STRATHCONA DAM & RESERVOIR
ELK RIVER
CHANNEL STABILITY
AND MITIGATIVE MEASURES

Prepared for:

Mr. G.J. Birch
Environmental Resources
B.C. HYDRO AND POWER AUTHORITY
#1312 - 808 Nelson Street
Vancouver, B.C.

PHONE: (604) 663-1803

Prepared by:

Dr. R. Kellerhals, P.Eng.
KELLERHALS ENGINEERING SERVICES LTD.
Box 250,
Heriot Bay, B.C.
V0P 1H0

PHONE: (604) 285-3570
FAX: (604) 285-2981

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ABSTRACT

The channel morphology of the lowermost 5 km of the Elk River in Strathcona Park has undergone quite drastic changes over the last 50 years. The channel is now much wider and far less stable than in 1940, and this, in turn, has resulted in less fish and elk habitat and degraded aesthetic values. Clear-cut logging of the flood plain and the diversion of Crest Creek and the Heber River into the Elk River are probably the main causes of this change. FO

The development of a more stable stream channel, as predicted by Karanka and Kellerhals (1980) has not materialized. Along Reach 1, below the gorge, the channel appears somewhat less stable now than in 1980. While this may be, at least partly, a result of the very large floods of November, 1990, it is noteworthy that channel width has remained reasonably stable since 1966. The observed fluctuations may well represent the variable magnitude of floods. It appears prudent to assume that the present, very unstable, channel morphology represents some kind of dynamic equilibrium which will persist for the foreseeable future unless remedial measures are implemented. FP

Rip-rap placement, the standard technical solution to channel instability problems, is not feasible as a mitigating option here because of cost and because of the intrusive nature of such work. Cable tying of log debris and standing trees, as first proposed by Karanka and Kellerhals (1980) has since been tried successfully on the Coldwater and Deadman Rivers in B.C. It is still the most realistic alternative here. It would need to be installed over longer, more continuous, bank reaches than proposed in the above report to achieve its objective. A test project is recommended and could be undertaken on short notice at any time, as long as only standing trees and existing bank debris is being tied. There would be some advantages to moving drift logs from gravel bars to the channel banks, but this would require instream work with an excavator.

Three other possibilities for improving fish habitat are identified. They are:

(i) improving the rip-rap protection of existing road embankments;

(ii) improving fish passage through culverts; and

(iii) excavating new and/or enlarging existing wetlands and back channels.

In all three cases staged implementation based on the availability of funds is feasible. Trial projects at one site each are strongly recommended.

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There is no need for further general engineering studies. The next phase should consist of the selection of experimental sites for some or all of the proposed mitigation measures, to be followed by detailed design, construction and several years of annual monitoring. Lack of inter-agency cooperation and lack of staff continuity within Parks B.C. are seen as the main obstacles to having any mitigation works implemented. To overcome this, a project coordinator needs to be designated or appointed with the clear understanding that it is for the intermediate to long term. After familiarizing him/herself with the river, he/she could carry out the detailed design of some initial mitigation works, supervise their construction and then monitor their performance.

In view of the major channel changes brought about by the floods of fall, 1990, new air photo coverage for the Elk River, at a scale of 1:10,000, is urgently needed. Based on that, the project coordinator should update the channel morphology monitoring work of Karanka and Kellerhals (1980).

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STRATHCONA DAM AND RESERVOIR
ELK RIVER CHANNEL STABILITY, MITIGATIVE MEASURES

1: INTRODUCTION

The Elk River originates in the Central Vancouver Island Mountains and flows northeastward towards the Campbell River and into Discovery Passage (*Figure 1.1*). At the point where the river now enters the Upper Campbell Lake reservoir, it had a natural drainage area of 262 km^2.

Although the entire natural Elk River drainage area has been part of Strathcona Provincial park since its creation in 1911, the lower reaches of the river are extensively modified by direct and indirect, mostly man-made, interferences. As indicated in Tredger et al. (1980), the main impacts are thought to be:

1. clear-cut logging of the flood plain (mid-40's);
2. flooding due to a landslide into a headwaters lake (1946); landslide
3. road construction on the flood plain (mid-40's to present); RD
4. flooding of the lowermost 10 km of river by B.C. Hydro's Strathcona Dam;
5. complete diversion of Crest Creek into the Elk River (drainage area 17 km^2), increasing the drainage area by 25 per cent at the point of diversion (to a total of 86 km^2) and by 6 per cent (to 279 km^2) at the mouth; and
6. diversion of parts of the Heber River (maximum capacity 8.5 m^3/s, mean flow 3 m^3/s) into the Elk River, which, together with item 5 above, increases the low to intermediate flows by some 60 to 80 per cent.

The overall effects of these interferences has been a rather drastic change in river morphology along the two lowermost alluvial reaches of the Elk River (*Figure 1.2*). The active un-vegetated channel zone is now 2 to 3 times as wide as it was before 1940 and this process of flood plain erosion appears to be continuing. Much fish and wildlife habitat has been lost in the process (Tredger et al., 1980; M.W. Patterson, 1989; Aquatic Resources Ltd., 1991).

Several studies have addressed this problem (Galbraith, 1973; Karanka and Kellerhals, 1980; Karanka, 1983; Kellerhals and Denton, 1984; Patterson, 1989) but only the first report was acted on by carrying out its recommendation of removing the large volume of debris from the active channel. This did not produce the desired result of stabilizing the river.

The present study is a follow-up on the earlier work by the writer and by others, to see whether the predictions made some 10 years ago are confirmed by recent developments and to determine if the earlier mitigation recommendations are still worth considering. The detailed Terms of Reference are attached here as Appendix 1.

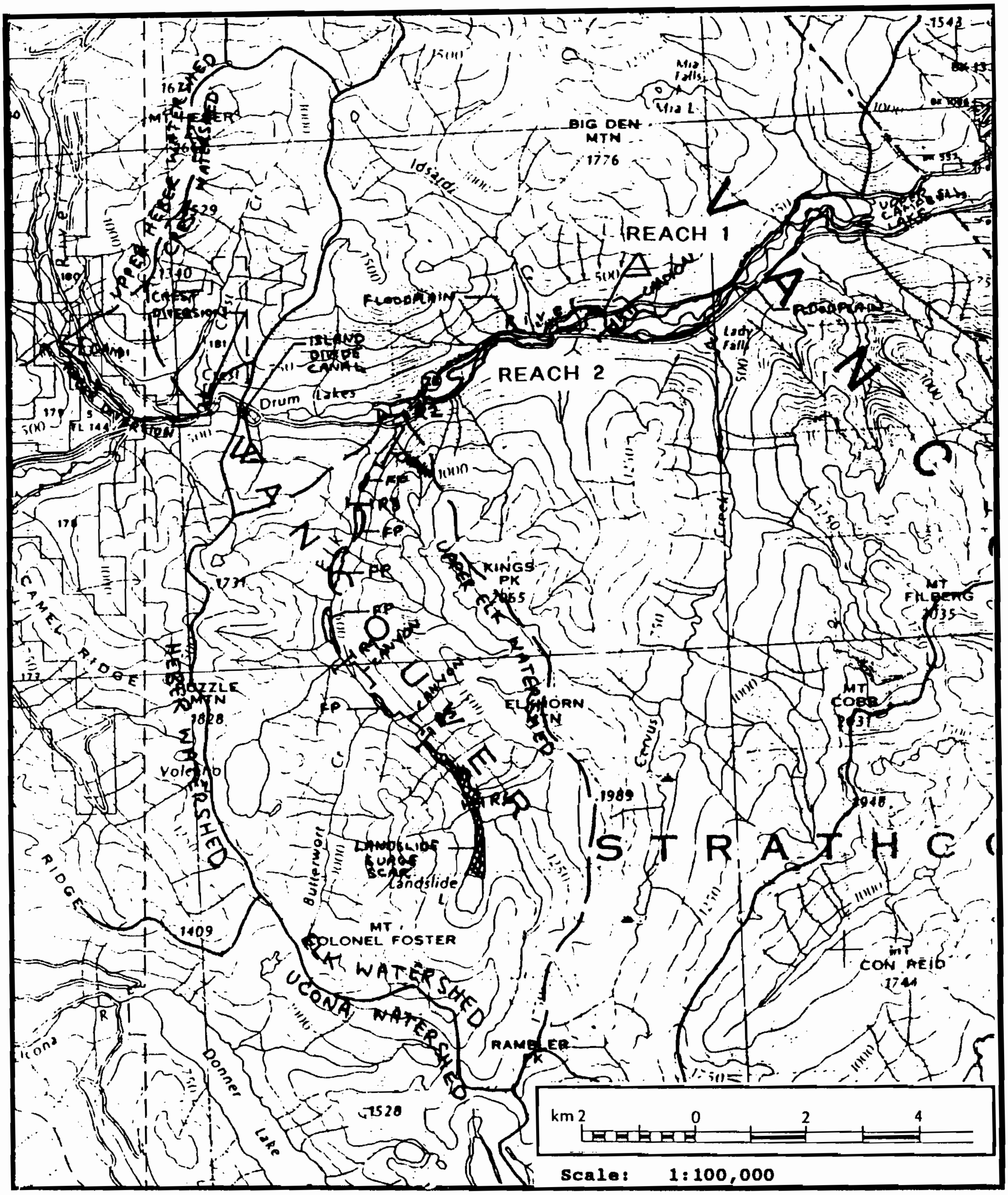

Figure 1.2: A map of the Elk River watershed showing the location of Reaches 1 and 2 (from Karanka and Kellerhals, 1980).

2: GENERAL CHANNEL STABILITY

During the fall of 1990, the Elk River experienced at least 3 large floods, which is an unusual occurrence. It has probably left the river looking less stable than what it might look after a more "*normal*" winter. However, even with some allowance for this, it is quite evident that neither of the two lower Elk River reaches (*Figure 1.2*) are becoming more stable.

The upper reach (Reach 2), between the gorge and Drum Creek has always been relatively more stable than Reach 1. Aquatic Resources Ltd. (1991) determined a channel width of 53 m in 1991, which compares to 50.1 m determined by Karanka and Kellerhals (1980) for 1976 and 44.0 m according to the 1977 habitat mapping.

Although the above numbers appear to suggest a possible trend towards some kind of dynamic equilibrium with a wider channel after major floods, such as fall 1990, and some flood plain building during years of lower flows, the field evidence indicates otherwise. There are practically no new flood plain surfaces, but many sites of bank erosion, where the river is eroding relatively high flood plain or terrace banks, consisting mainly of medium to coarse gravel (*Plates 2.1 and 2.2, also Figure 4.4*). Besides the on-going loss of flood plain areas, this has the added effect of supplying large volumes of gravel to Reach 1, downstream, which, in turn, is a major factor contributing to the instability of that reach.

The reason why the Elk River channel zone is narrower and more stable along Reach 2 than along Reach 1 is the much narrower valley floor and the smaller drainage area. The channel is extensively confined by non-alluvial banks or bedrock and by some rip-rap-protected road embankments. The flood plain banks are also significantly higher along Reach 2 than along Reach 1 and this too, tends to contribute to a more stable, narrower channel.

The trend towards channel incision and stability predicted for Reach 2 by Karanka and Kellerhals (1980) is not evident anywhere. While I still believe that a return to a more stable, dynamic equilibrium is inevitable, the changes over the last few years suggest that this might be quite far off in the future. Any land management decisions should be based on the assumptions of continuing, slow and irregular losses of flood plain area along Reach 2.

Along Reach 1, between the gorge and Upper Campbell Lake, channel instability and the rate of flood plain erosion appear to have increased lately. In 1980 there was definite evidence of extensive vegetation encroachment into the active channel zone, particularly near the upstream end of the reach on the large left bank gravel flats below the gorge. Karanka and Kellerhals (1980) interpreted this as a possible indication of channel incision and therefore the beginning of a trend towards a more stable, narrower channel. After the floods of fall 1990, there is little left of the above vegetation (although some has persisted elsewhere, see below). By all accounts the un-vegetated active channel zone is now wider and more unstable than in 1980.

The width measurements for the active channel (from air photos) of Karanka and Kellerhals (their Table 8), combined with the later data of Aquatic Resources Ltd. (1991), indicate that channel width has fluctuated in the range of 115 to 150 m over the period since 1966. This may well represent a more or less permanent dynamic equilibrium appropriate for the present conditions of increased flows (due to two upstream diversions), increased gravel supply (due to channel instability and extensive bank erosion along Reach 2) and an easily eroded flood plain covered by relatively sparse, mostly deciduous forest (due to past clear-cut logging of a mature, coniferous forest) (*Plates 2.3 and 2.4*). The corresponding pre-development equilibrium state was characterized by a channel width of around 45 m and a much more stable channel location.

In contrast to Reach 2, there is clear evidence along Reach 1 of some new, and very low, flood plain surfaces developing in parts of the active channel zone (*Plate 2.5*). Unfortunately the channel shifts about so much that the expected average time of persistence of all flood plain areas along Reach 1 has dropped drastically and this will continue to work against any re-establishment of a mature, coniferous forest cover.

As long as the two diversions are maintained, they, in turn, perpetuate the instability and bank erosion along Reach 2, and the elevated gravel supply to Reach 1. Increased flows and gravel supply are well known to cause channel shifting which closes the cycle of cause and effect that appears to determine the present dynamic equilibrium along Reach 1.

3: MITIGATION OF CHANNEL INSTABILITY

Reducing the rate at which the active channel zone of Reach 1 shifts about on the flood plain would clearly be beneficial from several points of view:

i. It would protect existing flood plain areas and, in the long term, help re-establish a more mature flood plain forest cover;

ii. It would provide more stable fish habitat; and

iii. As long as the channel zone is kept more or less at its present width, it would continue to produce areas of emerging pioneer vegetation, which might be of some benefit to wildlife.

The following two mitigation measures have been identified:

i. A continuing primary cause of the channel instability in Reach 1 is the increased flow due to the two diversions. If they could be eliminated, or at least reduced significantly, one might then also be able to address the bank erosion along Reach 2 and thereby eliminate the elevated gravel supply to Reach 1.

While abandoning the diversions altogether carries a rather large and long term economic penalty, modifying them in such a way that they no longer contribute to flood events would only incur initial design and construction costs while leaving the long-term power production benefits more or less intact. There is some evidence based on experience with the Kemano River, where the Alcan diversion affects mainly low to intermediate flows and contributes little to major floods, that both increased flood peaks and increased mean flows lead to channel widening, but the effects of the increased flood peaks are clearly more severe. Note, that in the present situation, it is mainly Crest Creek that contributes to the flooding.

ii. The only other option is to increase the erosion resistance of the flood plain banks with the twin objectives of reducing the rate of channel shifting and reducing the gravel supply to the channel. The standard engineering solution to such a problem is to protect the river banks with rip-rap or to confine the channel between rip-rap dikes. Although this is entirely feasible from a technical point of view, this solution would constitute a massive, unsightly, and very costly interference with the present, still relatively natural-looking, channel system. Clearly this is both too expensive and inappropriate for a park setting.

Placing rip-rap only at local trouble spots, where rapid banks erosion happens to be taking place at some particular time, is also not an effective alternative, certainly not along Reach 1, because the main channel shifts far too easily and frequently, and the areas where rapid bank recession takes place tend to shift with it. If the river succeeds in getting around or behind any short section of rip-rap-protected bank, the rip-rap often ends up contributing to channel instability rather than preventing it.

There are two situations where rip-rap placement might be effective and beneficial. Some of the highway embankments along the river are protected with relatively uniform and small rip-rap which is neither secure nor does it provide the excellent fish habitat that very coarse, irregularly placed, rip-rap can provide. Up-grading these embankments is discussed below in Section 4.

Along Reach 2 there are several high, eroding gravel banks, such as the one shown on *Plate 2.1*. These sites have been under river attack for a long time and continue to augment the gravel supply to the river. It would clearly be beneficial, particularly for Reach 1, if these banks could be protected. Since the general channel alignment is far more stable along Reach 2 than along Reach 1, and there are various in-erodible spots available, to which a bank erosion scheme can be tied, it should be feasible to protect a few of the main erosion spots along Reach 2 with rip-rap. However, this would be expensive and would require long term maintenance. A rip-rap bank protection scheme, which I helped design recently on a river of comparable size, was projected to cost approximately $1,500 per linear metre.

The tree and debris-tying alternative first proposed by Karanka and Kellerhals (1980) is probably the only viable alternative bank protection scheme. Since 1980 the method has been tried successfully on a few, albeit considerably smaller, streams where it has successfully retarded bank erosion and provided stable fish habitat (A. Kaverly and M.

Rosenau, pers. comm.; plus see Sheeter et al., 1981 and Binns, 1986). With 11 years of added growth, the new forest cover on the flood plain is now more suitable for applying this method than in 1980, because the trees, particularly the Alders, have grown significantly, while the large old stumps left from the pre-1940 forest are still capable of serving as cable anchors.

The basic design proposed in Karanka and Kellerhals (1980) remains valid and is reproduced as *Figure 3.1* in this report. Besides standing trees and large old stumps, one might also consider using cedar dead-men and logs wedged between standing trees as anchor points. If budget and fisheries constraints permit, it would be desirable to initiate the scheme by moving (with an excavator) some of the relatively unstable debris found on gravel bars (*Plate 3.1*) up against the channel banks and tying it to the bank. However, the scheme is certainly worth trying even if machine access to the river banks is not possible. In that case one would tie back only standing trees on the river bank and suitably-located debris near the banks.

In view of the exceedingly unstable nature of the main channel alignment along Reach 1, spot application of this scheme at a few rapidly-eroding sites (as shown on Figure 12, Karanka and Kellerhals, 1980) is no longer recommended. Once a certain river reach has been selected for treatment, the entire length of treatable river bank on one or both sides of the channel should be treated, regardless of the exact locations where the bank happens to be under attack at the moment. In-erodible, fixed points should be selected as upstream starting points whenever possible.

An excellent reach for a first trial application would be the lowermost 2 km of the Elk River north bank, from the Elk River Timber (ERT) road to the mouth of the river, including all of the Tlools Creek fan (*Plate 3.2*). This site is marked as "Site 2" on *Figure 4.1*. There are also other, shorter, reaches that could be used for an initial study such as "Site 3", upstream of Filberg Creek or "Site D", across the river from "Site 2".

4: OTHER MITIGATION OPTIONS

Channel instability and the much increased width of the active channel zone, are clearly the main problems along the Elk River, as they are associated with loss of fish habitat, loss of terrestrial flood plain habitat and degradation of aesthetic values. However, there are other problems, primarily associated with the road embankments on the flood plain, and they, too, can be mitigated to some degree.

4.1 RIP-RAP EMBANKMENTS

Data presented in Karanka and Kellerhals (1980), Table 8 show that some 15 per cent of the river banks in Reach 1 consist of rip-rap, associated with either the ERT road or Highway 28. Almost all of this rip-rap is too small to assure long-term stability (*Plate 4.1*) and there have, in fact, been recent failures (*Plate 4.2*). From a fisheries point of view, very large and irregularly placed rip-rap has been shown to be most beneficial. It should therefore be desirable, both from a fisheries and a purely engineering perspective, to upgrade the rip-rap protection of the road embankments. This is a practically risk-free mitigation option that could be implemented at any one or at all available sites, depending on the available funds.

In order to be effective, a quarry capable of producing very large rock (1,500 mm and up or 8 tonnes and up) would have to be found or opened up. Depending on the desired degree of protection, and on the state of the existing rip-rap, these very large rocks could be placed as a continuous single or double row over top of the existing rip-rap or as single rocks, one every 10 to 15 m along the toe of the existing embankments. Both schemes would add to the security of the embankments while improving the fish habitat diversity and stability. Good sites for an initial try-out of the scheme are Site 19 on Highway 28 (*Figure 4.3*) or Sites 15 and 16 along the ERT road (*Figure 4.2*).

4.2 FISH PASSAGE AT CULVERTS

Due to inadequate culverts, the Highway 28 and the ERT road embankments interfere with fish access into tributary streams and into some cut-off wetland areas (*Plate 4.3*). Five culverts have been identified as needing upgrading from a fisheries point of view near Sites "A" and "B" (*Figure 4.1 and 4.2*). Generally the work would call for the replacement of the existing culvert with a larger one, set at a lower elevation.

The proposed work is essentially free of technical risk and could be carried out in a piecemeal fashion as funds and other constraints permit. As in the case of cable tying debris for bank protection, it would be desirable to treat at least 1 site as soon as possible in order to gain experience on costs and on effectiveness. Site "A" is proposed, as it is apparently not used by fish now, and as it would also involve some channel excavation, thereby testing the mitigation technique addressed in Section 4.3, below.

Two of the sites also require some channel excavation on one or both sides of the new culvert. At Site 20 (Figure 4.4), where an unnamed creek crosses Highway 28 in two large culverts (*Plate 4.4*), the drop-off at the culvert outlet is an obstacle to fish passage which could be eliminated with a rip-rap weir downstream.

4.3 OFF CHANNEL FISH REARING HABITAT

There is some potential for adding to the amount of fish rearing habitat in back channels and wetlands by excavating some new, small backchannels or by deepening existing drainage courses or off-channel ponds. Sites "A", "B" and "C" (*Figure 4.1*) would appear to be particularly suitable, if the culverts at Sites "A" and "B" were to be improved simultaneously. Some work of this nature was carried out along the Coldwater River (near Merritt, B.C.) in connection with the Coquihalla Highway (see Beniston et al., 1987 and 1988) and has generally been effective in providing Coho rearing habitat.

5: CONCLUSIONS AND RECOMMENDATIONS

Fish habitat along the lower Elk River in Strathcona Park could be improved by various means, some rather experimental, others quite conventional. Previous studies have reached similar conclusions. The problems standing in the way of any implementation appear to be largely organisational. Several of the mitigating options, such as improved culverts or improved road embankments, require close cooperation between various agencies, which appears to be lacking. Another serious problem is the lack of staff continuity, particularly in the lead agency, the Ministry of Parks. Priorizing of project options, detailed design and construction supervision all require some familiarity with the Elk Valley. Once some mitigation measures are implemented, their performance will have to be monitored carefully so that future designs take full advantage of any lessons that might be learned. This, too, requires familiarity with the site and long-term continuity. It is therefore recommended that a project coordinator be appointed who should be willing and capable of acting for a minimum of 5 years. His/or her initial objective should be the implementation of a tree and debris tying bank protection scheme of 1 to 2 km in length (Section 3) and the development of one rearing habitat site involving the excavation of one or more channels, at least 1 deep pool (Section 4.3) and culvert rehabilitation (Section 4.2). Enhancing a number of existing rip-rap embankments (Section 4.1) should also be undertaken as soon as the necessary co-operative agreements and designs can be put in place. The modification of the Crest Creek diversion (Section 3, i.) is the most difficult measure proposed here as it would require a rather elaborate hydraulic structure. The implications of sending the Crest Creek flood peaks back into the Heber River would also need to be carefully evaluated.

Monitoring the general behaviour of the Elk River will require reasonably regular air photo coverage at a suitable, constant scale. In view of the large floods of fall, 1990, a new set of air photos is urgently needed. A scale of 1:10,000 is recommended. If possible, the air photos should be obtained at a time when the leaves are not yet out, or have fallen off, but without snow on the ground.

The air photo record needs to be supplemented by ground photos taken at sites of particular interest. The photos taken as part of this study (approximately 5 rolls of film) could serve as a starting point.

One of the first undertakings of a project coordinator should be to update the channel morphology monitoring from air photos initiated by Karanka and Kellerhals (1980)

6: SOURCES OF INFORMATION

6.1 REFERENCES

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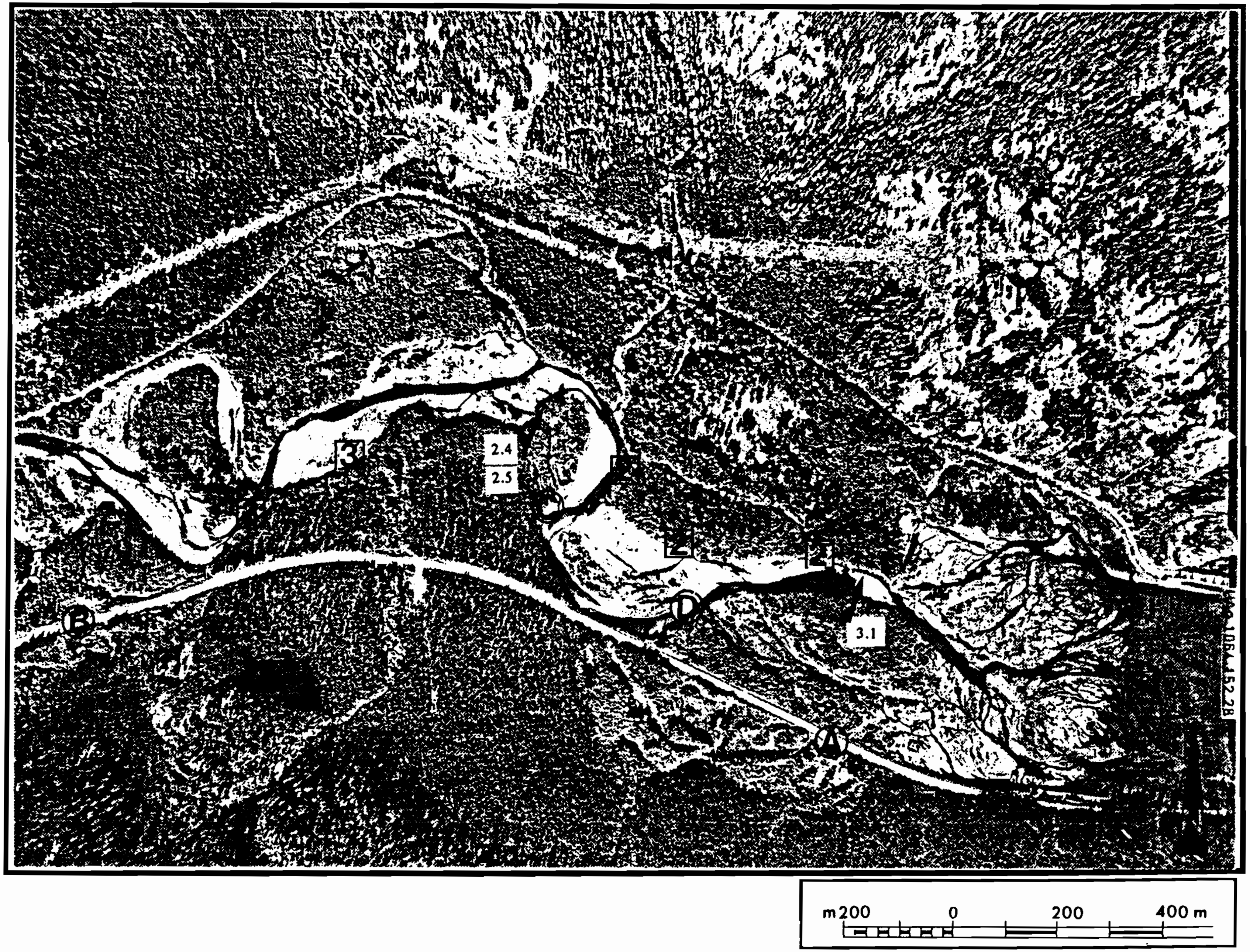
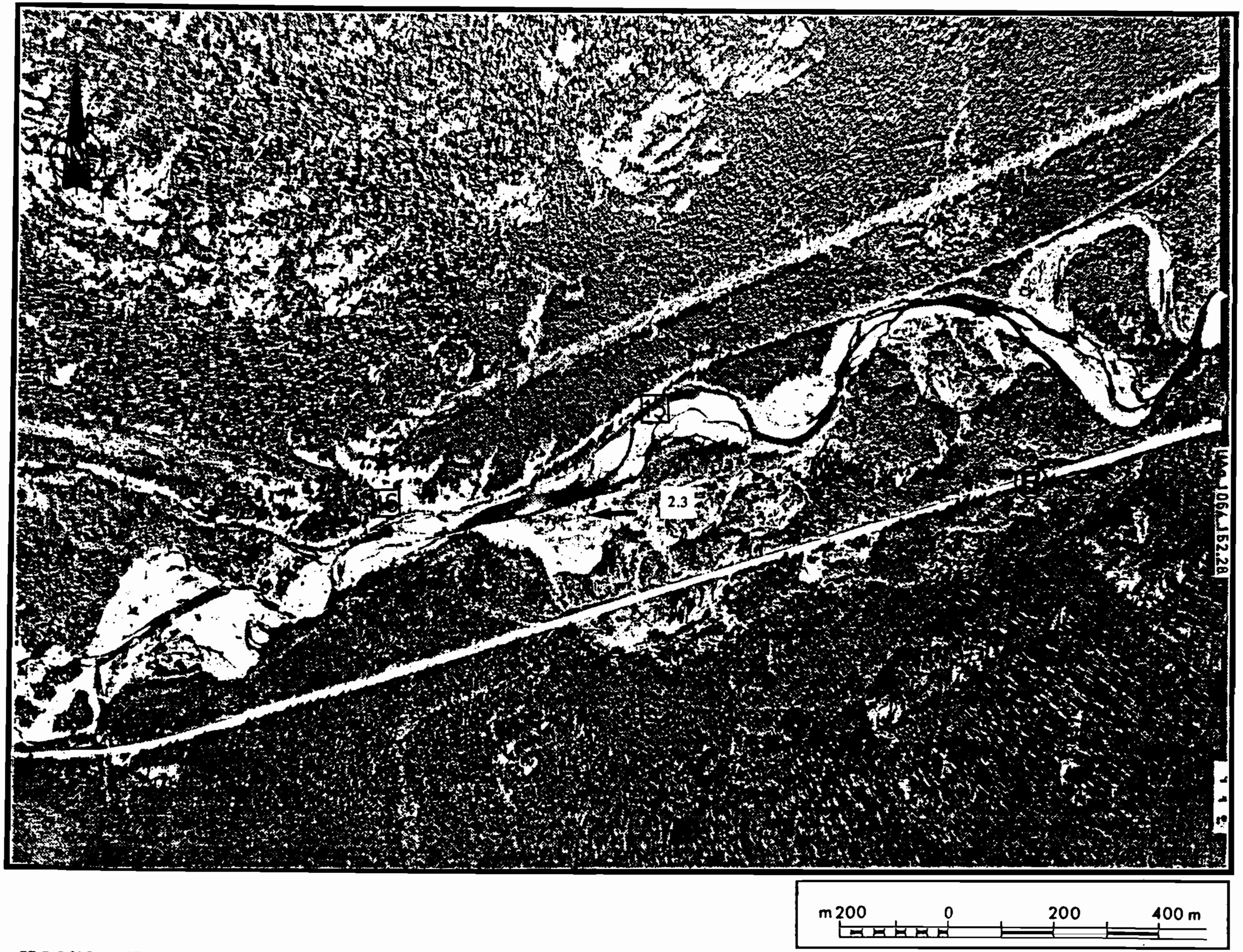


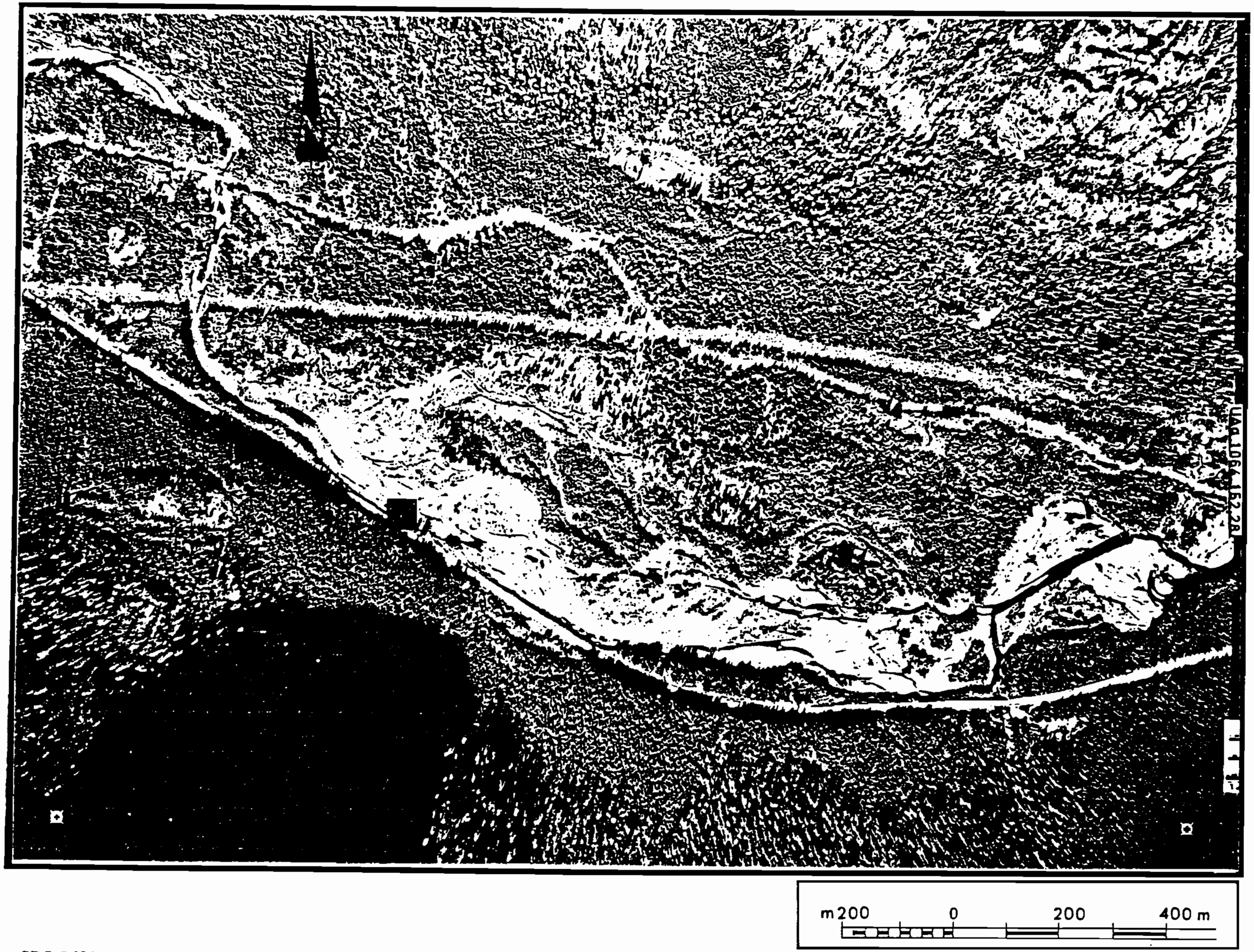
Air Photo SRS 3692 - 165, September 22, 1987. Scale: 1:10,000

Figure 4.1: Elk River downstream end of Reach 1.
Note: Numbers in boxes correspond to sites used in Karanka and Kellerhals, 1980. Lettered sites are new. Two digit #'s show Plate locations in this report.



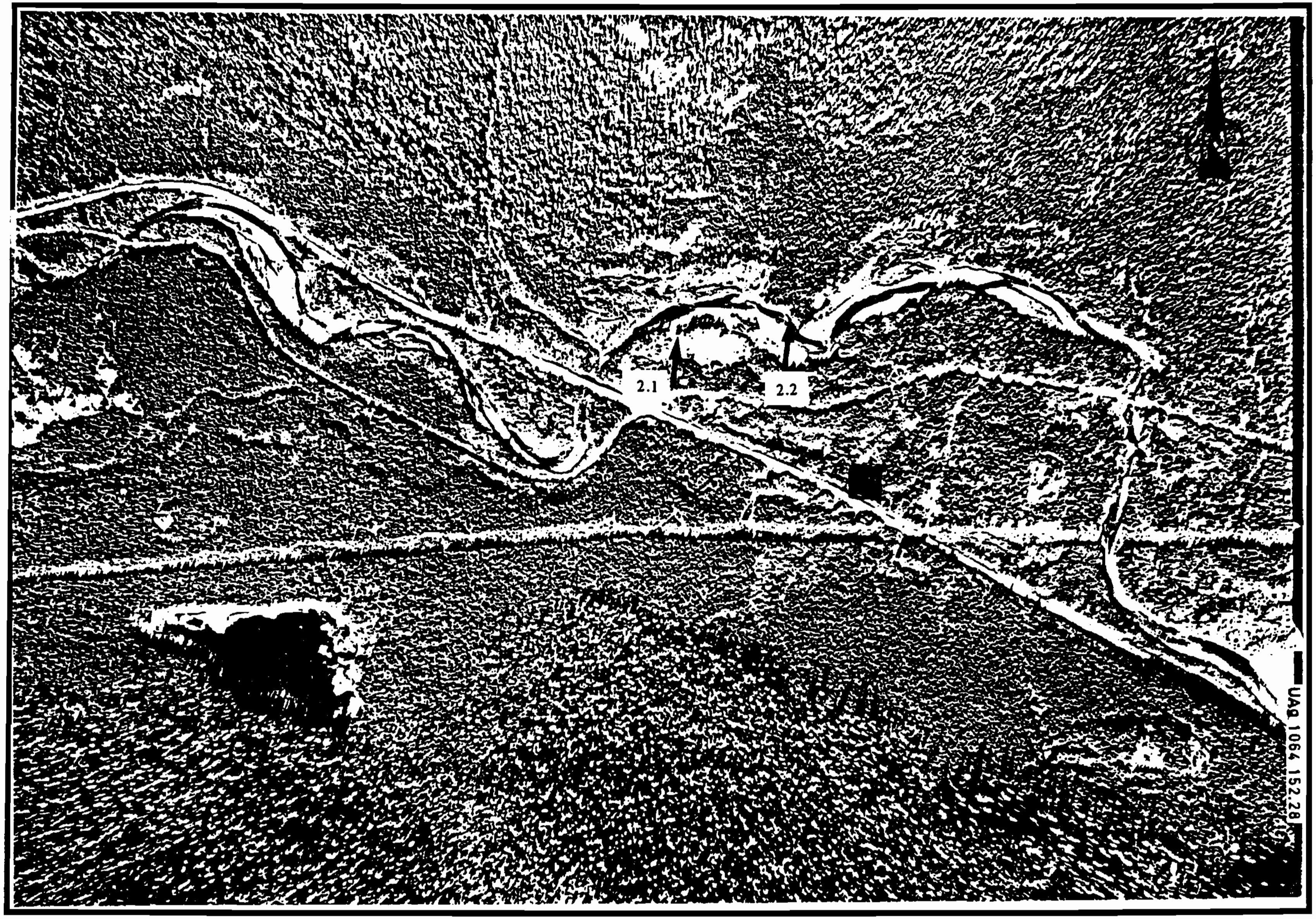
Air Photo SRS 3692 - 167, September 22, 1987. Scale: 1:10,000

Figure 4.2: Elk River central part of Reach 1.
Note: Numbers in boxes correspond to sites used in Karanka and Kellerhals, 1980. Lettered sites are new. Two digit #'s show Plate locations in this report.



Air Photo SRS 3692 - 169, September 22, 1987. Scale: 1:10,000

Figure 4.3: Elk River, the gorge and the upstream end of Reach 1.
Note: Numbered sites correspond to sites used in Karanka and Kellerhals, 1980. Lettered sites are new.



Air Photo SRS 3692 - 171, September 22, 1987. Scale: 1:10,000

Figure 4.4: Elk River, lower section of Reach 2 and the gorge (on right).
Note: Numbers in boxes correspond to sites used in Karanka and Kellerhals, 1980. Lettered sites are new. Two digit #'s show Plate locations in this report.