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ORIGINAL ARTICLE

Investigation of Culverts According to Fish-Passage and Geometric Design of Forest Road

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ABSTRACT
This study was conducted to investigate and compare the existence cross drainage with its standards in forest regions of Savad kooh, Iran. Research was done according to the importance of the planning issue of technical structures in forest roads based on wildlife habitat. In order to assess the characteristics of considered ravine different analysis was respectively carried out to achieve flow direction, flow length, cumulate center and flow rate. The Roadeng software, which has been produced for road construction project, was used to design existent road, streams and culvert in our study area. In this software the level of water depth in culvert is determined with combination of topographic layers, ravine properties (length, direction, flow intensity and catchment area) and status of culvert installation. A result of investigations in study area showed that skew of mounted culverts is not accordance to flow direction. So that, when the culverts causes to skew water flow from its main route it can be a barrier against aquatic migration. In this study the culvert had suitable status in viewpoint of gradient and water level (suitable depth for fish passage). So that, this issue causes to even level flow and balance along culvert. According to the results of this study it can be concluded that the correct installation of culverts in forest roads need accurate scientific studies in field of road engineering, forest and fishing.
Keywords : *Forest roads, Fish passage, Culvert Skew, Culvert gradient, Water depth, Roadeng*

INTRODUCTION

Roads throughout Iran invariably cross streams and rivers on a frequent basis, requiring installation of a crossing structure during road construction. Forest engineers and hydrologists regularly calculate design culvert dimensions for use in wildland road-stream crossings. culverts are used to intercept and manage subsurface drainage [1], and are made of different materials that are include metal, plastic and concrete pipes [2]. Choice of pipe material, shape, and size may be fixed by economics, availability, site conditions (fill, bedrock, bedload), and fish passage concerns [3].

Wildlife and habitat conservation has become increasingly important in future [4]. Stream channel crossings by roads have been the cause of serious losses of fish habitat due improperly designed culverts. One study estimated the loss in habitat from culverts on forest roads as 13% of the total decrease in coho salmon summer rearing habitat in the Skagit river basin in Washington state [5]. This percent decrease in summer habitat was considered greater than the sum total effects of all other forest management activities combined. Another paper reported that as many as 75% of culverts in given forested drainages are either outright blockages or impediments to fish passage based on field surveys done in Washington state [6]. Warren and Pardew [7], found reduced proportional fish passage through culvert and slab crossings compared with open-box and ford (submerged roadbed) crossings in Arkansas streams, and research has shown corrugated culvert crossings may reduce fish movement [8,9].

Water velocity through road culverts may affect swimming distance and frequency [10], and as velocity increases, the likelihood of fish passage through a crossing is reduced while energetic stress is amplified [11]. Fish passage within the culvert is controlled by the water velocities and availability of resting areas. Water velocities are highly dependent on the gradient of the culvert; limits of slope ranging from 0% to 5% are proposed in the literature to maximize fish passage. However, the most sensible criterion is proposed by Beschta [12], who recommends that gradients be as close to, and certainly no more than, that of the stream above and below the culvert. Steeper gradients increase barrel velocities, which in turn can lead to scouring below the outlet, creating vertical barriers for upstream migrating fish.

Align culverts with the existing stream channel to minimize changes in flow direction. This will reduce the need to armor stream banks and in stream structures. Straightening a stream meander by installing a culvert forces water to fall the same height but over a shorter distance, thereby increasing water velocities [13]. The resulting scour causes negative effect such as loss of streamside vegetation, downcutting of the streambed, and loss of spawning gravels. This study was conducted to investigate and compare the existence cross drainage with its standards in forest regions of Savad kooh, Iran. Research was done according to the importance of the planning issue of technical structures in forest roads based on wildlife habitat.

MATERIALS AND METHODS

Description of the Study Area

Birenjestanak forest is located in southeast of the city of Ghaemshahr in Mazandaran province, Iran. The latitude and longitude of this forest are 36° 19′ 08″ to 36° 23′ 30″ N, 52° 51′ 22″ to 52° 56′ 55″ E , respectively. Existence of fish nurture center in study area causes to increase the importance of cross drainage culverts because of the passage of fish. In this region the fish are entered into Talar River after passage from ravines. Thus, if the planning basis of culverts is not considered the barrier would prevent passage of fishes.

Get information about stream

In order to investigate the hydrologic properties of considered ravines (fish passage), at first the catchment of ravine is closed using digitizing and then separated from mentioned region using clip command. The area of the considered region was calculated using Calculate area command. In order to assess the characteristics of considered ravine the step 2 and 3 analysis was respectively carried out to achieve flow direction, flow length and cumulate center. Fourth step was conducted to achieve produced flow rate and determination of water depth in culvert. So, the mathematical calculation in arcinfo software was used (see figure 2).

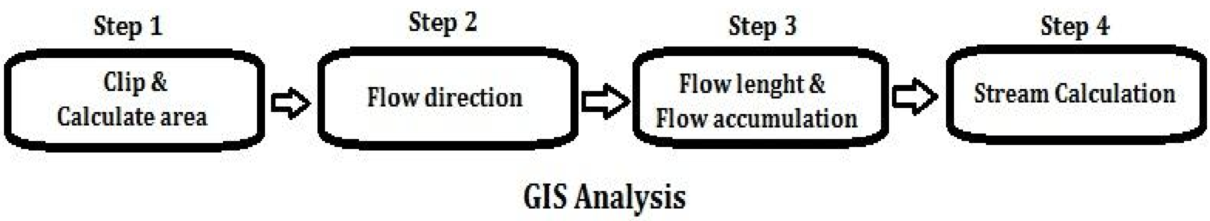

Figure 2. Calculations related to ravines using Arcinfo software

Stream calculation:

The most common method of estimating streamflows in natural and artificial stream channels is called the Manning’s equation. This equation uses a term for roughness called Mannings N. The Manning’s equation for streamflow is as follows:

Q = A *1.49/N * R2/3 * S1/2

Where:
A = Cross-sectional area in square feet
Q = Streamflow in cubic feet per second
N = Mannings N values varies by stream roughness conditions.
R = Hydraulic radius in feet which is the area of water flow divided by the wetted perimeter. This value is usually similar to average depth.
S = Stream slope in rise over run (i.e. percent divided by 100)

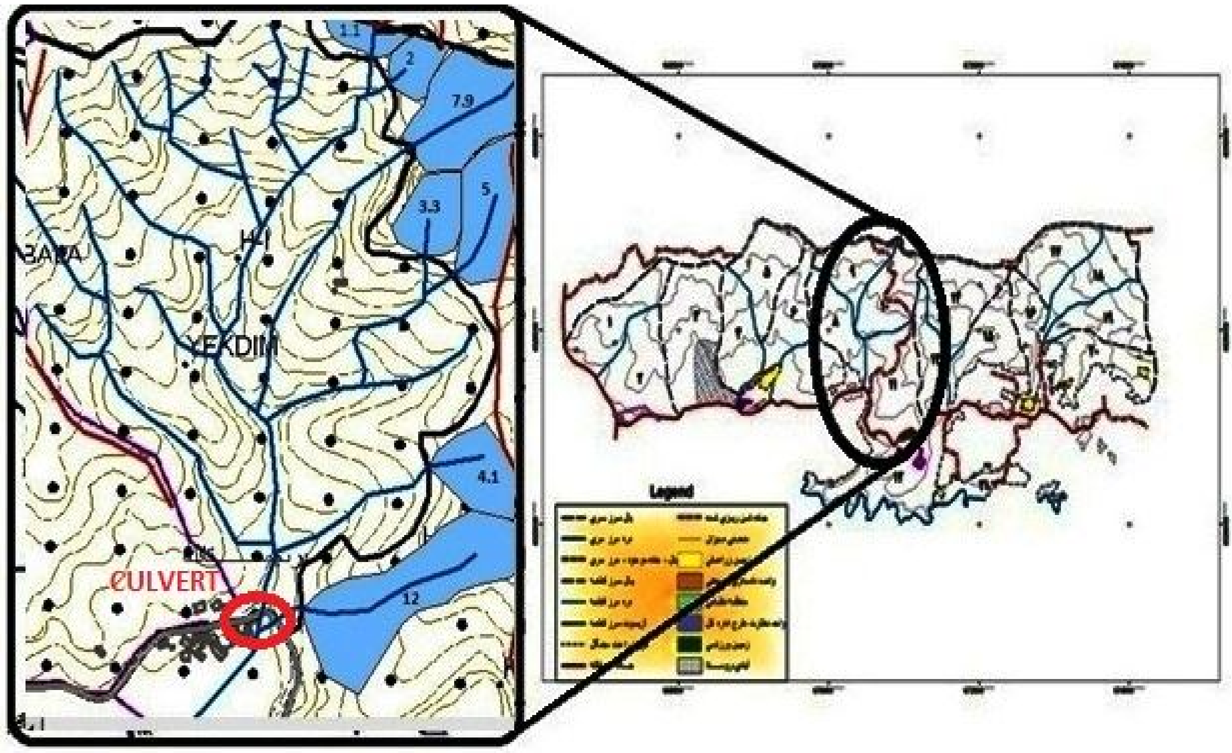

Figure 3. Passage of fishes in study area

Designing forest road and culvert simulation using Roadeng software: In this study the Roadeng software, which has been produced for road construction project, was used to design existent road in our study area. At first, the geometric specifications of longitudinal and cross sections of existent road were taken and then the collected data from field survey were inserted into TRAVERSE DOC of Survey-Map package. In the next step the map of existent road were extracted from TRRAIN package (see figure 4).

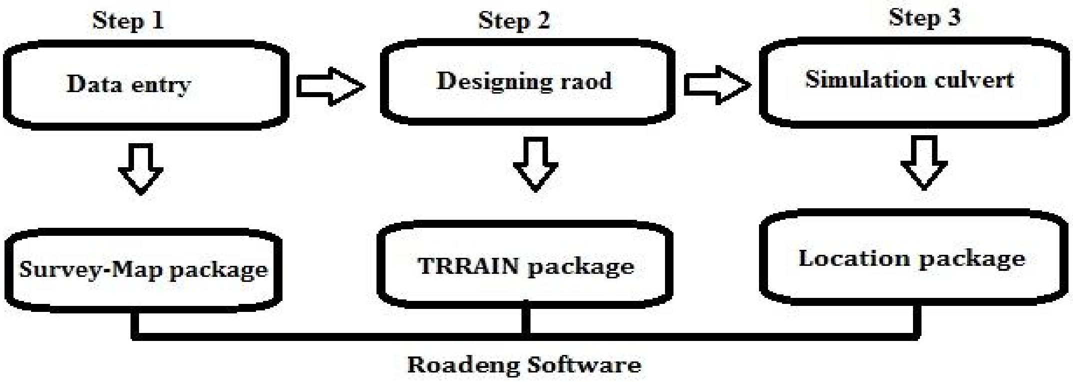

Figure 4. Road planning steps and culvert simulation using Roadeng software

In order to computer simulations of mounted culverts in forest road, at first the characteristics of existence culvert (slope, deviation rate, and installation depth and culvert length) were measured during field survey. Then, a mentioned property was inserted into roadeng software to simulate the method of culvert installation (see figure 5). After, mentioned hydrological analysis and hydrological calculations using manning equation in arcinfo LOCATION of Roadeng software. In this software the level of water depth in culvert is determined with combination of topographic layers, ravine properties (length, direction, flow intensity and catchment area) and status of culvert installation. So, with visualization of the status of culverts in studied area forest roads, the fish passage status was investigated.

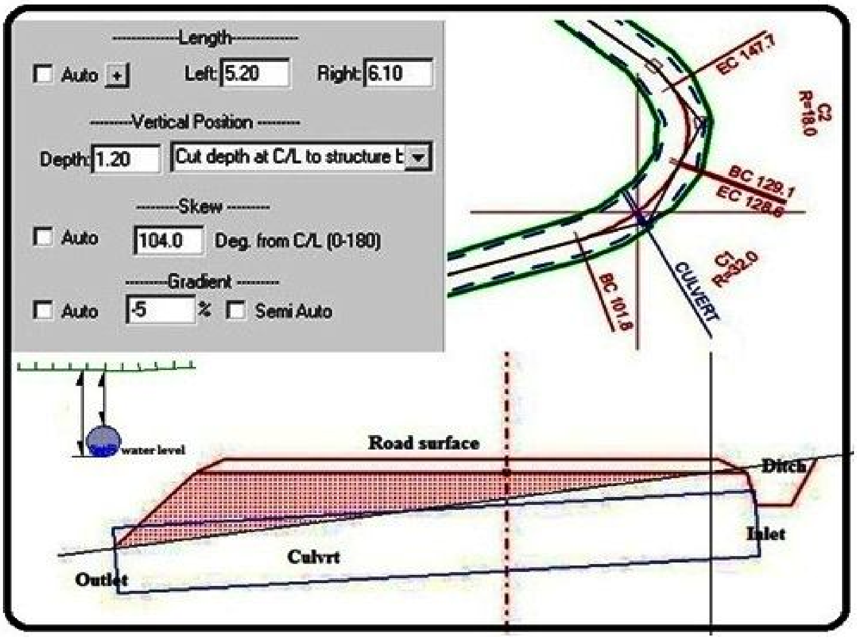

Figure 5. Locating and simulating culverts according to fish passage and geometric design of fores road in culvert installation point

RESULTS AND DISCUSSION

Incorrect planning and installing drainage culverts and especially inattention to crossing angle of road and ravine causes to deviate ravine from its main route. This causes to increase soil erosion from embankments and increase sediment [14, 15], as well as increase disturbance in migration of aquatic species. In many cases, in order to reduce costs during drainage culverts installation, the length and the depth of culverts is considered less. This cause to incorrect installation of culvert and disturb in flow intensity and water depth [16]. A result of investigations in study area showed that skew of mounted culverts is not accordance to flow direction (figure 6). This status causes to shock in water, unevenness and increase area of the ravine bed and increase environmental costs. In this region to better conduction of flow and prevent the increase of ravine bed area the Riprap is used. This material can reduce the damage to minimum. The results of this study and other studies [17, 18, 19], indicated that when the culverts causes to skew water flow from its main route it can be a barrier against aquatic migration.

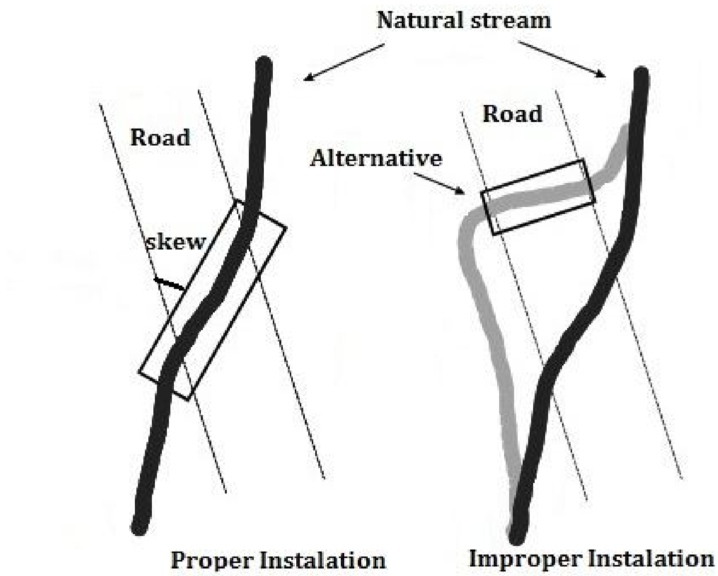

Figure 6. Correct locating of culvert according to skew angle from road

The length of culvert increased with increasing super elevation and road width in horizontal curves. The passage of trucks which are loaded by forest products causes to increase pressure on culverts and then lead to subside [16]. If culverts are not planned with suitable slope, the water is cumulate in center of culverts and causes to disturb in water flow. In this study the culverts had suitable status in viewpoint of slope (see figure 7). This slope causes to even level flow and balance along culverts. Moreover, in several studies [20, 21, 22], it was proved that when the culvert length isn't planned correctly, it may cause to produce problems such as uneven level of hydrologic flow, culvert blocking and finally blocking fish pass way. Installing a culvert on top of the existing streambed or installing undersized culverts can cause problems for fish as well as for the culvert itself. In these situations, water often begins to flow below the culvert and cause piping. Piping simply means that flowing water will carry away the soil from below and around the culvert increasing the chance of a washout. Another problem from this type of installation results when the outlet becomes perched above the level of the stream (see figure 7). Perched culverts are a serious barrier to fish and wildlife movement.

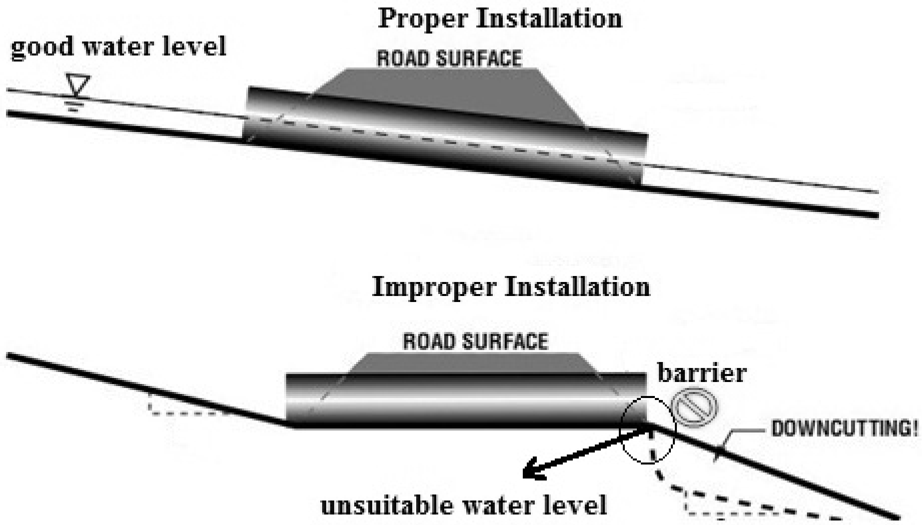

Figure 7. Correct locating of culvert according to gradient

Road/stream crossings represent the places where the road system and stream system intersect. Often times improperly designed or maintained fills will input significant amounts of fine sediment into the stream system (see figure 8). Kane and Wellen [23], determined that sediment accumulation and sediment depth was greater in streams with culverts than at streams with bridges. The storm events required to cause a road fill to input fine road based sediment into the stream are often not large, so sediment enters the stream at times when there is not as much energy available to transport the sediment and the fine sediment is able to intrude into the stream bed degrading spawning and other gravel deposits. Setting the culvert bottom at least 15 cm (or 10-20% of the culvert diameter, whichever is greater) below the stream bed elevation will allow for better fish passage and help reduce the risk of piping. Deeper placement may be necessary on certain high-gradient streams to allow sediment to reach equilibrium inside the pipe and establish a more "natural" slope. Inattention to this issue causes to block culverts in future years.

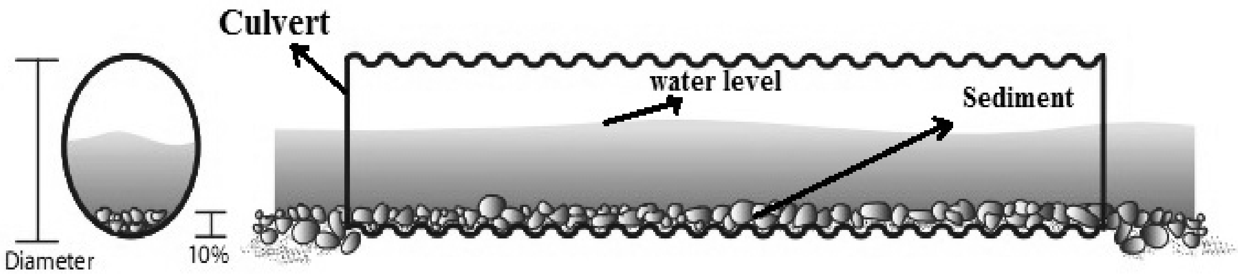

Figure 8. Suitable depth of water in culvert to prevent blocking by sediment

CONCLUSION

According to the results of this study it can be concluded that the correct installation of culverts in forest roads need accurate scientific studies in field of road engineering, forest and fishing. Inattention to each of this cases causes to incorrect installation of culverts and subsequently financial and environmental damage. In this study incorrect installation of culverts without attention to skew may causes to occur damage in future. Following items is suggested to reduce this damage:

1. Accordance of ravine flow with culverts skew during installation
2. Selecting of culvert size according to hydrological properties of the region
3. Selecting of the suitable slope and depth of culvert construction according to specific slope, road width and the type of vehicle for wood transportation
4. Consolidation of embankments using woody walls, Gabion and plastic fences to decrease produced sediment from cut slopes.
5. Baffles installation to facilitate fish passage and decrease the velocity of water flow in regions with probability of flood occurrence.

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