to the city to reduce construction time and minimize labor costs. The aqueduct design selected followed a long, low slope, winding covered channel path free of major construction obstacles along most of its route whose completion included the Pont du Garde aqueduct/bridge (Fig. 2) spanning the gorge of the Gardeon River; past the aqueduct/bridge, a covered continuation channel and tunnel led water to the terminal *castellum* located above the city. Details of the aqueduct geometry determined the design of the receiving *castellum* and its pipeline water distribution system as detailed in sections to follow. The aqueduct was designed and built to carry a given flow rate - the challenge to Roman engineers was to design the *castellum* to transport the large aqueduct input flow rate through a limited number of pipelines (13) in the most efficient manner. The innovative *castellum* design devised by Roman engineers to accomplish this end is described in later sections and gives a penetrating look into Roman hydraulic engineering

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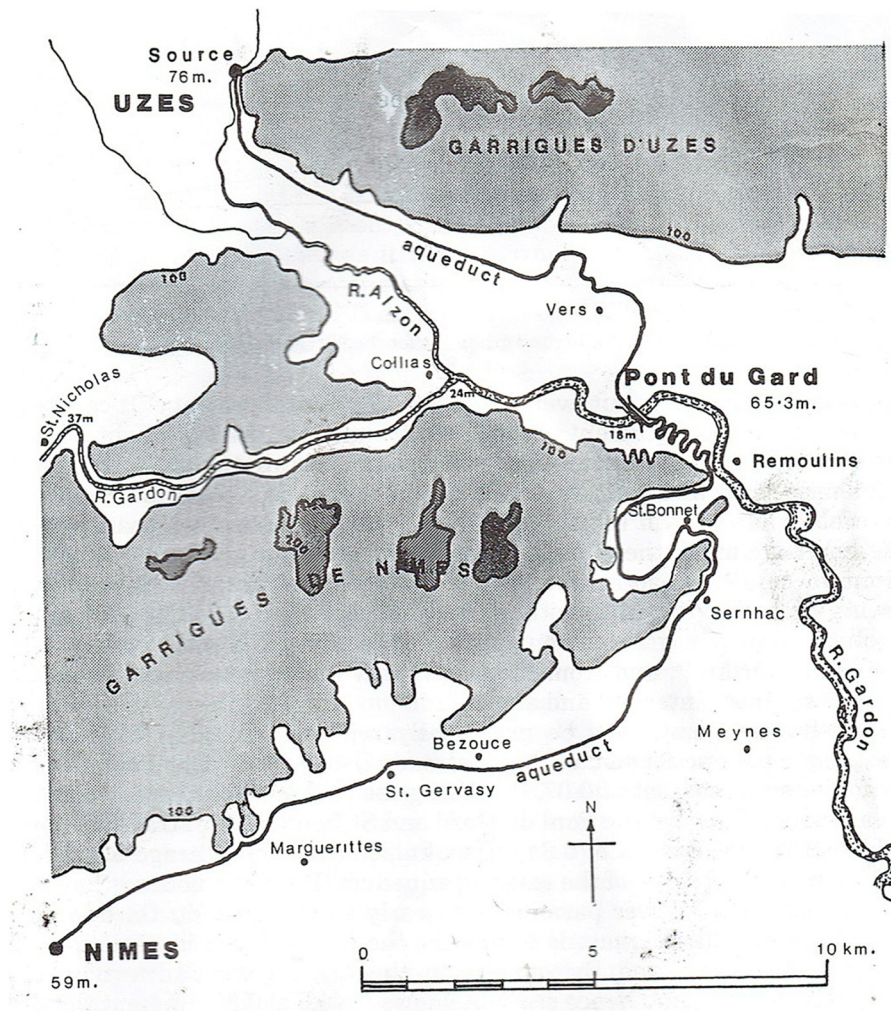


Fig. 1. Map of the Pont du Gard aqueduct water system from the Fontaine d'Eure at spring to the Nîmes castellum.



Fig. 2. The Pont du Gard aqueduct/bridge.

practice.

In the first century AD, Nemausus was a prosperous Roman colony whose resource base consisted of Rhone Valley agricultural fields and vineyards to support trade and export to central Rome. The colony's

prosperity was mirrored by population growth from 20,000 to 40,000 over a short time span leading to official Roman city status. At the foot of Mount Cavalier, the Nemausus fountain neither sufficed to provide the city with its daily need of potable drinking water nor sufficient water for the baths, fountains, temples, government and commercial sector buildings and the many garden areas that Roman cities incorporated as part of corporate Roman city design practice. Based upon increased water needs for the city, foresight and planning to start the early building of an aqueduct water supply system from the Eure Uzès spring source to Nemausus anticipated the future water needs of the city. It is estimated that about 70% of the aqueduct channel pathway was constructed as excavated stone lined trenches with slab or arched roof covering with the remainder largely in the form of short length tunnels and small bridges. As a major construction challenge, the Gardon River valley crossing required engineering innovations involving the design and construction of the multitiered Pont du Gard aqueduct/bridge to transport water across the river gorge area.

The planning and construction of the aqueduct has been credited to Augustus' son-in-law and aide, Marcus Vipsanius Agrippa, around the year 19 BCE. At that time, Agrippa was serving as *aedile*, the senior magistrate responsible for managing the water supply of Rome and its colonies. Espérandieu, writing in 1926 (Hodge, 2011), linked the construction of the aqueduct with Agrippa's visit to Narbonensis and newer excavations suggest the construction may have taken place between 40 and 60 CE. Earlier built tunnels bringing water from local springs to the city dating from the time of Augustus were bypassed by the builders of

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