Province of
British Columbia

Ministry of
Environment

# W A S A  L A K E

WATER MANAGEMENT BRANCH
Region 4, Nelson

R. Baker, P. ENG.,
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Section

# 1. RECOMMENDATIONS

IMMEDIATE

1.1 Prevent all overland flow from reaching Wasa Lake by:

a) installing a slide gate control structure in the breached section of the old highway (1 km south of Wasa Lake). See Section 5.1A, Objective #1, Alternative #1 for details.

b) sealing off the Hansen Creek channel by any of the priorized alternatives listed in Section 5.1A, Objective #2.

1.2 Negotiate with the Ministry of Transportation and Highways to allow the installation of flap gates on the southern ends of the two highways culverts (located at the south end of Wasa Lake).

1.3 Install debris barriers at both ends of all culverts and control; structures mentioned in recommendations 1.1 and 1.2.

1.4 Extend the present lake level gauge so that under no circumstances can it go underwater.

1.5 For each and every dwelling that is effected by high water levels, document the elevation at which specific problems occur (ie. septic backs up, water in basement, water damages to the household, etc.). In addition, plot the approximate location of each specific problem site on a map.

FUTURE

The following recommendations assume that the above mentioned IMMEDIATE recommendations have been successfully accomplished.

1.6 Install another water level gauge on the Kootenay River in the immediate vicinity of Hansen Creek.

1.7 Take lake and river levels at both Wasa Bridge (old) and Hansen Channel (new) at approximately the same time of day, daily from mid-April through to mid-September.

1.8 Repeat recommendation 1.7 for a minimum of 3 years but preferably long enough to record a significant Kootenay River flooding event.

1.9 Have the data obtained from 1.8 analyzed to determine whether a relationship can be established between the average daily rate of infiltration of ground water into Wasa Lake and either:

a) the average daily Kootenay River level (at Hansen Creek/at Wasa Bridge); or

b) the average daily head difference between Wasa Lake and Kootenay River (at Hansen Creek/at Wasa Bridge) levels.

1.10 Assuming a relationship discussed in recommendation 1.9 is found, have cost-benefit analyses performed on the installation and operation of a pumping station (to <u>control</u> Wasa Lake levels) under a wide range of operational objectives.

1.11 Select the operation plan that is the best mix of cost versus benefit and then decide whether or not to proceed with the installation and operation of a pumping station. The final decision on what to do with Hansen Channel should be delayed until this point (ie. fill it in, install a weir, use it as the pumping station location).

## 2.0 TERMS OF REFERENCE

In November 1984, the Trustees of the Wasa Lake Land Improvement District (W.L.L.I.D.) wrote to the Regional District of East Kootenay (R.D.E.K.) to request [1]"that a feasibility study be carried out to effect flood control by dyking the Kootenay River where it bypasses the District." R.D.E.K. advised the Improvement District that it was [2]"not prepared to fund an expensive Flood Control Feasibility Study" and encouraged the District to pursue the matter with the Ministry of Environment and Parks.

The Ministry decided that the request would be initially investigated at the conceptual stage by the Engineering Section of the Kootenay Regional office. This report is in response to the Improvement District's request.

The questions which required resolution were:

1) What are the problems of the Wasa Lake Area?

2) What is already known/what has been done in regards to studying the problem? and

3) Can any recommendations be made as to what steps should be taken next?

## 3.0 BACKGROUND

[3]Wasa Lake is a small (approximately 100 ha), shallow lake lying in the bottom of the Kootenay River Valley at the Western toe of the Rocky Mountains. Located 35 km north of Cranbrook, the lake is a very important recreational resource primarily because it is one of a few lakes which warms up enough for general swimming. The lake is surrounded by summer cottages, permanent homes, a provincial park and campground, as well as several public beaches. [4]"Approximately 60,000 tourists enjoy the recreational facilities offered by Wasa Lake in a three month summer season." [5]Wasa Lake, in simplistic geologic terms, is a large kettle. It was formed when a large block of ice broke off the face of a receding glacier. The block then prevented the accumulation of gravel which steadily outwashed from beneath the receding glacier. Eventually, the block melted leaving behind a depression in the deposited gravels.

As with most kettles, Wasa Lake has no continuous inlets or outlets. It is a lake only because the depression it forms is lower than the surrounding water table.

The geology of the Wasa Lake area is complicated (for a more complete discussion see reference 5) by it being on the western toe of the Rockies. Though the groundwater table is undoubtedly influenced to some degree by upland drainage, there appears little doubt that during freshet the major contributing factor is the Kootenay River. At extreme Kootenay River levels (ie. in excess of approximately 771.1 metres or 2530 feet at Wasa bridge), overland flow occurs into the lake resulting in a rapid rise of the lake's water level.

Wasa Lake levels usually start to rise in early May, peak in late June or early July, then slowly recede. Annual water level fluctuations range from 2.5 to 4.5 meters (7 to 13 ft). At extreme high lake levels, the use of the lake is impaired, the resultant ponding of water promotes mosquito production and dwellings are flooded. At extreme low lake levels, the sandy beaches are high and dry, the shoreline is muddy and boating is hazardous due to shoals.

During the early 1960's Wasa Lake residents formed an informal Association in an attempt to control the water level of the lake. With tourist interest in local camping on the increase, the association was offered assistance from the Parks Branch. Requests were made of the Regional Water Rights Branch for technical assistance which culminated in 1965 with water level gauges being established on Wasa Lake and the Kootenay River.

With these guages in place, the Parks Branch and local residents undertook the first series of daily readings in an attempt to determine what relationship existed between the Kootenay River and Wasa Lake.

Following extensive flooding in 1967 the Association was, in 1969, incorporated to form the Wasa Lake Land Improvement District. Flooding occurred again in 1972 resulting in six claimants receiving a total of $2,786.50 in flood relief. [6]"In 1974 flooding occured again and 22 claims totalling $16,989.56 were paid for flood damage. At this time the Regional District stopped issuing building permits" for houses (proposed to be located) below the flood construction level (FCL) set by the Ministry of Environment (see Section 4.0 for FCL details). The result was increased interest in the activities of the Improvement District.

About this time, the Improvement District hired Environmental Planning and Engineering Consultants (EPEC) to study the situation. Their Stage 1 Assessment Report was completed in November of 1975. Upon the completion of their Stage II Assessment Report it was anticipated that sufficient information would be available to make concrete recommendations to the trustees. However, by November of 1976, the Improvement District's main focus shifted from seeking protection from high lake levels to ensuring protection from extreme low lake levels. The switch in priorities was a direct result of B.C. Hydro's Kootenay Diversion Study.

Ed Livingston Associates produced The Hydrology of Wasa Lake, B.C. in December of 1976 for B.C. Hydro. This was followed by EPEC's Stage II Investigation, Assessment Report of 1976 Wasa Lake Monitoring in February of 1977 and EPEC's Stage III Investigation, Assessment Report of 1977 and 1978 Wasa Lake in April of 1979.

In summary, much effort has been put forth, a lot of data has been collected, many observations noted, conclusions drawn and recommendations made but mitigative proposals have yet to be initiated. Meanwhile the problems continue.

## 4.0 RIVER PROTECTION ASSISTANCE PROGRAM (R.P.A.P.)

Prior to the discussion of Water Control Measures that follows in Section 5.0, it would appear germane to discuss what type of assistance is available from the Ministry of the Environment & Parks to deal with problems such as those of the Wasa Lake area.

The Ministry's source of financial assistance for land owners with flooding and/or erosion problems is the River Protection Assistance Program. This program is administered by the Water Management Branch (formerly Water Rights Branch). Under this program, cost-sharing assistance, as well as technical support services are provided for approved dyking and riverbank protection projects. The RPAP program will pay 75% of an approved project's cost while the landowner(s) must agree to pay the remaining 25% as well as any future maintenance costs. Clearly, not all projects are approved and the level of funding can vary dramatically from year to year. The policy states that only works of a permanent nature are to be entertained. The decision as to whether or not to approve a project depends on a multitude of factors which include funding levels for the fiscal year in which the project is proposed, cost-benefit analysis as well as nature of the works proposed.

Preliminary discussions with Water Management Branch's head office in Victoria, indicate that if and when an acceptable proposal for R.P.A.P. funding was put forward, it would receive a high priority status due to the number of homes which would derive benefits from such a project.

As a cautionary note, the flap gates, control structure, dykes and pumping station recommended by this report are all potentially fundable works which may mitigate and/or eventually control Wasa Lake levels, however, such works will not affect the flood construction level.

The flood construction level (FCL) establishes the minimum elevation of the underside of floor systems for habitable buildings (or the pad elevation for mobile homes). The FCL in the Wasa Lake area is determined by adding a small freeboard/safety factor onto the expected 200 year return period Kootenay River level. The flood construction level for the Wasa Lake area is 772.6 m (2535 Ft.) G.S.C. datum.

## 5.0 WATER CONTROL MEASURES

In the subsections that follow, an attempt has been made to present and discuss every conceivable option. Clearly some proposals merit only cursory discussion.

5.1 Dyking
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5.2 Pumping Station

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5.4 Dredging the Kootenay River

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5.7 Installation of Weir(s) on the Kootenay River

### 5.1 Dyking

Two proposals will be discussed: dyking the Kootenay River and dyking Wasa Lake. The former would be a massive undertaking, the latter would require the installation of minimal works. In either case, DYKING IS A MITAGATIVE MEASURE AND NOT A SOLUTION. In spring the Kootenay River will rise, causing a hydraulic gradient to exist between itself and Wasa Lake and so water will move through the soil from the river to the lake.

What dyking does accomplish, however, is the prevention of all overland flow. Since water moves through soil much more slowly than over it, two positive results should be realized. Peak lake levels should occur later in the Kootenay River flood cycle and they should be lower. Without massive volumes of overland flow to cause the lake level to jump up to flood levels, the lake should simply continue to slowly rise. It is hoped that the peak Kootenay River levels will subside before Wasa Lake slowly reaches flood levels.

An analogy can be made to a row boat with a large hole in it anchored on a beach. Whether or not the boat will sink will depend solely upon how high the tide will be. However, shove a rag in the hole and now whether or not the boat sinks depends upon how fast the water leaks in <u>and</u> upon how long before the tide goes back out.

It is these two variables, the rate of infiltration of ground water into Wasa Lake and the duration of extreme Kootenay River flood levels that will determine what benefits will be acrued from dyking.

### 5.1A Dyking Wasa Lake

Figure 1 illustrates that aside from the Hansen Channel area and the sloughs to the south, Wasa Lake is surrounded by a ring of natural ground whose elevation is in excess of 2535 feet (772.6 metres) which is the 200 year flood construction level. Therefore all that must be done to complete a dyke around Wasa Lake is to dyke off these two low spots. Each of the low spots will be addressed separately. Alternatives will be presented, followed by a brief discussion of their pros and cons.

#### Objective #1: Seal off the southern sloughs.

Three alternatives will be discussed. The rebuilding of the abandoned highway (slough) crossing, the rebuilding of the abandoned rail line and the construction of a dyke immediately south of Wasa Lake.

Alternative #1: Rebuild the abandoned highway (slough) crossing which is about 1 km. south of Wasa Lake. See figure 2.

The breach itself is quite small being only approximately 25 metres in length, a cross section of which can be seen in figure 3. The breached section was at one time plugged in an attempt to generate flood relief. Unfortunately, proper discussions were not undertaken prior to installation, and waterfowl interests dictated the the plug be removed.

Discussion with Fish and Wildlife officials indicate that the concern for the waterfowl arose from the blocking of all surface flow to the more southerly sloughs. A consceptual sketch for a control structure which could perform both flood mitigation and surface flow control is presented in figure 4.

The slide gate control structure could be operated to mitigate not only the extreme high lake levels, but the extreme low lake levels as well. In the late spring, as rapidly rising Kootenay River levels cause the sloughs to the south to rise, the slide gate could be fully closed. After the freshet, as the Kootenay River levels recede causing the sloughs to the south to drop below the level of the slough to the north, the slide gate could be opened fully to encourage the water level in the slough to the north to follow the decending water levels of the slough to the south. When the water level in the slough to the north (and Wasa Lake) were within tolerable limits, the slide gate could be fully closed in an attempt to retard all subsequent decline of Wasa Lake levels. In essence, the attempt could be made to create a hydrostatic dam in the slough to the north (of the control structure) which might result in reducing the rate at which Wasa Lake levels fall.

Whenever waterfowl interest could be served by commencing some flow into the southernmost sloughs, the slide gate could be opened to meter out any desired flow.

In years when peak Kootenay River levels are low, and hence low Wasa Lake levels are feared, the timing of when the gate is opened or closed could be coordinated so that peak Kootenay River levels could be used to charge the northern slough. It may also be possible, if the system proves to operate in a predictable manner, to attempt to retain Lewis Creek freshet flows as well.

For typical slide gate specifications, see figures 5 and 6. It is important that the slide gate be operable under both a seating and and unseating head (ie. as discussed above, the slide gate would pond water on different sides depending on the circumstances). No size of slide gate and culvert is shown in the consceptual drawing. For strictly waterfowl management purposes, the smallest size would probably suffice. However, for flood mitigation purposes, the larger the diameter of the culvert, the faster the high water levels in the northernmost slough (and Wasa Lake) could be dropped. At a minimum therefore, matching the combined cross sectional area of the two 800 mm (30 inch) diameter culverts which presently drain Wasa Lake would appear reasonable (ie. approximately a 1100 mm or 42" dia.).

Should the flood mitigation measures mentioned above prove beneficial to the district, the crest elevation of the old highway could be raised to provide increased flood protection. Raising the crest elevation by 1.1 metres (3.5 feet) to approximately 772.0 metres (2533 feet) would prevent 200 year (return period) flood levels from overtopping the dyke (old highway). Therefore, the slide gate arrangement should be installed to be operated from this elevation or have the capability to be extended up to this higher level at a later date.

A land improvement licence would be required from our Branch to operate such a control structure.

Pros and Cons of Alternative #1

1. The entire Improvement District would derive flood mitigation benefits.

2. Requires the least fill, approximately 300 $m^3$ (400 $yd^3$) or 35 truck loads (dual tandems), hence is the least expensive alternative at approximately $2000 for the loading, hauling and compaction of the fill exclusive of the associated control structure costs.

3. A control structure must be included to meet waterfowl requirements.

4. Lewis Creek is enclosed behind the dyke, though its flows would be much less than the volumes of water that presently enter through the breach during freshet conditions.

Alternative #2: Raise and rebuild the abandoned rail line that crosses the northernmost slough. See figure 2.

The eastern portion of the abandoned bed is sufficiently wide to be used as a base for the dyke construction, and hence would only require the capping of the existing bed. The western portion however, would require the widening of the existing bed by as much as 6 metres (20 feet) to raise the 3 metres (10 feet) wide surface by up to 2 meters (6 feet). A short 3 metres (10 feet) wide breach section would also have to be reconstructed. While no figures are known, a crude estimate of between 3000 and 4000 cubic metres of fill would probably be required. Such a proposal would cost in the neighbourhood of $20,000 to construct.

Pros and Cons of Alternative #2

The main positive feature of this alternative is that it does not enclose Lewis Creek. Also, little land aquisition problems are foreseen. The main negative points are that it does not provide flood mitigation to the entire Improvement District and the estimated cost is several times that of Alternative #1.

Alternative #3: Construct an 800 metre (1/2 mile) dyke along the south side of the road which runs along the south end of Wasa Lake. See figure 2.

The western end of the dyke would be located close to the highway. The eastern end would tie into high ground approximately 450 metres up the road to Lazy Lake. No volumes are known for this alternative, though fill quantities should not be excessive as much of the land is less than 1 metre below the flood construction level.

Pros and Cons of Alternative #3

Encloses none of the northernmost slough. This is good from the point of view of not enclosing any areas of high permeability that may exist in the slough as well as not enclosing Lewis Creek. However, this alternative does nothing to mitigate the flood dammage for those homes immediately south of Wasa Lake.

It is understood that the western portion of this proposed location has in the recent past been sold to a party that plans to develop the lot. Therefore, serious land aquisition problems may exist.

Should no other recommendation be adhered to, the District should negotiate with the Ministry of Transportation and Highways to allow the installation of flap gates on the southern ends of both culverts that connect Wasa Lake with the northernmost slough. Typical flap gate specifications can be seen in figure 7. Under any scenario, flap gates would provide some degree of flood mitigation to Lake residents. The Ministry of Highways is on record as opposing this recommendation[7], however, no concrete problem with this recommendation has been put forth. Clearly, Highways (and C.P.R.) is not likely to eagerly embrace the generally poor practice of using beds for dykes.

Objective #2: Preventing flow through Hansen Creek Channel.

Three alternatives will be discussed. The installation of a flap gate on the C.P.R. culvert, the installation of a flap gate on the present highway culvert and the raising of the abandoned highway grade in conjunction with the installation of flap gates on its culverts.

A target elevation for relief from overland flood flow levels has been chosen to be 772.0 metres (2533 feet) which is the the 200 year return period level on the Kootenay River at Hansen Channel.

Alternative #1: Install a flap gate on the western end of the C.P.R. culvert.

As the Water Management Branch has no jurisdiction over existing C.P.R. culverts, C.P.R.'s permission is mandatory. Though the C.P.R. track could probably tolerate the difference in head for the entire freshet period with no ill effects, C.P.R. does not, as a general policy, like to use their grade as a dyke (which is why they installed a culvert there in the first place).

Should C.P.R. deem the entire freshet period to be 'too long' or the differences in head to be 'too high', the culvert under the abandoned highway could also be sealed (flap gated or welded) so that a flap gate on the C.P.R. culvert would be necessary for only a few days (ie. only when the abandoned highway was close to overtopping).

Pros and Cons of Alternative #1

At approximately 773.3 metres (2537 feet) the exisitng C.P.R. grade is the highest in the area. It could prevent overland flood flows which are well in excess of the 200 year return period flood level of 722.0 metres (2533 feet) from entering Hansen Channel. In addition, it would be an extremely inexpensive alternative. However, C.P.R.'s permission is mandatory.

Alternative #2: Install a flap gate on the western end of the new highway culvert (in Hansen Channel).

Water Management is not in a position to order the installation of such a flap gate. Therefore, the Improvement District would have to obtain permission for the Ministry of Transportation and Highways prior to proceeding with this alternative. Preliminary discussion with Gordon Sutherland, Regional Highways Director, indicates a willingness to seriously consider the matter should Highways be approached. Water Management would be willing to participate in any such discussions between the Improvement District and the Ministry of Transportation and Highways.

Pros and Cons of Alternative #2

Though 0.7 metres (27 inches) lower than the C.P.R. grade, the existing highway at approximately 772.6 metres (2535 feet) should provide overland flow protection from the 200 year return period flood levels. Clearly however, the higher the dyke the greater the protection. The cost of this alternative would be only marginally more expensive than the previous one as the culvert diameter is 900 mm (36 inches) versus 800 mm (30 inches) for C.P.R.'s.

Alternative #3: Raise the grade of the old highway in conjunction with the installation of a flap gate on the 900 mm (36 inch) diameter culvert and welding shut the 600 mm (24 inch) diameter culvert.

At approximately 770 metres (2527 feet) the existing grade of the old highway crossing would not meet the target flood relief elevation. 1986 freshet levels topped the structure by more than 0.3 metres (1 foot). This alternative would see the minimum elevation raised to 772.5 metres (to allow for some settling).

The raising of the old highway bed could be accomplished in numerous ways. Three possible alignments will be briefly discussed. The first option would be a horseshoe arrangement tieing into the C.P.R. grade (on the north and south sides of Hansen Channel). The second would be a similar horseshoe alignment, however, this option would tie into the new highway grade. Finally, a discussion of raising the existing grade along its existing alignment will be presented.

A horseshoe alignment tieing into the C.P.R. grade to the west, would require approximately 350 $m^3$ of fill at an estimated cost of approximately $2500. This option would, of course, require C.P.R.'s permission.

A horseshoe alignment tieing into the present highway grade to the east, would require approximately 900 $m^3$ and cost an estimated $5000. This option would require Highway's approval.

If the present alignment were used, approximately 1,300 $m^3$ of fill would be required at an estimated cost of $7500. The landowner's permission would be required and probably easily obtained.

Pros and Cons of Alternative #3

This alternative is the most expensive, with crude construction cost estimates ranging from $2500 up to $7500.

## 5.1B Dyking the Kootenay River

When considering dyking, there are two options, riverbank (training) dykes or setback dykes. Riverbank dykes are generally longer in length, since they must follow the riverbank, and are usually more expensive on a metre per metre basis as they usually require more riprap armourment for protection from active erosion. Provided that an adequate floodway exists, riverbank dykes are generally used when the additional land that they protect (when compared to set back dykes) is of sufficient benefit to warrant the increased expense. The unit cost for riprap armourment is approximately $13 per cubic metre to prepare the slopes, load, haul and place the rock (assuming a local supply). Should no local source be available, the unit cost per cubic metre could easily double. A setback dyke on the Kootenay would not be subject to direct impingment because of the nature of the widespread (low velocity) flooding, and would not, therefore, require riprap armourment. In addition, a set back dyke would be shorter in length than a riverbank dyke due to the meandering nature of the Kootenay River in the Wasa Lake area.

A crude estimate of relative costs, would place a setback dyke at approximately 30% of the cost of a riverbank dyke. From the preceeding discussion therefore, it would appear that should the Improvement District wish to construct a dyke, it should be a setback dyke.

The first step in determining the location of the setback dyke is to identify what area is to be protected. Assuming the entire improvement district is to be protected, the second step would be to look for high ground at either end to tie the dyke into Analysis of aerial photography and review of topographic orthophotos [8] show so much natural high ground exists, that no dykes are necessary other than for Hansen Channel and the slough area to the south. Clearly, this proposal is now reduced to the previous proposal presented in section 5.1A.

## 5.2 Pumping Station

The pumping station concept presupposes the existance of dyking which will prevent overland flow from reaching Wasa Lake. The idea is to bail out the lake as fast as water can infiltrate back in through its porous sand bottom.

Based on 1965 data, infiltration volumes range from a base level of 0.36 cubic metres per second ($m^3/s$) to over 1.71 $m^3/s$, and appear to average approximately 0.71 $m^3/s$ for a three week freshet period. Volumes of this magnitude can be handled by a low head (which is difference in elevation between 'in'and 'out') high volume pump. Further, when the lake level begins to drop below a desired elevation (2522.50 feet was suggested by the District), the pump could be readily reversed to pump Kootenay River water into the lake (theoretically) as fast as it drained out its porous bottom.

Depending on what measures were taken to restrict overland flow from accessing the lake, Hansen Creek Channel, the south end of the lake or the abandoned highway slough crossing, appear to be the most likely locations for such a station. A joint project with Ducks Unlimited and/or the Fish and Wildlife Branch at a more southerly location should not be ruled out. If overland flow could be prevented a pumping station could potentially solve both the high and low water level problems. The price tag on such a station would be in the order of $100,000 to make the installation operational and would probably require an annual expenditure of approximately $10,000 for operation and maintenance (these costs assume no volunteer labour).

In short, this solution will succeed only in conjunction with surface flow prevention devices in place. It's main drawback is that it is an active system, ie. it requires that energy be put into the system to work it and as such, requires a constant supply of money to operate the system. It's main positive point is that it is the only option that has the potential to control Wasa lake levels.

## 5.3 Diversion of Water into Wasa Lake

The purpose of this proposal is to attempt to mitigate extreme low lake levels by the introduction of an external water source into Wasa Lake. Three potential sources have been indentified: Lewis Creek, Lussier River and northernmost slough. The intent in each case would be to attempt to maintain some base lake level throughout the latter part of the summer. A desirable minimum lake level of 768.8 metres (2522.50 feet) has been identified by the district.

### 5.3A Lewis Creek Diversion

This option was explored quite extensively by the Water Management Branch in Nelson. The conclusion reached was that the amount of water available in the latter part of summer was insufficient due to existing licensing to warrant diversion. EPEC considered it unlikely that a minimum elevation of 767.8 metres (2519 feet) could be maintained, even if the entire flow of Lewis Creek were diverted.

### 5.3B Lussier River Diversion

A June 9th, 1980 workshop came up with this proposal. No other reference to it was found.

This option was considered by this writer to be too expensive to warrant exploring in any kind of technical detail. The proposal would require the construction of 12 kilometers of pipeline as well as a crossing of Wolf Creek.

## 5.3C Northernmost Slough Diversion

A 300 metre section of culverting/fluming/ditching could connect the northernmost slough to the south end of Wasa Lake. However, though the water level in the slough is between 1.3 and 2.0 metres (4 and 6 feet) higher than Wasa Lake at the latter part of summer, a Ducks Unlimited survey shows the depth of the slough to be too shallow to supply the volumes required to effect a meaningful change in Wasa Lake levels. Any such proposal affecting slough water levels would require taking into account waterfowl requirements.

## 5.4 Dredging the Kootenay River

Dredging is generally performed for one of two reasons. The first is a desire to increase the depth of water usually to enhance navigation. The second, is to lower water levels throughout the reach. Clearly, proponents of dredging in the Wasa Lake area desire the latter, ie. to lower average water levels. Unfortunately, the only result would be to increase the depth of water.

The primary prerequisite for the use of dredging to lower water levels, is a difference in elevation between the starting and ending points of the dredging operation. The greater the difference, the greater the new potential grade and resultant benefits. There is insufficient elevation difference, regardless of what starting and ending points are chosen, to warrant any type of dredging activity.

For lack of more up-to-date riverbed elevations, let us assume that the Kootenay River bed is as shown on M.S. Contour Map sheet No. 56 & 57[9]. Assuming a minimum dredging length of 5.5 kilometres (3.5 miles), the mapping shows a drop of less than 1 metre (3 feet) or .02 m/km (1ft/mi) for a maximum potential bottom slope of less than 0.0002. If the dredging operation were extended downstream to allow the removal of sandbars just north of the confluence of the St. Mary's River, a drop of no more than 2 metres (6.5 feet) could be hoped for. This drop over the new 20 kilometre (16 mile) length however, results in an even flatter potential bed slope, resulting in even less benefit.

A crude estimate of the cost involved in the dredging of the 5.5 kilometre (3.5 mile) reach of the Kootenay (where it passes the District) would be in the tens of millions of dollars. As the operation would be of no benefit to the district, and as the bottom would immediately begin to fill itself back in, no R.P.A.P. funding would be available. It is also doubtful that Approval under Section 7 of the Water Act could be obtained for such a proposal, given its temporary nature, lack of benefit and its negative impact on the fish and wildlife resources.

## 5.5 Channelization

Channelization or straightening the path that the Kootenay River takes in passing the Wasa Lake area, could theoretically increase the bottom slope by some 25%. The resultant bottom slope, however, would still be less than 0.0002 mentioned in Section 5.4 and be of virtually no benefit to the District. The negative aspects of this proposal are overwhelming. Land would have to be aquired, armourment installed (estimated cost 4.5 million), studies undertaken, negative downstream effects determined, compensation given, mitigative works constructed, etc.

In general, channelization has fallen into disrepute due to the associated negative effects, and so it should be expected that gaining permission under Section 7 of the Water Act for such work would be duely onerous.

## 5.6 Sealing Wasa Lake Bottom

Roughly 350,000 metric tons of clay could be used to seal the lake bottom. The sides, however, would require the installation of a layer of sand over the clay or the installation of an impervious membrane. This theoretical option is infeasible because of the associated cost, water stagnation and clarity problems, as well as its adverse effect on fish and plant life. What the regime of the new lake levels would be are unknown.

## 5.7 Installation of Weir(s) on the Kootenay River

This option would deal only with low water problems. While apparently studied by B.C. Hydro in some detail, the information related to this concept has been filed away in B.C. Hydro archives and as such is not readily available.

The basic concept was to construct a weir, perhaps in conjunction with control gates, which could dam the Kootenay River somewhere in the vicinity of the southern sloughs.[4] The weir's function would have been to dam the Kootemay River, causing it to pond. The resultant higher river level would cause the level of the surrounding water table to rise, hopefully creating a hydrostatic dam which would reduce the rate at which water perculated out of Wasa Lake. In essence, this proposal would have artifically induced pre-freshet water levels to exist on the Kootenay.

This proposition would be undesirable for numerous reasons:

1) Damming the Kootenay would mean that the water velocities would decrease and as such bedload deposition would increase. The resulting increase in deposition would most likely result in increased flooding during the freshet period due to reduced channel capacity.

   This option only makes sense in conjunction with a Kootenay Diversion (lower freshet volumes).

2) This option would pose a fish barrier to migrating kokanee. Studies would have to be made as the the effect on whitetail deer, etc.

3) Installation and maintenance of the weir(s) would be costly, expecially if fish ladders were required.

4) The weir would restrict boating on the Kootenay River.

5) The mosquito problem would be enhanced by the increased surface area of low velocity water in which to breed.

So, in short, the concept would require a major engineering study to: locate site(s), study bedload characteristics to determine the threat of increasing the annual high water, determine effects of pondage on upstream landowners and wildlife, not to mention design. The cost for these studies would have to be borne prior to application for the required permits and with no guarantee of issuance.

## 6.0 CONCLUSIONS AND FURTHER DISCUSSION OF RECOMMENDATIONS

Of all the water control measures presented in section 5.0, only the combination of dyking and pumping offer a potential solution to Wasa Lake's main problems. When considering dyking, natural high ground and existing grade beds should be used whenever possible to avoid duplication and cut down on costs. These considerations dictate recommendation 1.1.

The use of flap gates as per recommendation 1.2 will further retard the raising of Wasa Lake levels. It may also, at times, raise the elevation of the northernmost slough. Altering the use or nonuse of such a flap gate after a monitoring program was initiated, as outlined in recommendations 1.6 through 1.8, may invalidate recommendation 1.9.

Without debris barriers, the operation of any installed flap gates or control structre cannot be guarranteed due to the significant beaver activity and available debris in the area.

A water level gauge that goes completely underwater is next to useless, hence recommendations 1.4, for safety reasons the gauge should extend a minimum of 1.0 m above the highest expected lake level.

The information obtained from recommendation 1.5 would be essential to recommendations 1.10 and 1.11. The required data can easily be collected by one person with a minimum equipment (an inexpensive clinometer).

The reason for recommendation 1.6 is that the hydraulic gradient (ie. water surface slope) varies from 0.00023 for the one in 200 year return period flood[10] to approximately 0.00013 on May 10, 1976[11]. Therefore, no exact extrapolation can be made to move the Kootenay River levels from the Wasa Bridge, downstream 4 kilometres (2.5 miles) to Hansen Channel. The collection of Kootenay River levels at Hansen Channel (as per recommendation 1.7) should increase the likelihood of finding a correlation as well as improving whatever correlation is found.

The author believes that a correlation discussed in recommendation 1 can be found at least for the peak freshet period when the water table in the surrounding area is clearly dominated by the Kootenay River. All previous studies have merely plotted Kootenay River elevations (at Wasa bridge) and Wasa Lake levels on one sheet of paper. Such comparisons give us plots which look like figure 8. However, since one is a lake with flat banks and the other is a river with comparitively steep banks, it appears more reasonable to ask about a comparison with the <u>volume</u> of inflow into the lake (which is a function of both lake elevation <u>and lake area)</u>. The result of such a comparison would be similar to figure 9.

One of the major problems in determining the average volume or rate of infiltration into Wasa Lake, is that the surface area of the lake must be known for various lake elevations. To this end a topographic survey of the lake area in 0.5 metres (18 inches) contour intervals from approximately 766.2 metres up to 772.6 metres (2514 to 2535 feet) would be a valuable tool. Should cost considerations rule out such a survey, crude surface area approximations are available by planometric analysis of existing orthophotos.[8]. The following table was compiled by the writer.

| LAKE ELEVATION (feet) | LAKE AREA (acre) |
|---|---|
| 2520.8 | 242 |
| 2523.0 | 263 |
| 2526.4 | 301 |
| 2529.7 | 332 |

TABLE 6.1

This data may be best fit by the line

$$A = 10 L - 24965$$

Where: L is the lake elevation (feet)
A is the lake area (acre)

The stated goal of a minimum winter Wasa Lake level of 766.5 metre (2415 feet) and a June 15 to September 15 minimum lake level of 768.8 metres (2522.5 feet) may prove too expensive to achieve if a cost versus benefit analysis (as per recommendation 1.11) is performed. The following table suggests that a minimum June 15 to September 1 lake level of 768.1 metres (2520 feet) may be a more realistic target.

| Year | Number of days from June 15 to September 1 that Wasa Lake was below elevation | |
|---|---|---|
| | 768.8 metres | 768.1 metres |
| 1965 | 45 | 25 |
| 1966 | 45 | 0 |
| 1971 | 50 | 10 |
| 1972 | 25 | 5 |
| 1973 | 50 | 30 |

Also, a useable set of any useful information or data exists on Wasa Lake would prove invaluable and so should be carefully kept, such as:

(i) Aerial photos KAL-72-2 #9 through 11 inclusive, contact David A. Dakin, in Burnaby (formerly Kootenay Airlines). The 1972 photos were taken for Ducks Unlimited.

(ii) Orthophotos entitled B.C. Hydro and Power Authority, Kootenay River Diversion Project. Compiled by Intergrated Resources Photography Ltd. 78-46T-0, 2 sheets.

(iii) Wasa Marsh Development Plan, Ducks Unlimited, February 73.

(iv) A profile showing all culvert invert and grade elevations through Hansen Channel and southward through Lewis Slough to the location of the proposed control structure. An exact profile does not exist at the present time.

As a final comment, it should be noted, that in 1971 Francis West applied on behalf of the Improvement District to do much of what is now (for at least the third time) being proposed. Ed Livingston in 1979 recommended similar measures as well, though perhaps not as clearly.

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   78-46T-0.

9. Dept. of MINES AND RESOURCES (Federal)
   M.S. Maps #56 and 57.

10. Letter to W.L.L.I.D. from Ministry of the Environment April 5, 1978
    (W.M.B. File #281643).

11. Stage 3 Investigation Assessment Report of 1977 and 1978 Wasa Lake
    Monitoring April 1979, EPEC Consulting Western Ltd., Page 1.

# APPENDIX

## 8.0 LIST OF FIGURES

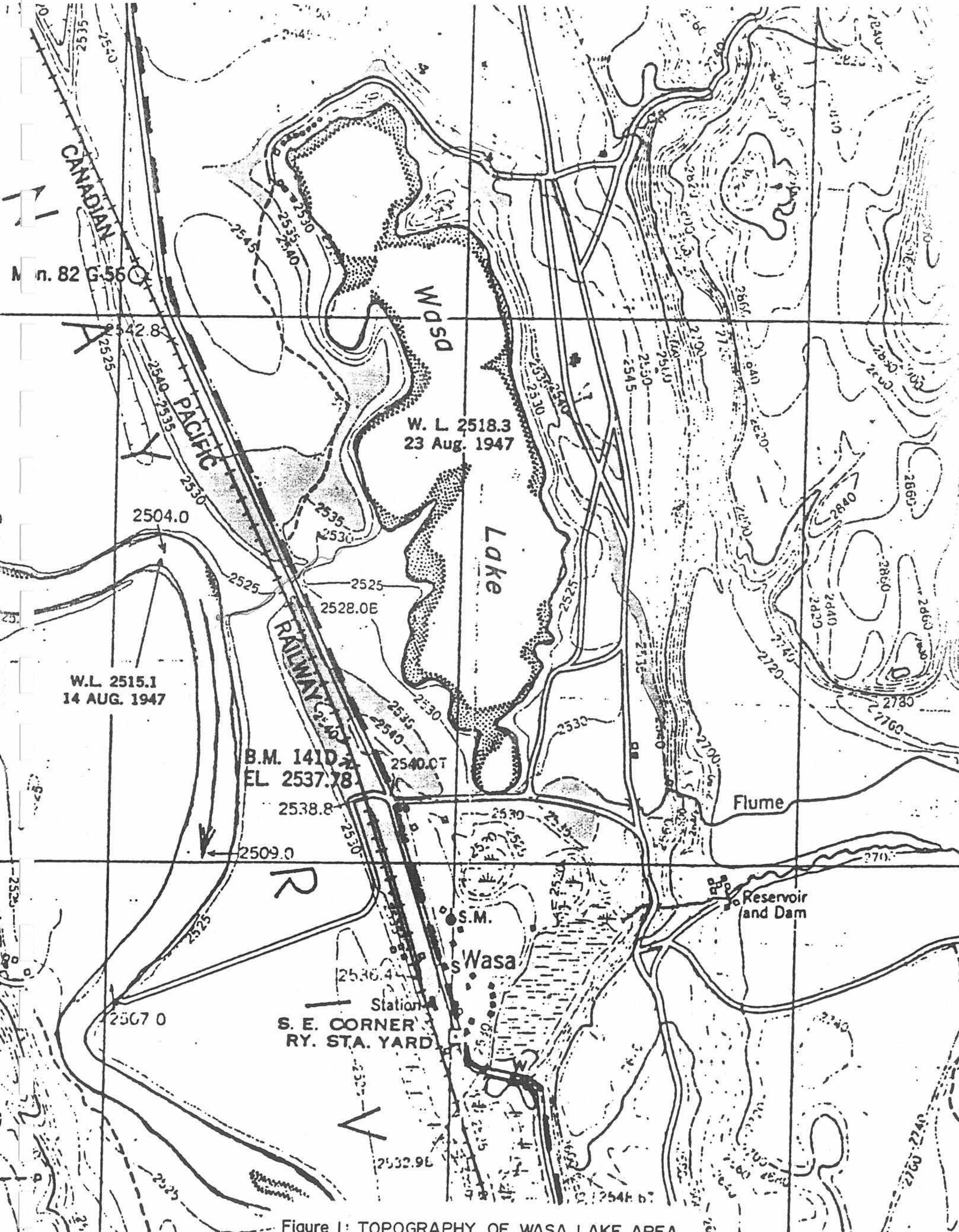
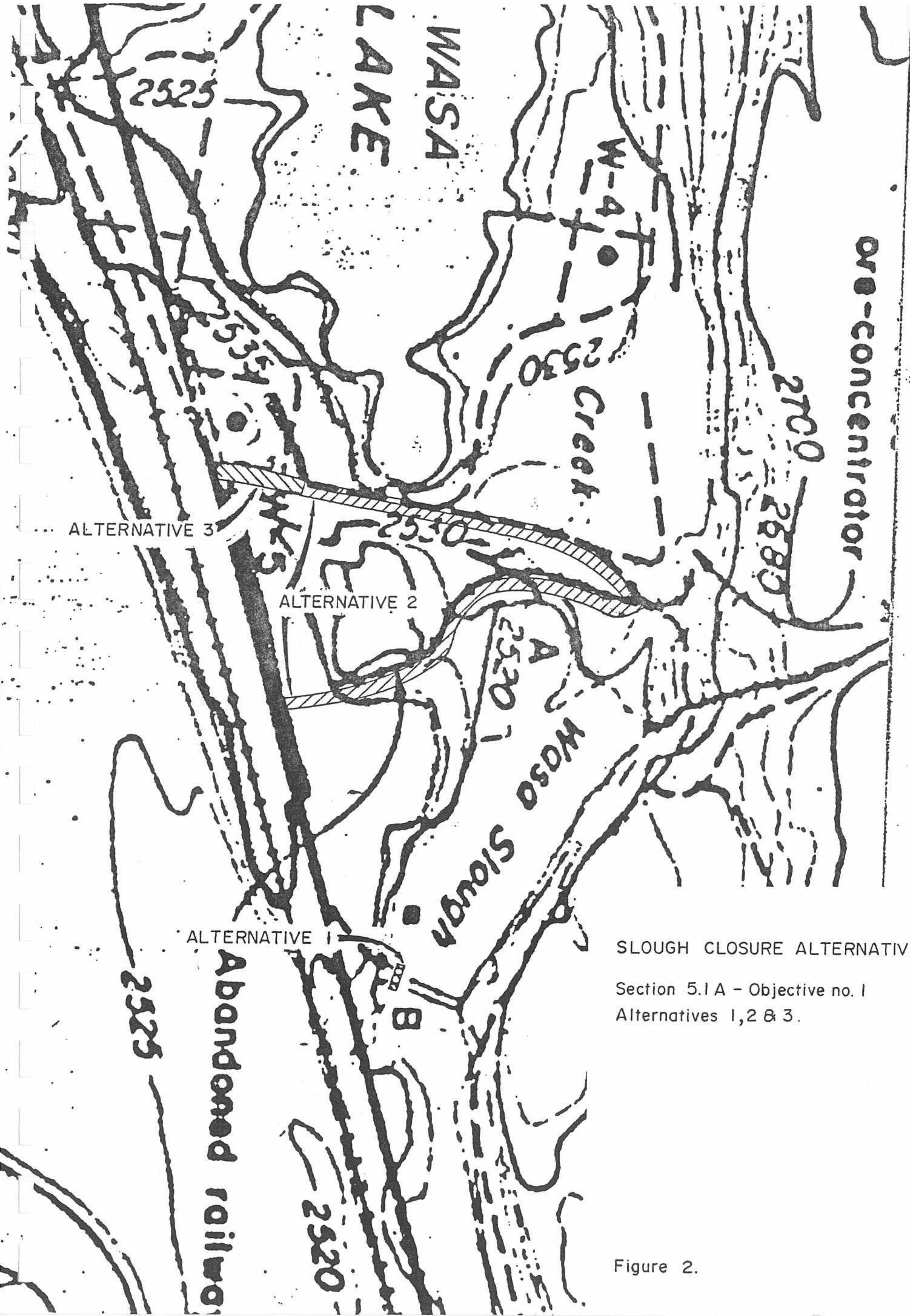


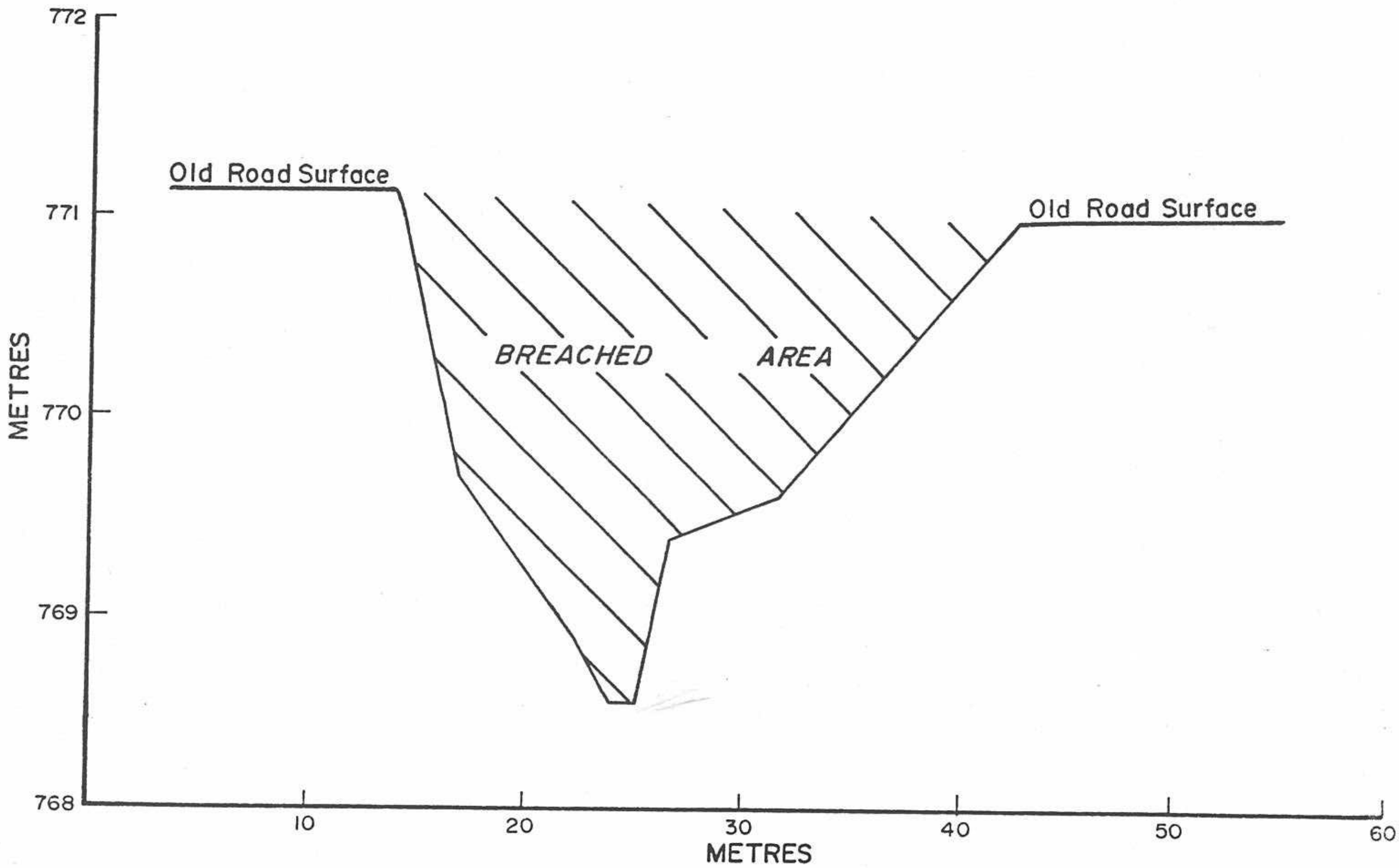

Figure I: TOPOGRAPHY OF WASA LAKE AREA




SLOUGH CLOSURE ALTERNATIVES

Section 5.1 A – Objective no. 1
Alternatives 1, 2 & 3.

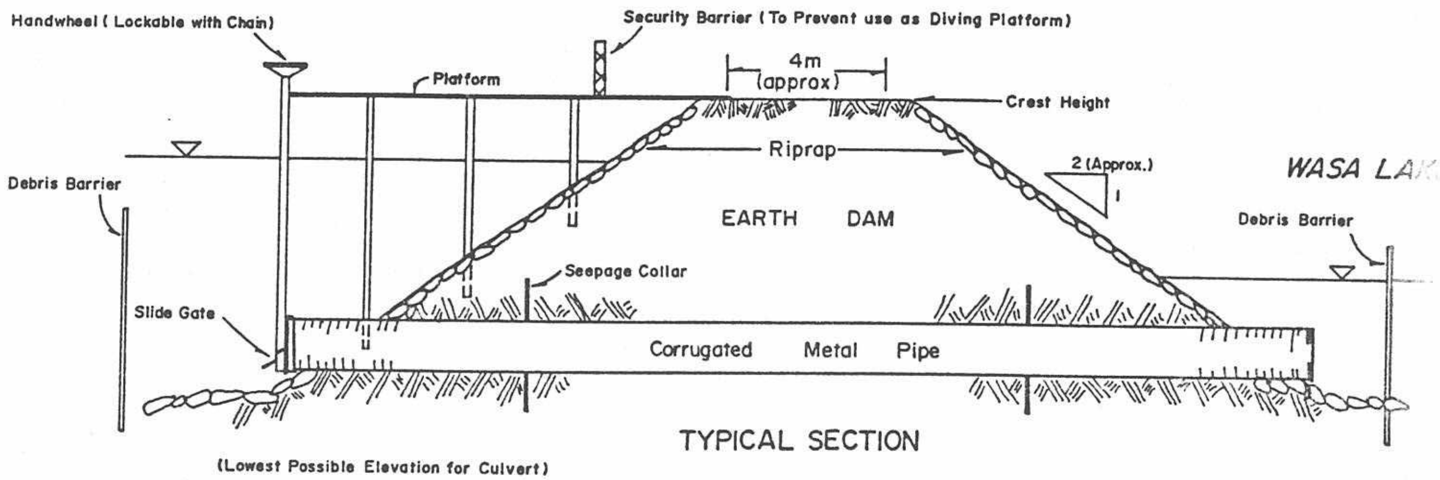
Figure 2.




CROSS-SECTION OF BREACH IN ABANDONED HIGHWAY

Figure 3

# TYPICAL CONTROL STRUCTURE



# TYPICAL SLIDE GATE SPECIFICATIONS

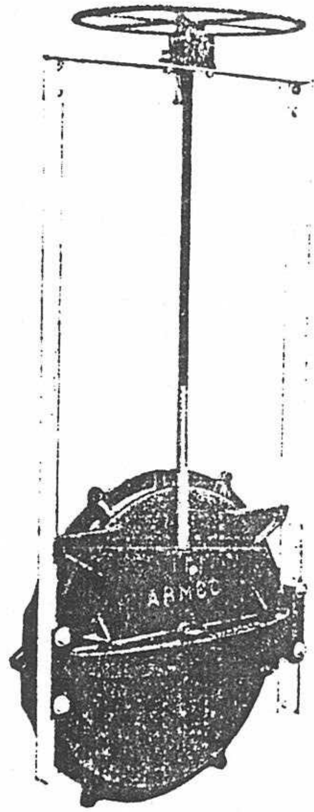
# Model 20-10C Slide Gate

*20-foot seating head or*
*10-foot unseating head*
*Round opening*
*Spigot or flat back*
*Unique wedging action*

*Cast iron or bronze seating surfaces*
*Galvanized steel guides and head angles*
*Rising stem*
*Cast iron frame, slide and yoke*

## APPLICATIONS

- Water treatment plants • Sewage treatment plants
- Flood control • Irrigation projects




## DESCRIPTION

Unique design of Model 20-10C makes it ideal for controlling flow through openings with up to 20-foot face head and 10-foot back head. The iron slide has an eye cast at the center of the dome on its seating pressure side. A heavy cast iron beam connects to this eye by bolting. The ends of the beam act as wedges. As the gate is closed, the ends of the horizontal beam make contact with the wedge blocks on the frame. The wedging action is transferred back through the beam to the center of the domed slide. By applying the wedging force at the center of the slide, wedging pressure is applied throughout the circumference of the slide to the corresponding seating faces on the frame.

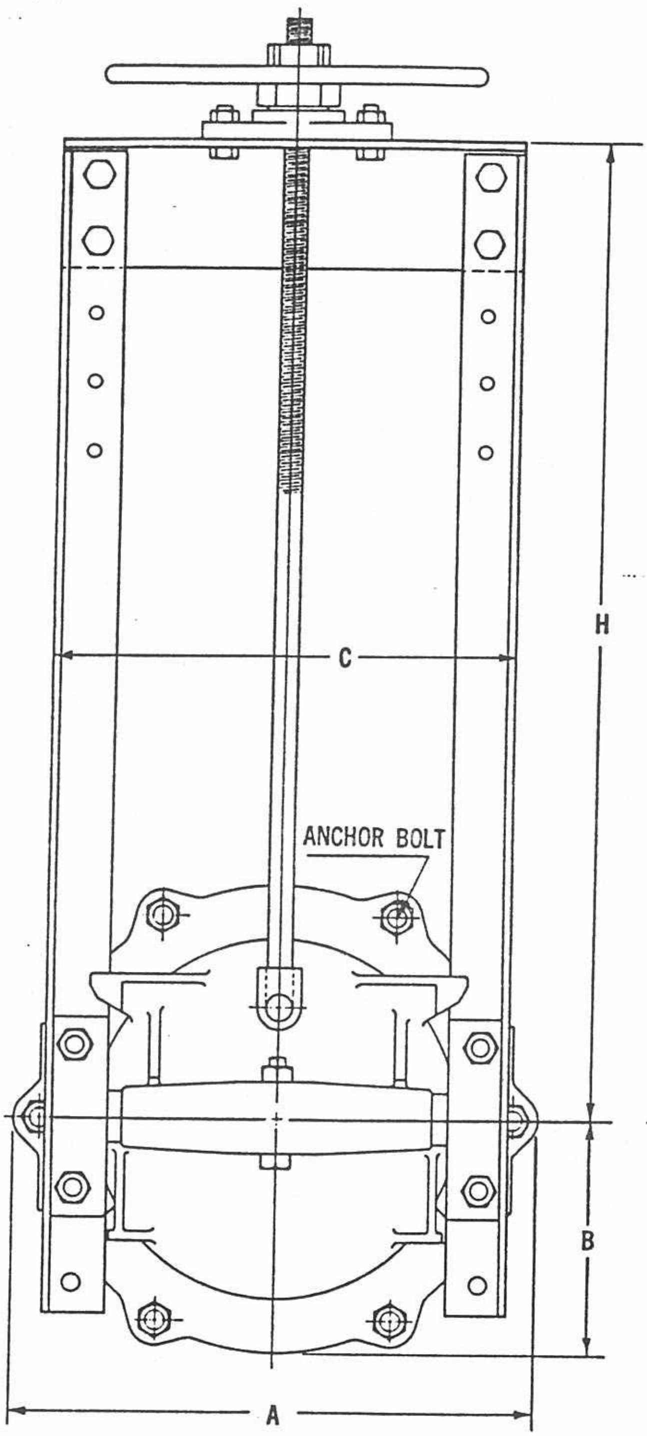
The gate is made with a spigot back seat for attaching to corrugated steel pipe or to be embedded in concrete. All sizes are available with a flat back seat for attaching to an existing headwall or flanges. In those locations where corrosive conditions require additional protection, galvanized steel guides and head angles can be replaced with a framework of stainless steel. Stems can likewise be stainless steel instead of galvanized.

(all dimensions in inches)

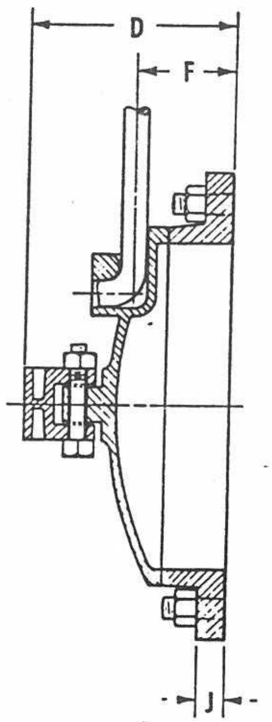
| GATE SIZE (diameter) | A | B | C | D | E | F | G | H | J | K | STEM SIZE |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 8 | 12 3/4 | 5 3/4 | 11 3/8 | 4 7/8 | 4 3/4 | 2 3/8 | 2 1/8 | 24 | 9/16 | 5/16 | 7/8 |
| 10 | 15 1/4 | 6 3/4 | 13 3/8 | 5 1/8 | 4 7/8 | 2 3/8 | 2 1/4 | 24 | 5/8 | 3/8 | 7/8 |
| 12 | 17 1/2 | 8 | 15 3/8 | 5 3/8 | 5 1/8 | 2 1/2 | 2 1/4 | 24 | 11/16 | 3/8 | 7/8 |
| 14 | 20 1/8 | 9 1/4 | 17 3/8 | 5 7/8 | 5 5/8 | 2 1/2 | 2 1/4 | 36 | 11/16 | 3/8 | 7/8 |
| 16 | 22 1/4 | 10 1/4 | 19 3/8 | 6 1/2 | 6 1/4 | 2 1/2 | 2 3/8 | 36 | 11/16 | 7/16 | 7/8 |
| 18 | 24 1/2 | 11 | 22 7/8 | 7 1/2 | 7 3/8 | 3 1/4 | 3 1/8 | 36 | 11/16 | 1/2 | 1 1/8 |
| 20 | 27 | 12 1/4 | 24 7/8 | 8 | 7 7/8 | 3 1/4 | 3 1/8 | 48 | 3/4 | 9/16 | 1 1/8 |
| 21 | 28 1/4 | 12 7/8 | 25 7/8 | 8 3/8 | 8 1/8 | 3 3/8 | 3 1/8 | 48 | 3/4 | 5/8 | 1 1/8 |
| 24 | 31 1/2 | 14 1/2 | 28 7/8 | 9 5/8 | 9 3/8 | 3 3/8 | 3 1/8 | 48 | 13/16 | 3/4 | 1 1/8 |
| 30 | 39 1/4 | 18 1/8 | 35 7/8 | 11 1/8 | 10 3/4 | 4 1/4 | 3 7/8 | 60 | 7/8 | 7/8 | 1 1/2 |
| 36 | 45 1/4 | 21 1/8 | 41 7/8 | 12 3/4 | 12 3/8 | 4 1/2 | 4 1/8 | 72 | 1 | 1 | 1 1/2 |

Figure 5

# TYPICAL SLIDE GATE SPECIFICATIONS




**Armco Model 20-10C**
**Slide Gate**
**over-all dimensions**



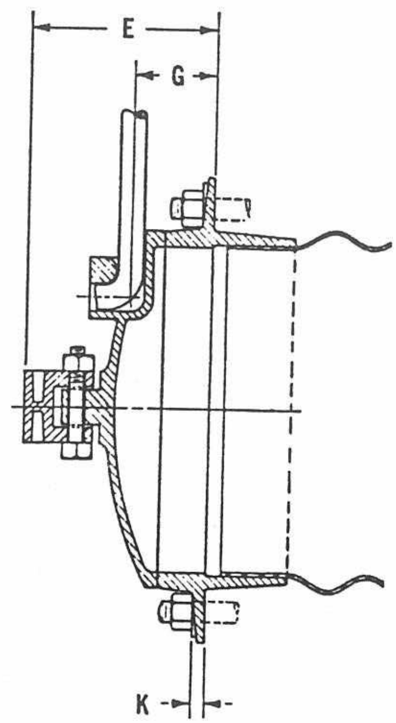




Figure 6

## TYPICAL FLAP GATE SPECIFICATIONS

# Model 10C Flap Gate

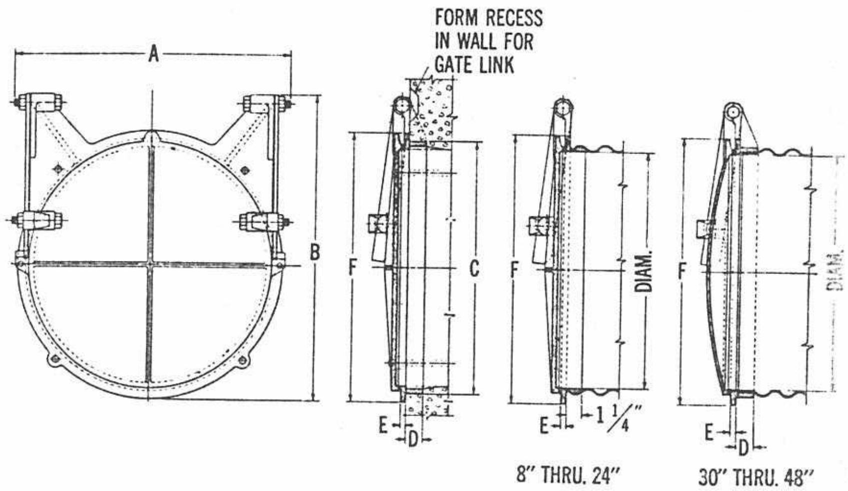
*10-foot seating head*
*Round opening*

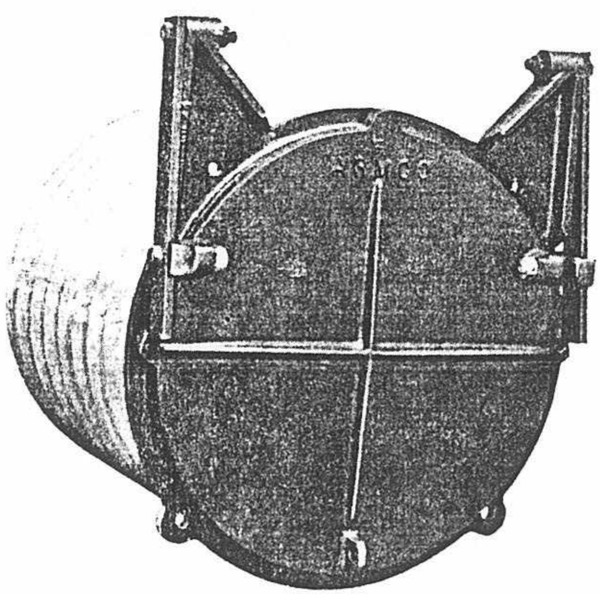
*Spigot back*
*Cast iron seating surfaces*

The Model 10C Flap Gate consists of the simplest possible design with double hinge action for heads to 10 feet. Pivot points are stationary. Ring and flap are of cast iron with galvanized steel hinge arms and assembly bolts. Extension of the cast iron bosses of the flap over the top of the pivot arms limits the double hinge action, and prevents the bottom of the flap from folding inside the ring and wedging the gate in the open position.

The gate is supplied only in spigot back for attaching to corrugated steel pipe or for attaching to a concrete headwall with anchor bolts at the time the wall is poured. The gate opens under a minimum head differential, yet is also positive closing under a few inches of water on the face of the gate.

### Over-all dimensions

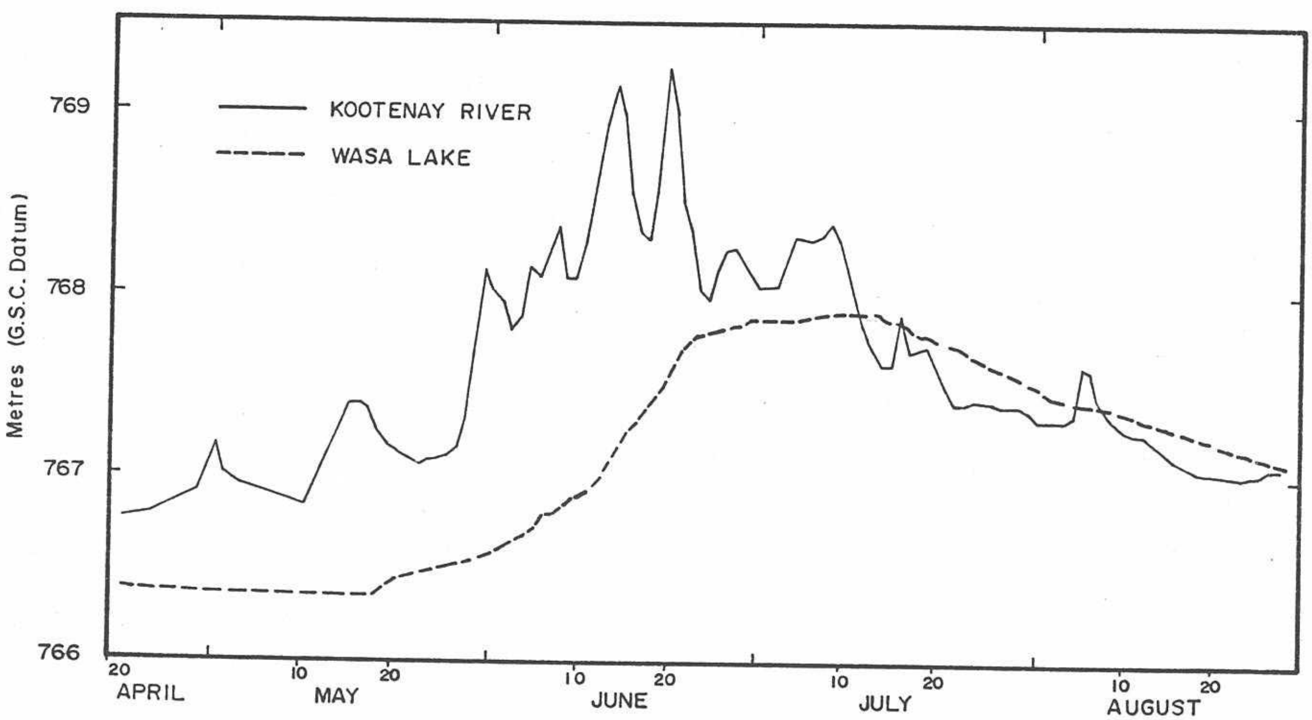


(all dimensions in inches)

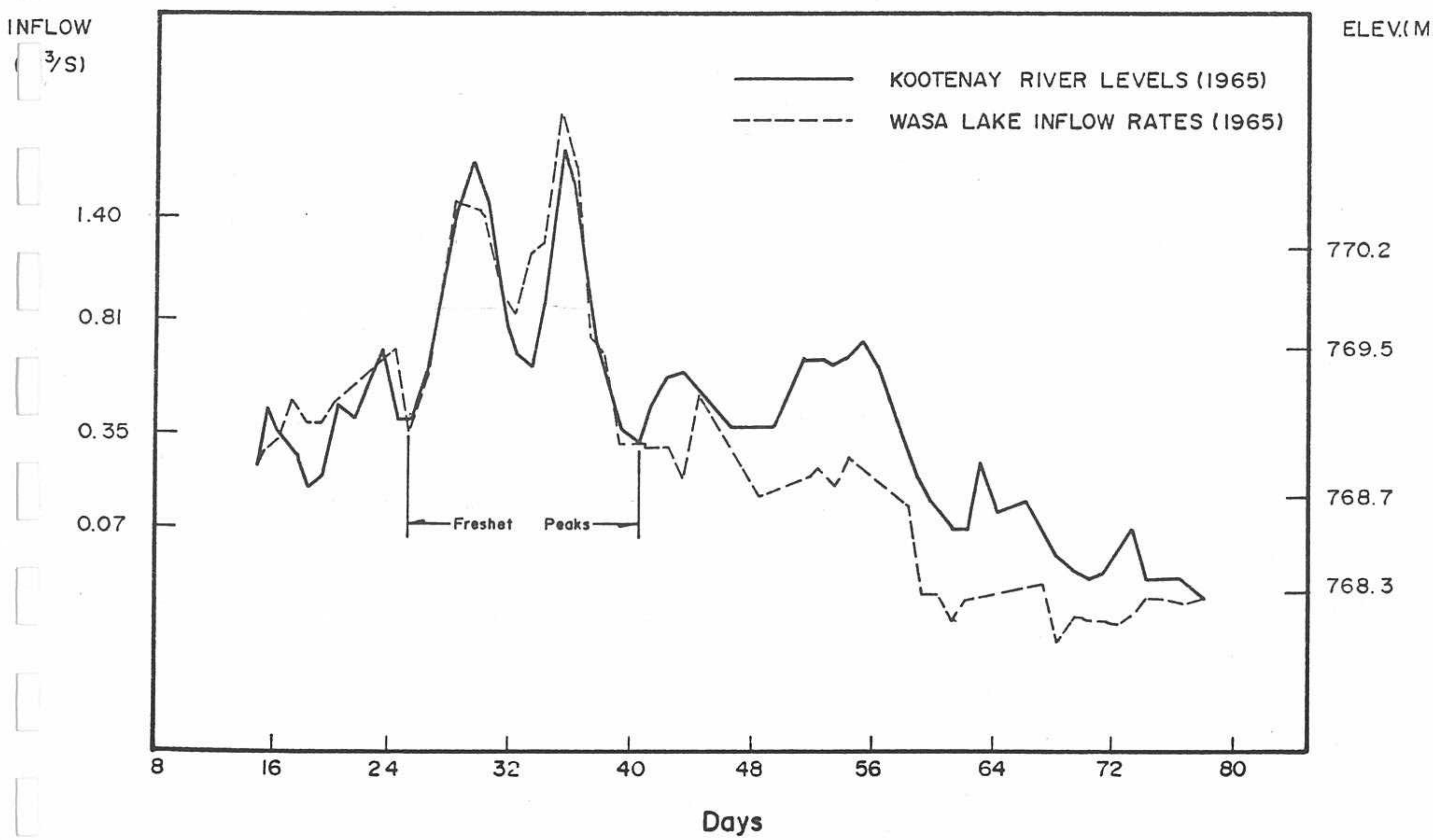
| GATE SIZE (diameter) | A | B | C | D | E | F |
|---|---|---|---|---|---|---|
| 4 | 6 | 5 7/8 | 4 1/2 | 7/8 | 1/4 | 5 1/4 |
| 6 | 8 1/8 | 8 3/8 | 6 1/2 | 7/8 | 1/4 | 7 1/4 |
| 8 | 11 1/4 | 11 3/8 | 8 3/4 | 1 1/8 | 3/8 | 10 |
| 10 | 13 1/4 | 14 | 11 | 1 1/8 | 7/16 | 12 1/4 |
| 12 | 15 1/4 | 16 1/2 | 13 | 1 1/8 | 1/2 | 14 1/2 |
| 14 | 17 1/4 | 19 | 15 | 1 1/4 | 9/16 | 16 3/4 |
| 15 | 13 1/4 | 20 1/4 | 16 | 1 1/4 | 9/16 | 17 3/4 |
| 16 | 19 1/4 | 21 3/8 | 17 | 1 1/4 | 9/16 | 18 3/4 |
| 18 | 22 3/4 | 24 1/8 | 19 1/8 | 1 9/16 | 9/16 | 21 |
| 20 | 24 3/4 | 26 3/4 | 21 1/4 | 1 3/8 | 5/8 | 23 1/4 |
| 21 | 25 3/4 | 28 | 22 1/4 | 1 3/8 | 5/8 | 24 1/4 |
| 24 | 28 3/4 | 31 3/4 | 25 1/4 | 1 1/2 | 5/8 | 27 1/2 |
| 30 | 35 1/2 | 38 3/4 | 32 1/8 | 1 9/16 | 5/8 | 34 |
| 36 | 41 1/2 | 46 3/4 | 38 1/4 | 2 1/16 | 11/16 | 40 7/8 |
| 42 | 47 1/2 | 54 1/2 | 44 1/4 | 2 5/16 | 3/4 | 47 |
| 48 | 53 1/2 | 62 1/4 | 50 3/4 | 2 3/4 | 3/4 | 54 |

Figure 7




Comparison of 1965 Lake and River Levels.

Figure 8




COMPARISON OF 1965 LAKE INFLOW RATE AND RIVER LEVELS.

Figure 9