EVALUATING BEAVER GUARDS ON RESTRICTED FLOW RISERS OF SOIL CONSERVATION SERVICE FLOOD CONTROL IMPOUNDMENTS IN OKLAHOMA

By

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PREFACE

The objectives of this study are: to determine the effectiveness of overflow riser guards in preventing blockage by beaver in Soil Conservation Service (SCS) watershed protection impoundments in Oklahoma, to seek an understanding of the advantages beaver obtain from blocking these orifices, and to obtain an understanding of the behavioral and ecological characteristics associated with beaver plugging activity. Eight types of beaver guards are evaluated. Some habitat characteristics associated with SCS impoundments occupied by beaver are also evaluated. The relative distribution of beaver populations within Oklahoma is presented.

This study was funded by the United States Department of Agriculture, Soil Conservation Service. The Soil Conservation Service also provided access to study sites and utilities for living quarters.

Sincere appreciation is expressed to my major adviser, Dr. James Lewis, Assistant Leader, Oklahoma Cooperative Wildlife Research Unit, for his guidance during the study and assistance in preparing this thesis. I wish to thank Dr.'s Jeff Powell, Associate Professor, Agronomy, and James Shaw, Assistant Professor, School of Biological Sciences, for serving on my graduate committee. Dr. William Warde, Assistant Professor, Statistics, assisted in the statistical analyses of data. Dr. John Morrison, Leader, Oklahoma Cooperative Wildlife Research Unit, prepared the initial research proposal and negotiated the contract for the study.

I wish to acknowledge the cooperation and assistance of all SCS personnel involved in this study, in particular Jim Hill, former Assistant State Conservationist, Don Vandersypen, Assistant State Conservationist, Jerome Sykora, State Biologist, and Neil Price, District Conservationist, Coal County.

I wish to thank Robert Stratton, Manager, Sequoyah National Wildlife Refuge, for providing living quarters during studies in Sequoyah County. Byron Moser, Assistant Game Chief, Oklahoma Department of Wildlife Conservation, and John Meyers, Wildlife Services Division, U. S. Fish and Wildlife Service, assisted in mail surveys for the study.

A special thanks is due my wife, Barbie, for her patience and understanding during the study.

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CHAPTER I

INTRODUCTION

This thesis is comprised of three manuscripts written in formats which will facilitate immediate submission to state or national scientific journals for publication. These manuscripts are presented as chapters in the thesis and each is complete in itself without additional supporting materials. The manuscript entitled "Evaluating beaver guards on restricted flow risers of flood control impoundments" (Chapter II) is the principal paper of the thesis and was written according to the style and format of the PROCEEDINGS OF THE SOUTHEASTERN ASSOCIATION OF GAME AND FISH COMMISSIONERS. The manuscript entitled "Shoreline vegetation and the plugging of overflow risers by beaver" (Chapter III) was written in the bulletin format of THE JOURNAL OF WILDLIFE MANAGEMENT. The manuscript entitled "Beaver distribution in Oklahoma" (Chapter IV) was written according to the style and format of the PROCEEDINGS OF THE OKLAHOMA ACADEMY OF SCIENCE.

Approval for presenting the thesis in this manner is based upon the Graduate College's policy of accepting a thesis written in manuscript form and is subject to the Graduate College's approval of the major professor's request for a waiver of the standard format.

CHAPTER II

EVALUATING BEAVER GUARDS ON RESTRICTED FLOW RISERS OF FLOOD CONTROL IMPOUNDMENTS

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Abstract: Eight types of guards, designed to prevent plugging of restricted flow risers by beaver, were tested on Soil Conservation Service flood control impoundments. The effectiveness of these guards was studied between August 1975 and September 1976. Four guard types were unsuccessful in preventing plugging of risers by beaver. Risers protected by the other four guard types were not plugged, although some had been plugged prior to installation of the guards. A guard similar to type 5 showed the most promise for preventing plugging.

The U. S. Department of Agriculture, Soil Conservation Service (SCS), first started construction of Watershed Protection and Flood Control Impoundments in Oklahoma under Public Law 566 during the late 1950's. In these impoundments water is released gradually through a restricted flow riser which consists of a concrete or metal tower near the upstream side of the dam. The riser (Fig. 1) has a water inlet near its top and a controlled drawdown orifice at the bottom through which the impoundment can be drained. The top of the riser is equipped with a

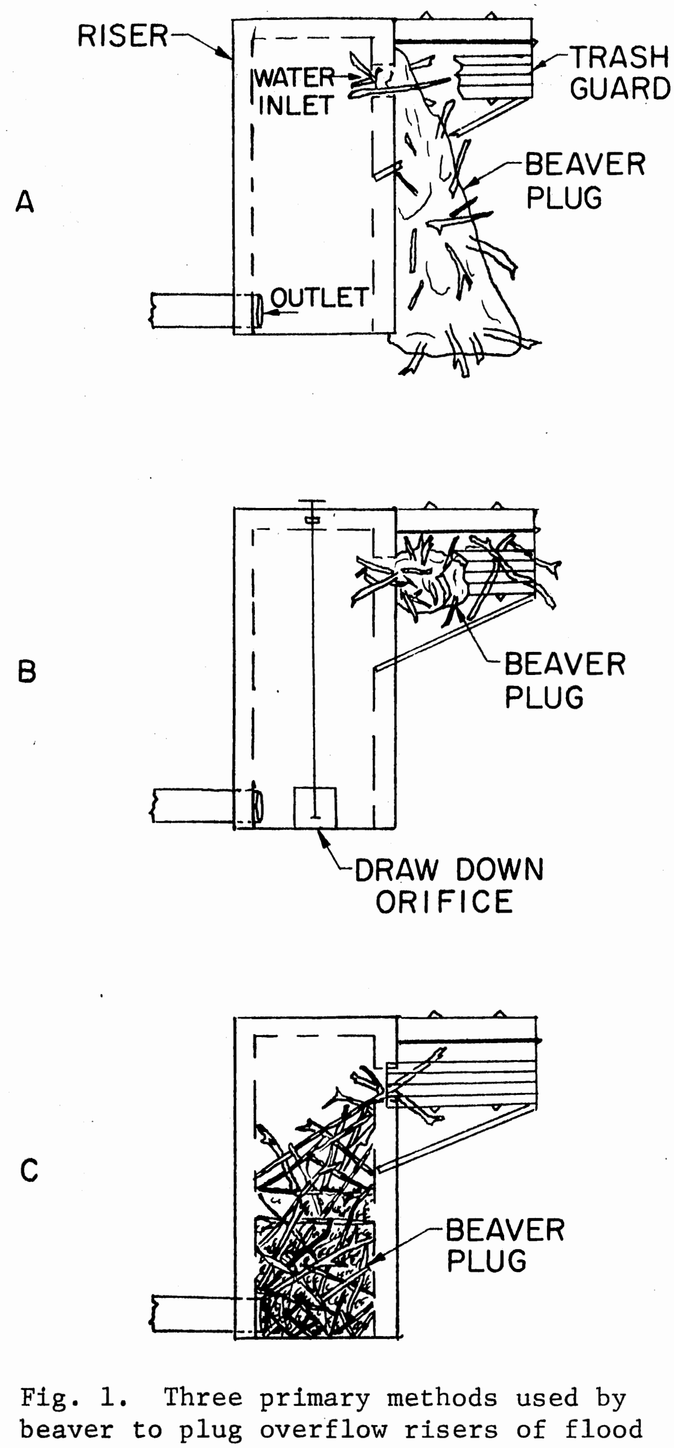

Fig. 1. Three primary methods used by beaver to plug overflow risers of flood control impoundments in Oklahoma. A, debris mounded up to cover water inlet; B, plug inside trash guard; and C, plug inside riser

trash guard to prevent floating debris from entering the structure.

Under normal conditions the bottom orifice of the riser is closed to retain water for livestock or for recreational purposes and the impoundment fills to the overflow orifice. Many of the streams entering these impoundments flow throughout the year, resulting in a stable lake level with water running out of the riser at the same rate it enters the impoundment. In addition to the restricted flow riser each impoundment has an emergency spillway to allow water to pass whenever the impoundment level approaches the maximum capacity.

SCS impoundments often create desirable habitat for beaver and the beaver apparently recognize the overflow orifice as a source of water loss. The beaver attempt to plug the orifice, slowing or stopping the flow of water. When they are successful in this effort, the water level of the impoundment is increased and flooding of crops, pasture, woods or roads may result. These circumstances are viewed with dissatisfaction by residents and landowners and the impoundment is rendered useless as a watershed protection device.

There appear to be three primary methods that beaver use in plugging the overflow orifice. One is to pile mud and sticks around the riser, eventually accumulating enough material to block the orifice (Fig. 1A). A second method is to fill the area within the trash guard with debris (Fig. 1B). The third method is to drop sticks, leaves, and other material through the top orifice into the riser (Fig. 1C). This latter type of plugging is extremely difficult to remove, and hazardous, especially if the water of the impoundment becomes high enough to cover the riser.

The SCS engineers, at the state office in Stillwater, Oklahoma, designed eight types of guards to prevent the plugging of risers by beavers. The Oklahoma Cooperative Wildlife Research Unit was chosen to evaluate the effectiveness of these guards. The authors acknowledge the cooperation and assistance of all SCS personnel involved in this project, in particular Jim Hill, Jerry Sykora, Neil Price, Charles Melton and Walter Hogue. Robert Stratton, Manager, Sequoyah National Wildlife Refuge, provided living quarters for the senior author during field studies in Sequoyah County. John Morrison, Leader Oklahoma Cooperative Wildlife Research Unit, prepared the initial research proposal and negotiated the contract for the study.

MATERIALS AND METHODS

The beaver-guard evaluation was conducted on SCS impoundments located primarily in eastern and southeastern Oklahoma. During the summer of 1975 the SCS installed 11 guards of eight types, one each, on 11 overflow risers of flood control impoundments. These impoundments, selected by SCS personnel, are located within five watersheds in four counties. The guards were designated numbers 1 through 7A. Each guard type was designed to present a different plugging problem to the beavers or to fit a particular type of riser. For the convenience of the readers, each guard type will be described when results of the experiments are discussed.

Impoundments with beaver guards were visited periodically by the senior author from August 1975 to September 1976 to determine if beaver had plugged or attempted to plug the water inlets or orifices. On guards with inlets below water, risers were checked for proper rate of flow to determine if the riser was plugged. SCS personnel also inspected study impoundments occasionally between visits by the senior author. Their vists were necessary to insure that plugging was discovered quickly and the problem corrected. When a riser was found plugged, the plugging materials were removed. The amount and type of materials were noted as well as the possible origin of the materials. Plugged guards were then modified or changed to see if a design could be developed that the beaver could not plug.

RESULTS AND DISCUSSION

Guard types 1 and 2 are functionally the same, differing only in modifications to fit a particular riser type. Guard type 1 (Fig. 2) is constructed from a corrugated metal culvert cut in half lengthwise and bolted onto the side of the riser. Type 1 covers an orifice in the top of the riser and consists of two sections of culvert joined at a 90° angle. Type 2 covers an orifice in the side of the riser and consists of only one section of culvert. Use of these guards is restricted to risers having orifice openings equal to or smaller in size than the diameter of the culvert guard. The only water inlet in each guard is at the bottom end of the culvert. When the impoundment is at normal pool level the water inlet on the guard is about 1.5 m below the water surface. The engineers hoped that beaver would not be able to identify the underwater inlet as the source of water loss and would find it difficult to plug this vertical entrance.

Guard types 1 and 2 were each installed on two SCS impoundments. They functioned propertly until late January 1976 when district SCS personnel discovered that the risers on Sallisaw Creek sites 27 (type 1) and 6 (type 2) had been plugged. By 4 February beaver had restricted waterflow 90 percent on site 6 and 100 percent on site 27. Site 27 was then drawn down to expose the guard orifice for inspection. Mud,

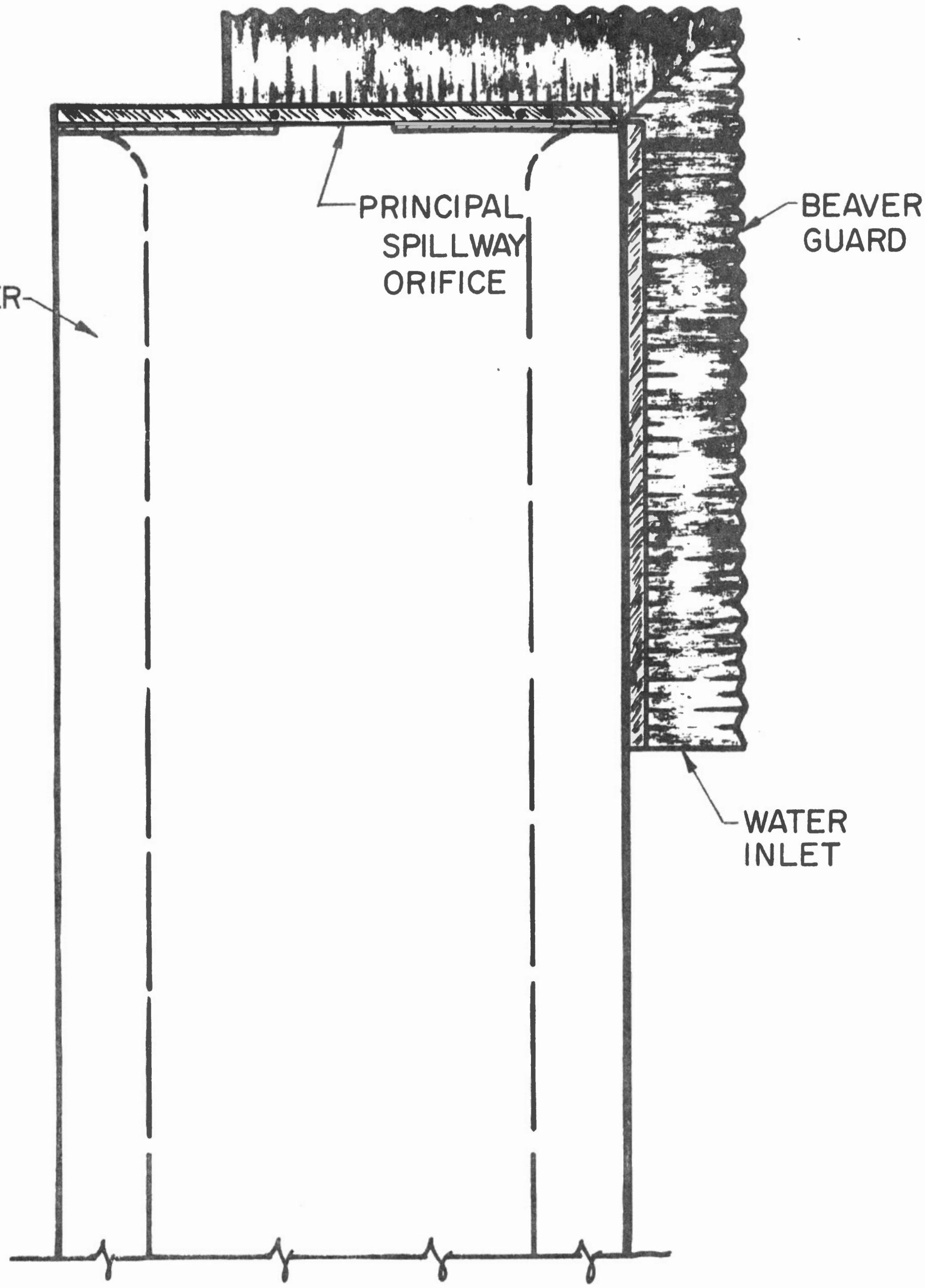

Fig. 2. Beaver guard type 1 which was unsuccessful in preventing plugging by beaver

sticks, leaves, rocks, and aquatic vegetation had been piled about 1 m high at the base of the guard.

Signs of digging near the dam clearly indicated that mud, some leaf litter, and aquatic plants were obtained within 8 m of the side of the riser. This area is under water when the impoundment is at normal pool level. A problem encountered with guard type 1 was that the lake had to be drawn down to facilitate removal of the plugging materials. Lowering the level of a lake is especially difficult when water covers the draw-down valve control on the riser.

Site 6 was not drawn down, but similarities between guard types on sites 6 and 27 suggest plugging methods were similar. On 6 March several slits were cut near the top of the guard on site 6 to allow for proper waterflow. By 1 September beaver had piled material, up the side of the beaver guard, to within 0.5 m of these slits. Plugging of guard types 1 and 2 followed rains that caused waterflow through the principal spillway orifice.

Guard type 3 (Fig. 3) consists of a 10-guage wire of 15.2 cm square mesh, approximately 18 m wide by 13 m long. This mesh is laid on the bottom of the impoundment and is designed to prevent beaver from mounding up debris until it covers the riser orifice(s). SCS personnel also believed that beaver needed mud to stop up the inside of the risers and that the mesh would prevent them from gathering this mud within a workable distance of the riser. The mesh guard could be installed around all types of risers. Guard type 3 was placed at one site. This riser was plugged in late December 1975. Beaver had deposited approximately 2 m^3 of sticks and leaves of various sizes, through the principal spillway orifice.

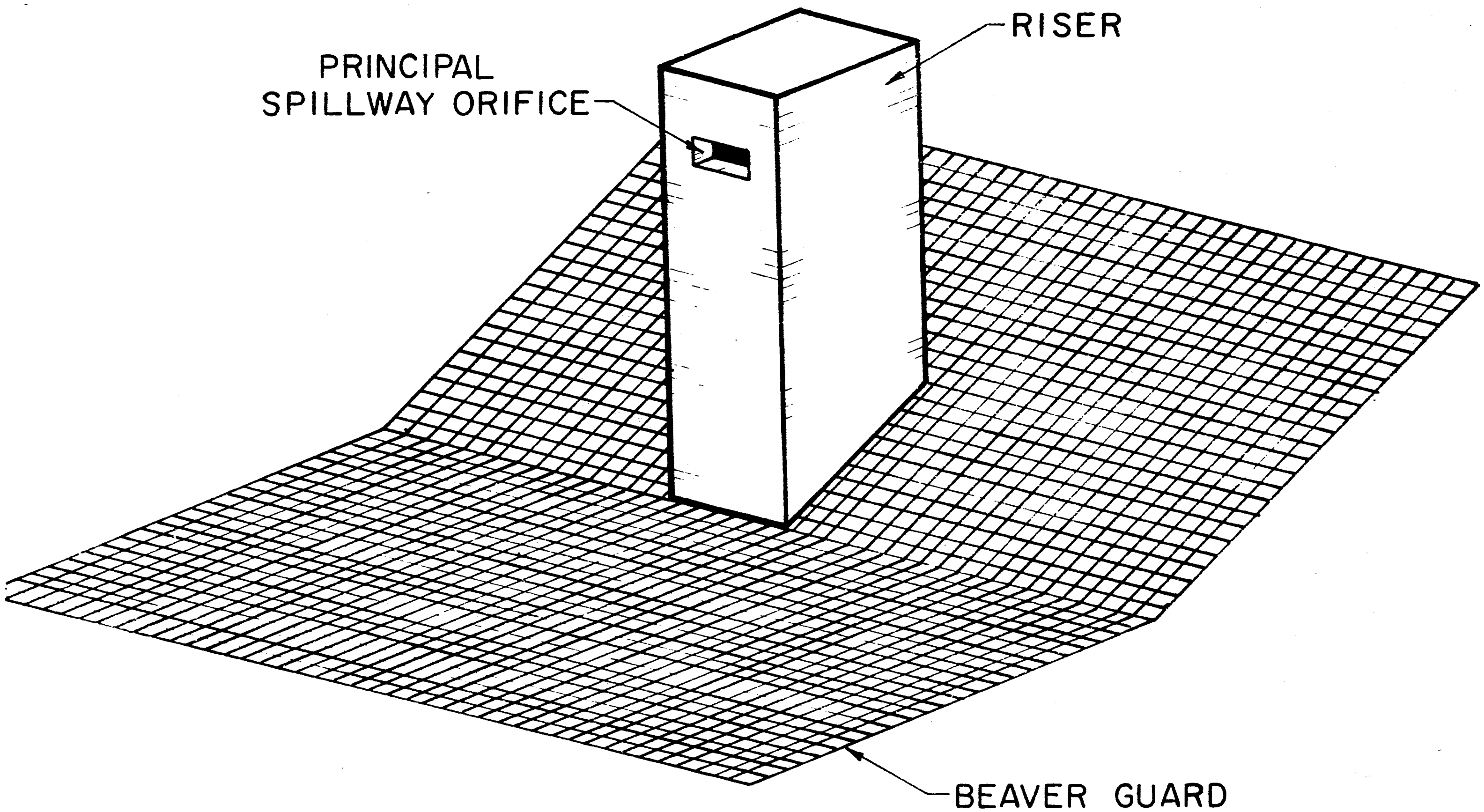

Fig. 3. Guard type 3 is only designed to prevent beaver from plugging a riser by mounding debris (Fig. 1A)

This material, apparently deposited by beaver from inside the trash guard, formed a tight plug compacted by the force of water. The outflow of water was not completely stopped, but if the watershed had received sufficient rains to fill the impoundment it would have been several weeks before the water level dropped to normal pool level. When operating properly this drawdown should require only several days. The absence of mud in the plugged riser indicates that mud is not necessary for the type of plugging found on site 14. A bar mesh guard, similar to beaver guard type 5, was then installed around the trash guard and has been successful in preventing further blockage by beaver.

One problem associated with guard type 3 is that it becomes silted over or sinks into the substrate. Eleven months after installation one-fourth of the mesh was covered with mud and it is likely that eventually the entire mesh will be covered. Another problem with this guard is the possibility of livestock entangling their feet in the loose mesh if the guard is used where they may enter the water to drink. Because of these problems, guard type 3, when used without any other beaver guard, seems not only unsuccessful in preventing beaver plugging, but may also be dangerous to livestock.

Guard type 4 is functionally similar to type 3. It consists of a rock riprap 18 m by 13 m laid on the bottom of the impoundment surrounding the riser. The riprap, like the wire mesh, is designed to prevent beaver from gathering mud within the immediate vicinity of the riser. This guard can be used around risers of any design.

Guard type 4 was installed on two sites and these guards functioned properly until May 1976 when beaver plugged the riser at Upper Clear Boggy Creek site 6. The riser was completely filled with sticks, leaves, and algae. The sticks were believed to be driftwood similar to that recently deposited along the dam near the riser after high water receded. Algae and leaves were available in the water near the riser. Mud was not used in this plugging. The riser was cleaned out and a wire mesh guard was installed enclosing the trash guard of the riser. No further plugging has occurred.

The rock riprap of the two sites has not silted over, probably because the ripraps were constructed higher than the surrounding bottom. With the wire mesh in place around the trash guard on site 6, further investigation will be needed to see if beaver can mound debris around the riser over the riprap.

Guard type 5 consists of a 12.7 square-cm mesh bar placed over the top and bottom of the grating on the trash guard of the riser (Fig. 4). This mesh prevents beaver from getting inside the trash guard and dropping material into the riser. Guard type 5 can be used on any riser equipped with a trash guard similar to the one shown in Fig. 4.

This guard was installed on one site and has not been plugged, however, there is no evidence that beaver attempted to plug it. This guard is very similar to guards placed on over 40 impoundment risers by employers of the Coal County Conservation District. Some of these guards have been in use longer than 3 years without being plugged. Beaver have been successful in mounding up debris around many of these guarded risers and in some cases have partially covered the trash guards, but waterflow was not restricted. Because of their numerous successes, these guards similar to type 5 have more supportive evidence for preventing riser blockage than any other type guard in this study.

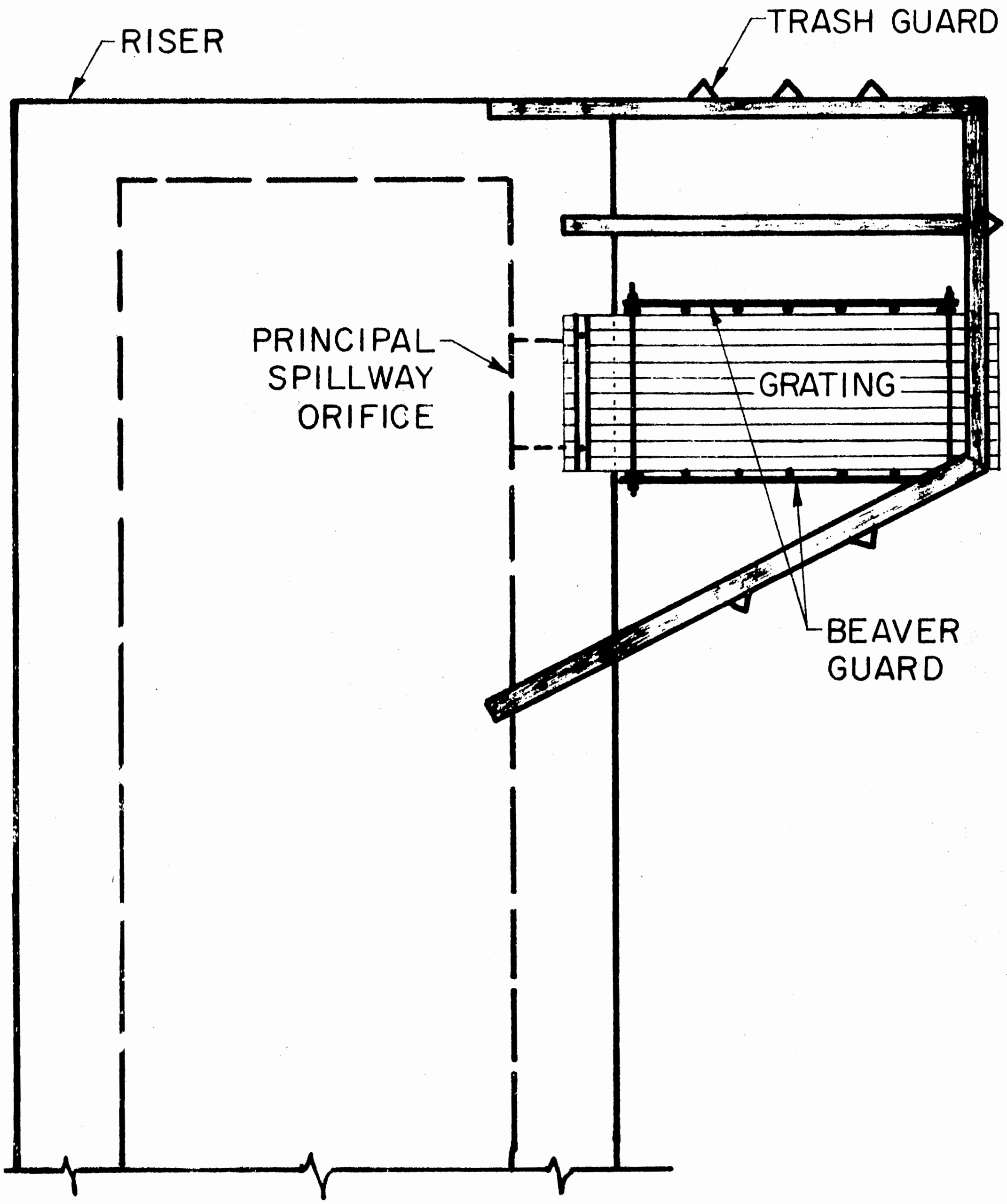

Fig. 4. Beaver guard type 5 which shows the greatest promise of preventing beaver from plugging the riser orifice

Guard type 6 was designed to fit risers with inlets on all four sides, protected by a trash guard made of angle iron. The beaver guard is an aluminum grating (Borden type A, size 1 or equivalent) that is attached to and extends below the trash guard, surrounding the water inlets (Fig. 5). This guard type prevents beaver from getting inside the trash guard and dropping material through the inlet to the inside of the riser.

Guard type 6 was installed on one site and has not been plugged. The habitat at this site is not ideal for beaver and there is no evidence that beaver have tried to plug the riser. More testing is needed before the value of this guard can be determined.

Guard type 7 consists of a corrugated metal culvert approximately 3 m long with a 90° elbow extending 1 m from the main pipe (Fig. 6). One end of the culvert is placed over the principal spillway orifice with the opposite end extending away from the riser. The open end of the culvert is placed over the principal spillway orifice with the opposite end extending away from the riser. The open end below the elbow is pointed down into the water, allowing the water to enter the opening approximately 60 cm below the water surface when the impoundment is at normal pool. Four openings, 7.6 cm x 35.3 cm were cut along the bottom of the culvert to allow for additional water flow. By positioning the principal inlet away from the riser, and under the water, the engineers hoped that beaver would not be successful in locating the source of water loss. If the source of water loss was discovered, the beaver would presumably find the vertical inlet difficult to plug. This type of guard could be used on any riser that has an orifice opening small enough to be covered by the open end of a culvert.

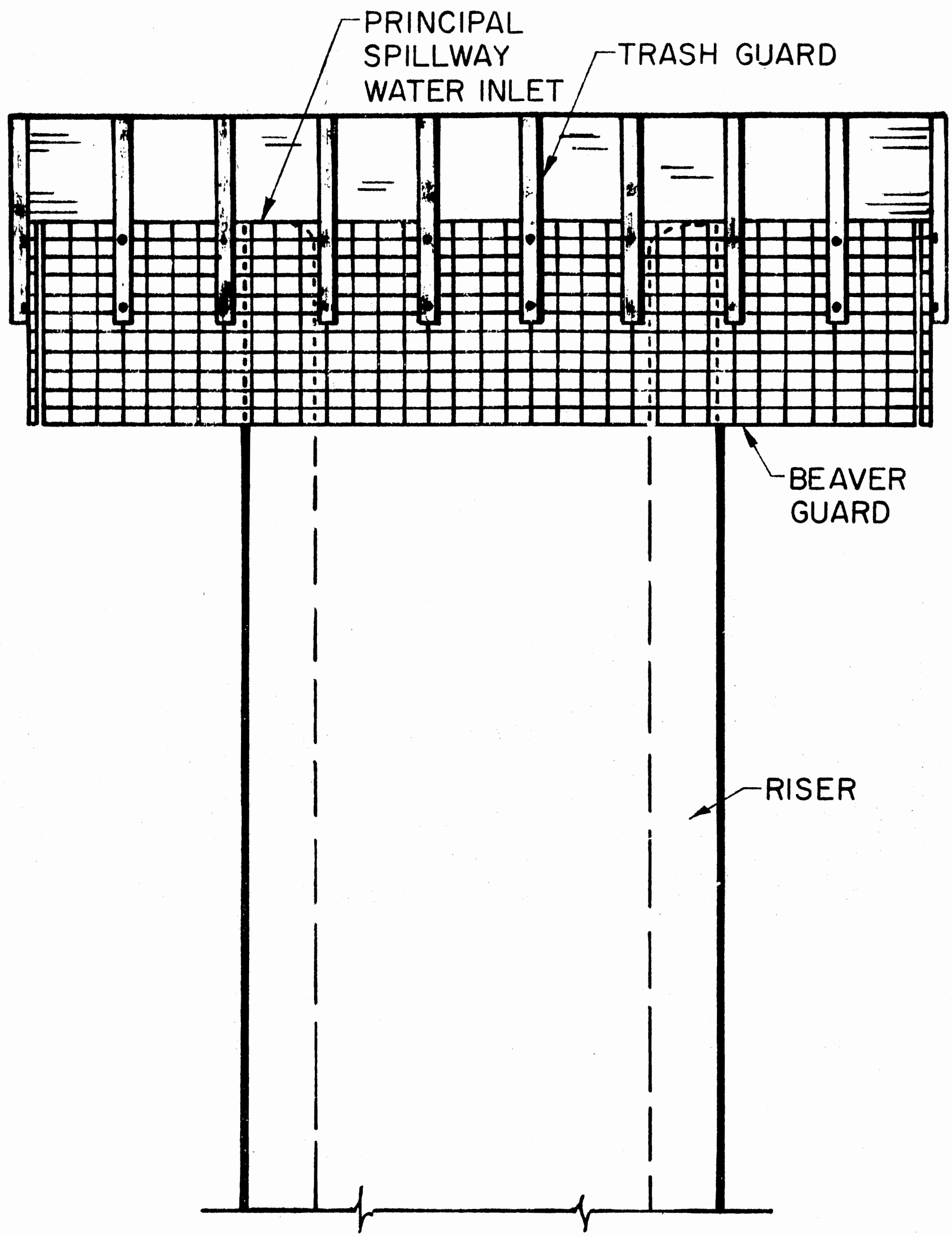

Fig. 5. Beaver guard type 6 has not been plugged, however there is no evidence that beaver have tried to plug it

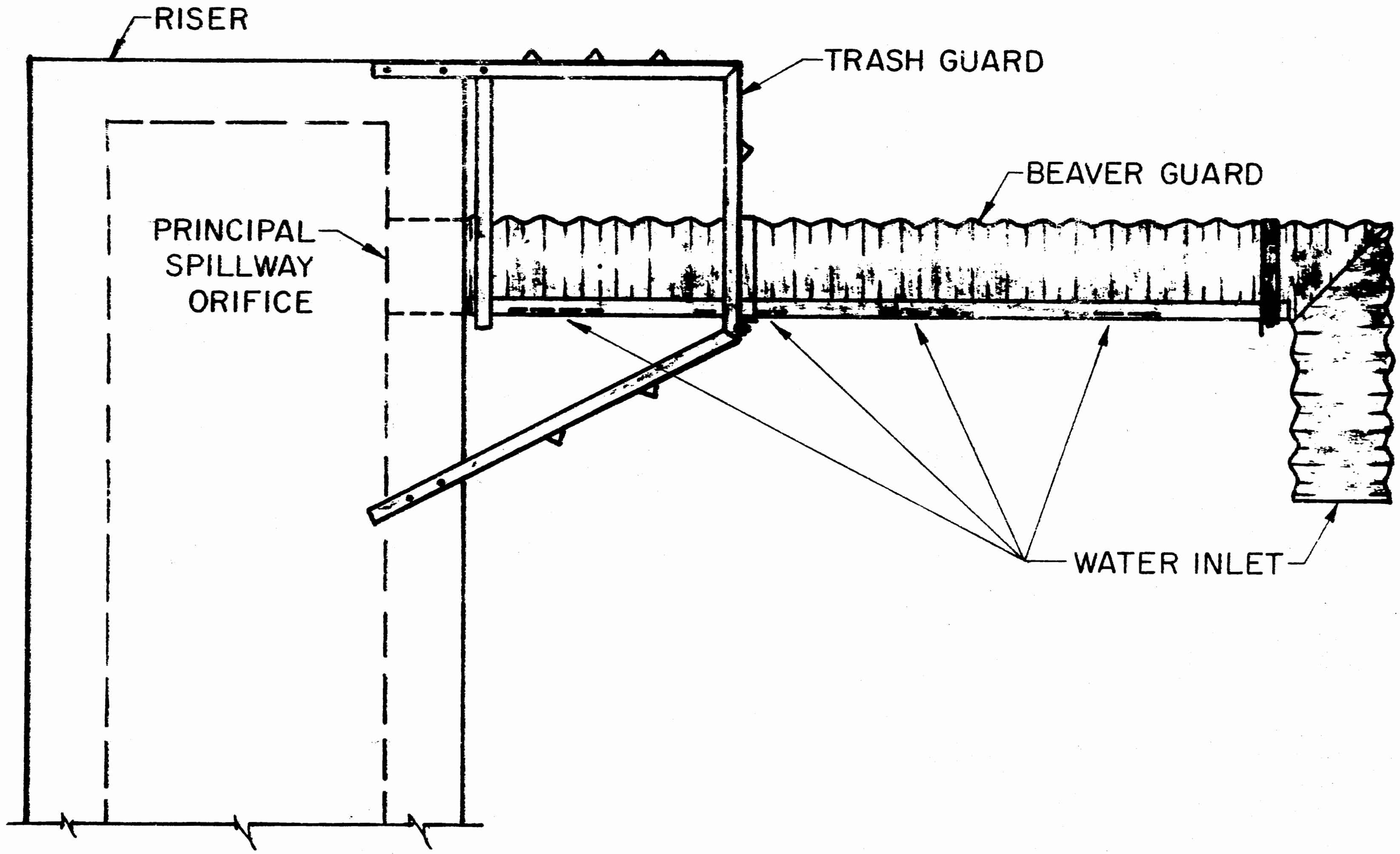

Fig. 6. Beaver guard type 7 has not been plugged, although it was installed on a riser which had been plugged by beaver just prior to installation of guard

Guard 7 was installed on two sites. When the SCS first installed guard type 7 on Upper Clear Boggy site 53 in July 1975 there were no beaver living at that site. Only once during the study were signs of beaver found at this impoundment. In June 1976 the riser in Sallisaw Creek site 3 was fitted with guard type 7. This riser had been plugged by beaver just prior to the installation of the guard and it has not been plugged since the guard was installed. More time and further tests are needed before any conclusions can be made about the guard's effectiveness.

Type 7A is a corrugated metal culvert approximately 3 m long extending away from the riser at a 20° angle (Fig. 7). One end of the culvert covers the principal spillway orifice and the other end is the water inlet. This design places the water inlet away from the riser and about 60 cm below the water surface. In addition, openings similar to those in guard 7 have been cut along the bottom of the culvert. This device is similar to the one described by Laramie (1963) and Webster (Personal communication 1976) used to control water level in beaver ponds or small impoundments. Like type 7, this guard may be used on any riser with an orifice opening small enough to be enclosed by a corrugated culvert.

Type 7A was placed on a site having a very active beaver colony and beaver had mounded mud along the riser up to the trash guard prior to the installation of the guard. This mound of material was removed before installing the guard. The riser has not been plugged, however, there is no evidence that beaver have tried to plug it. Guenther (1956) reported that beaver completely covered a culvert, similar to guard type 7A, that was 3 m above the pond bottom and placed through a beaver dam in the state of Washington. Further study is needed to determine the value of

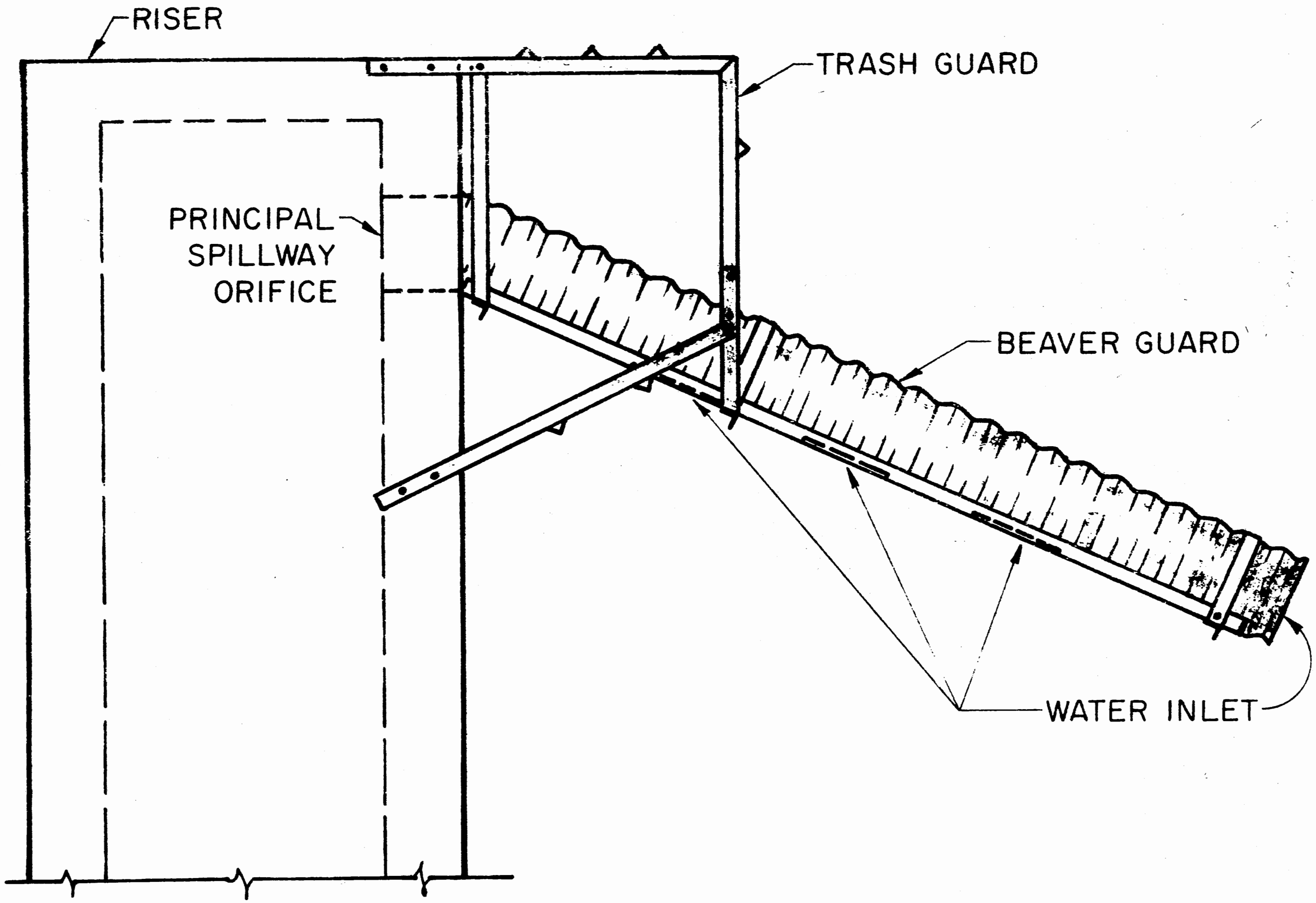

Fig. 7. Beaver guard type 7A has not been plugged, although it was installed on a riser which beaver had attempted to plug just prior to installation of guard

guard type 7A.

CONCLUSIONS

Risers protected by guard types 1, 2, 3, and 4 were plugged by beaver during the study. Because of the problems and ineffectiveness of guard types 1, 2, and 3 they should not be used in the future. Guard types 5, 6, 7, and 7A were not plugged, but they should be tested for a longer time interval before their effectiveness is conclusively stated. Guards similar to type 5 were used successfully in preventing riser blockage on more than 40 SCS impoundments; some have been in place more than three years. The riprap guard (type 4) may prove to be effective in preventing beaver from mounding material around the riser, but trials in additional impoundments are needed to determine this conclusively. The riprap, used with one of the successful orifice guards may be the solution to prevent both mounding and blockage of the principal spillway orifice by beaver.

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CHAPTER III

SHORELINE VEGETATION AND THE PLUGGING OF OVERFLOW RISERS BY BEAVER

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Abstract: Habitat of 14 Soil Conservation Service (SCS) flood control impoundments containing restricted flow risers, which had been plugged by beaver, was compared with habitat of 14 control impoundments that had not been plugged. There was no difference between the two categories of impoundments in the amount and location of woody vegetation along the shoreline. There was a habitat difference between those impoundments with risers plugged with freshly cut woody materials, and those plugged using old cut or drift materials.

During the late 1950's the United States Department of Agriculture, Soil Conservation Service (SCS) started constructing watershed protection and flood control impoundments in Oklahoma. Each of these impoundments is equipped with a restricted flow riser. The riser has one or more water inlets near the top by which water in excess of normal pool level is removed. The second inlet, through which an impoundment can be drained, is at the bottom of the riser. Impoundments normally fill to the overflow orifice at the top of the riser and then discharge excess water flowing into the impoundment. During heavy rainfall and water run off the water level may rise above the overflow orifice and then be slowly released through the riser into a downstream drainage.

These impoundments often create desirable habitat for beaver. Early succession plant species such as willow (*Salix* spp.), cottonwood (*Populus deltoides*), and buttonbush (*Cephalanthus occidentalis*) may become established along the shoreline, thereby providing a ready food source for beaver. When beaver occupy an impoundment they apparently recognize the overflow orifice as a cause of water loss and attempt to plug it. If the beaver are successful in this effort, the water level of the impoundment increases and crops, pasture, woods or roads are flooded. The impoundment is then useless for downstream flood prevention.

The problem of risers plugged by beaver is not restricted to flood control impoundments in Oklahoma; Texas and Mississippi have also experienced considerable trouble (F. Sprague, personal communication; E. Sullivan, personal communication).

The state SCS office in Stillwater, Oklahoma was authorized to fund a study of certain aspects of beaver plugging problems in flood control impoundments. The Oklahoma Cooperative Wildlife Research Unit was chosen to conduct the research. One objective of the study was to compare some habitat characteristics of impoundments in which risers had recently been plugged by beaver with other impoundments which also contained beaver, but in which risers had never been plugged. It was hoped that a habitat condition could be identified which could be altered to aid in preventing plugging problems, and that any advantage beaver might gain by plugging a riser could be better understood.

The authors acknowledge the cooperation and assistance of all SCS personnel involved in this study, in particular, Jerry Sykora, Neil Price, and Don Vandersypen. James Lewis, Assistant Leader, Oklahoma Cooperative Wildlife Research Unit, was major adviser during the study. John Morrison, former Leader, Oklahoma Cooperative Wildlife Research Unit, prepared the initial research proposal and negotiated the contract for the study.

STUDY AREA

The study impoundments are located primarily in east central, south central, and eastern Oklahoma. Most of the impoundments are located on private land which is currently being used for grazing. The east central and south central sites are within the Cross Timbers land resource areas of Oklahoma (Gray and Galloway 1959). The Cross Timbers is a large wooded area of rolling-to-hilly sandstone uplands extending from northeast to southwest through central Oklahoma. Impoundments and stream courses are characterized by woody species such as ash (*Fraxinus* spp.), water elm (*Planera aquatica*), white oak (*Quercus* spp.), and willow.

The sites in the eastern part of the state are within the Ouachita Highlands land resource area (Gray and Galloway 1959). High gradient streams are typical and woody species along streams and impoundments include willow, cottonwood, sycamore (*Platanus occidentalis*), and elm (*Ulmus* spp.).

METHODS

During February, 1976 a questionnaire was sent to each SCS District Conservationist in Oklahoma districts that had flood control impoundments. Each Conservationist was asked to list the impoundments in which the riser's principal spillway orifice had been plugged by beaver since July, 1974. Near each plugged impoundment chosen for study a control site, an impoundment that was occupied by beaver, but had no history of the riser being plugged was also selected. The control impoundments were selected by SCS district personnel in most instances and were located within the same watershed as the impoundment with the history of plugging. The type of material used by beaver in plugging the risers was determined by the author's investigation or from SCS district records.

The woody shoreline vegetation on each of these 28 impoundments was sampled during the summer of 1976. A surveying monitor was set up at the middle of the dam of each impoundment. The reason the monitor was not set up over the riser was that some risers were located in the corner of the impoundment along the dam and a clear view of the entire lake could not be obtained. After positioning on the dam the monitor was sighted on the water's edge at one end of the dam and then set on zero degrees. Next the monitor was sighted on the water's edge at the other end of the dam and the degree reading was recorded. The total degrees encompassed by the impoundment was divided into 30 equal angles. The monitor was then returned to the original setting at zero degrees and sightings were made from the 30 angles. Each angle and the name of the first woody plant whose canopy was intercepted along the line of sight, within 50 m of the shoreline, was recorded. A zero was recorded whenever woody vegetation was not intercepted by the line of sight within 50 m of the shoreline.

The incidence of vegetation along the dam was determined on 15 transects equally spaced along the length of the dam. These transects were run from the water's edge toward the top of the dam, at a 90 degree angle from the dam and the author recorded the name of the first woody species whose canopy was encountered before the top of the dam was reached. A total of 45 intercepts of woody vegetation was possible for each impoundment.

The plant interception points were later marked on SCS maps of the impoundment using a protractor (Fig. 1). The distances from the intercept points to the restricted flow risers were calculated from the map scale. The formula $\frac{h}{a} \times \frac{1000}{\bar{d}}$, where a = the total number of sample points (45), h = the number of points where "useful" woody vegetation was intercepted, and $\bar{d}$ = the average distance (m) to useful vegetation, was used to determine T, an index to beaver habitat at each impoundment.

"Useful" woody vegetation is defined here as those species that beaver prefer to cut for food and construction materials. Useful species for this study include cottonwood, willow, buttonbush, elm, ash, sycamore, plum (*Prunus* spp.), bald cypress (*Taxodium disticum*), hickory (*Carya* spp.), and dull leaf indigobush (*Amorpha fruticosa*). The value of the genera *Populus* and *Salix* to beaver is well documented (Bailey 1927, Shadle and Austin 1939, Beer 1942, Chapman 1949, and Brenner 1962). The other plants listed as "useful" were those that the author observed were commonly used by beaver at one or more of the impoundments. When the line of sight was blocked by a "non-useful" plant a zero was recorded for that sighting. Non-useful plants were oak, hackberry (*Celtis* spp.), and any other plants found by the author to be used infrequently by beaver at these impoundments.

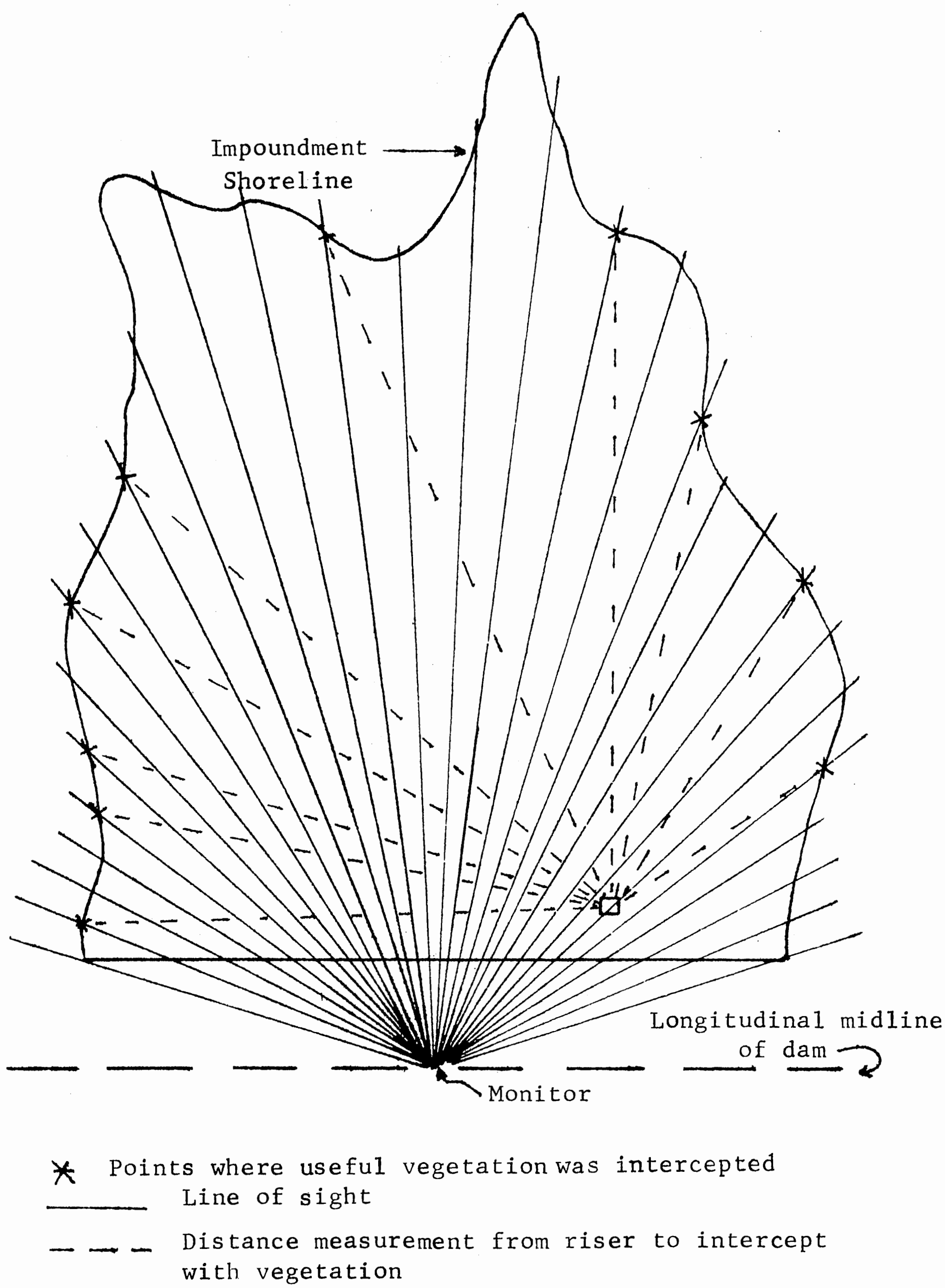

Fig. 1. Procedure used to evaluate woody shoreline vegetation on SCS impoundments

The shoreline closest to the dam was more intensively sampled than the shoreline at greater distances from the dam because all sightings were made at equal angles from the monitor. The author assumed woody vegetation near the dam and riser was more important, in terms of plugging material for use by beaver, than material at the upper end of the impoundment. Distances in meters from the riser to the vegetation intercepts were measured on the maps. Consequently, impoundments with a high number of vegetation intercepts close to the riser had a lower $\bar{d}$ than impoundments with the same number of intercepts far away from the riser. The lower the $\bar{d}$, the higher the habitat index value.

The Mann-Whitney U test (Conover 1971) was used to test differences in useful woody vegetation between impoundments that had risers plugged by beaver and impoundments in which risers had not been plugged. All differences discussed are significant at the 95% level of confidence unless otherwise indicated.

RESULTS AND DISCUSSION

The lowest index values represent impoundments with only a few useful woody plants near the riser. The high index values indicate impoundments with a large amount of useful woody plants near the riser (Table 1). These impoundments may also have woody vegetation at the upper end a considerable distance from the riser, but this vegetation adds little to the index value.

Differences in habitat index values between plugged and not-plugged impoundments were not significant. There is a large variation in the habitat values of impoundments with risers that have been plugged and risers that have not been plugged by beaver. Because of the variation in the habitat values of impoundments with risers plugged by beaver it appears that beaver can plug risers under many habitat conditions. The type of woody material used in plugging these risers fits into two categories (old and fresh cut). The old material consists of that cut sometime in the past and miscellaneous debris such as that found deposited along many dams near the riser. Risers plugged using freshly cut woody vegetation had similar vegetation growing near the riser.

Table 1. Number of intercepts with useful vegetation, average distance to intercepts and the resulting beaver habitat index value for impoundments with risers previously plugged and for control impoundments

Impoundments	Number of intercepts Mean ± SD	Average distance to intercepts (m) Mean ± SD	Beaver habitat index value Mean ± SD
Risers plugged	22 ± 12	156 ± 61	4.0 ± 3.9
Plug of freshly cut material	30 ± 12	122 ± 40	6.6 ± 4.9
Plug of drift or old cut material	11 ± 4	170 ± 60	1.6 ± 0.6
Plug materials unknown	23 ± 8	201 ± 57	2.8 ± 1.7
Control impoundments	18 ± 12	156 ± 67	3.3 ± 2.9

The habitat values of impoundments that had risers plugged by freshly cut materials were compared with those impoundments having risers that were plugged by beaver using old materials (Table 1).

Impoundments with risers plugged by beaver using freshly cut materials showed a significantly higher habitat index value than did impoundments with risers plugged with old woody materials.

All impoundments had woody vegetation in sufficient amounts to meet the food requirements of beaver. In impoundments with a low habitat index value this vegetation is located at the upper end of the impoundments far away from the riser. The evidence indicates that the beaver in these impoundments are unwilling or unable to transport freshly cut material over the long distance to the risers. Instead they take advantage of old material that may have drifted around the riser and use this in the plugging. When living woody vegetation and drifted materials are unavailable the beaver may still plug the riser by mounding mud from the bottom of the impoundment to the riser orifice to cover it. This type of plugging occured in some impoundments during the study.

The frequency with which various "useful" woody plants were present as intercepts on impoundments with plugged risers was as follows: willow, 254; elm, 19; buttonbush, 9; hickory, 8; green ash, 7; cottonwood, 2; sycamore, 2; and bald cypress, 1. On impoundments on which risers were not plugged the frequency with which useful woody plants were intercepted was as follows: willow, 186; sycamore, 23, buttonbush, 15; elm, 13; hickory, 7; cottonwood, 2; and plum, 1.

CONCLUSIONS

In most situations it appears that beaver gain no advantage by plugging the overflow riser and, thereby, increasing the water level of the impoundment. Ample woody vegetation is ususally available to the beaver when the impoundment is at normal pool level. The increased water level is actually detrimental to the beaver because it covers the den and lodge areas and much of the woody vegetation that would otherwise be available. It seems that the beaver are reacting to the stimulus of water flowing out of the impoundment and attempt to stop it.

Removal of drift and live woody vegetation near the edge of impoundments might delay or stop beaver from plugging some risers. However, this would only be a temporary deterrent, because additional drift would eventually float into the impoundment and trees would become reestablished along the shoreline near the riser. A more permanent solution might be to place the risers of future impoundments in deep water some distance from the dam. This placement of the riser might deter beaver from plugging it because of the greater distance that plugging material would have to be moved and the higher mound that would have to be constructed to plug the water inlet.

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CHAPTER IV

DISTRIBUTION OF BEAVER IN OKLAHOMA

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The relative distribution of beaver in the state was compared to the distribution of impounded potential beaver habitat. The importance of Soil Conservation Service flood control impoundments in providing potential beaver habitat, and the types of depredation caused by beaver in each county in the state were also investigated. The beaver population has increased from an estimated 485 restricted to west-central Oklahoma in 1952 to a population of thousands distributed statewide and a reported fur harvest of 1,941 during the 1974-75 trapping season. The highest density populations were found in areas with the most potential habitat ($P < 0.05$). SCS impoundments did not provide enough habitat to influence the statewide distribution of beaver. Almost every county reported some type of depredation caused by beaver.

INTRODUCTION

When the Washita River Watershed plan was authorized under the Flood Control Act of 1944 (1) beaver (*Castor canadensis*) were absent from many parts of Oklahoma. This Act and Public Law 566 provided for the construction of flood control impoundments in the state. Prior to

1944 the bulk of the beaver population was found in western Oklahoma especially along the Washita and North Canadian Rivers (2, 3) and by 1952 the statewide population was still estimated to be only 485 (4). At that time no Soil Conservation Service (SCS) flood control impoundments were completed.

By 1976, 1,692 floodwater retarding impoundments had been constructed (1) in Oklahoma by the United States Department of Agriculture, SCS. Most of these structures are permanent impoundments and they range in surface area from a few hectares to 887 ha. However, most impoundments are smaller than 35 ha. One result of the construction program has been a substantial increase in suitable beaver habitat in some parts of the state.

Much of this impounded habitat is now occupied by beaver. Based on an increase in complaints of depredation caused by beaver (John Meyers, Wildlife Services Division, U. S. Fish and Wildlife Service, Personal Communication 1976) and a beaver harvest of 1,941 during the 1974-75 trapping season (5), the state's beaver population appears to have increased. The increase in beaver populations is presumably a result of the construction of lakes and reservoirs, as well as, the occupation of previously unoccupied stream habitat.

Surveys were conducted to see if beaver were distributed statewide and to determine their relative abundance levels in various areas of the state. Another objective was to determine the types of depredation caused by beaver in Oklahoma and the distribution of these depredation problems.

METHODS

Survey questionnaires were sent to each SCS district field office, to rangers of the Oklahoma Department of Wildlife Conservation (ODWC) and to Wildlife Services personnel of the U. S. Fish and Wildlife Service (FWS) in Oklahoma. Each questionnaire recipient was asked to rate the beaver population of the county(ies) where they worked as rare, common, or abundant. This rating was to be arrived at by considering a combination of observations of beaver, beaver cuttings, tracks, lodges and dens, and depredation complaints that involved beaver.

Participants were also asked to indicate what percent of streams, ponds, and lakes in their counties have abundant woody vegetation near the edge. This estimate of woody vegetation available for food and construction materials was used to aid in determining an index to potential beaver habitat.

The goal was to acquire three responses from each county in the state, however, for a few counties only one or two questionnaires were completed and in two counties no questionnaires were returned. The returned questionnaires were pooled by county. A rating of beaver populations and a figure for the percentage of shoreline vegetation was derived for each county. Counties with conflicting vegetation or population ratings, based on only two returned questionnaires, and counties without returned questionnaires, were given population and vegetation rating similar to the majority of the surrounding counties.

After the ratings of beaver populations and shoreline vegetation, by county, were completed the relationship between relative distribution of beaver and the occurrence of impounded potential beaver habitat in the state was determined. An index for impounded potential beaver habitat in each county was arrived at as follows: HI (habitat index) = $(I \times r) \div (A \times 0.001)$ where I = the total area of all impoundments smaller than 364 ha in the county, r = the average percentage of streams, lakes, and ponds bordered by abundant woody vegetation in the county, and A = the area of each county.

Information regarding impounded water in the counties was obtained from the Oklahoma Water Resources Board (Personal Correspondence 1976). Data on potential beaver habitat along streams, and on reservoirs larger than 364 ha surface area, were not included in the analysis estimate of potential beaver habitat. Information about miles of various stream categories in each county is not available. Large reservoirs, arbitrarily defined as those with over 364 surface hectares have a large surface area to shoreline ratio. Consequently, the surface area of large reservoirs provides a poor measure of the potential beaver habitat they provide.

The Mann-Whitney U test was used to test the null hypothesis that there is no difference in the amount of impounded potential beaver habitat between counties containing abundant beaver populations and those counties with beaver populations rated as common or rare. In the latter test the samples to be compared (X and Y) are ranked from 1 to n + m where n equals the sample size of X, and m equals the sample size of Y. The number 1 is assigned to the smallest value of the combined sample of X's and Y's, the rank 2 to the next smallest, and so on to the largest, which is assigned a rank of n + m (6). The statistical test is then made using the ranks in place of the actual sample values.

The types of depredation problems that were caused by beaver were determined from the survey questionnaire.

RESULTS AND DISCUSSION

The questionnaire respondents indicate that beaver are now distributed statewide in contrast to the limited distribution of 25 years ago. The respondent's estimates (Table 1) indicate that the highest beaver populations are found in southeastern Oklahoma (Fig. 1). The letters A (abundant), C (common), and R (rare) under the "Pooled County Population Rating" column of Table 1 are responses taken from the questionnaires received from respondents in that county. The number listed under the "Pooled Vegetation Rating" is the average percentage of streams, lakes, and ponds bordered by abundant woody vegetation in the county (1 = 20 percent, 2 = 40 percent, 3 = 60 percent, 4 = 80 percent, and 5 = 100 percent). The total area of impoundments less than 364 ha, and the habitat index for each county is also listed. A high habitat index value indicates a county with large amounts of potential beaver habitat per unit area.

The Mann-Whitney U test rejects the null hypothesis for comparing impounded potential beaver habitat between areas containing abundant beaver populations and areas where beaver are rated as common or rare ($P < 0.05$). As might be expected, the highest beaver populations are found in areas with the best potential beaver habitat. The amount of suitable habitat for beaver is probably also influenced by the amount of precipitation received in an area. Annual rainfall is higher in southeastern Oklahoma (7) where beaver are most abundant.

It appears, then, that beaver are now distributed statewide in proportion to available habitat. Thus, beaver populations can now be expected to stabilize following the past quarter century of increase.

Table 1. Beaver population rating, pooled vegetation rating, total area of impoundments less than 364 ha, and impounded potential beaver habitat index of each county in Oklahoma

County	Pooled county population rating	Pooled vegetation rating	Total area of impoundments less than 364 ha	Habitat index
Adair	C	3.50	1915	18
Alfalfa	C	4.00	713	5
Atoka	A	5.00	3810	31
Beaver	R	1.00	2064	2
Beckham	C	3.33	2292	13
Blaine	A	3.00	1850	10
Bryan	C	4.00	5535	39
Caddo	C	5.00	6234	39
Canadian	C	3.50	4359	27
Carter	C	4.33	4952	40
Cherokee	R	5.00	1672	17
Choctaw	A	4.50	4072	38
Cimarron	R	1.00	916	1
Cleveland	C	3.33	2547	25
Coal	A	4.00	3280	39
Comanche	C	2.00	5373	16
Cotton	C	3.33	4108	34
Craig	R	3.50	3967	28
Creek	C	5.00	4351	36
Custer	C	2.66	4520	19
Delaware	C	4.67	1686	17

Table 1 (Continued)

County	Pooled county population rating	Pooled vegetation rating	Total area of impoundments less than 364 ha	Habitat index
Dewey	C	2.33	2057	8
Ellis	C	3.00	1484	6
Garfield	C	3.40	2769	14
Garvin	A	4.67	6783	61
Grady	C	2.66	6684	26
Grant	R	4.00	1501	9
Greer	C	3.00	2022	15
Harmon	C	3.00	1519	13
Harper	C	2.00	3379	10
Haskell	A	4.67	3184	41
Hughes	A	3.67	5406	38
Jackson	C	3.50	2110	15
Jefferson	C	3.00	3957	25
Johnston	A	4.67	2708	31
Kay	C	4.00	3630	24
Kingfisher	C	2.00	2506	9
Kiowa	C	3.00	6152	28
Latimer	A	4.00	3937	33
LeFlore	A	5.00	4837	24
Lincoln	C	4.33	6265	44
Logan	C	4.50	3815	36
Love	C	4.33	2362	33

Table 1 (Continued)

County	Pooled county population rating	Pooled vegetation rating	Total area of impoundments less than 364 ha	Habitat index
McClain	A	4.33	4506	55
McCurtain	A	5.00	4617	20
McIntosh	R	3.00	3069	23
Major	C	2.00	1985	7
Marshall	C	3.50	2269	34
Mayes	C	3.67	2197	19
Murray	C	4.33	4222	67
Muskogee	C	4.33	3424	29
Noble	C	3.33	4341	30
Nowata	C	4.00	2470	27
Okfuskee	C	4.00	3672	36
Oklahoma	C	3.67	3373	27
Okmulgee	C	3.94	5444	48
Osage	A	4.67	7480	24
Ottawa	C	4.67	2108	33
Pawnee	C	4.33	2843	33
Payne	C	3.67	3570	30
Pittsburg	A	4.50	4341	24
Pontotoc	A	4.00	4143	36
Pottawatomic	A	4.33	4136	35
Pushmataha	A	5.00	2535	14
Roger Mills	C	4.00	5621	31

Table 1 (Continued)

County	Pooled county population rating	Pooled vegetation rating	Total area of impoundments less than 364 ha	Habitat index
Seminole	A	3.00	6343	47
Sequoyah	A	5.00	3137	37
Stephens	A	4.00	5501	39
Texas	R	1.50	973	1
Tillman	C	2.00	3271	12
Tulsa	C	4.00	2797	31
Wagoner	C	3.33	3989	37
Washington	R	5.00	2321	43
Washita	C	3.33	6333	33
Woods	C	3.00	2746	10
Woodward	C	1.00	1698	2

SCS impoundments made up 5,350 ha or 15 percent of the impounded water, in small lakes, in the area with an abundant beaver population. SCS impoundments also provided a total of 15.5 percent (10,865 ha) of the impounded water, in small lakes, in the area with a common beaver population rating, and 1 percent of the water, in small lakes, in the area where beaver were rare. SCS impoundments would be a much smaller percentage of all impounded water and of all potential beaver habitat.

The presence of SCS impoundments does not appear to be a major factor in influencing the relative distribution of beaver or of beaver

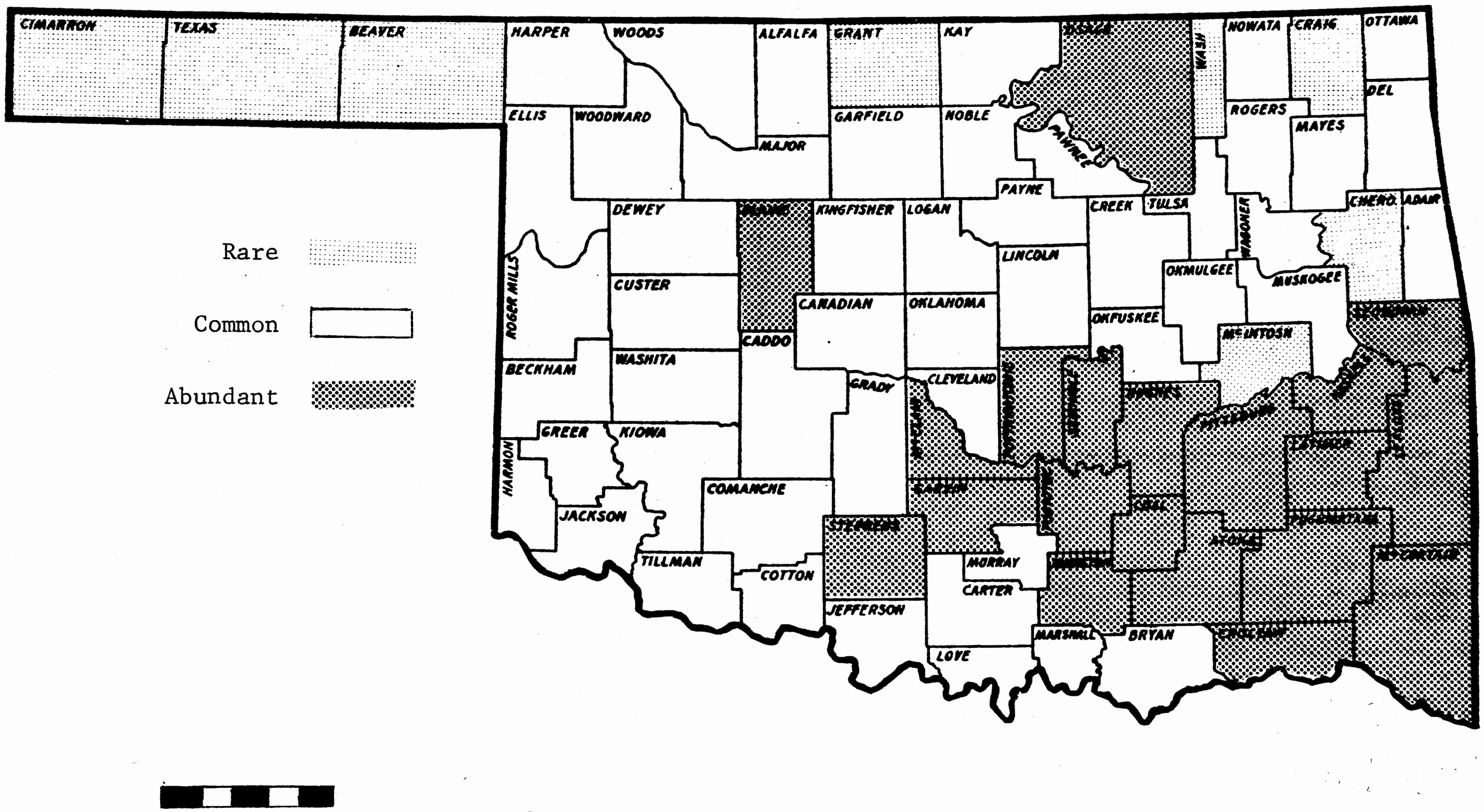

Fig. 1. Relative population distribution of beaver in Oklahoma

habitat across the state. The amount and distribution of all impounded waters and of stream habitat is probably the major factor determining the distribution of beaver.

However, in nine counties SCS impoundments provide more than 30 percent of the impounded water in small lakes and in these counties SCS impoundments presumably are significantly influencing the total numbers of beaver and their distribution. These counties are in west central (Beckham, Custer, Roger Mills, and Washita Counties), central (Grady, and McClain Counties), south central (Garvin, and Stephens Counties), and (Garfield) north central Oklahoma.

Several types of depredation were reported caused by beaver in Oklahoma (Table 2). Cutting of trees in the "other" category was reported in 58 counties (75 percent) and was the most common depredation complaint. Digging in pond dams by beaver was reported in 52 counties (68 percent). Beaver often dig dens into steep pond banks and dams, but some of the reported digging of pond dams may be a result of muskrats digging similar dens. The Central area of Oklahoma (8) had the highest average percent (58) of counties containing problems of all categories, possibly because of increased chance of beaver conflict with human interests due to the high human populations in this area. The Panhandle area had the lowest average percent (28) of counties containing problems of all categories. This low average would be expected for an area with sparse beaver and human populations (Fig. 1). Almost every county reported some type of depredation caused by beaver.

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Table 2. Percentage of counties reporting various kinds of depredation by beaver in areas of Oklahoma

Type of depredation	Areas and percentage of counties containing problem									
	Pan-handle	West central	South-west	North central	Central	South central	North-east	East central	South-east	Total
Flooding										
Cropland	20	83	63	38	62	50	09	44	60	47
Timber	0	67	38	25	69	42	27	56	80	45
Roads	60	83	38	50	69	42	45	44	80	55
Urban areas	0	17	13	13	31	17	0	11	0	10
Nuisance digging										
Canals	20	33	25	13	46	17	27	33	60	30
Dens	40	50	50	50	62	67	55	78	40	57
Pond dams	60	67	63	25	77	92	64	78	60	68
Cutting of grain crops	20	50	25	25	31	0	09	11	20	19

Table 2 (Continued)

Type of depredation	Pan-handle	West central	South-west	North central	Central	South central	North-east	East central	South-east	Total
	Areas and percentages of counties containing problem									
Cutting of trees										
Shade or ornamental	20	83	63	38	69	75	73	56	40	61
Commercial	0	17	13	0	46	17	18	33	80	25
Orchards	20	33	13	13	46	25	36	33	20	29
Other	80	67	88	63	85	75	73	67	80	75
Total percentage of counties containing some kind of problem	100	100	100	75	100	92	100	89	100	
Average percent of counties containing problems of all categories	28.3	54.2	41.0	29.4	57.8	43.3	36.3	45.3	51.7	

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APPENDIX

PARTIAL LISTING OF PLANT SPECIES FOUND CUT BY BEAVER AT SCS IMPOUNDMENTS

Common Name	Scientific Name
Post oak	*Quercus stellata*
Green ash	*Fraxinus pennsylvanica*
Eastern red cedar	*Juniperus virginianius*
Hackberry	*Celtis* spp.
American elm	*Ulmus americana*
Red bud	*Cercis canadensis*
Pecan	*Carya illinoensis*
Cottonwood	*Populus deltoides*
Black willow	*Salix nigra*
Hickory	*Carya* spp.
Winged elm	*Ulmus alata*
Sycamore	*Platanus occidentalis*
Bald cypress	*Taxodium distichum*
Sand plum	*Prunus angustifolia*
Dull leaf indigobush	*Amorpha fruticosa*
Blackberry	*Rubus* spp.
Buttonbush	*Cephalanthus occidentalis*
Wild rye	*Elymus* spp.
Lespedeza	*Lespedeza* spp.
Nutsedge	*Cyperus* spp.
Wild millet	*Echinochloa crusgalli*
Smartweed	*Polygonum* spp.
Water primrose	*Jussiaea repens*
Pondweed	*Potamogeton* spp.
Water willow	*Justicia americana*

Hardstem bulrush	_Scirpus acutus_
Cattail	_Typha_ spp.

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