Historic Bridge Preservation

An Integrated Approach.

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Abstract.

The primary purpose of this dissertation is to summarise the issues in historic bridge preservation. The current status of historic bridge preservation in New Zealand is discussed. From this discussion, a planned approach to historic bridge management is described. The significance of historic bridges is then described in relation to site selection. The report discusses the range of deposition alternatives available for historic bridges. Guidelines for restorative work are also included. The conclusion provides a suggested prescription for improvement in the identification, selection and management of New Zealand's historic bridges.

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Contents

Tables & Illustrations

Cover Illustration by Kath Irving, "Cleddau Horse Bridge, Milford Sound."
All photographs by the author.

Chapter 1: Introduction

New Zealand has a number of bridges which may be considered historic because of their significance in the settlement and industrial development of this country and because of their contribution to our engineering heritage. Increasingly, such bridges are being demolished and replaced with modern structures because they are considered to be either structurally deficient or functionally obsolete. Many of these bridges are of regional or national significance as historic structures. A few sites are considered to have international significance. The primary reasons for the permanent loss of such historic sites[1] is;

(1) No formal consideration is given to the possible historic value of a bridge prior to it's replacement by either of the major bridge administrative authorities.

(2) The present system of evaluating historic structures for inclusion in the national register of historic sites fails to identify and protect a representative selection of New Zealands most significant historic bridges.

This report seeks to, (1) identify the importance of bridges as historic sites, (2) discuss appropriate systems for the representative selection of historic bridges, (3) describe appropriate options for bridge preservation, and (4) suggest improvements in current bridge preservation management.

Importance of Bridges.

Lack of appreciation of the historical importance of bridges is the biggest obstacle in the securing their preservation. Historic bridges have yet to seep into the historic consciousness of many of those who use and live by them. In fairness it should be said that they may lack the the aesthetic or romantic appeal of other structures. However, the bridge was one of the most important elements in our societies development and expansion. The bridge has allowed otherwise unaccessible areas to be settled and continues to provide access to the farms, forests, coal and gold mines, the basis of New Zealands early economic existence.

Bridges are important individually when they exhibit some exceptional

[1] For the purpose of this report, the term *historic site* refers to the physical structure of the bridge *and* those surrounds which would be irrevocably transformed by the bridges absence.

feature such as the longest or highest bridge or the first bridge built using a particular design or method of construction or where they are associated with the settlement of a town or a notable event. Bridges are also important thematically where they represent the evolution of New Zealands structural technology and the economic development of larger historic districts. (Jackson, 1984). Bridges such as the Karwarau Gorge suspension bridge and the Wiarau ferry bridge in Hammer Springs are examples of this.

Historic bridges help towns to retain architectural and historic character. DeLony (1977.10) comments that, "The more modest spans maintain a sense of scale with the rural landscape not duplicated in the concrete girders that replace them. Those located near towns and cities serve to slow traffic, and thus contribute to preserving the human scale and nineteenth century character of many towns and urban neighborhoods." Sites such as these are an important element in the community consciousness. They maintain peoples sense of identity and familiarity with a particular area and promote a sense of security in the face of rapid change in the built environment. Christchurch has many such bridges crossing the Avon. The bridge of Rememberance not only maintains peoples sense of identity and security but also makes a social statement as a war memorial.

When considering the alternatives for bridge replacement, restoring a historic bridge (rather than constructing a new bridge) has several positive attributes. Experience in the United States has showed that bridge restoration is often completed at significantly less cost than replacement. (Lichtenstein, 1980; Zuk, 1981; N.T.H.P., 1983.) Restoration or rehabilitation has the added advantage of preserving the historic character of the site. When restoration or rehabilitation is impractical, a bridge may still continue to be economically productive through an adaptive or secondary use[2].

The argument for the preservation of historic bridges can therefore be seen as four fold. First, they are important historical objects; second, they contribute to the quality of the built environment by the nature of their scale and aesthetics; third, they have architectural and engineering value and last, historic bridge restoration or rehabilitation may offer considerable economic savings.

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2 See Chapter 8.

Status of Bridges

As of 1988, there are approximately eighteen thousand bridges in New Zealand.[3] (See Table 1) There is no estimate as to what proportion of these have sufficient historic value to warrant protection. The New Zealand Historic Places Trust lists 75 bridges in it's "Buildings Register". These sites have been nominated by the public because they are seen to have obvious historic value or are *monumental* structures such as the Kawarau Gorge Suspension Bridge. This selection however is only a small proportion of the sites that should be classified. Indeed many bridges are identified as "historic" by local people or termed as such in regional publicity material (as in the case of the Nelson Creek Swingbridge) but do not appear on the buildings register.

The H.P.T. buildings register does not adequately identify or protect the most significant and valuable examples of early bridge because it is unrepresentative and lacks legislative power. Permanent protection for a historic bridge can only be granted by the issuing of a protection notice by the Minister of Conservation. An example of this lack of protection was the demolition of the Mangaweka Viaduct on the Auckland - Wellington Railway. This viaduct was classified by the Historic Places Trust as an "A class" historic site. (A site where permanent protection is essential because of its national and international significance.)

APPROXIMATE NUMBER OF BRIDGES IN NEW ZEALAND IN 1988[4]

OWNERSHIP	NUMBER	NUMBER LISTED ON H.P.T. REGISTER
New Zealand Railways	2400	4
National Roads Board		
State highways	3146	6
Local Authority, Urban	916	14
Local Authority, Rural	10829	26
Private Ownership [5]	700	25
Total	**17981**	75

Table 1.

[3] A bridge is defined by the National Roads Board as " A structure having a waterway area of 3.4 square meters or more."

[4] Source: N.Z.R., pers.comm, Phillip Holmes. 10.11.88; N.R.B.,1987.

[5] Approxiamate number ncluding all other government departments.

The problems of restoration are compounded by the advances of time. A large number of New Zealand's bridges have been built from similar materials and are of a similar age. This has led to the current situation where those early bridges which have received little or no maintenance are now in need of urgent attention if they are to survive.

Neither the Works & Development Services Corporation, which deals with the maintenance and replacement of the majority of the bridges on New Zealand roads, or the Railways Corporation formally consider the historic value of a bridge prior to it's demolition. Both organisations rely on objections being raised by the public. This is an inadequate situation as the public cannot be expected to be informed as to the requirements for the representative preservation of New Zealands historic bridges.

Some sites have been extensively restored and preserved as members of larger historic districts such as the Nelson Creek Swing Bridge. (N.Z.F.S.,1984). These sites are generally on land now administered by the Department of Conservation and serve dual purposes as recreational facilities and historic sites. Major restoration or rehabilitation of road and rail bridges so that they can continue to be used has not taken place. Historically sensitive adaptive uses have simply not been considered. The only from of adaptive use in our road and rail bridges is to set structure aside as a historic ruin or to provide pedestrian access.

Consideration of adaptive uses and historic value is particularly important for railway bridges. Railway bridges are generally under less risk of demolition because, (1) Their present day loads are often lighter and less frequent than those that they were originally designed for, and (2) They do not have the alignment problems that plague highway bridges. Railway bridges are generally upgraded rather than replaced so the biggest risk for these bridges is closure of the railway line.[6] The N.Z.R policy on bridges in place on closed lines is to demolish the bridge prior to the sale of land.[7] Again, there is no formal consideration given to the historic value or possible adaptive use of a bridge prior to demolition.

As described earlier, people find it difficult to accept the historic value of a bridge. Upgrading work done by both the Works & Development Corporation and the N.Z.R has been more concerned with the preservation of aesthetics rather than preserving the historic integrity of the site.

[6] Criteria for decision making. p.14

[7] Phil Holmes, 10.11.88 : Bridge Engineer, N.Z.R.

An increasing awareness of the need for structure preservation, especially within our urban areas, may lead to increasing conflict between historic preservation and bridge renewal programmes which promote greater bridge safety. While the rate of bridge replacement is slow (current average rate of replacement 1.2 percent for road bridges[8] and almost zero replacement for rail bridges[9]) bridges are being lost to decay, neglect and re-development without there full potential as important historic sites being evaluated. As Chamberlin (1983.3) comments,"Failure to manage the historic bridge issue skilfully risks not only unnecessary delays to needed bridge projects but also irrevocable loss of important elements of the cultural environment as well as examples of our national engineering and industrial heritage." This dissertation therefore addresses the issues in the identifcation and management of New Zealand's historic bridges.

Figure 1. Percy Burn Viaduct, Waitutu Forest, Southern Fiordland. *"The challenge of spanning obstacles has led to a rich diversity in bridge design and material selection throughout time, the challenge facing our society today is to identify and preserve the outstanding examples in this continuum"*[10]

[8] Calculated from the National Roads Board Annual Report, 1987.

[9] pers.comm, Phillip Holmes, N.Z.R., 10.11.88.

[10] Texas Historical Commission. 1983. p.7

Chapter 2: Resource Inventories.

The nature, significance, and preservation requirements of New Zealand's historic bridges can be most effectively recognised by a comprehensive inventory. From this inventory informed decisions can be made on what should be and what can be preserved.

Status

The function of the New Zealand Historic Places Trust is to "identify, investigate, classify, protect and preserve, or assist therein, any historic place and to keep permanent records thereof."[11] To this date, seventy five bridges have been listed on the Historic Places Trust Buildings Register. Using the Trust's *Historic Buildings and Structures Record Form,* details concerning the location, ownership, year of construction, designer and builder, construction and materials, alterations and reasons for significance have been recorded.

While this register is not an inventory, It is a listing of sites that have been brought to the attention of the Trust because of their obvious historic value. The significance of these sites has been recognised by communities and the H.P.T and they have been placed on the register. The historical significance of bridges has also been recognised in general surveys of historical resources.[12]

Subsequently almost one hundred bridges have been identified on an ad hoc basis as being historically significant. Unfortunately there is nothing to suggest that the current selection of sites is representative of (a) what existed and (b) what is required by society.

Rationale

Inventories which deal specifically with bridges, either on a national or regional level, are more effective in terms of assuring representative preservation and cost efficiency when compared with individual surveys.[13]

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[11] Historic Places Act 1980, No.16, s.5 (a).

[12] The restored Nelson Creek Swingbridge was recognised as a significant historic site by a N.Z.F.S. survey of historical resources in Westland. (N.Z.F.S.,1984).

[13] Jackson.,1984. p.6., Chamberlin,1983. p.12.

Specific bridge inventories used extensively in the United States of America serve three important functions;

1. To Provide Context: Inventories allow for comparison between bridges to be made. Such comparison highlights the importance of individual bridges and shows apparent deficiencies in representative preservation. By assessing the relative value of each site, preservation effort can be focussed on the most significant and feasible bridges.

2. To Provide Recognition: Inventories can be important means for local communities to use in identifying historical significance and in making a case for the protection of locally important bridges.[14] Therefore inventories provide recognition that the resource is important, thus encouraging preservation efforts.

3. To Provide Data : Inventories provide base line data which can be used to plan for the representative conservation of bridges through national or regional preservation plans. Inventory data, showing the rarity or significance of a bridge, has been used to influence and resolve demolition / preservation decisions.[15] Unfortunately the current register of structures provides no protection for recognised historic sites.[16] This is because the register is only a listing of noted sites. It cannot comment on the representativeness or comparative significance of a particular site. A listing also lacks the required data to plan for representative preservation. The availability of comprehensive base line data, provided by inventories, enables the development of a preservation plan and may also help to avoid potential conflict in bridge replacement issues.

Considerations and Methods.

The exact nature of a comprehensive bridge inventory for New Zealand is governed by the following considerations;

1. Finance: The level, source and duration of funding. Cost is dependent on the extent of the inventory (number of bridges to be surveyed), inventory method (site visits versus postal inventories) and staffing

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14 Harney,1974. p.3.

15 Jackson et al.,1984. pp.7-11.

16 The Mangaweka Viaduct, listed as site for which permanent preservation was considered essential, was subseqently demolished. Pers.com., P.Mahoney. 11.8.88

levels. To enable financial planning, a pilot inventory of a few bridges will provide a typical cost per bridge estimate (in hours). Such an estimate should include all costs including planning, transportation, on site data collection, evaluation and presentation.

2. Previous Inventories: Examination of previous inventories, whether they be specific to historic bridges or concern some related field will yield site information and provide examples of inventory designs and appropriate survey methods. Care should be taken to avoid the duplication of information. Each subsequent inventory should compliment previous inventories.

3. Scope: Bridge inventories are usually limited in some way. The inventory of "all bridges", irrespective of their age or type would simply be too large and too expensive a task for most economies. Typical limitations used for bridge inventories conducted in the United States include;[17]
   - Location, (national, regional, district or county)
   - Type, (truss, suspension etc. Normally concrete slabs, culverts, spans less than 20ft or steel bridges have been excluded unless they are of exceptional age.)
   - Material, (timber, concrete, stone, iron etc.)
   - Age, (typically built before the beginning of World War II has been used as it provides a cut off point of approximately 50 years old and marks the temporary cessation of bridge development in the U.S.A.)
   - Usage, (vehicular, railway, pedestrian.)
   - Ownership, (public or private.)

   Excessive limitations reduce the effectiveness of the inventory to reflect the true nature of the status of historic bridges. Pre-inventory selection also affects the versatility of the data. Ideally it is better to undertake the broadest inventory possible and select the sites which best represent the desired attributes later. The inventory is normally a "one off" exercise, whereas site evaluation may take place many times using a variety of selection criteria.

4. Data collection: Existing statistical data will give an estimate of the number of bridges likely to be eligible for survey. This information, when combined with the resource constraints of the inventory, will dictate the most appropriate method of collecting bridge data. For

[17] Chamberlin,1983. p.13-14.

smaller inventories one group of staff may be able to collect all the data required and make site visits. In larger inventories, the task of data collection may be conducted on a regional basis using local staff. In this case, the data collected may be kept simple (eg. type, date, builder and a photo.) and used for pre visit screening. Site visits can then be conducted by the researcher who can provide a higher level of continuity. Irrespective of the method of data collection the recording procedure needs to be standardised for ease of comparison.

5. Method of analysis and reporting: The analysis and presentation of the data may be simple (e.g. an indexed collection of site records) or complex. Complex analysis and presentation may include a description of individual and collective site histories, statistical analysis of the data and a discussion of the limitations of the inventory.[18] Information recorded in the inventory must be presented in a usable form and should be stored in a system which allows for its easy retrieval.

Once the parameters of the inventory are established a pilot survey should be conducted to refine and test the method. After making any necessary modifications the complete inventory can then be undertaken.

[18] For an excellent example of a comprehensive analytical inventory see Georgia Dept. of Natural Resources.1981.

Chapter 3 : Site Selection

The selection of the nation's most significant sites is the key element in obtaining a representative and manageable selection of historic bridges. "The number of sites chosen must not be beyond the resources of the country to manage. The type of site must be chosen so as to present a balanced view of history, and the quality of site must be such that it attracts people and effectively interprets history to them."[19]

From the inventory sites are analysed in terms of their relevant importance, significance and practicality. A comparative evaluation of these attributes suggests which bridges have high potential for national legislative protection as historic sites.

Sites considered as nationally significant are normally of exceptional quality in terms of historic integrity and in ability to illustrate and interpret the heritage of our nation. On an international level those sites which can be identified as uniquely[20] New Zealand in nature should be considered to be of greater importance.

Evaluation of Significance

While it may be true that a bridge is purely a technical solution to a problem of access, it may also possess certain intrinsic values. For example the design of the structure may be aesthetically pleasing, distinctive or impressive in terms of its engineering. A bridge also develops extrinsic values through its interaction with people and the environment. Over time such values become important to society and the site may be recognised as being *historically significant.*

Sites which are considered historically significant have normally been;

- associated with a famous person or event,
- instrumental in the economic well being or settlement of an area,
- built using unique methods or materials,
- significant in terms of engineering history,
- typical of an early engineering structure,
- or is the sole remaining example of its type.

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[19] New Zealand Historic Places Trust,1987a. p.1.

[20] Daniels. (1984. p.3) identified adaption as the attribute unique to New Zealand

The above attributes represent significance and importance of a bridge on a national scale. On a local scale, a bridge is important if it is considered an important element in the community consciousness. Such a structure, (1) maintains people's sense of identity and familiarity with a particular area, and (2) promotes a sense of security in the face of rapid change in the built environment.

Chamberlin (1983.16-17) notes that sites considered significant possess integrity of location, design, setting, materials and workmanship in varying levels. Chamberlin defines a *significant site* as one which is..."not totally lacking" in any of the above attributes. Where these attributes are present in high levels the *integrity of feeling and association* is likely to be preserved. Integrity of feeling and association is present if the site communicates to an informed observer a sense of what it was like in its historic period.

Representation of a theme and the effectiveness of the site to communicate that theme in comparison with other sites is defined by Chamberlin as *importance*. Importance can also be defined as the ability of the site to relate its historic significance to the contemporary needs of society. An important site is more than historically significant, it has the potential to be managed to meet the needs of a society which requires historical context.

General Considerations

Because only limited resources can be provided for historic preservation, the following factors should be carefully considered when making a selection of significant and important bridges for preservation:[21]

A. Appropriateness: Is on-site preservation the best means of interpreting the characteristics of the site? If interpretation can be achieved more effectively in an archival form, or in some relocated or adaptive use then the site should not be sought.

B. Balance: Preservation of the site, when considered part of a group of sites, should present a balanced picture of the use and variety of bridges that were present in past history.

C. Location: Sites situated in localities that had a strong representation of bridge numbers, styles and uses but now suffer from under representation should be given priority over sites located in areas of

[21] New Zealand Historic Places Trust,1987a. p.2.

over representation.

D: Multiple values: A bridge may have one outstanding quality that justifies its preservation. However, consideration should be given to weighting the selection of sites in favour of those which rate highly on other values (e.g. tourism, recreation, education) and communicate other important historical themes such as settlement, timber, gold, engineering, transport and architecture.

E. Practicality: Preference should be given to sites where active use of the structure can be continued. Practicality of implementation will be a function of completeness, soundness, access and cost.

Figure 2. "Preservation must be for the living. Enshrinment is of little use if we cannot learn from it. If we can use a site to give ourselves a sence of our past, we have made a valuable contribution."[22]

22 Harney.(ed)1984. p10.

Chamberlin (1983.p17) comments that complications in historic bridge management have arisen due to absence of objective criteria for site evaluation. For example, a certain bridge which is common on a national scale may have significance on a local scale. It cannot simply be said that on a national scale, twenty of the best truss bridges should be protected as this is a manageable proportion of what existed in New Zealand. Statistical information is required but it should not be used solely for determining a representative and manageable selection of historic bridges.

Methods

Chamberlin (1983.17) comments that the evaluation of site significance and importance has typically been approached in two ways:

1. Systematically; By surveying all bridges and selecting which bridges best represent the desired theme . This requires the development of an objective system for site selection.

2. Intuitively; By using "gut feeling" that particular sites are good representations. Such a technique, whilst being far less objective has the advantage of being inexpensive and capable of being used on a case by case basis. As discussed, case by case preservation may develop a biassed representation on a national scale.

In the U.S.A. the most used approach in the evaluation of relative importance of sites is a numerical rating system.[23] This system awards points for the structure's desirable attributes. Each attribute is given a relative weighting depending on the defined requirements of the selection. The final score is then used as a measure of the bridge's relative importance. Normally a cut off point is imposed on the final score to identify sites which are eligible for legislative protection.[24]

Numerical rating systems are as objective as possible. Even so, three subjective judgements must be made. These are, (1) Which factors should be included (table 1); (2) How should these factors be weighted and (3) At what level should cut off points be imposed. Chamberlin (1983.p19-20) lists some of the advantages and disadvantages of numerical rating systems as follows;

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23 Chamberlin,1983.pp.17-22.

24 For an example see *Point System for Evaluation of North Carolina Truss Bridges*. Appendix 2.

1. They add specificity to established legislative criteria, yet many factors remain highly judgemental, particularly the weight given to the various factors and the cut off value chosen.

2. The "checklist" approach helps standardise evaluation, but only if all factors deemed relevant are included.

3. Easily communicable results are produced. More intuitive methods of evaluation are hard to defend and communicate. For this reason numerical rating systems may be more consistent.

4. Eligibility standards or cut off points can be easily applied and used to reach certain goals. (ie to save three bridges in each region.) Numerical systems have the ability to juggle the numbers (by changing weights and eligibility standards) around to serve different needs.

5. When evaluating a small sample or an individual bridge, numerical rating systems are far more time consuming than intuitive methods and may not offer advantages in terms of selecting an appropriate and representative sample.

6. It is possible to make judgements on individual bridges if a proven format is developed prior to inventory. In the Georgia Bridge Survey (1981.p.55), extrapolation or inference was used in an intensive study of 67 of the state's 209 truss bridges to determine their eligibility for the National Register of Historic Places.

7. Ranking procedures tend to focus on the few best areas and cast the remaining sites aside as unimportant. Because of this the *typical* bridge is rarely identified as important. Therefore representativeness needs to be actively selected in order to retain a high level of integrity and avoid subjective bias.

8. Environmental factors are the most subjective yet are typically given the highest weightings. The degree to which aesthetics are considered as a determining factor in historical preservation needs to be carefully questioned in relation to the objectives of the selection.[25]

9. Numerical rating systems rely on accurate base line data. Inventories normally only identify surviving bridges. Therefore study yields information only on those survivors , not the real situation as it was.

[25] Georgia Bridge Survey. 1981. p56.

The second method of site selection is the stratifed sampling method where surveyed bridges are grouped into specific categories.[26] The best examples in each category are then identified. Categories are normally based on the age, function, location or type of bridge.

Theme analysis is a form of stratified sampling where bridges are grouped into the themes and sub themes that they represent. How effectively they represent and interpret these themes will determine their importance as national historic sites.

Stratified sampling methods using objective groupings achieve a high level of site representation despite the very subjective analysis which takes place in the second part of the process.

26 Chamberlin, 1983. p.21

Summary of Evaluation Factors in U.S.A Numerical Rating Systems Stated or Implied.[27]

Factor	H.I.	Mich.	N.C.	Ohio	Va.	W.Va.	Wis.
A. INTRINSIC							
1. Builder identified on bridge	√	√	√	√	√	√	√
2. Construction date identified on bridge	√	√	√	√	√	√	√
3. Patented elements	√	√	√	√	√		
4. Ornamental features	√	√	√	√	√	√	√
5. Distinctive or artistic structural details	√	√	√	√	√	√	√
6. Unusual materials	√	√	√	√	√	√	
7. Structural integrity	√	√	√	√	√	√	√
8. Materials integrity							
9. Number of spans	√	√	√	√	√	√	√
10. Span length	√	√	√	√	√	√	√
11. height	√						
B. EXTRINSIC - HISTORICITY							
1. Builder known, and significance	√	√	√	√	√	√	√
2. Construction date known, and significance	√	√	√	√	√	√	√
3. Rarity at present	√	√	√	√	√	√	
4. Typicality in its time	√	√	√		√	√	
5. Site Significance	√	√	√	√	√	√	√
6. Association with events/persons		√	√	√	√	√	√
C. EXTRINSIC- ENVIRONMENTAL QUALITY							
1. Structure esthetics						√	
2. Site esthetics	√	√	√	√	√	√	√
3. Site integrity	√	√	√	√	√	√	√
4. Site accessibility	√						
5. Vantage quality	√						
D. EXTRINSIC- PRESERVATION POTENTIAL							
1. Condition				√			√
2. Route compatibility						√	
3. Bypass potential				√			
4. Maintenance difficulty.				√			
E. ENDEMIC							
1. Local designer/builder		√					
2. Geographic distribution			√				
3. Oldest/longest.		√				√	

Table 2. The choice of appropriate selection factors is one of the three typical subjective judgements made in bridge selection.

[27] From Chamberlin, 1983. p.19

Chapter 4 : Management

This chapter discusses the nature of the management environment for restoration projects. This discussion is then followed by a procedure for historic resource management. While such procedures enable a planned approach to representative site selection, the most important factors in succesful restoration projects are a common understanding of the aims of the restoration project, a clear philosophy of the benefits that historic bridges provide and a willingness to preserve historic structures among staff.

Restoration work is of a complex nature. Managers need to take a multi-disciplinary approach, drawing on the expertise and experiences of other restoration workers and dealing with unforeseen problems, whether they be technical, human or conceptual in nature. Ritchie (1984) comments that " almost certainly other site managers (in New Zealand and overseas) have encountered the problems you face and have developed a response. The idea is to draw on that knowledge, assess the pros and cons of other responses and develop your own, within your particular financial and resource constraints." Obtaining specialist help may be expensive but in most cases will prove extremely cost effective. Generally the role of specialists will be to offer technical advice on such aspects as decay detection, inspection, structural analysis and assessment and appropriate preservation techniques.

Restoration projects often involve people with various levels of skills and experience. It is important to provide appropriate training where necessary and to utilize each persons skills in the most effective manner. Resorting to a 'do it yourself' approach without the technical experience or required resources may damage the site (a unique and finite resource).

Planning Systems

Effective planning systems for recreational site management have been used in New Zealand for several years.[28] Prescription planning systems are a means of ensuring quality control on site. They also offer compatibility and continuity of style with other similar sites. Care must be taken to avoid overuse of one particular set of solutions to a problem or a style of

28 The *Recreation Operations Planning System* has been a planning tool of the New Zealand Forest Service and has been used to aid in the management of restoration projects. N.Z.F.S 1984.

approach. Each site is unique and over use of planning, or more specifically design prescriptions risks leaving a trail of mono specific sites throughout New Zealand.

A useful set of guidelines prepared to show the factors involved in evaluating and implementing a preservation project has been developed by Mahoney (1986) This procedure takes the following format.[29]

HISTORIC RESOURCE MANAGEMENT PROCEDURE

1. IDENTIFY THE RESOURCE:

(a) Site location; management region, map grid reference, legal description.

(b) Values of site: e.g., historical, cultural, educational, recreational, scenic, ecological, economic (i.e. still in use). Are these other values important and if so do they require a separate detailed assessment?

(c) History of site: (i) archival resource: newspapers, manuscripts, diaries, maps, photographs, plans, files, etc.

(ii) oral resource: old timers recollections.

(iii) produce a report on the history of the site.

(d) Historic site features: (i) archaeological resource: record surface and subsurface evidence, site plan, measured drawings, photographs.

(ii) produce a separate report on the archaeology of the site.

2. ESTABLISH CONSTRAINTS.

(a) Threats to site.

(b) Legal status of site: ownership and status under Historic Places Act

(c) Predict future user groups: Contemporary road traffic, pedestrians,

[29] summerised and adapted from Mahoney,P.J. 1986.

cyclists, trampers, families, guided tours, schools etc.

(d) Quality of Access: Proximity to centers of population and main tourist travel routes, attractions of access route. Proximity of vehicle access to site.

(e) Provision of on-site facilities: parking, shelter, waste disposal, etc.

(f) "Ways of the World":

(i) Political: personality conflicts with staff, local prejudices, parochialism, interdepartmental feuds, etc.

(ii) Practical: difficulty of access of site for development work, skills shortage, materials unavailability, using untried processes etc.

(iii) Pecuniary: "shortage of money" claims.

3. ASSESSMENT.

(a) Historic significance of site: local, regional or national ranking ie., how does it relate to history in a wide context? Uniqueness, integrity, representativeness. What are the historical themes that this site interprets. Which of the identified values offer the most tangible cultural and historical linkages for the present day people?

(b) Linkages: establish relationships between sites if this is a complex site with more than one location.

4. DEVELOPMENT

(a) Site management development options: Do nothing, record, adaptive use, dismantle and store for future use, relocation, reconstruction, renovation, stabilisation, reinstatement.

(b) Interpretation of site: possibilities include entrance panels, on site panels, brochures. These should have complementary roles which are identified in an interpretation plan.

(c) Budget: should also address financing of future maintenance.

(d) Timetable: site development should not proceed until research and planning are complete.

(e) Implementation: when appropriate, use a prescription planning system to safeguard quality control.

(f) Opening: site and public may be at risk until development complete. Press releases and other publicity. Opening ceremony.

(g) Maintenance: requires scheduling on an annual basis.

Mahoney (1986) shows the planning process diagrammatically (see figure 1). The first step is to establish the goals. The goal may be simple and specific such as "The protection of all remaining pre 1900 timber truss bridges in the Waikato" or it may be broad and complex such as "The protection of a system of bridges throughout New Zealand that are historically significant and representative of the following themes...". Once the goal(s) is/are established an inventory of sites (together with the oral and archival resource) can begin. From the analysis of the inventory, rational options can be developed. The appropriate option is then selected.

From this point the planning process deals with the individual project. The prescription for the work to be carried out is developed and submitted for approval. When approved the work programme is developed and implemented. The final stage of the process is to develop and initiate a programme of maintenance. The site is then monitored for problems that create deviations from the original goal. This feedback is used to initiate the problem solving phase contained within the prescription. Serious or unexpected problems may lead to the development of new goals.

Throughout all stages the manager will be undertaking research, using specialists to overcome particular problems and providing training to staff in the necessary skills and techniques required for the effective restoration of the site.

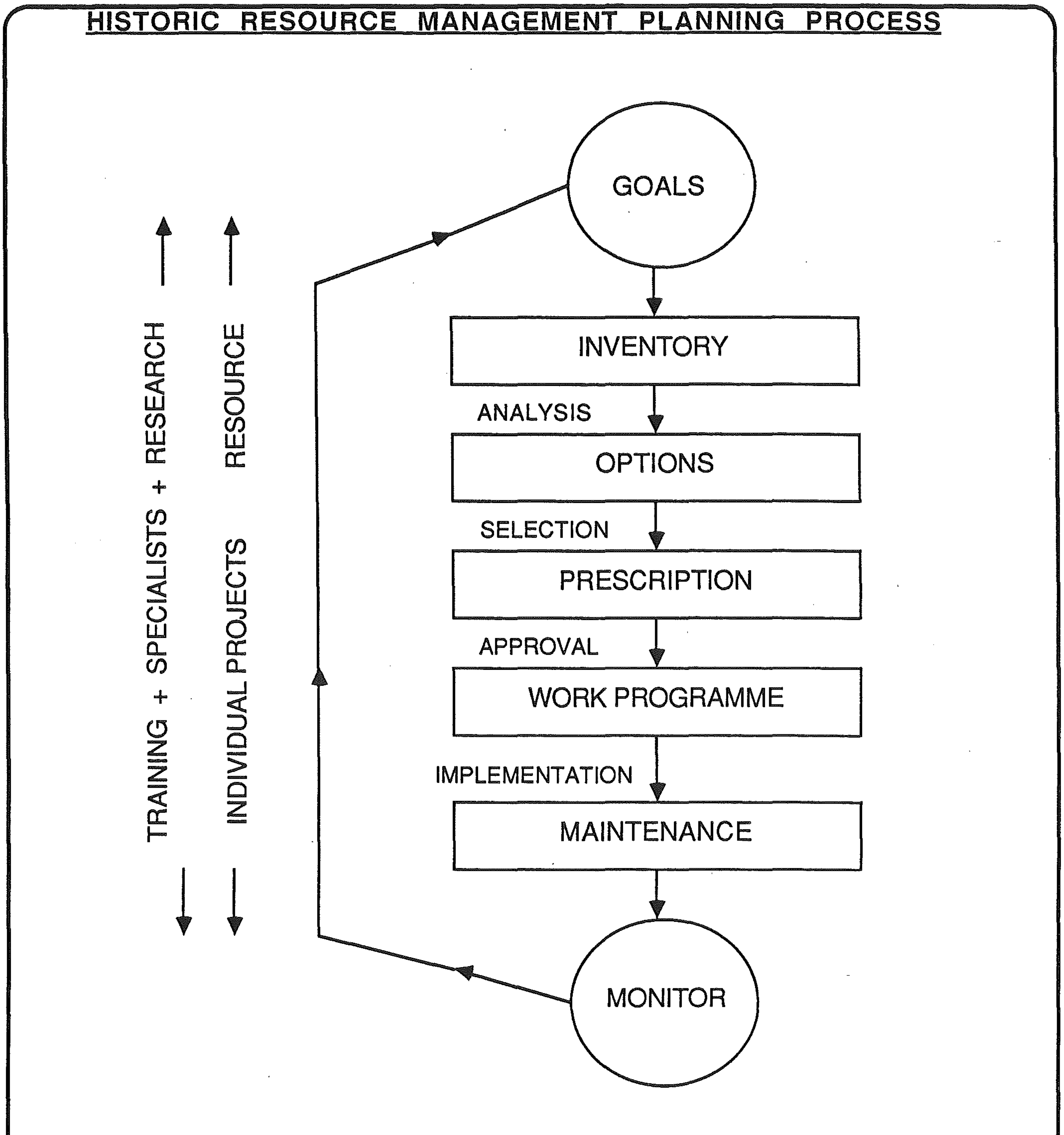
HISTORIC RESOURCE MANAGEMENT PLANNING PROCESS
GOALS
INVENTORY
ANALYSIS
OPTIONS
SELECTION
PRESCRIPTION
APPROVAL
WORK PROGRAMME
IMPLEMENTATION
MAINTENANCE
MONITOR
TRAINING + SPECIALISTS + RESEARCH
INDIVIDUAL PROJECTS RESOURCE

Figure 3.

Common Factors in Successful Projects.

Six common factors govern the success of any particular restoration project.[30] These are, good will and community spirit, adequate funding, effective communications, strong management, comprehensive planning, and continued coordination.

Jackson et.al. (1984) identifies strong local support as "The most important element in the successful, long term preservation of historic bridges." Good will and community spirit help ensure a resource pool of local information and interested and committed work effort both in research, restoration and continued maintenance. Established community groups may provide labor, material, financial or political support. Previous restoration projects, such as the Waiuta Hospital, have benefited from the formation of specialized community groups (Friends of Waiuta) to provide closer and more direct support.

In the United States preservation groups have been used to advocate the preservation of historic bridges and to overcome specific legal constraints to restoration projects.[31] The success of these groups is due largely to well developed and informed public support.

Community involvement throughout the entire restoration project (including the continuing care of the site) will develop pride, respect and a sense of ownership for the site by the community. Restoration is for the benefit of people. Without the involvement and support of the community, restoration will be difficult and futile. Development of local support is not an easy task. Delony (1984) argues that because bridges are not popular subjects in the public eye (on a national level) even more emphasis is needed on gathering local support. Delony continues, "The gestation period between a well intentioned idea and actual work underway is long term." This is because of the difficulty in arousing local support and obtaining finance. To get a conceived restoration project off the ground adequate funding is required. There must be enough finance for completion of the project and continued maintenance. If funding is not adequate to sustain a particular restoration option then a less modest but sustainable option such as stabilisation may have to be selected.

[30] Find reference and rephrase sentence accordingly.

[31] refer Pasco-Kennewick bridge, Washington. Jackson et.al. 1984. pp 9-11.

Effective communication is required to make public support for restoration projects visible to public sector decision makers. Preparing media releases and progress reports may be used to provide information and raise public awareness.

Strong management, comprehensive planning and continued coordination with researchers, specialists, restoration staff and the local community are the key elements in seeing a restoration project through successfully.

Chapter 5 : Research

Comprehensive research is required to answer basic questions about a bridge's history. Research is the basis for the establishment of site signicance. Research also develops one's understanding and appreciation of the site which aids in sensitive and relevant restoration and ensures the integrity of the site is preserved.

Two categories of information are required;- structural and social. Structural research provides information concerning the engineering history of the bridge. This information is valuable in the structural analysis of the site and forms the basis for restoration work.

Structural Research.

Structural research is used to gather the following information;

Construction date and designer/builder: This information allows consideration of the historical elements that influenced the design and the construction technique. When data is scarce or non existent this information allows comparison with bridges of similar age, style, design or construction techniques in view of extrapolating missing information.

Design documents: Relating to the prescribed use of the structure. For example the original design calculations may provide assumptions and loadings considered in the original design. These may be used as a means for comparing the loadings actually experienced with those anticipated by the designer. This becomes the basis for evaluating if the structure has been overloaded. Freas (1982.)

Specifications: Such as the exact quantities and state and origin of the materials used. These may also contain details of timber moisture content, preservatives applied, concrete mix ratios and paint colour etc.

Plans and drawings: These provide working drawings for accurate restoration. They also provide the basis for comparison of the structure as actually built with the prescribed design and may show post construction repair work or alterations. Plans may also give clues to the reasons for present engineering difficulties inherent in the structure.

Oral history and informal notes: These give important insights to construction techniques, changes and additions not shown in the original drawings. Old timers memories and photos may also reveal information about the loading history of the bridge. Particularly events when exceptional loads or stresses were placed upon the bridge.

Unfortunately much of this information is extremely difficult to locate. Either it has been misplaced, destroyed or simply never documented. The Bridge design and construction manual of the Ministry of Works (M.O.W.) stated in 1956 that "In a recently developed country like New Zealand these (bridge engineering records) have been somewhat neglected and steps must now be taken to set up adequate record systems."[32] Bridges built by the M.O.W.D., post 1950 are of little historical interest at present, but should have a "General Bridge File" and a "Design Dossier"[33] that "should not be destroyed during the life of the structure." Similar, but far less comprehensive files for bridges pre 1950 may exist.

When structural information of a bridge is lacking, researchers may have to come to their own conclusions as to the structural history of the bridge by comparing evidence from the site with another similar site which has a known structural history.

Social Research

Social research information, relating to the life history of the bridge, will include the reasons and the social climate that led to the bridges construction and development. Social research will be more general in nature and may often involve research into some particular theme on a regional or national scale. This information is the basis for an understanding of the cultural value and significance of the site. The research will seek examples of the impact between the bridge and the lives of the local people. Examples of this type of information are: (1) Stories of the construction of the bridge and of the people that built the bridge. (2) Unusual problems that were encountered and the solutions to those problems. (3) Details of opening ceremonies, centenaries or special local events that involve the bridge. (4) Details pertaining to the effect of the bridge on the economic well being of the district and the general role of bridges in the development of the district, region or nation.

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32 Turner, et al 1956. p 26.

33 See Turner, et al 1956. pp. 26-29 for the contents of these files.

Contemporary Research

A third category of information collection is contemporary research. This is the research required to establish the range of inspection, evaluation and preservation techniques available and to seek out suitable consultants. This research will continue throughout the restoration project and will also seek out legal information such as status, ownership and the range and flexibility of national and local building and construction regulations.

Information Sources

The most likely sources of oral and archival history of sites, for both structural and social research are:

(1) Government departments and corporations. Especially M.W.D. (old Public Works Department files), New Zealand Department of Tourist and Publicity, New Zealand Railways Corporation, and the Department of Conservation.
(2) Local government and ad hoc bodies such as water authorites, habour boards.
(3) Museums, public libraries and art collections,
(4) Newspapers.
(5) People who have been involved with the bridge or relatives of those people. This information may be in the form of memories and diaries, letters, news clippings, books, photos, movies, tapes etc.

Guidelines for Researchers

Hanger (1984) gives three important suggestions for researchers:

1. "Always research a site before undertaking work."

Failure to do so may result in irrevocable damage to the site, or seriously diminish the integrity of the site through inaccurate or inappropriate restoration work.

2. "Never rely on only one information source."

Wherever possible, cross reference information to avoid inaccuracies, for example by comparing an 'as built' plan with a photo or in the case of oral history, by comparing the statements of two old timers.

3. "Store information in a readily retrievable form."

Develop a safe and workable filing system that allows for the storage and retrieval of a number of different media such as photographs, voice recordings and written material. Be sure to properly reference all material collected.

Time invested research to obtain adequate and relevant information will enable a good understanding of the nature and significance of the site. This will enable planners to make sound decisions in the later stages of the planning process.

Chapter 6 : The Threats to Bridges.

When considering the planning options for historic bridges, one must establish the constraints to the development or preservation of the site. Technical constraints such as the structural condition of the site is the major limiting factor in the preservation of New Zealand's historic bridges. This chapter discusses the factors and processes which act as constraints in preservation projects.

Intangible Threats.

Intangible threats are those over which we have no direct control . Generally these are all the natural processes such as (1) Climate, (2) Natural aging, corrosion and decay, (3) Flood damage and drainage, and (4)"Acts of God" such as earthquakes. While there is no direct means of control over these processes, there are ways in which we can either slow down or limit the impact of such events.

(1) Climate: Levels of relative humidity, precipitation, sunshine hours, and temperature will have the most drastic effect on the life of a bridge. A wet and warm environment will offer optimum conditions for decay. Other climatic conditions will provide the stimulus for catastrophic events to take place such as landslides or avalanches.

(2) Aging, Corrosion and Decay: Many early New Zealand bridges were constructed from naturally durable Australian hardwoods. For economic reasons, locally available native timbers were utilized when the intended life of the bridge was short .

Nauta comments, " In earlier days Australian hardwood was the preferred bridge building material. North of Auckland, locally grown Puriri was nearly as long lasting. For reasons of economy the New Zealand Forest Service used mainly local red beech which depending on position and location has a life of 15-30 years."[34] Until effective preservation techniques were developed for both indigenous and exotic softwoods it was accepted that timber bridges had a relatively short life span.[35] The majority of bridges built from indigenous timbers were considered to have a life span from 10 to 20 years.

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[34] Nauta, F. 1984. p.109

[35] See Appendix 1

"Since about 1960 a large variety of materials have been used; treated solid and glue laminated timber, reinforced and prestressed concrete and steel (for a few jobs second hand)...Since corrugated steel culverts were manufactured in New Zealand these were at times used to replace small timber bridges."[36] Timber has been the primary material for the construction of bridges in our short term or extractive industries, and hence most of our bridges remaining in our park settings are constructed of imported or indigenous timbers. In early times there were few economical alternatives to timber for bridge building. When the greater diversity of materials became readily available and the intended life and load carrying capacities expected of bridges justified their use, such as in our road and rail transportation system, iron, steel and concrete were used. New Zealand is now dotted with the historical remains of bridges which show ingenious use of materials and design.

Timber has good technical properties; high strength to weight ratio, low coefficient of expansion and resilience under shock loading; all important aspects in bridge construction. Timber has the disadvantages of being susceptible to decay and fungal attack, requires regular maintenance for long life and is variable in its performance.

Much has been written on decay and preservative treatments.[37] Decay requires the presence of fungal spores, oxygen, food in the form of sap wood, heart wood and moisture. Timber with a moisture content below 20 percent is generally safe from decay. Decay is likely in timber with a moisture content above 30 percent. Fungi have a reasonable tolerance to temperature extremes. The optimal temperature for growth is between 20°C and 30°C.[38] By removing any one of these causal factors decay is halted.

The most easily controllable factor is moisture content. The covered bridges of Northern America are a classic example of this understanding. Pre stressed decking is another more recently developed technique to provide adequate shelter for the sub structure of a bridge. For the restorer of a simple bridge these options are not practical or desirable. Plugging and sealing of bolt holes, application of preservative treatments, minimising and diverting water running onto a bridge from the embankments and over-hanging vegetation will be the main methods of control.

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[36] Nauta, F. 1984. pp.110

[37] The New Zealand Ministry of Forestry and the Timber Preservation Authority can provide current information on decay inspection and control. See also reference list.

[38] Summarised from Buchanan, 1986.

Buchanan comments that surface checking provides a path for water to penetrate and remain trapped. These checks are the result of higher tangential rather than radial shrinkage. This is particularly common in large cross section members of sawn timber if the pith is included in the member (Box hearted). Replacement members should be specified to exclude the pith. These members are expensive as it requires timber sawn from a large log.

Chemical reduction of wood strength takes place when steel fasteners come in contact with wood. The steel fasteners will also suffer accelerated corrosion. By nature fasteners are under high stress and are ideal places for the penetration and entrapment of water. Fasteners and wood should be kept in a dry condition. Steel surfaces can be protected with galvanizing, grease, tar, plastic sleeves, rubber or silicone sealants. It is important to be discreet when using modern day materials. Compromise on the effectiveness of a technique or method of protection may be necessary to preserve the authenticity of a structure.

When restoring a bridge we must work with the natural properties of the materials originally given to a structure. The main steps in restorative maintenance are:(1) Identify weaknesses in members, (2) Identify the factors that cause these weaknesses, (3) Repair or replace deficient members, (4) Carry out maintenance regularly to slow the deterioration of the remainder of the structure.

(3) Water Damage: Considering the costs and effort required to restore bridges it makes good sense to pay particular care to flood protection. Changes in flow patterns of rivers can cause damage to abutments and piles. This is perhaps the most dramatic threat to a bridge. .

Careful observation and monitoring of the effects of natural and human induced changes to a river's flow pattern will enable protective measures to be taken. It is important to gather a past history of river course and peak water levels. Aerial photographs together with site inspection is a good way to spot old river channels. Information from the appropriate water authority and local knowledge should enable predictions to be made as to the extent of protection required for particular statistical flood levels. If flood protection is a serious problem for the bridge then a hydrology engineer should be consulted.

Roads and tracks leading onto bridges provides a natural path for water.

Decay damage occurring from water running onto the bridge decking can be controlled with adequate drainage. Particular attention should be paid to keeping anchors, piles and abutments free from the corrosive and erosive effects of water.

(4) Acts of God: Fire, earthquakes, landslides, avalanches and gales destroy or damage both modern day and early bridges regularly. Little can be done to avoid these perils in many cases. One can only accept that a risk of irreparable damage exists. The only decision to be made is whether the risks are acceptable. If for example the eventual destruction of a unique or historic bridge by avalanche is considered to be imminent, then it may be decided that efforts may be better spent on simply recording the features of the bridge and concentrate on the preservation of a bridge with less historical significance and a longer anticipated lifespan.

Often measures can be taken to lessen the risk of destruction. Vegetation can be selectively trimmed to lessen the risk of windfall. Fire breaks can be created if the risk is great enough. In all cases the risk can only be lessened or the probability of disaster reduced. In can never be totally eliminated.

Tangible Threats.

Ritchie (1984), introduces the concept of tangible threats to a site. That is, those threats which are directly under our control. The tangible threats to a bridge would be as follows, (1)Vandalism, (2) Condemnation leading to destruction, (3) Visitor access and impact, and (4) Misguided restoration attempts.

(1) Vandalism is a real threat to any historic site. An example of vandalism to a historic bridge was the attempted burning in 1983 of the Percy Burn viaduct in the Waitutu State Forest, Southern Fiordland. The Percy Burn Viaduct is one of four Australian hardwood viaducts constructed to give access to logging trains for the early forestry of this area.

After the completion of logging activities the viaducts became used by trampers walking around the southern coast to cross the four deep gorges that bisect the terraced track. The decking of the viaduct was in very poor condition and made the crossing of the 35 meter high viaduct unsafe. A concerned member of the public attempted to destroy the viaduct by setting it on fire.[39] The viaduct suffered moderate damage but fortunately it was not completely destroyed. All four viaducts have since been re-decked by the New Zealand Forest Service. Wilful destruction often appears

39 Pers. comm, K.Hamilton. 5.1987.

completely senseless. Other times vandalism may stem from a person's dislike of what another group of people are doing. In this case the individual believed he was doing the right thing. This shows the need for bringing public structures up to safe standards and involving the community and the users of a bridge in the decision making as to a bridge's future. Community involvement in restoration projects is emphasized as a method of enhancing pride and respect for historic structures, thus reducing vandalism. While the possibility of vandalism can never be fully discounted, a well maintained and safe facility will generally be greeted with respect from users.

(2) Condemnation leading to destruction: The legal status of the structure under the relevant laws needs to be examined. These acts may highlight threats to the site or show possible legal solutions, aiding in the mitigation of these threats. Matters of vital interest will be the ownership of the structure. Check to see who is legally responsible for the maintenance of the structure, and compare this with the party who is actually maintaining the structure. This is important if the bridge is say the legal responsibility of the National Roads Board but is actually being maintained by a second party such as a National Park or a private landowner.

The previous example of the Percy Burn Viaduct also illustrates the need to act swiftly to stabilize structures and either make the structure safe for public use or close it. In some cases where risk is severe, the law may require a bridge to be demolished. In some instances, the administering authority may be considered negligent and thus held liable if a bridge considered unsafe, remains open to the public. In this way, bridges that could have been suitably restored end up being demolished and a new, safe bridge built in its place. The possibilities of rehabilitation or restoration for historic purposes are not even considered.

The main reason for the classification of bridges as structurally deficient is that they can no longer support modern day loadings. For many vehicle bridges structural upgrading to contemporary standards seriously alters the integrity of the bridge design. Safety of the approaches and lane width will also be determining factors in assessment of bridge safety. While these factors may be significant enough to close a bridge to vehicular traffic, several other alternatives exist[40]. If the historic nature of the site is recognized by the administering authority and the lobbying public as significant enough to warrant preservation, an adaptive use will exist. All that is required is the determination to see the project through and the

[40] See chapter 8.

willingness to accept compromises.

The question of rehabilitation, restoration or demolition is well aired in the United States of America where much more stringent liability laws exist. After the 1967 collapse of the Point Pleasant Bridge over the Ohio River in which forty six people died the United States Government introduced a "Special Bridge Replacement Programme" which provided funds for the demolition and reconstruction of bridges on the country's highway system. No funds were allocated for rehabilitation or restoration. At that stage inventories of historic bridges were not in place. Therefore only those bridges recognized by the national register of historic places were safe from possible demolition. Historic bridges on the highway system had to be restored to the same standards as modern bridges, even if they were to be restored or rehabilitated with private funds.

Historians and bridge preservationists have fought over the last twenty years to save their bridges. The efforts of the preservationists caused the American congress in 1987[41] to:

(A) Hereby define and declare it in the national interest to encourage the rehabilitation, re-use and preservation of bridges significant in American history, architecture, engineering and culture. Historic bridges are important links to our past, serve as safe and vital transportation routes in the present, and can represent significant resources in the future.

(B) Implement a program of inventory, retention, rehabilitation, adaptive re-use and future study of historic bridges.

(C) Each state is to conduct an inventory to determine historic significance.

(D) Reasonable costs will be met for actions to preserve or reduce impact on the historical integrity of motorized traffic bridges. Non vehicle traffic costs will be met if the cost does not exceed demolition.

(E) If demolition is elected, the Department of Transportation must make the bridge available as a donation. If accepted, the receiver must enter into agreement with the department that they will maintain the bridge and assume legal and financial responsibility.

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41 Congressional Record:- Senate S.152 "Historic Bridges" January 1987.

(F) Study to be carried out to; Examine the effect of the"Special Bridge Replacement Programme" on historic bridges. Develop special rehabilitation standards for historic bridges. Provide analysis of other factors which would serve to enhance the rehabilitation of historic bridges."

There can be no doubt that New Zealand's resource of historic bridges is being slowly eroded by individual demolitions and may at some time in the future be faced with a well publicised legislative directive to rid the country of structurally deficient or functionally obsolete bridges. If this is the case we may well be able to avoid twenty years of toil (and loss of resource) by studying the progress of bridge restoration in the United States.

(3) Visitor Impact: Public access and continued use of historic structures is a fundamental goal of any restoration project. Unlike an endangered animal or a threatened forest, structures themselves do not have an intrinsic right to exist. Therefore any reason for preservation of a historic structure is based upon the importance that people place upon the sites continued existence. The level of importance will be a function of the net benefit that people receive in economic, recreational or cultural terms.

Visitors can impact upon a site either directly, by imposing excessive loading or indirectly such as when obtaining access to a site, by camping or pursuing other recreational activities (both compatible and incompatible) or by vandalism.The increase in loading of a bridge can be mitigated by either increasing the load bearing capacity of the structure or by limiting visitor access (Such as imposing a load restriction).

As Ritchie (1984) comments, "The objective is to control visitors as unobtrusively as possible, yet achieve a high level of site protection and visitor accessibility compatible with the objective of long term preservation of the site." This can be achieved passively through subtle sign posting, landscaping and interpretive techniques . It may also be achieved actively by enforcement and the imposition of physical barriers. The need for imposing active restriction must be well founded. It should be used for the legitimate protection of the site, when more passive means do not exist or are ineffective, rather than simply having some heavy handed control on a site.

(4) Misguided Restorative Attempts: Bridge restoration is a specialised task of which few park managers have had experience. Restoration requires skills in bridge erection, engineering, research, management, design and conservation as well as a sense of respect for the historic nature of the

structure. The number of skilled bridge carpenters for the repair and maintenance of timber truss and timber tressle bridges has been rapidly decreasing.

Bridges are complex. The problems of stress, acceptable loads and decay become increasingly difficult to calculate as the bridge ages. The result is an increasing margin of uncertainty concerning the soundness of structural members. Park managers must recognize the complex nature of bridge restoration and seek advice from experienced specialists when undertaking bridge restoration projects.

Failure to obtain a detailed knowledge of the history of the site and a appreciation of the character and intrinsic value of the structure may lead managers to alter or destroy the essential quality of the site in an irreversible manner. "This can be a significant source of site damage and its containment is particularly important when considering the management of sites on public lands. The damage usually occurs when well intentioned but inexperienced or ill advised personnel are asked to do a task without adequate supervision or understanding of the nature of historic sites and their components, or without due regard for the long term consequences of their actions."[42]

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[42] Ritchie, 1984.pp 109.

Chapter 7: Structural Inspection and Evaluation

Accurate and thorough structural inspection is required to determine the full range of site management options available and to evaluate the practicality of these options.

Bridge inspection and structural evaluation should be undertaken by an engineer, preferably one who has experience in the structural analysis of bridges effected by decay and corrosion. Lay people involved with site restoration can carry out a simple inspection, (noting areas of decay and other obvious factors affecting the structural integrity of the bridge) but an engineer has the ability to discern between critical deficiencies and cosmetic deficiencies. A complete structural evaluation has three steps; Record, inspect and assess.

Recording the Site.[43]

A contempory structural recording of the site is used to establish the exact nature of the structure for restoration purposes. This allows comparison with the original plans and documents the bridges present form for archival purposes.

The structure and relevant surroundings should be recorded to enable observations concerning changes over periods of time.

It is important to be methodical when recording sites. Care must be taken with reference to scale. The chosen scale must be appropriate and accurate. Most structures of historical interest have been designed and constructed using imperial measurements. This should be carried through to the contemporary recording. Converting imperial measurements into metric adds confusion and increases the potential for error.

Photography and measured drawings may be used together for a complete and accurate site documentation. In the photographic medium, a combination of black & white photographs and colour transparencies is the most versatile system. Black & white prints have the advantage of easy and accessible printing (many organisations have their own facilities) and should be used as the primary recording film. Colour transparencies offer high quality reproduction and projection. They are best used for publicity work.

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43 After Fearnley, Staffan & Briston. 1973.

There are six steps involved in the photographic recording of a site. They are:

1. Photograph the structure in its general environment. This is both historically and aesthetically important.

2. Circumnavigate the bridge, taking photographs of the various elevations. Also attempt to obtain some sort of a plan view (From the abutments or towers is adequate).

3. Photograph structural details (scale is important) typical of the design or unique in nature.

4. Include close ups of states of decay or preservation.

5. Investigate and photograph post built additions and any evidence of construction methods used.

6. Provide a written description of each photograph, date and file all photographs in a suitable retrieval system.

Measured drawings are required to complement a photographic survey. These drawings offer detail and precision which photographs lack. Contemporary measured drawings enable direct comparison with the original plans. Information which is difficult to express pictorially such as cross sections, plan view, and the materials used can be shown.

The technique used to produce measured drawings will depend on the available technology, ease of recording, desired accuracy and cost. For small, uncomplicated and easily accessible spans, simple manual measurements with a tape measure may be feasible. For larger or less easily measurable spans more advanced methods of survey may be required.

Rectified photography (plotting measurements from photographs printed at a predetermined scale) is an uncomplicated and accurate technique best suited for the recording of simple elevations. For complex sites requiring a variety of perspectives, stereophotogrammetry yields a better result. This technique is more time consuming than rectified photography in its method and analysis but has broader applications. When a structure or a portion of a structure is missing, plans of the missing items may be reconstructed through analysis of old photos. This technique, called analytical photogammetry, relies on a good quantity of detailed photographs and careful geometric calculations to locate camera position.[44]

Whilst these techniques are relatively complex they allow for the rapid and accurate recording of structures. This is an important factor when environmental conditions are unpleasant on site, or demolition is imminent.

Site Inspection

The extent and type of inspection undertaken will be dictated by the age, size, design of bridge. The bridge inspection is most likely to follow a prescribed format such as the one used by the National Roads Board (N.R.B.-11). An inspection for the purpose of assessment of preservation options may need to be more rigorous. The requirements of such an inspection should be considered on a case by case basis.

The effectiveness and quality of the inspection will be dictated by the ability and experience of the bridge inspector. In order to make judgements about the type of data to be collected and sensible evaluations of that data, the bridge inspector requires experience. This experience is based on the inspector's understanding of the nature of bridges and a knowledge of past performance of designs and materials. For instance, Freas (1982) suggests the performance of glue laminated timbers, despite changes in glue-lamination technology, should be assessed using current standards. However the performance of nineteenth century wrought iron, because of its greater resistance to corrosion than twentieth century steel, may be assessed using nineteenth century standards.[45] Judgement is required to apply the relevant standards on a case by case basis.

It is important to examine and evaluate the structure with the most passive technique available to minimise damage and loss of historic fabric. Both non destructive and destructive techniques have been used to evaluate internal decay in bridge members. Non destructive testing techniques such as visual detection of external signs, sounding, ultra sonic sounding, the use of X-rays and a device measuring electrical resistance called a Shigometer are evaluated by Buchanan (1986b).

Drilling and core sampling are effective but destructive techniques used for the evaluation of decay in timber members. These are the most common

44 For a discription of the above techniques see Trends, Jan -Mar 1987. pp24-27.

45 Jackson. 1984. pp 2

techniques used in New Zealand (Primarily by the M.O.W.D. and the Railways Corporation[46]). A concentration of sampling holes may cause a reduction in the strength of the member. If the sample hole is not adequately sealed, they can act as a passage and trap for water, thus encouraging decay.

Buchanan comments that some of the more high technology methods for decay evaluation in timber require specialised and experienced operators and documented cases of their application are few and far between. The small advantage in decay detection that these new non destructive techniques may offer is probably insignificant when compared with the present techniques used by our local bridge inspectors who are very skilled in decay detection.

Structural Assessment.

Data obtained from the inspection is used in a detailed structural analysis. The analysis establishes the design load and compares this with the estimated load. The known stresses working on the bridge are then defined and calculated, then compared with the prescribed allowable stresses. An estimation of the rate of decay should also be conducted.[47] From these calculations the range and suitability of preservation alternatives (and adaptive uses) can be assessed from a structural point of view.

An estimation of the "remaining useful life" of the bridge (if no additional or restorative maintenance is carried out) should be conducted to enable well informed preservation (or non preservation) decisions to be made. Hypothetical estimations of life expectancy for the preservation options would be useful in the evaluation and selection of the most appropriate option.[48]

The structural assessment should also include a detailed account of specific problem areas. These problems could be rated for their significance in relation to the anticipated use of the structure. Recommendations as to the suitability of proposed development options and suggestions as to the range of structurally possible options will form the final part of the assessment.

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[46] Buchanan 1986d. pp18-19.

[47] After Buchanan 1986d.

[48] A research proposal for the development of a reliable and accurate system for the estimation of "remaining useful life" was instigated by the A.S.C.E. See A.S.C.E. 1981

Chapter 8: Options for Bridge Preservation

To ensure the effective and representative conservation of bridges that possess historical value the full range of deposition alternatives must be considered prior to a bridge's irrevocable modification or demolition. The preservation of historic bridges in the nation's highway system has been limited primarily to the creation of national monuments which offer limited opportunities for human interaction. National parks and conservation areas have restored decrepit bridges for non vehicular recreational use. However, despite the extent of the resource more creative or adaptive use of historic bridges has not yet been investigated in New Zealand.

Zuk et al (1981) has developed and identified a wide range of adaptive uses for bridges. Zuk comments that "identification of a bridge as historically significant carries with it the responsibility to consider strategies for continuing the structure in service or finding sympathetic adaptive uses." Once a bridge has been identified as historically significant an evaluation of the feasibility for preservation can be undertaken, and suitable options developed.

Unlike historic buildings, which can be rehabilitated for other uses than originally intended, bridges are shaped and sited to serve very specific functions, limiting their potential for preservation. Despite this, a variety of uses have been developed which, in varying degrees, allow for adequate preservation. As with other researchers, Zuk identifies three categories of deposition options for historic bridges;

1. Continued Use for Intended Purpose.

Continuing use of the structure for its originally intended purpose with minimal modification is the most favourable option from a preservation viewpoint. The bridge continues service to the community, providing historical and practical justification for its preservation. For the bridge to be used in its originally intended purpose, it may require the following treatment:

A. Structural Upgrading. The structure is restored to a desired load carrying capacity using historically sympathetic means. Restoration attempts to repair or strengthen the structure to a former state with the minimum amount of change to the bridge character of the site. There is no change to the overall design of the bridge. Removal or alteration of historic material is avoided.

B. Geometric Modification. To accommodate contemporary usage of the structure such as high speed traffic, heavy or wide loads, design modifications are required. Geometric modifications should mitigate the effect they have on the character of the bridge through sympathetic design. Removal or alteration of historic material should be kept to a minimum. Rehabilitation can offer significant financial savings when compared with the cost of replacement.[49]

C. Realignment. Highway safety standards developed to accommodate high speed traffic have made many bridges functionally obsolete[50]. Rather than replacing an old bridge with a wider and safer bridge, realignment and improvement of the approaches may be sufficient to meet safety requirements with minimal loss of historic integrity.

2. Restricted Use.

Restrictive use of a bridge should be applied when the restorative maintenance required to maintain the original use of the bridge seriously affects the historic integrity of the site. Restricted use allows historical protection while maintaining the active use of the structure.

A. Load limiting. The most common forms of restrictive use are limiting the type or extent of usage to one way vehicular traffic, pedestrian or bicycle traffic. Structural upgrading is decreased in proportion to reduction in loading. This is cost effective and limits the reduction of historic integrity. Other restrictive uses which avoid architectural adaptation are cited by Chamberlin (1983.p30). In Virginia, U.S.A. a section of a concrete girder bridge was left standing to serve as a fishing pier while another Virginian bridge was retained as an historical attraction and scenic overlook.

B. Architectural adaptation. Possible architectural adaptations to bridges include the construction of information centers, vacation homes, picnic shelters, museums and restaurants (Zuk et al.1981). A further architectural adaptation is the reconstruction of a new bridge incorporating the remains of an old bridge. Such an adaptation has been used recently in New Zealand at Charming Creek, Westport and

49 Chamberlin,1983., Lichtenstein,1980.

50 22 percent of U.S.A. bridges have been identified as functionally obsolete due to deck geometry, underclearences or approach alignment. Chamberlin. 1983. p.9.

Kawatiri Junction, Murchison (see fig. 4). In both instances modern footbridges have been constructed on the abutments of previous railway bridges. When designed and constructed in an historically sympathetic manner, architectural adaptation can offer a valuable contribution to the overall historic representation of bridges. Architectural adaptations also provide an opportunity for commercial use of historic bridges.

Figure 4. Exisiting railway piers and abutments become the basis for a footbridge which provides access and is part of a walkway interpreting the history of the railway at Kawatiri Junction, Murchison.

Conversion of an historic bridge into some architectural use compromises the historical integrity of the site in favor of use. The decision to pursue such adaptation will be a function of the chosen preservation policy. Such an option may be severe in terms of preservation but has considerable merit in terms of maintaining function.

C. Relocation. Relocation is the most appropriate option when (1) The bridge can no longer accommodate contemporary traffic, or (2) geometric modifications are impractical or would destroy the character of the site. Relocation of the bridge to a less demanding site, where a sense of scale and feeling is retained, may be an appropriate option. Zuk et al. (1981,p.12) suggests an alternative form of relocation as a possible solution to widening requirements for two lane traffic. The historic bridge might be left in place to carry a single lane, and a visually compatible bridge be moved to an adjacent site to carry the second lane.

Relocation is cost effective and maintains the advantage of continuing use. In truss bridge the ability to relocate is a design feature, one which was utilised regularly in the United States at the beginning of the century.[51] Therefore relocation does not have to reduce the integrity of the site. However, in most situations location plays a key role in the historical significance of the bridge. Relocation of such bridges may incur an unacceptable loss of historical context.

D. Historic landmark. When continuing the use of the structure is not possible, it may be set off as an historic landmark, monument or ruin. This comparatively inexpensive option (low implementation and maintenance costs) has been a popular form of preservation in New Zealand. The result has been a trail of historic bridges adjacent to our present highway system. Such bridges function as monuments to our cultural heritage, providing a physical link with the past. The actual contribution of these monuments in the effective representation of bridge history is limited when compared with the more active uses described.

E. Stabilisation. Stabilisation of the structure allows for the consideration of other options over a period of time without jeopardising the historical or structural condition of the site. By removing a bridge from service and carrying out sufficient remedial maintenance, decay may be controlled and further deterioration of the structure avoided. This option is particularly suitable when environmental, economic or political conditions are expected to change.

51 Georgia Department of Transportation. 1981.p31

3. Destruction with Acceptable Mitigation.

When one of the options discussed above has not been implemented, destruction usually follows. The opportunity for some form of historical representation is not lost however. The following options mitigate the complete loss of the bridge.

A. Dismantle and store. In this option the bridge is carefully dismantled. The individual parts are then match marked, cleaned, treated and stored for future use at another site. This technique is more suited to smaller bridges, particularly truss bridges which are easily dismantled. This option is costly and there a risk of parts being misplaced or used for another purpose. A simpler alternative is to remove and store selected components of the bridge which would be suitable for educational, ornamental or functional uses. Chamberlin (1983.p.36) gives the example of using trusses from a former bridge as guide rails or edge delineators on a new structure.

B. Document. When physical preservation of the structure is not possible, documentation (as discussed in chapter 7) allows for aspects of the bridge's technology to be preserved. This archival information may be of use in future study. Site documentation is the minimum level of acceptable mitigation from an historic preservation viewpoint.

Chapter 9 : Guidelines for Restorative Work.

The purpose of maintaining and upgrading historic structures is to preserve the essential historic elements of the site so that they may be enjoyed by the public in safety. The level of maintenance and upgrading required will be a function of maintenance received and anticipated use.[52] The historic integrity of the site will decrease in proportion to the extent of the restorative maintenance or upgrading undertaken. For this reason,the need for restorative work should be carefully evaluated, thereby minimising the level of interference to the distinctive and characteristic features of the site.

Prescription

Several organisations have produced guidelines for conducting historically sensitive restorative work. A particularly comprehensive and relevant prescription proposed by the U.S. National Park Service follows[53];

1. Every reasonable effort shall be made to use a structure for its originally intended purpose or to provide a compatible use which will require minimum alteration to the structure and its environment.

2. Distinguishing qualities or characteristics of the structure, site and environment should not be altered or destroyed. The removal or alteration of any historic material or architectural feature should be held to a minimum.

3. Deteriorated architectural features should be repaired rather than replaced wherever possible. New material should match the material being replaced in composition, design, colour, texture and other visual qualities. repair or replacement of missing architectural features should be based on accurate duplications of original features, substantiated by pictorial or historical evidence rather than on conjectural designs or availability of different architectural features from other sites.

4. Distinctive stylistic features or examples of skilled craftsmanship which characterise the structure and often predate the mass production of building materials must be treated with sensitivity.

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52 Eslyn & Clark (1979. p23)

53 Described by Goodell, 1977. p13.

5. Changes which may have taken place in time are evidence of the history and development of the structure and its environment. These changes may have acquired significance in their own right. This should be recognized and respected.

6. All structures should be recognised as products of their own time. Alterations must have historical basis and should not attempt to create an earlier appearance.

7. Contemporary design for additions to existing structures or landscaping should not be discouraged if such design is compatible with the size, scale, colour, material and character of the structure or its environment.

8. Wherever possible, new additions or alterations to structures should be done in such a manner that if removed in the future, the essential form and integrity of the original structure would be unimpaired.

9. Protect and preserve archaeological resources by or adjacent to any projects.

The restoration of historic buildings has a much higher public profile than bridge restoration. Accordingly, technology and experience in building restoration is advanced. Finding practical and historically sensitive solutions to bridge restoration problems come from adapting the work of preservationists in the restoration of buildings.

Most information concerned with bridge preservation places priority on the recognition of bridges as historically significant and with finding legislative means to protect such historic bridges. Few authors deal specifically with finding technical solutions to the problems of historic bridge restoration. Occasional papers in engineering journals continue to be the major source of technical information. This information is scattered and does not always relate to the specific problems of historic bridges. Freas (1982) produces the most comprehensive description of the evaluation, maintenance and upgrading of structures. However, this relates to timber structures generally rather than historic bridges specifically. This paper does not attempt to offer technical solutions. However by combining the observations of bridge preservationists with the work of building preservationists a list of restoration considerations can be developed.

CONSIDERATIONS IN BRIDGE RESTORATION.[54]

Consider	Avoid
The Environment:	
Retaining distinctive features such as the size, scale, mass, colour and materials of surrounding structures that give the site distinguishing character.	Introducing new construction to the site which is incompatible with the character of the site because of size, scale, colour, architectural design and materials.
Retaining the distinctive landscape features of the site which link the structure to its environment and reflect the history & development of the site.	Destroying the relationship of the bridge tits environment by widening or modifying approaches or by changing the texture,colour, scale and form of the existing components.
Using new plant materials, signs, seating and associated visitor facilities which are compatible with the character of the site in size, scale, material and colour.	Introducing interpretive and visitorfacilities which are inappropriate to the character of the site.
Basing all decisions for new work on actual knowledge of the past appearance of the site.	Over-restoring the site to an appearance it never had.
Placing modern visitor services, (toilets, carparks, picnic areas etc) in inconspicuous locations.	Placing modern visitor services too close to the structure where they may intrude on the character of the site.
The Structure:	
Replacement of structural members only when necessary. Provide structural support for inadequate features.	Attempting to reveal complex problems unless adequate planning and support is arranged.
Correct structural deficiencies without substantial alterations or loss of integrity.	Leaving structural problems untreated that will cause continuing deterioration and will shorten the life of the structure.
Removal of historically insignificant material to lighten the dead load as long as this material does not contribute to the architectural character of the structure	Removing rather than repairing historically important features which are structurally deficient.
Respecting structural integrity by minimising cutaways or sample holes in structural members.	Using modern devices to support structures where other, more sympathetic alternatives exist.
Applying preservatives discreetly.	Applying preservatives which change the appearance of architectural features.

54 Adapted from Goodell, 1977. p14-17.

Consider	Avoid
Discovering & retaining original decorative work including paint colours. Repainting with colours based on the original to illustrate the distinctive characteristics of the structure.	Constructing decorative features or repainting with colours that can not be substantiated through research to be true or accurate.
Planning and Function;	
Using the structure for its originally intended purpose, and finding adaptive uses which are compatible with the nature of the bridge when necessary.	Altering the structure to accommodate incompatible use requiring extensive alterations.
Instigating a comprehensive inspection and maintenance plan to ensure the continued protection of the restored site.	Handing over the control of the site to other organisations or groups if the continued maintenance and protection can not be assured.
New Additions:	
Keeping new additions to a minimum. Contemporary designs must be compatible with the mood of the design.	Making unnecessary new additions or Designing incompatible additions which imitate an earlier style or design which changes the mood of the site especially if new additions have a contemporary function. i.e.Vehicle barriers for high speed traffic.
Consider the Engineering:	
Maintaining historic accuracy by using the most appropriate materials available.	Using durable materials created by recent technology. These may prove physically and aesthetically incompatible or may accelerate deterioration if adequate testing is not undertaken.
Maintaining historic accuracy by using appropriate technology and construction techniques wherever possible.	

Consider

The Interpretation:

Interpretation mediums which are compatible and appropriate. Interpretation should provoke exploration and must be historically accurate and honest.

Safety and Legal Requirements:

Upgrading to meet existing safety standards with the minimum loss of historic integrity.

Complying with requirements in such a manner that the essential character of the site is preserved.

Investigating variances for historic structures granted in previous case studies.

Avoid

Interpretation which clutters the site physically or interrupts the process of exploration

Chapter 10: Conclusion

Historic preservation in New Zealand has in the past concentrated on a very narrow portion of our history. Much effort has been placed on the preservation of our early historic buildings or places of war, discovery and associated settlement. Recognition that bridges are important historic sites, interpreting various aspects of our history and having an association with a number of different historical themes, is an important step in the broadening of New Zealands historical spectrum.

As time advances, the technical and financial constraints in the practical preservation of bridges becomes restrictive. In order to minimise the effects of such restrictions, a national bridge preservation plan is required. The goal of a bridge preservation plan would be to; *Preserve an adequate and sustainable selection of bridges that exhibit exceptional historic values through their significance to the economic development, settlement and/or engineering and architectural heritage of New Zealand.*

To achieve this goal the following process should be followed;

(1) Identify those bridges which are worthy of preservation because of their exceptional historic value and their significance to the economic development, settlement and/or engineering heritage of New Zealand. Propose these sites as national historic sites worthy of permanent protection.

(2) Prevent any further loss of bridges which are, or have potential to be considered as historic sites. In order to prevent the loss of historic sites the following objectives should be carried out;

(a) Identify at a early stage historic sites which are under threat of permanent damage or loss and attempt to mitigate or prevent the effects of the threat.

(b) Develop effective legislative protection for historic bridges. Such legislation should formally recognise the historical significance of bridges and encourage the protection of nationally important sites. Formal recognition of the importance of historic bridges should be fostered in the organisations that administer bridges. This could be achieved by making the consideration of the historical value of a site mandatory in the planning process for bridge replacement proposals. Guidelines, similar to those described in Chapter 9, should be used by organisations carrying out rehabilitation works on bridges classified as historic.

(c)Continue routine inspection and risk assessment of bridges after they have been removed from the road and rail system.

(d)Ultimately develop a preservation plan for each historic bridge. For those sites that are of extreme importance and are under considerable threat, develop a well researched preservation plan. Such a plan would involve a detailed engineering study that would seek to establish strong economic and technical arguments for preservation and examine historically sensitive alternatives to demolition.

(3) Promote historic bridges through the development of local support so they may be recognised as important historic sites and their preservation encouraged, especially within larger historic districts. Promote and continue to develop the thematic analysis of history[55] to assist in the development of balanced approach to historic place management.

While bridge preservation is seen as a low priority when compared with other conservation issues, the opportunity for representative preservation of historic bridges should not be forsaken. New Zealand's bridge preservation policy will be shaped by the technical, legal and financial considerations of the day. Ensuring that we understand the importance, status and extent of New Zealands historic bridge resource is therefore of primary importance. Such an understanding will enable, (1) the consideration of as large a pool of suitable and significant bridges for restoration and rehabilitation, and (2) enable sound judgements to be made as to which bridges should be preserved.

With any bridge preservation project, the most appropriate option will be one that ensures the highest level of site protection while maintaining the highest level of safe and productive use. Preservationists and bridge administrative authorities must be prepared to compromise if the representative preservation of our most historically interesting and significant bridges is to proceed. If New Zealand is to retain the most significant examples of our historic bridges, then the inventory and assessment of historic bridge sites must be carried out in the near future.

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[55] See N.Z.H.P.T. 1987b.

Suggestions for Further Study.

This report has primarily dealt with the issues relating to the selection, use and preservation of historic bridges. Further study is required in;

(1) The field of structural evaluation of historic bridges, specifically the formulation of appropriate techniques and technology for the historically sympathetic restoration or rehabilitation of historic bridges. Such research would be of value to bridge preservation in New Zealand and overseas.

(2) The economics of bridge restoration or rehabilitation compared with demolition. Economic assessment of all the values associated with historic bridges is required to make sound judgements as to the furture of historic bridges.

(3) Historical analysis of the history of bridges and bridge building in New Zealand. Such a study would lead to a list of bridges which are considered historically significant on a national and international scale as engineering structures. This list would aid in the identification of historic bridges.

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Appendix 1: Timber Species and Fields of Application. Pre 1956[56]

The following tabulation sets out in summarised form most of the species used in bridge work and gives an indication of their usefulness. The classification for durability is based on use as a pole in the ground and is:-

Class 1 - Good for 20 -25 years
Class 2 - Good for 15 -20 years
Class 3 - Good for 8 -15 years.
Class 4 - Good for 3 - 8 years.

Where timbers can be graded up substantially for durability provided there is no ground contact an asterisk will be placed alongside the classification value. The classification for strength is that used in the A.C.S.I.R. handbook.[57] Timbers other than Australian have been assessed in a general way and without extensive testing.

Variety	Durability	Strength	Suitability for Bridge Work
Australian.			
Ironbark	1	A^+	First Class for all purposes but expensive.
Grey Gum	1	A	All purposes incld. ground contact. Good Piles.
Grey Box	1	A	All purposes incld. ground contact. Good Piles.
Tallow wood	1	A	All purposes incld. ground contact. GoodPiles.
White mahogany	1	B	All purposes incld. ground contact. GoodPiles.
Red mahogany	2 or 3	B	Most purposes including track sleepers.
Yellow stringy bark	2	B	Most purposes including track sleepers.
White stringy bark	2 or 3	B	Most purposes including track sleepers.
Forest Red Gum	2	B	Most purposes including track sleepers.
River red gum	2	B	Most purposes including track sleepers.
Wolly butt	1	A	Most purposes including track sleepers.
Black butt	3	B	Most purposes including track sleepers.
Spotted gum	2 or 3	A+B	Most purposes including track sleepers.
Sydney bluegum	3	B	Handrails and decking.
Brush Box	3	B	Especially for decking.
Turpentine	1	B	All purposes but especially piling.
Jarrah	2	C	All purposes but weathers& is short in grain.
Karri	3	B	Decking and Wharf timbers.

56Summarized from *Bridge Manual,*Ministry of Works, 1956. pp 51-52.

57*Handbook of Structural Timber design,* Australian Council for Scientific and Industrial Research. Langlands and Thomas. Date and page unknown.

Variety	Durability	Strength	Suitability for Bridge Work
Malayan			
Chengal	1	B	Superior to other species in warm moist air.
Balau	2	B	Superior to other species in warm moist air.
Keruing	2 or 3	B	All bridge purposes except piling.
Karpur	2 or 3	B	All bridge purposes except piling
Kempas	2 or 3	B	All bridge purposes except piling
New Zealand Native			
Kauri	3*	D	Widely used previously but now far to Scarce.
Totara	1	D	Not suitable for members in bending. Brittle.
Matai	3*	D	Rots from inside.
Rimu	3*	D	Decking.
Miro	3*	D	Decking.
Kahikitea	5	D	Not Usable.
Silver Pine	1	D	Good piling timber. Suitable for other uses.
Beech, Silver	4	D	Warps badly, not really good timbers. Usable
for Beech,Red	2 or 3*	D	decking. (Should be laid with heart side up)
Beech, Hard	2 or 3*	CD	to retain moisture and prevent springing
Beech,Black	2 or 3*	CD	Spiking should commence at the centre and
Beech, Mountain	3	D	work towards the ends).
Puriri	1	B	Good timber but not normally available.
Mangeao	4	D	
Tanekaha	3	CD	
Maire	2 or 3*	BC	Very little available.
Taraire	5	D	
Hinau (Black)	1 or 2	D	
Rata	3	C	From green sound logs only.
Tawa	5	D	Inside uses only.
New Zealand exotics			
Macrocapa	2 or 3	D	Suitable for decking
Douglas fir	3 or 4	C	Not comparable with same specie grown elsewhere
Pinus radiata	2	E	Usable for running planks, considered for decking.
Larch (treated)	1 or 2	D	Usable for handrails, pile leaders in soft driving.
Eucalypts			Very little available in durable species; generally poorer in durability and stength than Australian grown of same species.

Appendix 2: Point System for Evaluation of North Carolina Truss Bridges.[58]

Factor	Points
A. Documentation:	
1. Builder: a. Unknown	0
b. Known, contribution to truss technology not known	1
c. Known, prolific builder or N.C. Company	2
d. Known, unusual designer	3
2. Date: a. Post -1940	0
b. 1931-1940	1
c. 1921-1930	2
d. 1901-1920	3
e. Pre -1900	4
	(7 points max.)
B. Technological Significance:	
1. Technology: a. Patented inovations in truss technology.	1
b. No. of spans (point for 3 + spans, 1920 or ealier)	1
c. Length of individual spans (point for span of 100' or more built 1920 or earlier).	1
d. Integrity (No changes to truss)	1
e. Special features	1
2. Geometry: a. Rare (three or less of the type existant)	4
b. Unusual (4-20 of the type existant)	2
c. Novel, or Parker or Camelback type	1
	(9 Points max.)
C. Environment:	
1. Aesthetics: a. Excellent	4
b. Fair	2
c. Poor	0
2. History: a. Excellent, Significance known, bridge and crossing of historical importance	4
b. Good. Local significance very likely	2
c. Significance undetermined	0
3. Integrity of Location:	
a. Original location and substructure	4
b. Original location, substructure replaced	2
c. Not original location	0
	(10 points max.)
	TOTAL 26 POSSIBLE POINTS

58 Chamberlin, 1983. pp 64-65.