ABSTRACT

Manmade canal networks are used to transport, distribute, and deliver water to the end users for various purposes such as irrigation, water supply, and flood control etc. These canals carry water over the distance of hundreds of kilometers, thus, they make irrigation projects extremely costly. The unlined/earthen canals are cheap but incur higher seepage losses, whereas, the lined channels are costly with little seepage as the aging and constructional faults in canal lining make them seepage prone. Therefore, improvisation in the design of the earthen channels seems appropriate. Froehlich (2011a) designed a hydraulically efficient channel riveted with subround and subangular riprap to prevent the erosion of the side banks. Experimental (Canovaro et al. 2003, 2004; Pagliara and Chiavaccini 2006a, 2006b, Canovaro and Solari 2005, 2006) and numerical (Stoesser et al. 2004) studies on macro scale roughness reveal that the higher macro roughness density does not accrue to high mean flow resistance but a particular geometric arrangement of the roughness elements yield the maximum flow resistance. Therefore, the present study investigates into the designs of riprap riveted earthen channels for cost and performance optimality. Different types (round, subround, subangular, and angular) of riprap stones (USBR 1991) with varying physical characteristics (specific gravity, shape and size) are available for the revetment of the channel side slopes and their stability on the side slopes is expected to vary with the changing physical properties. It leaves a room for investigation into the optimal designs of earthen channels whose side

slopes are riveted with loose riprap and bottom is unlined by incorporating the shape and size of riprap stones into consideration.

Design of earthen channels for the minimum cost involving different types of the riprap stones on side slopes with unlined bottom is not available in literature, hence this problem is worthy of investigation (Froehlich 2012). The published literature on the design of canals incorporating the land acquisition cost (Swamee et al. 2000a) is yet sparse, hence additional scope arises out of this gap. The earthen canals usually carry sediment-laden flow under different operating conditions and a study relating to the effect of flowing water characteristics on channel specifications for cost and performance optimality is not available. An investigation into this aspect adds another novelty in the present work.

Several design alternatives for a non-symmetric trapezoidal earthen channel whose side slopes are riveted with riprap *and bottom is unlined* were determined by using different types of stones (round, subround and subangular, and angular) for comparison of their performances to achieve minimum cost. Particle Swarm Optimization algorithm was applied to determine the least cost channels. Both the clear water and the sediment-laden flow conditions in the channel were considered to investigate the effect of flowing water characteristics on optimality. Literature on optimal design of channels incorporating land acquisition cost is scanty; therefore, land acquisition cost was also included. In addition to a channel without freeboard, different freeboard scenarios, including a fixed magnitude and depth-dependent cases, were applied to design the channel for assessing the impact of freeboard provision methodologies on optimal channel dimensions and cost. It was found that the channel having angular riprap revetment offered the least cost channel with subround and subangular, and round stones, respectively, coming next in sequence. It was also observed that the sediment laden flow condition near channel bottom offered a relatively lower cost than those carrying clear water. The freeboard provision was also found to have an influence on the channel shape, dimensions as well as the cost. However, the application of particle swarm optimization needed three computational programs with different sets of penalty functions for each type of riprap stone to evaluate the performance of the various types of riprap stones for cost optimality. It seems better to evaluate them on a single benchmark by involving a single program with the same set of penalty functions, which would be similar to giving the same question paper with the same negative marking scheme to all the candidates for the award of some scholarships. Thus, it leaves a scope for other research to further investigate into the topic dealt herewith.

In order to resolve the issue emerged out of the application of particle swarm optimization method for the minimum cost designs of riveted earthen channels, a novel methodology which can identify the most suitable type of the riprap stones for the design of a minimum cost earthen canal having loose riprap riveted side slopes with unlined bottom has also been developed. To identify the most suitable type of the riprap stones for the side slope revetment, a novel capability is introduced into the Particle Swarm Optimization technique to trigger the search operation in 6-D Euclidean space, and the method is referred to as Fish Shoal Optimization algorithm to portray its resemblance with the biological character of a fish shoal (aggregation of mixed species of fish) in nature. The Fish Shoal Optimization algorithm accommodated all types of riprap stones into its single computational program to generate a population of mixed species to imitate the social characteristics of a fish shoal. The dissimilar members of a shoal socially interact-a characteristic of Particle Swarm Optimization, and compete- a feature of Genetic Algorithms, with their own class and other subgroup species to capture the leadership role to steer the movement of shoal for finding the global optimum in search space. The Fish Shoal Optimization algorithm offers the solution comprising canal bottom width, side slopes, flow depth, stable riprap stone size, and the most suitable type of the stone for revetment of canal side slopes, which was not been investigated earlier by involving different types of riprap stones into a single computational procedure for optimal canal design. A novel concept for developing a facility to recharge groundwater reservoirs using earthen canal is also suggested.

The thesis has been organized into eight chapters. It includes chapters entitled as: Introduction; Literature Review; Optimal Design of Earthen

Channel: Problem Domain, Rationale, Definition and Models; Particle Swarm Optimization; Application of Particle Swarm Optimization: Results and Discussion; Development of a Novel Optimization Algorithm: Fish Shoal Optimization; Application of Fish Shoal Optimization: Results and Discussion; and Conclusions and Suggestions for the Future Work. The last chapter is followed by the relevant references, related publications, and resume of the author.