Application of Different Algorithms to Optimal Design of Canal Sections

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ABSTRACT

Today the increased world population and therefore the growth demand has forced the researchers to investigate better water canal networks distributing much more water while at least keeping its quality. Canal design formulas are explicitly obtained for different cross-sections considering minimum area but optimal design of canal sections considering seepage and evaporation losses are still an open area to study. In this study, two different algorithms are applied to this problem and results are compared with the one in literature. Genetic algorithm and sequential quadratic programming technique are used in optimization. Triangular, rectangular and trapezoidal cross-sections are optimized. It is seen that both algorithms are giving more accurate results than in literature.

Keywords: Design of canal section, genetic algorithm, sequential quadratic programming, seepage loss.

1. Introduction

Water is the key element of life and its importance for life beings has not changed over the centuries. Even though today there are many investigations and consequently inventions on new kind of materials, a simple solution on using water effectively is still concerned as much important as them [1]. Saving water used in irrigation, cleaning, cooking and even transferring energy is necessary for a sustainable life [2].

Much of the water used by mankind is used in irrigation. Many different irrigation ways are applied over the years but water has been always conveyed and distributed by using canals. Today the increased world population and therefore the growth demand has forced the researchers to investigate better water canal networks distributing much more water while at least keeping its quality. The uncertainty of canal's nature may cause the failure of the canals to convey water during periods of high flow which may lead to the overall failure of many surface water resource systems. Therefore the loss of water from irrigation canals has to be minimized.

Swamee et al. has shown that more than half of the water supplied at the head of the canal is lost in seepage and evaporation by the time water reaches the field [3]. Seepage loss is the important part of the total water loss. In fact, significant part of loss comes from the evaporation however seepage takes place on a canal even respectively at small amount. The correct lining could stop this seepage loss but the change over the time in lining makes the finding correct lining a difficult problem to solve. Even though evaporation loss changes with time whether it is winter or summer and also concrete lining conditions (cracks etc.) affect the seepage loss, they can be estimated under certain conditions. Therefore, design of a canal cross section should be optimized considering minimization of the seepage loss and evaporation loss over the time. In this study, a previously defined canal cross section problem is solved with different techniques.

Minimizing cross section area has already been studied by a few researchers [4]. Different cross section types are concerned: Triangular [5-6], Rectangular [5-6], Trapezoidal [5-9], Parabolic [10-12], Curvilinear Bottomed Channel [13] and Circular [15,21,26,27]. In this study only triangular, rectangular and trapezoidal cross-sections are concerned due they are much widely used as benchmark problems.

Different set of conditions are considered. Guo and Hughes accounted freeboard as input parameter [14]. Aksoy and Altan-Sakarya used Mannig's formula in calculating flow velocity [15]. Bhattacharjya combined the critical flow condition with other conditions [16]. Jain et al. followed Lotter's approach in defining composite canal section [17]. Easa et al. considered the criterion for the side slope stability (soil conditions) [18].

Different optimization methodologies are applied (Direct algebraic technique [19], Complex variables and series expansions [20], Lagrange's method [21-22], Nonlinear optimization techniques [3,23], Sequential quadratic programming [16], Lagrange's undetermined multiplier approach [13], a hybrid model of genetic algorithm and sequential quadratic programming hybrid model [9], genetic algorithm [17], ant colony optimization [24] to design open channels. Adarsh modelled uncertainty [25].

Also different topics are taken as objectives. Trout considered lining material cost [19]. Das minimized the flooding probabilities [8]. However studies concerning the minimum seepage loss are limited in literature. Kacimov merged seepage losses and channel lining [20]. Swamee et al. [26-27] merged earth work and lining cost. Chahar also considered seepage loss [13]. Swamee et al. [3, 23] considered the seepage loss in the objective functions.

This study aimed to simplify the current canal section problem concerning water losses. Equations for seepage loss [5], the evaporation in flowing channels [28], and the resistance in open channel flow [29] are taken from literature. Two different algorithms (Genetic Algorithm and Sequential Quadratic Program) are applied to compare the results with existing literature to evaluate their effectiveness. Minimum water loss sections have been obtained for three different canal sections (triangular, rectangular, and trapezoidal). Following section briefly overviews water loses. Section 3 presents the problem formulation and Section 4 gives brief explanation on the methodology used in the study. Section 5 provides the results and last section presents the research conclusions and future work plans.

2. Water losses

Water moves continuously on earth by changing its phase gas to liquid or to solid and vice versa. It flows as rivers and streams, moves in air as clouds and is stored in lakes, in oceans, and sometimes as icebergs. We use dams to store it and canals to distribute to where it is needed. Water continues its movement while distributing to the target place. It evaporates and goes up according to the weather conditions and infiltrates and goes down according to condition of soil where canal is built. So, particular amount of water will be lost in distribution. This section explains how to calculate seepage [5] and evaporation [28] losses and how much resistance [29] occurs in channel.

2.1 Water losses due to seepage

Continuous seepage from canal may results in local water-logging problem with salt accumulation. There should be regular checking in lining to maintain its proper work but many unavoidable factors will cause the performance of canal gradually decrease even if extreme care is taken [30].

The seepage loss from a canal in a homogeneous and isotropic porous medium when the water table is at very large depth was written as [3]

$$q_s = kyF \tag{1}$$

where q_s = seepage discharge per unit length of canal (m^2/s); k = hydraulic conductivity of the porous medium (m/s); y = depth of water in the canal (m); F = function of channel geometry (dimensionless); and yF = width of seepage flow at the infinity. Hereafter, F will be referred to as the seepage function.

2.2 Water losses due to evaporation

Loss due to evaporation depends on the many factors. Increase in temperature boosts evaporation. Increase in wind velocity also raises the amount of evaporation. Evaporation is related with the specific humidity gradient in the air and